Ansys
2024 R2
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Nexxim Components Help

Ansys

ANSYS, Inc.
Southpointe
2600 Ansys Drive
Canonsburg, PA 15317
ansysinfo@ansys.com
https://www.ansys.com
(T) 724-746-3304
(F) 724-514-9494

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Table of Contents

1 - Nexxim Component Models

This topic describes all the components available with the Circuit simulator. Most of these components are available from the Components tab in the Project window when a Circuit design is active in the **Schematic Editor**. Netlist-only elements are so noted in the help topics.

General Components

"Capacitors" on page 3-1

"Coaxial Cables" on page 4-1

"Controlled Sources" on page 5-1

"Diodes" on page 7-1

"Equalizers" on page 9-1

"FETs (JFETs and MESFETs)" on page 10-1

"Lumped Elements General" on page 12-1

" Nexxim Filters " on page 13-1

"IBIS Buffer Elements" on page 16-1

"Nexxim Ideal Distributed" on page 14-1

"Nexxim Ideal Microwave" on page 15-1

"Independent Sources " on page 17-1

"Inductors" on page 18-1

"LoadPull Behavioral Elements " on page 19-1

"Maxwell Spice Legacy Elements" on page 20-1

"Optoelectronic Elements" on page 28-1

Power Electronics Tools

"Probes" on page 30-1

"Resistors" on page 32-1

"S-Parameter Elements" on page 33-1

"Switches" on page 37-1

"Transmission Lines" on page 39-1

"Varactors" on page 40-1

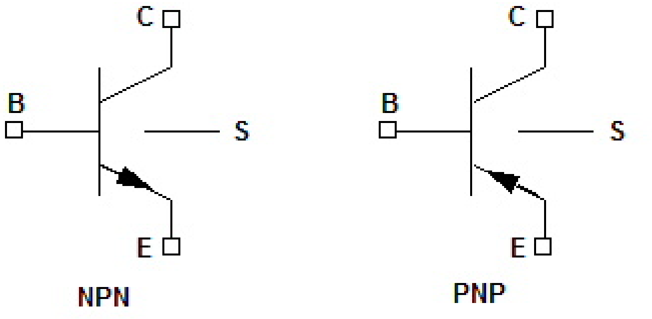
Distributed Elements

Transistors

2 - BJTs

This topic describes the following bipolar junction transistors (BJTs):

Bipolar Transistor Instance, Linear (Level 1)



The syntax for a Level 1 bipolar junction transistor (BJT) instance is:

```
Qxxxx nc nb ne [ns] modelname
[[AREA=]val] [AREAB=val] [AREAC=val]
[M=val] [DTEMP=val]
```

nc is the collector node, *nb* is the base node, *ne* is the emitter node, and *ns* is the substrate node of the transistor. The *modelname* is the name of a Level 1 BJT model defined in a .MODEL statement elsewhere in the netlist.

Table 1: Level 1 BJT Instance Parameters

Instance Parameter	Description	Unit	Default
AREA	Emitter area factor for currents, resistances, and capacitances	None	1.0
AREAB	Base area factor for currents, resistances, and capacitances. Applied to transistors with vertical geometry.	None	1.0
AREAC	Collector area factor for currents, resistances, and capacitances. Applied to transistors with lateral geometry.	None	1.0
DTEMP	Difference between capacitor and circuit temperatures	°C	0
M	Multiplier: simulates parallel devices	None	1.0

Linear BJT Instance Netlist Examples

```
Q1 20 34 0 bipolar1
```

```
Qtest input vcc gnd gnd bipolar1 area=1.1
```

```
.MODEL bipolar1 NPN LEVEL=1
```

BJT Level 1 Output Quantities

The BJT Level 1 instance can output the quantities in the following list. The output quantities are the values of model parameters and the values of variables that are calculated internally to the model.

In the **Schematic Editor**, you request Nexxim to create these outputs with the Output Quantities selection on the Solution Setup windows.

In a netlist, you request Nexxim to create these outputs with the following statement:

```
.PRINTanalysis_type O(instance_name)
```

Where *analysis_type* identifies the Nexxim analysis (TRAN, HB, etc.) and *instance_name* identifies the device instance in the netlist, shown as **Q***xxxx* in the netlist syntax.

Table 2: BJT Level 1 Output Quantities

Output Code	Parameter or Variable	Description	Unit
LV1	AREA	Area factor	Meter^2
LV4	M	Multiplier for multiple parallel devices	None
LV5	FT	Unity gain bandwidth	Hertz
LV6	ISUB	Substrate current	Amp
LV7	GSUB	Substrate conductance	Mho
LV8	LOGIC	Log$_{10}$(IC) [IC = collector current]	None
LV9	LOGIB	Log$_{10}$(IB) [IB = base current]	None
LV10	BETA	Transistor BETA	
LV11	LOGBETAI	Log$_{10}$(BETA Current)	
LV14	RB	Base resistance	Ohm
LV15	GRE	Emitter conductance	Mho
LV16	GRC	Collector conductance	Mho
LX0	VBE	Base-emitter potential	Volt
LX1	VBC	Base-collector potential	Volt
LX2	CCO	Collector current	Amp
LX3	CBO	Base current	Amp
LX4	GPI	IB/VBE for constant VBC	
LX5	GU	IB/VBC for constant VBE	

Output Code	Parameter or Variable	Description	Unit
LX6	GM	IC/VBE + IB/VBE for constant VCE	
LX7	GO	IC/VCE for constant VBE	
LX8	QBE	Base-emitter charge	Coulomb
LX9	CQBE	Base-emitter charge current	Amp
LX10	QBC	Base-collector charge	Coulomb
LX11	CQBC	Base-collector charge current	Amp
LX12	QCS	Collector-substrate charge	Coulomb
LX13	CQCS	Collector-substrate charge current	Amp
LX14	QBX	Base-internal charge	Coulomb
LX15	CQBX	Base-internal charge current	Amp
LX16	GXO	Internal conductance (1/RBeff)	Mho
LX17	CEXBC	Base-collector equivalent current	Amp
LX19	CAP_BE	CBE capacitance (C_π)	Farad
LX20	CAP_IBC	CBC internal base-collector capacitance (C_μ)	Farad
LX21	CAP_SCB	CSC substrate-collector capacitance for vertical transistors CSB substrate-base capacitance for lateral transistors	Farad
LX22	CAP_XBC	CBCX external base-collector capacitance	Farad
LX23	CMCMO	TF*IBE/VBI	
LX24	VSUB	Substrate voltage	Volt

Level 1 Linear BJT Model (NPN or PNP)

The .MODEL statement for the Level 1 BJT specifies values for one or more model parameters.

```
.MODELmodelname NPN [LEVEL=1] [modelparameter=val] ...
```

or

```
.MODELmodelname PNP [LEVEL=1] [modelparameter=val] ...
```

Table 3: Level 1 BJT Model DC Parameters

Model Parameter	Description	Unit	Default
LEVEL	1 selects the Level 1 BJT model	None	1 (default if LEVEL parameter is omitted)
BF (**BFM**)	Ideal maximum forward Beta	None	100.0
BR (**BRM**)	Ideal maximum reverse Beta	None	1.0
BULK (**NSUB**)	Global node name/number for bulk or substrate node.	None	0
DCAP	Selects equations used to calculate depletion capacitance	None	2
EXPLI	Current explosion factor EXPLIeff = EXPLI × AREA	Amp	0.0
IBC	Reverse saturation current between base and collector. IBCeff = IBC × AREA × M	Amp	0.0
IBE	Reverse saturation current between base and emitter. IBEeff = IBE × AREA × M	Amp	0.0
IS	Transport saturation current. Used to calculate DC current when IBC and IBE are not specified. ISeff = IS × AREA × M	Amp	1.0e-16
ISS	Reverse saturation current. Vertical geometry: bulk-to collector. Lateral geometry: bulk-to substrate	Amp	0.0
NF	Forward current emission coefficient	None	1.0
NR	Reverse current emission coefficient	None	1.0
NS	Substrate current emission coefficient	None	1.0
SUBS	Selects geometry and corresponding substrate connection. +1 = vertical geometry, substrate connected to internal collector -1 = lateral geometry, substrate connected to internal base	None	+1 for NPN -1 for PNP

UPDATE	Base charge equation selector 0 = default, 1 = alternate equation	None	0

Table 4: Level 1 BJT Model Low-Current Beta Degradation Parameters

Model Parameter	Description	Unit	Default
ISC (**C4**, **JLC**)	Base-collector leakage saturation current. If ISC > 1e-4: ISCeff = ISC × IS If ISC < 1e-4 and SUBS = 1: ISCeff = ISC × AREAB × M If ISC < 1e-4 and SUBS = -1: ISCeff = ISC × AREAC × M	Amp	0.0
ISE (**C2**, **JLE**)	Base-emitter leakage saturation current. If ISC > 1e-4: ISEeff = ISE × IS If ISC < 1e-4: ISEeff = ISE × AREA × M	Amp	0.0
NC (**NLC**)	Base-collector leakage emission coefficient	None	2.0
NE (**NLE**)	Base-emitter leakage emission coefficient	None	1.5

Table 5: Level 1 BJT Model Base Width Parameters

Model Parameter	Description	Unit	Default
VAF (**VA**, **VBF**)	Forward early voltage. Zero represents infinite voltage	Volt	0.0
VAR (**VB**, **VRB**, **BV**)	Reverse early voltage. Zero represents infinite voltage	Volt	0.0

Table 6: Level 1 BJT Model High-Current Beta Degradation Parameters

Model Parameter	Description	Unit	Default
IKF (**IK**, **JBF**)	Knee or corner for forward Beta high-current rolloff. Zero	Amp	0.0

	represents infinite current. IKFeff = IKF × AREA × M		
IKR (**JBR**)	Knee or corner for reverse Beta high-current rolloff. Zero represents infinite current. IKReff = IKR × AREA × M	Amp	0.0
NKF (**NK**)	High-current Beta rolloff exponent	None	0.5

Table 7: Level 1 BJT Model Parasitic Resistance Parameters

Model Parameter	**Description**	**Unit**	**Default**
IRB (**IOB**)	Base current where base resistance falls halfway to RBM. Zero represents infinite current. IRBeff = IRB × AREA × M	Amp	0.0
RB	Base resistance RBeff = RB / (AREA × M)	Ohm	0.0
RBM	Minimum high-current base resistance RBMeff = RBM / (AREA × M)	Ohm	RB
RC	Collector resistance RCeff =RC / (AREA × M)	Ohm	0.0
RE	Emitter resistance REeff =RE / (AREA × M)	Ohm	0.0

Table 8: Level 1 BJT Model Junction Capacitance Parameter

Model Parameter	**Description**	**Unit**	**Default**
CJC	Base-collector zero-bias depletion capacitance. When both IBC and IBE > 0 and SUBS = +1: CJCeff = CJC × AREAB × M When both IBC and IBE > 0 and SUBS = -1: CJCeff = CJC × AREAC × M	Farad	0.0
CJE	Base-emitter zero-bias depletion capacitance.	Farad	0.0

	CJCeff = CJC × AREA × M		
CJS (**CCS**, **CSUB**)	Zero-bias collector-substrate capacitance. When both IBC and IBE > 0 and SUBS = +1: CJSeff = CJS × AREAB × M When both IBC and IBE > 0 and SUBS = -1: CJSeff = CJS × AREAC × M	Farad	0.0
FC	Coefficient used in forward bias depletion capacitance calculation when DCAP = 1	None	0.5
MJC (**MC**)	Base-collector junction grading factor (exponent)	None	0.33
MJE (**ME**)	Base-emitter junction grading factor (exponent)	None	0.33
MJS (**ESUB**)	Substrate junction grading factor (exponent)	None	0.5
VJC (**PC**)	Built in base-collector potential	Volt	0.75
VJE (**PE**)	Built in base-emitter potential	Volt	0.75
VJS (**PSUB**)	Built in substrate junction potential	Volt	0.75
XCJC (**CDIS**)	Internal base fraction of base-collector depletion capacitance	None	1.0

Table 9: Level 1 BJT Model Parasitic Capacitance Parameters

Model Parameter	**Description**	**Unit**	**Default**
CBCP	External base-collector constant capacitance CBCPeff = CBCP × AREA × M	Farad	0.0
CBEP	External base-emitter constant capacitance CBEPeff = CBEP × AREA × M	Farad	0.0
CCSP	External collector-substrate constant capacitance (vertical) or base-substrate (lateral) CCSPeff = CCSP × AREA × M	Farad	0.0

Table 10: Level 1 BJT Model Transit Time Parameters

Model Parameter	**Description**	**Unit**	**Default**
ITF (**JTF**)	TF high-current parameter	Amp	0.0

	ITFeff = ITF × AREA × M		
PTF	Excess phase factor	Degree	0.0
TF	Ideal forward transit time	Second	0.0
TR	Ideal reverse transit time	Second	0.0
VTF	TF base-collector voltage dependence coefficient. Zero represents an infinite value.	Volt	0.0
XTF	TF bias dependence coefficient	None	0.0

Table 11: Level 1 BJT Model Noise Parameters

Model Parameter	Description	Unit	Default
AF	Flicker noise exponent	None	1.0
KF	Flicker noise coefficient	None	0.0

Table 12: Level 1 BJT Model Temperature Parameters

Model Parameter	Description	Unit	Default
CTC	Zero-bias base-collector capacitance temperature coefficient (TLEVC > 0).	$(°C)^{-1}$	0.0
CTE	Zero-bias base-emitter capacitance temperature coefficient (TLEVC > 0).	$(°C)^{-1}$	0.0
CTS	Zero-bias substrate capacitance temperature coefficient (TLEVC > 0).	(°C)-1	0.0
EG	PN junction energy gap	electron-Volt	TLEV = 0 or 1: 1.11 TLEV = 2: 1.16
GAP1	Band gap correction factor #1 (Sze alpha term)	electron-Volt/°C	7.02e-4
GAP2	Band gap correction factor #2 (Sze beta term)	None	1108
TBF1	1st-order temperature coefficient for BF	$(°C)^{-1}$	0.0
TBF2	2nd-order temperature coefficient for BF	$(°C)^{-2}$	0.0
TBR1	1st-order temperature coefficient for BR	$(°C)^{-1}$	0.0
TBR2	2nd-order temperature coefficient for BR	$(°C)^{-2}$	0.0

TIKF1	1st-order temperature coefficient for IKF	$(^{\circ}\mathrm{C})^{-1}$	0.0
TIKF2	2nd-order temperature coefficient for IKF	$(^{\circ}\mathrm{C})^{-2}$	0.0
TIKR1	1st-order temperature coefficient for IKR	$(^{\circ}\mathrm{C})^{-1}$	0.0
TIKR2	2nd-order temperature coefficient for IKR	$(^{\circ}\mathrm{C})^{-2}$	0.0
TIRB1	1st-order temperature coefficient for IRB	$(^{\circ}\mathrm{C})^{-1}$	0.0
TIRB2	2nd-order temperature coefficient for IRB	$(^{\circ}\mathrm{C})^{-2}$	0.0
TIS1	1st-order temperature coefficient for IS or IBE and IBC (TLEV = 3)	$(^{\circ}\mathrm{C})^{-1}$	0.0
TIS2	2nd-order temperature coefficient for IS or IBE and IBC (TLEV = 3)	$(^{\circ}\mathrm{C})^{-2}$	0.0
TISC1	1st-order temperature coefficient for ISC (TLEV = 3)	$(^{\circ}\mathrm{C})^{-1}$	0.0
TISC2	2nd-order temperature coefficient for ISC (TLEV = 3)	$(^{\circ}\mathrm{C})^{-2}$	0.0
TISE1	1st-order temperature coefficient for ISE (TLEV = 3)	$(^{\circ}\mathrm{C})^{-1}$	0.0
TISE2	2nd-order temperature coefficient for ISE (TLEV = 3)	$(^{\circ}\mathrm{C})^{-2}$	0.0
TISS1	1st-order temperature coefficient for ISS (TLEV = 3)	$(^{\circ}\mathrm{C})^{-1}$	0.0
TISS2	2nd-order temperature coefficient for ISS (TLEV = 3)	$(^{\circ}\mathrm{C})^{-2}$	0.0
TITF1	1st-order temperature coefficient for ITF	$(^{\circ}\mathrm{C})^{-1}$	0.0
TITF2	2nd-order temperature coefficient for ITF	$(^{\circ}\mathrm{C})^{-2}$	0.0
TLEV	Selector for temperature equations	None	0.0
TLEVC	Selector for temperature equations	None	0.0
TMJC1	1st-order temperature coefficient for MJC	$(^{\circ}\mathrm{C})^{-1}$	0.0
TMJC2	2nd-order temperature coefficient for MJC	$(^{\circ}\mathrm{C})^{-2}$	0.0
TMJE1	1st-order temperature coefficient for MJE	$(^{\circ}\mathrm{C})^{-1}$	0.0
TMJE2	2nd-order temperature coefficient for MJE	$(^{\circ}\mathrm{C})^{-2}$	0.0
TMJS1	1st-order temperature coefficient for MJS	$(^{\circ}\mathrm{C})^{-1}$	0.0
TMJS2	2nd-order temperature coefficient for MJS	$(^{\circ}\mathrm{C})^{-2}$	0.0
TNC1	1st-order temperature coefficient for NC	$(^{\circ}\mathrm{C})^{-1}$	0.0
TNC2	2nd-order temperature coefficient for NC	$(^{\circ}\mathrm{C})^{-2}$	0.0
TNE1	1st-order temperature coefficient for NE	$(^{\circ}\mathrm{C})^{-1}$	0.0

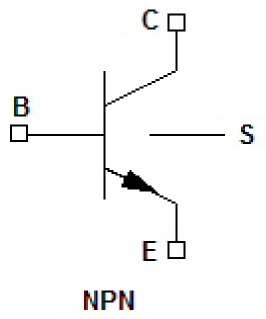
TNE2	2nd-order temperature coefficient for NE	$(^\circ C)^{-2}$	0.0
TNF1	1st-order temperature coefficient for NF	$(^\circ C)^{-1}$	0.0
TNF2	2nd-order temperature coefficient for NF	$(^\circ C)^{-2}$	0.0
TNOM (**TREF**)	Circuit temperature	°C	25
TNR1	1st-order temperature coefficient for NR	$(^\circ C)^{-1}$	0.0
TNR2	2nd-order temperature coefficient for NR	$(^\circ C)^{-2}$	0.0
TNS1	1st-order temperature coefficient for NS	$(^\circ C)^{-1}$	0.0
TNS2	2nd-order temperature coefficient for NS	$(^\circ C)^{-2}$	0.0
TRB1 (**TRB**)	1st-order temperature coefficient for RB	$(^\circ C)^{-1}$	0.0
TRB2	2nd-order temperature coefficient for RB	$(^\circ C)^{-2}$	0.0
TRC1 (**TRC**)	1st-order temperature coefficient for RC	$(^\circ C)^{-1}$	0.0
TRC2	2nd-order temperature coefficient for RC	$(^\circ C)^{-2}$	0.0
TRE1 (**TRE**)	1st-order temperature coefficient for RE	$(^\circ C)^{-1}$	0.0
TRE2	2nd-order temperature coefficient for RE	$(^\circ C)^{-2}$	0.0
TRM1	1st-order temperature coefficient for RBM	$(^\circ C)^{-1}$	TRB1
TRM2	2nd-order temperature coefficient for RBM	$(^\circ C)^{-2}$	TRB2
TTF1	1st-order temperature coefficient for TF	$(^\circ C)^{-1}$	0.0
TTF2	2nd-order temperature coefficient for TF	$(^\circ C)^{-2}$	0.0
TTR1	1st-order temperature coefficient for TR	$(^\circ C)^{-1}$	0.0
TTR2	2nd-order temperature coefficient for TR	$(^\circ C)^{-2}$	0.0
TVAF1	1st-order temperature coefficient for VAF	$(^\circ C)^{-1}$	0.0
TVAF2	2nd-order temperature coefficient for VAF	$(^\circ C)^{-2}$	0.0
TVAR1	1st-order temperature coefficient for VAR	$(^\circ C)^{-1}$	0.0
TVAR2	2nd-order temperature coefficient for VAR	$(^\circ C)^{-2}$	0.0
TVJC	Temperature coefficient for VJC (TLEVC = 1 or 2)	Volt/°C	0.0
TVJE	Temperature coefficient for VJE (TLEVC = 1 or 2)	Volt/°C	0.0
TVJS	Temperature coefficient for VJS (TLEVC = 1 or 2)	Volt/°C	0.0
XTB (**TBT**, **CB**, **XBT**)	Forward and reverse Beta temperature exponent (TLEV = 0, 1, or 2)	None	0.0
XTI	Saturation current temperature exponent Silicon diffused junction: 3.0	None	3.0

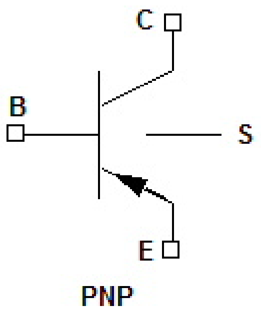
	Schottky barrier diode: 2.0		

Linear BJT Model Netlist Example

```
.MODEL bjttest1 NPN LEVEL=1 update=1 is=4.0e-16
```

Bipolar Transistor Instance, Quasi-Saturation (Level 2)





Quasi-Saturation BJT Instance Netlist Syntax

The syntax for a Level 2 quasi-saturation BJT instance is:

```
Qxxxx nc nb ne [ns] modelname
[[AREA=]val] [AREAB=val] [AREAC=val]
[M=val] [TNOM=val] [DTEMP=val]
```

nc is the collector node, *nb* is the base node, *ne* is the emitter node, and *ns* is the substrate node of the transistor. The *modelname* is the name of a Level 2 BJT model defined in a .MODEL statement elsewhere in the netlist.

The Level 2 quasi-saturation model BJT has the same instance parameters and default values as the Level 1 BJT. See "Bipolar Transistor Instance, Linear (Level 1)" on page 2-1.

Level 2 Quasi-Saturation BJT Model

The .MODEL statement for the Level 2 quasi-saturation BJT specifies values for one or more model parameters.

```
.MODELmodelname NPN LEVEL=2 [modelparameter=val] ...
```

or

```
.MODELmodelname PNP LEVEL=2 [modelparameter=val] ...
```

The Level 2 quasi-saturation model BJT includes all the model parameters and default values given above for the Level 1 BJT. See "Level 1 Linear BJT Model (NPN or PNP)" on page 2-4.

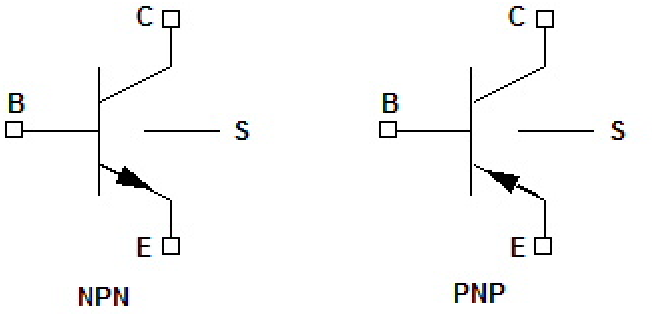
Table 13: Level 2 BJT Additional Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	2 is required to select the Level 2 BJT model	None	1 (default if LEVEL parameter is omitted)
BEX	VO temperature exponent	None	2.42
BEXV	RC temperature exponent	None	1.90
BRS	Reverse Beta for substrate BJT	None	0.0
GAMMA	Epitaxial doping factor GAMMA = $(2 \times n_i / n_e)^2$, where n_i = intrinsic carrier concentration and n_e = epitaxial dopant concentration	None	0.0
NEPI	Emission coefficient	None	1.0
QCO	Epitaxial charge factor. When both IBC and IBE > 0 and SUBS = +1: QCOeff = QCO × AREAB × M When both IBC and IBE > 0 and SUBS = -1: QCOeff = QCO × AREAC × M	Coulomb	0.0
VO	Carrier velocity saturation voltage. Zero represents infinite voltage.	Volt	0.0

Quasi-Saturation BJT Model Netlist Example

```
.MODEL bjttest2 NPN LEVEL=2 gamma=1.0e-9
```

Bipolar Transistor Instance, VBIC95 (Level 4)



VBIC95 BJT Instance Netlist Syntax

The syntax for a Level 4 VBIC95 model BJT instance is:

```
Qxxxx nc nb ne [ns] [nt] modelname
[AREA=val]  [M=val] [DTEMP=val] [TNODEOUT]
```

nc is the collector node, *nb* is the base node, *ne* is the emitter node, *ns* is the substrate node, and *nt* is the self-heating node of the transistor. The *modelname* is the name of a Level 4 BJT model defined in a .MODEL statement elsewhere in the netlist. The **TNODEOUT** flag indicates that node *nt* is present but node *ns* is not present.

Table 14: Level 4 VBIC95 BJT Instance Parameters

Instance Parameter	Description	Unit	Default
AREA	Emitter area factor for currents, resistances, and capacitances	None	1.0
DTEMP	Difference between capacitor and circuit temperatures	°C	0.0
M	Multiplier: simulates parallel devices	None	1

VBIC95 BJT Instance Netlist Examples

```
Q12 10 20 0 bjt95
```

Level 4 VBIC95 BJT Model

The .MODEL statement for the Level 4 VBIC95 BJT specifies values for one or more model parameters.

```
.MODELmodelname NPN LEVEL=4 [modelparameter=val] ...
```

or

```
.MODELmodelname PNP LEVEL=4 [modelparameter=val] ...
```

Table 15: Level 4 VBIC95 BJT Model Basic Parameters

Model Parameter	Description	Unit	Default
LEVEL	4 is required to select the Level 4 BJT model	None	1 (default if LEVEL parameter is omitted)
AVC1	Base-collector avalanche parameter 1	Volt^{-1}	0.0
AVC2	Base-collector avalanche parameter 2	Volt^{-1}	0.0
EA	Activation energy for IS	electron-Volt	1.12
EAIC	Activation energy for IBCI/IBEIP	electron-Volt	1.12
EAIE	Activation energy for IBEI	electron-Volt	1.12
EAIS	Activation energy for IBCIP	electron-Volt	1.12
EANC	Activation energy for IBCN/IBENP	electron-Volt	1.12
EANE	Activation energy for IBEN	electron-Volt	1.12
EANS	Activation energy for IBCNP	electron-Volt	1.12
GAMM	Epitaxial doping factor	None	0.0
HRCF	High current RC factor. Zero represents infinite value.	None	0.0
IBCI	Ideal base-collector saturation current	Amp	1.0e-16
IBCIP	Ideal parasitic base-collector saturation current	Amp	0.0
IBCN	Non-ideal base-collector saturation current	Amp	0.0
IBCNP	Non-ideal parasitic base-collector saturation current	Amp	0.0
IBEI	Ideal base-emitter saturation current	Amp	1.0e-18
IBEIP	Ideal parasitic base-emitter saturation current	Amp	0.0

IBEN	Non-ideal base-emitter saturation current	Amp	0.0
IBENP	Non-ideal parasitic base-emitter saturation current	Amp	0.0
IKF	Forward knee current. Zero represents infinite current.	Amp	0.0
IKP	Parasitic knee current. Zero represents infinite current.	Amp	0.0
IKR	Reverse knee current. Zero represents infinite current.	Amp	0.0
IS	Transport saturation current	Amp	1.0e-16
ISMIN	Parameter for extending the minimum value of IS	Amp	1.0e-19
ISP	Parasitic transport saturation current	Amp	0.0
ISPMIN	Parameter for extending the minimum value of ISP	Amp	1.0e-19
ITF	Coefficient of TF dependence on I_C. Zero represents infinite value.	Amp	0.0
LAMBDA			0.0
MC	Base-collector grading coefficient	None	0.33
MCMIN	Parameter for extending the minimum value of MC	None	1.0e-2
ME	Base-emitter grading coefficient	None	0.33
MEMIN	Parameter for extending the minimum value of ME	None	1.0e-2
MS	Substrate-collector grading coefficient	None	0.33
MSMIN	Parameter for extending the minimum value of MS	None	1.0e-2
NCI	Ideal base-collector emission coefficient	None	1.0
NCIP	Ideal parasitic base-collector emission coefficient	None	1.0
NCN	Non-ideal base-collector emission coefficient	None	2.0
NCNP	Non-ideal parasitic base-collector emission coefficient	None	2.0
NEI	Ideal base-emitter emission coefficient	None	1.0

NEN	Non-ideal base-emitter emission coefficient	None	2.0
NF	Forward emission coefficient	None	1.0
NFP	Parasitic forward emission coefficient	None	1.0
NR	Reverse emission coefficient	None	1.0
PC	Built-in base-collector potential	Volt	0.75
PE	Built-in base-emitter potential	Volt	0.75
PS	Built-in substrate-collector potential	Volt	0.75
QTF	Variant of TF with base-width modulation	None	0.0
RBI	Intrinsic base resistance	Ohm	1.0e-5
RBP	Parasitic base resistance	Ohm	1.0e-5
RBPMIN	Parameter for extending the minimum value of RBP	Ohm	1.0e-3
RBX	Extrinsic base resistance	Ohm	1.0e-5
RCI	Intrinsic collector resistance	Ohm	1.0e-5
RCX	Extrinsic collector resistance	Ohm	1.0e-5
RE	Emitter resistance	Ohm	1.0e-5
RS	Substrate resistance	Ohm	1.0e-5
TF	Forward transit time	Second	1.0e-11
TR	Reverse transit time	Second	1.0e-11
TREF	Nominal circuit temperature	°C	25
VEF	Forward early voltage. Zero represents infinite voltage	Volt	0.0
VER	Reverse early voltage. Zero represents infinite voltage	Volt	0.0
VO (**V0**)	Epitaxial drift saturation voltage. Zero represents infinite value.	Volt	0.0
VTF	Coefficient of TF dependence on V_{bc}. Zero represents infinite value.	Volt	0.0
WBE	Portion of IBEI derived from V_{bei}, (1-WBE) derived from V_{bex}	None	1.0
WSP	Portion of ICCP derived from V_{bep}, (1-WBE) derived from V_{bci}	None	1.0
XTF	Coefficient of TF bias dependence	None	0.0

Table 16: Level 4 VBIC95 BJT Model Capacitance and Charge Parameters

Model Parameter	**Description**	**Unit**	**Default**
AJC	Base-collector capacitance switching parameter	None	-0.5
AJE	Base-emitter capacitance switching parameter	None	-0.5
AJS	Substrate-collector capacitance switching parameter	None	-0.5
CBCO (**CBC0**)	Extrinsic base-collector overlap capacitance	Farad	0.0
CBEO (**CBE0**)	Extrinsic base-emitter overlap capacitance	Farad	0.0
CJC	Base-collector intrinsic zero-bias capacitance	Farad	0.0
CJCP	Substrate-collector zero-bias capacitance	Farad	0.0
CJE	Base-emitter zero-bias capacitance	Farad	0.0
CJEP	Base-collector extrinsic zero-bias capacitance	Farad	0.0
FC	Forward bias depletion capacitance limit	None	0.9
QCO (**QC0**)	Epitaxial charge parameter	Coulomb	0.0

Table 17: Level 4 VBIC95 BJT Model Temperature Coefficient Parameters

Model Parameter	**Description**	**Unit**	**Default**
TAVC	Temperature coefficient of AVC2	$°K^{-1}$	0.0
TNF	Temperature exponent of NF	$°K^{-1}$	0.0
XII	Temperature exponent of IBEI/IBCI/IBEIP/IBCIP	None	3.0
XIN	Temperature exponent of IBEN/IBCN/IBENP/IBCNP	None	3.0
XIS	Temperature exponent of IS	None	3.0
XRB (**XRBI**)	Temperature exponent of RBI	None	0.0
XRC (**XRCI**)	Temperature exponent of RCI	None	0.0
XRE	Temperature exponent of RE	None	0.0
XRS	Temperature exponent of RS	None	0.0
XVO (**XV0**)	Temperature exponent of VO	None	0.0

Table 18: Level 4 VBIC95 BJT Model Noise Parameters

Model Parameter	**Description**	**Unit**	**Default**
AFN	Base-emitter flicker noise exponent	None	1.0

BFN	Base-emitter flicker noise 1/f dependency	None	1.0
KFN	Base-emitter flicker noise constant	None	0.0

Table 19: Level 4 VBIC95 BJT Model Self-Heating Parameters

Model Parameter	Description	Unit	Default
RTH	Thermal resistance	°K/Watt	0.0
CTH	Thermal capacitance	Joule/°K	0.0

Table 20: Level 4 VBIC95 BJT Model Excess Phase Parameter

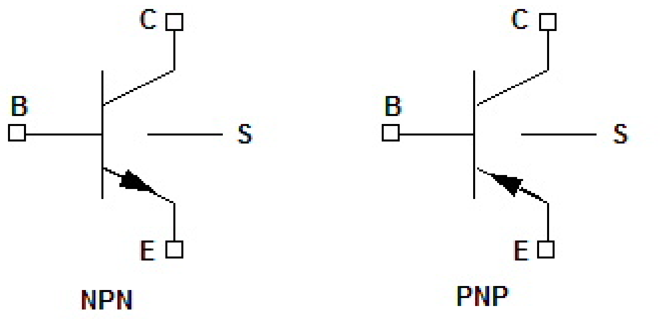
Model Parameter	Description	Unit	Default
TD	Forward excess-phase delay time	Second	0.0

VBIC95 BJT Model Netlist Example

```
.Model Q4_Model NPN LEVEL=4
+ afn = 1 ajc = -0.5 aje = -0.5
+ ajs = -0.5 area = 1 avc1 = 0 avc2 = 0 bfn = 1.0 cbco = 0
+ cbeo = 0 cjc = 0 cjcp = 0 cje = 0 cjep = 0 cth = 0 ea = 1.12
+ eaic = 1.12 eaie = 1.12 eais = 1.12 eanc = 1.12 eane = 1.12
+ eans = 1.12 fc = 0.9 gamm = 0 hrcf = 1.0 ibci = 1e-16
+ ibcip = 0
+ ibcn = 1e-15 ibcnp = 0 ibei = 1e-18 ibeip = 0 iben = 1e-15
+ ibenp = 0 ikf = 2e-3 ikp = 200e-6 ikr = 200e-6 is = 1e-16
+ isp = 1e-16 itf = 1e-3 kfn = 0 mc = 0.330 me = 0.330
+ ms = 0.330
+ nci = 1.0 ncip = 1.0 ncn = 2.0 ncnp = 2.0 nei = 1.0
+ nen = 2.0 nf = 1.0 nfp = 1.0 nr = 1.0 pc = 0.75 pe = 0.75
+ ps = 0.75 qco = 1e-12 qtf = 0 rbi = 0.1 rbp = 0.1
```

```
+ rbx = 0.1 rci = 0.1 rcx = 0.1 re = 0.1 rs = 0.1 rth = 0

+ tavc = 0

+ td = 0 tf = 1e-12 tnf = 0 tnom = 25 tr = 10e-12 vbmn = 0.7

+ vbmx = 0.86 vcmx = 5 vef = 1e34 ver = 1e34 vo = 1e34

+ vtf = 1e34

+ wbe = 1.0 wsp = 1.0 xii = 3.0 xin = 3.0 xis = 3.0 xrb = 1.0

+ xrc = 1.0 xre = 1.0 xrs = 1.0 xtf = 0 xvo = 0
```

Bipolar Transistor Instance, Philips MEXTRAM 503/504 (Level 6)



Philips MEXTRAM 503/504 BJT Instance Netlist Syntax

The syntax for a Level 6 Philips MEXTRAM Version 503 or Version 504 BJT instance is:

Q*xxxx nc nb ne* [*ns*] *modelname*
[[**AREA=**]*val*] [**M=***val*] [**TNOM=***val*] [**DTEMP=***val*]

nc is the collector node, *nb* is the base node, *ne* is the emitter node, and *ns* is the substrate node of the transistor. The *modelname* is the name of a Level 6 Philips MEXTRAM Version 503 or 504 BJT model defined in a .MODEL statement elsewhere in the netlist.

Philips MEXTRAM Version 503 and Version 504 have the same instance parameters.

Table 21: Level 6 Philips MEXTRAM 503/504 BJT Instance Parameters

Instance Parameter	Description	Unit	Default

AREA	Emitter area factor for currents, resistances, and capacitances	None	1.0
M (**MULT**)	Multiplier: simulates parallel devices	None	1
DTEMP (**DTA**)	Difference between transistor and circuit temperatures	°C	0

Philips MEXTRAM 503/504 BJT Instance Netlist Example

```
Q23 87 88 89 90 bjt504 AREA=1.15
```

Level 6 BJT Philips MEXTRAM (503 or 504) Model

The .MODEL statement for the Level 6 Philips MEXTRAM Version 503 or 504 BJT specifies values for one or more model parameters.

```
.MODELmodelname NPN LEVEL=6 VERS=val [modelparameter=val] ...
```

or

```
.MODELmodelname PNP LEVEL=6 VERS=val [modelparameter=val] ...
```

Table 22: Level 6 BJT Model Flag Parameters

Model Parameter	Description	Unit	Default
LEVEL	6 is required to select the Level 6 BJT model	None	1 (default if LEVEL parameter is omitted)
VERS	Selects Version 503 or 504	None	503
EXAVL	Flag for extended modeling of avalanche currents	None	0
EXMOD	Flag for extended modeling of reverse current gain	None	503: 1 504: 1
EXPHI	Flag for distributed high frequency effects	None	503: 0 504: 1.0
SUBS	Flag for controlling substrate effect	None	1

Table 23: Level 6 BJT Model Basic Parameters

Model Parameter	Description	Unit	Default

BF	Ideal forward current gain	None	503: 140 504: 215.0
BRI	Ideal reverse current gain	None	503: 16 504: 7.0
ETA	Factor for built-in base field (503 only)	None	4.0
DAIS	(504 only)		0.0
IBF	Saturation current for the non-ideal forward base current	Amp	503: 2.0e-14 504: 2.7e-15
IBR	Saturation current for the non-ideal reverse base current	Amp	503: 8.0e-15 504: 1.0e-15
IK	Collector-emitter high-injection knee current	Amp	503: 1.5e-2 504: 0.1
IS	Collector-emitter saturation current	Amp	503: 5.0e-17 504: 2.2e-17
MLF	Non-ideality factor of the non-ideal forward base current (504 only)	Volt	2.0
QBO (**QB0**)	Zero-bias base charge (503 only)	Coulomb	1.2e-12
VER	Reverse early voltage (504 only)	Volt	2.5
VEF	Forward early voltage (504 only)	Volt	44.0
VLF	Cross-over voltage of the non-ideal forward base current (503 only)	Volt	0.5
VLR	Cross-over voltage of the non-ideal reverse base current	Volt	503: 0.5 504: 0.2
XEXT	The part of I_{ex}, Q_{ex}, Q_{tex}, and I_{sub} that depends on the base-collector voltage V_{bc1}	None	503: 0.5 504: 0.63
XIBI	Fraction of ideal base current that belongs to the sidewall	None	0.0

Table 24: Level 6 BJT Model Avalanche Parameters

Model Parameter	Description	Unit	Default
AXI	Smoothness parameter for the onset of quasi-saturation (504 only)	None	0.3
AVL	Weak avalanche parameter (503 only)	None	50.0
EFI	Electric field intercept (enabled when EXAVL = 1) (503 only)	None	0.7
IHC	Critical hot-carrier current for velocity saturation in the epilayer	Amp	503: 3.0e-3 504: 4.0e-3
KAVL	(504 only)		0.0
RBC	Constant part of the base resistance	Ohm	503: 50 504: 23
RBV	Variable part of the base resistance at zero bias	Ohm	503: 100 504: 18
RCC	Constant part of the collector resistance	Ohm	503: 25.0 504: 12.0
RCV	Resistance of the unmodulated epilayer	Ohm	503: 750.0 504: 150.0
RE	Emitter resistance	Ohm	503: 2.0 504: 5.0
SCRCV	Space charge resistance of the epilayer	Ohm	503: 1000.0 504: 1250.0
SFH	Epilayer current spreading factor for avalanche model (enabled when EXAVL = 1)	None	503: 0.6 504: 0.3
VAVL	Voltage that determines the curvature of the avalanche model (504 only)	Volt	3.0
WAVL	Epilayer thickness used for avalanche model (504 only)	Meter	1.1e-6

Table 25: Level 6 BJT Model Base-Emitter Capacitance Parameters

Model Parameter	Description	Unit	Default
CJE	Zero-bias emitter-base depletion capacitance	Farad	503: 2.5e-13 504: 7.3e-14
CJC	Zero-bias collector-base depletion capacitance	Farad	503: 1.3e-13 504: 7.8e-14
MC	Coefficient for the current modulation of the collector-base depletion capacitance	None	0.5
PC	Collector-base grading coefficient (variable part)	None	503: 0.4 504: 0.5
PE	Emitter-base grading coefficient	None	503: 0.33 504: 0.4
VDC	Collector-base diffusion voltage	Volt	503: 0.6 504: 0.68
VDE	Emitter-base diffusion voltage	Volt	503: 0.9 504: 0.95
XCJC	Fraction of the collector-base depletion capacitance under the emitter	None	503: 0.1 504: 3.2e-2
XCJE	Fraction of the collector-base depletion capacitance that belongs to the sidewall	None	503: 0.5 504: 0.4
XP	Constant part of CJC	Farad	503: 0.2 504: 0.35

Table 26: Level 6 BJT Model Transit Time Parameters

Model Parameter	Description	Unit	Default
MTAU	503: Non-ideality factor of the neutral and emitter charge 504: Non-ideality factor of the emitter charge	None	503: 1.18 504: 1.0
TAUB	Transit time of stored base charge (504 only)	Second	4.2e-12

TAUE	Minimum transit time of stored emitter charge (504 only)	Second	2.0e-12
TAUNE	Minimum transit time of neutral and emitter charge (503 only)	Second	3.0e-10
TAUR	Transit time of reverse extrinsic stored base charge (504 only)	Second	5.2e-10
TEPI	Transit time of stored epilayer charge (504 only)	Second	4.1e-11
XREC	Pre-factor of the recombination part of I_{b1} (504 only)	None	0.0

Table 27: Level 6 BJT Model Temperature Parameters

Model Parameter	Description	Unit	Default
AB	Temperature coefficient for the resistivity of the base	None	503: 1.35 504: 1.0
AC	Temperature coefficient for the resistivity of the buried layer	None	503: 0.4 504: 2.0
AE	Temperature coefficient for the resistivity of the emitter (504 only)	None	0.0
AEPI	Temperature coefficient for the resistivity of the epilayer	None	503: 2.15 504: 2.5
AEX	Temperature coefficient for the resistivity of the extrinsic base	None	503: 1.0 504: 0.62
AQBO	Temperature coefficient for the zero-bias base charge (504 only)	None	0.3
ER	Temperature coefficient of VLF and VLR (503 only)	None	2.0e-3
TREF (**TNOM**)	Nominal circuit temperature	°C	25
TSCALE	(504 only)		1.0

Table 28: Level 6 BJT Model Bandgap and Base Doping Parameters

Model Parameter	Description	Unit	Default
DEG	Bandgap difference over the base (504 only)	electron-	0.0

		Volt	
DVGBF	Bandgap voltage difference of forward current gain (504 only)	Volt	5.0e-2
DVGBR	Bandgap voltage difference of reverse current gain (504 only)	Volt	4.5e-2
DVGTE	Bandgap voltage difference of emitter stored charge (504 only)	Volt	0.05
NA	Maximum base doping concentration	cm^{-3}	3.0e17
VGB	Band gap voltage of the base	Volt	503: 1.18 504: 1.17
VGC	Band gap voltage of the collector	Volt	503: 1.205 504: 1.18
VGE	Band gap voltage of the emitter (503 only)	Volt	1.01
VGJ	Band gap voltage recombination, emitter-base junction	Volt	503: 1.1 504: 1.15
VI	Ionization voltage of base doping	Volt	0.040

Table 29: Level 6 BJT Model Noise Parameters

Model Parameter	Description	Unit	Default
AF	Flicker noise exponent	None	503: 1.0 504: 2.0
KF	Flicker noise coefficient for ideal base current	None	503: 2.0e-16 504: 2.0e-11
KFN	Flicker noise coefficient for non-ideal base current	None	503: 2.0e-16 504: 2.0e-11

Table 30: Level 6 BJT Model Substrate Parameters

Model Parameter	Description	Unit	Default

AS	Temperature coefficient for the resistivity of the substrate For a closed buried layer, AS = AC For an open buried layer, AS = AEPI	None	503: 2.15 504: 1.58
CJS	Zero-bias collector-substrate depletion capacitance	Farad	503: 1.0e-12 504: 3.15e-13
IKS	Base-substrate high-injection knee current	Amp	503: 5.0e-6 504: 2.5e-4
ISS	Base-substrate saturation current	Amp	503: 6.0e-16 504: 4.8e-17
PS	Collector-substrate grading coefficient	None	503: 0.33 504: 0.34
VDS	Collector-substrate diffusion voltage	Volt	503: 0.5 504: 0.62
VGS	Bandgap voltage of the substrate	Volt	503: 1.15 504: 1.2

Table 31: Level 6 BJT Model Self-Heating Parameters

Model Parameter	Description	Unit	Default
ATH	RTH exponential factor	None	0.0
RTH	Self-heating thermal resistance (504 only)	°C/Ohm	300
CTH	Self-heating thermal capacitance (504 only)	Joule/°C	3.0e-9

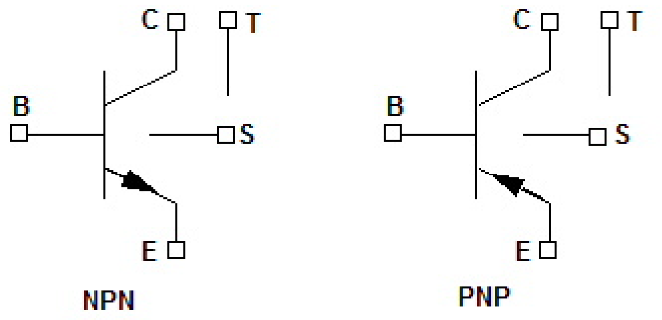
Table 32: Level 6 BJT Model Extrinsic Capacitance Parameters

Model Parameter	Description	Unit	Default
CBEO	Extrinsic base-emitter capacitance (504 only)	Farad	0.0
CBCO	Extrinsic base-collector capacitance (504 only)	Farad	0.0

Philips MEXTRAM 503/504 BJT Model Netlist Example

```
.MODEL bjt504 npn LEVEL=6 VERS=503
+EXMOD=1 EXPHI=0 EXAVL=0 IS=7.95796e-019 BF=221 XIBI=0.0567287
+IBF=6.29244e-017 VLF=0.2628 IK=0.00626479 BRI=42.6425
+IBR=7.6517e-017 VLR=0.4567 XEXT=0.253481 QBO=4.59895e-015
+ETA=4 AVL=24.58 EFI=0.8877 IHC=0.00122637 RCC=116.57
+RCV=236.584 SCRCV=2633.37 SFH=0.491741 RBC=103.06 RBV=299.727
+RE=30.1239 TAUNE=7.70958e-013 MTAU=1 CJE=5.52608e-015
+VDE=0.8517 PE=0.289704 XCJE=0.654501 CJC=1.74037e-015
+VDC=0.69837 PC=0.3373 XP=0.1711 MC=0.468182 XCJC=0.191763
+VGE=1.14 VGB=1.18 VGC=1.206 VGJ=1.22 VI=0.02 NA=1e+018
+ER=0.002 AB=1 AEPI=1.529 AEX=2.3 AC=0.4 KF=2.17634e-009 KFN=0
+AF=2 ISS=2.48987e-020 IKS=0.011044 CJS=2.04924e-015 VDS=0.5
+PS=0.261133 VGS=1.12 AS=1.021e-015
```

Bipolar Transistor Instance, HiCUM Model (Level 8)



Netlist Syntax

The syntax for a level 8 HiCUM model BJT instance is:

Q*xxxx nc nb ne* [*ns*] [*nt*] *modelname* [**AREA=***val*]

[**M=***val*] [**TNOM=***val*] [**DTEMP=***val*] [**TNODEOUT**] *nc* is the collector node, *nb* is the base node, *ne* is the emitter node, *ns* is the substrate node, and *nt* is the self-heating node of the transistor. The *modelname* is the name of a level 8 BJT model defined in a .MODEL statement elsewhere in the netlist. The **TNODEOUT** flag indicates that node *nt* is present but node *ns* is not present.

Table 33: Level 8 HiCUM BJT Instance Parameters

Instance Parameter	Description	Unit	Default
AREA	Emitter area factor for currents, resistances, and capacitances	None	1.0
M	Multiplier: simulates parallel transistors	None	1
TNOM	Circuit temperature	°C	27
DTEMP	Difference between capacitor and circuit temperatures	°C	0
TNODEOUT	Flag to indicate that node *nt* is present but node *ns* is not present	None	None

Netlist Example

```
Q21 22 33 44 bjth8 DTEMP=5
```

Level 8 HiCUM BJT Model

Netlist Form for Level 8 BJT Model

The .MODEL statement for the level 8 HiCUM BJT specifies values for one or more model parameters.

`.MODEL``modelname` **`NPN LEVEL=8`** `[modelparameter=val] ...`

or

`.MODEL``modelname` **`PNP LEVEL=8`** `[modelparameter=val] ...`

Table 34: Level 8 BJT Model Basic Parameters

Model Parameter	Description	Unit	Default
LEVEL=8	Selects level 8 HiCUM BJT model	None	1
IS	Ideal saturation current	Amp	-1.0
MCF	Non-ideality factor for base-collector reverse current (VT = VT × MCF)	None	1.0

TREF (**TNOM**)	Reference temperature	°C	26.85

Table 35: Level 8 BJT Model Transfer Current Parameters

Model Parameter	Description	Unit	Default
ALIT	Additional delay time factor for iT	None	0.45
C10	Constant C10 = IS × QP0	Amp^2-second (Meter^2)	3.76e-32
HFC	Weighting factor for Qfc in HBTs	None	1.0
HFE	Weighting factor for Qfe in HBTs	None	1.0
HJCI	Weighting factor for Qjci in HBTs	None	1.0
HJEI	Weighting factor for Qjei in HBTs	None	0.0
ICH	High-current correction for 2D/3D	Amp	2.09e-2
QP0	Zero-bias hole charge	Amp-second	2.78e-14

Table 36: Level 8 BJT Model B-E Depletion Capacitance Parameters

Model Parameter	Description	Unit	Default
ALJEI	Ratio of maximum to zero-bias value	None	1.8
CJEI0	Zero-bias value	Farad	8.11e-15
VDEI	Built-in voltage	Volt	0.95
ZEI	Exponent coefficient	None	0.5

Table 37: Level 8 BJT Model B-C Depletion Capacitance Parameters

Model Parameter	Description	Unit	Default
CJCI0	Zero-bias value	Farad	1.16e-15
VDCI	Built-in voltage	Volt	0.8
VPTCI	Punch-through voltage	Volt	416
ZCI	Exponent coefficient	None	0.333

Table 38: Level 8 BJT Model Forward Transit Time Parameters

Model	Description	Unit	Default

Parameter			
ALHC	Smoothing factor for current depletion collector and base transit time	None	0.75
ALQF	Factor for additional delay of Q_f	None	0.225
DTOH	Time constant for base and BC SCR width modulation	Second	2.1e-12
FTHC	Partitioning factor for base and collector portion	None	0.6
GTFE	Smoothing factor for current depletion emitter transit time	None	1.4
TBVL	Voltage for modeling carrier jam at low $V_{C'E'}$	Second	40e-12
TEF0	Storage time in neutral emitter	Second	1.8e-12
THCS	Saturation time constant at high current densities	Second	3.0e-11
T0	Low current transit time at $V_{B'C'} = 0$	Second	4.75e-12

Table 39: Level 8 BJT Model Critical Current Parameters

Model Parameter	Description	Unit	Default
RCI0	Low-field resistance of internal collector region	Ohm	127.8
VCES	Internal collector-emitter saturation voltage	Volt	0.1
VLIM	Voltage separating ohmic and SCR regime	Volt	0.7
VPT	Epitaxial punch-through voltage on base-collector SCR	Volt	5.0

Table 40: Level 8 BJT Model Inverse Transit Time Parameter

Model Parameter	Description	Unit	Default
TR	Time constant for inverse operation	Second	1.0e-9

Table 41: Level 8 BJT Model Base Current Components Parameters

Model Parameter	Description	Unit	Default
IBCIS	Base-collector saturation current	Amp	1.16e-20
IBEIS	Base-emitter saturation current	Amp	1.16e-20
IREIS	Base-emitter recombination saturation current	Amp	1.16e-6
MBCI	Base-collector non-ideality factor	None	1.015

MBEI	Base-emitter non-ideality factor	None	1.015
MREI	Base-emitter recombination non-ideality factor	None	2.0

Table 42: Level 8 BJT Model B-C Avalanche Breakdown Parameters

Model Parameter	**Description**	**Unit**	**Default**
FAVL	Prefactor for collector-base avalanche effect	Volt^{-1}	1.186
QAVL	Exponent factor for collector-base avalanche effect	Amp-second	1.11e-14

Table 43: Level 8 BJT Model Internal Base Resistance Parameters

Model Parameter	**Description**	**Unit**	**Default**
FCRBI	Ratio of high-frequency shunt to total internal capacitance	None	0.0
FDQR0	Correction factor for modulation by base-emitter and base-collector SCR	None	0.0
FGEO	Geometry factor (value corresponding to long emitter stripe)	None	0.73
FQI	Ratio of internal to total minority charge	None	0.9055
RBI0	Value at zero bias	Ohm	0.0

Table 44: Level 8 BJT Model Lateral Scaling Parameters

Model Parameter	**Description**	**Unit**	**Default**
LATB	Scaling factor for Qfc in 1_E	None	3.765
LATL	Scaling factor for Qfc in 1_E direction	None	0.342

Table 45: Level 8 BJT Model Peripheral B-E Depletion Capacitance Parameters

Model Parameter	**Description**	**Unit**	**Default**
ALJEP	Ratio of maximum to zero-bias value	None	2.4
CJEP0	Zero-bias value	Farad	2.07e-15

VDEP	Built-in voltage	Volt	1.05
ZEP	Depletion coefficient	None	0.4

Table 46: Level 8 BJT Model Peripheral Base Current Parameters

Model Parameter	Description	Unit	Default
IBEPS	Saturation current	Amp	3.72e-21
IREPS	Recombination saturation factor	Amp	1.0e-30
MBEP	Saturation current non-ideality factor	None	1.015
MREP	Recombination non-ideality factor	None	2.0

Table 47: Level 8 BJT Model Peripheral B-E Tunneling Parameters

Model Parameter	Description	Unit	Default
ABET	Exponent coefficient	None	0.0
IBETS	Saturation current	Amp	0.0

Table 48: Level 8 BJT Model External B-C Capacitance Parameters

Model Parameter	Description	Unit	Default
CCOX	Collector oxide capacitance	Farad	2.97e-15
CJCX0	Zero-bias depletion value	Farad	5.393e-15
FBC (**FBCS**)	Partitioning factor for external base-collector capacitance C_BCX FBC = C’_BCx + C”_BCc	None	0.1526
VDCX	Built-in voltage	Volt	0.7
VPTCX	Punch-through voltage	Volt	100
ZCX	Exponent coefficient	None	0.333

Table 49: Level 8 BJT Model External B-C Current Component Parameters

Model Parameter	Description	Unit	Default
IBCXS	Saturation current	Amp	4.39e-20
MBCX	Non-ideality factor	None	1.03

Table 50: Level 8 BJT Model Miscellaneous External Element Parameters

Model Parameter	Description	Unit	Default
CEOX	Emitter-base isolation overlap capacitance	Farad	1.13e-15
RBX	External base series resistance	Ohm	0.0
RCX	Emitter series resistance	Ohm	0.0
RE	External base series resistance	Ohm	0.0

Table 51: Level 8 BJT Model Substrate Transistor Parameters

Model Parameter	Description	Unit	Default
ISCS	Saturation current of collector-substrate diode	Amp	0.0
ITSS	Transfer saturation current	Amp	0.0
MSC	Non-ideality factor of collector-substrate diode	None	1.0
MSF	Non-ideality factor of forward transfer current	None	0.0
MSR	Non-ideality factor for base-collector substrate transistor (VT = VT × MCF)	None	1.0
TSF	Minority charge storage transit time factor	Second	0.0

Table 52: Level 8 BJT Model C-S Depletion Capacitance Parameters

Model Parameter	Description	Unit	Default
CJS0	Zero-bias value of collector-substrate depletion capacitance	Farad	3.64e-14
VDS	Built-in voltage	Volt	0.6
VPTS	Punch-through voltage	Volt	1000
ZS	Exponent coefficient	None	0.447

Table 53: Level 8 BJT Model Base Current Components Parameters

Model Parameter	Description	Unit (Factor)	Default
CSU	Substrate capacitance from permittivity of bulk material	Farad	0.0
RSU	Substrate series resistance	Ohm	0.0

Table 54: Level 8 BJT Model Noise Parameters

Model Parameter	Description	Unit	Default
AF	Flicker noise exponent factor (no unit only for AF = 2)	None	2.0
KF	Flicker noise factor	None	1.43e-08
KRBI	Internal base resistance factor	None	1.114

Table 55: Level 8 BJT Model Temperature Dependence Parameters

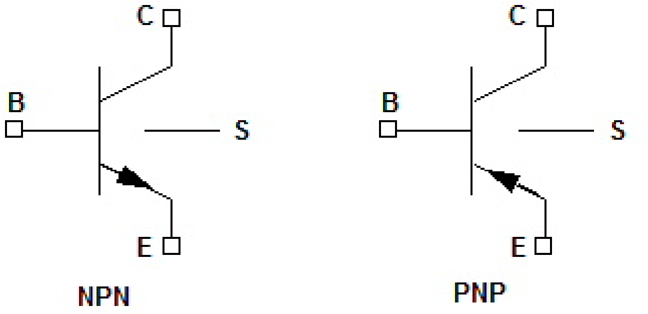
Model Parameter	Description	Unit	Default
ALB	Relative temperature coefficient of forward current gain	$°K^{-1}$	6.3e-3
ALCES	Relative temperature coefficient of VCES	$°K^{-1}$	0.4e-3
ALFAV	Relative temperature coefficient for avalanche breakdown	$°K^{-1}$	8.25e-5
ALQAV	Relative temperature coefficient for avalanche breakdown	$°K^{-1}$	1.96e-4
ALT0	1st-order relative temperature coefficient of TEF0	$°K^{-1}$	0.0
ALVS	Relative temperature coefficient of saturation drift velocity	$°K^{-1}$	1.0e-3
KT0	2nd-order relative temperature coefficient of TEF0	$°K^{-1}$	0.0
VGB	Bandgap voltage	Volt	1.17
ZETACI	Temperature exponent factor of RCI0	None	1.6

ZETACX	Temperature exponent factor for epitaxial layer	None	1.0
ZETARE	Temperature exponent factor of RE	None	0.0
ZETARBI	Temperature exponent factor of RBI0	None	0.588
ZETARBX	Temperature exponent factor of RBX	None	0.2060
ZETARCX	Temperature exponent factor of RCX	None	0.2230

Table 56: Level 8 BJT Model Self-Heating Parameters

Model Parameter	Description	Unit	Default
CTH	Thermal capacitance (Not supported)	Joule/°K	0.0
RTH	Thermal resistance (Not supported)	°K/Ohm	0.0

Bipolar Transistor Instance, VBIC99 (Level 9)



VBIC99 BJT Instance Netlist Syntax

The syntax for a Level 9 VBIC99 model BJT instance is:

Q*xxxx nc nb ne* [*ns*] [*nt*] *modelname*
[**AREA=***val*] [**M=***val*] [**DTEMP=***val*] [**TNODEOUT**]

nc is the collector node, *nb* is the base node, *ne* is the emitter node, *ns* is the substrate node, and *nt* is the self-heating node of the transistor. The *modelname* is the name of a Level 9 BJT model defined in a .MODEL statement elsewhere in the netlist. The **TNODEOUT** flag indicates that node *nt* is present but node *ns* is not present.

Table 57: Level 9 VBIC99 BJT Instance Parameters

Instance	Description	Unit	Default

Parameter			
AREA	Emitter area factor for currents, resistances, and capacitances	None	1.0
DTEMP	Difference between capacitor and circuit temperatures	°C	0
M	Multiplier: simulates parallel devices	None	1.0

VBIC99 BJT Instance Netlist Examples

```
Q15 3 4 5 6 bjtvbic99 DTEMP=20
```

Level 9 VBIC99 BJT Model

The .MODEL statement for the Level 9 VBIC99 BJT specifies values for one or more model parameters.

`.MODEL`*`modelname`* **`NPN LEVEL=9`** `[`*`modelparameter`***`=`***`val`*`] ...`

or

`.MODEL`*`modelname`* **`PNP LEVEL=9`** `[`*`modelparameter`***`=`***`val`*`] ...`

Table 58: Level 9 VBIC99 BJT Model Basic Parameters

Model Parameter	Description	Unit	Default
LEVEL	9 is required to select the Level 9 BJT model	None	1 (default if LEVEL parameter is omitted)
ART	Smoothing parameter for reach-through	None	0.1
AVC1	Base-collector avalanche parameter 1	Volt^{-1}	0.0
AVC2	Base-collector avalanche parameter 2	Volt^{-1}	0.0
DEAR	Delta activation energy for ISRR	electron-Volt	0.0
EA	Activation energy for IS	electron-Volt	1.12
EAIC	Activation energy for IBCI/IBEIP	electron-Volt	1.12
EAIE	Activation energy for IBEI	electron-	1.12

		Volt	
EAIS	Activation energy for IBCIP	electron-Volt	1.12
EANC	Activation energy for IBCN/IBENP	electron-Volt	1.12
EANE	Activation energy for IBEN	electron-Volt	1.12
EANS	Activation energy for IBCNP	electron-Volt	1.12
EAP	Activation energy for ISP	electron-Volt	1.12
EBBE	exp(-VBBE / (NBBE × V_{tv}))	None	0.0
GAMM	Epitaxial doping factor	None	0.0
HRCF	High current RC factor	None	0.0
IBBE	Base-emitter breakdown current	Amp	1.0e-6
IBCI	Ideal base-collector saturation current	Amp	1.0e-16
IBCIP	Ideal parasitic base-collector saturation current	Amp	0.0
IBCN	Non-ideal base-collector saturation current	Amp	0.0
IBCNP	Non-ideal parasitic base-collector saturation current	Amp	0.0
IBEI	Ideal base-emitter saturation current	Amp	1.0e-18
IBEIP	Ideal parasitic base-emitter saturation current	Amp	0.0
IBEN	Non-ideal base-emitter saturation current	Amp	0.0
IBENP	Non-ideal parasitic base-emitter saturation current	Amp	0.0
IKF	Forward knee current. Zero represents infinite current.	Amp	0.0
IKP	Parasitic knee current. Zero represents infinite current.	Amp	0.0
IKR	Reverse knee current. Zero represents infinite current.	Amp	0.0

IS	Transport saturation current	Amp	1.0e-16
ISP	Parasitic transport saturation current	Amp	0.0
ISRR	Reverse transport saturation current	Amp	1.0
ITF	Coefficient of TF dependence on Ic	Amp	0.0
LAMBDA			0.0
MC	Base-collector grading coefficient	None	0.33
ME	Base-emitter grading coefficient	None	0.33
MS	Substrate-collector grading coefficient	None	0.33
NBBE	Base-emitter breakdown emission coefficient	None	1.0
NCI	Ideal base-collector emission coefficient	None	1.0
NCIP	Ideal parasitic base-collector emission coefficient	None	1.0
NCN	Non-ideal base-collector emission coefficient	None	2.0
NCNP	Non-ideal parasitic base-collector emission coefficient	None	2.0
NEI	Ideal base-emitter emission coefficient	None	1.0
NEN	Non-ideal base-emitter emission coefficient	None	2.0
NF	Forward emission coefficient	None	1.0
NFP	Parasitic forward emission coefficient	None	1.0
NKF	High-current Beta rolloff parameter	None	0.5
NR	Reverse emission coefficient	None	1.0
PC	Built-in base-collector potential	Volt	0.75
PE	Built-in base-emitter potential	Volt	0.75
PS	Built-in substrate-collector potential	Volt	0.75

QBM	Base charge model selection	None	0.0
QTF	Variant of TF with base-width modulation	Second	0.0
RBI	Intrinsic base resistance	Ohm	1.0e-5
RBP	Parasitic base resistance	Ohm	1.0e-5
RBX	Extrinsic base resistance	Ohm	1.0e-5
RCI	Intrinsic collector resistance	Ohm	1.0e-5
RCX	Extrinsic collector resistance	Ohm	1.0e-5
RE	Emitter resistance	Ohm	1.0e-5
RS	Substrate resistance	Ohm	1.0e-5
TF	Forward transit time	Second	1.0e-11
TNBBE	Temperature coefficient of NBBE	None	0.0
TR	Reverse transit time	Second	1.0e-11
TREF (**TNOM**)	Nominal circuit temperature	°C	25
TVBBE1	Linear temperature coefficient of VBBE	None	0.0
TVBBE2	Quadratic temperature coefficient of VBBE	None	0.0
VBBE	Base-emitter breakdown voltage	Volt	0.0
VEF	Forward early voltage. Zero represents infinite voltage	Volt	0.0
VER	Reverse early voltage. Zero represents infinite voltage	Volt	0.0
VO (**V0**)	Epitaxial drift saturation voltage	Volt	0.0
VRT	Reach-through voltage for Cbc limiting	Volt	0.0
VTF	Coefficient of TF dependence on V_{bc}	Volt	0.0
WBE	Portion of IBEI derived from V_{bei}, (1-WBE) derived from V_{bex}	None	1.0
WSP	Portion of ICCP derived from V_{bep}, (1-WBE) derived from V_{bci}	None	1.0
XTF	Coefficient of TF bias	None	0.0

	dependence		

Table 59: Level 9 VBIC99 BJT Model Capacitance and Charge Parameters

Model Parameter	Description	Unit	Default
AJC	Base-collector capacitance smoothing factor	None	-0.5
AJE	Base-emitter capacitance smoothing factor	None	-0.5
AJS	Substrate-collector capacitance smoothing factor	None	-0.5
CBCO (**CBC0**)	Extrinsic base-collector overlap capacitance	Farad	0.0
CBEO (**CBE0**)	Extrinsic base-emitter overlap capacitance	Farad	0.0
CCSO	Fixed collector-substrate capacitance	Farad	0.0
CJC	Base-collector intrinsic zero-bias capacitance	Farad	0.0
CJCP	Substrate-collector zero-bias capacitance	Farad	0.0
CJE	Base-emitter zero-bias capacitance	Farad	0.0
CJEP	Base-collector extrinsic zero-bias capacitance	Farad	0.0
FC	Forward bias depletion capacitance limit	None	0.9
QCO (**QC0**)	Epitaxial charge parameter	Coulomb	0.0

Table 60: Level 9 VBIC99 BJT Model Temperature Coefficient Parameters

Model Parameter	Description	Unit	Default
TAVC	Temperature exponent of AVC2	$°K^{-1}$	0.0
TNF	Temperature exponent of NF	$°K^{-1}$	0.0
XII	Temperature exponent of IBEI/IBCI/IBEIP/IBCIP	None	3.0
XIKF	Temperature exponent of IKF	None	0.0
XIN	Temperature exponent of IBEN/IBCN/IBENP/IBCNP	None	3.0
XIS	Temperature exponent of IS	None	3.0
XISR	Temperature exponent of ISRR	None	0.0
XRB (**XRBI**)	Temperature exponent of RBI	None	0.0
XRBP	Temperature exponent of parasitic base resistance	None	0.0

XRBX	Temperature exponent of extrinsic base resistance	None	0.0
XRC (**XRCI**)	Temperature exponent of RCI	None	0.0
XRCX	Temperature exponent of extrinsic collector resistance	None	0.0
XRE	Temperature exponent of RE	None	0.0
XRS	Temperature exponent of RS	None	0.0
XVO (**XV0**)	Temperature exponent of VO	None	0.0

Table 61: Level 9 VBIC99 BJT Model Noise Parameters

Model Parameter	**Description**	**Unit**	**Default**
AFN	Base-emitter flicker noise exponent	None	1.0
BFN	Base-emitter flicker noise 1/f dependency	None	1.0
KFN	Base-emitter flicker noise constant	None	0.0

Table 62: Level 9 VBIC99 BJT Model Self-Heating Parameters

Model Parameter	**Description**	**Unit**	**Default**
RTH	Thermal resistance	°K/Ohm	0.0
CTH	Thermal capacitance	Joule/°K	0.0

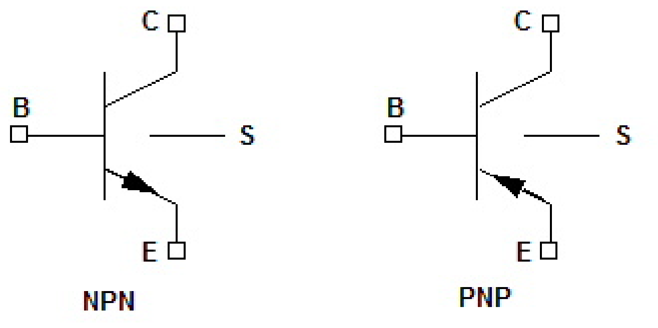
Table 63: Level 9 VBIC99 BJT Model Excess Phase Parameter

Model Parameter	**Description**	**Unit**	**Default**
TD	Forward excess-phase delay time	Second	0.0

VBIC99 BJT Model Netlist Example

```
.MODEL bjtvbic99 NPN LEVEL=9
```

Bipolar Transistor Instance, Philips MODELLA Model (Level 10)



Netlist Syntax

The syntax for a level 10 Philips MODELLA model BJT instance is:

Q*xxxx nc nb ne* [*ns*] *modelname* [**M=***val*] [**DTEMP=***val*]

nc is the collector node, *nb* is the base node, *ne* is the emitter node, and *ns* is the substrate node of the transistor. The *modelname* is the name of a level 10 BJT model defined in a .MODEL statement.

Table 64: Level 10 Philips MODELLA BJT Instance Parameters

Instance Parameter	Description	Unit	Default
M (**MULT**)	Multiplier: simulates parallel transistors	None	1.0
DTEMP (**DTA**)	Difference between capacitor and circuit temperatures	°C	0

Netlist Example

```
Q5 10 11 12 13 bjt24 DTEMP=5
```

Level 10 Philips MODELLA BJT Model

Netlist Form for Level 10 BJT Model

The .MODEL statement for the level 10 Philips MODELLA BJT specifies values for one or more model parameters.

```
.MODELmodelname NPN LEVEL=10 [modelparameter=val] ...
```

or

```
.MODELmodelname PNP LEVEL=10 [modelparameter=val] ...
```

Table 65: Level 10 BJT Model Parameters

Model Parameter	Description	Unit	Default
LEVEL=10	Selects level 10 Philips MODELLA BJT model	None	1
AE	Temperature coefficient of the resistivity of BF	None	4.48
AF	Flicker noise exponent	None	1.0
BF	Ideal forward common-emitter current gain	None	131.0
BR	Ideal reverse common-emitter current gain	None	25.0
CJC	Zero-bias collector-base depletion capacitance	Farad	3.90e-13
CJE	Zero-bias emitter-base depletion capacitance	Farad	6.10e-14
CJS	Zero-bias substrate-base depletion capacitance	Farad	1.30e-12
EAFL	Early voltage of the lateral forward current component at zero collector-base bias	Volt	20.50
EAFV	Early voltage of the vertical forward current component at zero collector-base bias	Volt	75.0
EARL	Early voltage of the lateral reverse current component at zero collector-base bias	Volt	13.10
EARV	Early voltage of the vertical reverse current component at zero collector-base bias	Volt	104.0
EXPHI	Excess phase shift	Radians	0.0
IBF	Saturation current of the non-ideal forward base current	Amp	2.60e-14
IBR	Saturation current of the non-ideal reverse base current	Amp	1.20e-13
IK	High-injection knee current	Amp	1.10e-4
IS	Collector-emitter saturation current	Amp	1.80e-16
ISS	Substrate-base saturation current	Amp	4.00e-13
KF	Flicker noise coefficient	None	0.00
PC	Collector-base grading coefficient	None	0.36
PE	Emitter-base grading coefficient	None	0.30

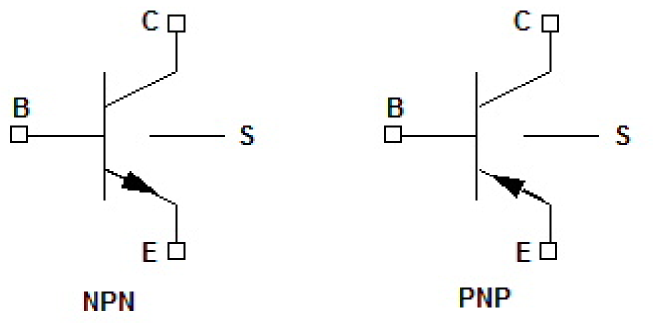
PS	Substrate-base grading coefficient	None	0.35
RBCC	Constant part of base resistance RBC	Ohm	10.00
RBCV	Variable part of base resistance RBC at zero bias	Ohm	10.00
RBEC	Constant part of base resistance RBE	Ohm	10.00
RBEV	Variable part of base resistance RBE at zero bias	Ohm	50.00
RCEX	External part of collector resistance	Ohm	5.00
RCIN	Internal part of collector resistance	Ohm	47.00
REEX	External part of emitter resistance	Ohm	27.00
REIN	Internal part of emitter resistance	Ohm	66.00
RSB	Substrate-base leakage resistance	Ohm	1.00e+15
SNB	Temperature coefficient of the epitaxial base electron mobility	None	2.60
SNBN	Temperature coefficient of buried layer electron mobility	None	0.30
SPB	Temperature coefficient of the epitaxial base hole mobility	None	2.853
SPC	Temperature coefficient of collector hole mobility	None	0.73
SPE	Temperature coefficient of emitter hole mobility	None	0.73
SX	Temperature coefficient of combined minority carrier mobilities in emitter and buried layer	None	1.00
TFN	Low-injection forward transit time due to charge stored in the emitter and the buried layer under the emitter	Second	2.00e-10
TFVR	Low-injection forward transit time due to charge stored in the epilayer under the emitter	Second	3.00e-8
TLAT	Low-injection forward and reverse transit time of charge stored in the epilayer between emitter and collector	Second	2.40e-9
TNOM (**TREF**)	Nominal circuit temperature	°C	25
TRN	Low-injection reverse transit time due to charge stored in the collector and the buried layer under the collector	Second	3.00e-9
TRVR	Low-injection reverse transit time due to charge stored in the epilayer under the collector	Second	1.00e-9
VDC	Collector-base diffusion voltage	Volt	0.57
VDE	Emitter-base diffusion voltage	Volt	0.52
VDS	Substrate-base diffusion voltage	Volt	0.52
VGB	Bandgap voltage of the base between emitter and collector	Volt	1.206

VGCB	Bandgap voltage of the collector-base depletion region	Volt	1.206
VGE	Bandgap voltage of the emitter	Volt	1.206
VGEB	Bandgap voltage of the emitter-base depletion region	Volt	1.206
VGJE	Bandgap voltage recombination emitter-base junction	Volt	1.123
VGSB	Bandgap voltage of the substrate-base depletion region	Volt	1.206
VLF	Cross-over voltage of non-ideal forward base current	Volt	0.54
VLR	Cross-over voltage of non-ideal reverse base current	Volt	0.48
XCS	Ratio between saturation currents of c-b-s transistor and c-b-e transistor	None	3.00
XES	Ratio between saturation currents of e-b-s transistor and e-b-c transistor	None	2.70e-3
XHCS	Fraction of substrate current of c-b-s transistor subject to high injection	None	1.00
XHES	Fraction of substrate current of e-b-s transistor subject to high injection	None	0.70
XIFV	Vertical fraction of forward current	None	0.43
XIRV	Vertical fraction of reverse current	None	0.43

Netlist Example

```
.MODEL bjt34 PNP LEVEL=10 ae=4.48 af=1.0 bf=131.0 br=25.0

+ cjc=3.9e-13 cje=6.10e-14 cjs=1.3e-12 eafl=20.5 eafv=75.0

+ earl=13.1 earv=104.0 exphi=0.0 ibf=2.6e-14 ibr=1.2e-13

+ ik=1.1e-4 is=1.8e-16 iss=4.0e-13 kf=0.0 pc=0.36 pe-0.30

+ ps=0.35 rbcc=10.0 rbcv=10.0 rbec=10.0 rbev=50.0 rcex=5.0

+ rcin=47.0 reex=27.0 rein=66.0 rsb=1e15 snb=2.60 snbn=0.30

+ spb=2.853 spc=0.73 spe=0.73 sx=1.0 tfn=2e-10 tfvr=3e-8

+ tlat=2.4e-9 trn=3e-9 trvr=1e-9 vdc=0.57 vde=0.52 vds=0.52

+ vgcb=1.206 vge=1.206 vgeb=1.206 vgje=1.123 vgsb=1.206

+ vlf=0.54 vlr=0.48 xcs=3.0 xes=2.7e-3 xhcs=1.0 xhes=0.70

+ xivf=0.43 xirv=0.43
```

Bipolar Transistor Instance, UCSD HBT Model (Level 11)



Level 11 HBT Instance Netlist Syntax

The syntax for a level 11 UCSD model heterojunction bipolar transistor (HBT) instance is:

`Qxxxx nc nb ne [ns] [nt] modelname`

`[AREA=val]  [M=val] [TNOM=val] [DTEMP=val] [TNODEOUT]`

nc is the collector node, *nb* is the base node, *ne* is the emitter node, *ns* is the substrate node, and *nt* is the self-heating node of the transistor. The *modelname* is the name of a level 11 BJT model defined in a .MODEL statement elsewhere in the netlist. The **TNODEOUT** flag indicates that node *nt* is present but node *ns* is not present.

Table 66: Level 11 UCSD HBT Instance Parameters

Instance Parameter	Description	Unit	Default
AREA	Emitter area factor for currents, resistances, and capacitances	None	1.0
M	Multiplier: simulates parallel transistors	None	1
TNODEOUT	Flag to indicate that node *nt* is present but node *ns* is not present	None	None
TNOM	Circuit temperature	°C	27
DTEMP	Difference between capacitor and circuit temperatures	°C	0

Level 11 BJT Instance Netlist Example

```
Q15 3 4 5 6 bjthbt11 DTEMP=5
```

Level 11 UCSD HBT Model

Netlist Form for Level 11 HBT Model

The .MODEL statement for the level 11 UCSD HBT specifies values for one or more model parameters.

```
.MODELmodelname NPN LEVEL=11 [modelparameter=val] ...
```

or

```
.MODELmodelname PNP LEVEL=11 [modelparameter=val] ...
```

Table 67: Level 11 UCSD HBT Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	11 is required to select the Level 11 HBT model	None	1 (default if LEVEL parameter is omitted)
AFN	Base-emitter flicker noise current exponent	None	1
BF	Forward ideal current gain	None	10000
BFN	Base-emitter flicker noise frequency exponent	None	1
BKDN	Flag to include base-collector breakdown	None	0
BR	Reverse ideal current gain	None	10000
BVC	Collector-base breakdown voltage BVcbo	Volt	1000
CCMIN	Minimum value of intrinsic base-collector junction capacitance (Cj)	Farad	0.0
CEMIN	Minimum base-emitter capacitance	Farad	0
CJC	Intrinsic base-collector depletion capacitance as zero bias	Farad	0
CJCX	Extrinsic base-collector depletion capacitance as zero bias	Farad	0
CJE	Base-emitter depletion capacitance as zero bias	Farad	0
CJS	Collector-substrate depletion capacitance at zero bias	Farad	0.0

CTH	Thermal capacitance of device	°C/Joule	0
CXMIN	Minimum value of extrinsic base-collector junction capacitance (Cj)	Farad	0.0
DTMAX	Maximum expected temperature rise above heat sink	°C	1000
EAA	Activation energy for ISE temperature dependence	Volt	0.0
EAB	Activation energy for ISC temperature dependence	Volt	0.0
EAC	Activation energy for ISB temperature dependence	Volt	0.0
EAE	Activation energy for ISA temperature dependence	Volt	0.0
EAX	Activation energy for ISEX temperature dependence	Volt	0.0
EG	Activation energy for IS temperature dependence	Volt	1.5
FA	Factor for specification of avalanche voltage	None	0.9
FC	Factor for start of high-bias base-collector junction capacitance (Cj) approximation	None	0.8
FCE	Factor for start of high-bias base-emitter junction capacitance (Cj) approximation	None	0.8
FEX	Factor to determine excess phase	None	0.0
ICRIT0	Critical current for intrinsic junction capacitance (Cj) variation	Amp	1.0e+3
ICS	Saturation value for collector-substrate current	Amp	1.0e-30
IK	Knee current for DC high-injection effect	Amp	1.0e+10
IKRK	Characteristic current for Kirk effect	Amp	1.0e3
IS	Saturation value for forward collector current	Amp	1.0e-25
ISA	Collector current emitter-base barrier limiting current	Amp	1.0e+10
ISB	Collector current base-collector barrier limiting current	Amp	1.0e+10
ISC	Saturation value for intrinsic base-collector junction current	Amp	1.0e-30
ISCX	Saturation value for extrinsic base-collector	Amp	1.0e-30

	junction current		
ISE	Saturation value for non-ideal forward base current	Amp	1.0e-30
ISEX	Saturation value for emitter leakage diode	Amp	1.0e-30
ITC	Characteristic current for TFC	Amp	0.0
ITC2	Characteristic current for TFC	Amp	0.0
KFN	Base-emitter flicker noise constant	None	0.0
MJC	Exponent for voltage variation of intrinsic base-collector junction capacitance (Cj)	None	0.33
MJCX	Exponent for voltage variation of extrinsic base-collector junction capacitance (Cj)	None	0.33
MJE	Exponent for voltage variation of base-emitter junction capacitance (Cj)	None	0.5
MJS	Exponent for voltage variation of intrinsic collector-substrate junction capacitance (Cj)	None	0.5
NA	Collector current emitter-base barrier ideality factor	None	2
NB	Collector current base-collector barrier ideality factor	None	2
NBC	Exponent for base-collector multiplication factor vs voltage	None	8
NC	Ideality factor for intrinsic base-collector junction current	None	2
NCS	Ideality factor for collector-substrate current	None	2
NCX	Ideality factor for extrinsic base-collector junction current	None	2
NE	Ideality factor for non-ideal forward base current	None	2
NEX	Ideality factor for emitter leakage diode	None	2
NF	Ideality factor for forward collector current	None	1.0
NR	Ideality factor for reverse collector current	None	1.0
RBI	Intrinsic base resistance	Ohm	0
RBX	Extrinsic base resistance	Ohm	0
RCI	Intrinsic collector resistance	Ohm	0
RCX	Extrinsic collector resistance	Ohm	0
RE	Emitter resistance	Ohm	0

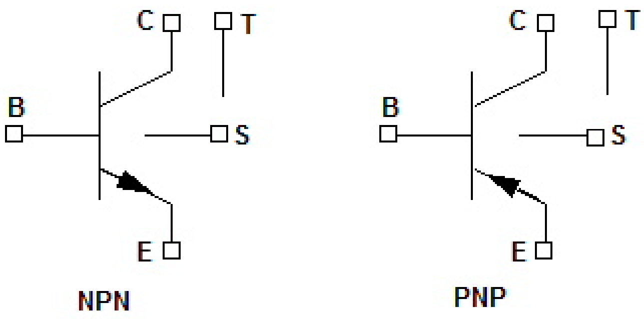
REX	Extrinsic emitter leakage diode series resistance	Ohm	0
RTH	Thermal resistance from device to thermal ground	°C/Watt	0.0
SELFT	Flag to enable self-heating effect calculations (0 = disable self-heating, 1 = enable self-heating)	None	0
TBCXS	Excess base-collector heterojunction transit time	Second	0
TBEXS	Excess base-emitter heterojunction transit time	Second	0
TFB	Base forward transit time	Second	0
TFC0	Collector forward transit time	Second	0
TKRK	Forward transit time for Kirk effect	Second	0.0
TNC	NC temperature dependence coefficient	None	0.0
TNE	NE temperature dependence coefficient	None	0.0
TNEX	NEX temperature dependence coefficient	None	0.0
TNOM (**TREF**)	Reference temperature	°C	27
TR	Reverse charge storage time, intrinsic base-collector diode	Second	0.0
TRX	Reverse charge storage time, extrinsic base-collector diode	Second	0.0
TVJC	VJC temperature dependence coefficient	Volt/°C	0.0
TVJCX	VJCX temperature dependence coefficient	Volt/°C	0.0
TVJE	VJE temperature dependence coefficient	Volt/°C	0.0
TVJS	VJS temperature dependence coefficient	Volt/°C	0.0
VAF	Forward early voltage	Volt	1000
VAR	Reverse early voltage	Volt	1000
VJC	Intrinsic base-collector diode built-in potential for junction capacitance (Cj) estimation	Volt	1.4
VJCX	Extrinsic base-collector diode built-in potential for junction capacitance (Cj) estimation	Volt	1.4
VJE	Base-emitter diode built-in potential for junction capacitance (Cj) estimation	Volt	1.6
VJS	Intrinsic collector-substrate diode built-in potential for junction capacitance (Cj) estimation	Volt	1.4

VKRK	Characteristic voltage for Kirk effect	Volt	1.0e3
VTC	Characteristic voltage for TFC	Volt	1.0e3
XCJC	Factor for partitioning extrinsic base-collector junction capacitance (Cj)	None	1.0
XRB	RB temperature dependence exponent	None	0
XRC	RC temperature dependence exponent	None	0
XRE	RE temperature dependence exponent	None	0
XREX	REX temperature dependence exponent	None	0
XRT	Temperature exponent of RTH	None	0.0
XTB	Beta temperature dependence exponent	None	2
XTI	IS temperature dependence exponent	None	2
XTIKRK	IKRK temperature dependence exponent	None	0
XTITC	ITC temperature dependence exponent	None	0
XTITC2	ITC2 temperature dependence exponent	None	0
XTTF	TF temperature dependence exponent	None	0
XTTKRK	TKRK temperature dependence exponent	None	0
XTVKRK	VKRK temperature dependence exponent	None	0

Level 11 BJT Model Netlist Example

```
.MODEL bjthbt11 PNP LEVEL=11
```

Bipolar Transistor Instance, HiCUM L0 Model (Level 13)



Netlist Syntax

The syntax for a level 13 HiCUM L0 model BJT instance is:

Q*xxxx nc nb ne* [*ns*] [*nt*] *modelname* [**AREA=***val*]

[**M=***val*] [**DTEMP=***val*] [**TNODEOUT**]

nc is the collector node, *nb* is the base node, *ne* is the emitter node, *ns* is the substrate node, and *nt* is the self-heating node of the transistor. The *modelname* is the name of a level 8 BJT model defined in a .MODEL statement elsewhere in the netlist. The **TNODEOUT** flag indicates that node *nt* is present but node *ns* is not present.

Table 68: Level 13 HiCUM BJT Instance Parameters

Instance Parameter	Description	Unit	Default
AREA	Emitter area factor for currents, resistances, and capacitances	None	1.0
M	Multiplier: simulates parallel transistors	None	1
TNOM	Circuit temperature	°C	27
DTEMP	Difference between capacitor and circuit temperatures	°C	0
TNODEOUT	Flag to indicate that node *nt* is present but node *ns* is not present	None	None

Netlist Example

```
Q21 22 33 44 bjth13 DTEMP=5
```

Level 13 HiCUM L0 BJT Model

Netlist Form for Level 13 BJT Model

The .MODEL statement for the level 13 HiCUM L0 BJT specifies values for one or more model parameters.

.MODEL*modelname* **NPN LEVEL=13** [*modelparameter***=***val*] ...

or

.MODEL*modelname* **PNP LEVEL=13** [*modelparameter***=***val*] ...

Table 69: Level 13 BJT Model Basic Parameters

Model	Description	Unit	Default

Parameter			
LEVEL=13	Selects level 13 HiCUM L0 BJT model	None	1
MCF	Base-collector depletion charge weighting factor for Qjci in HBTs		1.0
CJCI0	Internal base-collector zero-bias depletion capacitance	Farad	1e-20
VDCI	Internal base-collector built-in potential	Volt	0.7
ZCI	Internal base-collector grading coefficient		0.333
VPTCI	Internal base-collector punch-through voltage	Volt	100.0
T0	Low-current forward transit time at Vbc=0	Second	0.0
DT0H	Time constant for base and base-collector space charge layer width modulation	Second	0.0
TBVL	Time constant for modelling carrier jam at low Vce	Second	0.0
TEF0	Neutral emitter storage time	Second	0.0
GTE	Exponent factor for current dependence of TEF0		1.0
THCS	Saturation time constant at high current densities	Second	0.0
AHC	Smoothing factor for current dependence of base-collector transit time		0.1
RCI0	Internal collector resistance at low electric field	Ohm	150.0
VLIM	Voltage separating ohmic and saturation velocity regime	Volt	0.5
VPT	Collector punch-through voltage	Volt	100.0
VCES	Internal collector-emitter saturation voltage	Volt	0.1
TR	Storage time for inverse operation	Second	0.0
RBI0	Zero-bias internal base resistance	Ohm	0.0
FGEO	Factor for geometry dependence of emitter current crowding		0.656
CJCX0	External base-collector zero-bias depletion capacitance	Farad	1e-20
VDCX	External base-collector built-in potential	Volt	0.7
ZCX	External base-collector grading coefficient		0.333
VPTCX	External base-collector punch-through voltage	Volt	100.0
FBC	Partitioning factor for external base-collector capacitance		1.0

RBX	External base series resistance	Ohm	0.0
RE	Emitter series resistance	Ohm	0.0
RCX	External collector series resistance	Ohm	0.0
ISCS	Saturation current of collector-substrate diode	Ampere	0.0
MSC	Ideality factor of collector substrate diode current		1.0
CJS0	Collector-substrate zero-bias depletion capacitance	Farad	1.0e-20
VDS	Collector-substrate built-in potential	Volt	0.3
ZS	Collector-substrate grading coefficient		0.3
VPTS	Collector-substrate punch-through voltage	Volt	100.0
KF	Flicker noise coefficient		0.0
AF	Flicker noise exponent factor		2.0
VGB	Band-gap voltage extrapolated to 0°K	Volt	1.2
ALT0	First-order relative temperature coefficient of parameter T0	1/°K	0.0
KT0	Second-order relative temperature coefficient of parameter T0	1/°K^2	0.0
ZETACI	Temperature coefficient for RCI0		0.0
ALVS	Relative temperature coefficient of saturation drift velocity	1/°K	0.0
ALCES	Relative temperature coefficient of VCES	1/°K	0.0
ZETARBI	Temperature exponent of internal base resistance		0.0
ZETARBX	Temperature exponent ofexternal base resistance		0.0
ZETARCX	Temperature exponent of external collector resistance		0.0
ZETARE	Temperature exponent of emitter resistance		0.0
ALKAV	Relative temperature coefficient for avalanche breakdown KAVL	1/°K	0.0
ALEAV	Relative temperature coefficient for avalanche breakdown EAVL	1/°K	0.0
TNOM	Temperature at which parameters are specified	°C	27.0
RTH	Thermal resistance	°K/Watt	0.0
CTH	Thermal capacitance	Watt-second/°K	0.0
MINR	Minimum resistance	Ohm	0.001

IS	Ideal saturation current	Ampere	1.0e-16
MCR	Non-ideality coefficient of forward collector current		1.0
VEF	Forward Early voltage (normalization voltage)	Volt	
IQF	Forward DC high-injection roll-off current	Ampere	
IQR	Inverse DC high-injection roll-off current	Ampere	
IQFH	High-injection correction current	Ampere	
TFH	High-injection correction factor		
IBES	Base-emitter saturation current	Ampere	1.0e-18
MBE	Base-emitter non-ideality factor		1.0
IRES	Base-emitter recombination saturation current	Ampere	0.0
MRE	Base-emitter recombination non-ideality factor		2.0
IBCS	Base-collector saturation current	Ampere	0.0
MBC	Base-collector non-ideality factor		1.0
CJE0	Zero-bias base-emitter depletion capacitance	Farad	1.0e-20
VDE	Base-emitter built-in voltage	Volt	0.9
ZE	Base-emitter exponent factor		0.5
AJE	Ratio of maximum to zero-bias value		2.5
VR0E	Forward Early voltage (normalization voltage)	Volt	2.5
VROC	Forward Early voltage (normalization voltage)	Volt	
CBCPAR	Collector-base isolation (overlap) capacitance	Farad	0.0
CBEPAR	Emitter-base oxide capacitance	Farad	0.0
EAVL	Exponent factor for collector-base avalanche effect		0.0
KAVL	Prefactor for collector-base avalanche effect		0.0
VGE	Effective emitter bandgap voltage	Volt	1.17
VGC	Effective collector bandgap voltage	Volt	1.17
VGS	Effective substrate bandgap voltage	Volt	1.17
F1VG	Coefficient K1 in temperature-dependent bandgap equation		-1.02377e-4
F2VG	Coefficient K2 in temperature-dependent bandgap equation		4.3215e-4
ZETACT	Exponent coefficient in transfer current temperature dependence		3.0
ZETABET	Exponent coefficient in Base-emitter junction current		3.5

	temperature dependence		
ITSS	Substrate transistor transfer saturation current	Ampere	0.0
MSF	Substrate transistor transfer current non-ideality factor		1.0
FLSH	Flag for self-heating	None	0.0

3 - Capacitors

This topic describes the following capacitors:

"Capacitor" below

"Capacitor Device" on the next page

"Capacitor Device Model" on page 3-4

"Capacitor, Polynomial" on page 3-5

"Polynomial Capacitor Model" on page 3-5

"Capacitor with Q Factor" on page 3-6

"Chip Capacitor, Dissipation Factor" on page 3-7

"Chip Capacitor, Q Factor" on page 3-8

"Chip Capacitor, ESR" on page 3-9

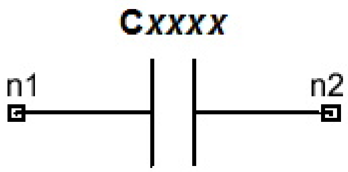
"Capacitor, Expression-Based (Netlist Only)" on page 3-10

"Expression-Based Capacitor Model (Netlist Only)" on page 3-12

"Capacitor, Frequency-Dependent (Netlist Only)" on page 3-12

"Capacitor Model, Frequency-Dependent (Netlist Only)" on page 3-14

Capacitor



This basic capacitor is available in the **Electronics Desktop** Schematic Editor. The basic capacitor has only the capacitance (**C**) parameter, and does not have a corresponding capacitor model. Netlist versions should use the "Capacitor Device" on the next page instance.

The syntax for the basic capacitor instance is:

```
Cxxxx n1 n2 [[C=]val]
```

n1 is the positive node and *n2* is the negative node of the capacitor. The capacitance defaults to 1e-12 Farads.

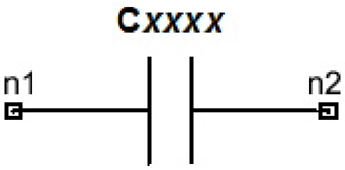
An expression can be used for the capacitance value. In a netlist, the Nexxim expression parser handles the expression. See *Names, Number, Constructs, and Expressions* in the Circuit Design Technical Notes for information on expressions in Nexxim. From the component Properties window in AED, an internal parser handles the expression. See *Displaying and Editing Component Properties* in the **Schematic Editor** topic for information on expressions in the Property window.

In a Nexxim netlist, the expression for capacitance can include the special token 'HERTZ' denoting the operating frequency. When this token is detected, Nexxim uses the "Capacitor, Frequency-Dependent (Netlist Only)" on page 3-12 rather than the simple capacitor. From the component Property window, use the special token 'f' (or 'F') to designate the frequency. When the **Electronics Desktop** internal parser sees 'f' or 'F' in the expression, it converts the token to 'HERTZ' and passes the expression to the netlist where it is handled by the Nexxim expression parser, and Nexxim uses the frequency-dependent capacitor definition.

Capacitor Netlist Example

```
C1 1 2
```

Capacitor Device



Capacitor Device Instance Netlist Syntax

The syntax for a capacitor device instance is:

```
Cxxxx n1 n2 [modelname] [[C=]val] [[TC1=]val] [[TC2=]val]
[M=val] [L=val] [W=val] [DTEMP=val]
[SCALE=val] [IC=val] [Rser=val]  [Lser=val]
[Rpar=val] [Cpar=val] [RLshunt=val]
```

n1 is the positive node and *n2* is the negative node of the capacitor. The current is assumed to flow from *n1* through the capacitor to **n2**. The *modelname* is the name of a .MODEL statement associated with the instance.

In the syntax above, both *modelname* and the capacitance value are shown as optional, but at least one of the two must be supplied. The label **C=** is optional, but the presence or absence of the **C=** label affects the interpretation of other unlabeled entries in the statement. The first unlabeled value after a *modelname* is taken to be the capacitance value.

> **Note:**
>
> treating the branch as an open circuit, and a warning is issued.

The syntax above shows the labels **TC1=** and **TC2=** as optional, but this option depends on the presence or absence of the capacitance value, labeled or unlabeled.

- When the *modelname* is present without a capacitance value, the label **TC1=** or **TC2=** must be used.
- When both *modelname* and the capacitance value are present but the capacitance value does not have the **C=** label, the next two unlabeled values are taken to be **TC1**, then **TC2**. To specify a value for **TC2**, either a value for **TC1** must be given as well, or the label **TC2=** must be used.
- When the capacitance value is present with the **C=** label, the labels**TC1=** and **TC2=** are required.

All instance parameters except **C** and **IC** can also be entered as model parameters. When a parameter has both an instance value and a model value, the instance value prevails.

Table 68: Capacitor Instance Parameters

Instance Parameter	Description	Unit	Default
C	Capacitance	Farad	Calculated from geometry or set to CAP (model parameter)
DTEMP	Difference between capacitor and circuit temperatures	Celsius	0.0
IC	Initial voltage across capacitor	Volt	None
L	Capacitor length	Meter	0.0
M	Multiplier to simulate parallel capacitors	None	1.0
SCALE	Scale factor	None	1.0
TC1	1st-order temperature coefficient	$^{\circ}K^{-1}$	0.0
TC2	2nd-order temperature coefficient	$^{\circ}K^{-2}$	0.0

W	Capacitor width	Meter	0.0
Rser	Series resistance	Ohm	0.0
Lser	Series inductance	Henry	0.0
Rpar	Parallel resistance. For power electronics simulations where PSPICE import is used, a default **Rpar** is used if a value is not provided.	Ohm	$1/(G_{farad}*\mathbf{C})$
Cpar	Parallel capacitance	Farad	0.0
RLshunt	Parallel resistance of Lser	Ohm	Calculated from geometry

Capacitor Device Netlist Example

```
C1 3 4 C=5PF
```

```
C2 5 6 C=5PF TC1=0.01
```

Capacitor Device Model

The .MODEL statement for the capacitor device specifies values for one or more model parameters.

```
.MODEL modelname C [modelparameter=val] ...
```

Table 69: Capacitor Model Parameters

Model Parameter	Description	Unit	Default
CAP	Default capacitance value	Farad	0.0
CAPSW	Sidewall fringing capacitance	Farad/Meter	0.0
COX	Bottomwall capacitance	Farad/Meter 2	0.0
DEL	Difference between actual dimensions (length and width) and drawn dimensions	Meter	0.0
DI	Relative dielectric constant	None	0.0
SCALM	Model parameter scaling factor	None	1.0
SHRINK	Reduction scale factor	None	1.0
THICK	Dielectric insulator thickness	Meter	0.0

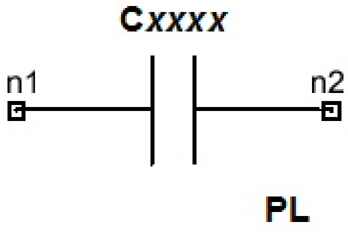
TNOM	Nominal device temperature	°C	25.0

Capacitor Model Netlist Example

```
C5 7 8 MYCAP 2PF
```

```
.MODEL MYCAP C TC1=0.02 TC2=0.005 TNOM=27
```

Capacitor, Polynomial



For the polynomial capacitor, the capacitance is defined by a polynomial function of the voltage across it.

Polynomial Capacitor Netlist Syntax

The format for a polynomial-based capacitor is:

```
Cxxxx n1 n2 [modelname] POLYc0 c1 ...
[instance_parameter=val] ...
```

The **POLY** keyword is required for this type of capacitor syntax. The entries *c0*, *c1*, ... are the polynomial coefficients of the capacitance given by C = $c0 + c1*v + c2*v^2$... , where *v* is the voltage difference across the capacitor.

The instance parameters for the polynomial capacitor are the same as for the expression-based capacitor, except for the **CTYPE** parameter, which is specific to the expression-based capacitor.

Polynomial Capacitor Netlist Example

```
C5 9 10 POLY MYCAPP 1.5 1.0 0.5
```

Polynomial Capacitor Model

The .MODEL statement syntax for the polynomial capacitor specifies values for one or more model parameters.

```
.MODELmodelname C [modelparameter=val] ...
```

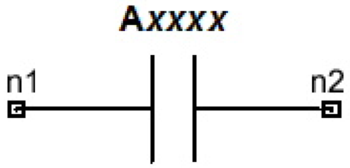
Table 70: Polynomial Capacitor Model Parameters

Instance Parameter	Description	Unit	Default
TC1	1st-order temperature coefficient	°K^{-1}	0.0
TC2	2nd-order temperature coefficient	°K^{-2}	0.0
TNOM	Nominal temperature	°C	25

Polynomial Capacitor Model Netlist Example

```
.MODEL MYCAPP C TC1=0.02 TC2=0.005 TNOM=27
```

Capacitor with Q Factor



Capacitor with Q Factor Instance Netlist Syntax

The syntax for a capacitor with Q factor instance is:

```
Axxxx n1 n2 [C=val] [Q=val] [EXP=val] [F=val]
[DTEMP=val] [TC1=val] [TC2=val] [M=val] COMPONENT=capacitor_q
```

n1 is the positive node and *n2* is the negative node of the capacitor. The current is assumed to flow from *n1* through the capacitor to *n2*. The **COMPONENT=capacitor_q** entry identifies the component as a capacitor with Q factor.

Table 71: Capacitor with Q Factor Instance Parameters

Instance Parameter	Description	Unit	Default
C	Capacitance	Farad	1.0e-11
DTEMP	Difference between capacitor and circuit temperatures	Celsius	0.0

EXP	Q exponent. Must be positive (>=0)	None	0.5
F	Reference frequency at which Q is specified	Hertz	1.0e9
M	Multiplier to simulate parallel capacitors	None	1.0
Q	Quality factor at reference frequency	None	300.0
TC1	1st-order temperature coefficient	$^\circ K^{-1}$	0.0
TC2	2nd-order temperature coefficient	$^\circ K^{-2}$	0.0

Capacitor with Q Factor Netlist Example

```
A12 3 4 C=5e-12 Q=240 F=2e9 COMPONENT=capacitor_q
```

Technical Notes

The frequency-dependent Q Factor is calculated by:

$$Q(f) = Q(f_{ref})\left(\frac{f_{ref}}{f}\right)^{EXP}$$

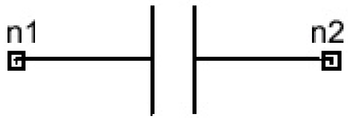
Where f_{ref} is the reference frequency given by instance parameter **F**, $Q(f_{ref})$ is the Q factor at the reference frequency given by instance parameter **Q,** and the exponent *EXP* is the instance parameter **EXP**. EXP=0 results in constant Q. EXP=1 results in constant resistance. Calculation of S-parameters with EXP=0 has been made analytically causal. For other values of EXP (>0), Nexxim does not guarantee causality.

The temperature-dependent effective capacitance is calculated by:

$$C_{eff} = \mathbf{C} \times \mathbf{M} \times (1.0 + \mathbf{TC1} \times \mathbf{DTEMP} + \mathbf{TC2} \times \mathbf{DTEMP}^2)$$

Where **C**, **M**, **TC1**, **TC2**, and **DTEMP** are the instance parameters.

Chip Capacitor, Dissipation Factor



Netlist Syntax

The syntax for a chip capacitor with dissipation factor is:

A*xxxx n1 n2* [**C=***val]* [**FRES=***val*] [**DF=***val*] [**FDF=***val*][**F=***val*]
[**TEMP=***val*] [**TC=***val*] **COMPONENT=chipcapd**

n1 is the positive node and *n2* is the negative node of the capacitor. The current is assumed to flow from *n1* through the capacitor to *n2*. The **COMPONENT=chipcapd** entry identifies the component as a chip capacitor with dissipation factor (DF).

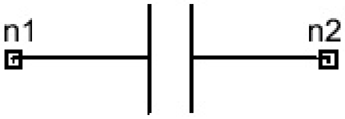
Table 72: Chip Capacitor with DF Factor Instance Parameters

Instance Parameter	Description	Unit	Default
C	Chip capacitance	Farad	1.0e-12
TEMP	Device temperature	Celsius	25.0
FDF	Reference frequency at which DF is specified	Hertz	1.0e9
FRES	Self-resonant frequency	Hertz	1.0e9
DF	Dissipation factor at reference frequency	None	0.0
TC	Temperature coefficient	Celsius	0.0

Chip Capacitor, Dissipation Factor Netlist Example

```
A12 3 4 C=5e-12 DF=0.1 FDF=2e9 COMPONENT=chipcapd
```

Chip Capacitor, Q Factor



Netlist Syntax

The syntax for a chip capacitor with Q factor is:

A*xxxx n1 n2* [**C=***val*] [**FRES=***val*] [**Q=***val*] [**FDF=***val*][**F=***val*]
[**TEMP=***val*] [**TC=***val*] **COMPONENT=chipcapq**

n1 is the positive node and *n2* is the negative node of the capacitor. The current is assumed to flow from *n1* through the capacitor to *n2*. The **COMPONENT=chipcapq** entry identifies the component as a capacitor with Q factor.

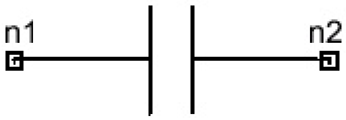
Table 73: Chip Capacitor with Q Factor Instance Parameters

Instance Parameter	Description	Unit	Default
C	Chip capacitance	Farad	1.0e-12
TEMP	Device temperature	Celsius	25.0
FQ	Reference frequency at which DF is specified	Hertz	1.0e9
FRES	Self-resonant frequency	Hertz	1.0e9
Q	Quality factor at reference frequency	None	300
TC	Temperature coefficient	Celsius	0.0

Chip Capacitor, Q Factor Netlist Example

```
A12 3 4 C=5e-12 Q=100 FDF=2e9 COMPONENT=chipcapq
```

Chip Capacitor, ESR



Netlist Syntax

The syntax for a chip capacitor with ESR is:

A*xxxx n1 n2* [**C=***val*] [**FRES=***val*] [**ESR=***val*] [**FDF=***val*][**F=***val*]
[**TEMP=***val*] [**TC=***val*] **COMPONENT=chipcapr**

n1 is the positive node and *n2* is the negative node of the capacitor. The current is assumed to flow from *n1* through the capacitor to *n2*. The **COMPONENT=chipcapr** entry identifies the component as a chip capacitor with ESR.

Table 74: Chip Capacitor with ESR Instance Parameters

Instance Parameter	Description	Unit	Default

C	Chip capacitance	Farad	1.0e-12
TEMP	Device temperature	Celsius	25.0
FESR	Reference frequency at which ESR is specified	Hertz	1.0e9
FRES	Self-resonant frequency	Hertz	1.0e9
ESR	Effective series resistance at reference frequency	Ohm	0
TC	Temperature coefficient	Celsius	0.0

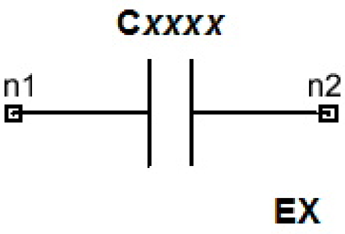
Chip Capacitor, ESR Netlist Example

```
A12 3 4 C=5e-12 ESR=50 FESR=2e9 COMPONENT=chipcapr
```

Notes

1. This chip capacitor employs an internal model that is noncausal. The noncausal model can lead to fitting problems during transient analysis.

Capacitor, Expression-Based (Netlist Only)



For the expression-based capacitor, the charge is defined by an expression.

Expression-Based Capacitor Netlist Syntax

The equation-based capacitor has the format:

```
Cxxx n1 n2 [modelname] Q= 'expression' [CTYPE=val]
[instance_parameter=val] ...
```

The *expression* (enclosed in single quotes) defines the capacitor charge Q as a function of voltages in the circuit. The equivalent capacitance is then obtained using the differential equation:

$$C = \frac{dQ}{dV}$$

The capacitance calculation is controlled by the **CTYPE** parameter. If Q is a function only of its terminal voltages V(*n1*, *n2*), set **CTYPE** =0 (the default). Otherwise, set **CTYPE** =1.

> **Note:** The expression-based capacitor and its corresponding model are available for use in netlists, but are not supported in the Components window of the **Electronics Desktop Schematic Editor**.

An alternative syntax is accepted:

```
Cxxx n1 n2 [modelname] [C=]'expression' [CTYPE=val]
[instance_parameter=val] ...
```

Specifying the capacitance directly in the expression can lead to formulations that do not conserve charge, especially if the relationship between capacitance and voltage is nonlinear.

> **Note:** If a capacitance expression contains a voltage dependency, and the expression is not in the form **Q=** '*expression*', Nexxim issues the following warning: capacitance based expression worsens convergence. Replace with charge based expression if possible.

Table 75: Expression-Based Capacitor Instance Parameters

Instance Parameter	Description	Unit	Default
CTYPE	0: Charge is a function of terminal voltages only 1: Charge is a function of one or more voltages other than the terminal voltages	None	0
DTEMP	Difference between capacitor and circuit temperatures	Celsius	0.0
M	Multiplier to simulate parallel capacitors	None	1.0
SCALE	Scale factor	None	1.0
TC1	1st-order temperature coefficient	$°K^{-1}$	0.0
TC2	2nd-order temperature coefficient	$°K^{-2}$	0.0

Expression-Based Capacitor Netlist Example

```
C21 54 55 Q='cos(V(54,55))' CTYPE=0
```

The example above calculates the capacitance as the derivative of the Q-expression with respect to V(54,55).

Expression-Based Capacitor Model (Netlist Only)

The .MODEL statement syntax for the expression-based capacitor specifies values for one or more model parameters.

```
.MODELmodelname C [modelparameter=val] ...
```

Table 76: Expression-Based Capacitor Model Parameters

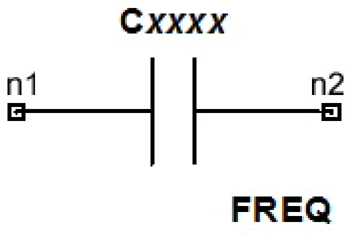
Instance Parameter	Description	Unit	Default
TC1	1st-order temperature coefficient	°K^{-1}	0.0
TC2	2nd-order temperature coefficient	°K^{-2}	0.0
TNOM	Nominal temperature	°C	25

> **Note:** The expression-based capacitor and its corresponding model are available for use in netlists, but are not supported in the Components window of the **Electronics Desktop Schematic Editor**.

Expression-Based Capacitor Model Netlist Example

```
.MODEL MYCAPEX C TC1=0.02 TC2=0.005 TNOM=27
```

Capacitor, Frequency-Dependent (Netlist Only)



Instead of the standard capacitor syntax with a specified capacitance value, define the capacitance by an expression involving the frequency, using the syntax given in this topic.

> **Note:** The frequency-dependent capacitor is available for use in netlists.
>
> The frequency-dependent capacitor is supported only for frequency-domain analyses such as AC and LNA. To run a time-domain analysis such as TRAN on a circuit including a frequency-dependent capacitor, set the **TRAN_EVAL_FREQ** parameter to a constant frequency value.

Frequency-Dependent Capacitor Instance Netlist Syntax

The general form for a frequency-dependent capacitor instance is:

```
Cxxxx n1 n2 [modelname] [C=]'freq_dependent_expr'

[M=val] [DTEMP=val] [TRAN_EVAL_FREQ=val]
```

n1 is the positive node and *n2* is the negative node of the capacitor. The current is assumed to flow from *n1* through the capacitor to *n2*. If a model statement is provided for the capacitor, the *modelname* is its name. The *modelname* is identified by matching it to the **.MODEL** statements in the netlist.

The frequency-dependent expression should be enclosed in single quotation marks. The token **HERTZ** can be used in the expression to indicate the frequency as supplied by the analysis. The circuit frequency is available to the model each time the model equations are evaluated. The label **C=** is optional. The first unlabeled value after a *modelname* is taken to be the capacitance.

The frequency-dependent capacitance expression is evaluated by the Nexxim expression parser, and follows the rules for operands defined in *Names, Number, Constructs, and Expressions* in the Circuit Design Technical Notes. In particular, the Nexxim parser cannot accept complex numbers as operands or arguments to built-in functions.

When the parameter **TRAN_EVAL_FREQ** is provided, Nexxim can run a transient (time-domain) analysis, substituting the value of **TRAN_EVAL_FREQ** for the variable **HERTZ** to produce a constant freqeuncy value for the transient analysis.

Table 77: Frequency-Dependent Capacitor Instance Parameters

Instance Parameter	Description	Unit	Default
C	Capacitance	Farad	Calculated from frequency expression
DTEMP	Difference between capacitor and circuit temperatures	Celsius	0.0
M	Multiplier to simulate parallel capacitors	None	1.0
TRAN_EVAL_FREQ	Frequency to use for transient analysis	Hertz	0.0

Frequency-Dependent Capacitor Netlist Examples

Frequency-domain analysis:

```
C1 1 2 capacitorF1 C='1e-12*sqrt(HERTZ)' M=2

.LNA LIN 100 1e6 10e6

.MODEL capacitorF1 C TC1=0.1 TC2=0.05
```

Time-domain analysis:

```
C23 11 22 capacitorF1 C='1e-12*sqrt(HERTZ)' TRAN_EVAL_FREQ=1e8

.TRAN -.01ns 10ns

.MODEL capacitorF1 C TC1=0.1 TC2=0.05
```

Capacitor Model, Frequency-Dependent (Netlist Only)

The .MODEL statement syntax for the frequency-dependent capacitor specifies values for one or more model parameters.

.MODEL modelname **C** [**TC1=***val*] [**TC2=***val*] [**M=***val*] [**SCALE=***val*]

[**DTEMP=***val*] [**TNOM=***val*]

Table 78: Frequency-Dependent Capacitor Model Parameters

Instance Parameter	Description	Unit	Default
DTEMP	Difference between capacitor and circuit temperatures	Celsius	0.0
M	Multiplier to simulate parallel capacitors	None	1.0
SCALE	Scale factor	None	1.0
TC1	1st-order temperature coefficient	$°K^{-1}$	0.0
TC2	2nd-order temperature coefficient	$°K^{-2}$	0.0
TNOM (**TREF**)	Nominal temperature	°C	25

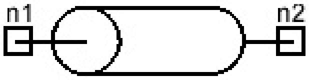
Frequency-Dependent Capacitor Model Netlist Example

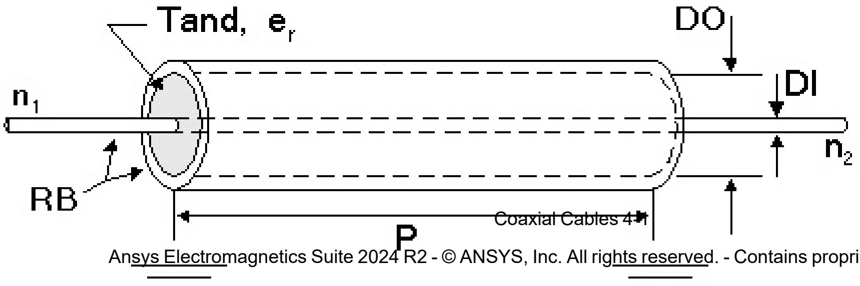
```
.MODEL capacitorF1 C TC1=0.1 TC2=0.05
```

4 - Coaxial Cables

This topic describes the following Nexxim coaxial cable elements:

Coaxial Cable, Physical Model





Coaxial Cable Netlist Format

The netlist syntax for a coaxial cable, physical model is:

```
Axxxx n1 n2 COMPONENT=coax_cable_physical

 + DI=val DO=val P=val ER=val TAND=val RB=val
```

n1 and *n2* are the nodes attached to the cable. The entry **COMPONENT=coax_cable_physical** is required.

Table 12: Coaxial Cable, Physical Model Parameters

Parameter	Description	Unit	Default
DI	Diameter of inner conductor	Meter	2.54e-4
DO	Inner diameter of outer conductor	Meter	1.016e-3
P	Physical length of cable	Meter	0.0127
ER	Dielectric constant of the insulator	None	1.0
TAND	Dielectric loss tangent of the insulator	None	0.0
RB	Conductor resistivity	µOhm-cm	0.0

Coaxial Cable, Physical Model Netlist Example

```
Acable1 net_34 net_27 DI=0.001 DO=0.003 P=.10
+ ER=2.1 TAND=0.002 RB=1.64 component=coax_cable_physical
```

Notes

1. Applicable for TEM mode .

Coaxial Cable, Physical Model with Reference

Coaxial Cable Netlist Format

The netlist syntax for a coaxial cable, physical model with reference is:

```
Axxxx n1 n2 n3 n4 COMPONENT=coax_cable_physical

 + DI=val DO=val P=val ER=val TAND=val RB=val
```

n1 and *n2* are the nodes attached to the cable. *n3* and *n4* are the reference nodes. The entry **COMPONENT=coax_cable_physical** is required.

Table 13: Coaxial Cable, Physical Length with Reference Parameters

Parameter	Description	Unit	Default
DI	Diameter of inner conductor	Meter	2.54e-4
DO	Inner diameter of outer conductor	Meter	1.016e-3
P	Physical length of cable	Meter	0.0127
ER	Dielectric constant of the insulator	None	1.0
TAND	Dielectric loss tangent of the insulator	None	0.0
RB	Conductor resistivity	µOhm-cm	0.0

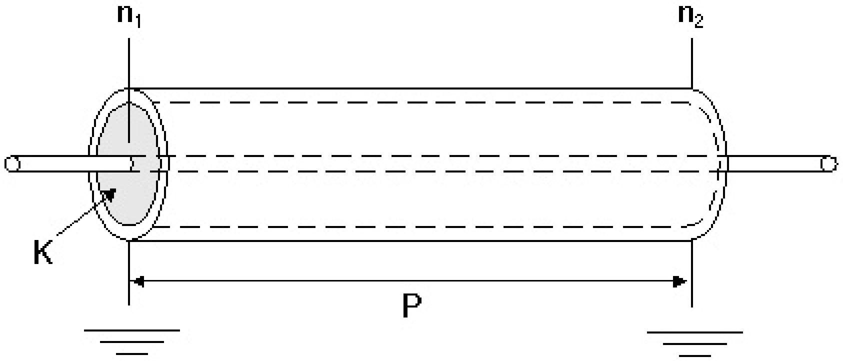
Coaxial Cable, Physical Model with Reference Netlist Example

```
Acable2 net_34 net_27 0 0 DI=0.001 DO=0.003 P=.10
+ ER=2.1 TAND=0.002 RB=1.64 component=coax_cable_physical
```

Notes

1. Applicable for TEM mode .

Coaxial Cable, Dielectric Constant



Coaxial Cable Dielectric Constant Netlist Format

The netlist syntax for a coaxial cable, dielectric constant specified, is:

```
Axxxx n1 n2 COMPONENT=coax_cable_k

 + K=val P=val Z=val C1=val C2=val RB=val
```

n1 and *n2* are the nodes attached to the cable. The entry **COMPONENT=coax_cable_k** is required.

Table 14: Coaxial Cable, Dielectric Constant Parameters

Parameter	Description	Unit	Default
K	Dielectric constant of material filling the coaxial cable	None	1.0
P	Physical length of cable	Meter	0.0127
Z	Characteristic impedance of lossless line	Ohm	50
C1	Conductor loss coefficient	dB/Meter	0.0
C2	Dielectric loss coefficient	dB/Meter	0.0

Coaxial Cable, Dielectric Constant Netlist Example

```
Acable1 net_34 net_27 K=2.6 P=0.01 Z=50 C1=0.31622 C2=1.5e-2
+ component=coax_cable_k
```

Notes

1. The one-way attenuation is given by:

$$A = P \cdot (C_1 \sqrt{f_{GHz}} + C_2 \cdot f_{GHz})[dB]$$

where f_{GHz} is the frequency in GHz.

Coaxial Cable, Dielectric Constant with Reference

The netlist syntax for a coaxial cable, dielectric constant specified, is:

```
Axxxx n1 n2 COMPONENT=coax_cable_k

 + K=val P=val Z=val C1=val C2=val RB=val
```

n1 and *n2* are the nodes attached to the cable. The entry **COMPONENT=coax_cable_k** is required.

Table 15: Coaxial Cable, Dielectric Constant Parameters

Parameter	Description	Unit	Default
K	Dielectric constant of material filling the coaxial cable	None	1.0
P	Physical length of cable	Meter	0.0127
Z	Characteristic impedance of lossless line	Ohm	50
C1	Conductor loss coefficient	dB/Meter	0.0
C2	Dielectric loss coefficient	dB/Meter	0.0

Coaxial Cable, Dielectric Constant Netlist Example

```
Acable1 net_34 net_27 0 0 K=2.6 P=0.01 Z=50 C1=0.31622
+ C2=1.5e-2 component=coax_cable_k
```

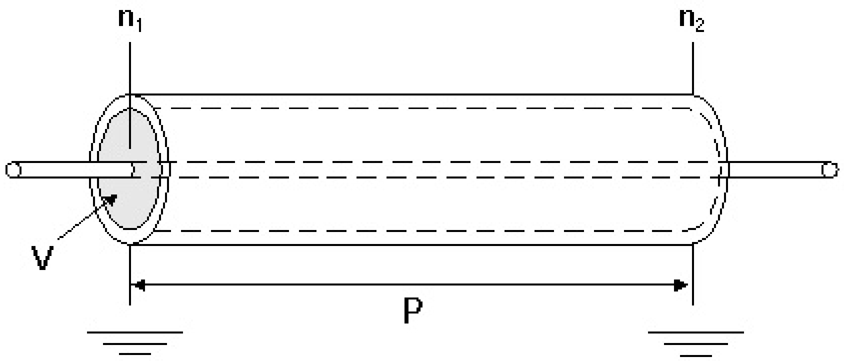
Notes

1. The one-way attenuation is given by:

$$A = P \cdot (C_1 \sqrt{f_{GHz}} + C_2 \cdot f_{GHz})[dB]$$

where f_{GHz} is the frequency in GHz.

Coaxial Cable, Phase Velocity



Coaxial Cable Netlist Format

The netlist syntax for a coaxial cable, relative phase velocity specified, is:

A*xxxx n1 n2* **COMPONENT=coax_cable_v**

+ **V=***val* **P=***val* **Z=***val* **C1=***val* **C2=***val* **RB=***val*

n1 and *n2* are the nodes attached to the cable. The entry **COMPONENT=coax_cable_v** is required.

Table 16: Coaxial Cable, Phase Velocity Parameters

Parameter	Description	Unit	Default
V	Relative phase velocity	None	1.0
P	Physical length of cable	Meter	0.0127
Z	Characteristic impedance of lossless line	Ohm	50
C1	Conductor loss coefficient	dB/Meter	0.0
C2	Dielectric loss coefficient	dB/Meter	0.0

Coaxial Cable, Dielectric Constant Netlist Example

```
Acable1 net_34 net_27 V=0.5 P=0.075 Z=50 C1=0.31622
+ C2=1.5e-2 component=coax_cable_v
```

Notes

1. The one-way attenuation is given by:

$$A = P \cdot (C_1 \sqrt{f_{GHz}} + C_2 \cdot f_{GHz})[dB]$$

where f_{GHz} is the frequency in GHz.

2. Relative phase velocity is defined as:

$$V = \frac{1}{\sqrt{K}}$$

Where K is the dielectric constant of the cable filling material.

Coaxial Cable, Phase Velocity with Reference

Coaxial Cable Netlist Format

The netlist syntax for a coaxial cable, relative phase velocity specified, is:

```
Axxxx n1 n2 n3 n4 COMPONENT=coax_cable_v

 + V=val P=val Z=val C1=val C2=val RB=val
```

n1 and *n2* are the nodes attached to the cable. *n3* and *n4* are the reference nodes. The entry **COMPONENT=coax_cable_v** is required.

Table 17: Coaxial Cable, Phase Velocity Instance Parameters

Parameter	Description	Unit	Default
V	Relative phase velocity	None	1.0
P	Physical length of cable	Meter	0.0127
Z	Characteristic impedance of lossless line	Ohm	50
C1	Conductor loss coefficient	dB/Meter	0.0
C2	Dielectric loss coefficient	dB/Meter	0.0

Coaxial Cable, Phase Velocity Netlist Example

```
Acable1 net_34 net_27 0 0 V=0.5 P=0.075 Z=50 C1=0.31622
+ C2=1.5e-2 component=coax_cable_v
```

Notes

1. The one-way attenuation is given by:

$$A = P \cdot (C_1 \sqrt{f_{GHz}} + C_2 \cdot f_{GHz})[dB]$$

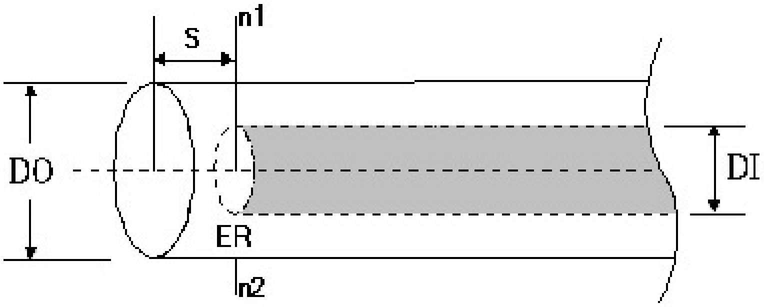
where f_{GHz} is the frequency in GHz.

2. Relative phase velocity is defined as:

$$V = \frac{1}{\sqrt{K}}$$

Where K is the dielectric constant of the cable filling material.

Coaxial Cable, Open



Coaxial Cable Open Netlist Format

The netlist syntax for a coaxial cable, open is:

```
Axxxx n1 COMPONENT=coax_cable_open

 + DI=val DO=val S=val ER=val
```

n1 is the node attached to the cable. The entry **COMPONENT=coax_cable_open** is required.

Table 18: Coaxial Cable, Open Parameters

Parameter	Description	Unit	Default
DI	Diameter of inner conductor	Meter	2.0e-3
DO	Inner diameter of outer conductor	Meter	6.0e-3
S	Gap between open end and inner conductor wall	Meter	0.1e-3
ER	Dielectric constant of the filler material	None	1.0

Coaxial Cable, Open Netlist Example

```
Acable1 net_34 DI=0.001 DO=0.003 S=0.0002
+ ER=2.1 component=coax_cable_open
```

Coaxial Cable, Open with Reference

Coaxial Cable Netlist Format

The netlist syntax for a coaxial cable, open with reference is:

```
Axxxx n1 n2 COMPONENT=coax_cable_open

 + DI=val DO=val S=val ER=val
```

n1 is the node attached to the cable. *n2* is the reference node. The entry **COMPONENT=coax_cable_open** is required.

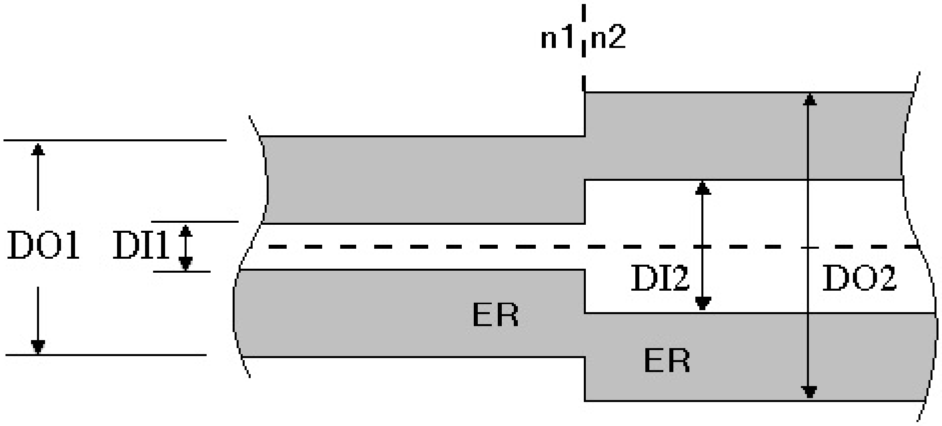
Table 19: Coaxial Cable, Open with Reference Parameters

Parameter	Description	Unit	Default
DI	Diameter of inner conductor	Meter	2e-3
DO	Inner diameter of outer conductor	Meter	6e-3
S	Gap between open end and inner conductor wall	Meter	0.1e-3
ER	Dielectric constant of the insulator	None	1.0

Coaxial Cable, Open with Reference Netlist Example

```
Acable2 net_34 0 DI=0.001 DO=0.003 S=0.2e-3
+ ER=2.1 component=coax_cable_open
```

Coaxial Cable, Step



Coaxial Cable Netlist Format

The netlist syntax for a coaxial cable, step is:

```
Axxxx n1 n2 COMPONENT=coax_cable_step

 + DI1=val DI2=val DO1=val DO2=val ER=val
```

n1 and *n2* are the nodes attached to the cable. The entry **COMPONENT=coax_cable_step** is required.

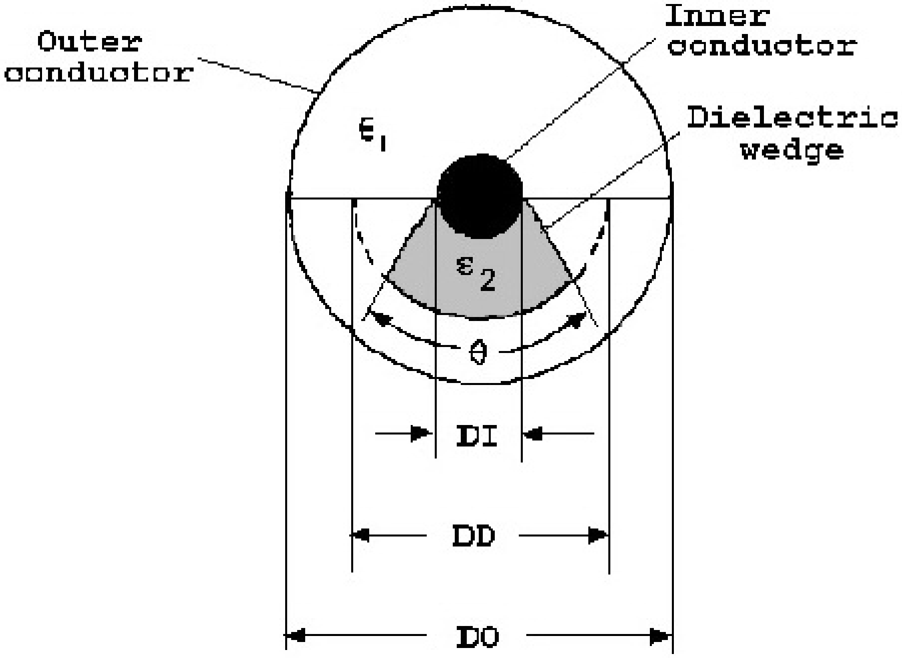
Table 20: Coaxial Cable, Step Parameters

Parameter	Description	Unit	Default
DI1	Smaller diameter of inner conductor	Meter	0.50e-3
DI2	Larger diameter of inner conductor	Meter	0.75e-3
DO1	Smaller diameter of outer conductor	Meter	1.00e-3
DO2	Larger diameter of outer conductor	Meter	1.50e-3
ER	Dielectric constant of the cable filler material	None	1.0

Coaxial Cable, Step Netlist Example

```
Acable1 net_34 net_27 DI1=0.4e-3 DI2=0.8e-3 DO1=1.1e-3
+ DO2=1.6e-3 ER=2.1 component=coax_cable_step
```

Coaxial Cable, Partially Filled



Coaxial Cable Netlist Format

The netlist syntax for a coaxial cable, partially filled is:

```
Axxxxx n1 n2 COMPONENT=coax_cable_partfilled

 + DI=val DO=val P=val ER1=val ER2=val

+ TAND1=val TAND2=val THETA=val RB=val
```

n1 and *n2* are the nodes attached to the cable. The entry **COMPONENT=coax_cable_partfilled** is required.

Table 21: Coaxial Cable, Partially Filled Parameters

Parameter	Description	Unit	Default
DI	Diameter of inner conductor	Meter	0.25e-3
DO	Inner diameter of outer conductor	Meter	0.75e-3
DD	Diameter of electric wedge	Meter	0.5e-3
P	Physical length of cable	Meter	10e-3
ER1	Dielectric constant of the material filling the main line	None	3.0

Parameter	Description	Unit	Default
ER2	Dielectric constant of the dielectric wedge	None	10.0
TAND1	Dielectric loss tangent of the material filling the main line	None	0.0
TAND2	Dielectric loss tangent of the dielectric wedge	None	0.0
THETA	Angle of the wedge	Degree	30.0
RB	Conductor resistivity	µOhm-cm	0.0

Coaxial Cable, Partially Filled Netlist Example

```
Acable1 net_34 net_27 DI=0.001 DO=0.003 DD=0.002 P=.10
+ ER1=1 ER2=2.6 THETA=30 RB=1.64
+ component=coax_cable_partfilled
```

Coaxial Cable, Partially Filled with Reference

Coaxial Cable Netlist Format

The netlist syntax for a coaxial cable, partially filled with reference is:

```
Axxxx n1 n2 n3 n4 COMPONENT=coax_cable_partfilled

 + DI=val DO=val P=val ER1=val ER2=val

+ TAND1=val TAND2=val THETA=val RB=val
```

n1 and *n2* are the nodes attached to the cable. *n3* and *n4* are the reference nodes. The entry **COMPONENT=coax_cable_partfilled** is required.

Table 22: Coaxial Cable, Partially Filled Parameters

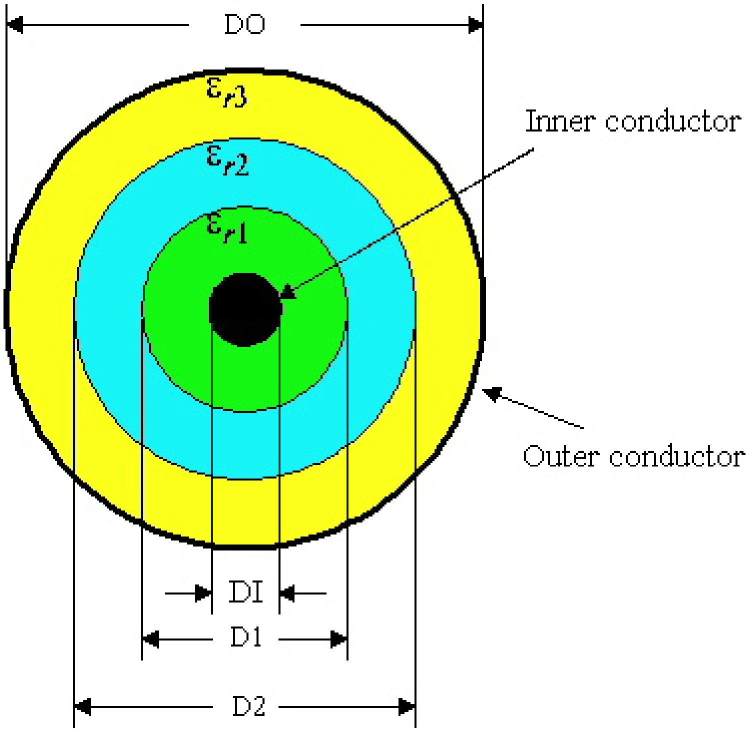
Parameter	Description	Unit	Default
DI	Diameter of inner conductor	Meter	50
DO	Inner diameter of outer conductor	Meter	0.0127
DD	Diameter of electric wedge	Meter	0.0127
P	Physical length of cable	Meter	0.0127
ER1	Dielectric constant of the material filling the main line	None	1.0
ER2	Dielectric constant of the dielectric wedge	None	1.0
TAND1	Dielectric loss tangent of the material filling the main line	None	0.0
TAND2	Dielectric loss tangent of the dielectric wedge	None	0.0

Parameter	Description	Unit	Default
THETA	Angle of the wedge	Degree	0.0
RB	Conductor resistivity	µOhm-cm	0.0

Coaxial Cable, Partially Filled Netlist Example

```
Acable1 net_34 net_27 DI=0.001 DO=0.003 DD=0.002 P=.10
+ ER1=1 ER2=2.6 THETA=30 RB=1.64
+ component=coax_cable_partfilled
```

Coaxial Cable, Three Layers



Coaxial Cable Netlist Format

The netlist syntax for a coaxial cable, three layers is:

A*xxxx n1 n2* **COMPONENT=coax_cable_threelayer**

\+ **DI=***val* **DO=***val* **D1=***val* **D2=***val* **P=***val* **RB=***val*

\+ **ER1=***val* **ER2=***val* **ER3=***val* **TAND1=***val* **TAND2=***val* **TAND3=***val*

n1 and *n2* are the nodes attached to the cable. The entry **COMPONENT=coax_cable_threelayer** is required.

Table 23: Coaxial Cable, Three Layer Parameters

Parameter	Description	Unit	Default
DI	Diameter of inner conductor	Meter	0.25e-3
DO	Inner diameter of outer conductor	Meter	1e-3
D1	Diameter to edge of layer 1	Meter	0.5e-3
D2	Diameter to edge of layer 2	Meter	0.75e-3
P	Physical length of cable	Meter	0.0127
ER1	Dielectric constant of medium 1	None	2.0
ER2	Dielectric constant of medium 2	None	5.0
ER3	Dielectric constant of medium 3	None	8.0
TAND1	Dielectric loss tangent for medium 1	None	0.0
TAND2	Dielectric loss tangent for medium 2	None	0.0
TAND3	Dielectric loss tangent for medium 3	None	0.0
RB	Conductor resistivity	μOhm-cm	0.0

Coaxial Cable, Three Layer Netlist Example

```
Acable1 net_34 net_27 DI=0.00 1 DO=0.003 D1=-.5e-7 D2=0.75e-3
+ P=.10 RB=1.64 ER1=2.1 ER2=5.2
+ component=coax_cable_threelayer
```

Coaxial Cable, Three Layers with Reference

Coaxial Cable Netlist Format

The netlist syntax for a coaxial cable, three layers with reference is:

A*xxxx n1 n2 n3 n4* **COMPONENT=coax_cable_threelayer**

\+ **DI=***val* **DO=***val* **D1=***val* **D2=***val* **P=***val* **RB=***val*

\+ **ER1=***val* **ER2=***val* **ER3=***val* **TAND1=***val* **TAND2=***val* **TAND3=***val* *n1* and *n2* are the nodes attached to the cable. *n3* and *n4* are the reference nodes. The entry **COMPONENT=coax_cable_threelayer** is required.

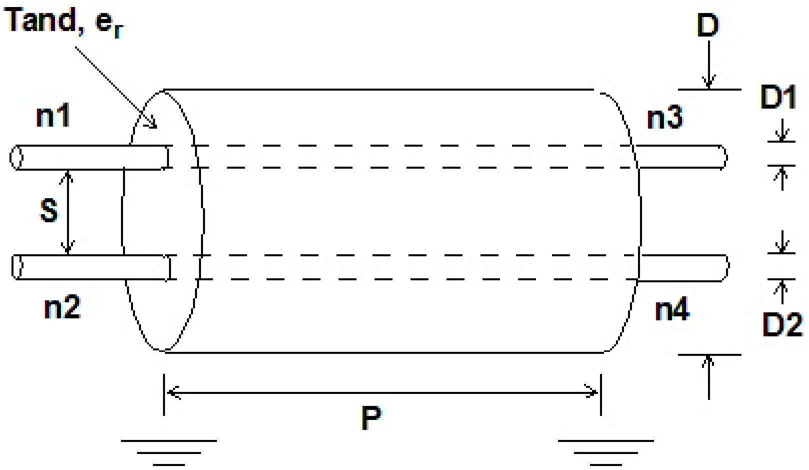
Table 24: Coaxial Cable, Three Layer Parameters

Parameter	Description	Unit	Default
DI	Diameter of inner conductor	Meter	0.25e-3
DO	Inner diameter of outer conductor	Meter	1e-3
D1	Diameter to edge of layer 1	Meter	0.5e-3
D2	Diameter to edge of layer 2	Meter	0.75e-3
P	Physical length of cable	Meter	0.0127
ER1	Dielectric constant of medium 1	None	2.0
ER2	Dielectric constant of medium 2	None	5.0
ER3	Dielectric constant of medium 3	None	8.0
TAND1	Dielectric loss tangent for medium 1	None	0.0
TAND2	Dielectric loss tangent for medium 2	None	0.0
TAND3	Dielectric loss tangent for medium 3	None	0.0
RB	Conductor resistivity	μOhm-cm	0.0

Coaxial Cable, Three Layer Netlist Example

```
Acable1 net_34 net_27 0 0 DI=0.00 1 DO=0.003
+ D1=-.5e-7 D2=0.75e-3
+ P=.10 RB=1.64 ER1=2.1 ER2=5.2
+ component=coax_cable_threelayer
```

Twinaxial Cable



Twinaxial Cable Netlist Format

The netlist syntax for a twinaxial cable is:

ATWINAX*xxxx n1 n2 n3 n4* **COMPONENT=twinax D=***val* **D1=***val* **D2=***val* **S=***val* **P=***val* **ER=***val* **TAND=***val* **RB1=***val* **RB2=***val*

n1 and *n2* are the input nodes attached to the cable. *n3* and *n4* are the corresponding output nodes. The entry **COMPONENT=twinax** identifies the component.

Table 25: Twinaxial Cable Parameters

Parameter	Description	Unit	Default
D	Diameter of shield. Required parameter, must be greater than 0. See Note 1.	Meter	22e-3
D1	Diameter of conductor 1. Required parameter, must be greater than 0. See Note 2.	Meter	2e-3
D2	Diameter of conductor 2. Required parameter, must be greater than 0. See Note 2.	Meter	2e-3
S	Spacing between conductors. Required parameter, must be greater than 0.	Meter	9e-3
P	Physical length of cable. Required parameter, must be greater than 0.	Meter	10e-3
ER	Dielectric constant of material filling the twinaxial line.	None	1.0

Parameter	Description	Unit	Default
	Required parameter, must be greater than or equal to 1.		
TAND	Dielectric loss tangent of the material filling the twinaxial line. Required parameter, must be greater than or equal to 0.	None	0.0
RB1	Resistivity of conductor 1. Required parameter, must be greater than 0.	µOhm-cm	1.724138
RB2	Resistivity of conductor 2. Required parameter, must be greater than 0.	µOhm-cm	1.724138

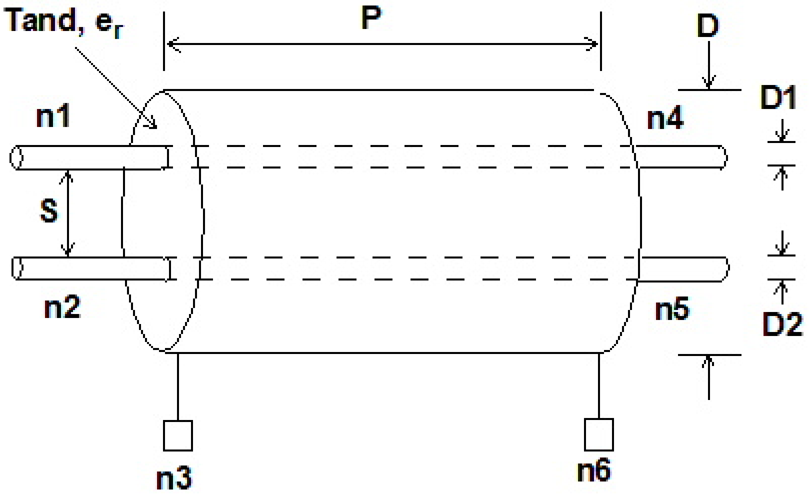
Twinaxial Cable Netlist Example

```
Atwinax1 net_1 net_2 net_3 net_4 D=20mm D1=1.5mm D2=1.5mm S=8mm
+ P=14.6mm ER=2.1 TAND=0.002 RB1=1.64 RB2=1.64
+ component=twinax
```

Twinaxial Cable Notes

1. The shield diameter D must be greater than (D1 + D2 + S).
2. When D1 is not equal to D2, the location of the inner conductors is chosen such that the clearance between the conductors and the shield is equal.
3. The twinaxial cable is modeled using the Nexxim Method of Moments (MoM) field solver. See *The MPIE Method* in the HFSS 3D LayoutTechnical Notes for details.

Twinaxial Cable with Reference Nodes



Twinaxial Cable with Reference Nodes Netlist Format

The netlist syntax for a twinaxial cable with reference nodes is:

```
ATWINAXxxxx n1 n2 n3 n4 n5 n6 COMPONENT=twinax D=val D1=val
D2=val S=val P=val ER=val TAND=val RB1=val RB2=val
```

n1 and *n2* are the input nodes attached to the cable. *n3* is the reference node for the inputs. *n4* and *n5* are the corresponding output nodes. *n6* is the reference node for the outputs. The entry **COMPONENT=twinax** identifies the component.

Table 26: Twinaxial Cable Parameters

Parameter	Description	Unit	Default
D	Diameter of shield. Required parameter, must be greater than 0. See Note 1.	Meter	22e-3
D1	Diameter of conductor 1. Required parameter, must be greater than 0. See Note 2.	Meter	2e-3
D2	Diameter of conductor 2. Required parameter, must be greater than 0. See Note 2.	Meter	2e-3
S	Spacing between conductors. Required parameter, must be greater than 0.	Meter	9e-3
P	Physical length of cable. Required parameter, must be greater than 0.	Meter	10e-3
ER	Dielectric constant of material filling the twinaxial line. Required parameter, must be greater than or equal to 1.	None	1.0
TAND	Dielectric loss tangent of the material filling the twinaxial line. Required parameter, must be greater than or equal to 0.	None	0.0
RB1	Resistivity of conductor 1. Required parameter, must be greater than 0.	μOhm-cm	1.724138
RB2	Resistivity of conductor 2. Required parameter, must be greater than 0.	μOhm-cm	1.724138

Twinaxial Cable with Reference Nodes Netlist Example

```
Atwinax1 net_1 net_2 net_3 net_4 net5 net6 D=20mm D1=1.5mm
+ D2=1.5mm S=8mm
+ P=14.6mm ER=2.1 TAND=0.002 RB1=1.64 RB2=1.64
+ component=twinax
```

Twinaxial Cable with Reference Notes

1. The shield diameter D must be greater than (D1 + D2 + S).
2. When D1 is not equal to D2, the location of the inner conductors is chosen such that the clearance between the conductors and the shield is equal.
3. The twinaxial cable is modeled using the Nexxim Method of Moments (MoM) field solver. See *The MPIE Method* in the HFSS 3D LayoutTechnical Notes for details.

5 - Controlled Sources

This topic describes the following controlled current and voltage sources:

"Voltage-Controlled Voltage Source, Multiplier" on page 5-66

"Voltage-Controlled Voltage Source, Op Amp" on page 5-67

"Voltage-Controlled Voltage Source, Polynomial" on page 5-69

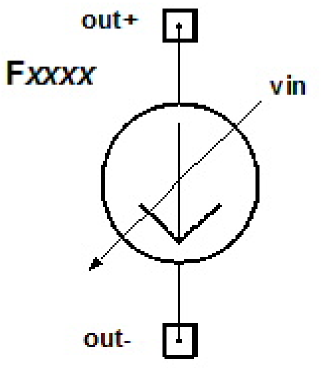
"Voltage-Controlled Voltage Source, Piecewise Linear" on page 5-73

"Voltage-Controlled Voltage Source, S-Domain" on page 5-74

"Voltage-Controlled Voltage Source, Transformer" on page 5-76

"Voltage-Controlled Voltage Source, Behavioral (Netlist Only)" on page 5-77

Current-Controlled Current Source, Delay



CCCS Delay Netlist Format

The format for a current-controlled current source with delay is:

F*xxxx out+ out-* [**CCCS**] **DELAY***vin* **TD=***val*
[**SCALE=***val*] [**TC1=***val*] [**TC2=***val*]

out+ is the positive node and *out-* is the negative node of the current source. The entry **CCCS** is the default for the **F** element type. The entry **DELAY** selects the F element delay type. *vin* is a voltage source through which the control current flows. The input voltage source must be defined elsewhere in the netlist.

The following figure illustrates the operation of the CCVS delay element:

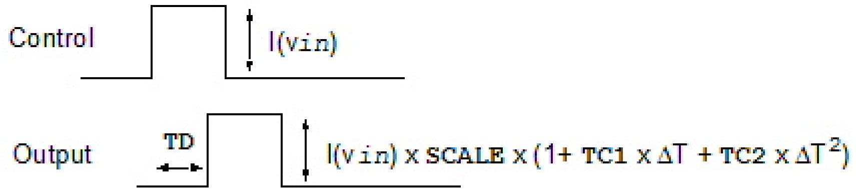


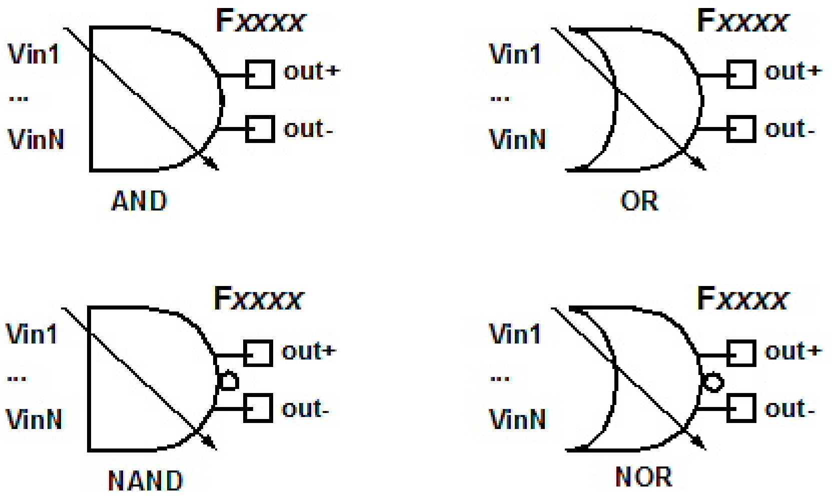
Table 14: Delay CCCS Instance Parameters

Parameter	Description	Unit	Default
SCALE	Multiplier for current	None	1.0
TC1	Linear (1st-order) temperature coefficient	$°K^{-1}$	0.0
TC2	Quadratic (2nd-order) temperature coefficient	$°K^{-2}$	0.0
TD	Time delay. Must be ≥ 0.	Second	None

CCCS Delay Netlist Example

```
F23 in5 0 CCCS DELAY V11 TD=2.0e-5
```

Current-Controlled Current Source, Multi-Input Gate



The format for an N-input AND gate CCCS is:

```
Fxxxx out+ out- [CCCS] AND(N)vin1 ... vinN
minval1   outval1 ... minvalK   outvalK
[DELTA=val] [TC1=val] [TC2=val]
[SCALE=val] [M=val] [ABS=0|1]
```

The format for an N-input NAND gate CCCS is:

```
Fxxxx out+ out- [CCCS] NAND(N)vin1 ... vinN
minval1   outval1 ... minvalK   outvalK
[DELTA=val] [TC1=val] [TC2=val]
[SCALE=val] [M=val] [ABS=0|1]
```

The format for an N-input OR gate CCCS is:

```
Fxxxx out+ out- [CCCS] OR(N)vin1 ... vinN
maxval1   outval1 ... maxvalK   outvalK
[DELTA=val] [TC1=val] [TC2=val]
[SCALE=val] [M=val] [ABS=0|1]
```

The format for an N-input NOR gate CCCS is:

```
Fxxxx out+ out- [CCCS] NOR(N)vin1 ... vinN
maxval1   outval1 ... maxvalK   outvalK
[DELTA=val] [TC1=val] [TC2=val]
[SCALE=val] [M=val] [ABS=0|1]
```

out+ and *out-* are the nodes of the current output. The entry **CCCS** is the default for the **F** element type. *vin1* ... *vinN* are the voltage sources through which the multiple control current inputs flow. The input voltage sources must be defined elsewhere in the netlist. The number of input sources (*N*) in the list must be the same as the value specified for **AND(***N***)**, **NAND(***N***)**, **OR(***N***)**, or **NOR(***N***)**. For current-controlled sources, *N* must be in the range 2≤*N*≤4.

Table 15: Multi-Input Gate CCCS Instance Parameters

Parameter	Description	Unit	Default
ABS	Output is absolute when ABS=1	None	0
DELTA	Distance over which curvature is applied in the interpolation function Zero produces linear interpolation, positive values produce continuous curvature over the waveform Maximum is one-half of the smallest difference between control (input) values	None	One-fourth of the smallest difference between control (input) values
M	Multiplier to simulate multiple elements	None	1.0

Parameter	Description	Unit	Default
SCALE	Scale factor for current	None	1.0
TC1	Linear (1st-order) temperature coefficient	°K^{-1}	0.0
TC2	Quadratic (2nd-order) temperature coefficient	°K^{-2}	0.0

CCCS Gate Netlist Examples

These two-input examples assume logic “0” is 0.0 mA output at 0.0 mA input, and logic “1” is 5.0 mA output at 5.0 mA input.

```
Fand2 30 0 CCCS AND(2) V21 V22
+ 0.0 0.0
+ 0.5e-3 0.1e-3
+ 1.0e-3 0.2e-3
+ 4.0e-3 4.5e-3
+ 4.5e-3 4.75e-3
+ 5.0e-3 5.0e-3
```

```
Fnand2 40 0 CCCS NAND(2) V23 V24
+ 0.0 5.0e-3
+ 0.5e-3 4.75e-3
+ 1.0e-3 4.5e-3
+ 4.0e-3 0.2e-3
+ 4.5e-3 0.1e-3
+ 5.0e-3 0.0
```

```
For2 50 0 CCCS OR(2) V25 V26
+ 0.0 0.0
+ 0.5e-3 0.1e-3
+ 1.0e-3 0.2e-3
+ 4.0e-3 4.5e-3
+ 4.5e-3 4.75e-3
+ 5.0e-3 5.0e-3
```

```
Fnor2 60 0 CCCS NOR(2) V27 V28
+ 0.0 5.0e-3
+ 0.5e-3 4.75e-3
+ 1.0e-3 4.5e-3
+ 4.0e-3 0.2e-3
+ 4.5e-3 0.1e-3
+ 5.0e-3 0.0
```

See the examples for the "Voltage-Controlled Voltage Source, Multi-Input Gate" on page 5-57 element for samples of simulation runs produced by these devices.

Notes on minval, maxval, outval parameters

The output is specified as a function of the inputs using a set of pairs (*minval*, *outval* or *maxval*, *outval*), separated by spaces and/or commas. Currents are specified in amperes. The pairs should be entered in ascending order of *minval* or *maxval* (see Netlist Examples). Any number of pairs may be specified.

> **Note:** In the **Schematic Editor** component Property windows, the Gate components use property names **IN1**, **IN2**, ...**IN***K* for the *minval* and *maxval* parameters, and **OUT1**, **OUT2**, ...**OUT***K* for the *outval* parameters.

For **AND** and **NAND** gates, the simulator finds the minimum current across all voltage source inputs:

minI = MIN[I(*vin1*), I(*vin2*), ... I(*vinN*)]

The simulator matches *minI* to the list of entries *minval1* ... *minvalK* in the instance statement, and sets the output to the corresponding *outval*.

When *minI* is equal to the current that represents logic “0” or logic “1,” the corresponding output from an **AND** or **NAND** gate should be set accordingly.

Values of *minI* that are intermediate between the logic “0” and “1” currents represent transitional values. For intermediate values that are not in the list of *minvals*, the simulator calculates the corresponding output by interpolation from the given values. The use of the **DELTA** parameter allows you to control the curvature of the interpolation to guarantee that the 1st derivative of the curve is continuous.

For values of *minI* that are below the range of listed input current, the simulator sets the output current to the one corresponding to the smallest input voltage in the list. For values of *minI* that are above the range of listed input currents, the simulator sets the output current to the one corresponding to the largest input current in the list.

For **OR** and **NOR** gates, the simulator finds the maximum difference between all pairs of inputs:

maxI = MAX[I(*vin1*), I(*vin2*), ... I(*vinN*)]

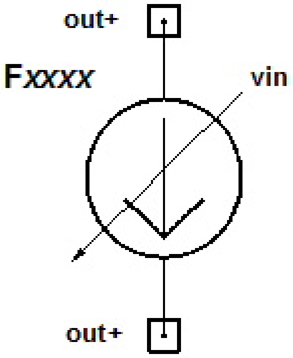
The simulator matches *maxI* to the list of entries *maxval1* ... *maxvalK* in the instance statement, and sets the output to the corresponding *outval*.

When *maxI* is equal to the current that represents logic “0” or logic “1,” the corresponding output from an **OR** or **NOR** gate should be set accordingly.

Values of *maxI* that are intermediate between the logic “0” and “1” current represent transitional values. For intermediate values that are not in the list, the simulator calculates the corresponding output by linear interpolation on the given values, using the **DELTA** parameter as discussed above.

For values of *maxI* that are below the range of listed input currents, the simulator sets the output current to the one corresponding to the smallest input voltage in the list. For values of *maxI* that are above the range of listed input currents, the simulator sets the output current to the one corresponding to the largest input current in the list.

Current-Controlled Current Source, Linear



Linear CCCS Netlist Format

The format for a linear current-controlled current source (CCCS) is:

```
Fxxxx out+ out- [CCCS] vin [GAIN=]gain
[MAX=val] [MIN=val] [M=val]
[SCALE=val] [TC1=val] [TC2=val] [ABS=0|1]
```

out+ is the positive node and *out-* is the negative node of the current source. The entry **CCCS** is the default for the **F** element type. *vin* is a voltage source through which the control current flows. The input voltage source must be defined elsewhere in the netlist.

The functional equation for the linear VCCS is:

$I(out+, out-) = \mathbf{GAIN} \times I(vin) \times \mathbf{SCALE} \times \mathbf{M} \times (1 + \Delta T \times \mathbf{TC1} + \Delta T^{2} \times \mathbf{TC2})$

If the result is less than **MIN**,

$I(out+, out-) = \mathbf{MIN}$

If the result is greater than **MAX**,

$I(out+, out-) = \mathbf{MAX}$

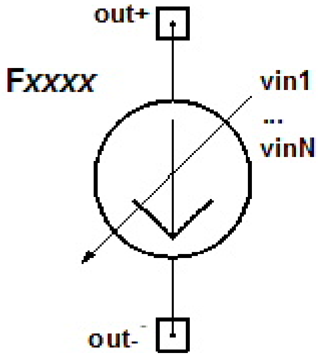
Table 16: Linear CCCS Instance Parameters

Parameter	Description	Unit	Default
ABS	1 = Output is an absolute value	None	0
GAIN	Current gain	None	1.0
M	Number of elements in parallel	None	1.0
MAX	Maximum output current	Amp	None
MIN	Minimum output current	Amp	None
SCALE	Multiplier for current	None	1.0
TC1	Linear (1st-order) temperature coefficient	°K^{-1}	0.0
TC2	Quadratic (2nd-order) temperature coefficient	°K^{-2}	0.0

Linear CCCS Netlist Example

```
F33 12 0 CCCS V2 GAIN=3.1e-2
```

Current-Controlled Current Source, Polynomial



Polynomial CCCS Netlist Format

The format for a polynomial current-controlled current source (CCCS) is:

F*xxxx out+ out-* [**CCCS**] **POLY(***N***)**

vin1 [*vin2* [*vin3*]]

[**MAX=***val*] [**MIN=***val*] [**SCALE=***scale*] [**M=***val*]

[**TC1=***val*] [**TC2=***val*] [**ABS=0**|**1**]

```
p0 [p1 ... pK]
```

n+ is the positive node and *n-* is the negative node of the current source. The entry **CCCS** is the default for the **F** element type. The entry **POLY** is required to identify the polynomial CCCS type. The number of inputs, *N*, can be 1, 2, or 3. The controls are currents through voltage sources defined elsewhere in the netlist. If *N* is not specified, 1 is the default. *vin1* through *vin3* are the *N* sources for the control currents. *p0* through *pK* are the *K* coefficients for the polynomial function. One coefficient must be provided.

Table 17: Polynomial CCCS Instance Parameters

Parameter	Description	Unit	Default
ABS	1 = Output is an absolute value	None	0
M	Multiplier to simulate multiple elements	None	1.0
MAX	Maximum output current	Volt	None
MIN	Minimum output current	Volt	None
SCALE	Multiplier for current	None	1.0
TC1	Linear (1st-order) temperature coefficient	°K-1	0.0
TC2	Quadratic (2nd-order) temperature coefficient	°K^{-2}	0.0

Polynomial CCCS Netlist Examples

```
F21 21 0 CCCS POLY(1) V1 1.1 2.1 0 3.1

F31 31 0 CCCS POLY(2) V1 V2 1.2 2.2 0 0 0 0 0 0 3.2 0

F41 41 0 CCCS POLY(3) V1 V2 V3 1.3 2.3 0 0

+ 0 0 0 0 0 0

+ 0 3.3 0 0 0 0 0 0 0 4.3
```

Notes

The functional equation for the polynomial CCCS is:

I(*n+*, *n-*) = *polynomial*×**SCALE** × (1 + ΔT ×**TC1** + ΔT^2×**TC2**)

If the result is less than **MIN**,

I(*n+*, *n-*) = **MIN**

If the result is greater than **MAX**,

I(*n+*, *n-*) = **MAX**

The polynomial depends on the number of inputs (*N*) and the number of polynomial coefficients (*K*). Each polynomial has terms of order (**O**), the sum of the exponents of the elements in the term. The list of coefficients must include coefficients for every term up to and including the complete group of terms with the highest order in the specified polynomial, using zero coefficients for any intermediate or trailing terms that should not be computed.

When *N*=1, the polynomial formula has one term each of order **O** {0, 1, ... *K*}:

$p0 + p1 \times \mathrm{I}(vin1) + \ldots pK \times \mathrm{I}(vin1)^K$

Each coefficient must be a real value or zero to represent a missing term. For example, to specify a CCCS between nodes 21 and 0 whose output, controlled by the current across voltage source V1, is described by the one-input polynomial $1.1 + 2.1 \times \mathrm{I(V1)} + 3.1 \times \mathrm{I(V1)}^3$, the instance statement sets coefficients *p0*=1.1, *p1*=2.1, *p2*=0, and *p3*=3.1:

```
F21 21 0 CCCS POLY(1) V1 1.1 2.1 0 3.1
```

(The control voltage source V1 is defined on its own instance line elsewhere in the netlist.)

When *N*=2, the polynomial formula can have more than one term in each order grouping:

O (0)

$p0 +$

O (1)

$p1 \times \mathrm{I}(vin1) +$

$p2 \times \mathrm{I}(vin2) +$

O (2)

$p3 \times \mathrm{I}(vin1)^2 +$

$p4 \times \mathrm{I}(vin1) \times \mathrm{I}(vin2^-) +$

$p5 \times \mathrm{I}(vin2)^2 +$

O (3)

$p6 \times \mathrm{I}(vin1)^3 +$

$p7 \times \mathrm{I}(vin1)^2 \times \mathrm{I(vin2)} +$

$p8 \times \mathrm{I}(vin1) \times \mathrm{I}(vin2)^2 +$

$p9 \times \mathrm{I}(vin2)^3 +$

O (4)

...

For example, to specify a CCCS between nodes 31 and 0 whose output, controlled by the currents across voltage sources V1 and V2, is described by the two-input polynomial $1.2 + 2.2 \times I(V1) + 3.2 \times I(V1) \times I(V2)^2$, the instance statement sets coefficients *p0*=1.2, *p1*=22, and *p8*=3.2. Intermediate coefficients *p2* through *p7* and trailing coefficient *p9* are set to 0:

```
F31 31 0 CCCS POLY(2) V1 V2 1.2 2.2 0 0 0 0 0 0 3.2 0
```

When *N*=3, the polynomial formula becomes:

O (0)

`p0 +`

O (1)

$p1 \times I(vin1) +$

$p2 \times I(vin2) +$

$p3 \times I(vin3) +$

O (2)

$p4 \times I(vin1)^2 +$

$p5 \times I(vin1) \times I(vin2) +$

$p6 \times I(vin1) \times I(vin3) +$

$\mathrm{p7} \times \mathrm{I(vin2)}^2 +$

$p8 \times I(vin2) \times I(vin3) +$

$p9 \times I(vin3)^2 +$

O (3)

$p10 \times I(vin1)^3 +$

$p11 \times I(vin1)^2 \times I(vin2) +$

$p12 \times I(vin1)^2 \times I(vin3) +$

$p13 \times I(vin1) \times I(vin2)^2 +$

$p14 \times I(vin1) \times I(vin2) \times I(vin3) +$

$p15 \times I(vin1) \times I(vin3)^2 +$

$p16 \times I(vin2)^3 +$

$p17 \times I(vin2)^2 \times I(vin3) +$

$p18 \times I(vin2) \times I(vin3)^2 +$

$p19 \times \mathrm{I}(vin3)^3 +$

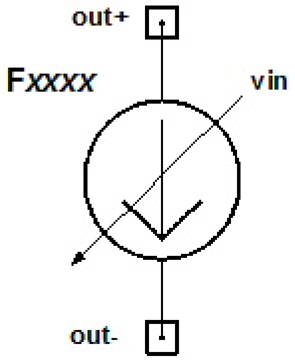
O (4)

...

For example, to specify a CCCS between nodes 41 and 0 whose output, controlled by the currents across voltage sources V1, V2, and V3, is described by the three-input polynomial 1.3 + 2.3 × I(V1) + 3.3 × I(V1)^2× I(V2) + 4.3 × I(V3)^3, the instance statement sets coefficients *p0*=1.3, *p1*=2.3, *p11*=3.3, and *p19*=4.3. Intermediate coefficients *p2* through *p10* and *p12* through *p18* are set to 0 (since *p19* is the coefficient for the highest term with order 3, no trailing zeros are needed):

```
F41 41 0 CCCS POLY(3) V1 V2 V3 1.3 2.3 0 0

+ 0 0 0 0 0 0

+ 0 3.3 0 0 0 0 0 0 0 4.3
```

Current-Controlled Current Source, Piecewise Linear



Piecewise Linear CCCS Netlist Format

The format for a piecewise linear current-controlled current source (CCCS) is:

F*xxxx out+ out-* [**CCCS**] **PWL(1)** *vin*

[**DELTA=***val*] [**SCALE=***scale*] [**M=***val*]

[**TC1=***val*] [**TC2=***val*]

x1 y1 [... xK yK]

out+ is the positive node and *out-* is the negative node of the current source. The entry **CCCS** is the default for the **F** element type. The entry **PWL** is required to identify the piecewise linear CCCS type. *vin* is the voltage source through which the control current flows. The input voltage source must be defined elsewhere in the netlist.

The *x y* pairs are the input current values and the corresponding output voltage values. For intermediate values that are not in the list of *x* values, the simulator calculates the corresponding output by interpolation on the given values. The use of the **DELTA** parameter allows you to control the curvature of the interpolation to guarantee that the 1st derivative of the curve is continuous.

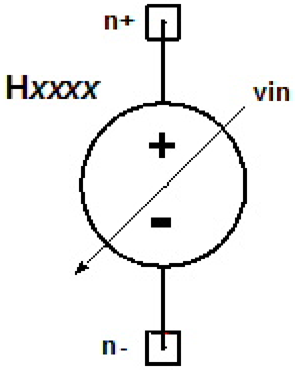
Table 18: Piecewise Linear CCCS Instance Parameters

Parameter	Description	Unit	Default
DELTA	Distance over which curvature is applied in the interpolation function Zero produces linear interpolation, positive values produce continuous curvature over the waveform Maximum is one-half of the smallest difference between control (input) values	None	One-fourth of the smallest difference between control (input) values
M	Multiplier to simulate multiple elements	None	1.0
SCALE	Multiplier for current	None	1.0
TC1	Linear (1st-order) temperature coefficient	°K^{-1}	0.0
TC2	Quadratic (2nd-order) temperature coefficient	°K^{-2}	0.0

Piecewise Linear CCCS Netlist Examples

```
Fpwl1 30 0 CCCS PWL(1) 21 0
+ 0.0 0.0
+ 0.5e-3 0.1e-3
+ 1.0e-3 0.2e-3
+ 4.0e-3 4.5e-3
+ 4.5e-3 4.75e-3
+ 5.0e-3 5.0e-3
```

Current-Controlled Voltage Source, Delay



CCVS Delay Netlist Format

The format for a current-controlled voltage source with delay is:

```
Hxxxx n+ n- [CCVS] DELAYvin TD=val
[SCALE=val] [TC1=val] [TC2=val]
```

n+ is the positive node and *n-* is the negative node of the voltage source. The entry **CCVS** is the default for the **H** element type. The entry **DELAY** selects the H element delay type. *vin* is a voltage source on the branch through which the control current flows.

The following figure illustrates the operation of the CCVS delay element:

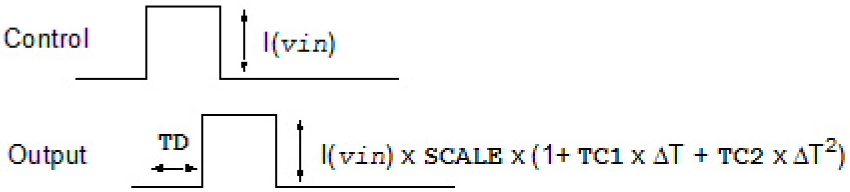


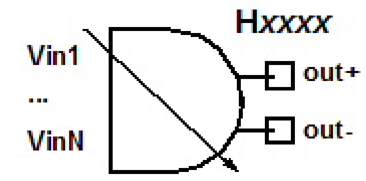
Table 19: Delay CCVS Instance Parameters

Parameter	Description	Unit	Default
SCALE	Multiplier for voltage	None	1.0
TC1	Linear (1st-order) temperature coefficient	°K^{-1}	0.0
TC2	Quadratic (2nd-order) temperature coefficient	°K^{-2}	0.0
TD	Time delay. Must be ≥ 0.	Second	None

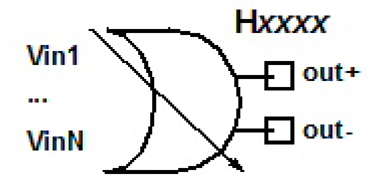
CCVS Delay Netlist Example

```
H23 inplus 0 CCVS DELAY V13 TD=2.0e-2
```

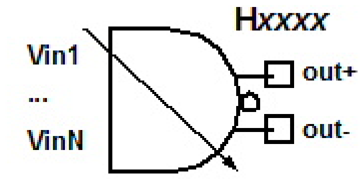
Current-Controlled Voltage Source, Multi-Input Gate



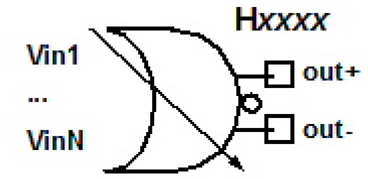
AND



OR



NAND



NOR

The format for an N-input AND gate CCVS is:

H*xxxx out+ out-* [**CCVS**] **AND(***N***)***vin1* ... *vinN*
minval1 *outval1* ... *minvalK* *outvalK*
[**DELTA=***val*] [**TC1=***val*] [**TC2=***val*]
[**SCALE=***val*] [**M=***val*] [**ABS=0**|**1**]

The format for an N-input NAND gate CCVS is:

H*xxxx out+ out-* [**CCVS**] N**AND(***N***)***vin1* ... *vinN*
minval1 *outval1* ... *minvalK* *outvalK*
[**DELTA=***val*] [**TC1=***val*] [**TC2=***val*]
[**SCALE=***val*] [**M=***val*] [**ABS=0**|**1**]

The format for an N-input OR gate CCVS is:

H*xxxx out+ out-* [**CCVS**] **OR(***N***)***vin1* ... *vinN*
maxval1 *outval1* ... *maxvalK* *outvalK*
[**DELTA=***val*] [**TC1=***val*] [**TC2=***val*]
[**SCALE=***val*] [**M=***val*] [**ABS=0**|**1**]

The format for an N-input NOR gate CCVS is:

```
Hxxxx out+ out- [CCVS] NOR(N) vin1 ... vinN
maxval1   outval1 ... maxvalK   outvalK
[DELTA=val] [TC1=val] [TC2=val]
[SCALE=val] [M=val] [ABS=0|1]
```

out+ and *out-* are the nodes of the voltage output. The entry **CCVS** is the default for the **H** element type. *vin1* ... *vinN* are the voltage sources through which the multiple control current inputs flow. The number of input sources (*N*) in the list must be the same as the value specified for **AND(***N***)**, **NAND(***N***)**, **OR(***N***)**, or **NOR(***N***)**. For current-controlled sources, *N* must be in the range 2 ≤ *N*≤ 4.

Table 20: Multi-Input Gate CCVS Instance Parameters

Parameter	Description	Unit	Default
ABS	Output is absolute when ABS=1	None	0
DELTA	Distance over which curvature is applied in the interpolation function Zero produces linear interpolation, positive values produce continuous curvature over the waveform Maximum is one-half of the smallest difference between control (input) values	None	One-fourth of the smallest difference between control (input) values
M	Multiplier to simulate multiple elements	None	1.0
SCALE	Scale factor for voltage	None	1.0
TC1	Linear (1st-order) temperature coefficient	°K^{-1}	0.0
TC2	Quadratic (2nd-order) temperature coefficient	°K^{-2}	0.0

CCVS Gate Netlist Examples

These two-input examples assume logic “0” is 0.0 volts output at 0.0 mA input, and logic “1” is 5.0 volts output at 5.0 mA input.

```
Hand2 30 0 CCVS AND(2) V21 V22
+ 0.0 0.0
+ 0.5e-3 0.1
+ 1.0e-3 0.2
+ 4.0e-3 4.5
+ 4.5e-3 4.75
+ 5.0e-3 5.0
```

```
Hnand2 40 0 CCVS NAND(2) V23 V24
+ 0.0 5.0
+ 0.5e-3 4.75
+ 1.0e-3 4.5
+ 4.0e-3 0.2
+ 4.5e-3 0.1
+ 5.0e-3 0.0

Hor2 50 0 CCVS OR(2) V25 V26
+ 0.0 0.0
+ 0.5e-3 0.1
+ 1.0e-3 0.2
+ 4.0e-3 4.5
+ 4.5e-3 4.75
+ 5.0e-3 5.0

Hnor2 60 0 CCVS NOR(2) V27 V28
+ 0.0 5.0
+ 0.5e-3 4.75
+ 1.0e-3 4.5
+ 4.0e-3 0.2
+ 4.5e-3 0.1
+ 5.0e-3 0.0
```

See the examples for the "Voltage-Controlled Voltage Source, Multi-Input Gate" on page 5-57 element for samples of simulation runs produced by these devices.

Notes on minval, maxval, outval parameters

The output is specified as a function of the inputs using a set of pairs (*minval*, *outval* or *maxval*, *outval*), separated by spaces and/or commas. Currents are specified in amperes, voltages in volts. The pairs should be entered in ascending order of *minval* or *maxval* (see Netlist Examples). Any number of pairs may be specified.

> **Note:** In the **Schematic Editor** component Property windows, the Gate components use property names **IN1**, **IN2**, ...**IN***K* for the *minval* and *maxval* parameters, and **OUT1**, **OUT2**, ...**OUT***K* for the *outval* parameters.

For **AND** and **NAND** gates, the simulator finds the minimum current across all voltage source inputs:

minI = MIN[I(*vin1*), I(*vin2*), ... I(*vinN*)]

The simulator matches *minI* to the list of entries *minval1* ... *minvalK* in the instance statement, and sets the output to the corresponding *outval*.

When *minI* is equal to the current that represents logic “0” or logic “1,” the corresponding output from an **AND** or **NAND** gate should be set accordingly.

Values of *minI* that are intermediate between the logic “0” and “1” currents represent transitional values. For intermediate values that are not in the list of *minvals*, the simulator calculates the corresponding output by interpolation from the given values. The use of the **DELTA** parameter allows you to control the curvature of the interpolation to guarantee that the 1st derivative of the curve is continuous.

For values of *minI* that are below the range of listed input current, the simulator sets the output voltage to the one corresponding to the smallest input voltage in the list. For values of *minI* that are above the range of listed input currents, the simulator sets the output voltage to the one corresponding to the largest input current in the list.

For **OR** and **NOR** gates, the simulator finds the maximum difference between all pairs of inputs:

maxI = MAX[I(*vin1*), I(*vin2*), ... I(*vinN*)]

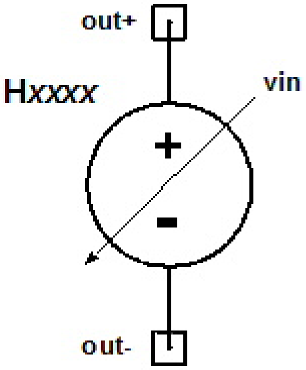
The simulator matches *maxI* to the list of entries *maxval1* ... *maxvalK* in the instance statement, and sets the output to the corresponding *outval*.

When *maxI* is equal to the current that represents logic “0” or logic “1,” the corresponding output from an **OR** or **NOR** gate should be set accordingly.

Values of *maxI* that are intermediate between the logic “0” and “1” current represent transitional values. For intermediate values that are not in the list, the simulator calculates the corresponding output by linear interpolation on the given values, using the **DELTA** parameter as discussed above.

For values of *maxI* that are below the range of listed input currents, the simulator sets the output voltage to the one corresponding to the smallest input voltage in the list. For values of *maxI* that are above the range of listed input currents, the simulator sets the output voltage to the one corresponding to the largest input current in the list.

Current-Controlled Voltage Source, Linear



Linear CCVS Netlist Format

The format for a linear current-controlled voltage source (CCVS) is:

```
Hxxxx out+ out- [CCVS] vin [GAIN=]transresistance [MAX=val]

[MIN=val] [SCALE=val] [TC1=val] [TC2=val] [ABS=0|1] [M=val]
```

out+ is the positive node and *out-* is the negative node of the voltage source. The entry **CCVS** is the default for the **H** element type. *vin* is a voltage source through which the control current flows. The *vin* source must be defined in a separate instance line elsewhere in the netlist.

Table 21: Linear CCVS Instance Parameters

Parameter	Description	Unit	Default
ABS	When ABS=1, output is an absolute value	None	0
GAIN	Transresistance of the control current	Ohm	1.0
M	Multiplier to simulate multiple parallel inputs	None	1.0
MAX	Maximum output voltage	Volt	None
MIN	Minimum output voltage	Volt	None
SCALE	Multiplier for voltage	None	1.0
TC1	Linear (1st-order) temperature coefficient	$^{\circ}K^{-1}$	0.0
TC2	Quadratic (2nd-order) temperature coefficient	$^{\circ}K^{-2}$	0.0

Linear CCVS Netlist Examples

```
H23 inplus inminus CCVS V23 GAIN=2.0e-5

H11 34 35 CCVS V25 GAIN=1.0e-2
```

Notes

The functional equation for the linear CCVS is:

$$V(out+) - V(out-) = \mathbf{GAIN} \times I(vin) \times \mathbf{SCALE} \times \mathbf{M} \times (1 + \Delta T \times (\mathbf{TC1} + \Delta T \times \mathbf{TC2}))$$

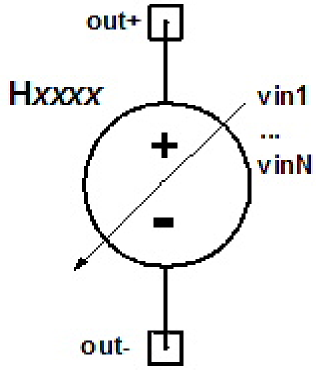
If the result is less than **MIN**,

$$V(out+) - V(out-) = \mathbf{MIN}$$

If the result is greater than **MAX**,

$$V(out+) - V(out-) = \mathbf{MAX}$$

Current-Controlled Voltage Source, Polynomial



Polynomial CCVS Netlist Format

The format for a polynomial current-controlled voltage source (CCVS) is:

H*xxxx out+ out-* [**CCVS**] **POLY(***N***)**

vin1 [*vin2* [*vin3*]]

[**MAX=***val*] [**MIN=***val*] [**SCALE=***scale*] [**M=***val*]

[**TC1=***val*] [**TC2=***val*] [**ABS=0**|**1**]

p0 [*p1* ... *pK*]

out+ is the positive node and *out-* is the negative node of the voltage source. The entry **CCVS** is the default for the **H** element type. The entry **POLY** is required to identify the polynomial CCVS type. The number of inputs, *N*, can be 1, 2, or 3. If *N* is not specified, 1 is the default. *vc1* through *vc3* are the *N* sources for the control currents. The voltage sources must be defined elsewhere in the netlist. *p0* through *pK* are the *K* coefficients for the polynomial function. One coefficient must be provided.

Table 22: Polynomial CCVS Instance Parameters

Parameter	Description	Unit	Default
ABS	1 = Output is an absolute value	None	0
M	Multiplier to simulate multiple elements	None	1.0
MAX	Maximum output voltage	Volt	None
MIN	Minimum output voltage	Volt	None
SCALE	Multiplier for voltage	None	1.0
TC1	Linear (1st-order) temperature coefficient	°K^{-1}	0.0

Parameter	Description	Unit	Default
TC2	Quadratic (2nd-order) temperature coefficient	$°K^{-2}$	0.0

Polynomial CCVS Netlist Examples

```
H21 21 0 CCVS POLY(1) V1 1.1 2.1 0 3.1

H31 31 0 CCVS POLY(2) V1 V2 1.2 2.2 0 0 0 0 0 0 3.2 0

H41 41 0 CCVS POLY(3) V1 V2 V3 1.3 2.3 0 0

+ 0 0 0 0 0 0

+ 0 3.3 0 0 0 0 0 0 0 4.3
```

Notes

The functional equation for the polynomial CCVS is:

V(*out*+) - V(*out*-) = *polynomial*× **SCALE** × (1 + ΔT ×**TC1** + ΔT^2× **TC2**)

If the result is less than **MIN**,

V(*out*+) - V(*out*-) = **MIN**

If the result is greater than **MAX**,

V(*out*+) - V(*out*-) = **MAX**

The polynomial depends on the number of inputs (*N*) and the number of polynomial coefficients (*K*). Each polynomial has terms of order (**O**), the sum of the exponents of the elements in the term. The list of coefficients must include coefficients for every term up to and including the complete group of terms with the highest order in the specified polynomial, using zero coefficients for any intermediate or trailing terms that should not be computed.

When *N*=1, the polynomial formula has one term each of order **O** {0, 1, ... *K*}:

$p0 + p1 \times I(vin1) + \ldots pK \times I(vin1)^K$

Each coefficient must be a real value or zero to represent a missing term. For example, to specify a CCVS between nodes 21 and 0 whose output, controlled by the current through voltage source V1, is described by the one-input polynomial $1.1 + 2.1 \times I(V1) + 3.1 \times I(V1)^3$, the instance statement sets coefficients *p0*=1.1, *p1*=2.1, *p2*=0, and *p3*=3.1:

```
H21 21 0 CCVS POLY(1) V1 1.1 2.1 0 3.1
```

(The control voltage source V1 is defined on its own instance line elsewhere in the netlist.)

When *N*=2, the polynomial formula can have more than one term in each order grouping:

O (0)

$p0 +$

O (1)

$p1 \times I(vin1) + p2 \times I(vin2) +$

O (2)

$p3 \times I(vin1)^2 +$

$p4 \times I(vin1) \times I(vin2^{-}) +$

$p5 \times I(vin2)^2 +$

$p6 \times I(vin1)^3 +$

$p7 \times I(vin1)^2 \times I(vin2) +$

$p8 \times I(vin1) \times I(vin2)^2 +$

$p9 \times I(vin2)^3 +$

O (3)

...

If the polynomial includes any terms from an order group, the list of coefficients must include intermediate and trailing zeros to complete the order. For example, to specify a CCVS between nodes 31 and 0 whose output, controlled by the currents through voltage sources V1 and V2, is described by the two-input polynomial $1.2 + 2.2 \times I(V1) + 3.2 \times I(V1) \times I(V2)^2$, the instance statement sets coefficients $p0$=1.2, $p1$=2.2, and $p8$=3.2. Intermediate coefficients $p2$ through $p7$ and trailing coefficient $p9$ are set to 0:

```
H31 31 0 CCVS POLY(2) V1 V2 1.2 2.2 0 0 0 0 0 0 3.2 0
```

When N=3, the polynomial formula becomes:

O (0)

$p0 +$

O (1)

$p1 \times I(\mathrm{vin1}) +$

$p2 \times I(vin2) +$

$p3 \times I(vin3) +$

O (2)

$p4 \times I(vin1)^2 +$

p5 × I(*vin1*) × I(*vin2*) +

p6 × I(*vin1*) × I(*vin3*) +

p7 × I(*vin2*)^2 +

p8 × I(*vin2*) × I(*vin3*) +

p9 × I(*vin3*)^2 +

O (3)

p10 × I(*vin1*)^3 +

p11 × I(*vin1*)^2 × I(*vin2*) +

p12 × I(*vin1*)^2 × I(*vin3*) +

p13 × I(*vin1*) × I(vin2)^2 +

p14 × I(*vin1*) × I(*vin2*) × I(*vin3*) +

p15 × I(*vin1*) × I(*vin3*)^2 +

p16 × I(*vin2*)^3 +

p17 × I(*vin2*)^2 × I(*vin3*) +

p18 × I(*vin2*) × I(*vin3*)^2 +

p19 × I(*vin3*)^3 +

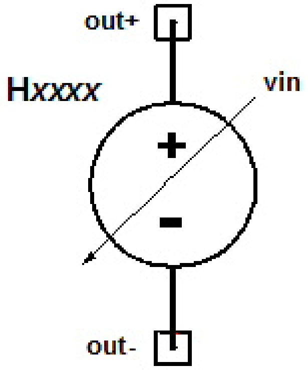
O (4)

...

For example, to specify a CCVS between nodes 41 and 0 whose output, controlled by currents across voltage sources V1, V2, and V3, is described by the three-input polynomial 1.3 + 2.3 × I (V1) + 3.3 × I(V1)^2× I(V2) + 4.3 × I(V3)^3, the instance statement sets coefficients *p0*=1.3, *p1*=2.3, *p11*=3.3, and *p19*=4.3. Intermediate coefficients *p2* through *p10* and *p12* through *p18* are set to 0 (since *p19* is the coefficient for the highest term with order 3, no trailing zeros are needed):

```
H41 41 0 CCVS POLY(3) V1 V2 V3 1.3 2.3 0 0

+ 0 0 0 0 0 0

+ 0 3.3 0 0 0 0 0 0 0 4.3
```

Current-Controlled Voltage Source, Piecewise Linear



Piecewise Linear CCVS Netlist Format

The format for a piecewise linear current-controlled voltage source (CCVS) is:

```
Hxxxx out+ out- [CCVS] PWL(1)vin

[DELTA=val] [SCALE=scale] [M=val]

[TC1=val] [TC2=val]

x1 y1 [... xK yK ]
```

out+ is the positive node and *out-* is the negative node of the voltage source. The entry **CCVS** is the default for the **H** element type. The entry **PWL** is required to identify the piecewise linear CCVS type. *vin* is the voltage source through which the control current flows. The input voltage source must be defined elsewhere in the netlist.

The *x y* pairs are the input current values and the corresponding output voltage values. For intermediate values that are not in the list of *x* values, the simulator calculates the corresponding output by interpolation on the given values. The use of the **DELTA** parameter allows you to control the curvature of the interpolation to guarantee that the 1st derivative of the curve is continuous.

Table 23: Piecewise Linear CCVS Instance Parameters

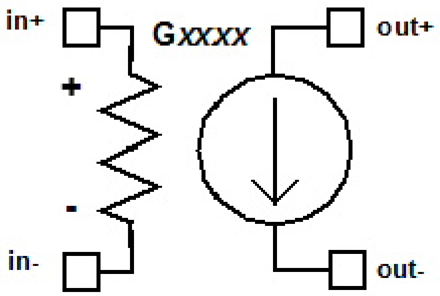
Parameter	Description	Unit	Default
DELTA	Distance over which curvature is applied in the interpolation function Zero produces linear interpolation, positive values produce continuous curvature over the waveform Maximum is one-half of the smallest difference between control (input) values	None	One-fourth of the smallest difference between control (input) values

Parameter	Description	Unit	Default
M	Multiplier to simulate multiple elements	None	1.0
SCALE	Multiplier for voltage	None	1.0
TC1	Linear (1st-order) temperature coefficient	°K^{-1}	0.0
TC2	Quadratic (2nd-order) temperature coefficient	°K^{-2}	0.0

Piecewise Linear CCVS Netlist Examples

```
Hpwl1 30 0 CCVS PWL(1) 21 0
+ 0.0 0.0
+ 0.5e-3 0.1
+ 1.0e-3 0.2
+ 4.0e-3 4.5
+ 4.5e-3 4.75
+ 5.0e-3 5.0
```

Voltage-Controlled Current Source, Delay



VCCS Delay Netlist Format

The format for a voltage-controlled current source with delay is:

G`xxxx out+ out-` [**VCVS**] **DELAY**`in+ in-` **TD=**`val`
[**SCALE=**`val`] [**TC1=**`val`] [**TC2=**`val`]

out+ is the positive node and *out-* is the negative node of the current source. The entry **VCCS** is the default for the **G** element type. The entry **DELAY** selects the **G** element delay type. *in+* and *in-* are the positive and negative nodes for the control voltage.

Table 24: Delay VCCS Instance Parameters

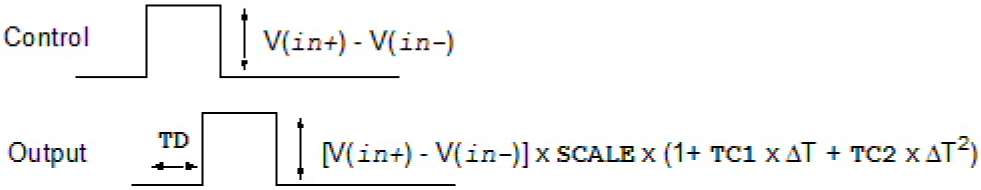
Parameter	Description	Unit	Default
SCALE	Scale factor for current	None	1.0
TC1	Linear (1st-order) temperature coefficient	°K^{-1}	0.0
TC2	Quadratic (2nd-order) temperature coefficient	°K^{-2}	0.0
TD	Time delay. Must be ≥ 0.	Second	None

VCCS Delay Netlist Example

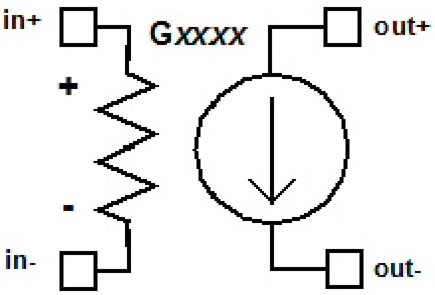
```
G23 inplus inminus VCCS DELAY cplus cminus TD=2.0e-5
```

Notes

The following figure illustrates the operation of the VCCS delay element:



Voltage-Controlled Current Source, Foster (Netlist Only)



Foster VCCS Netlist Format

The format for a Pole-Residue (Foster) format voltage-controlled current source (VCCS) is:

```
Gxxxx out+ out- FOSTERin+ in- C1 C2
+ ( Re{r1}, Im{r1}) / ( Re{p1}, Im{p1})
+ [( Re{r2}, Im{r2}) / ( Re{p2}, Im{p2})] ...
```

out+ is the positive node and *out-* is the negative node of the current source. **FOSTER** identifies the element type. *in+* and *in-* are the positive and negative nodes for the control voltage drop.

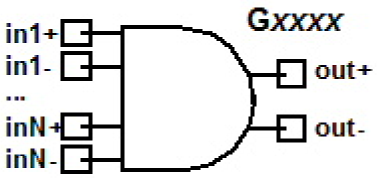
C1 is the proportional constant (trans-conductance) and *C2* is the derivative constant (trans-capacitance). Re{*ri*} and Im{*ri*} are the real and imaginary parts of the residues. Re{*pi*} and Im{*pi*} are the real and imaginary parts of the corresponding poles.

The Foster VCCS is available for use in netlists, but is not supported in the Components window of the **Schematic Editor**.

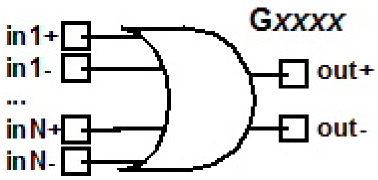
Foster VCCS Netlist Example

```
G20 net25 0 FOSTER net26 0 0.002 -0.005
+ (-2.23e12, 0) / (-9.534e12, 0)
+ (-54.959e10, 1) / (-1.1165e11, -1e-10)
+ (-54.959e10, -1) / (-1.1165e11, 1e-10)
```

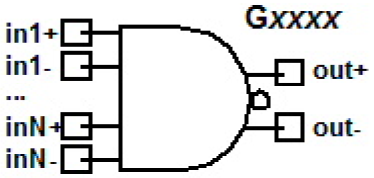
Voltage-Controlled Current Source, Multi-Input Gate



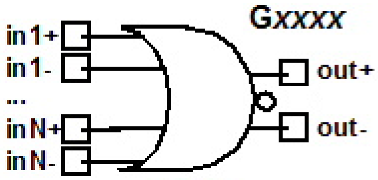
AND



OR



NAND



NOR

The format for an N-input AND gate VCCS is:

```
Gxxxx out+ out- [VCCS] AND(N)in1+ in1- ... inN+ inN-
minval1  outval1 ... minvalK  outvalK
[DELTA=val] [TC1=val] [TC2=val] [SCALE=val] [M=val]
```

The format for an N-input NAND gate VCCS is:

```
Gxxxx out+ out- [VCCS] NAND(N)in1+ in1- ... inN+ inN-
minval1  outval1 ... minvalK  outvalK
[DELTA=val] [TC1=val] [TC2=val] [SCALE=val] [M=val]
```

The format for an N-input OR gate VCCS is:

```
Gxxxx out+ out- [VCCS] OR(N)in1+ in1- ... inN+ inN-
maxval1  outval1 ... maxvalK  outvalK
[DELTA=val] [TC1=val] [TC2=val] [SCALE=val] [M=val]
```

The format for an N-input NOR gate VCCS is:

```
Gxxxx out+ out- [VCCS] NOR(N)in1+ in1- ... inN+ inN-
maxval1  outval1 ... maxvalK  outvalK
[DELTA=val] [TC1=val] [TC2=val] [SCALE=val] [M=val]
```

out+ and *out-* are the nodes of the current output. The entry **VCCS** is the default for the **G** element type. *in1+ in1-* ... *inN+ inN-* are the positive and negative node pairs for the multiple control voltage inputs. The number of input node pairs (*N*) in the list must be the same as the value specified for **AND (***N***)**, **NAND (***N***)**, **OR (***N***)**, or **NOR (***N***)**.

Table 25: Multi-Input Gate VCCS Instance Parameters

Parameter	Description	Unit	Default
DELTA	Distance over which curvature is applied in the interpolation function Zero produces linear interpolation, positive values produce continuous curvature over the waveform Maximum is one-half of the smallest difference between control (input) values	None	One-fourth of the smallest difference between control (input) values
M	Multiplier to simulate multiple elements	None	1.0
SCALE	Scale factor for voltage	None	1.0
TC1	Linear (1st-order) temperature coefficient	°K^{-1}	0.0
TC2	Quadratic (2nd-order) temperature coefficient	°K^{-2}	0.0

VCCS Gate Netlist Examples

These two-input examples assume logic “0” is 0.0 mA output at 0.0 volts input, and logic “1” is 5.0 mA output at 5.0 volts input.

```
Gand2 30 0 VCCS AND(2) 21 0 22 0
+ 0.0 0.0
+ 0.5 0.1e-3
+ 1.0 0.2e-3
+ 4.0 4.5e-3
+ 4.5 4.75e-3
+ 5.0 5.0e-3
```

```
Gnand2 40 0 VCCS NAND(2) 23 0 24 0
+ 0.0 5.0e-3
+ 0.5 4.75e-3
+ 1.0 4.5e-3
+ 4.0 0.2e-3
+ 4.5 0.1e-3
+ 5.0 0.0e-3
```

```
Gor2 50 0 VCCS OR(2) 25 0 26 0
+ 0.0 0.0e-3
+ 0.5 0.1e-3
+ 1.0 0.2e-3
+ 4.0 4.5e-3
+ 4.5 4.75e-3
+ 5.0 5.0e-3
```

```
Gnor2 60 0 VCCS NOR(2) 27 0 28 0
+ 0.0 5.0e-3
+ 0.5 4.75e-3
+ 1.0 4.5e-3
+ 4.0 0.2e-3
+ 4.5 0.1e-3
+ 5.0 0.0e-3
```

See the examples for the "Voltage-Controlled Voltage Source, Multi-Input Gate" on page 5-57 element for samples of simulation runs produced by these devices.

Notes on minval, maxval, outval parameters

The output is specified as a function of the inputs using a set of pairs (*minval*, *outval* or *maxval*, *outval*), separated by spaces and/or commas. Voltages are specified in volts, currents in amperes. The pairs should be entered in ascending order of *minval* or *maxval* (see Netlist Examples). Any number of pairs may be specified.

> **Note:** In the **Schematic Editor** component Property windows, the Gate components use property names **IN1**, **IN2**, ...**IN***K* for the *minval* and *maxval* parameters, and **OUT1**, **OUT2**, ...**OUT***K* for the *outval* parameters.

For **AND** and **NAND** gates, the simulator finds the minimum difference between all pairs of inputs:

mindiff = MIN[$V(in1^{+}\text{-}in1^{-}), V(in2^{+}\text{-}in2^{-}), ...V(inN^{+}\text{-}inN^{-})$]

The simulator matches *mindiff* to the list of entries *minval1 ... minvalK* in the instance statement, and sets the output to the corresponding *outval*.

When *mindiff* is equal to the voltage that represents logic “0” or logic “1,” the corresponding output from an **AND** or **NAND** gate should be set accordingly.

Values of *mindiff* that are intermediate between the logic “0” and “1” voltages represent transitional values. For intermediate values that are not in the list of *minvals*, the simulator calculates the corresponding output by interpolation from the given values. The use of the **DELTA** parameter allows you to control the curvature of the interpolation to guarantee that the 1st derivative of the curve is continuous.

For values of *mindiff* that are below the range of listed input voltages, the simulator sets the output current to the one corresponding to the smallest input voltage in the list. For values of *mindiff* that are above the range of listed input voltages, the simulator sets the output current to the one corresponding to the largest input voltage in the list.

For **OR** and **NOR** gates, the simulator finds the maximum difference between all pairs of inputs:

maxdiff = MAX[$V(in1^{+} - in1^{-}), V(in2^{+} - in2^{-}), ...V(inN^{+} - inN^{-})$]

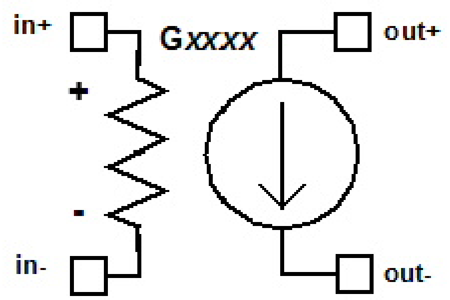
The simulator matches *maxdiff* to the list of entries *maxval1 ... maxvalK* in the instance statement, and sets the output to the corresponding *outval*.

When *maxdiff* is equal to the voltage that represents logic “0” or logic “1,” the corresponding output from an **OR** or **NOR** gate should be set accordingly.

Values of *maxdiff* that are intermediate between the logic “0” and “1” voltages represent transitional values. For intermediate values that are not in the list, the simulator calculates the corresponding output by interpolation on the given values, using the **DELTA** parameter as discussed above.

For values of *maxdiff* that are below the range of listed input voltages, the simulator sets the output current to the one corresponding to the smallest input voltage in the list. For values of *maxdiff* that are above the range of listed input voltages, the simulator sets the output voltage to the one corresponding to the largest input voltage in the list.

Voltage-Controlled Current Source, Laplace



VCCS Laplace Netlist Format

The voltage-controlled current source with Laplace transfer function uses two different formats, the coefficient format and the pole zero format.

Coefficient Format

In the coefficient format, H(s) is specified by giving the coefficients of the transfer function polynomials:

`Gxxxx out+ out- LAPLACEin+ in- a0[,] ... aN /b0[,] ...bD`

`[SCALE=val] [TC1=val] [TC2=val] [M=val]`

out+ is the positive node and *out-* is the negative node of the current source. The entry **LAPLACE** selects the G element Laplace transfer function type. *in+* and *in-* are the positive and negative nodes for the control voltage. The division symbol (*/*) in the instance line is required syntax.

> **Note:**
>
> Comma separators between the *a* and *b* entries are optional. Spaces may be used as separators instead of commas.

The function of the device is expressed as:

I(*out+*, *out-*) = SCALE × H(s) × V(*in+*, *in-*)

The transfer function H(s) is the ratio of two polynomials in the complex variable *s*.

$$H(s) = \frac{a_0 + a_1 s + a_2 s^2 + \ldots}{b_0 + b_1 s + b_2 s^2 + \ldots}$$

The coefficients (a_0 ... a_N) specify the numerator polynomial of the ratio. The coefficients (b_0 ... b_D) specify the denominator polynomial. The subscripts *N* and *D* represent the order of the numerator and denominator respectively. The first coefficients in both numerator and denominator (a_0 and b_0) are constants, which must be specified even if they are zero. Thus, leading zeros are significant. In addition, intermediate zero-valued coefficients must be explicitly supplied in order to have the non-zero coefficients applied to the correct powers of *s*. Trailing zeros are not significant, and are automatically removed.

For example, to specify the following transfer function (where coefficient a_1=0):

$$H(s) = \frac{1+2s^2}{1+s+3s^2}$$

A coefficient format netlist has the following statement:

```
Gex1 out gnd LAPLACE in gnd 1, 0, 2 / 1, 1, 3
```

> **Note:**
>
> The order of the numerator (N) may not exceed the order of the denominator (D), otherwise Nexxim posts an error message and disregard the device.

Pole Zero Format

The pole zero format specifies the complex roots of the transfer function polynomials:

```
Gxxxx out+ out- LAPLACEin+ in-

rz1 iz1 ... rzN izN /rp1 ip1 ... rpD ipD

POLE [SCALE=val] [TC1=val] [TC2=val] [M=val]
```

The pole zero syntax must include the keyword **POLE**. The slash (/) is required. The nodes and other parameters are the same as for the coefficient format.

The parameters rz_1 iz_1... $rz_N iz_N$ in the numerator are the complex zeros of the transfer function. The parameters rp_1 ip_1... $rp_D ip_D$ in the denominator are the complex poles of the transfer function.

$$H(s) = \frac{(s - rz_1 + j \times iz_1) \times (s - rz_2 + j \times iz_2) \times \ldots}{(s - rz_1 + j \times ip_1) \times (s - rz_2 + j \times ip_2) \times \ldots}$$

Both poles and zeros are complex numbers with a real part and an imaginary part. Each root must specify the magnitudes of both real and imaginary parts even if one of them is zero (*j*, the square root of -1, does not need to be entered). The list must also provide the complex conjugate of each root when the magnitude of the imaginary part is nonzero. The roots may be entered in any order.

For example, to specify zeros of s-1, s-2j with complex conjugate s-(-2j), s-(-1+3j) with complex conjugate s-(-1-3j), the denominator entry is:

```
1 0 0 2 0 -2 -1 3 -1 -3
```

Table 26: Laplace VCCS Instance Parameters

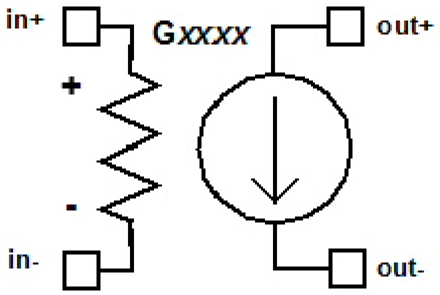
Parameter	Description	Unit	Default
a0 ... aN	Coefficients of the numerator polynomial (coefficient syntax)	None	None
b0 ... bD	Coefficients of the denominator polynomial (coefficient syntax)	None	None
rz1 iz1 ... rzN izN	Complex zeros (pole/zero syntax)	None	None
rp1 ip1 ... rpD ipD	Complex poles (pole/zero syntax)	None	None
POLE	Selects pole/zero syntax	None	Coefficient syntax
M	Multiplier to simulate multiple elements	None	1.0
SCALE	Scale factor for current	None	1.0
TC1	Linear (1st-order) temperature coefficient	°K^{-1}	0.0
TC2	Quadratic (2nd-order) temperature coefficient	°K^{-2}	0.0

VCCS Laplace Element Netlist Examples

```
G21 21 0 LAPLACE 31 0 0.1 2.2 -.3 / 0.25 -2.1 0.33 -.4
```

```
G14 33 0 LAPLACE 44 0 .4 0 .35 -.2 .35 .2 / 1.0 2.5 1.0 -2.5
+ .56 0 1.8 0 POLE
```

Voltage-Controlled Current Source, Linear



Linear VCCS Netlist Format

The format for a linear voltage-controlled current source (VCCS) is:

```
Gxxxx out+ out- [VCCS] in+ in- [TRANS=]transconductance
[MAX=val] [MIN=val] [M=val]
[SCALE=val] [TC1=val] [TC2=val] [ABS=0|1]
```

out+ is the positive node and *out-* is the negative node of the current source. **VCCS** is the default for the **G** element type. *in+* and *in-* are the positive and negative nodes for the control voltage drop.

The functional equation for the linear VCCS is:

$I(out+, out-) = \mathbf{TRANS} \times (V(in+) - V(in-)) \times \mathbf{SCALE} \times (1 + \Delta T \times \mathbf{TC1} + \Delta T^2 \times \mathbf{TC2})$

If the result is less than **MIN**,

$I(out+, out-) = \mathbf{MIN}$

If the result is greater than **MAX**,

$I(out+, out-) = \mathbf{MAX}$

Table 27: Linear VCCS Instance Parameters

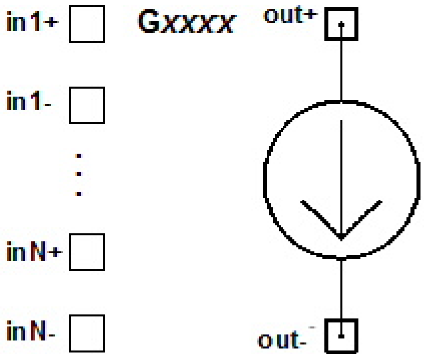
Parameter	Description	Unit	Default
ABS	When ABS=1, output is an absolute value	None	0
M	Number of elements in parallel	None	1.0
MAX	Maximum output current	Amp	None
MIN	Minimum output current	Amp	None
SCALE	Multiplier for current	None	1.0
TC1	Linear (1st-order) temperature coefficient	$°K^{-1}$	0.0

Parameter	Description	Unit	Default
TC2	Quadratic (2nd-order) temperature coefficient	°K^{-2}	0.0
TRANS	Transconductance of the voltage-to-current conversion	Mho	1.0

Linear VCCS Netlist Example

```
G20 42 0 VCCS 12 34 TRANS=0.004
```

Voltage-Controlled Current Source, Polynomial



Polynomial VCCS Netlist Format

The format for a polynomial voltage-controlled current source (VCCS) is:

G*xxxx out+ out-* [**VCCS**] **POLY(***N***)**

in1+ in1- [*in2+ in2-* [*in3+ in3-*]]

[**MAX=***val*] [**MIN=***val*] [**SCALE=***scale*] [**M=***val*]

[**TC1=***val*] [**TC2=***val*] [**ABS=0**|**1**]

p0 [*p1* ... *pK*]

out+ is the positive node and *out-* is the negative node of the current source. The entry **VCCS** is the default for the **G** element type. The entry **POLY** is required to identify the polynomial VCCS type. The number of input voltage pairs, *N*, can be 1, 2, or 3. If *N* is not specified, 1 input is the default. *in+* and *in-* are the *N* pairs of positive and negative nodes for the control voltages. *p0* through *pK* are the *K* coefficients for the polynomial function. One coefficient must be provided.

> **Note:**
>
> When *N*=1 (one input pair), a single coefficient is interpreted as *p1* (*p0* is set to 0.0). Two or more coefficients are interpreted according to the syntax above.

Table 28: Polynomial VCCS Instance Parameters

Parameter	Description	Unit	Default
ABS	1 = Output is an absolute value	None	0
M	Multiplier to simulate multiple elements	None	1.0
MAX	Maximum output current	Volt	None
MIN	Minimum output current	Volt	None
SCALE	Multiplier for current	None	1.0
TC1	Linear (1st-order) temperature coefficient	°K^{-1}	0.0
TC2	Quadratic (2nd-order) temperature coefficient	°K^{-2}	0.0

Polynomial VCCS Netlist Examples

```
G21 21 0 VCCS POLY(1) 1 0 1.1 2.1 0 3.1

G31 31 0 VCCS POLY(2) 1 0 2 0 1.2 2.2 0 0 0 0 0 0 3.2 0

G41 41 0 VCCS POLY(3) 1 0 2 0 3 0 1.3 2.3 0 0

+ 0 0 0 0 0 0

+ 0 3.3 0 0 0 0 0 0 0 4.3
```

Notes

The functional equation for the polynomial VCCS is:

I(*out*+, *out*-)) = *polynomial*×**SCALE** ×**M** × (1 + ΔT ×**TC1** + ΔT^2×**TC2**)

If the result is less than **MIN**,

I(*out*+, *out*-) = **MIN**

If the result is greater than **MAX**,

I(*out*+, *out*-) = **MAX**

The polynomial depends on the number of inputs (*N*) and the number of polynomial coefficients (*K*). Each polynomial has terms of order (**O**), the sum of the exponents of the elements in the term. The list of coefficients must include coefficients for every term up to and including the complete group of terms with the highest order in the specified polynomial, using zero coefficients for any intermediate or trailing terms that should not be computed.

When *N*=1, the polynomial formula has one term each of order **O** {0, 1, ... *K*}:

$p0 + p1 \times V(in1^{+}, in1^{-}) + \ldots pK \times V(in1^{+}, in1^{-})^{K}$

For example, to specify a VCCS between nodes 21 and 0 whose output, controlled by the voltagte across nodes 1 and 0, is described by the one-input polynomial $1.1 + 2.1 \times V(1, 0) + 3.1 \times V(1, 0)^{3}$, the instance statement sets coefficients *p0*=1.1, *p1*=2.1, *p2*=0, and *p3*=3.1:

```
G21 21 0 VCCS POLY(1) 1 0 1.1 2.1 0 3.1
```

When *N*=2, the polynomial formula can have more than one term in each order grouping:

O (0)

$p0 +$

O (1)

$p1 \times V(in1^{+}, in1^{-}) +$

$p2 \times V(in2^{+}, in2^{-}) +$

O (2)

$p3 \times V(in1^{+}, in1^{-})^{2} +$

$p4 \times V(in1^{+}, in1^{-}) \times V(in2^{+}, in2^{-}) +$

$p5 \times V(in2^{+}, in2^{-})^{2} +$

O (3)

$p6 \times V(in1^{+}, in1^{-})^{3} +$

$p7 \times V(in1^{+}, in1^{-})^{2} \times V(in2^{+}, in2^{-}) +$

$p8 \times V(in1^{+}, in1^{-}) \times V(in2^{+}, in2^{-})^{2} +$

$p9 \times V(in2^{+}, in2^{-})^{3} +$

O (4)

...

For example, to specify a VCCS between nodes 31 and 0 whose output, controlled by voltages across node pairs (1,0) and (2,0), is described by the two-input polynomial $1.2 + 2.2 \times V(1, 0) + 3.2 \times V(1, 0) \times V(2, 0)^{2}$, the instance statement sets coefficients *p0*=1.2, *p1*=2.2, and *p8*=3.2. Intermediate coefficients *p2* through *p7* and trailing coefficient *p9* are set to 0:

```
G31 31 0 VCCS POLY(2) 1 0 2 0 1.2 2.2 0 0 0 0 0 0 3.2 0
```

When N=3, the polynomial formula becomes:

O (0)

$p0 +$

O (1)

$p1 \times V(in1^{+}, in1^{-}) +$

$p2 \times V(in2^{+}, in2^{-}) +$

$p3 \times V(in3^{+}, in3^{-}) +$

O (2)

$p4 \times V(in1^{+}, in1^{-})^{2} +$

$p5 \times V(in1^{+}, in1^{-}) \times V(in2^{+}, in2^{-}) +$

$p6 \times V(in1^{+}, in1^{-}) \times V(in3^{+}, in3^{-}) +$

$p7 \times V(in2^{+}, \mathrm{in2}^{-})^{2} +$

$p8 \times V(in2^{+}, in2^{-}) \times V(in3^{+}, in3^{-}) +$

$p9 \times V(in3^{+}, in3^{-})^{2} +$

O (3)

$p10 \times V(in1^{+}, in1^{-})^{3} +$

$p11 \times V(in1^{+}, in1^{-})^{2} \times V(in2^{+}, in2^{-}) +$

$p12 \times V(in1^{+}, in1^{-})^{2} \times V(in3^{+}, in3^{-}) +$

$p13 \times V(in1^{+}, in1^{-}) \times V(in2^{+}, in2^{-})^{2} +$

$p14 \times V(in1^{+}, in1^{-}) \times V(in2^{+}, in2^{-}) \times V(in3^{+}, in3^{-}) +$

$p15 \times V(in1^{+}, in1^{-}) \times V(in3^{+}, in3^{-})^{2} +$

$p16 \times V(in2^{+}, in2^{-})^{3} +$

$p17 \times V(in2^{+}, in2^{-})^{2} \times V(in3^{+}, in3^{-}) +$

$p18 \times V(in2^{+}, in2^{-}) \times V(in3^{+}, in3^{-})^{2} +$

$p19 \times V(in3^{+}, in3^{-})^{3} +$

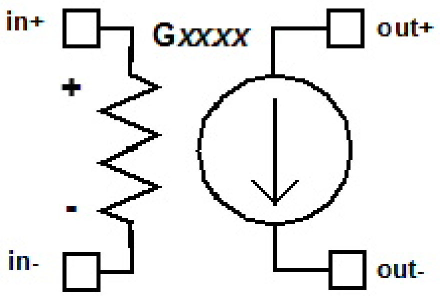
O (4)

...

For example, to specify a VCCS between nodes 41 and 0 whose output, controlled by the voltages across node pairs (1, 0), (2, 0), and (3, 0), is described by the three-input polynomial 1.3 + 2.3 × V(1, 0) + 3.3 × $V(1, 0)^2$× V(2, 0) + 4.3 × $V(3, 0)^3$, the instance statement sets coefficients *p0*=1.3, *p1*=2.3, *p11*=3.3, and *p19*=4.3. Intermediate coefficients *p2* through *p10* and *p12* through *p18* are set to 0 (since *p19* is the coefficient for the highest term with order 3, no trailing zeros are needed):

```
G41 41 0 VCCS POLY(3) 1 0 2 0 3 0 1.3 2.3 0 0

+ 0 0 0 0 0 0

+ 0 3.3 0 0 0 0 0 0 0 4.3
```

Voltage-Controlled Current Source, Piecewise Linear



Piecewise Linear VCCS Netlist Format

The format for a piecewise linear voltage-controlled current source (VCCS) is:

G*xxxx out+ out-* [**VCCS**] **PWL(1)***in+ in-*

[**DELTA=***val*] [**SCALE=***scale*] [**M=***val*]

[**TC1=***val*] [**TC2=***val*]

x1 y1 [... *xK yK*]

or

G*xxxx out+ out-* [**VCCS**] **NPWL(1)***in+ in-*

[**DELTA=***val*] [**SCALE=***scale*] [**M=***val*]

[**TC1=***val*] [**TC2=***val*]

x1 y1 [... *xK yK*]

or

G*xxxx out+ out-* [**VCCS**] **PPWL(1)***in+ in-*

[**DELTA=***val*] [**SCALE=***scale*] [**M=***val*]

[**TC1=***val*] [**TC2=***val*]

x1 y1 [... *xK yK*]

out+ is the positive node and *out-* is the negative node of the current source. The entry **VCCS** is the default for the **G** element type. The entry **PWL**, **NPWL**, or **PPWL** is required to identify the piecewise linear VCVS type. **NPWL** simulates an N-type symmetrical bidirectional switch or transfer gate, **PPWL** simulates the P-type device. *in+* and *in-* are the positive and negative nodes for the control voltage.

The *x y* pairs are the input voltage values and the corresponding output current values. For intermediate values that are not in the list of *x* values, the simulator calculates the corresponding output by interpolation on the given values. The use of the **DELTA** parameter allows you to control the curvature of the interpolation to guarantee that the 1st derivative of the curve is continuous.

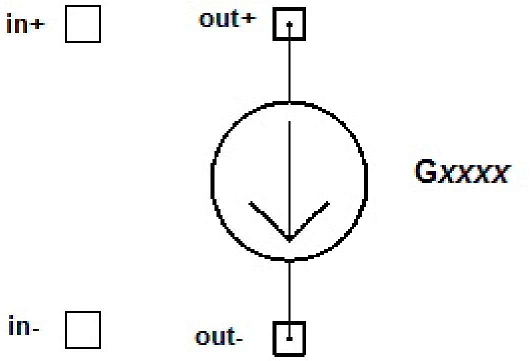
Table 29: Piecewise Linear VCCS Instance Parameters

Parameter	Description	Unit	Default
DELTA	Distance over which curvature is applied in the interpolation function Zero produces linear interpolation, positive values produce continuous curvature over the waveform Maximum is one-half of the smallest difference between control (input) values	None	One-fourth of the smallest difference between control (input) values
M	Multiplier to simulate multiple elements	None	1.0
SCALE	Multiplier for current	None	1.0
TC1	Linear (1st-order) temperature coefficient	$°K^{-1}$	0.0
TC2	Quadratic (2nd-order) temperature coefficient	$°K^{-2}$	0.0

Piecewise Linear VCCS Netlist Example

```
Gpwl1 30 0 VCCS PWL(1) 21 0
+ 0.0 0.0
+ 0.5 0.1e-3
+ 1.0 0.2e-3
+ 4.0 4.5e-3
+ 4.5 4.75e-3
+ 5.0 5.0e-3
```

Voltage-Controlled Current Source, Behavioral (Netlist Only)



Behavioral VCCS Netlist Format

The format for a behavioral voltage-controlled current source (VCCS) is:

`Gxxxx out+ out- CUR= 'expression' [MAX=val] [MIN=val]`

`[M=val] [SCALE=val]`

out+ is the positive node and *out-* is the negative node of the current source.

The label **CUR=** is optional, but the *expression* must be given, and should be enclosed in single or double quotes. The *expression* defines the output current as a function of the input voltage V (*in+*, *in-*) and other values in the circuit.

See *Names, Numbers, Constructs, and Expressions* in the Circuit Design File Formats help topic for details.

> **Note:**
>
> The Behavioral VCCS is available for use in netlists, but is not supported in the Components window of the **Electronics Desktop Schematic Editor**.

Table 30: Behavioral VCCS Instance Parameters

Parameter	Description	Unit	Default
CUR	Expression for output current	Amp	None
M	Multiplier to simulate multiple elements	None	1.0
MAX	Maximum output current	Volt	None
MIN	Minimum output current	Volt	None
SCALE	Multiplier for current	None	1.0

Netlist Example

```
G21 21 0 CUR='V(25,0)/2' MAX=5.0e-3 MIN=0.1e-3
```

Voltage-Controlled Voltage Source, Behavioral Delay (Netlist Only)

VCVS Behavioral Delay Netlist Format

The format for a voltage-controlled voltage source (VCVS) with behavioral delay is:

E*xxxx out+ out-* [**VCVS**] [**DELAY**] *in+ in-* **TD=**'*expression*' [**SCALE=***val*] [**MAX=***val*] [**MIN=***val*] [**TDMIN=***val*] [**TDMAX=***val*]

Out+ is the positive node and *out-* is the negative node of the voltage source. The optional entry **VCVS** is the default for the E element type. The optional entry **DELAY** selects the E element delay type. *In+* and *in-* are the positive and negative nodes for the control voltage.

The *expression* should be enclosed in single or double quotes. The *expression* defines the device delay as a function of node voltage and current branch values in the circuit. See *Names, Numbers, Construc ts, and Expressions* in the Circuit Design File Formats topic for details.

If the result of the expression is less than **MIN**,

V(*out+*) - V(*out-*) = **MIN**

If the result is greater than **MAX**,

V(*out+*) - V(*out-*) = **MAX**

Also, if the result of the expression is less than **TDMIN**,

TD = **TDMIN**

If the result is greater than **TDMAX**,

TD = **TDMAX**

Table 44: Behavioral VCVS Instance Parameters

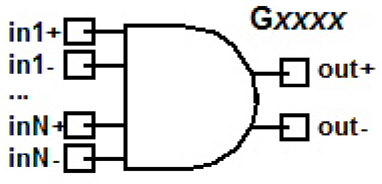
Parameter	Description	Unit	Default
SCALE	Multiplier for voltage	None	1.0
MAX	Maximum output voltage	Volt	None
MIN	Minimum output voltage	Volt	None
TD	Expression for time delay (must be ≥ 0	Second	None
TDMAX	Maximum time delay	Second	10ns
TDMIN	Minimum timedelay	Second	0+

Netlist Example

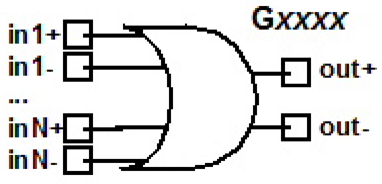
```
E23 outplus outminus VCVS DELAY cplus cminus TD='V(1)* I(V2)'
```

> **Note:**
> 1. The Behavioral Delay VCVS is available for use in netlists, but is not supported in the Components window of the **Electronics Desktop Schematic Editor**.
> 2. The expression for time delay cannot be a function of only in and out nodes of the device.

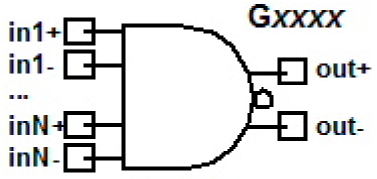
Voltage-Controlled Resistor, Multi-Input Gate



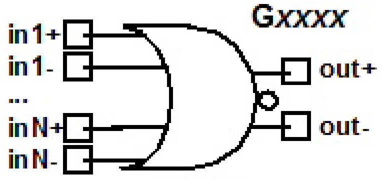
AND



OR



NAND



NOR

The format for an N-input AND gate voltage-controlled resistor (VCR) is:

```
Gxxxx out+ out- VCR AND(N)in1+ in1- ... inN+ inN-
minval1   outval1 ... minvalK   outvalK
[DELTA=val] [TC1=val] [TC2=val] [SCALE=val] [M=val]
```

The format for an N-input NAND gate VCR is:

```
Gxxxx out+ out- VCR NAND(N)in1+ in1- ... inN+ inN-
minval1   outval1 ... minvalK   outvalK
[DELTA=val] [TC1=val] [TC2=val] [SCALE=val] [M=val]
```

The format for an N-input OR gate VCR is:

```
Gxxxx out+ out- VCR OR(N)in1+ in1- ... inN+ inN-
maxval1   outval1 ... maxvalK   outvalK
[DELTA=val] [TC1=val] [TC2=val] [SCALE=val] [M=val]
```

The format for an N-input NOR gate VCR is:

```
Gxxxx out+ out- VCR NOR(N)in1+ in1- ... inN+ inN-
maxval1   outval1 ... maxvalK   outvalK
[DELTA=val] [TC1=val] [TC2=val] [SCALE=val] [M=val]
```

out+ and *out-* are the nodes of the output resistance. The entry **VCR** is required to identify the voltage-controlled resistor type. *in1+ in1-* ... *inN+ inN-* are the positive and negative node pairs for the multiple control voltage inputs. The number of input node pairs (*N*) in the list must be the same as the value specified for **AND(*N*)**, **NAND(*N*)**, **OR(*N*)**, or **NOR(*N*)**.

Table 31: Multi-Input Gate VCR Instance Parameters

Parameter	Description	Unit	Default
DELTA	Distance over which curvature is applied in the interpolation function Zero produces linear interpolation, positive values produce continuous curvature over the waveform Maximum is one-half of the smallest difference between control (input) values	None	One-fourth of the smallest difference between control (input) values
M	Divisor to simulate parallel elements	None	1.0
SCALE	Scale factor for resistance	None	1.0
TC1	Linear (1st-order) temperature coefficient	°K^{-1}	0.0
TC2	Quadratic (2nd-order) temperature coefficient	°K^{-2}	0.0

VCR Gate Netlist Examples

These two-input examples assume logic “0” is 0.0 mΩ output at 0.0 volts input, and logic “1” is 5.0 mΩ output at 5.0 volts input.

```
Gand2 30 0 VCR AND(2) 21 0 22 0
+ 0.0 0.0
+ 0.5 0.1e-3
+ 1.0 0.2e-3
+ 4.0 4.5e-3
+ 4.5 4.75e-3
+ 5.0 5.0e-3
```

```
Gnand2 40 0 VCR NAND(2) 23 0 24 0
+ 0.0 5.0e-3
+ 0.5 4.75e-3
+ 1.0 4.5e-3
+ 4.0 0.2e-3
+ 4.5 0.1e-3
+ 5.0 0.0e-3
```

```
Gor2 50 0 VCR OR(2) 25 0 26 0
+ 0.0 0.0e-3
+ 0.5 0.1e-3
+ 1.0 0.2e-3
+ 4.0 4.5e-3
```

```
+ 4.5 4.75e-3
+ 5.0 5.0e-3

Gnor2 60 0 VCR NOR(2) 27 0 28 0
+ 0.0 5.0e-3
+ 0.5 4.75e-3
+ 1.0 4.5e-3
+ 4.0 0.2e-3
+ 4.5 0.1e-3
+ 5.0 0.0e-3
```

See the examples for the "Voltage-Controlled Voltage Source, Multi-Input Gate" on page 5-57 element for samples of simulation runs produced by these devices.

Notes on minval, maxval, outval parameters

The output is specified as a function of the inputs using a set of pairs (*minval*, *outval* or *maxval*, *outval*), separated by spaces and/or commas. Voltages are specified in volts, resistances in Ohms. The pairs should be entered in ascending order of *minval* or *maxval* (see Netlist Examples). Any number of pairs may be specified.

> **Note:** In the **Schematic Editor** component Property windows, the Gate components use property names **IN1**, **IN2**, ...**IN***K* for the *minval* and *maxval* parameters, and **OUT1**, **OUT2**, ...**OUT***K* for the *outval* parameters.

For **AND** and **NAND** gates, the simulator finds the minimum difference between all pairs of inputs:

$mindiff = \mathrm{MIN}[V(in1^{+}-in1^{-}), V(in2^{+}-in2^{-}), \ldots V(inN^{+}-inN^{-})]$

The simulator matches *mindiff* to the list of entries *minval1 ... minvalK* in the instance statement, and sets the output to the corresponding *outval*.

When *mindiff* is equal to the voltage that represents logic “0” or logic “1,” the corresponding output from an **AND** or **NAND** gate should be set accordingly.

Values of *mindiff* that are intermediate between the logic “0” and “1” voltages represent transitional values. For intermediate values that are not in the list of *minvals*, the simulator calculates the corresponding output by interpolation from the given values. The use of the **DELTA** parameter allows you to control the curvature of the interpolation to guarantee that the 1st derivative of the curve is continuous.

For values of *mindiff* that are below the range of listed input voltages, the simulator sets the output resistance to the one corresponding to the smallest input voltage in the list. For values of *mindiff* that are above the range of listed input voltages, the simulator sets the output resistance to the one corresponding to the largest input voltage in the list.

For **OR** and **NOR** gates, the simulator finds the maximum difference between all pairs of inputs:

maxdiff = MAX[$V(in1^{+} - in1^{-}), V(in2^{+} - in2^{-}), ...V(inN^{+} - inN^{-})$]

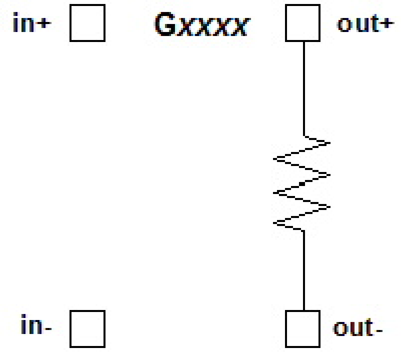
The simulator matches *maxdiff* to the list of entries *maxval1 ... maxvalK* in the instance statement, and sets the output to the corresponding *outval*.

When *maxdiff* is equal to the voltage that represents logic “0” or logic “1,” the corresponding output from an **OR** or **NOR** gate should be set accordingly.

Values of *maxdiff* that are intermediate between the logic “0” and “1” voltages represent transitional values. For intermediate values that are not in the list, the simulator calculates the corresponding output by interpolation on the given values, using the **DELTA** parameter as discussed above.

For values of *maxdiff* that are below the range of listed input voltages, the simulator sets the output resistance to the one corresponding to the smallest input voltage in the list. For values of *maxdiff* that are above the range of listed input voltages, the simulator sets the output resistance to the one corresponding to the largest input voltage in the list.

Voltage-Controlled Resistor, Linear



Linear VCR Netlist Format

The format for a linear voltage-controlled resistor (VCR) is:

```
Gxxxx out+ out- VCRin+ in- [TRANS=]transfactor
[MAX=val] [MIN=val] [M=val]
[TC1=val] [TC2=val] [SCALE=val]
```

out+ is the positive node and *out-* is the negative node of the resistor. **VCR** is required for the **G** element voltage-controlled resistor type. *in+* and *in-* are the positive and negative nodes for the control voltage. The label **TRANS=** is optional, but the *transfactor* must be given. *transfactor* is the conversion factor from input voltage to output resistance.

Table 32: Linear VCR Instance Parameters

Parameter	Description	Unit	Default
M	Number of elements in parallel (divisor)	None	1.0
MAX	Maximum output resistance	Ohm	None
MIN	Minimum output resistance	Ohm	None
SCALE	Multiplier for resistance	None	1.0
TC1	Linear (1st-order) temperature coefficient	$°K^{-1}$	0.0
TC2	Quadratic (2nd-order) temperature coefficient	$°K^{-2}$	0.0
TRANS	Conversion factor from input voltage to output resistance	Ohm/Volt	0.0

Linear VCR Netlist Example

```
Gres1 22 23 VCR 32 33 200 MAX=1000 MIN=50
```

Notes

The functional equation for the linear VCR is:

$R(n+, n-) = [transfactor \times (V(in+) - V(in-)) \times \mathbf{SCALE} \times (1 + \Delta T \times \mathbf{TC1} + \Delta T^2 \times \mathbf{TC2})] / \mathbf{M}$

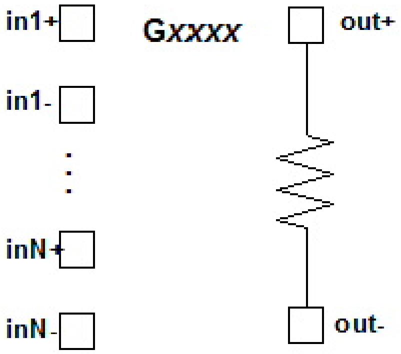
If the result is less than **MIN**,

$R(n+, n-) = \mathbf{MIN}$

If the result is greater than **MAX**,

$R(n+, n-) = \mathbf{MAX}$

Voltage-Controlled Resistor, Polynomial



Polynomial VCR Netlist Format

The format for a polynomial voltage-controlled resistor (VCR) is:

```
Gxxxx out+ out- VCR POLY(N)
in1+ in1- [in2+ in2- [in3+ in3-]]
[MAX=val] [MIN=val] [SCALE=scale] [M=val]
[TC1=val] [TC2=val]
p0 [p1 ... pK ]
```

out+ is the positive node and *out-* is the negative node of the resistor. The entry **VCR** is required to select the voltage-controlled resistor type. The entry **POLY** is required to identify the polynomial VCR. The number of input voltage pairs, *N*, can be 1, 2, or 3. If *N* is not specified, 1 input is the default. *in+* and *in-* are the *N* pairs of positive and negative nodes for the control voltages. *p0* through *pK* are the *K* coefficients for the polynomial function. One coefficient must be provided.

> **Note:**
>
> When *N*=1 (one input pair), a single coefficient is interpreted as *p1* (*p0* is set to 0.0). Two or more coefficients are interpreted according to the syntax above.

Table 33: Polynomial VCR Instance Parameters

Parameter	Description	Unit	Default
M	Divisor to simulate multiple elements	None	1.0
MAX	Maximum output resistance	Volt	None
MIN	Minimum output resistance	Volt	None

Parameter	Description	Unit	Default
SCALE	Multiplier for resistance	None	1.0
TC1	Linear (1st-order) temperature coefficient	°K^{-1}	0.0
TC2	Quadratic (2nd-order) temperature coefficient	°K^{-2}	0.0

Polynomial VCR Netlist Examples

```
G21 21 0 VCR POLY(1) 1 0 1.1 2.1 0 3.1

G31 31 0 VCR POLY(2) 1 0 2 0 1.2 2.2 0 0 0 0 0 0 3.2 0

G41 41 0 VCR POLY(3) 1 0 2 0 3 0 1.3 2.3 0 0

+ 0 0 0 0 0 0

+ 0 3.3 0 0 0 0 0 0 0 4.3
```

Notes

The functional equation for the polynomial VCR is:

R(*out*+, *out*-)) = [*polynomial*×**SCALE** × (1 + ΔT ×**TC1** + ΔT^2×**TC2**)] /**M**

If the result is less than **MIN**,

R(*out*+, *out*-) = **MIN**

If the result is greater than **MAX**,

R(*out*+, *out*-) = **MAX**

The polynomial depends on the number of inputs (*N*) and the number of polynomial coefficients (*K*). Each polynomial has terms of order (**O**), the sum of the exponents of the elements in the term. The list of coefficients must include coefficients for every term up to and including the complete group of terms with the highest order in the specified polynomial, using zero coefficients for any intermediate or trailing terms that should not be computed.

When *N*=1, the polynomial formula has one term each of order **O** {0, 1, ... *K*}:

$p0 + p1 \times V(in1^{+}, in1^{-}) + \ldots pK \times V(in1^{+}, in1^{-})^{K}$

Each coefficient must be a real value or zero to represent a missing term. For example, to specify a VCR between nodes 21 and 0 whose output, controlled by the voltage across nodes 1 and 0, is described by the one-input polynomial $1.1 + 2.1 \times V(1, 0) + 3.1 \times V(1, 0)^3$, the instance statement sets coefficients *p0*=1.1, *p1*=2.1, *p2*=0, and *p3*=3.1:

```
G21 21 0 VCR POLY(1) 1 0 1.1 2.1 0 3.1
```

When *N*=2, the polynomial formula can have more than one term in each order grouping:

O (0)

$p0 +$

O (1)

$p1 \times \mathrm{V}(in1^{+}, in1^{-}) +$

$p2 \times \mathrm{V}(in2^{+}, in2^{-}) +$

O (2)

$p3 \times \mathrm{V}(in1^{+}, in1^{-})^{2} +$

$p4 \times \mathrm{V}(in1^{+}, in1^{-}) \times \mathrm{V}(in2^{+}, in2^{-}) +$

$p5 \times \mathrm{V}(in2^{+}, in2^{-})^{2} +$

O (3)

$p6 \times \mathrm{V}(in1^{+}, in1^{-})^{3} +$

$p7 \times \mathrm{V}(in1^{+}, in1^{-})^{2} \times \mathrm{V}(in2^{+}, in2^{-}) +$

$p8 \times \mathrm{V}(in1^{+}, in1^{-}) \times \mathrm{V}(in2^{+}, in2^{-})^{2} +$

$p9 \times \mathrm{V}(in2^{+}, in2^{-})^{3} +$

O (4)

...

For example, to specify a VCR between nodes 31 and 0 whose output, controlled by the voltages across node pairs (1, 0) and (2, 0), is described by the two-input polynomial $1.2 + 2.2 \times \mathrm{V}(1, 0) + 3.2 \times \mathrm{V}(1, 0) \times \mathrm{V}(2, 0)^{2}$, the instance statement sets coefficients *p0*=1.2, *p1*=22, and *p8*=3.2. Intermediate coefficients *p2* through *p7* and trailing coefficient *p9* are set to 0:

```
G31 31 0 VCR POLY(2) 1 0 2 0 1.2 2.2 0 0 0 0 0 0 3.2 0
```

When *N*=3, the polynomial formula becomes:

O (0)

$p0 +$

O (1)

$p1 \times \mathrm{V}(in1^{+}, in1^{-}) +$

$p2 \times \mathrm{V}(in2^{+}, in2^{-}) +$

$p3 \times \mathrm{V}(in3^{+}, in3^{-}) +$

O (2)

$p4 \times \mathrm{V}(in1^+, in1^-)^2 +$

$p5 \times \mathrm{V}(in1^+, in1^-) \times \mathrm{V}(in2^+, in2^-) +$

$p6 \times \mathrm{V}(in1^+, in1^-) \times \mathrm{V}(in3^+, in3^-) +$

$p7 \times \mathrm{V}(in2^+, \mathrm{in}2^-)^2 +$

$p8 \times \mathrm{V}(in2^+, in2^-) \times \mathrm{V}(in3^+, in3^-) +$

$p9 \times \mathrm{V}(in3^+, in3^-)^2 +$

O (3)

$p10 \times \mathrm{V}(in1^+, in1^-)^3 +$

$p11 \times \mathrm{V}(in1^+, in1^-)^2 \times \mathrm{V}(in2^+, in2^-) +$

$p12 \times \mathrm{V}(in1^+, in1^-)^2 \times \mathrm{V}(in3^+, in3^-) +$

$p13 \times \mathrm{V}(in1^+, in1^-) \times \mathrm{V}(in2^+, in2^-)^2 +$

$p14 \times \mathrm{V}(in1^+, in1^-) \times \mathrm{V}(in2^+, in2^-) \times \mathrm{V}(in3^+, in3^-) +$

$p15 \times \mathrm{V}(in1^+, in1^-) \times \mathrm{V}(in3^+, in3^-)^2 +$

$p16 \times \mathrm{V}(in2^+, in2^-)^3 +$

$p17 \times \mathrm{V}(in2^+, in2^-)^2 \times \mathrm{V}(in3^+, in3^-) +$

$p18 \times \mathrm{V}(in2^+, in2^-) \times \mathrm{V}(in3^+, in3^-)^2 +$

$p19 \times \mathrm{V}(in3^+, in3^-)^3 +$

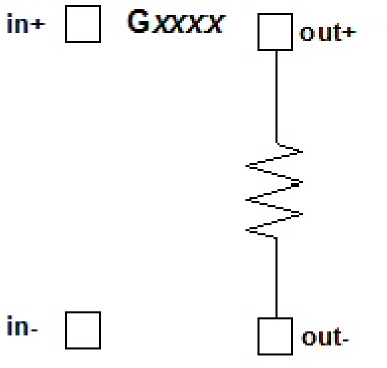
O (4)

...

For example, to specify a VCR between nodes 41 and 0 whose output, controlled by voltages across node pairs (1, 0), (2, 0), and (3, 0), is described by the three-input polynomial $1.3 + 2.3 \times \mathrm{V}(1, 0) + 3.3 \times \mathrm{V}(1, 0)^2 \times \mathrm{V}(2, 0) + 4.3 \times \mathrm{V}(3, 0)^3$, the instance statement sets coefficients *p0*=1.3, *p1*=2.3, *p11*=3.3, and *p19*=4.3. Intermediate coefficients *p2* through *p10* and *p12* through *p18* are set to 0 (since *p19* is the coefficient for the highest term with order 3, no trailing zeros are needed):

```
G41 41 0 VCR POLY(3) 1 0 2 0 3 0 1.3 2.3 0 0

+ 0 0 0 0 0 0

+ 0 3.3 0 0 0 0 0 0 0 4.3
```

Voltage-Controlled Resistor, Piecewise Linear



Piecewise Linear VCR Netlist Format

The format for a piecewise linear voltage-controlled resistor (VCR) is:

G*xxxx out+ out-* **VCR PWL(1)** *in+ in-*

[**DELTA=***val*] [**SCALE=***scale*] [**M=***val*]

[**TC1=***val*] [**TC2=***val*]

x1 y1 [... *xK yK*]

or

G*xxxx out+ out-* **VCR NPWL(1)** *in+ in-*

[**DELTA=***val*] [**SCALE=***scale*] [**M=***val*]

[**TC1=***val*] [**TC2=***val*]

x1 y1 [... *xK yK*]

or

G*xxxx out+ out-* **VCR PPWL(1)** *in+ in-*

[**DELTA=***val*] [**SCALE=***scale*] [**M=***val*]

[**TC1=***val*] [**TC2=***val*]

x1 y1 [... *xK yK*]

out+ is the positive node and *out-* is the negative node of the resistor. The entry **VCR** is required to select the voltage-controlled resistor element type. The entry **PWL**, **NPWL**, or **PPWL** is required to identify the piecewise linear VCR type. **NPWL** simulates an N-type device, **PPWL** simulates the P-type device. *in+* and *in-* are the positive and negative nodes for the control voltage.

The *x y* pairs are the input voltage values and the corresponding output resistance values. **The x-values (voltages) must be in ascending order.** For intermediate values that are not in the list of *x* values, the simulator calculates the corresponding output by interpolation on the given values. The use of the **DELTA** parameter allows you to control the curvature of the interpolation to guarantee that the 1st derivative of the curve is continuous.

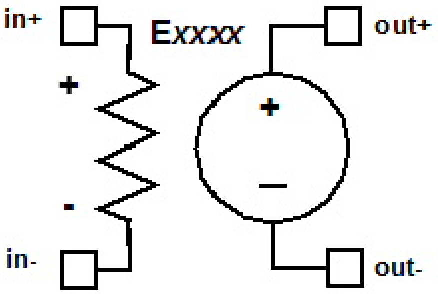
Table 34: Piecewise Linear VCR Instance Parameters

Parameter	Description	Unit	Default
DELTA	Distance over which curvature is applied in the interpolation function Zero produces linear interpolation, positive values produce continuous curvature over the waveform Maximum is one-half of the smallest difference between control (input) values	None	One-fourth of the smallest difference between control (input) values
M	Divisor to simulate multiple elements	None	1.0
SCALE	Multiplier for resistance	None	1.0
TC1	Linear (1st-order) temperature coefficient	$°K^{-1}$	0.0
TC2	Quadratic (2nd-order) temperature coefficient	$°K^{-2}$	0.0

Piecewise Linear VCR Netlist Example

```
G231 30 0 VCR PWL(1) 21 0
+ 0.0 0.0
+ 0.5 10
+ 1.0 50
+ 4.0 100
+ 4.5 500
+ 5.0 1000
```

Voltage-Controlled Voltage Source, Delay



VCVS Delay Netlist Form

The format for a voltage-controlled voltage source with delay is:

```
Exxxx out+ out- [VCVS] DELAYin+ in- TD=val
[SCALE=val] [TC1=val] [TC2=val]
```

out+ is the positive node and *out-* is the negative node of the voltage source. The entry **VCVS** is the default for the **E** element type. The entry **DELAY** selects the E element delay type. *in+* and *in-* are the positive and negative nodes for the control voltage.

Table 35: Delay VCVS Instance Parameters

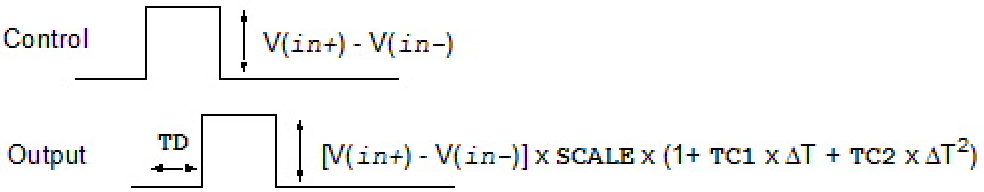
Parameter	Description	Unit	Default
SCALE	Multiplier for voltage	None	1.0
TC1	Linear (1st-order) temperature coefficient	°K^{-1}	0.0
TC2	Quadratic (2nd-order) temperature coefficient	°K^{-2}	0.0
TD	Time delay (must be ≥ 0)	Second	None

VCVS Delay Netlist Example

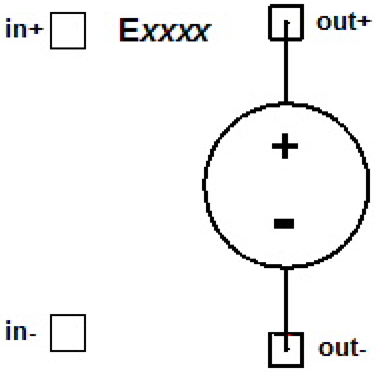
```
E23 outplus outminus VCVS DELAY cplus cminus TD=2.0e-5
```

Notes

The following figure illustrates the operation of the VCVS delay element:



Voltage-Controlled Voltage Source, Foster (Netlist Only)



Foster VCVS Netlist Format

The format for a Pole-Residue (Foster) format voltage-controlled voltage source (VCVS) is:

```
Exxxx out+ out- FOSTERin+ in- C1 C2
+ ( Re{r1}, Im{r1}) / ( Re{p1}, Im{p1})
+ [( Re{r2}, Im{r2}) / ( Re{p2}, Im{p2})] ...
```

out+ is the positive node and *out-* is the negative node of the voltage source. **FOSTER** identifies the element type. *in+* and *in-* are the positive and negative nodes for the control voltage drop.

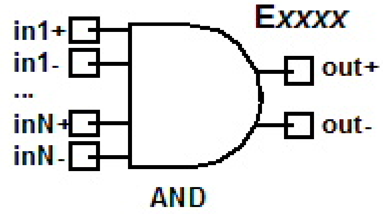
C1 is the proportional constant and *C2* is the derivative constant. Re{*ri*} and Im{*ri*} are the real and imaginary parts of the residues. Re{*pi*} and Im{*pi*} are the real and imaginary parts of the corresponding poles.

The Foster VCVS is available for use in netlists, but is not supported in the Components window of the **Schematic Editor**.

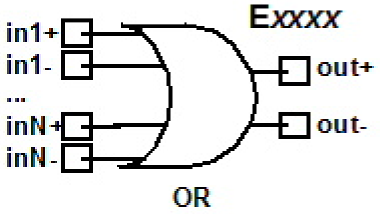
Foster VCVS Netlist Example

```
E55 net2 0 FOSTER net6 0 0.002 -0.005
+ (-2.23e12, 0) / (-9.534e12, 0)
+ (-54.959e10, 1) / (-1.1165e11, -1e-10)
+ (-54.959e10, -1) / (-1.1165e11, 1e-10)
```

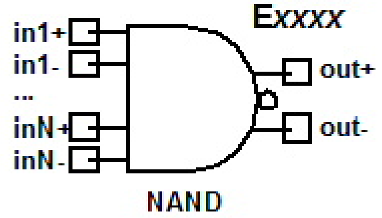
Voltage-Controlled Voltage Source, Multi-Input Gate



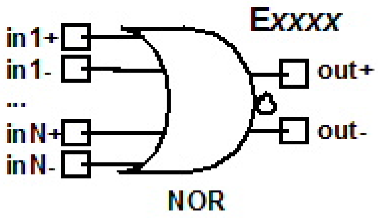
AND



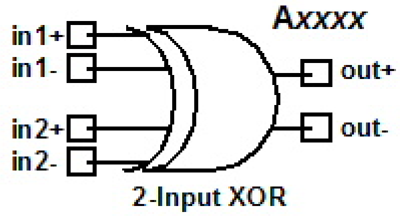
OR



NAND



NOR



2-Input XOR

VCVS Gate Netlist Format

The format for an N-input AND gate VCVS is:

E*xxxx out+ out-* [**VCVS**] **AND(***N***)***in1+ in1- ... inN+ inN-*
minval1 outval1 ... minvalK outvalK
[**DELTA=***val*] [**TC1=***val*] [**TC2=***val*] [**SCALE=***val*]

The format for an N-input NAND gate VCVS is:

```
Exxxx out+ out- [VCVS] NAND(N)in1+ in1- ... inN+ inN-
minval1   outval1 ... minvalK  outvalK
[DELTA=val] [TC1=val] [TC2=val] [SCALE=val]
```

The format for an N-input OR gate VCVS is:

```
Exxxx out+ out- [VCVS] OR(N)in1+ in1- ... inN+ inN-
maxval1   outval1 ... maxvalK  outvalK
[DELTA=val] [TC1=val] [TC2=val] [SCALE=val]
```

The format for an N-input NOR gate VCVS is:

```
Exxxx out+ out- [VCVS] NOR(N)in1+ in1- ... inN+ inN-
maxval1   outval1 ... maxvalK  outvalK
[DELTA=val] [TC1=val] [TC2=val] [SCALE=val]
```

The format for a 2-input XOR gate VCVS is:

```
Axxxx out+ out- in1+ in1- in2+ in2- [SCALE=val]
+ component=vcvs_xor
```

out+ and *out-* are the nodes of the voltage output. The entry **VCVS** is the default for the **E** element type. *in1+ in1- ... inN+ inN-* are the positive and negative node pairs for the multiple control voltage inputs. The number of input node pairs (*N*) in the list must be the same as the value specified for **AND(***N***)**, **NAND(***N***)**, **OR(***N***)**, or **NOR(***N***)**.

The entry **component=vcvs_xor** is required only for the 2-input VCVS XOR gate. The 2-input VCVS XOR gate syntax uses inputs *in1+*, *in1-*, *in2+*, and *in2-* and only one parameter, **SCALE**.

Table 36: Multi-Input Gate VCVS Instance Parameters

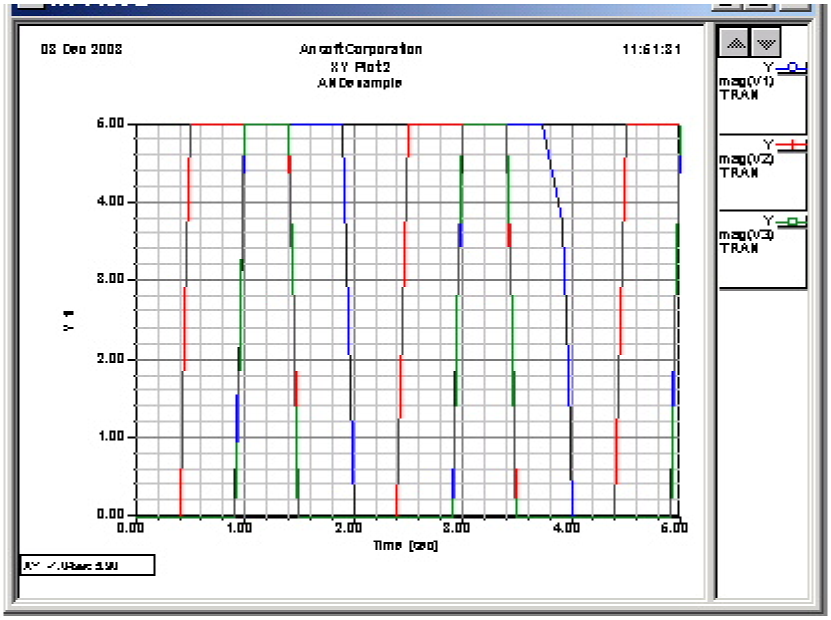
Parameter	Description	Unit	Default
DELTA	Distance over which curvature is applied in the interpolation function Zero produces linear interpolation, positive values produce continuous curvature over the waveform Maximum is one-half of the smallest difference between control (input) values	None	One-fourth of the smallest difference between control (input) values
SCALE	Scale factor for voltage	None	1.0
TC1	Linear (1st-order) temperature coefficient	$^{\circ}K^{-1}$	0.0
TC2	Quadratic (2nd-order) temperature coefficient	$^{\circ}K^{-2}$	0.0

VCVS Gate Netlist Examples

These two-input examples assume logic “0” is 0.0 volts output at 0.0 volts input, and logic “1” is 5.0 volts output at 5.0 volts input.

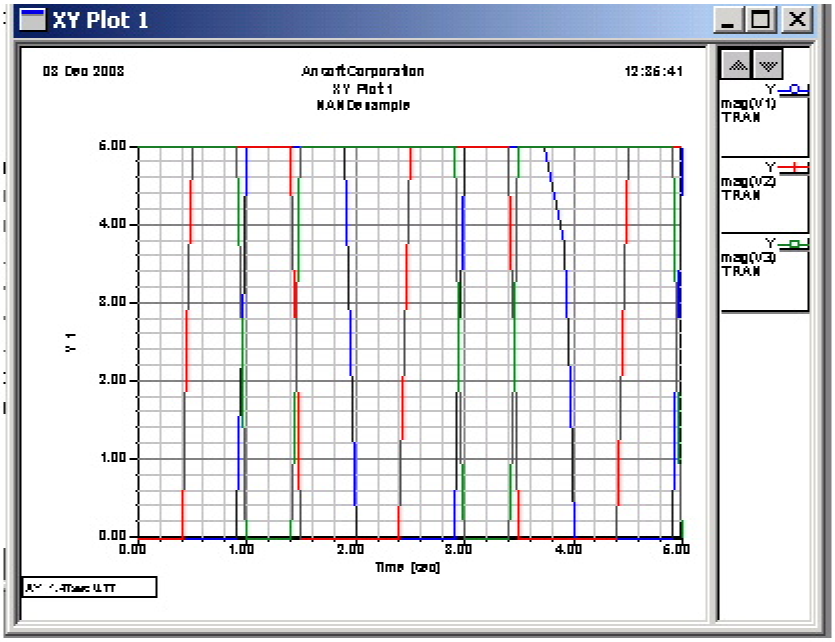
```
Eand2 30 0 VCVS AND(2) 21 0 22 0
+ 0.0 0.0
+ 0.5 0.1
+ 1.0 0.2
+ 4.0 4.5
+ 4.5 4.75
+ 5.0 5.0
```

Here is a sample simulation showing the output of this element:



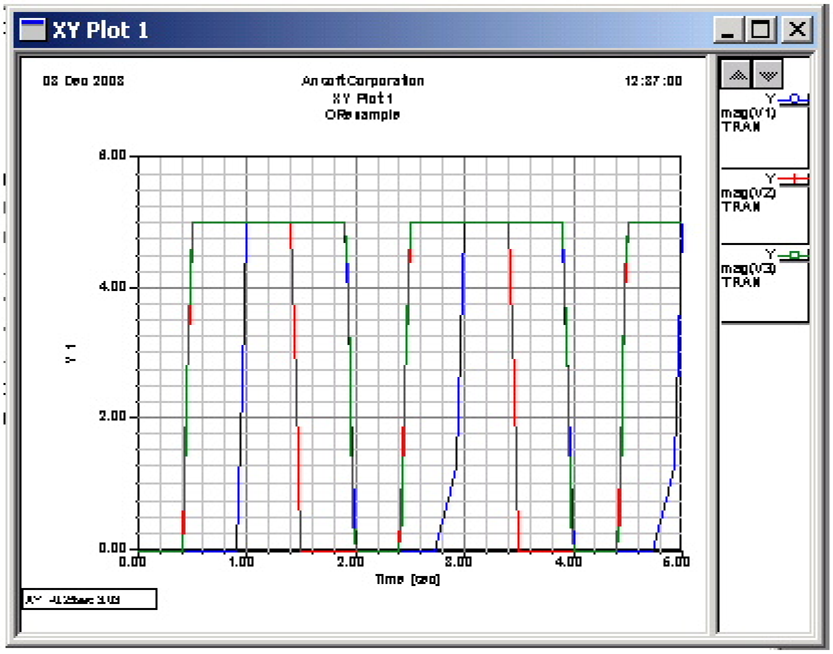
```
Enand2 40 0 VCVS NAND(2) 23 0 24 0
+ 0.0 5.0
+ 0.5 4.75
+ 1.0 4.5
+ 4.0 0.2
+ 4.5 0.1
+ 5.0 0.0
```

Here is a sample simulation showing the output of this element:



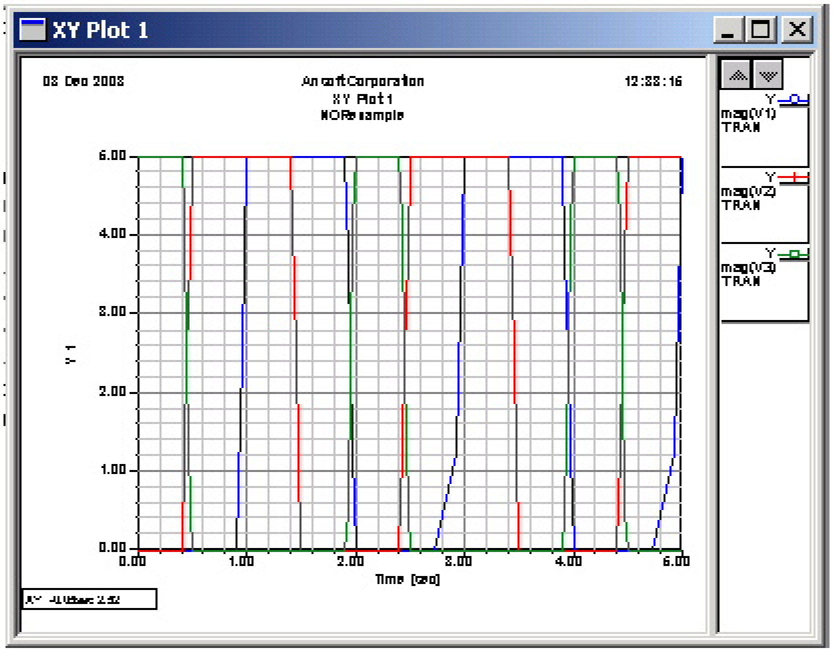
```
Eor2 50 0 VCVS OR(2) 25 0 26 0
+ 0.0 0.0
+ 0.5 0.1
+ 1.0 0.2
+ 4.0 4.5
+ 4.5 4.75
+ 5.0 5.0
```

Here is a sample simulation showing the output of this element:



```
Enor2 60 0 VCVS NOR(2) 27 0 28 0
+ 0.0 5.0
+ 0.5 4.75
+ 1.0 4.5
+ 4.0 0.2
+ 4.5 0.1
+ 5.0 0.0
```

Here is a sample simulation showing the output of this element:



Notes on minval, maxval, outval parameters

The output for the **AND** (*N*), **NAND** (*N*), **OR** (*N*), and **NOR** (*N*)is specified as a function of the inputs using a set of pairs (*minval*, *outval* or *maxval*, *outval*), separated by spaces and/or commas. Voltages are specified in volts. The pairs should be entered in ascending order of *minval* or *maxval* (see Netlist Examples). Any number of pairs may be specified.

NOTE: In the **Schematic Editor** component Property dialogs, the Gate components use property names **IN1**, **IN2**, ...**IN***K* for the *minval* and *maxval* parameters, and **OUT1**, **OUT2**, ...**OUT***K* for the *outval* parameters.

For **AND** and **NAND** gates, the simulator finds the minimum difference between all pairs of inputs:

mindiff = MIN[$V(in1^{+}-in1^{-}), V(in2^{+}-in2^{-}), ...V(inN^{+}-inN^{-})$]

The simulator matches *mindiff* to the list of entries *minval1 ... minvalK* in the instance statement, and sets the output to the corresponding *outval*.

When *mindiff* is equal to the voltage that represents logic “0” or logic “1,” the corresponding output from an **AND** or **NAND** gate should be set accordingly.

Values of *mindiff* that are intermediate between the logic “0” and “1” voltages represent transitional values. For intermediate values that are not in the list of *minvals*, the simulator calculates the corresponding output by interpolation from the given values. The use of the **DELTA** parameter allows you to control the curvature of the interpolation to guarantee that the 1st derivative of the curve is continuous.

For values of *mindiff* that are below the range of listed input voltages, the simulator sets the output voltage to the one corresponding to the smallest input voltage in the list. For values of *mindiff* that are above the range of listed input voltages, the simulator sets the output voltage to the one corresponding to the largest input voltage in the list.

For **OR** and **NOR** gates, the simulator finds the maximum difference between all pairs of inputs:

maxdiff = MAX[$V(in1^{+} - in1^{-}), V(in2^{+} - in2^{-}), ...V(inN^{+} - inN^{-})$]

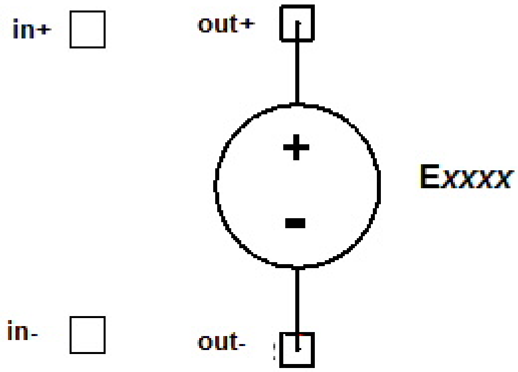
The simulator matches *maxdiff* to the list of entries *maxval1 ... maxvalK* in the instance statement, and sets the output to the corresponding *outval*.

When *maxdiff* is equal to the voltage that represents logic “0” or logic “1,” the corresponding output from an **OR** or **NOR** gate should be set accordingly.

Values of *maxdiff* that are intermediate between the logic “0” and “1” voltages represent transitional values. For intermediate values that are not in the list, the simulator calculates the corresponding output by interpolation on the given values, using the **DELTA** parameter as discussed above.

For values of *maxdiff* that are below the range of listed input voltages, the simulator sets the output voltage to the one corresponding to the smallest input voltage in the list. For values of *maxdiff* that are above the range of listed input voltages, the simulator sets the output voltage to the one corresponding to the largest input voltage in the list.

Voltage-Controlled Voltage Source, Laplace



VCVS Laplace Netlist Format

The voltage-controlled voltage source with Laplace transfer function has the following format:

```
Exxxx out+ out- LAPLACEin+ in- a0[,] ... aN /b0[,] ...bD
[SCALE=val] [TC1=val] [TC2=val]
```

out+ is the positive node and *out*- is the negative node of the current source. The entry **LAPLACE** selects the E element Laplace transfer function type. *in*+ and *in*- are the positive and negative nodes for the control voltage. The division symbol (/) in the instance line is required syntax.

> **Note:**
>
> Comma separators between the *a* and *b* entries are optional. Spaces may be used as separators instead of commas.

The function of the device is expressed as:

V(*out*+, *out*-) = SCALE × H(s) × V(*in*+, *in*-)

The transfer function H(s) is the ratio of two polynomials in the complex variable *s*.

H(s) is specified by giving the coefficients of the transfer function polynomials:

$$H(s) = \frac{a_0 + a_1 s + a_2 s^2 + \ldots}{b_0 + b_1 s + b_2 s^2 + \ldots}$$

The coefficients (a_0 ... a_N) specify the numerator polynomial of the ratio. The coefficients (b_0 ... b_D specify the denominator polynomial. The subscripts *N* and *D* represent the order of the numerator and denominator respectively. The first coefficients in both numerator and denominator (a_0 and b_0) are constants, which must be specified even if they are zero. Thus, leading zeros are significant. In addition, intermediate zero-valued coefficients must be explicitly supplied in order to have the non-zero coefficients applied to the correct powers of *s*. Trailing zeros are not significant, and are automatically removed.

For example, to specify the following transfer function (where coefficient a_1=0):

$$H(s) = \frac{1 + 2s^2}{1 + s + 3s^2}$$

The netlist contains the following statement:

```
Eex1 out gnd LAPLACE in gnd 1, 0, 2 / 1, 1, 3
```

> **Note:**
>
> The order of the numerator (N) may not exceed the order of the denominator (D), otherwise Nexxim posts an error message and disregard the device.

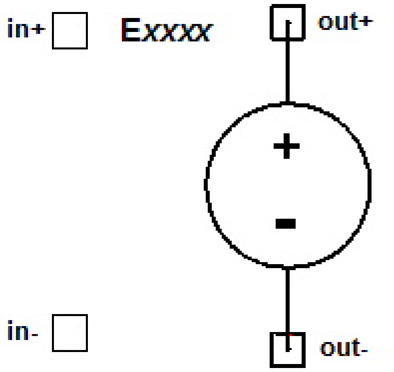
Table 37: Laplace VCVS Instance Parameters

Parameter	Description	Unit	Default
a0 ... aN	Coefficients of the numerator polynomial (coefficient syntax)	None	None
b0 ... bD	Coefficients of the denominator polynomial (coefficient syntax)	None	None
SCALE	Scale factor for voltage	None	1.0
TC1	Linear (1st-order) temperature coefficient	°K^{-1}	0.0
TC2	Quadratic (2nd-order) temperature coefficient	°K^{-2}	0.0

VCVS Laplace Netlist Example

```
E21 21 0 LAPLACE 31 0 0.1 2.2 -.3 / 0.25 -2.1 0.33 -.4
```

Voltage-Controlled Voltage Source, Linear



Linear VCVS Netlist Format

The format for a linear voltage-controlled voltage source (VCVS) is:

E*xxxx out+ out-* [**VCVS**] *in+ in-* [**GAIN=**]*gain*

[**MAX=***val*] [**MIN=***val*]

[**SCALE=***scale*] [**TC1=***val*] [**TC2=***val*] [**ABS=0**|**1**]

out+ is the positive node and *out-* is the negative node of the voltage source. The entry **VCVS** is the default for the **E** element type. *in+* and *in-* are the positive and negative nodes for the control voltage.

The functional equation for the linear VCVS is:

$V(out+) - V(out-) = \mathbf{GAIN} \times (V(in+) - V(in-)) \times \mathbf{SCALE} \times (1 + \Delta T \times (\mathbf{TC1} + \Delta T \times \mathbf{TC2}))$

If the result is less than **MIN**,

$V(out+) - V(out-) = \mathbf{MIN}$

If the result is greater than **MAX**,

$V(out+) - V(out-) = \mathbf{MAX}$

Table 38: Linear VCVS Instance Parameters

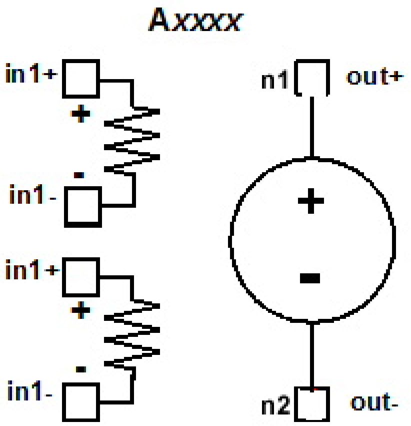
Parameter	Description	Unit	Default
ABS	1 = Output is an absolute value	None	0
GAIN	Voltage gain (multiplier applied to control voltage)	None	1.0
MAX	Maximum output voltage	Volt	None
MIN	Minimum output voltage	Volt	None
SCALE	Multiplier for voltage	None	1.0
TC1	Linear (1st-order) temperature coefficient	$°K^{-1}$	0.0
TC2	Quadratic (2nd-order) temperature coefficient	$°K^{-2}$	0.0

Linear VCVS Netlist Examples

```
E23 outplus outminus VCVS ctrlplus ctrlminus GAIN=2.0
```

```
Evcvs1 34 35 VCVS 25 26 E=1.0
```

Voltage-Controlled Voltage Source, Multiplier



Multiplier VCVS Netlist Format

The format for a multiplier voltage-controlled voltage source (VCVS) is:

```
Axxxx out+ out- in1+ in1- in2+ in2-
[SCALE=scale] [TC1=val] [TC2=val] COMPONENT=vcvs_multiplier
```

out+ is the positive node and *out-* is the negative node of the voltage source. *in1+* and *in1-* are the positive and negative nodes for the first input voltage, *in2+* and *in2-* are the positive and negative nodes for the second input voltage. The entry **COMPONENT=vcvs_multiplier** is required.

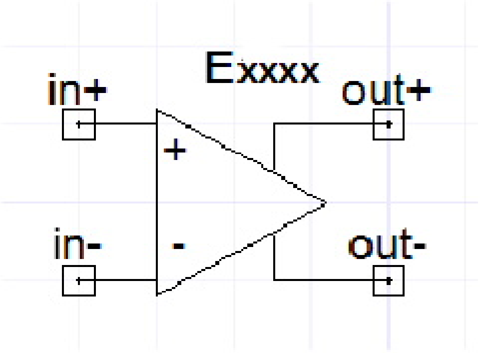
Table 39: Multiplier VCVS Instance Parameters

Parameter	Description	Unit	Default
SCALE	Multiplier for voltage	None	1.0
TC1	Linear (1st-order) temperature coefficient	°K^{-1}	0.0
TC2	Quadratic (2nd-order) temperature coefficient	°K^{-2}	0.0

Multiplier VCVS Netlist Example

```
A23 outplus outminus LOplus LOminus RFplus RFminus
+ COMPONENT=vcvs_multiplier
```

Voltage-Controlled Voltage Source, Op Amp



VCVS Op Amp Netlist Format

The format for a voltage-controlled voltage source ideal op amp is:

E*xxxx out+ out-* **OPAMP***in+ in-* **GAIN=***val* **MIN=***val* **MAX=***val*

out+ is the positive node and *out-* is the negative node of the voltage source. The entry **OPAMP** selects the **E** element op amp type. *in+* and *in-* are the positive and negative nodes for the control voltage.

The **VCVS OPAMP** is an ideal op amp with a very high gain.

Table 40: OP AMP VCVS Instance Parameters

Parameter	Description	Unit	Default
GAIN	Element gain	None	1e12
MIN	Minimum output voltage	Volt	-5.0
MAX	Maximum output voltage	Volt	5.0

VCVS Op Amp Netlist Examples

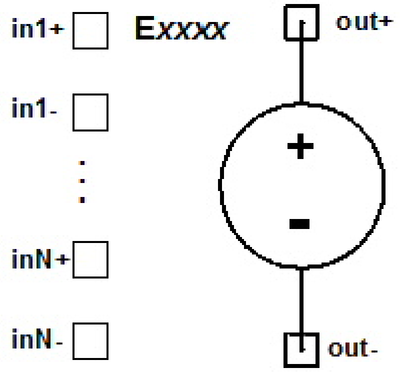
```
E9 outplus outminus OPAMP ctrlplus ctrlminus
```

```
Eopamp n34 n35 OPAMP n25 n26 GAIN=.5e12 min=-3.0 max=3.0
```

Notes

1. If MIN>MAX, the two values are swapped.
2. Choosing a value of GAIN greater than the default can lead to convergence problems and is not recommended.
3. If convergence problems occur, try setting GAIN to lower and lower values below the default until convergence succeeds.

Voltage-Controlled Voltage Source, Polynomial



Polynomial VCVS Netlist Format

The format for a polynomial voltage-controlled voltage source (VCVS) is:

```
Exxxx out+ out- [VCVS] POLY(N)
in1+ in1- [in2+ in2- [in3+ in3-]]
[MAX=val] [MIN=val] [SCALE=scale]
[TC1=val] [TC2=val] [ABS=0|1]
p0 [p1 ... pK ]
```

out+ is the positive node and *out-* is the negative node of the voltage source. The entry **VCVS** is the default for the **E** element type. The entry **POLY** is required to identify the polynomial VCVS type. The number of input voltage pairs, *N*, can be 1, 2, or 3. If *N* is not specified, 1 input is the default. *in+* and *in-* are the *N* pairs of positive and negative nodes for the control voltages. *p0* through *pK* are the K coefficients for the polynomial function. One coefficient must be provided.

> **Note:**
>
> When *N*=1 (one input pair), a single coefficient is interpreted as *p1* (*p0* is set to 0.0). Two or more coefficients are interpreted according to the syntax above.

Table 41: Polynomial VCVS Instance Parameters

Parameter	Description	Unit	Default
ABS	1 = Output is an absolute value	None	0

Parameter	Description	Unit	Default
MAX	Maximum output voltage	Volt	None
MIN	Minimum output voltage	Volt	None
SCALE	Multiplier for voltage	None	1.0
TC1	Linear (1st-order) temperature coefficient	$°K^{-1}$	0.0
TC2	Quadratic (2nd-order) temperature coefficient	$°K^{-2}$	0.0

Polynomial VCVS Netlist Examples

```
E21 21 0 VCVS POLY(1) 1 0 1.1 2.1 0 3.1

E31 31 0 VCVS POLY(2) 1 0 2 0 1.2 2.2 0 0 0 0 0 0 3.2 0

E41 41 0 VCVS POLY(3) 1 0 2 0 3 0 1.3 2.3 0 0

+ 0 0 0 0 0 0

+ 0 3.3 0 0 0 0 0 0 0 4.3
```

Notes

The functional equation for the polynomial VCVS is:

V(*out*+) - V(*out*-) = *polynomial*×**SCALE** × (1 + ΔT ×**TC1** + ΔT^2×**TC2**)

If the result is less than **MIN**,

V(*out*+) - V(*out*-) = **MIN**

If the result is greater than **MAX**,

V(*out*+) - V(*out*-) = **MAX**

The *polynomial* depends on the number of inputs (*N*) and the number of polynomial coefficients (*K*). Each polynomial has terms of order (**O**), the sum of the exponents of the elements in the term. The list of coefficients must include coefficients for every term up to and including the complete group of terms with the highest order in the specified polynomial, using zero coefficients for any intermediate or trailing terms that should not be computed.

When *N*=1, the polynomial formula has one term each of order **O** {0, 1, ... *K*):

$p0 + p1 \times V(in1^+, in1^-) + \ldots pK \times V(in1^+, in1^-)^K$

Each coefficient must be a real value or zero to represent a missing term. For example, to specify a VCVS between nodes 21 and 0 whose output, controlled by a voltage source between nodes 1 and 0, is described by the one-input polynomial 1.1 + 2.1 x V(1, 0) + 3.1 x $V(1, 0)^3$, the instance statement sets coefficients *p0*=1.1, *p1*=2.1, *p2*=0, and *p3*=3.1:

```
E21 21 0 VCVS POLY(1) 1 0 1.1 2.1 0 3.1
```

When *N*=2, the polynomial formula can have more than one term in each order grouping:

O (0)

$p0 +$

O (1)

$p1 \times V(in1^+, in1^-) +$

$p2 \times V(in2^+, in2^-) +$

O (2)

$p3 \times V(in1^+, in1^-)^2 +$

$p4 \times V(in1^+, in1^-) \times V(in2^+, in2^-) +$

$p5 \times V(in2^+, in2^-)^2 +$

O (3)

$p6 \times V(in1^+, in1^-)^3 +$

$p7 \times V(in1^+, in1^-)^2 \times V(in2^+, in2^-) +$

$p8 \times V(in1^+, in1^-) \times V(in2^+, in2^-)^2 +$

$p9 \times V(in2^+, in2^-)^3 +$

O (4)

...

If the polynomial includes any terms from an order group, the list of coefficients must include intermediate and trailing zeros to complete the order. For example, to specify a VCVS between nodes 31 and 0, whose output is controlled by voltages across node pairs (1, 0), and (2, 0), is described by the two-input polynomial 1.2 + 2.2 × V(1, 0) + 3.2 × V(1, 0) × $V(2, 0)^2$, the instance statement sets coefficients *p0*=1.2, *p1*=2.2, and *p8*=3.2. Intermediate coefficients *p2* through *p7* and trailing coefficient *p9* are set to 0:

```
E31 31 0 VCVS POLY(2) 1 0 2 0 1.2 2.2 0 0 0 0 0 0 3.2 0
```

When *N*=3, the polynomial formula becomes:

O (0)

$p0 +$

O (1)

$p1 \times V(in1^+, in1^-) +$

$p2 \times V(in2^+, in2^-) +$

$p3 \times V(in3^+, in3^-) +$

O (2)

$p4 \times V(in1^+, in1^-)^2 +$

$p5 \times V(in1^+, in1^-) \times V(in2^+, in2^-) +$

$p6 \times V(in1^+, in1^-) \times V(in3^+, in3^-) +$

$p7 \times V(in2^+, \mathrm{in}2^-)^2 +$

$p8 \times V(in2^+, in2^-) \times V(in3^+, in3^-) +$

$p9 \times V(in3^+, in3^-)^2 +$

O (3)

$p10 \times V(in1^+, in1^-)^3 +$

$p11 \times V(in1^+, in1^-)^2 \times V(in2^+, in2^-) +$

$p12 \times V(in1^+, in1^-)^2 \times V(in3^+, in3^-) +$

$p13 \times V(in1^+, in1^-) \times V(in2^+, in2^-)^2 +$

$p14 \times V(in1^+, in1^-) \times V(in2^+, in2^-) \times V(in3^+, in3^-) +$

$p15 \times V(in1^+, in1^-) \times V(in3^+, in3^-)^2 +$

$p16 \times V(in2^+, in2^-)^3 +$

$p17 \times V(in2^+, in2^-)^2 \times V(in3^+, in3^-) +$

$p18 \times V(in2^+, in2^-) \times V(in3^+, in3^-)^2 +$

$p19 \times V(in3^+, in3^-)^3 +$

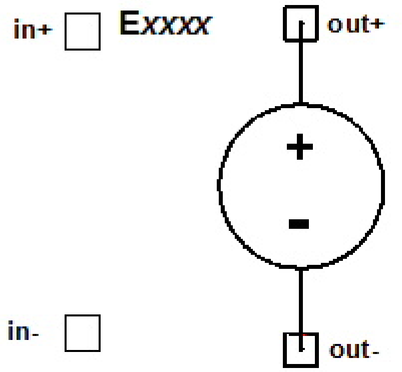
O (4)

...

For example, to specify a VCVS between nodes 41 and 0 whose output, controlled by voltages across node pairs (1, 0), (2, 0), and (3, 0) is described by the three-input polynomial $1.3 + 2.3 \times V(1, 0) + 3.3 \times V(1, 0)^2 \times V(2, 0) + 4.3 \times V(3, 0)^3$, the instance statement sets coefficients *p0*=1.3, *p1*=2.3, *p11*=3.3, and *p19*=4.3. Intermediate coefficients p3 through *p10* and *p12* through *p18* are set to 0 (since *p19* is the coefficient for the highest term with order 3, no trailing zero coefficients are needed):

```
E41 41 0 VCVS POLY(3) 1 0 2 0 3 0 1.3 2.3 0 0

+ 0 0 0 0 0 0

+ 0 3.3 0 0 0 0 0 0 0 4.3
```

Voltage-Controlled Voltage Source, Piecewise Linear



Piecewise Linear VCVS Netlist Format

The format for a piecewise linear voltage-controlled voltage source (VCVS) is:

E*xxxx out+ out-* [**VCVS**] **PWL(1)***in+ in-*

[**DELTA=***val*] [**SCALE=***scale*]

[**TC1=***val*] [**TC2=***val*]

x1 y1 [... *xK yK*]

out+ is the positive node and *out-* is the negative node of the voltage source. The entry **VCVS** is the default for the **E** element type. The entry **PWL** is required to identify the piecewise linear VCVS type. *in+* and *in-* are the positive and negative nodes for the control voltage.

The *x y* pairs are the input voltage values and the corresponding output voltage values. For intermediate values that are not in the list of *x* values, the simulator calculates the corresponding output by interpolation on the given values. The use of the **DELTA** parameter allows you to control the curvature of the interpolation to guarantee that the 1st derivative of the curve is continuous.

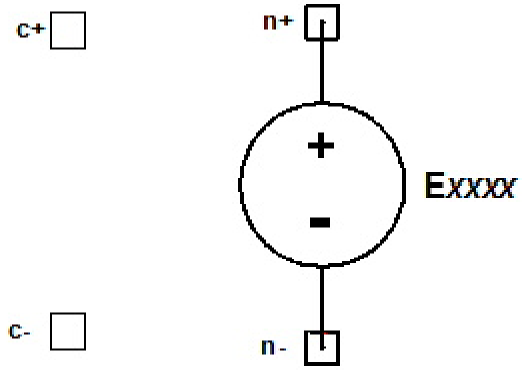
Table 42: Piecewise Linear VCVS Instance Parameters

Parameter	Description	Unit	Default
DELTA	Distance over which curvature is applied in the interpolation function Zero produces linear interpolation, positive values produce continuous curvature over the waveform Maximum is one-half of the smallest difference between control (input) values	None	One-fourth of the smallest difference between control (input) values
SCALE	Multiplier for voltage	None	1.0
TC1	Linear (1st-order) temperature coefficient	°K^{-1}	0.0
TC2	Quadratic (2nd-order) temperature coefficient	°K^{-2}	0.0

Piecewise Linear VCVS Netlist Example

```
Epwl1 11 0 VCVS PWL(1) 21 0
+ 0.0 0.0
+ 0.5 0.1
+ 1.0 0.2
+ 4.0 4.5
+ 4.5 4.75
+ 5.0 5.0
```

Voltage-Controlled Voltage Source, S-Domain



S-Domain VCVS Netlist Format

The S-domain voltage-controlled voltage source (SVCVS) uses the following netlist format:

```
Exxxx n+ n- SVCVSc+ c- [GAIN=gain]   [TC1=val] [TC2=val]
NUMER=[a0 a1 ...] DENOM=[b0 b1 ...]
```

n+ is the positive node and *n-* is the negative node of the source. The entry **SVCVS** is required to identify the SVCVS element type. *c+* and *c-* are the positive and negative nodes for the control voltage.

The element is specified using a transfer function given as the ratio of two polynomials in the complex variable *s*. The bold brackets for the **NUMER** and **DENOM** entries are required.

The function of the device is expressed as:

V(*n*+, *n*-) = GAIN × H(s) × V(*c*+, *c*-)

The transfer function H(s) is specified by giving the coefficients:

$$H(s) = \frac{a_0 + a_1 s + a_2 s^2 + \dots}{b_0 + b_1 s + b_2 s^2 + \dots}$$

The first coefficients in both numerator and denominator (a_0 and b_0) are constants, which must be specified even if they are zero. Thus, leading zeros are significant. In addition, intermediate zero-valued coefficients must be explicitly supplied in order to have the non-zero coefficients applied to the correct powers of *s*. Trailing zeros are not significant, and are automatically removed. The ratio of a_0/b_0 must be unity (when both $a_0 \neq 0$ and $b_0 \neq 0$). If the ratio is not unity, the numerator coefficients are scaled to make it unity, before the GAIN is applied.

For example, to specify the following transfer function (where coefficient a_1=0):

$$H(s) = \frac{1 + 2s^2}{1 + s + 3s^2}$$

The netlist is:

```
E21 out gnd SVCVS out gnd NUMER=[1 0 2] DENOM=[1 1 3]
```

Table 43: S-Domain VCVS Instance Parameters

Parameter	Description	Unit	Default
a0 ... aN	Coefficients of the numerator polynomial	None	None
b0 ... bD	Coefficients of the denominator polynomial (coefficient syntax)	None	None
GAIN	DC gain multiplier	None	1.0
TC1	Linear (1st-order) temperature coefficient	°K^{-1}	0.0
TC2	Quadratic (2nd-order) temperature coefficient	°K^{-2}	0.0

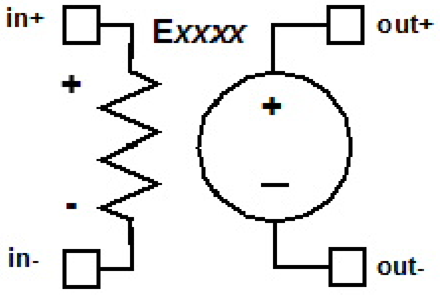
S-Domain VCVS Netlist Example

```
E1 2 0 SVCVS 1 0 GAIN=2 NUMER=[0 0.5 1] DENOM=[1 2 3]
```

This example implements the transfer function:

$$H(s) = \frac{0.5s + s^2}{1 + 2s + 3s^2}$$

Voltage-Controlled Voltage Source, Transformer



VCVS Transformer Netlist Format

The format for a voltage-controlled voltage source transformer is:

```
Exxxx out+ out- [VCVS] TRANSFORMERin+ in- [TURN_RATIO=]ratio
```

out+ and *out*- are the output nodes for the transformer. The entry **VCVS** is the default for the **E** element type. The entry **TRANSFORMER** selects the E element transformer type. *in*+ and *in*- are the control nodes for the transformer.

The **TURN_RATIO** entry specifies the ratio of the input winding to the output winding of the transformer. The **TURN_RATIO=** prefix may be omitted, but a *ratio* value must be specified.

The equations for the VCVS transformer are:

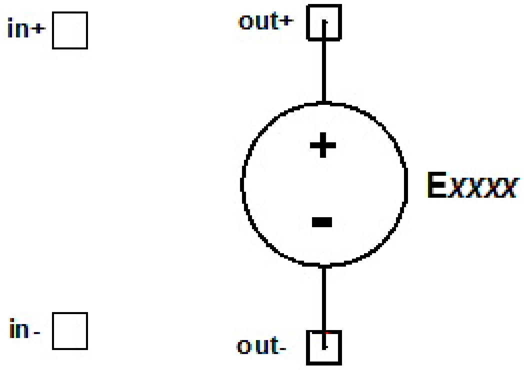
V(*out*+) - V(*out*-) = [V(*in*+) - V(*in*-)] / **TURN_RATIO**

I(*in*+, *in*-) + **TURN_RATIO** × I(*out*+, *out*-) = 0

VCVS Transformer Netlist Example

```
E23 outp outm VCVS TRANSFORMER ctrlp ctrlm TURN_RATIO=50
```

Voltage-Controlled Voltage Source, Behavioral (Netlist Only)



Behavioral VCVS Netlist Format

The format for a behavioral voltage-controlled voltage source (VCVS) is:

E*xxxx out+ out-* **VOL=**'*expression*' [**MAX=***val*] [**MIN=***val*]

out+ is the positive node and *out*- is the negative node of the voltage source.

The *expression* should be enclosed in single or double quotes. The *expression* defines the output voltage V(*out*+) - V(*out*-) as a function of the input voltage V(*in*+, *in*-) and other values in the circuit.

See *Names, Numbers, Constructs, and Expressions* in the Circuit Design File Formats topic for details.

If the result of the expression is less than **MIN**,

V(*out*+) - V(*out*-) = **MIN**

If the result is greater than **MAX**,

V(*out*+) - V(*out*-) = **MAX**

> **Note:**
>
> The Behavioral VCVS is available for use in netlists, but is not supported in the Components window of the **Electronics Desktop Schematic Editor**.

Table 44: Behavioral VCVS Instance Parameters

Parameter	Description	Unit	Default
MAX	Maximum output voltage	Volt	None
MIN	Minimum output voltage	Volt	None
VOL	Expression for output voltage	Volt	None

Netlist Example

```
E5 5 0 VOL='V(23,0)/2' MAX=5 MIN=1
```

6 - Coplanar Waveguide Elements

This topic describes the coplanar waveguide distributed elements available in Nexxim.

General Components

Bends

Coupled Lines

Couplers

Gaps

Inductors

Open Stubs

"Open Stub, Physical Length with Reference" on page 6-34

"Open Stub, Electrical Length" on page 6-35

"Open Stub, Electrical Length with Reference" on page 6-36

Resistors

"Thin Film Resistor " on page 6-31

Shorted Stubs

"Shorted Stub, Physical Length " on page 6-38

"Shorted Stub, Physical Length with Reference " on page 6-39

"Shorted Stub, Electrical Length " on page 6-40

"Shorted Stub, Electrical Length with Reference " on page 6-42

Transmission Lines

"Tapered Line " on page 6-43

"Transmission Line, Physical Length " on page 6-44

"Transmission Line, Physical Length with Reference" on page 6-46

"Transmission Line, Electrical Length" on page 6-47

"Transmission Line, Electrical Length with Reference" on page 6-48

This topic also describes the Coplanar Waveguide substrate type.

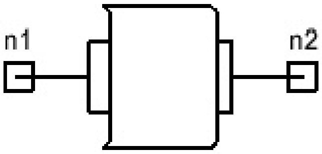
"Selecting None for the Initial Substrate " on page 6-53

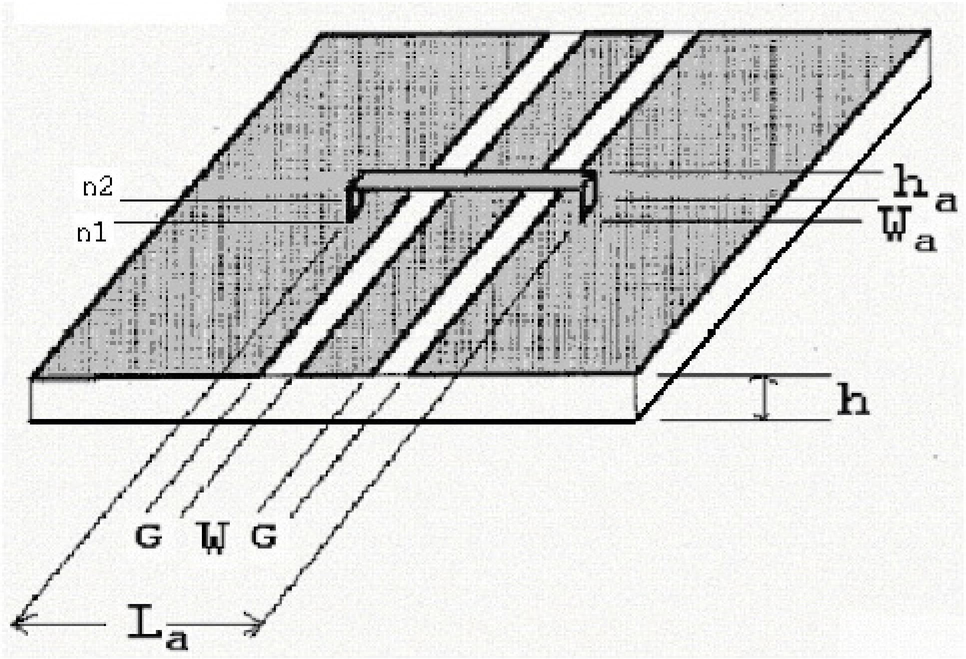
"Creating a Custom Coplanar Waveguide Substrate" on page 6-54

"Selecting a Coplanar Waveguide Substrate at the Component Level " on page 6-55

"Coplanar Waveguide Substrate Model" on page 6-55

Air Bridge, Rectangular Cross Section





Netlist Form

An instance of a coplanar waveguide air bridge with rectangular cross-section has the following Nexxim netlist syntax:

```
Axxx n1 n2 [W=val] [G=val] [HA=val] [WA=val] [LA=val]
+ COMPONENT=cpwbridge SUBSTRATE=substrate_name
```

n1 and *n2* are the nodes connected to the bridge. The entry **COMPONENT=cpwbridge** identifies the element.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Coplanar Waveguide Substrate Model" on page 6-55 for details).

Table 31: Air Bridge Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Width of slots	Meter	1.0e-3
HA	Height of air bridge above conductor plane	Meter	3.0e-6
WA	Width of air bridge	Meter	10.0e-6
LA	Length of air bridge	Meter	3.5e-3

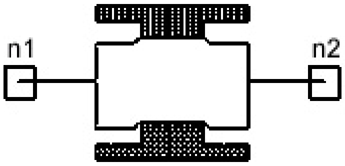
Netlist Example

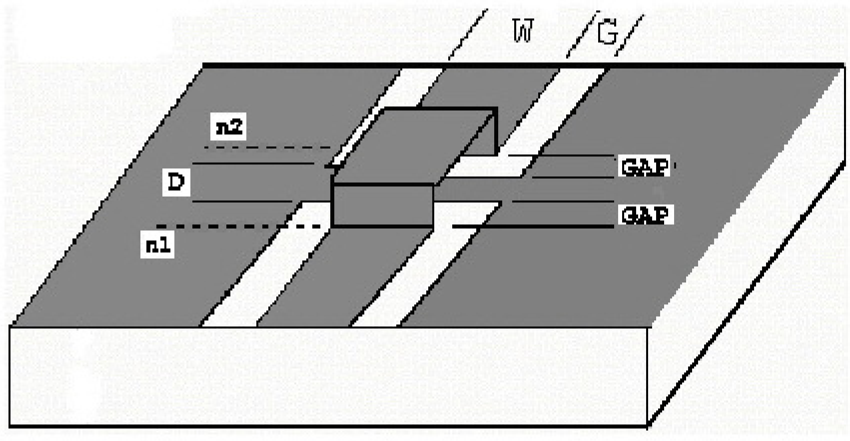
```
Ajumper1 1 2 W=0.3e-3 G=0.5e-3 HA=2.0e-6 WA=5.0e-6 LA=2.0e-3
+ COMPONENT=cpwbridge SUBSTRATE=CPW1
```

where CPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB CPW1 CPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4 HL=2.54e-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Air Bridge, Cross Over





Netlist Form

An instance of a coplanar waveguide air bridge cross over has the following Nexxim netlist syntax:

```
Axxx n1 n2 [W=val] [G=val] [HA=val] [GAP=val] [D=val]
+ COMPONENT=cpw_crossbridge SUBSTRATE=substrate_name
```

n1 and *n2* are the nodes connected to the bridge. The entry **COMPONENT=cpw_crossbridge** identifies the element.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Coplanar Waveguide Substrate Model" on page 6-55 for details).

Table 32: Air Bridge Cross Over Instance Parameters

Parameter	Description	Units	Default
W	Width of crossover bridge	Meter	1.0e-3
G	Width of gaps	Meter	1.0e-3
HA	Height of air bridge above conductor plane	Meter	3.0e-3
GAP	Width of open-end gap	Meter	1.0e-3
D	Distance of separation	Meter	3.0e-3

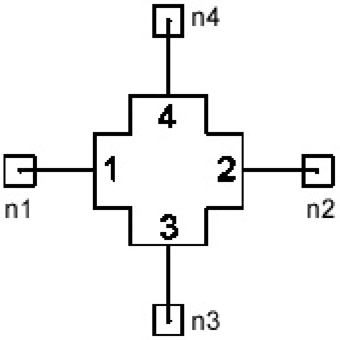
Netlist Example

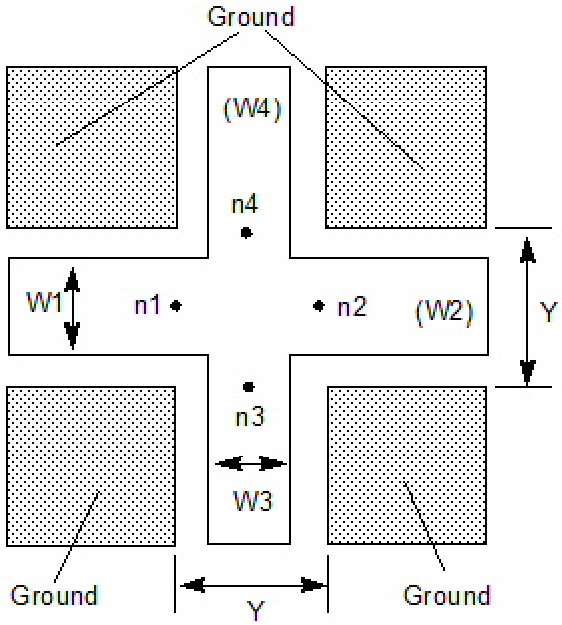
```
Ajumper1 1 2 W=0.3e-3 G=0.5e-3 HA=2.0e-3 GAP=0.5e-3 D=2.0e-3
+ COMPONENT=cpw_crossbridge SUBSTRATE=CPW1
```

where CPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB CPW1 CPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4 HL=2.54e-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Cross





Netlist Format

An instance of a symmetric coplanar waveguide cross has the following netlist syntax:

A*xxx n1 n2 n3 n4* [**W1=***val*] [**W3=***val*][**Y=***val*] **COMPONENT=cpwcross SUBSTRATE=***substrate_name*

n1, *n2*, *n3*, and *n4* are the names of the nodes attached to the cross.

The implementation of the coplanar waveguide cross element requires the element to be symmetric. Only widths W1 and W3 are specified, with W2=W1and W4=W3.

The entry **COMPONENT=cpwcross** identifies the element as a coplanar waveguide cross element.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Coplanar Waveguide Substrate Model" on page 6-55 for details).

Table 33: Coplanar Waveguide Cross Instance Parameters

Parameter	Description	Units	Default
Y	Ground-to-ground spacing at all ports. Must be greater than both W1 and W3.	Meter	3e-3
W1	Conductor width at ports 1 and 2	Meter	1e-3
W3	Conductor width at ports 3 and 4	Meter	1e-3

Netlist Example

```
A23 Port1 Port2 Port3 Port4 W1=4.0e-004 W3=2.0e-4 Y=6.0e-4
+ COMPONENT=CPWCROSS   SUBSTRATE=CPW1
```

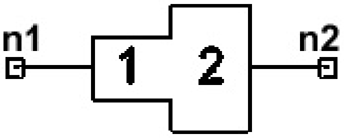
where CPW1, the selected layout technology or substrate type, has a definition such as:

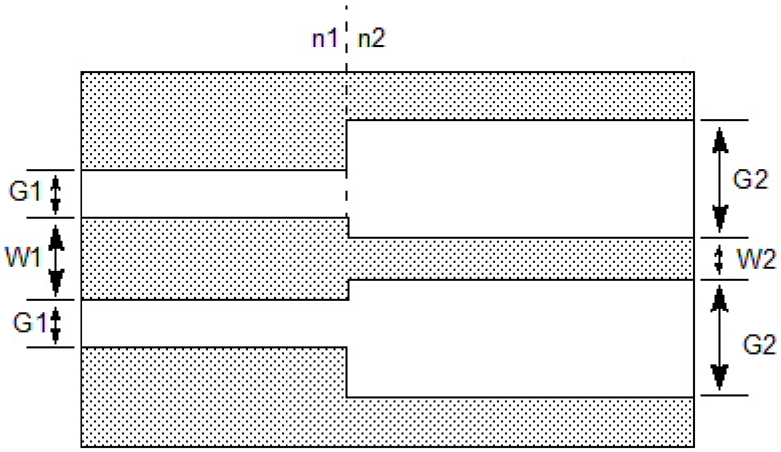
```
.SUB CPW1 CPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4 HL=2.54e-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. The ground-to-ground distance Y is the same at all ports.
2. W1 = W2 and W3 = W4.
3. For accurate results, the substrate definition should specify:
   2 < ER <14, H > Y
   0.1 < W*n*/Y <0.9, where W*n* is the conductor width at any port.
4. The coplanar mode is assumed to exist only. Parasitic effects due to air bridges are not considered by this model.

Step





Netlist Format

An instance of a coplanar waveguide step has the following netlist syntax:

```
Axxx n1 n2 [W1=val] [P=val]
COMPONENT=cpwstep SUBSTRATE=substrate_name
```

n1 and *n2* are the names of the nodes attached to the step. The entry **COMPONENT=cpwstep** identifies the element as a coplanar waveguide step.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Coplanar Waveguide Substrate Model" on page 6-55 for details).

Table 34: Coplanar Waveguide Step Instance Parameters

Parameter	Description	Units	Default
W1	Conductor width of line connected to node 1	Meter	1.5e-3
G1	Slot width of line connected to node 1	Meter	1e-3
W2	Conductor width of line connected to node 2	Meter	1e-3
G2	Gap width of line connected to node 2	Meter	1.5e-3

Netlist Example

```
A5 Port1 Port2 W1=0.75e-3 G1=1.1e-3 W2=0.5e-3 G2=1.3e-3
COMPONENT=cpwstep SUBSTRATE=CPW1
```

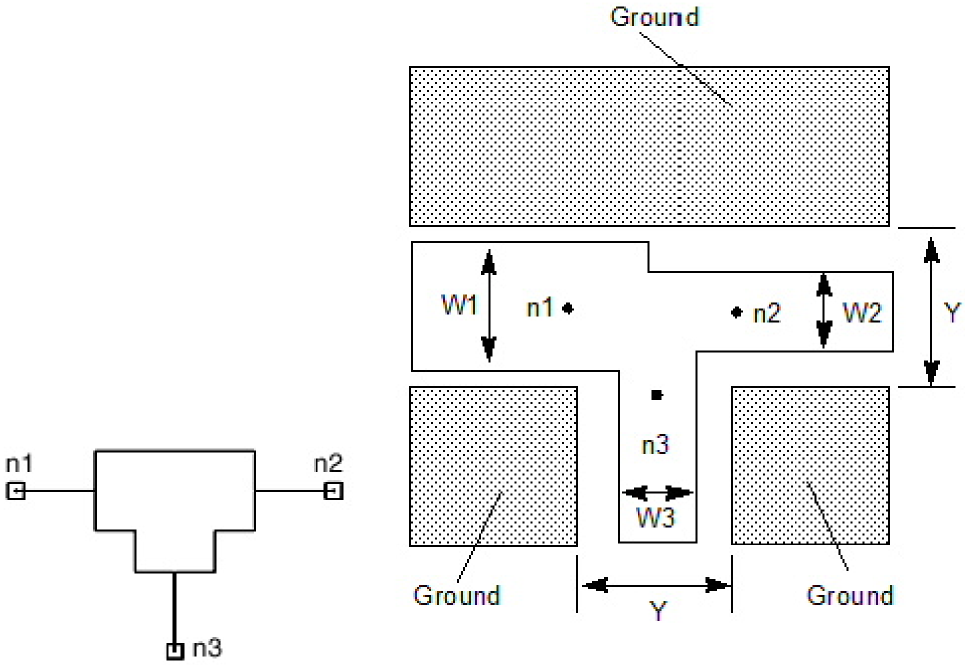
where CPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB CPW1 CPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4 HL=2.54e-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. The model computes the equivalent T-network of the CPW step, which consists of two series inductors and a shunt capacitor.
2. For accurate results, the substrate definition should specify:
   $H > W1 + 2 \times G1$
   $H > W2 + 2 \times G2$
   $0.1 < k1 < 0.9$, where $k1 = W1/(W1 + 2 \times G1)$
   $0.1 < k2 < 0.9$, where $k2 = W2/(W2 + 2 \times G2)$
3. When G2>G1, W1>W2. When G2<G1, W1<W2.

Tee



Netlist Format

An instance of a coplanar waveguide tee has the following netlist syntax:

`A`*`xxx n1 n2 n3`* `[`**`W1=`***`val`*`] [`**`W3=`***`val`*`][`**`Y=`***`val`*`]` **`COMPONENT=cpwtee`**
`SUBSTRATE=`*`substrate_name`*

n1, *n2*, and *n3* are the names of the nodes attached to the tee.

The entry **COMPONENT=cpwtee** identifies the element as a coplanar waveguide tee element.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Coplanar Waveguide Substrate Model" on page 6-55 for details).

Table 35: Coplanar Waveguide Tee Instance Parameters

Parameter	Description	Units	Default
Y	Ground-to-ground spacing at all ports. Must be greater than W1, W2, and W3.	Meter	4e-3
W1	Conductor width at port 1	Meter	1e-3
W2	Conductor width at port 2	Meter	1e-3
W3	Conductor width at port 3	Meter	1e-3

Netlist Example

```
A23 Port1 Port2 Port3 W1=4.0e-4 W2=3.0e-4 W3=2.0e-4 Y=6.0e-4
+ COMPONENT=CPWTEE   SUBSTRATE=CPW1
```

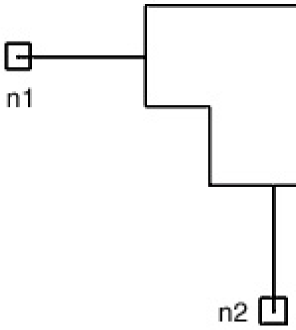
where CPW1, the selected layout technology or substrate type, has a definition such as:

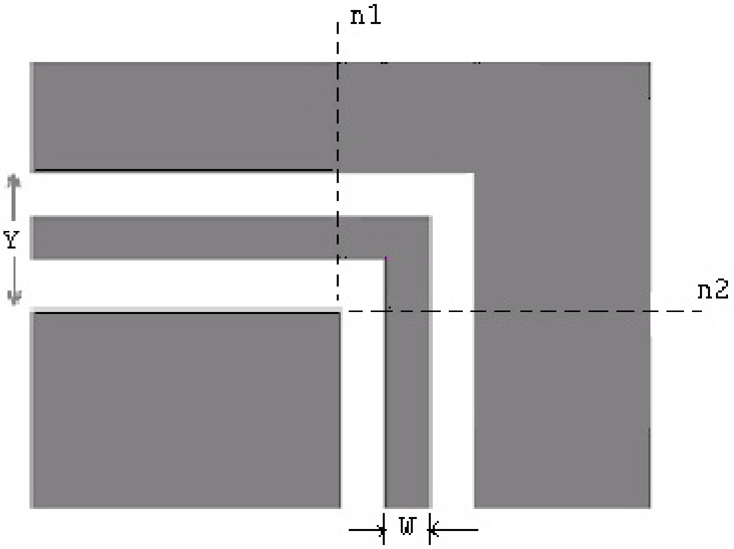
```
.SUB CPW1 CPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4 HL=2.54e-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. The lines connected to nodes n1 and n2 are collinear, with conductor widths W1 and W2. The perpendicular line is connected to node n3 and has center conductor width W3. The ground-to-ground distance Y is the same for all ports.
2. For accurate results, the substrate definition should specify:
   H > Y
   0.1 < W*n*/Y <0.9, where W*n* is the conductor width at any port.
3. The coplanar mode is assumed to exist only. Parasitic effects due to air bridges are not considered by this model.

Unmitered Bend, Distance Between Ground Planes





Netlist Format

An instance of a coplanar waveguide unmitered bend, gap width, has the following netlist syntax:

```
Axxx n1 n2 [W=val] [Y=val]
+ COMPONENT=cpw_bend_ground_plane_distance SUBSTRATE=substrate_name
```

n1 and *n2* are the names of the nodes attached to the bend. The entry **COMPONENT=cpw_bend_ground_plane_distance** identifies the element as a coplanar waveguide unmitered bend, gap width specified.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Coplanar Waveguide Substrate Model" on page 6-55for details).

Table 36: Coplanar Waveguide Unmitered Bend, Gap Widthm Instance Parameters

Parameter	Description	Units	Default
W	Center conductor width	Meter	1.0e-3
Y	Distance between ground planes	Meter	3.0e-3

Netlist Example

```
A5 Port1 Port2 W=0.75e-3 Y=2.1e-3
+ COMPONENT=cpw_bend_ground_plane_distance SUBSTRATE=CPW1
```

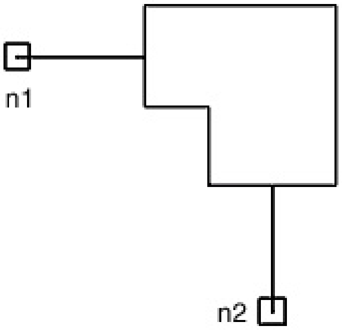
where CPW1, the selected layout technology or substrate type, has a definition such as:

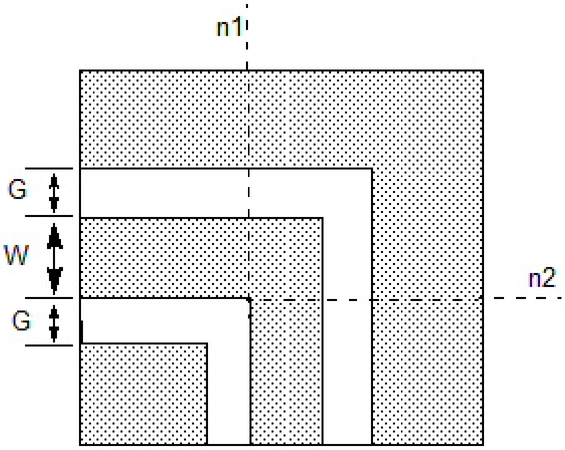
```
.SUB CPW1 CPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4 HL=2.54e-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. Reference planes coincide with the inside vertex of the corner, as shown in the figure.
2. For accurate results, the substrate definition should specify:
   H > Y
   0.1 < W/Y < 0.9
3. The coplanar mode is assumed to exist only. The CPW Air Bridge can be used if parasitic effects due to air bridges can be considered.

Unmitered Bend, Gap Width





Netlist Format

An instance of a coplanar waveguide unmitered bend, gap width, has the following netlist syntax:

A*xxx n1 n2* [**W=***val*] [**G=***val*]

COMPONENT=cpw_unmitered_bend SUBSTRATE=*substrate_name*

n1 and *n2* are the names of the nodes attached to the bend. The entry **COMPONENT=cpw_unmitered_bend** identifies the element as a coplanar waveguide unmitered bend, gap width specified.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Coplanar Waveguide Substrate Model" on page 6-55 for details).

Table 37: Coplanar Waveguide Unmitered Bend, Gap Widthm Instance Parameters

Parameter	Description	Units	Default
W1	Center conductor width	Meter	1.0e-3
G	Gap width	Meter	1.0e-3

Netlist Example

```
A5 Port1 Port2 W=0.75e-3 G=1.1e-3 COMPONENT=cpw_unmitered_bend
SUBSTRATE=CPW1
```

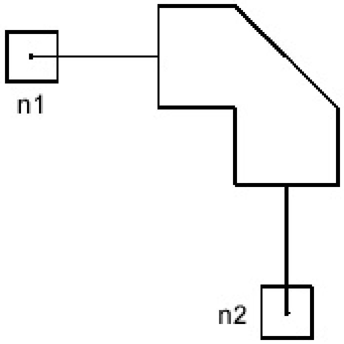
where CPW1, the selected layout technology or substrate type, has a definition such as:

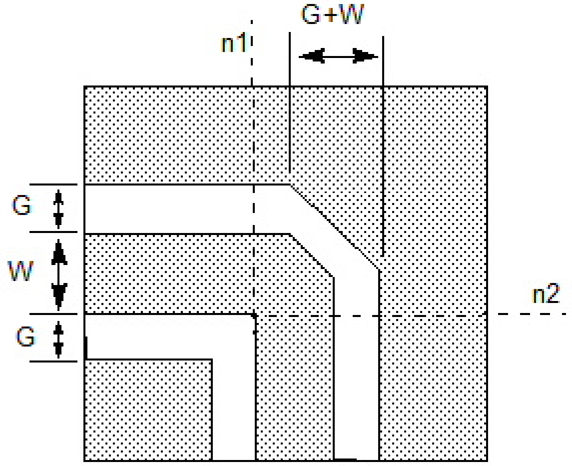
```
.SUB CPW1 CPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4 HL=2.54e-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. Reference planes coincide with the inside vertex of the corner, as shown in the figure.
2. For accurate results, the substrate definition should specify:
   H > W + 2×G
   0.1 < W/(W1 + 2 × G) < 0.9
3. The coplanar mode is assumed to exist only. Parasitic effects due to air bridges are not considered by this model.

Mitered Bend





Netlist Format

An instance of a coplanar waveguide mitered bend has the following netlist syntax:

A*xxx n1 n2* [**W=***val*] [**G=***val*]
COMPONENT=cpw_mitered_bend SUBSTRATE=*substrate_name*

n1 and *n2* are the names of the nodes attached to the bend. The entry **COMPONENT=cpw_mitered_bend** identifies the element as a coplanar waveguide unmitered bend.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Coplanar Waveguide Substrate Model" on page 6-55 for details).

Table 38: Coplanar Waveguide Step Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3

Netlist Example

```
A5 Port1 Port2 W=0.75e-3 G=1.1e-3 COMPONENT=cpw_mitered_bend
SUBSTRATE=CPW1
```

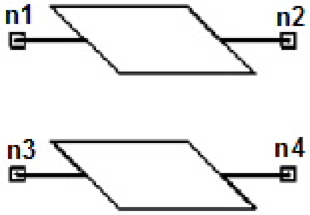
where CPW1, the selected layout technology or substrate type, has a definition such as:

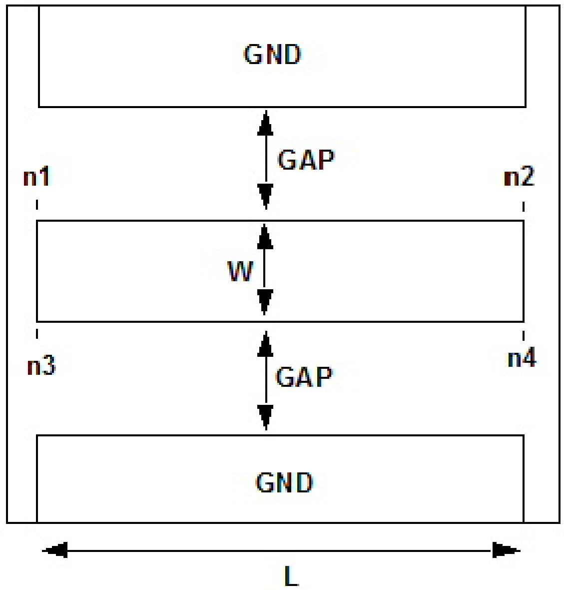
```
.SUB CPW1 CPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4 HL=2.54e-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

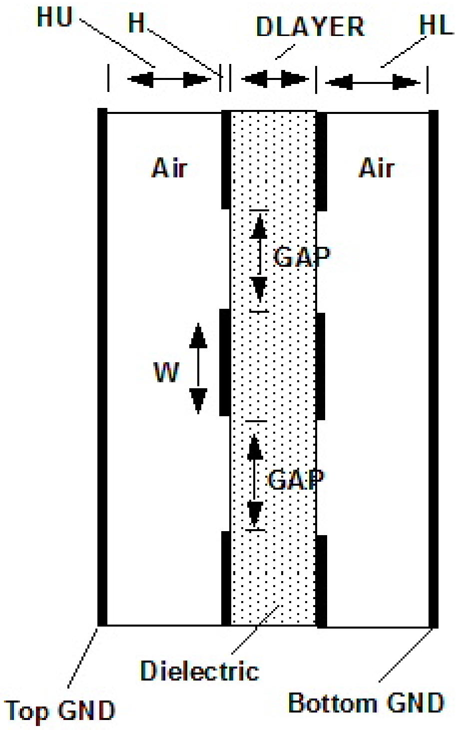
Notes

1. Reference planes coincide with the inside vertex of the corner, as shown in the figure.
2. For accurate results, the substrate definition should specify:
   $H > W + 2 \times G$
   $0.1 < W/(W1 + 2 \times G) < 0.9$
3. The coplanar mode is assumed to exist only. Parasitic effects due to air bridges are not considered by this model.

Coupled Lines, Broadside, Physical Length, Field Solver







Netlist Form

A broadside coupled line, physical length, field solver instance has the following netlist syntax:

```
Wxxx n1 n2 0 n3 n4 0 [L=length]    N=2 FSmodel=modelname

.MATERIAL conductor METAL CONDUCTIVITY=conductivity

.MATERIAL dielectric DIELECTRIC ER=er LOSSTANGENT=losstangent

.SHAPE RECT1 RECTANGLE WIDTH=w HEIGHT=h // Conductors
.SHAPE RECT2 RECTANGLE WIDTH='10*w' HEIGHT=h // Ground lines
```

```
.LAYERSTACK STACK1
+ LAYER=(conductor, h) // Bottom ground
+ LAYER=(AIR, hl)
+ LAYER=(dielectric, dlayer)
+ LAYER=(AIR, hu)
+ LAYER=(conductor, h) // Top ground
.MODEL modelname W MODELTYPE=Fieldsolver
+ LAYERSTACK=STACK1
+ CONDUCTOR=(SHAPE=RECT2, ORIGIN=('-gap-10*w', hl),
+ MATERIAL=conductor, TYPE=REFERENCE)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=(0, hl)
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT2, ORIGIN=('w+gap', hl

+ MATERIAL=conductor, TYPE=REFERENCE)
+ CONDUCTOR=(SHAPE=RECT2, ORIGIN=('-gap-10*w', 'hl+h+dlayer')
+ MATERIAL=conductor, TYPE=REFERENCE)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=(0, 'hl+h+dlayer')
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT2, ORIGIN=('w+gap', 'hl+h+dlayer')
+ MATERIAL=conductor, TYPE=REFERENCE)
```

n1 and *n3* are the names of the input nodes. *n2* and *n4* are the corresponding output nodes. The entry **N=2** is required.

The entry **FSmodel=***modelname* identifies the field solver coplanar waveguide model.

Table 39: Broadside Coupled Line, Physical Length, Field Solver Instance Parameters

Parameter	Description	Units	Default
L	Physical length	Meter	1e-3
N	Number of lines (must be 2)	None	2
conductor	Conductor material	None	cond1
conductivity	Conductivity of conductor material		57.6e6
dielectric	Dielectric material	None	diel1
dlayer	Thickness of dielectric layer	Meter	1e-3
er	Dielectric constant		2.2
losstangent	Dielectric loss tangent		0
w	Width of conductor	Meter	1e-3
gap	Gap width between conductor and grounds	Meter	1e-3

hu	Thickness of upper air layer	Meter	5e-3
hl	Thickness of lower air layer	Meter	5e-3
h	Thickness of conductors and grounds	Meter	1.7145e-5

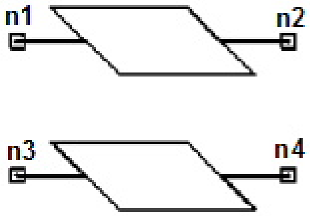
> **Note:** The default values for the Broadside coupled line are the ones assigned when placing a component on the Component library in a schematic. There are NO defaults for netlist designs; all values must be specified.

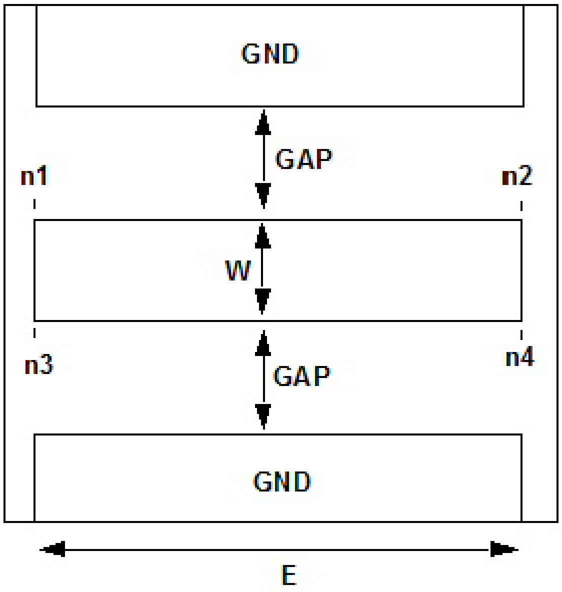
Netlist Example

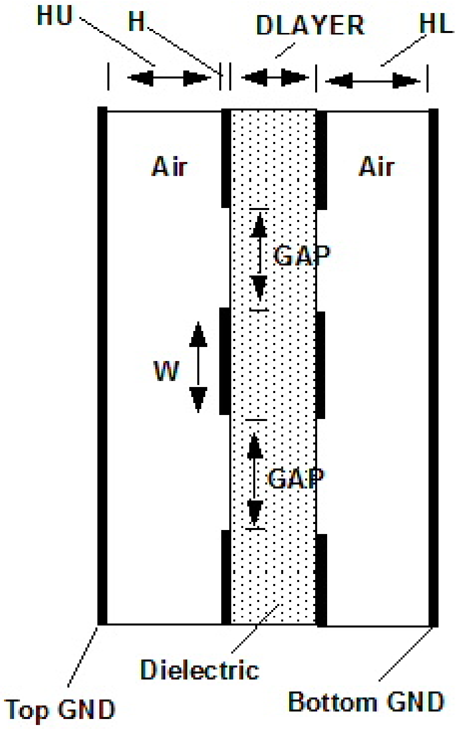
```
W3 Port1 Port2 0 net_1911 net_2 0 N=2 L=0.002 FSmodel=BCL1
```

```
.MATERIAL copper METAL CONDUCTIVITY=5.8e7
.MATERIAL dielectric DIELECTRIC ER=4.4 LOSSTANGENT=0.02
.SHAPE RECT1 RECTANGLE WIDTH=.002 HEIGHT=.001   // Conductors
.SHAPE RECT2 RECTANGLE WIDTH='10*.002' HEIGHT=.001   // Ground
lines
.LAYERSTACK STACK1
+ LAYER=(copper, .001) // Bottom ground
+ LAYER=(AIR, .02)
+ LAYER=(dielectric, .01)
+ LAYER=(AIR, .03)
+ LAYER=(copper, .001)
.MODEL BCL1 W MODELTYPE=Fieldsolver
+ LAYERSTACK=STACK1
+ CONDUCTOR=(SHAPE=RECT2, ORIGIN=('-.005-10*.002', .02)
+ MATERIAL=conductor, TYPE=REFERENCE)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=(0, .02)
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT2, ORIGIN=('.002+.005', .02)
+ MATERIAL=conductor, TYPE=REFERENCE)
+ CONDUCTOR=(SHAPE=RECT2,
+ ORIGIN=('-.005-10*.002', '.02+.001+.01')
+ MATERIAL=conductor, TYPE=REFERENCE)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=(0, '.02+.001+.01')
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT3, ORIGIN=('.002+.005', '.02+.001+.01')
+ MATERIAL=conductor, TYPE=REFERENCE)
```

Coupled Lines, Broadside, Electrical Length, Field Solver







Netlist Form

A broadside coupled line, electrical length, field solver instance has the following netlist syntax:

```
Wxxx n1 n2 0 n3 n4 0

+ L= '(e * 3e8)/(360*F*SQRT(er))' // Convert to physical length
+ N=2 FSmodel=modelname

.MATERIAL conductor METAL CONDUCTIVITY=conductivity

.MATERIAL dielectric DIELECTRIC ER=er LOSSTANGENT=losstangent
```

```
.SHAPE RECT1 RECTANGLE WIDTH=w HEIGHT=h // Conductors
.SHAPE RECT2 RECTANGLE WIDTH='10*w' HEIGHT=h // Ground lines
.LAYERSTACK STACK1
+ LAYER=(conductor, h) // Bottom ground
+ LAYER=(AIR, hl)
+ LAYER=(dielectric, dlayer)
+ LAYER=(AIR, hu)
+ LAYER=(conductor, h)
.MODEL modelname W MODELTYPE=Fieldsolver
+ LAYERSTACK=STACK1
+ CONDUCTOR=(SHAPE=RECT2, ORIGIN=('-gap-10*w', hl)
+ MATERIAL=conductor, TYPE=REFERENCE)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=(0, hl)
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT2, ORIGIN=('w+gap', hl)
+ MATERIAL=conductor, TYPE=REFERENCE)
+ CONDUCTOR=(SHAPE=RECT2, ORIGIN=('-gap-10*w', 'hl+h+dlayer')
+ MATERIAL=conductor, TYPE=REFERENCE)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=(0, 'hl+h+dlayer')
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT3, ORIGIN=('w+gap', 'hl+h+dlayer')
+ MATERIAL=conductor, TYPE=REFERENCE)
```

n1 and *n2* are the names of the input nodes. *n3* and *n4* are the corresponding output nodes. The entry **N=2** is required.

The entry **FSmodel=***modelname* identifies the field solver coplanar waveguide model.

Table 40: Broadside Coupled Line, Electrical Length, Field Solver Instance Parameters

Parameter	Description	Units	Default
E	Electrical length	Degree	45
F	Frequency at which E is specified	Hertz	1e9
N	Number of lines (must be 2)	None	2
conductor	Conductor material	None	cond1
conductivity	Conductivity of conductor material		0
dielectric	Dielectric material	None	diel1
dlayer	Thickness of dielectric layer	Meter	1e-3
er	Dielectric constant		2.2

losstangent	Dielectric loss tangent		0
w	Width of conductor	Meter	1e-3
gap	Gap width between conductor and grounds	Meter	1e-3
hu	Thickness of upper air layer	Meter	5e-3
hl	Thickness of lower air layer	Meter	5e-3
h	Thickness of conductor	Meter	1.7145e-5

> **Note:** The default values for the Broadside coupled line are the ones assigned when placing a component on the Component library in a schematic. There are NO defaults for netlist designs; all values must be specified.

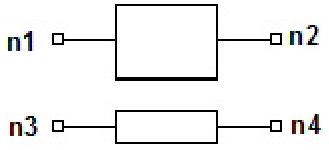
Netlist Example

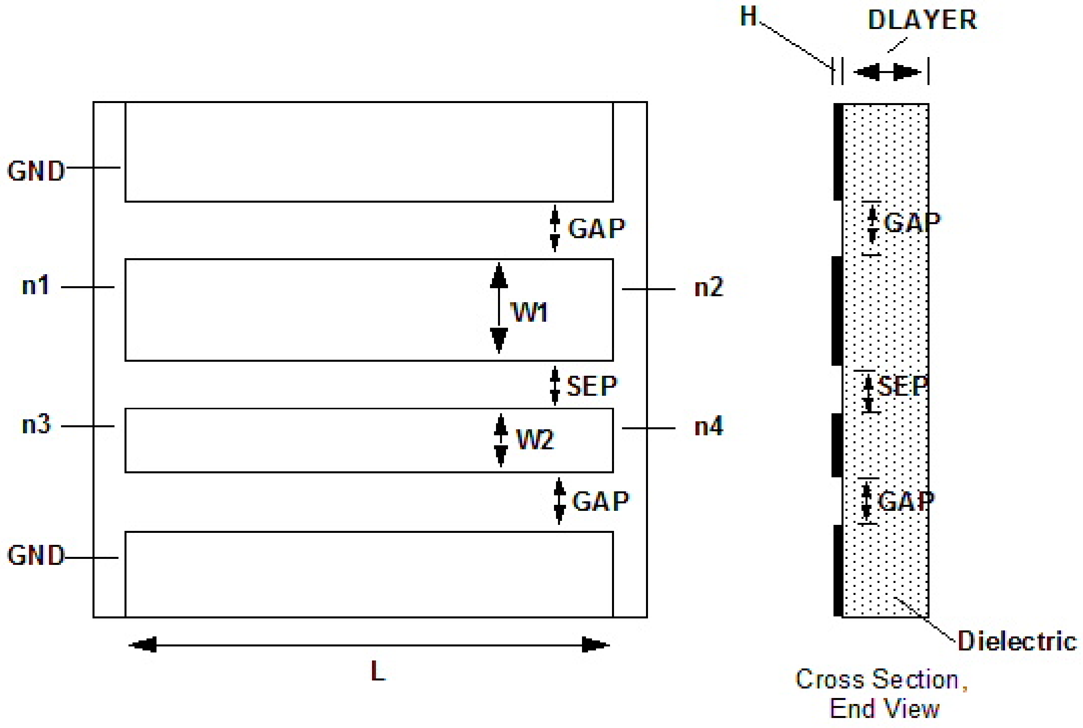
```
W3 Port1 Port2 0 net_1911 net_2 0 N=2
+ L=’(45*3e8)/(360*1e9*SQRT(4.4)
+ FSmodel=BCL1
```

```
.MATERIAL copper METAL CONDUCTIVITY=5.8e7
.MATERIAL dielectric DIELECTRIC ER=4.4 LOSSTANGENT=0.02
.SHAPE RECT1 RECTANGLE WIDTH=.002 HEIGHT=.001   // Conductors
.SHAPE RECT2 RECTANGLE WIDTH='10*.002' HEIGHT=.001   // GND lines
.LAYERSTACK STACK1
+ LAYER=(copper, .001) // Bottom ground
+ LAYER=(AIR, .02)
+ LAYER=(dielectric, .01)
+ LAYER=(AIR, .03)
+ LAYER=(copper, .001)
.MODEL BCL1 W MODELTYPE=Fieldsolver
+ LAYERSTACK=STACK1
+ CONDUCTOR=(SHAPE=RECT2, ORIGIN=('-.005-10*.002', .02)
+ MATERIAL=conductor, TYPE=REFERENCE)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=(0, .02)
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT2, ORIGIN=('.002+.005', .02)
+ MATERIAL=conductor, TYPE=REFERENCE)
+ CONDUCTOR=(SHAPE=RECT2, ORIGIN=('-.005-10*.002',
'.02+.001+.01')
+ MATERIAL=conductor, TYPE=REFERENCE)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=(0, '.02+.001+.01')
+ MATERIAL=conductor, TYPE=SIGNAL)
```

```
+ CONDUCTOR=(SHAPE=RECT3, ORIGIN=('.002+.005', '.02+.001+.01')
+ MATERIAL=conductor, TYPE=REFERENCE)
```

Coupled Lines, Asymmetric, Physical Length, Field Solver





Netlist Form

An asymmetric coupled line, physical length, field solver instance has the following netlist syntax:

W*xxx n1 n2* 0 *n3 n4* 0 [**L=***length*] **N=2 FSmodel=***modelname*

.MATERIAL *material* METAL CONDUCTIVITY=*conductivity*

.MATERIAL *dielectric* DIELECTRIC ER=*er* LOSSTANGENT=*losstangent*

```
.SHAPE RECT1 RECTANGLE WIDTH=w1 HEIGHT=h

.SHAPE RECT2 RECTANGLE WIDTH=w2 HEIGHT=h

.SHAPE RECT3 RECTANGLE WIDTH='5*(w1+w2)' HEIGHT=h

.LAYERSTACK STACK1
+ LAYER=(dielectric,dlayer)
.MODEL modelname W MODELTYPE=Fieldsolver
+ LAYERSTACK=STACK1
+ CONDUCTOR=(SHAPE=RECT3, ORIGIN=('-gap-5*(w1+w2)',dlayer)
+ MATERIAL=conductor, TYPE=REFERENCE)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=(0,dlayer)
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT2, ORIGIN=('w1+sep',dlayer)
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT3, ORIGIN=('w1+sep+w2+gap', dlayer)
+ MATERIAL=conductor, TYPE=REFERENCE)
```

n1 and *n3* are the names of the input nodes. *n2* and *n4* are the corresponding output nodes. The entry **N=2** is required.

The entry **FSmodel=***modelname* identifies the field solver coplanar waveguide model.

Table 41: Asymmetric Coupled Line, Physical Length, Field Solver Instance Parameters

Parameter	Description	Units	Default
L	Physical length	Meter	1e-3
N	Number of lines (must be 2)	None	2
material	Conductor material	None	cond1
conductivity	Conductivity of conductor material		57.6e6
dielectric	Dielectric material	None	diel1
er	Dielectric constant		2.2
losstangent	Dielectric loss tangent		0
w1	Width of first conductor	Meter	1e-3
w2	Width of second conductor	Meter	1e-3
gap	Gap width between outer conductors and grounds	Meter	1e-3
sep	Spacing between conductors	Meter	1e-3

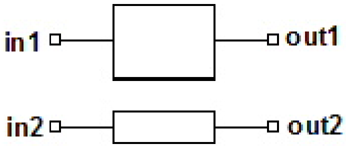
> **Note:** The default values for the coupled line are the ones assigned when placing a component from the Component library in a schematic. There are NO defaults for netlist designs; all values must be specified.

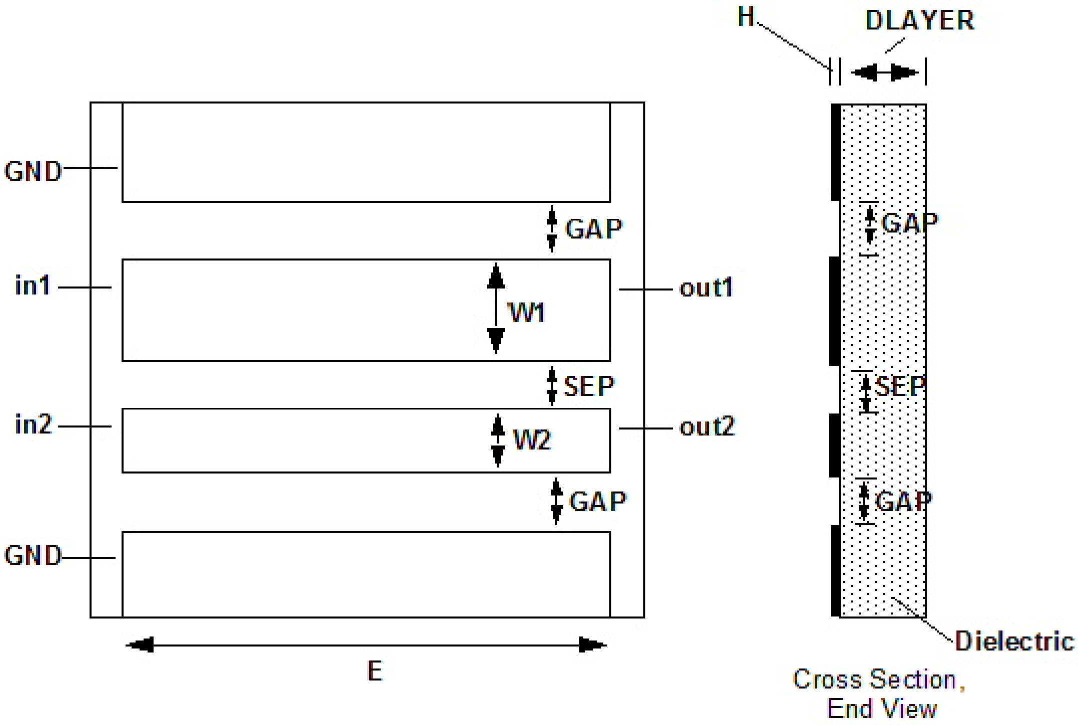
Netlist Example

```
W3 Port1 Port2 0 net_1911 net_2 0 N=2 L=0.002 FSmodel=CPW1
```

```
.MATERIAL COPPER METAL CONDUCTIVITY=58000000
.MATERIAL dielectric1 DIELECTRIC ER=4.4 LOSSTANGENT=0.02
.SHAPE RECT1 RECTANGLE WIDTH=0.001 HEIGHT=0.002
.SHAPE RECT2 RECTANGLE WIDTH=0.002 HEIGHT=0.002
.SHAPE RECT3 RECTANGLE WIDTH='5*(.001+.002)' HEIGHT=0.002
.LAYERSTACK STACK1
+ LAYER=(dielectric1,0.010)
.MODEL CPW1 W MODELTYPE=Fieldsolver
+ LAYERSTACK=STACK1
+ CONDUCTOR=(SHAPE=RECT3, ORIGIN=('-.005-5*(.001+.002)',.010)
+ MATERIAL=conductor, TYPE=REFERENCE)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=(0,.010)
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT2, ORIGIN=('.001+.003',.010)
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT3, ORIGIN=('.001+.003+.002+.005', .010)
+ MATERIAL=conductor, TYPE=REFERENCE)
```

Coupled Lines, Asymmetric, Electrical Length, Field Solver





Netlist Form

An asymmetric coupled line, physical length, field solver instance has the following netlist syntax:

```
Wxxx n1 n2 0 n3 n4 0
+ L= '(e *3e8)/(360*F*SQRT(er))' // Convert to physical length
+ N=2 FSmodel=modelname
.MATERIAL material METAL CONDUCTIVITY=conductivity

.MATERIAL dielectric DIELECTRIC ER=er LOSSTANGENT=losstangent

.SHAPE RECT1 RECTANGLE WIDTH=w1 HEIGHT=h

.SHAPE RECT2 RECTANGLE WIDTH=w2 HEIGHT=h

.SHAPE RECT3 RECTANGLE WIDTH='5*(w1+w2)' HEIGHT=h

.LAYERSTACK STACK1
+ LAYER=(dielectric,dlayer)
.MODEL modelname W MODELTYPE=Fieldsolver
```

```
+ LAYERSTACK=STACK1
+ CONDUCTOR=(SHAPE=RECT3, ORIGIN=('-gap-5*(w1+w2)',dlayer)
+ MATERIAL=conductor, TYPE=REFERENCE)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=(0,dlayer)
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT2, ORIGIN=('w1+sep',dlayer)
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT3, ORIGIN=('w1+sep+w2+gap', dlayer)
+ MATERIAL=conductor, TYPE=REFERENCE)
```

n1 and *n3* are the names of the input nodes. *n2* and *n4* are the corresponding output nodes. The entry **N=2** is required.

The entry **FSmodel=***modelname* links the field solver coplanar waveguide instance to the model code.

Table 42: Asymmetric Coupled Line, Electrical Length, Field Solver Instance Parameters

Parameter	Description	Units	Default
E	Electrical length	Degree	45
F	Reference frequency for electrical length	Hertz	1e9
N	Number of lines (must be 2)	None	2
material	Conductor material	None	cond1
conductivity	Conductivity of conductor material		576.e6
dielectric	Dielectric material	None	diel1
er	Dielectric constant		2.2
losstangent	Dielectric loss tangent		0
w1	Width of first conductor	Meter	1e-3
w2	Width of second conductor	Meter	1e-3
gap	Gap width between outer conductors and grounds	Meter	1e-3
sep	Spacing between conductors	Meter	1e-3

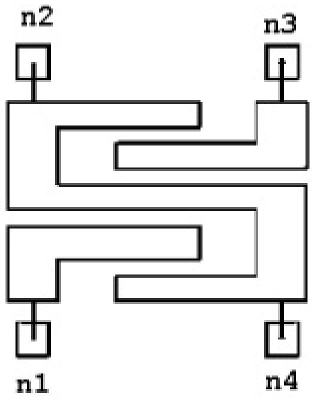
> **Note:** The default values for the coupled line are the ones assigned when placing a component from the Component library in a schematic. There are NO defaults for netlist designs; all values must be specified.

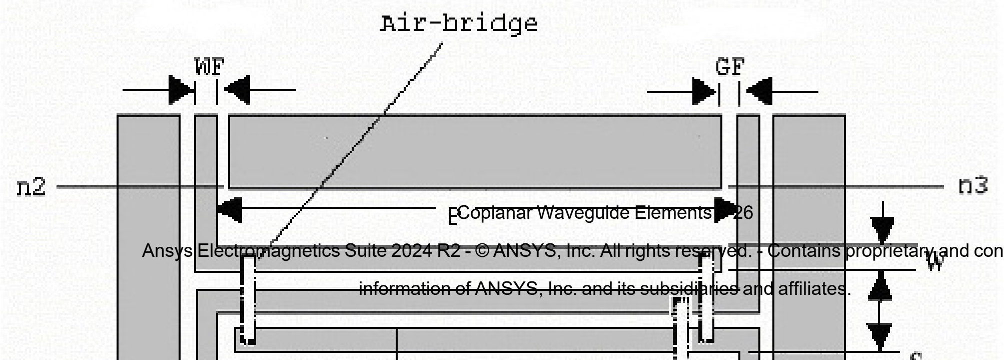
Netlist Example

```
W3 Port1 Port2 0 net_1911 net_2 0 N=2
+ L=’(45*3e8)/(360*1e9*SQRT(4.4)
+ FSmodel=CPW1
```

```
.MATERIAL COPPER METAL CONDUCTIVITY=58000000
.MATERIAL dielectric1 DIELECTRIC ER=4.4 LOSSTANGENT=0.02
.SHAPE RECT1 RECTANGLE WIDTH=0.001 HEIGHT=0.002
.SHAPE RECT2 RECTANGLE WIDTH=0.002 HEIGHT=0.002
.SHAPE RECT3 RECTANGLE WIDTH='5*(.001+.002)' HEIGHT=0.002
.LAYERSTACK STACK1
+ LAYER=(dielectric1,0.010)
.MODEL CPW1 W MODELTYPE=Fieldsolver
+ LAYERSTACK=STACK1
+ CONDUCTOR=(SHAPE=RECT3, ORIGIN=('-.005-5*(.001+.002)',.010)
+ MATERIAL=conductor, TYPE=REFERENCE)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=(0,.010)
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT2, ORIGIN=('.001+.003',.010)
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT3, ORIGIN=('.001+.003+.002+.005', .010)
+ MATERIAL=conductor, TYPE=SIGNAL)
```

Lange Coupler, Physical Length





Netlist Format

A Lange coupler, physical length instance has the following netlist format:

ACPWLANG*xxx n1 n2 n3 n4* **N=4 W=***val* **S=***val* **P=***val*
WF=*val* **GF=***val* **WA=***val* **HA=***val* **SO=***val*
COMPONENT=cpwlange_physical SUBSTRATE=*substrate_name*

n1, *n2*, *n3*, and *n4* are the names of the nodes attached to the coupler. The entry **COMPONENT=cpwlange_physical** identifies the element.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Coplanar Waveguide Substrate Model" on page 6-55 for details).

Table 43: Lange Coupler, Physical Length Instance Parameters

Parameter	Description	Unit	Default
N	Number of lines. Must be 4.	None	4
W	Conductor width	Meter	1e-3
S	Conductor spacing	Meter	1e-3
P	Physical length	Meter	10e-3
WF	Center conductor width of feeding lines	Meter	0.5e-3
GF	Slot width of feeding lines	Meter	0.5e-3
WA	Width of air bridges	Meter	0.1e-3
HA	Height of air bridges	Meter	0.1e-3
SO	Distance to ground plane	Meter	1e-3

Netlist Example

```
ACPWLANG1 Port1 Port2 Port3 Port4 N=4 W=1e-3 S=.2e-3 P=10e-3
+ COMPONENT=cpwlange_physical SUBSTRATE=CPW1
```

where CPW1, the selected layout technology or substrate type, has a definition such as:

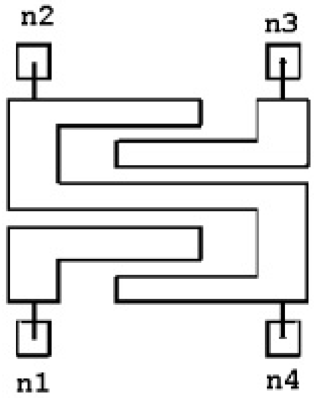
```
.SUB CPW1 CPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4 HL=2.54e-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

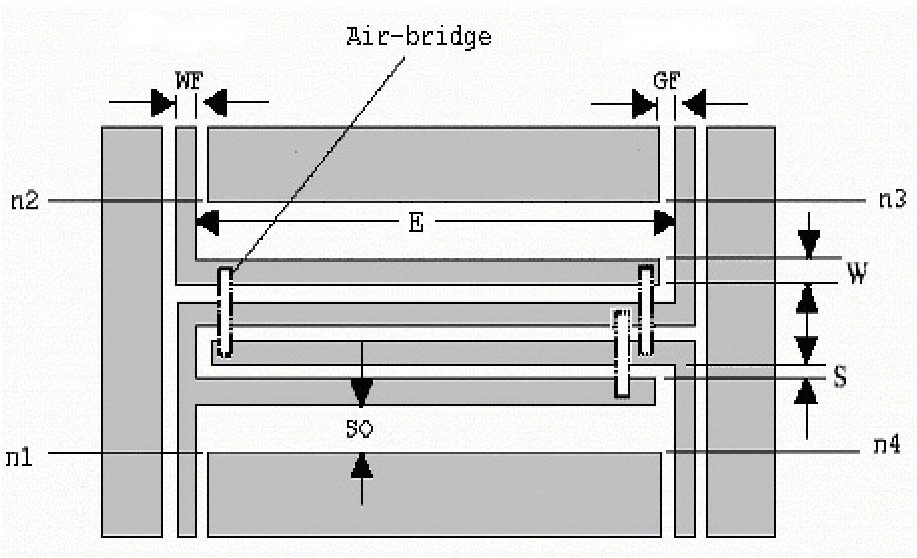
Notes

1. The conductor width of all fingers is W. The distance between all fingers is S.
2. The number of fingers, N, must be 4.

3. Port 1 is the input port, port 2 is the coupled port, port 3 is the through port, and port 4 is the isolated port.
4. The length of air bridges used to approximate their parasitic effects, is 2*(W+S).

Lange Coupler, Electrical Length





Netlist Format

A Lange coupler, electrical length instance has the following netlist format:

```
ACPWLANGExxx n1 n2 n3 n4 N=4 W=val S=val E=val F=val
WF=val GF=val WA=val HA=val SO=val
COMPONENT=cpwlange_electrical SUBSTRATE=substrate_name
```

n1, *n2*, *n3*, and *n4* are the names of the nodes attached to the coupler. The entry **COMPONENT=cpwlange_electrical** identifies the element.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Coplanar Waveguide Substrate Model" on page 6-55 for details).

Table 44: Lange Coupler, Electrical Length Instance Parameters

Parameter	Description	Unit	Default
N	Number of lines. Must be 4.	None	4
W	Conductor width	Meter	1e-3
S	Conductor spacing	Meter	1e-3
E	Electrical length	Degree	90
F	Frequency at which E is taken	Hz	1e9
WF	Center conductor width of feeding lines	Meter	0.5e-3
GF	Slot width of feeding lines	Meter	0.5e-3
WA	Width of air bridges	Meter	0.1e-3
HA	Height of air bridges	Meter	0.1e-3
SO	Distance to ground plane	Meter	1e-3

Netlist Example

```
ACPWLANGE1 Port1 Port2 Port3 Port4 N=4 W=1e-3 S=.2e-3 E=75
+ COMPONENT=cpwlange_electrical SUBSTRATE=CPW1
```

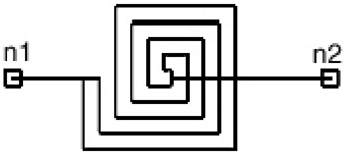
where CPW1, the selected layout technology or substrate type, has a definition such as:

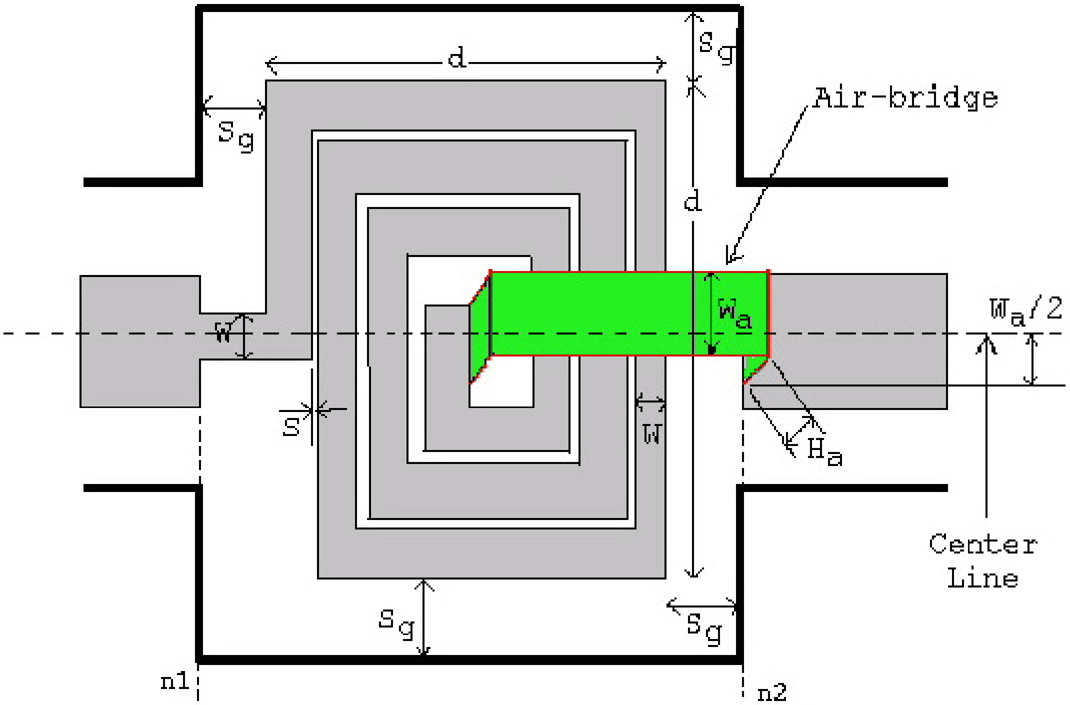
```
.SUB CPW1 CPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4 HL=2.54e-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. The conductor width of all fingers is W. The distance between all fingers is S.
2. The number of fingers, N, must be 4.
3. Port 1 is the input port, port 2 is the coupled port, port 3 is the through port, and port 4 is the isolated port.
4. The length of air bridges used to approximate their parasitic effects, is 2*(W+S).

Rectangular Inductor





Netlist Format

An instance of a coplanar waveguide rectangular inductor has the following netlist syntax:

A*xxx n1* **N=***val* **D=***val* **W=***val* **S=***val*] **HA=***val* **WA=***val* **SG=***val* **T=***val*] **RB=***val* **COMPONENT=cpwreci SUBSTRATE=***substrate_name* *n1* is the name of the node attached to the rectangular inductor. The entry **COMPONENT=cpwreci** identifies the element as a coplanar waveguide open stub, physical length.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Coplanar Waveguide Substrate Model" on page 6-55 for details).

Table 45: Coplanar Waveguide Rectangular Inductor Instance Parameters

Parameter	Description	Units	Default
N	Number of turns	None	5.5
D	Spiral outer dimension	Meter	10e-3
W	Conductor width	Meter	0.5e-3
S	Spacing between turns	Meter	0.2e-3
HA	Height of air bridge	Meter	3.0e-6
WA	Width of air bridge	Meter	10e-6
SG	Distance to ground plane	Meter	0.5e-6
T	Conductor thickness	Meter	Substrate Metallization
RB	Bulk resistivity	μ-Ohm/cm	Substrate Metallization

Netlist Example

```
A2 Port1 Port2 D=12e-3 N=4 W=0.6e-3 S=0.3e-3 HA=7e-6 WA=11e-6
SG=0.4e-6 COMPONENT=cpwreci SUBSTRATE=CPW1
```

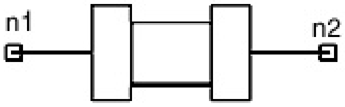
where CPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB CPW1 CPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4 HL=2.54e-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. This model is not recommended beyond the first resonant frequency.
2. The model is restricted to a square CPW spiral.
3. An error occurs if the size of the inductor cannot accommodate the specified number of turns.
4. The number of turns N has to be an integer multiple of half a turn, i.e., 0.5, 1, 1.5, …

Thin Film Resistor



Netlist Format

An instance of a coplanar waveguide thin film resistor has the following netlist syntax:

`ACPWTFR``xxx n1 n2` **`W=`**`val` **`G=`**`val` **`P=`**`val` **`RB=`**`val` **`T=`**`val`
`COMPONENT=cpw_thinfilm_rb SUBSTRATE=``substrate_name`

n1 and *n2* are is the names of the nodes attached to the resistor. The entry **COMPONENT=cpw_thinfilm_rb** identifies the element.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Coplanar Waveguide Substrate Model" on page 6-55 for details).

Table 46: Coplanar Waveguide Thin-Film Resistor Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3
P	Physical length	Meter	1.0e-3
RB	Bulk resistivity	µohm-cm	300
T	Thickness of thin-film resistor	Meter	1e-3

Netlist Example

```
ACPWTFR5 net1 net5 W=0.75e-3 G=1.1e-3 P=2.5e-3 T=1.75e-4
+ COMPONENT=cpw_thinfilm_rb SUBSTRATE=CPW1
```

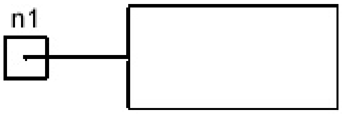
where CPW1, the selected layout technology or substrate type, has a definition such as:

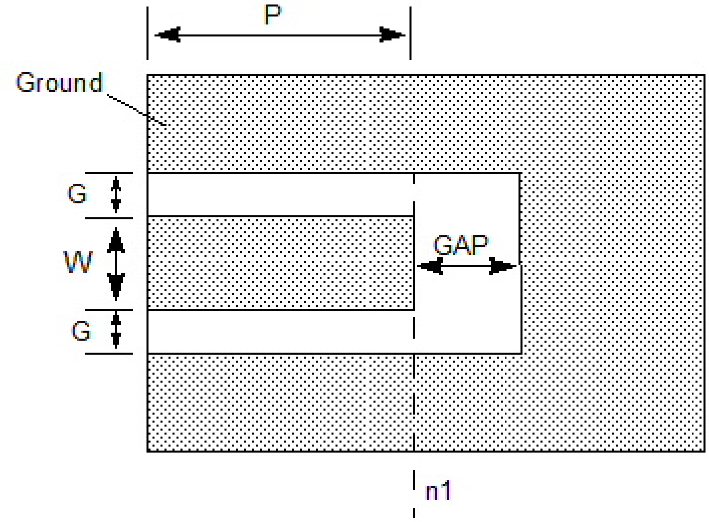
```
.SUB CPW1 CPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4 HL=2.54e-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. A lossy transmission line is used to model the TFR section. Distributed effects are thus taken into consideration.
2. The user needs to define the CPW steps, if any. They are not included in the TFR model.

Open Stub, Physical Length





Netlist Format

An instance of a coplanar waveguide open stub, physical length has the following netlist syntax:

```
Axxx n1 [W=val] [G=val] [P=val] [GAP=val]
COMPONENT=cpw_open_stub_physical SUBSTRATE=substrate_name
```

n1 is the name of the node attached to the open stub. The entry **COMPONENT=cpw_open_stub_physical** identifies the element as a coplanar waveguide open stub, physical length.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Coplanar Waveguide Substrate Model" on page 6-55 for details).

Table 47: Coplanar Waveguide Open Stub, Physical Length Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3
P	Physical length	Meter	5.0e-3
GAP	Gap width at end of CPW line	Meter	1.0e-3

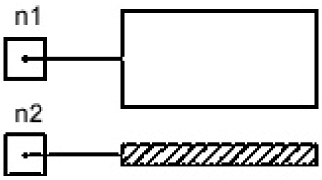
Netlist Example

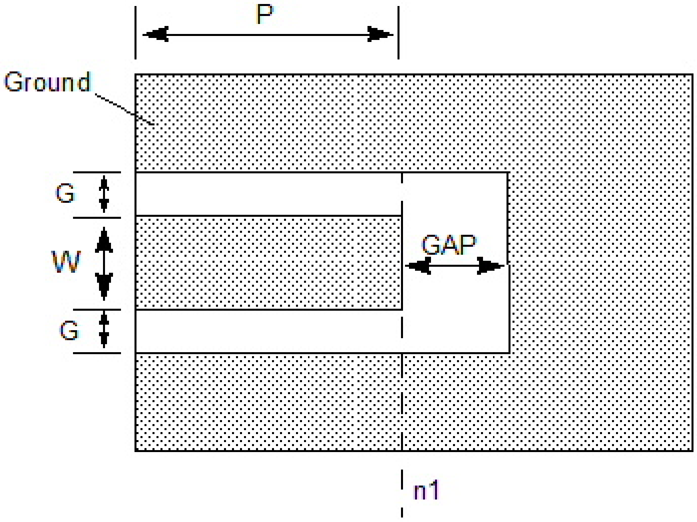
```
A5 Port1 W=0.75e-3 G=1.1e-3 P=2.5e-3 GAP=1.75e-3
COMPONENT=cpw_open_stub_physical SUBSTRATE=CPW1
```

where CPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB CPW1 CPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4 HL=2.54e-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Open Stub, Physical Length with Reference





Netlist Format

An instance of a coplanar waveguide open stub, physical length with reference has the following netlist syntax:

```
Axxx n1 n2 [W=val] [G=val] [P=val] [GAP=val]
COMPONENT=cpw_open_stub_physical SUBSTRATE=substrate_name
```

n1 is the name of the node attached to the open stub. *n2* is the reference node. The entry **COMPONENT=cpw_open_stub_physical** identifies the element as a coplanar waveguide open stub, physical length.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Coplanar Waveguide Substrate Model" on page 6-55 for details).

Table 48: Coplanar Waveguide Open Stub, Physical Length with Reference Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3
P	Physical length	Meter	5.0e-3
GAP	Gap width at end of CPW line	Meter	1.0e-3

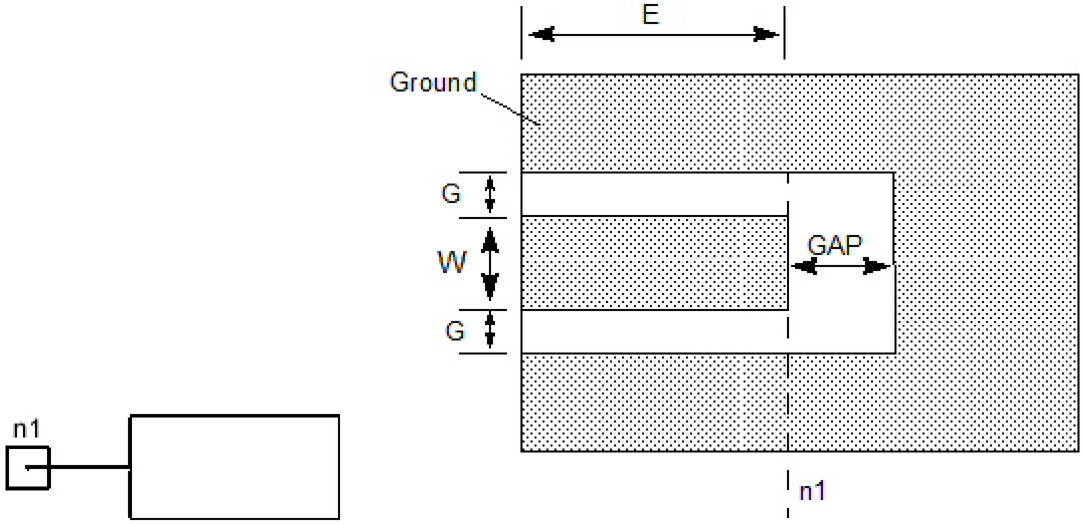
Netlist Example

```
A5 Port1 Port2 W=0.75e-3 G=1.1e-3 P=2.5e-3 GAP=1.75e-3
COMPONENT=cpw_open_stub_physical SUBSTRATE=CPW1
```

where CPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB CPW1 CPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4 HL=2.54e-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Open Stub, Electrical Length



Netlist Format

An instance of a coplanar waveguide open stub, electrical length has the following netlist syntax:

```
Axxx n1 [W=val] [G=val] [GAP=val] [E=val] [F=val]
COMPONENT=cpw_open_stub_e SUBSTRATE=substrate_name
```

n1 is the name of the node attached to the open stub. The entry **COMPONENT=cpw_open_stub_e** identifies the element as a coplanar waveguide open stub, electrical length.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Coplanar Waveguide Substrate Model" on page 6-55 for details).

Table 49: Coplanar Waveguide Open Stub, Electrical Length Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3
GAP	Gap width at end of CPW line	Meter	1.0e-3
E	Electrical length	Degree	45
F	Reference frequency for E	Hz	1.0e9

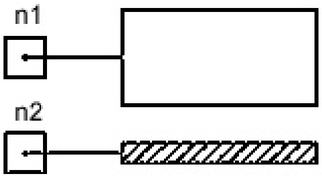
Netlist Example

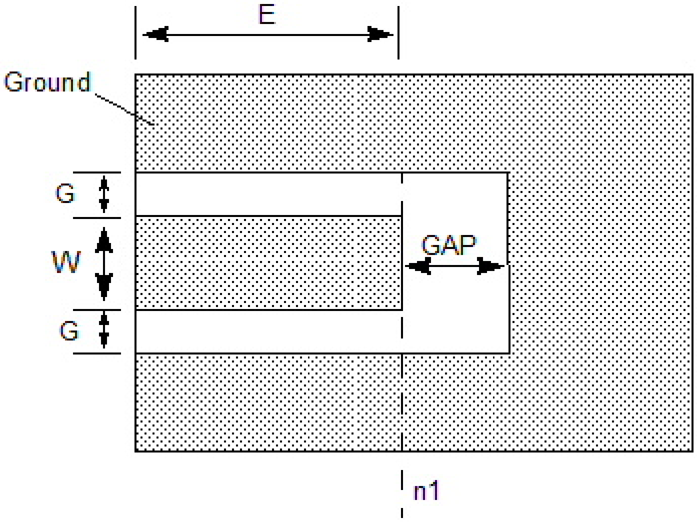
```
A5 Port1 W=0.75e-3 G=1.1e-3 GAP=1.75e-3 E=50 F=2.0e9
COMPONENT=cpw_open_stub_e SUBSTRATE=CPW1
```

where CPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB CPW1 CPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4 HL=2.54e-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Open Stub, Electrical Length with Reference





Netlist Format

An instance of a coplanar waveguide open stub, electrical length with reference has the following netlist syntax:

A*xxx n1 n2* [**W=***val*] [**G=***val*] [**GAP=***val*] [**E=***val*] [**F=***val*]
COMPONENT=cpw_open_stub_e SUBSTRATE=*substrate_name*

n1 is the name of the node attached to the open stub. *n2* is the reference node. The entry **COMPONENT=cpw_open_stub_e** identifies the element as a coplanar waveguide open stub, electrical length.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Coplanar Waveguide Substrate Model" on page 6-55 for details).

Table 50: Coplanar Waveguide Open Stub, Electrical Length with Reference Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3
GAP	Gap width at end of CPW line	Meter	1.0e-3
E	Electrical length	Degree	45
F	Reference frequency for E	Hertz	1.0e9

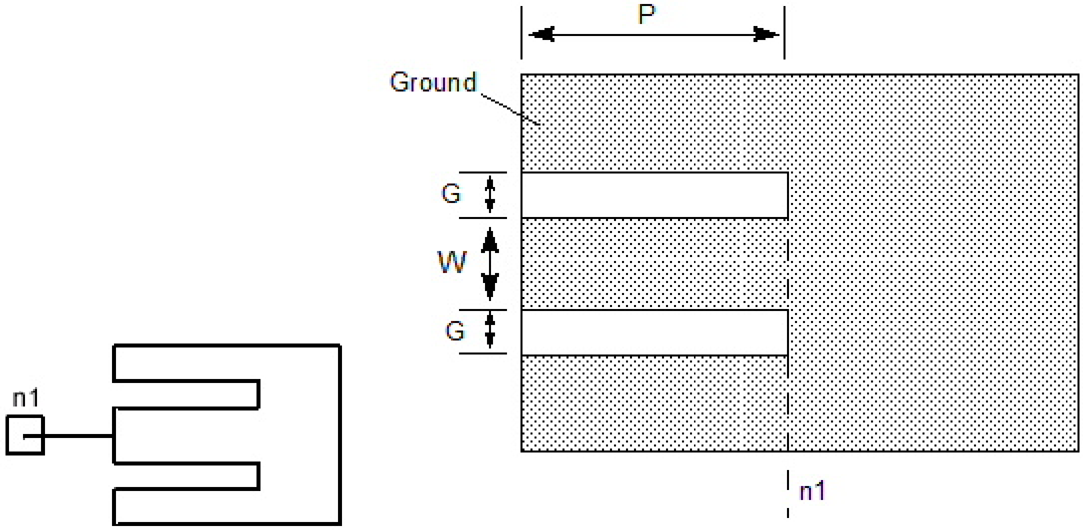
Netlist Example

```
A5 Port1 Port2 W=0.75e-3 G=1.1e-3 GAP=2.5e-3 E=50 F=2.0e9
COMPONENT=cpw_open_stub_e SUBSTRATE=CPW1
```

where CPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB CPW1 CPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4 HL=2.54e-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Shorted Stub, Physical Length



Netlist Format

An instance of a coplanar waveguide shorted stub, physical length has the following netlist syntax:

A*xxx n1* [**W=***val*] [**G=***val*] [**P=***val*]
COMPONENT=cpw_short_stub_physical SUBSTRATE=*substrate_name*

n1 is the name of the node attached to the shorted stub. The entry **COMPONENT=cpw_short_stub_physical** identifies the element as a coplanar waveguide shorted stub, physical length.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Coplanar Waveguide Substrate Model" on page 6-55 for details).

Table 51: Coplanar Waveguide Shorted Stub, Physical Length Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3
P	Physical length	Meter	1.0e-3

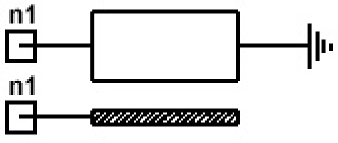
Netlist Example

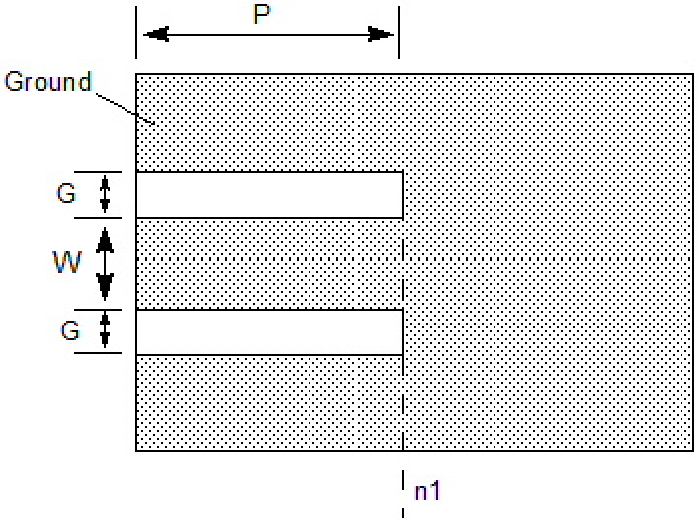
```
A5 Port1 W=0.75e-3 G=1.1e-3 P=2.5e-3
COMPONENT=cpw_short_stub_physical SUBSTRATE=CPW1
```

where CPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB CPW1 CPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4 HL=2.54e-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Shorted Stub, Physical Length with Reference





Netlist Format

An instance of a coplanar waveguide shorted stub, physical length with reference has the following netlist syntax:

```
Axxx n1 n2 [W=val] [G=val] [P=val]
COMPONENT=cpw_short_stub_physical SUBSTRATE=substrate_name
```

n1 is the name of the node attached to the open stub. *n2* is the reference node. The entry **COMPONENT=cpw_short_stub_physical** identifies the element as a coplanar waveguide shorted stub, physical length.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Coplanar Waveguide Substrate Model" on page 6-55 for details).

Table 52: Coplanar Waveguide Shorted Stub, Physical Length with Reference Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3
P	Physical length	Meter	1.0e-3

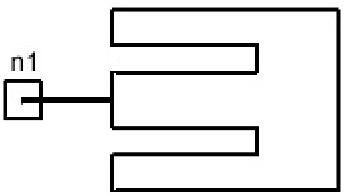
Netlist Example

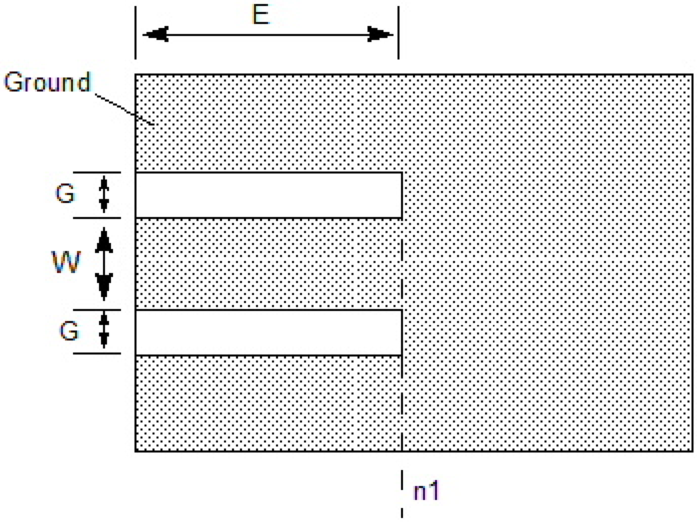
```
A5 Port1 Port2 W=0.75e-3 G=1.1e-3 P=2.5e-3
COMPONENT=cpw_short_stub_physical SUBSTRATE=CPW1
```

where CPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB CPW1 CPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4 HL=2.54e-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Shorted Stub, Electrical Length





Netlist Format

An instance of a coplanar waveguide shorted stub, electrical length has the following netlist syntax:

```
Axxx n1 [W=val] [G=val] [E=val] [F=val]
COMPONENT=cpw_short_stub_electrical SUBSTRATE=substrate_name
```

n1 is the name of the node attached to the shorted stub. The entry **COMPONENT=cpw_short_stub_electrical** identifies the element as a coplanar waveguide shorted stub, electrical length.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Coplanar Waveguide Substrate Model" on page 6-55 for details).

Table 53: Coplanar Waveguide Shorted Stub, Electrical Length Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3
E	Electrical length	Degree	45
F	Reference frequency for E	Hz	1.0e9

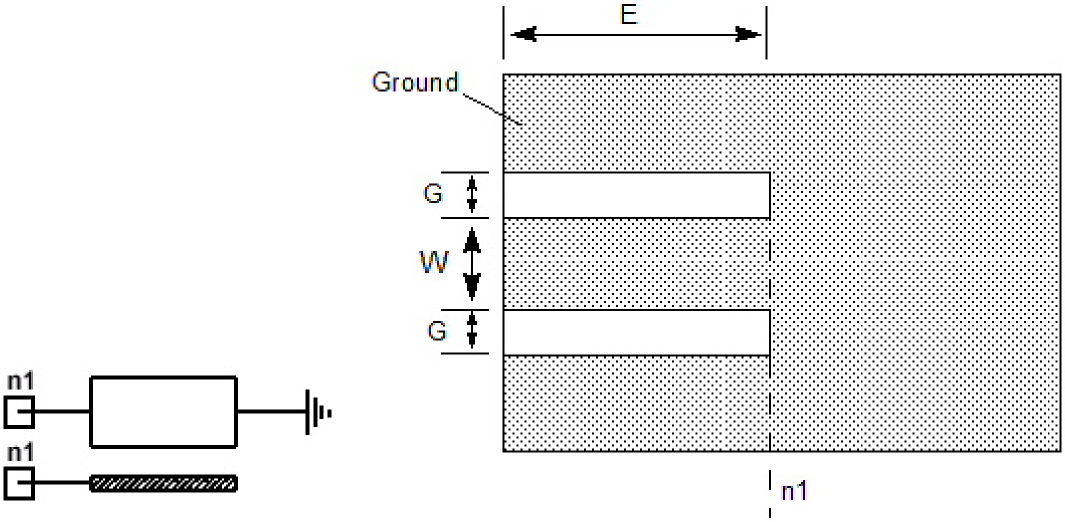
Netlist Example

```
A5 Port1 W=0.75e-3 G=1.1e-3 E=50 F=2.039
COMPONENT=cpw_short_stub_electrical SUBSTRATE=CPW1
```

where CPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB CPW1 CPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4 HL=2.54e-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Shorted Stub, Electrical Length with Reference



Netlist Format

An instance of a coplanar waveguide shorted stub, electrical length with reference has the following netlist syntax:

A*xxx n1 n2* [**W=***val*] [**G=***val*] [**E=***val*] [**F=***val*]
COMPONENT=cpw_short_stub_electrical SUBSTRATE=*substrate_name*

n1 is the name of the node attached to the shorted stub. *n2* is the reference node. The entry **COMPONENT=cpw_short_stub_electrical** identifies the element as a coplanar waveguide shorted stub, electrical length.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Coplanar Waveguide Substrate Model" on page 6-55 for details).

Table 54: Coplanar Waveguide Shorted Stub, Physical Length with Reference Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3
E	Electrical length	Degree	45
F	Reference frequency for E	Hertz	1.0e9

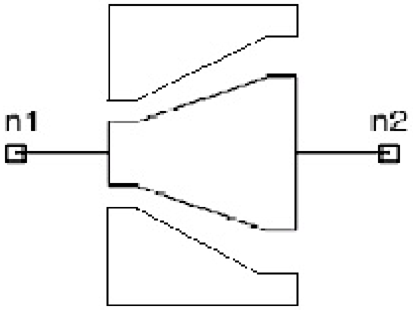
Netlist Example

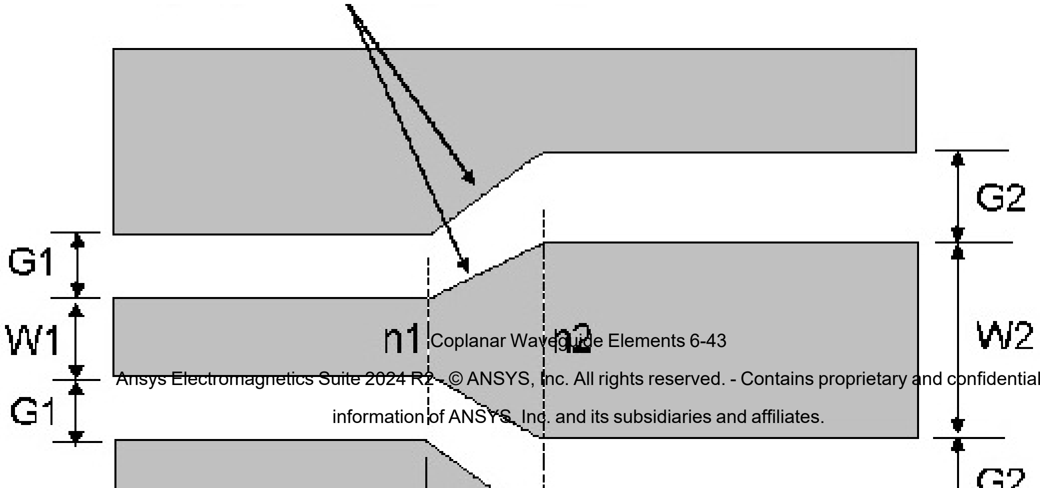
```
A5 Port1 Port2 W=0.75e-3 G=1.1e-3 E=50 F=.0e9
COMPONENT=cpw_short_stub_electrical SUBSTRATE=CPW1
```

where CPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB CPW1 CPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4 HL=2.54e-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Tapered Line





Netlist Format

An instance of a grounded coplanar waveguide tapered line has the following netlist syntax:

A*xxx n1 n2* [**W1=***val*] [**W2=***val*] [**G1=***val*] [**G2=***val*] [**P=***val*]
[**TAPER="LINWIDTH"**|**"EXPWIDTH"**]
COMPONENT=cpw_tapered_line SUBSTRATE=*substrate_name*

n1 and *n2* are the names of the nodes attached to the transmission line. The entry **COMPONENT=cpw_tapered_line** identifies the element as a grounded coplanar waveguide transmission line, physical length.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Coplanar Waveguide Substrate Model" on page 6-55 for details).

Table 55: Coplanar Waveguide Tapered Line Instance Parameters

Parameter	Description	Units	Default
W1	Width of node 1 conductor	Meter	1.0e-3
W2	Width of node 2 conductor	Meter	2.0e-3
G1	Slot width at node 1	Meter	0.5e-3
G2	Slot width at node 2	Meter	0.75e-3
P	Physical length	Meter	1.0e-2

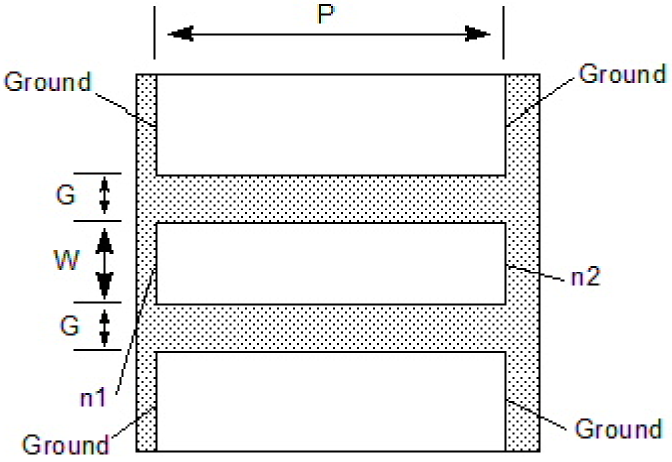
Netlist Example

```
A5 Port1 Port2 W1=0.75e-3 W2=1.5e-3 G1=1.1e-3 G2=2.1e-3 P=2e-2
+ COMPONENT=cpw_tapered_line SUBSTRATE=CPW1
```

where CPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB CPW1 CPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4 HL=2.54e-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Transmission Line, Physical Length



Netlist Format

An instance of a coplanar waveguide transmission line, physical length has the following netlist syntax:

A*xxx n1 n2* [**W=***val*] [**G=***val*] [**P=***val*]
COMPONENT=cpwtrl SUBSTRATE=*substrate_name*

n1 and *n2* are the names of the nodes attached to the transmission line. The entry **COMPONENT=cpwtrl** identifies the element as a coplanar waveguide transmission line, physical length.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Coplanar Waveguide Substrate Model" on page 6-55 for details).

Table 56: Coplanar Waveguide Transmission Line, Physical Length Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3
P	Physical length	Meter	1.0e-2

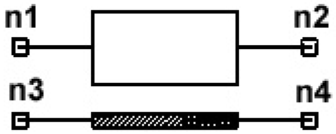
Netlist Example

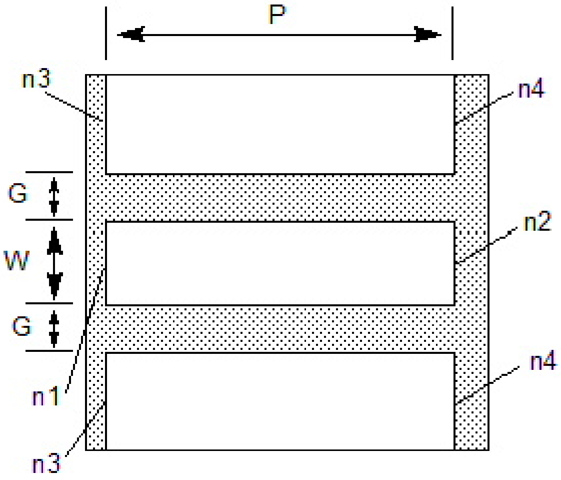
```
A5 Port1 Port2 W=0.75e-3 G=1.1e-3 P=2e-2 COMPONENT=cpwtrl
SUBSTRATE=CPW1
```

where CPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB CPW1 CPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4 HL=2.54e-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Transmission Line, Physical Length with Reference





Netlist Format

An instance of a coplanar waveguide transmission line, physical length with reference has the following netlist syntax:

A*xxx n1 n2 n3 n4* [**W=***val*] [**G=***val*]
COMPONENT=cpwtrl SUBSTRATE=*substrate_name*

n1 and *n2* are the names of the nodes attached to the transmission line. *n3* and *n4* are the reference nodes. The entry **COMPONENT=cpwtrl** identifies the element as a coplanar waveguide transmission line, physical length.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Coplanar Waveguide Substrate Model" on page 6-55 for details).

Table 57: Coplanar Waveguide Transmission Line, Physical Length with Reference Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3
P	Physical length	Meter	1.0e-2

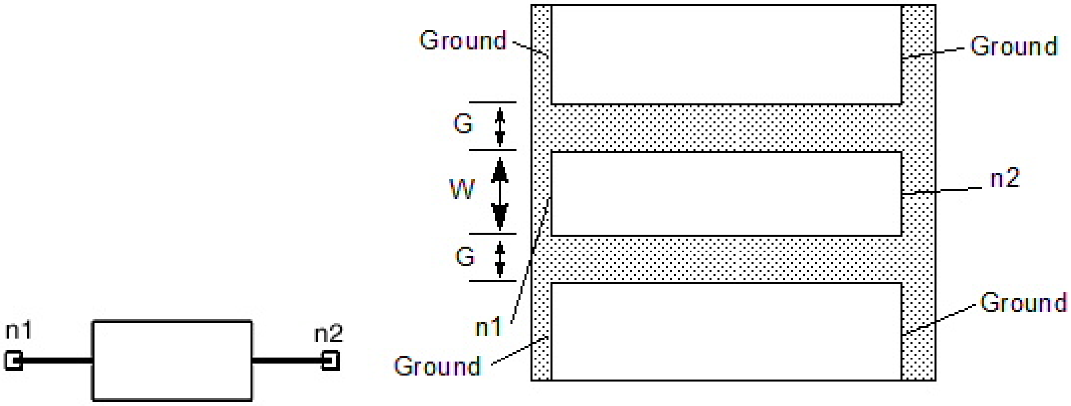
Netlist Example

```
A5 Port1 Port2 Port3 Port4 W=0.75e-3 G=1.1e-3 P=2e-2
COMPONENT=cpwtrl SUBSTRATE=CPW1
```

where CPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB CPW1 CPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4 HL=2.54e-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Transmission Line, Electrical Length



Netlist Format

An instance of a coplanar waveguide transmission line, electrical length has the following netlist syntax:

A*xxx n1 n2* [**W=***val*] [**E=***val*] [**F=***val*] [**G=***val*]
COMPONENT=cpwtrl_e SUBSTRATE=*substrate_name*

n1 and *n2* are the names of the nodes attached to the bend. The entry **COMPONENT=cpwtrl_e** identifies the element as a coplanar waveguide transmission line, electrical length.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Coplanar Waveguide Substrate Model" on page 6-55 for details).

Table 58: Coplanar Waveguide Transmission Line, Electrical Length Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3
E	Electrical length	Degree	45
F	Reference frequency for electrical length	Hertz	1e9

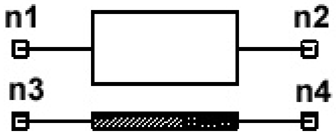
Netlist Example

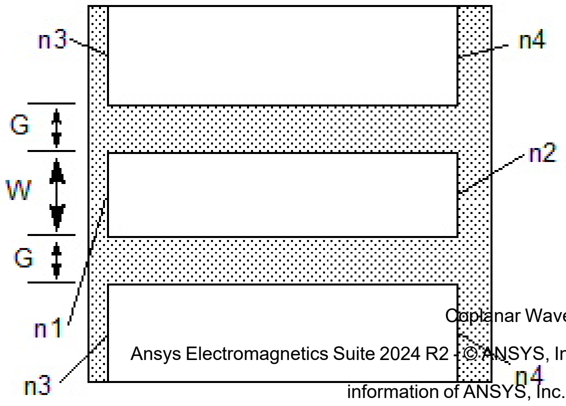
```
A5 Port1 Port2 W=0.75e-3 G=1.1e-3 F=2e9 COMPONENT=cpwtrl_e
SUBSTRATE=CPW1
```

where CPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB CPW1 CPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4 HL=2.54e-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Transmission Line, Electrical Length with Reference





Netlist Format

An instance of a coplanar waveguide transmission line, electrical length has the following netlist syntax:

```
Axxx n1 n2 n3 n4 [W=val] [E=val] [F=val] [G=val]
COMPONENT=cpwtrl_e SUBSTRATE=substrate_name
```

n1 and *n2* are the names of the nodes attached to the bend. *n3* and *n4* are the reference nodes. The entry **COMPONENT=cpwtrl_e** identifies the element as a coplanar waveguide transmission line, electrical length.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Coplanar Waveguide Substrate Model" on page 6-55 for details).

Table 59: Coplanar Waveguide Transmission Line, Electrical Length with Reference Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3
E	Electrical length	Degree	45
F	Reference frequency for electrical length	Hertz	1e9

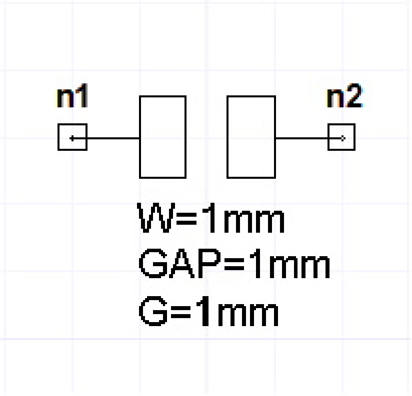
Netlist Example

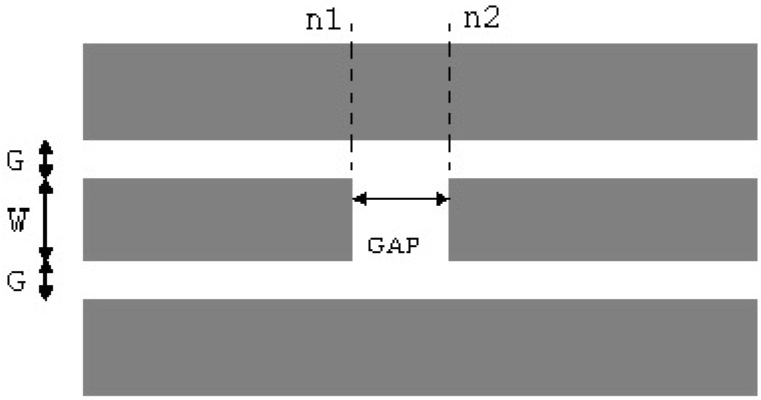
```
A5 Port1 Port2 Port3 Port4 W=0.75e-3 G=1.1e-3 F=2e9
COMPONENT=cpwtrl_e SUBSTRATE=CPW1
```

where CPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB CPW1 CPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4 HL=2.54e-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Gap





Netlist Format

An instance of a coplanar waveguide gap has the following netlist syntax:

`ACPWGAP``*xxxx n1 n2*` **`COMPONENT=cpw_gap W=`**`*val*` **`G=`**`*val*` **`GAP=`**`*val*`
`SUBSTRATE=``*substrate_name*`

n1 and *n2* are the names of the nodes attached to the gap. The entry **COMPONENT=cpw_gap** identifies the element.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Coplanar Waveguide Substrate Model" on page 6-55 for details).

Table 60: Coplanar Waveguide Gap Instance Parameters

Parameter	Description	Units	Default

W	Width of center conductor	Meter	1.0e-3
G	Slot width	Meter	1.0e-3
GAP	Gap width	Meter	1.0e-3

Netlist Example

```
ACPWGAP:5 Port1 Port2 W=1.1mm G=0.75mm GAP=1.5mm
COMPONENT=cpw_gap   SUBSTRATE=CPW1
```

where CPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB CPW1 CPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4 HL=2.54e-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

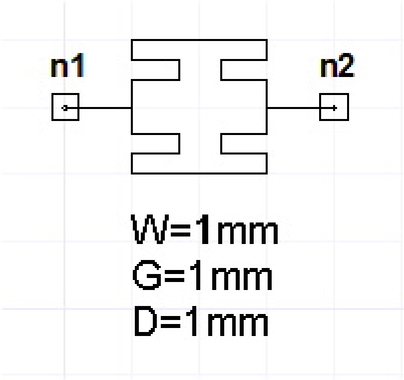
1. Quasi-Static behavior is assumed in the analysis. This assumption is valid for most CPW applications in a wide frequency range.
2. Only the symmetrical case is considered.
3. The model computes the equivalent PI-network capacitances.
4. In the derivation for the capacitances, an infinitely thick homogeneous substrate is assumed. Thus, these expressions are limited to thick CPW substrates (t > W + 2G).

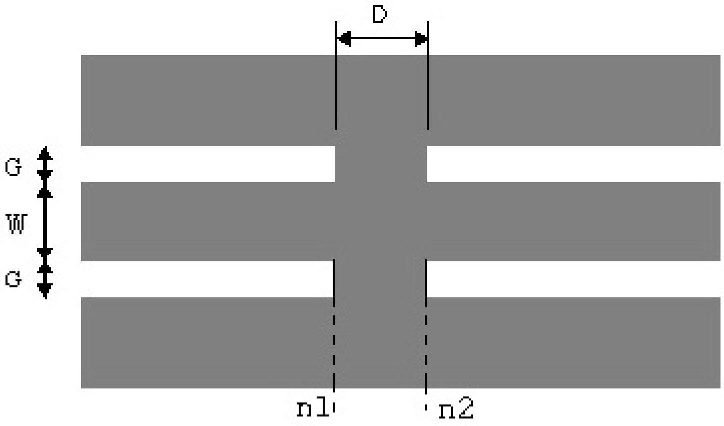
References

[1] Gevorgian, S., Deleniv, A., Martinson, T., Galchenko, S., Linner, P. and Vendik, I., “CAD model of a gap in a coplanar waveguide,” Int. J. Microw. Millim.-Wave Computer-Aided Eng., pp. 369-377.

[2] Dib, N., ``Comprehensive study of CAD models of several coplanar waveguide discontinuities, '' IEEE Proc-Microwave Antennas Propagation, Vol. 152, No. 2, April 2005, pp. 69-76.

Slot Gap





Netlist Format

An instance of a coplanar waveguide slot gap has the following netlist syntax:

`ACPWSGAP:``xxxx n1 n2` **`COMPONENT=cpw_slot_gap W=`**`val` **`G=`**`val` **`D=`**`val`
`SUBSTRATE=``substrate_name`

n1 and *n2* are the names of the nodes attached to the slot gap. The entry **COMPONENT=cpw_slot_gap** identifies the element.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Coplanar Waveguide Substrate Model" on page 6-55 for details).

Table 61: Coplanar Waveguide Slot Gap Instance Parameters

Parameter	Description	Units	Default

W	Width of center conductor	Meter	1.0e-3
G	Slot width	Meter	1.0e-3
D	Separation distance	Meter	1.0e-3

Netlist Example

```
ACPWSGAP:5 Port1 Port2 W=1.1mm G=0.75mm D=1.5mm
COMPONENT=cpw_slot_gap SUBSTRATE=CPW1
```

where CPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB CPW1 CPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4 HL=2.54e-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. Quasi-Static behavior is assumed in the analysis. This assumption is valid for most CPW applications in a wide frequency range.
2. Only the symmetrical case is considered.
3. The model computes the equivalent T-network inductances.

References

[1] W. Getsinger, “Circuit Duals of Planar Transmission Media,” 1983 IEEE MTT-S Digest, pp. 154-156.

[2] J. Everard, and K. Cheng, ``High performance Direct Coupled Bandpass Filters on Coplanar Waveguide, '' IEEE Trans. on MTT, Sep. 1993, pp. 1568-1573.

Selecting None for the Initial Substrate

For Nexxim designs that are created with the **Schematic Editor**, the initial selection of a global substrate type is made on the **Choose Layout Technology** window that appears when you select Insert Nexxim Circuit Design on the Project menu.

However, no coplanar waveguide substrates are available in the **Choose Layout Technology** window.

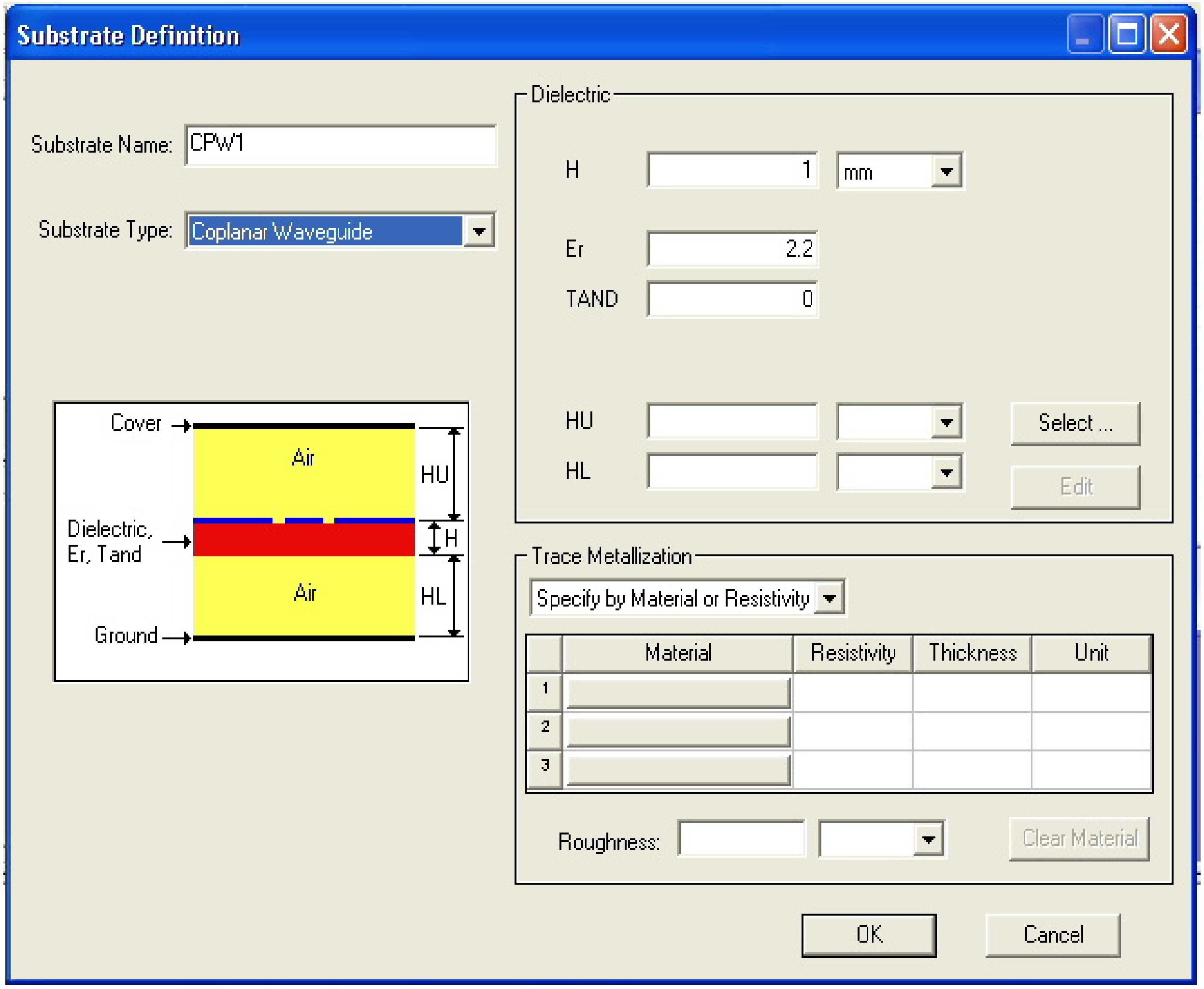
If you wish to use a coplanar waveguide substrate, you must create it as a custom substrate type.

In the **Choose Layout Technology** window, click **None**. The design opens, but no substrate type is applied to instances of distributed elements until you create a custom substrate type.

See "Coplanar Waveguide Substrate Model" on page 6-55 for details.

Creating a Custom Coplanar Waveguide Substrate

To create a coplanar waveguide substrate definition, open the Nexxim design icon (e.g., “Nexxim1”), then right-click the **Data** field and select **Add Substrate Definition** to open the **Substrate Definition** window. Specify the name of your new substrate (the following example uses the name “CPW_custom”).



Substrate Name: CPW1

Substrate Type: Coplanar Waveguide

Dielectric

H: 1 mm

Er: 2.2

TAND: 0

Trace Metallization: Specify by Material or Resistivity

	Material	Resistivity	Thickness	Unit
1				
2				
3				

Select **Coplanar Waveguide** as the **Substrate Type**. Complete the specifications for the **Dielectric** and the **Trace Metallization**.

(see the "Coplanar Waveguide Substrate Model" on the facing page help topic for guidelines on defining coplanar waveguide substrates.

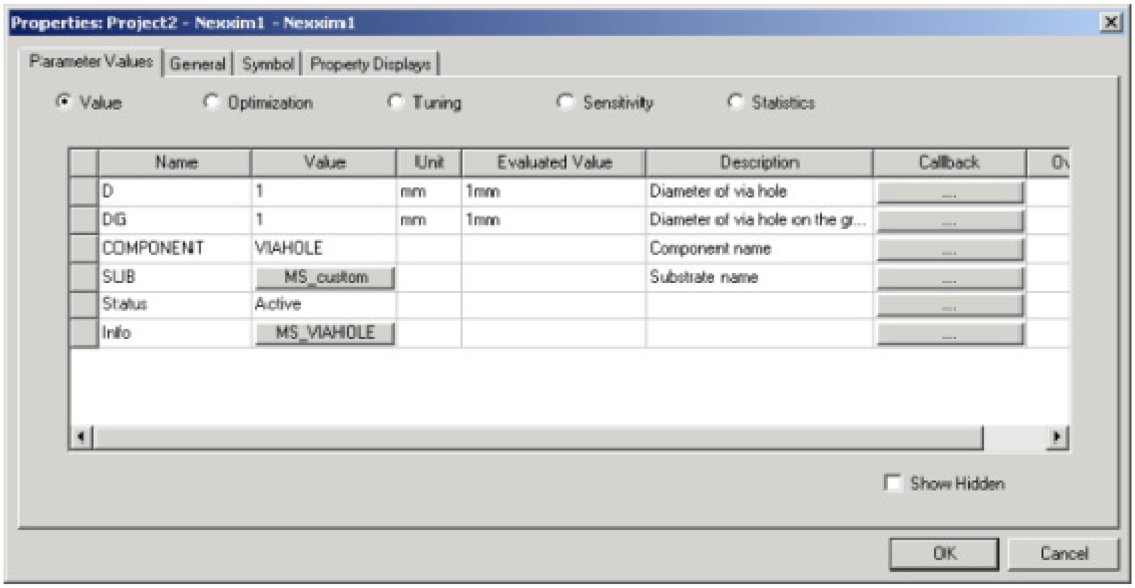
When the substrate definition is complete, click **OK**.

If you selected **None** for the global substrate type in the **Choose Layout Technology** window, the custom coplanar waveguide substrate becomes the global substrate type.

When an element is instantiated, it includes a **SUBSTRATE=***substrate_name* entry in its netlist syntax. **Electronics Desktop** automatically inserts the global *substrate_name* into the netlist entry for the instantiated element.

Selecting a Coplanar Waveguide Substrate at the Component Level

To specify a custom substrate type, or to change to a different predefined substrate type, you must make the assignment individually for each component. Double-click the distributed element to open the **Properties** window:



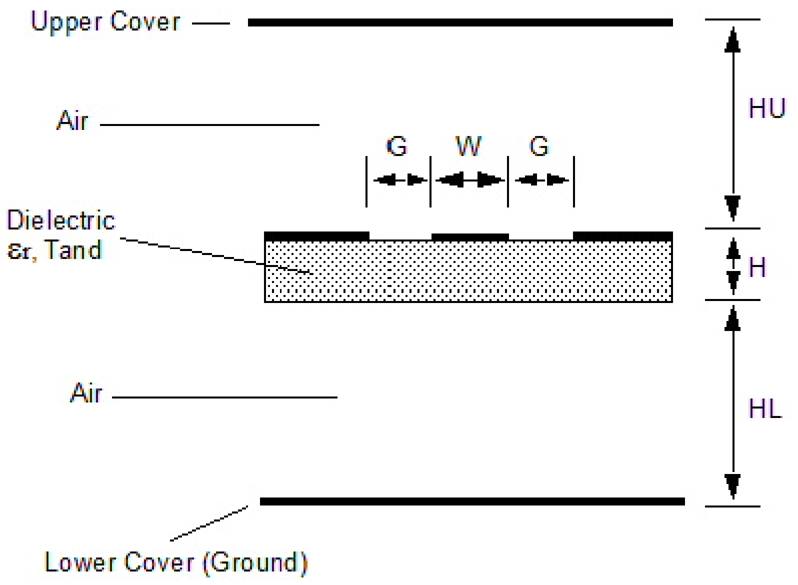
Name	Value	Unit	Evaluated Value	Description	Callback	O
D	1	mm	1mm	Diameter of via hole	...	
DIG	1	mm	1mm	Diameter of via hole on the gr...	...	
COMPONENT	VIAHOLE			Component name	...	
SUB	MS_custom			Substrate name	...	
Status	Active				...	
Info	MS_VIAHOLE				...	

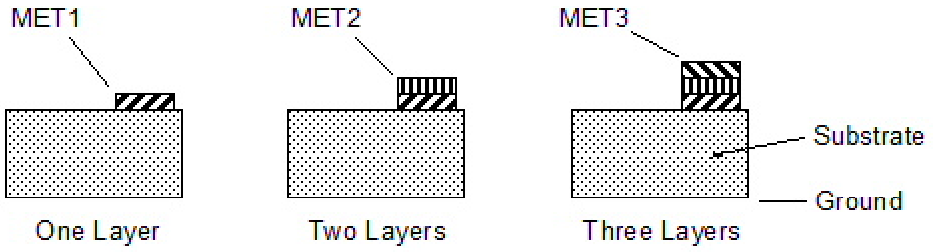
The **SUB** property identifies the substrate that is currently applied to the element. In the example above, a custom substrate type named “MS_custom”appears as the value of the **SUB** property.

To change to a different substrate type, click in the **SUB** Value field and select the appropriate substrate name as the value of the **SUB** property. Then click **OK**.

> **Note:** All distributed elements in a given design must use the same substrate type.

Coplanar Waveguide Substrate Model





Metallization

Defining a Coplanar Waveguide Substrate

To add a new coplanar waveguide substrate definition to an existing design, expand the **Project** icon, the **Design** icon. Right-click the **Data** icon and select **Add Substrate Definition** to open the **Substrate Definition** window. Then add the substrate name and parameters as appropriate, and click **OK**.

To edit the definition of an existing substrate, expand the **Project** icon, the **Design** icon, the **Data** icon. Click icon for a substrate to open the **Substrate Definition** window. Then add or modify the substrate parameters as appropriate, and click **OK**.

Coplanar Waveguide Substrate Model Netlist Format

The Coplanar Waveguide substrate model has the following netlist format:

```
.SUBsubstrate_name CPW ( [H=val] [HU=val] [HL=val]
[ER=val] [TAND=val]
[MET1=val] [T1=val] [MET2=val] [T2=val] [MET3=val]   [T3=val]
[RGH=val])
```

The *substrate_name* is the name for the substrate type used in distributed elements that refer to this substrate definition. The entry **CPW** is required to identify the Coplanar Waveguide substrate type. The **CPW** identifier must immediately follow the *substrate_name*.

Inside the parentheses, the labeled parameters may be entered in any order.

Table 62: Coplanar Waveguide Substrate Parameters

Parameter	Description	Unit	Default
H	Thickness of dielectric	Meter	1e-3
HU	Spacing between top of dielectric and upper cover	Meter	0.0
HL	Spacing between bottom of dielectric and lower cover	Meter	0.0
ER	Dielectric constant of substrate, $1 \le ER \le 128$	None	4.5
TAND	Dielectric loss tangent, [0,0.1]	None	0.0
MET1, **MET2**, **MET3**	Resistivity of metal layer 1, 2, 3	μOhm-cm	0.0
T1, **T2**, **T3**	Thickness of metal layer 1, 2, 3	Meter	0.0
RGH	RMS surface roughness	Meter	0.0

Coplanar Waveguide Substrate Model Netlist Example

```
.SUB CPW1 CPW(
+ H=0.001524 HU=0.003 HL=0.004 Er=4.4 TAND=0.02
+ MET1=1.724137931034483 T1=2.5400e-005
+ RGH=0)
```

7 - Diodes

The LEVEL model parameter selects the diode type. When a diode MODEL statement does not include a valid LEVEL parameter, the LEVEL is chosen as follows:

- Within a PSpice import, diode LEVEL is typically not specified. If you do specify a LEVEL in the range 4...9 inclusive, Nexxim respects that selection. If you do not specify a LEVEL, or if you specify a LEVEL outside the 4...9 range, Nexxim silently changes it to 7.
- Outside a PSpice import, Nexxim respects a LEVEL selection in the range 1...9 inclusive. If you do not specify a LEVEL, it silently defaults to 1. If you specify a LEVEL outside the range, it issues a warning and changes to LEVEL 1.

This topic describes the following diodes:

" Diode Instance, Non-Geometric (Level 1)" below

"Non-Geometric Diode Model, Level 1" on the next page

" Diode Instance, Fowler-Nordheim (Level 2)" on page 7-5

" Fowler-Nordheim Diode Model, Level 2" on page 7-6

" Diode Instance, Geometric (Level 3)" on page 7-7

" Geometric Diode Model, Level 3" on page 7-9

" Diode Instance, Junction Capacitance (Level 4)" on page 7-12

" Junction Capacitance Diode Model, LEVEL=4" on page 7-13

" Diode Instance, PIN Model, Level = 5" on page 7-15

"PIN Diode Model, Level = 5" on page 7-16

" Diode Instance, Nonlinear Microwave Model, Level = 6" on page 7-21

"Nonlinear Microwave Diode Model, Level = 6" on page 7-21

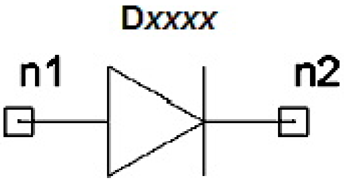
" Diode Instance, Enhanced SPICE Model, Level = 7" on page 7-26

" Enhanced SPICE Diode Model, Level = 7" on page 7-27

" Diode Instance, Step Recovery (Level 9)" on page 7-33

" Step Recovery Diode Model, Level 9" on page 7-33

Diode Instance, Non-Geometric (Level 1)



Non-Geometric Diode Netlist Syntax

The syntax for a Level1 non-geometric diode instance is:

D*xxxx n1 n2 modelname* [**AREA=**]*val* [**L=***val*] [**PJ=***val*]
[**M=***val*] [**DTEMP=***val*]

n1 is the anode and *n2* is the cathode of the diode. *modelname* identifies the .MODEL statement associated with the diode instance. The label **AREA=** is optional, but is recommended.

Table 1: LEVEL 1 Non-Geometric Diode Instance Parameters

Instance Parameter	Description	Unit	Default
AREA	Area of the diode	None	1.0
DTEMP	Diode and circuit temperature difference	°C	0.0
L	Diode length	Meter	0.0
M	Multiplier to simulate parallel diodes	None	1.0
PJ	Junction periphery	None	0.0

Non-Geometric Diode Instance Netlist Examples

```
D1 112 314 diode1 AREA=1.05
```

```
D12 node3 node22 diode1 M=2 DTEMP=30
```

Non-Geometric Diode Model, Level 1

The syntax for a Level 1 non-geometric diode model is:

.MODEL*modelname* **D** [**LEVEL=1**] [*model_parameter***=***val*] ...

modelname is the name used by the diode instance to refer to the .MODEL statement.

Table 2: Level 1 Diode Junction DC Model Parameters

Model	Description	Unit	Default

Parameter			
LEVEL	1 selects the non-geometric diode model	None	1 (default if LEVEL parameter is omitted)
AREA	Diode area	None	1.0
EXPLI	Current-explosion model parameter	Amp/Meter^2	1.0e15
IB (**IBV**)	Current at breakdown voltage	Amp/Meter^2	1.0e-3
IK (**IKF**, **JBF**)	Forward-knee current	Amp/Meter^2	0.0
IKR (**JBR**)	Reverse-knee current	Amp/Meter^2	0.0
IS (**JS**)	Saturation current	Amp/Meter^2	1.0e-14
JSW (**ISP**, **ISW**)	Sidewall saturation current normalized to junction periphery	Amp/Meter	0.0
M	Multiplier for multiple devices	None	1.0
PJ	Junction periphery	None	0.0
L	Diode length	Meter	0.0
N	Emission coefficient	None	1.0
RS	Series resistance	Ohm	0.0
SHRINK	Shrink factor	None	1.0
TNOM	Nominal temperature	°C	25.0
VB (**BV**, **VAR, VRB**)	Reverse breakdown voltage	Volt	0.0

Table 3: Level 1 Diode Junction Capacitance Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
CJ (**CJA**, **CJO**)	Junction capacitance at zero bias, normalized to junction area	Farad/Meter^2	0.0
CJP (**CJSW**)	Junction capacitance at zero bias, normalized to junction periphery	Farad/Meter	0.0
DCAP	Diode depletion capacitance equation selector	None	2
EXA (**MJ**)	Grading coefficient at area junction	None	0.5
FC	Coefficient used in forward-bias depletion area	None	0.5

	calculation		
FCS	Coefficient used in forward-bias depletion periphery calculation	None	0.5
MJSW (**EXP**)	Grading coefficient at periphery junction	None	0.33
PB (**PHI, VJ, PHA**)	Contact potential at area junction	Volt	0.8
PHP	Contact potential at periphery junction	Volt	PB
TT	Transit time	Second	0.0

Table 4: Level 1 Diode Noise Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
AF	Flicker noise exponent	None	1.0
KF	Flicker noise coefficient	None	0.0

Table 5: Level 1 Diode Temperature Effect Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
CTA (**CTC**)	Temperature coefficient for area junction capacitance CJ (TLEVC = 1)	°C^{-1}	0.0
CTP	Temperature coefficient for periphery junction capacitance CJP (TLEVC = 1)	°C^{-1}	0.0
EG	Energy gap for pn junction diode	electron-Volt	TLEV=0 or 1: 1.11 TLEV=2: 1.16
GAP1	First band gap correction factor	electron-Volt/°C	7.02e-4
GAP2	Second band gap correction factor	°C	1108
TCV	Temperature coefficient of breakdown voltage	°C^{-1}	0.0
TLEV	Diode temperature equation selector	None	0
TLEVC	Level selector for diode temperature, junction capacitance, and contact potential calculations	None	0
TM1	1st-order MJ temperature coefficient	°C^{-1}	0.0

TM2	2nd-order MJ temperature coefficient	°C^{-2}	0.0
TPB (**TVJ**)	PB temperature coefficient (TLEVC = 1 or 2)	Volt/°C	0.0
TPHP	PHP temperature coefficient (TLEVC = 1 or 2)	Volt/°C	0.0
TRS	Resistance temperature coefficient	°C^{-1}	0.0
TTT1	1st-order TT temperature coefficient	°C^{-1}	0.0
TTT2	2nd-order TT temperature coefficient	°C^{-2}	0.0
XTI	Saturation current temperature exponent	None	3.0

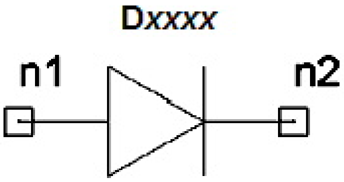
Non-Geometric Diode Instance and Model Netlist Examples

```
D1 112 314 diode1 AREA=1.05
```

```
D12 node3 node22 diode1 M=2 DTEMP=30
```

```
.MODEL diode1 D IS=14.24e-9 N=1.981 RS=32.0e-3
+ MJ=0.26 TT=4.9e-6 IKF=93.23 EG=1.11
```

Diode Instance, Fowler-Nordheim (Level 2)



Fowler-Nordheim Diode Netlist Syntax

The syntax for a Level 2 Fowler-Nordheim diode instance is:

```
Dxxxx n1 n2 modelname [W=val] [L=val][M=val]
```

n1 is the anode and *n2* is the cathode of the diode. *modelname* is the name of a Fowler-Nordheim (**LEVEL=2**) diode model defined in a .MODEL statement elsewhere in the netlist.

Table 6: Fowler-Nordheim Diode Instance Parameters

Instance Parameter	Description	Unit	Default
AREA	Diode area	$Meter^2$	1.0

DTEMP	Difference between diode and circuit temperatures	°C	0.0
L	Length of the diode	Meter	0.0
M	Multiplier to simulate parallel diodes	None	1.0
PJ	Junction periphery	Meter	0.0
W	Width of the diode	Meter	0.0

Fowler-Nordheim Diode Netlist Examples

```
D1 112 314 diodefn W=3e-3

D12 node3 node22 diodefn M=2

Dtest 34 56 diodefn2
```

Fowler-Nordheim Diode Model, Level 2

The syntax for a Level 2 Fowler-Nordheim diode model is:

`.MODELmodelname D LEVEL=2 [model_parameter=val] ...`

modelname is the name for used by diode instances to refer to this .MODEL statement. LEVEL=2 is required to select the Fowler-Nordheim diode model.

Table 7: Level 2 Fowler-Nordheim Diode Model Parameters

Model Parameter	Description	Unit	Default
LEVEL=2	LEVEL=2 selects the Fowler-Nordheim diode model	None	1 (default if LEVEL parameter is omitted)
AF	Flicker noise exponent	None	1.0
EF	Forward critical electric field	Volts/cm	1.0e+8
ER	Reverse critical electric field	Volts/cm	EF
JF	Forward Fowler-Nordheim current coefficient	Amp/Volts ^{2}	1.0e-10
JR	Reverse Fowler-Nordheim current coefficient	Amp/Volts ^{2}	JF
KF	Flicker noise coefficient	None	0.0
L	Length of the diode	Meter	0.0
M	Multiplier to simulate parallel diodes	None	1.0

SHRINK	Shrink factor for diode length	None	1.0
TOX	Oxide layer thickness	Å	100.0
W	Width of the diode	Meter	0.0
XW	Mask and etch correction factor	Meter	0.0

Notes

The Fowler-Nordheim diode current is modeled as follows:

For Vd > 0

```
Id = AREAeff * JF * (Vd/TOX)^2 * exp[(-EF*TOX)/Vd]
```

For Vd < 0

```
Id = -AREAeff * JR * (Vd/TOX)^2 * exp[(ER*TOX)/Vd]
```

For Vd = 0

```
Id = 0
```

where:

```
Leff = L * SCALM * SHRINK + XWeff

Weff = W * SCALM * SHRINK + XWeff

XWeff = XW * SCALM

AREAeff = Weff * Leff * M
```

The Fowler-Nordheimdiode capacitance is modeled as:

```
 Cd = AREAeff * Eox / TOX
```

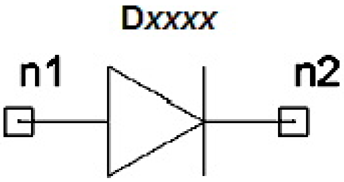
where Eox is the permittivity of SiO_2:

```
 Eox = 3.9*eps0 = 3.453133e-11 (F/m)
```

Fowler-Nordheim Diode Model Netlist Examples

```
.MODEL diodefn LEVEL=2

.MODEL diodefn2 LEVEL=2 L=1.0e-4 W=2.7e-5
```

Diode Instance, Geometric (Level 3)



Geometric Diode Netlist Syntax

The Level 3 geometric diode instance has two formats:

```
Dxxxx n1 n2 modelname [[AREA=]val [PJ=val]
[WP=val] [LP=val] [WM=val] [LM=val]
[M=val] [DTEMP=val]
```

or

```
Dxxxx n1 n2 modelname [W=val] [L=val]
[WP=val] [LP=val][WM=val] [LM=val]
[M=val] [DTEMP=val]
```

n1 is the anode and *n2* is the cathode of the diode. *modelname* is the name of a geometric (Level 3) diode model defined in a .MODEL statement elsewhere in the netlist. In the first format, the label **AREA=** is optional, but is recommended for clarity.

Table 8: Level 3 Geometric Diode Instance Parameters

Instance Parameter	Description	Unit	Default
AREA	Area of the diode	Meter^2	1.0
DTEMP	Difference between diode and circuit temperatures	°C	0.0
L	Diode length	Meter	0.0
LM	Metal capacitor length	Meter	0.0
LP	Polysilicon capacitor length	Meter	0.0
M	Multiplier: simulates parallel diodes	None	1.0
PJ	Junction periphery	Meter	0.0
SCALE	Scaling factor	None	1.0
W	Diode width	Meter	0.0
WM	Metal capacitor width	Meter	0.0
WP	Polysilicon capacitor width	Meter	0.0

Geometric Diode Instance Netlist Examples

```
D1 112 314 diodeg AREA=1.05

D12 node3 node22 diodeg M=2 DTEMP=3

Dtest 34 56 diode3 W=1e-3 L=2e-3
```

Geometric Diode Model, Level 3

The syntax for a LEVEL 3 geometric diode model is:

`.MODELmodelname D LEVEL=3 [model_parameter=val] ...`

modelname is the name for used by diode instances to refer to this .MODEL statement.

Table 9: Level 3 Diode Junction DC Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	LEVEL=3 selects the geometric diode model	None	1 (default if LEVEL parameter is omitted)
AREA	Area of the diode	Meter^2	1.0
EXPLI	Explosion current (linear threshold)	Amp/Meter^2	1.0e+15
IB (**IBV**)	Current at breakdown voltage	Amp/Meter^2	1.0e-3
IK (**IKF**, **JBF**)	Forward-knee current (intersection of high-current and low-current slopes)	Amp/Meter^2	0.0
IKR (**JBR**)	Reverse-knee current (intersection of high-current and low-current slopes)	Amp/Meter^2	0.0
IS (**JS**)	Saturation current	Amp/Meter^2	0.0
JSW (**ISP**, **ISW**)	Sidewall saturation current normalized to junction periphery	Amp/Meter	0.0
L	Diode length	Meter	0.0
M	Multiplier: simulates parallel diodes	None	1.0
N	Emission coefficient	None	1.0
PJ	Junction periphery	Meter	0.0

RS	Series resistance	Ohm/Meter^2	0.0
SCALM	Scaling factor	None	1.0
SHRINK	Shrink factor for diode length	None	1.0
TNOM	Nominal temperature	°C	25.0
VB (**BV, VAR, VRB**)	Reverse breakdown voltage. Default 0.0 represents infinite breakdown voltage	Volt	0.0
W	Diode width	Meter	0.0
XW	Mask and etch correction factor	Meter	0.0

Table 10: Level 3 Diode Junction Capacitance Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
CJ (**CJA**, **CJO**)	Junction capacitance at zero bias, normalized to junction area	Farad/Meter^2	0.0
CJP (**CJSW**)	Junction capacitance at zero bias, normalized to junction periphery	Farad/Meter	0.0
DCAP	Diode depletion capacitance equation selector	None	2
EXA (**MJ**)	Grading coefficient at area junction	None	0.5
FC	Coefficient used in forward-bias depletion area calculation	None	0.5
FCS	Coefficient used in forward-bias depletion periphery calculation	None	0.5
MJSW (**EXP**)	Grading coefficient at periphery junction	None	0.33
PB (**PHI, VJ, PHA**)	Contact potential at area junction	Volt	0.8
PHP	Contact potential at periphery junction	Volt	PB
TT	Transit time	Second	0.0

Table 11: Level 3 Diode Metal/Poly Capacitance Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
XM	Correction factor for metal masking and etching effects.	Meter	0.0

XOI	Polysilicon to bulk oxide thickness	Å	1.0e+4
XOM	Metal to bulk oxide thickness	Å	1.0e+4
XP	Correction factor for polysilicon masking and etching effects.	Meter	0.0

Table 12: Level 3 Diode Noise Model Parameters

Model Parameter	Description	Unit	Default
AF	Flicker noise exponent	None	1.0
KF	Flicker noise coefficient	None	0.0

Table 13: Level 3 Diode Temperature Effect Model Parameters

Model Parameter	Description	Unit	Default
CTA (**CTC**)	Temperature coefficient for area junction capacitance CJ (TLEVC = 1)	°C^{-1}	0.0
CTP	Temperature coefficient for periphery junction capacitance CJP (TLEVC = 1)	°C^{-1}	0.0
EG	Energy gap for pn junction diode	electron-Volt	TLEV=0 or 1: 1.11 TLEV=2: 1.16
GAP1	First band gap correction factor	electron-Volt/°C	7.02e-4
GAP2	Second band gap correction factor	°C	1108
TCV	Temperature coefficient of breakdown voltage	°C^{-1}	0.0
TLEV	Diode temperature equation selector	None	0
TLEVC	Level selector for diode temperature, junction capacitance, and contact potential calculations	None	0
TM1	1st-order MJ temperature coefficient	°C^{-1}	0.0
TM2	2nd-order MJ temperature coefficient	°C^{-2}	0.0
TPB (**TVJ**)	PB temperature coefficient (TLEVC = 1 or 2)	Volt/°C	0.0
TPHP	PHP temperature coefficient	Volt/°C	0.0

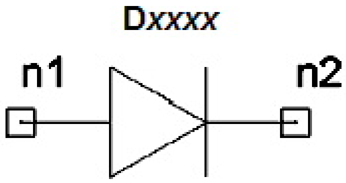
	(TLEVC = 1 or 2)		
TREF	Model reference temperature	°C	25
TRS	Resistance temperature coefficient	°C^{-1}	0.0
TTT1	1st-order TT temperature coefficient	°C^{-1}	0.0
TTT2	2nd-order TT temperature coefficient	°C^{-2}	0.0
XTI	Saturation current temperature exponent		3.0

Geometric Diode Model Netlist Examples

```
.MODEL diodeg LEVEL=3
```

```
.MODEL diode3 LEVEL=3 AREA=1.05
```

Diode Instance, Junction Capacitance (Level 4)



Junction Capacitance Diode Instance Netlist Syntax

The Level 4 junction capacitance diode instance has the syntax:

```
Dxxxx n1 n2 modelname [AREA=]val [[PERI=]val]
[PGATE=val] [M=val] [DTEMP=val]
```

n1 is the positive node (anode) and *n2* is the negative node (cathode) of the diode. The current is assumed to flow from *n1* through the diode to *n2*. *modelname* is the name of a junction capacitance (Level 4) diode model defined in a .MODEL statement elsewhere in the netlist. The labels **AREA=** and **PERI=** are optional, but are recommended for clarity.

Table 14: Level 4 Junction Capacitance Diode Instance Parameters

Instance Parameter	Description	Unit	Default
AREA	Diffusion area of the diode	$Meter^2$	1.0
DTEMP	Difference between diode and circuit temperatures	°C	0.0
M	Multiplier: simulates parallel diodes	None	1.0
PERI (**LS**)	Length of sidewall in diffusion area not under the gate	Meter	1.0e-6

PGATE (**LG**)	Length of sidewall in diffusion area under the gate	Meter	1.0e-6

Junction Capacitance Diode Instance Netlist Example

```
D1 112 314 diodejc AREA=1.05

D12 node3 node22 diodejc M=2 DTEMP=30

Dtest 34 56 diode4
```

Junction Capacitance Diode Model, LEVEL=4

The syntax for a Level 4 junction capacitance diode model is:

`.MODELmodelname D LEVEL=4 [model_parameter=val] ...`

modelname is the name for used by diode instances to refer to this .MODEL statement.

Table 15: Level 4 Diode Model Parameters

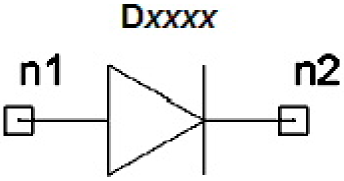
Model Parameter	Description	Unit	Default
LEVEL	LEVEL=4 selects the junction capacitance diode model	None	1 (default if LEVEL parameter is omitted)
AREA	Diffusion area of the diode	Meter^2	1.0
AB	Diffusion area of the diode	Meter^2	1.0e-12
CJBR	Bottom junction capacitance at V=VR	Farad/Meter 2	1.0e-12
CJGR	Gate-edge junction capacitance at V=VR	Farad/Meter 2	1.0e-12
CJSR	Sidewall junction capacitance at V=VR	Farad/Meter 2	1.0e-12
DTA	Difference between diode and circuit temperatures	°C	0.0
JSDBR	Bottom saturation-current density due to diffusion from back-contact	Amp/Meter^2	1.0e-3
JSDGR	Gate-edge saturation-current density due to diffusion from back-contact	Amp/Meter^2	1.0e-3
JSDSR	Sidewall saturation-current density due to diffusion from back-contact	Amp/Meter^2	1.0e-3

JSGBR	Bottom saturation-current density due to generating holes at V=VR	Amp/Meter^2	1.0e-3
JSGGR	Gate-edge saturation-current density due to generating holes at V=VR	Amp/Meter^2	1.0e-3
JSGSR	Sidewall saturation-current density due to generating holes at V=VR	Amp/Meter^2	1.0e-3
LG (**PGATE**)	Length of sidewall in diffusion area which is under the gate	None	1.0e-6
LS (**PERI**)	Length of sidewall in diffusion area which is not under the gate	None	1.0e-6
M	Multiplier: simulates parallel diodes	None	1.0
NB	Emission coefficient, bottom forward current	None	1.0
NG	Emission coefficient, gate-edge forward current	None	1.0
NS	Emission coefficient, sidewall forward current	None	1.0
PB (**VJ**, **PHI**, **PHA**)	Bottom junction grading coefficient	None	0.40
PG	Gate-edge junction grading coefficient	None	0.40
PS	Sidewall junction grading coefficient	None	0.40
SCALM	Scale factor for model parameters	None	1.0
TNOM (**TREF**)	Circuit temperature	°C	25.0
TR	Temperature used to simulate parameter values	°C	25.0
VB (**BV**, **VAR**, **VRB**)	Reverse breakdown voltage	Volt	0.9
VDBR	Diffusion voltage of the bottom junction at Temp=TR	Volt	1.00
VDGR	Diffusion voltage of the gate-edge junction at Temp=TR	Volt	1.00
VDSR	Diffusion voltage of the sidewall junction at Temp=TR	Volt	1.00
VR	Voltage used to simulate parameter values	Volt	0.0

Junction Capacitance Diode Model Netlist Example

```
.MODEL DJUNCAP0 D level=4 AB=2.5e-013 LS=2e-006 LG=0
+ m=1 TR=27 VR=0 JSGBR=1.892E-007 JSDBR=1.798E-008
+ JSGSR=2.905E-011 JSDSR-1.198E-014 JSGGR=4.15E-011
+ JSDGR=1.628E-014 NB=1 NS=1 NG=1 CJBR=0.000767
+ CJSR=1E-010 CJGR=3.24E-010 VDBR=0.497 VDGR=0.3581
+ PB=0.315 PS=0.1 PG=0.2433
```

Diode Instance, PIN Model, Level = 5



PIN Model Diode Instance Netlist Syntax

The PIN model diode instance has the syntax:

`Dxxxx n1 n2 modelname [AREA=val] [TJ=val]`

n1 is the positive node (anode) and *n2* is the negative node (cathode) of the diode. The current is assumed to flow from *n1* through the diode to *n2*. *modelname* is the name of a PIN diode model defined in a .MODEL statement elsewhere in the netlist.

Table 16: PIN Model Diode Instance Parameters

Instance Parameter	Description	Unit	Default
AREA	Area multiplier	None	1.0
TJ	Junction temperature	°C	25

PIN Diode Instance Netlist Example

```
D24 Port1 23 DPIN1 TJ=27
```

PIN Diode Model, Level = 5

The syntax for a PIN diode model is:

`.MODELmodelname D LEVEL=5 [model_parameter=val] ...`

modelname is the name for used by diode instances to refer to this .MODEL statement.

Table 17: PIN Diode Intrinsic Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	LEVEL=5 selects the PIN diode model	None	1 (default if LEVEL parameter is omitted)
IS	Saturation current	Ampere	1.0e-14
N	Emission coefficient	None	1.0
IBV	Magnitude of current at the reverse breakdown voltage	Ampere	1.0e-11
BV	Magnitude of the reverse breakdown voltage	Volt	1.0e37
K1	Variable resistance coefficient	Volt	0.0
K2	Variable resistance current exponent	None	1.0
RMAX	Maximum resistance of PIN intrinsic region	Ohm	0.0
RS	Series resistance (M<inimum resistance of PIN diode)	Ohm	0.0
T (**TT**)	Transit time constant	Second	0.0

Table 18: PIN Diode Model Capacitance Parameters

Model Parameter	Description	Unit	Default
CJ0	Zero-bias PN junction capacitance	Farad	0.0
FC	Coefficient for forward-bias depletion capacitance	None	0.5
VJ	Built-in junction potential	Volt	1.0
M	PN junction grading coefficient	None	0.5
GC1	Varactor capacitance polynomial coefficient 1	1/Volt	0.0
GC2	Varactor capacitance polynomial coefficient 2	1/Volt^2	0.0

GC3	Varactor capacitance polynomial coefficient 3	1/Volt^3	0.0

Table 19: PIN Diode Model Temperature Parameters

Model Parameter	Description	Unit	Default
TNOM	Reference temperature	°C	25
XTI	IS temperature exponent	None	2.0
EG	Barrier height at reference temperature	Volt	0.8

Table 20: PIN Diode Model Noise Parameters

Model Parameter	Description	Unit	Default
KF	Flicker noise coefficient	None	0.0
AF	Flicker noise exponent	None	1.0
SN	Switch to turn device shot noise ON (1) or OFF (0)	None	1
FCP	Flicker noise frequency shape factor	None	1.0

PIN Diode Model Netlist Example

```
.MODEL PIN1 D Level=5
```

PIN Diode Model Notes

[1] The PIN diode model provides a bias-dependent RF resistance for use in PIN diode circuits such as attenuators and switches. A resistance RS is placed in series with two parallel resistances:

$$R_C = RMAX - RS$$

A constant resistance,

A variable resistance,

$$R_V = \frac{K1}{I_d^{K2}}$$

$I_d > 0$

for

$$R_v = \infty$$

$I_d \le 0$

for

[2] The transit time parameter **T** can approximately model the reverse-recovery time of a switching PIN diode, a value aften provided by the manufacturer.

[3] Diode breakdown is modeled when the **IBV** and **BV** parameters are specified.

[4] To improve the accuracy of the reverse-bias capacitance characteristics, the capacitance grading coefficient is a polynomial function of voltage using **GC1**, **GC2**, and **GC3**.

[5] Following Sze, *Physics of Semiconductor Devices*, the variable resistance parameters *K1* and *K2* may be modeled by setting:

$$K1 = \frac{3}{8} \times V_t \times \frac{W^2}{D_\alpha \times \tau_\alpha}$$

$$K2 = 1$$

Where:

W = Width of the intrinsic region

Dα = Ambipolar diffusion coefficient

τα = Ambipolar lifetime

V_t = Thermal voltage

PIN Diode Model Equations

All components of the equivalent circuit are assumed to be functions of the junction voltage Vj. The program automatically selects this voltage as the only state variable for the microwave diode model. The equations use the following definitions:

V_j = Intrinsic junction voltage state variable

V_t = Thermal voltage = k*TJ/q

k = Boltzmann’s constant

q = Electron charge

TJ = Analysis temperature

Area effects

$$I_d = AREA \times I_d C_j = AREA \times C_j R_s = R_s / (AREA)\, R_{max} = R_{max} / (AREA)$$

Basic Equations

$$I_d = JS(TJ)\left[\exp\left(\frac{V_j}{N \times V_t}\right) - 1\right] - I_B\, I_B = IBV \times \exp\left[\frac{-(V_j + BV)}{V_t}\right]$$

$$C_j = C_t + C_d\, C_t = TT \times \frac{\partial I_d}{\partial V_j}$$

$$C_d = CJ0 \times \left(1 - \frac{V_j}{FI}\right)^{-\gamma(V_j)}$$

$$V_j \le FC \times VJ(TJ)$$

for

$$C_d = CJ0(1-FC)^{-(1+\gamma(V_j))} \times \left(1 - FC[1+\gamma(V_j)] + \gamma V_j \times \frac{V_j}{VJ(TJ)}\right)$$

$$V_j > FC \times VJ(TJ)$$

$$\gamma(V_j) = M + GC1 \times V_j + GC2 \times V_j^2 + GC3 \times V_j^3$$

Temperature Effects

$$\Delta t = TJ - TNOM \quad tn = \frac{TJ}{TNOM} \quad IS(TJ) = IS\left(\exp\left[\frac{(tn-1)\times EG}{V_t}\right]\right) \times tn^{XTI/N}$$

$$VJ(TJ) = VJ \times tn - 3V_t \times \ln(tn) - tn \times EGap(TNOM) + Egap(TJ)$$

$$EGap(TNOM) = EG - 0.000702 \times \frac{TNOM^2}{TNOM + 1108}$$

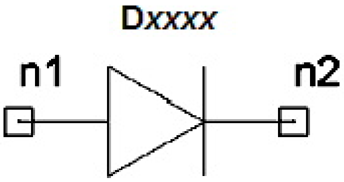
$$EGap(TJ) = EG - 0.000702 \times \frac{TJ^2}{TJ + 1108}$$

$$CJO(T) = CJO^{cjoxp} \quad cjoxp = 0.004 \times \Delta t + 1 - \frac{VJ(TJ)}{VJ}$$

PIN Diode Model Reference

[1] J. Walston, “SPICE Circuit Yields Recipe for PIN Diode,” *Microwaves & RF*, November 1992.

Diode Instance, Nonlinear Microwave Model, Level = 6



Nonlinear Microwave Model Diode Instance Netlist Syntax

The nonlinear microwave model diode instance has the syntax:

```
Dxxxx n1 n2 modelname [AREA=val] [TJ=val]
```

n1 is the positive node (anode) and *n2* is the negative node (cathode) of the diode. The current is assumed to flow from *n1* through the diode to *n2*. *modelname* is the name of a nonlinear microwave diode model defined in a .MODEL statement elsewhere in the netlist.

Table 21: Nonlinear Microwave Model Diode Instance Parameters

Instance Parameter	Description	Unit	Default
AREA	Area multiplier	None	1.0
TJ	Junction temperature	°C	25

Nonlinear Microwave Diode Instance Netlist Example

```
D24 Port1 23 DNM1 TJ=27
```

Nonlinear Microwave Diode Model, Level = 6

The syntax for a nonlinear microwave diode model is:

```
.MODELmodelname D LEVEL=6 [model_parameter=val] ...
```

modelname is the name for used by diode instances to refer to this .MODEL statement.

Table 22: Nonlinear Microwave Diode Intrinsic Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	LEVEL=6 selects the nonlinear microwave diode model	None	1 (default if LEVEL parameter is omitted)
JS	Saturation current	Ampere	1.0e-9
ALFA	Slope factor of conduction current	None	38.696
JB	Magnitude of current at the reverse breakdown voltage	Ampere	10e-6
VB	Magnitude of the reverse breakdown voltage	Volt	-1.0e36
EE	Power-law parameter of breakdown current	None	10.0
R0	Bias-dependent part of series resistance in forward-bias condition	Ohm	0.0
T (**TT**)	Transit time	Second	0.0

Table 23: Nonlinear Microwave Diode Model Capacitance Parameters

Model Parameter	Description	Unit	Default
AFAC	Slope factor of diffusion capacitance	1/Volt	38.696
CT0	Zero-bias depletion capacitance	Farad	0.0
CD0	Zero-bias diffusion capacitance	Farad	0.0
FI	Built-in junction potential	Volt	0.8
GAMA	Capacitance power-law parameter	1/Volt	0.5
GC1	Varactor capacitance polynomial coefficient 1	1/Volt	0.0
GC2	Varactor capacitance polynomial coefficient 2	$1/\text{Volt}^2$	0.0
GC3	Varactor capacitance polynomial coefficient 3	$1/\text{Volt}^3$	0.0

Table 24: Nonlinear Microwave Diode Model Temperature Parameters

Model Parameter	Description	Unit	Default
TNOM	Reference temperature	°C	25
XTI	IS temperature exponent	None	2.0
EG	Barrier height at reference temperature	Volt	0.8

M	Junction grading coefficient	None	0.5
AVB	VB linear temperature coefficient	1/°C	0.0
BVB	VB quadratic temperature coefficient	1/°C^2	0.0
AR0	R0 linear temperature coefficient	1/°C	0.0
BR0	R0 quadratic temperature coefficient	1/°C^2	0.0

Table 25: Nonlinear Microwave Diode Model Noise Parameters

Model Parameter	Description	Unit	Default
KF	Flicker noise coefficient	None	0.0
AF	Flicker noise exponent	None	1.0
FCP	Flicker noise frequency shape factor	None	1.0

Nonlinear Microwave Diode Model Netlist Example

```
.MODEL NM1 D Level=6
```

Nonlinear Microwave Diode Model Equations

All components of the equivalent circuit are assumed to be functions of the junction voltage V_j. Nexxim selects this voltage as the only state variable for the microwave diode model. The equations use the following definitions:

V_j = Intrinsic junction voltage state variable

V_t = Thermal voltage = k*TJ/q

k = Boltzmann’s constant

q = Electron charge

TJ = Analysis temperature

Area Effects

$$I_d = AREA \times I_d C_j = AREA \times C_j R_d = R_d / AREA$$

Basic Equations

$$I_d = IS(TJ)[\exp(ALFA \times V_j) - 1] - I_B \, I_B = 0$$

$V_j \geq 1 + V_B$

for

$$I_B = JB(Tj) \times (1 + VB(TJ) - V_j)^{EE}$$

$V_j < 1 + V_B$

for

$$C_j = CT0(TJ) \times \left(1 - \frac{V_j}{FI(TJ)}\right)^{-\gamma(V_j)} + CD$$

$V_j \leq 0.8 \times FI(TJ)$

for

$$C_j = CT0(TJ) \times 0.2^{-\gamma(V_j)} + CD$$

$V_j > 0.8 \times FI(TJ)$

for

$$\gamma(V_j) = GAMA + GC1 \times V_j + GC2 \times V_j^2 + GC3 \times V_j^3$$

$$CD = CD0[\exp(AFAC \times V_j)]$$

$$R_d = R0 - \frac{T}{C_j}$$

$$R_0 > T / C_j$$

for

$$R_d = 0$$

$$R0 \le T / C_j$$

for

Temperature Effects

$$\Delta t = TJ - TNOM \quad tn = \frac{TJ}{TNOM} \quad JS(TJ) = JS\left(\exp\left[\frac{(tn-1)\times EG}{V_t}\right]\right) \times tn^{XTI/N}$$

$$N = \frac{1}{ALFA \times V_t}$$

$$JB(TJ) = JB\left(\exp\left[\frac{(tn-1)\times EG}{V_t}\right]\right) \times tn^{XTI/N}$$

$$FI(TJ) = FI \times tn - 3V_t \times \ln(tn) - tn \times EGap(TNOM) + Egap(TJ)$$

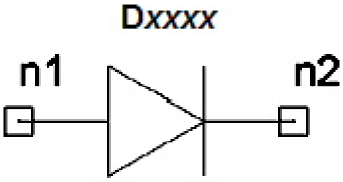
$$EGap(TNOM) = EG - 0.000702 \times \frac{TNOM^2}{TNOM + 1108}$$

$$EGap(TJ) = EG - 0.000702 \times \frac{TJ^2}{TJ + 1108}$$

$$CT0(TJ) = CT0\left(1 + M\left[0.0004\Delta t + 1 - \frac{FI(TJ)}{FI}\right]\right)$$

$$R0(TJ) = R0 \times (1 + AR0 \times \Delta t + BR0 \times \Delta t^2) \; VB(TJ) = VB \times (1 + AVB \times \Delta t + BVB \times \Delta t^2)$$

Diode Instance, Enhanced SPICE Model, Level = 7



Enhanced SPICE Model Diode Instance Netlist Syntax

The enhanced SPICE model diode instance has the syntax:

```
Dxxxx n1 n2 modelname [AREA=val] [TJ=val] [M=val]
```

n1 is the positive node (anode) and *n2* is the negative node (cathode) of the diode. The current is assumed to flow from *n1* through the diode to *n2*. *modelname* is the name of an enhanced SPICE diode model defined in a .MODEL statement elsewhere in the netlist.

Table 26: Enhanced SPICE Model Diode Instance Parameters

Instance Parameter	Description	Unit	Default

AREA	Area multiplier	None	1.0
TJ	Junction temperature	°C	25
M	Multiplier for multiple parallel diodes NOTE: The M instance parameter does not override the M model parameter (junction grading coefficient).	None	1.0

Enhanced SPICE Diode Instance Netlist Example

```
D12 Port1 44 DIODES1 TJ=27
```

Enhanced SPICE Diode Model, Level = 7

The syntax for an enhanced SPICE diode model is:

`.MODELmodelname D [LEVEL=7] [model_parameter=val] ...`

modelname is the name used by diode instances to refer to this .MODEL statement.

Table 27: Enhanced SPICE Diode Intrinsic Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	LEVEL=7 selects the enhanced SPICE diode model LEVEL=7 is the default for PSpice imports	None	PSpice:7 (default if LEVEL parameter is omitted) Others:1
IS	Saturation current	Ampere	1.0e-14
N	Emission coefficient	None	1.0
IKF	High injection knee current	Ampere	1.0e37
IBV	Magnitude of current at the reverse breakdown voltage	Ampere	1.0e-10
BV	Magnitude of the reverse breakdown voltage	Volt	1.0e37
ISR	Recombination current parameter	Ampere	0.0
NR	Emission coefficient for Isr	None	2.0
NBV	Reverse breakdown ideality factor	None	1.0

NBVL	Low-level reverse breakdown ideality factor	None	1.0
IBVL	Low-level reverse breakdown knee current	Ampere	0.0
T (**TT**)	Transit time	Second	0.0
RS	Series resistance	Ohm	0.0

Table 28: Enhanced SPICE Diode Model Capacitance Parameters

Model Parameter	**Description**	**Unit**	**Default**
CJ0, **CJO**	Zero-bias PN junction capacitance. A minimum value of CJO is set for simulation of Pspice models by specifying the option DIODECJO. CJO=DIODECJO/n, where the default for DIODECJO is 5e-17 and n is the emission coefficient. Specify DIODECJO=0 to force CJO to 0.	Farad	0.0
FC	Coefficient for forward-bias depletion capacitance	None	0.5
VJ	Built-in junction potential	Volt	1.0
M	PN junction grading coefficient	None	0.5

Table 29: Enhanced SPICE Diode Model Temperature Parameters

Model Parameter	**Description**	**Unit**	**Default**
TNOM	Reference temperature	°C	25
XTI	IS temperature exponent	None	3.0
EG	Barrier height at reference temperature	Volt	1.11
TBV1	BV temperature coefficient (linear)	1/°C	0.0
TBV2	BV temperature coefficient (quadratic)	1/°C^2	0.0
TRS1	RS temperature coefficient (linear)	1/°C	0.0
TRS2	RS temperature coefficient (quadratic)	1/°C^2	0.0
TIKF	IKF temperature coefficient (linear)	1/°C	0.0

Table 30: Enhanced SPICE Diode Model Noise Parameters

Model Parameter	**Description**	**Unit**	**Default**

KF	Flicker noise coefficient	None	0.0
AF	Flicker noise exponent	None	1.0
SN	Switch to turn device shot noise ON (1) or OFF (0)	None	1
FCP	Flicker noise frequency shape factor	None	1.0

Enhanced SPICE Diode Model Netlist Example

```
.MODEL ESD1 D LEVEL=7
```

Model Notes

1. The transit-time parameter, TT, can also be used to approximate the reverse-recovery time of a diode.
2. Diode breakdown can be modeled by specifying IBV and BV parameters.
3. The reverse-bias capacitance characteristics can be more accurately modeled than the common expression derived from PN junction theory. The capacitance grading coefficient exponent can be expressed as a polynomial function of voltage by specifying values for GC1, GC2, and GC3.

Area Effects

I_{d} = AREA ×I_{d}

I_{sr}= AREA ×I_{sr}

I_{bv}= AREA ×I_{bv}

I_{bvl} = AREA ×I_{bvl}

C_{j} = AREA ×C_{j}

R_{s} = R_{s} / AREA

Device Equations

All components of the equivalent circuit are assumed to be functions of the junction potential voltage Vj. This voltage is automatically selected by the program as the only state-variable for the diode model. The following expressions are used:

V_{j} = intrinsic junction voltage state variable

V_{t} = k TJ/q (thermal voltage)

k = Boltzmann’s constant

q = Electron charge

TJ = Analysis temperature (internally converted from °C to °K)

DC Current

`Id = AREA(Ifwd-Irev)`

Forward current:

`Ifwd = If * Kinj + Irec * Kgen`

Where:

Normal forward current

$$I_f = IS \cdot \left(e^{\frac{V_d}{N \cdot V_t}} - 1 \right)$$

Recombination current

$$I_{rec} = ISR \cdot \left(e^{\frac{Vd}{NR \cdot VT}} - 1 \right)$$

Injection factor when IKF=0

K_{inj}= 1

Injection factor when IKF>0

$$K_{inj} = \sqrt{\frac{IKF}{IKF + I_f}}$$

Generation factor

$$K_{gen} = \left(\left(1 - \frac{V_d}{VJ} \right)^2 + 0.005 \right)^{M/2}$$

Reverse Current

`Irev = Ib + Ibl`

Where:

Reverse breakdown current

$$I_b = I_{bv} \cdot e^{\frac{-(V_d + BV)}{NBV \cdot VT}}$$

Low-level reverse breakdown current

$$I_{bl} = I_{bvl} \cdot e^{\frac{-(V_d + BV)}{NVBL \cdot VT}}$$

Capacitance

Junction capacitance

$$C_j = C_t + C_d$$

Transit time capacitance

$$C_t = TT \cdot \frac{dI_d}{dV_j}$$

Depletion capacitance when Vd <= FC*Vj

$$C_d = CJO\left(1 - \frac{V_d}{VJ}\right)^{-M}$$

Depletion capacitance when Vd > FC*Vj

$$C_d = CJO(1-FC)^{-(1+M)} \cdot \left(1 - FC(1+M) + M \cdot \frac{V_d}{VJ}\right)$$

Where **M** is the Diode 7 Model parameter (PN junction grading coefficient), not the Diode 7 instance parameter (multiple parallel diodes).

Temperature Effects

$$IS(T) = IS \cdot e^{(T/TNOM-1) \cdot EG/(N \cdot V_t)} \cdot (T/TNOM)^{XTI/N}$$

$$ISR(T) = ISR \cdot e^{(T/TNOM-1) \cdot EG/(NR \cdot V_t)} \cdot (T/TNOM)^{XTI/NR}$$

$$RS(T) = RS \cdot (1 + TRS1 \cdot (T-TNOM) + TRS2 \cdot (T-TNOM)^2)$$

$$IKF(T) = IKF \cdot (1 + TIKF \cdot (T-TNOM))$$

$$BV(T) = BV \cdot (1 + TBV1 \cdot (T-TNOM) + TBV2 \cdot (T-TNOM)^2)$$

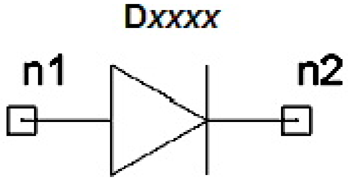
$$\begin{aligned} VJ(T) &= VJ \cdot T/TNOM - 3 \cdot V_t \cdot \ln(T/TNOM) \\ &\quad - E_g(TNOM) \cdot T/TNOM + E_g(T) \end{aligned}$$

Where Eg(T) is the silicon bandgap energy:

$$E_g(T) = 1.16 - 0.000702 \cdot T^2/(T + 1108)$$

$$CJO(T) = CJO \cdot (1 + M \cdot (0.0004 \cdot (T - TNOM)) + (1 - (VJ(T))/(VJ)))$$

Diode Instance, Step Recovery (Level 9)



Step Recovery Diode Netlist Syntax

The syntax for a Level 9 Step recovery diode instance is:

```
Dxxxx n1 n2 modelname [AREA=val] [M=val]
```

n1 is the anode and *n2* is the cathode of the diode. *modelname* identifies the .MODEL statement associated with the diode instance.

Table 32: LEVEL 9 Step Recovery Diode Instance Parameters

Instance Parameter	Description	Unit	Default
AREA	Area of the diode	None	1.0
M	Multiplier to simulate parallel diodes	None	1.0

Step Recovery Diode Instance Netlist Example

```
D1 112 314 diodeSR AREA=0.95
```

Step Recovery Diode Model, Level 9

The syntax for a Level 9 step recovery diode model is:

```
.MODELmodelname D LEVEL=9 [model_parameter=val] ...
```

modelname is the name used by the diode instance to refer to the .MODEL statement. **LEVEL=9** selects the step recovery diode mode.

Table 33: Step Recovery Diode Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	LEVEL=9 selects the step recovery diode model	None	1 (default if LEVEL parameter is omitted)
AF	Flicker noise exponent	None	1.0
BV	Reverse breakdown voltage	Volt	30.0
CF	Junction capacitance at forward bias	Farad	2.0e-8
CR	Junction capacitance at reverse bias	Farad	0.0
EG	Energy gap for pn junction	Electron-Volt	1.11
FC	Coefficient for forward-bias depletion area capacitance	None	0.5
IBV	Current at breakdown voltage	Amp/Meter 2	1.0e-3
IS	Saturation current	Amp/Meter 2	1.0e-14
KF	Flicker noise coefficient	None	0.0
M	Area junction grading coefficient	None	0.5
N	Emission coefficient	None	1.0
RS	Ohmic series resistance	Ohm	0.0
TNOM	Nominal temperature	°C	25.0
VJ	Junction potential	Volt	1.0
XTI	Saturation current temperature exponent	None	3.0

Step Recovery Diode Model Netlist Example

```
.MODEL DiodeSR D LEVEL=9
```

Device Equations

Area Effects

IS= AREA × IS

CR = AREA ×*CR*

CF= AREA ×*CF*

RS = *RS* / AREA

Current Equations

The current equations are based on the SPICE diode with breakdown.

The following expressions are used:

VT = k*temperature/q (circuit thermal voltage)

VTNOM= k*tnom_kelvin/q (nominal thermal voltage,)

k = Boltzmann’s constant

tnom_kelvin = Analysis temperature converted from °C to °K

q = Electron charge

$$IS(T) = IS \times \left(\frac{temperature}{tnomkelvin}\right)^{\frac{XTI}{N}} \times \exp\left(\frac{EG}{VTNOM} - \frac{EG}{VT}\right)$$

$$IBREAK = -IS(T) \times \exp\left(\frac{-BV}{VT}\right) - 1.0$$

For IBV > IBREAK:

$$BFeff = BV - VT \times \log\left(\frac{IBV}{IBREAK}\right)$$

For IBV <= IBREAK:

$$BVeff = BV$$

For VD >=0.0:

$$ID = IS(T) \times (xpvdnvt - 1.0)$$

For VD <0.0:

$$ID = IS(T) \times (xpvdnvt - 1) - IS \times (xpvdbvvt - xpbvvt)$$

Where:

$$xpvdnvt = \exp\left(\frac{VD}{N \times VT}\right) \quad vpvdbvvt = \exp\left(\frac{-(VD + BVeff)}{VT}\right) \quad xpbvvt = \exp\left(\frac{-BVeff}{VT}\right)$$

Charge Equations

The charge equations are based on Zhang and Rasmussen, “A New Model of Step Recovery Diode for CAD,” MTT-S 1995, pp 1459-1462.

If VD <=0.0:

$$QD = CR \times VD$$

Else if 0.0<VD<FC*VJ:

$$QD = \frac{0.5(CF - CR)}{FC \times VJ} \times \left[VD + \frac{CR \times FC \times VJ}{CF - CR}\right]^2 - \frac{0.5 \times CR^2 \times FC \times VJ}{CF - CR}$$

Else:

$$QD = CF \times VD - 0.5 \times FC \times VJ \times (CF - CR)$$

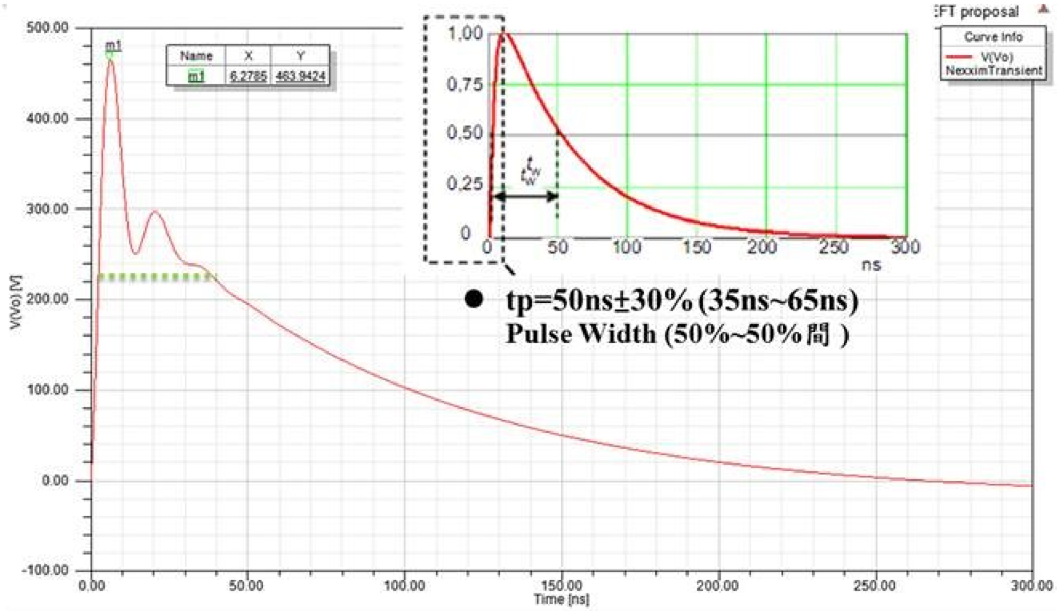
8 - EMC Tools

This topic describes the following elements of the EMC Tools:

Electrical Fast Transient (EFT) Source

When de-energized, inductive loads such as relays, switch contactors, and heavy-duty motors produce bursts of narrow high-frequency transients on the power distribution system. The EFT source replicates the effect of an EFT event.

The EFT source is available in the Schematic Editor. It is implemented via a .SUBCKT instance. It does not have a netlist form. The EFT_IEC source simultaneously models the idealized IEC61000-4-4/Burst standard and the measured physical effects associated with waveform testing[1]. Consequently, the resulting model looks different on the IEC61000-4-4/Burst standard model, but still conforms.



The EFT source has the following parameters:

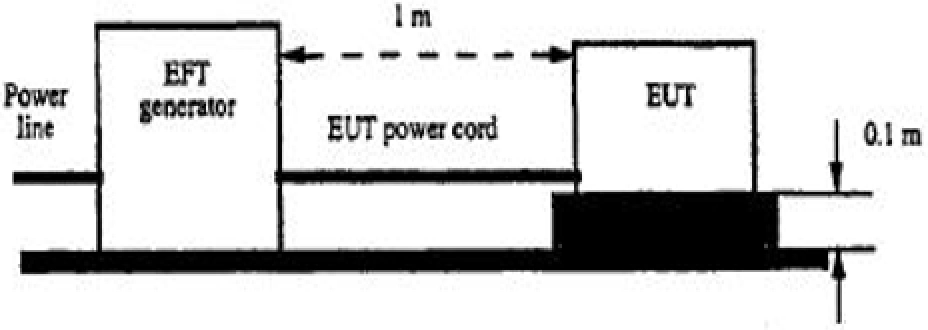
VA – Sets the input voltage (default is 500V)

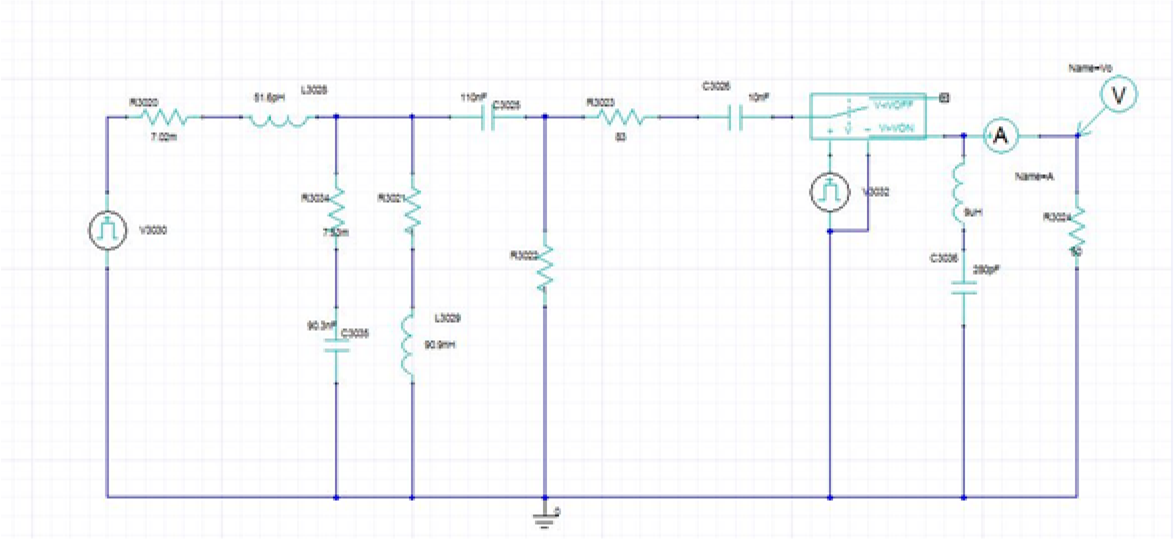
FR – Sets the burst frequency of repeated pulses (default is 5 kHz)

Burst_Period – Period of burst (default is 300ms)

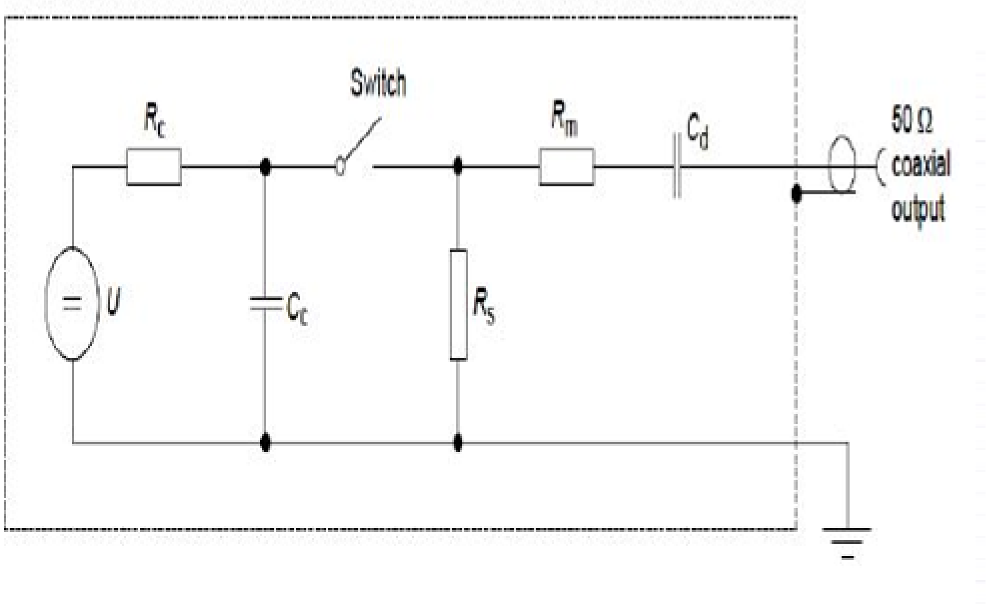
Burst_Duration – Duration of Burst (default is 15ms)

EFT_Out is the node connected to the power cable and *Gnd*. It is the grounded node of the source.


1 m
Power line
EFT generator
EUT power cord
EUT
0.1 m


R3020
7.00m
51.6pH
L3028
110nF
C3025
R3023
83
C3026
10nF
V=VOFF
V=VON
Name=Vo
V
A
Name=A
V3030
R3024
7.52m
R3021
R3022
90.3nF
C3035
L3029
90.9nH
V3032
9uH
C3036
280pF
R3024
50
0

>



Where:

- U is a voltage source with voltage equal to VA.
- Rc is a charging resistor.
- Cc is an energy storage capacitor.
- Rs is the Impulse duration shaping resistor.
- Rm is an impedance matching resistor.
- Cd is a DC blocking capacitor.
- Switch is a high-voltage electronic switch.

When the Switch is open, the Energy Storage capacitor is recharged with the high voltage provided on the High Voltage power source and a small current flow on the output loop due to the energy stored on the DC Blocking capacitor. When the switch closes, the energy previously stored on the Energy Storage capacitor is sent to the output through the Impedance Matching resistor and the DC Blocking capacitor. This produces a burst of pulses, each one with a standard specified waveform.

References

1. Francesco Musolino, “Modeling the IEC 61000-4-4 EFT Injection Clamp”, IEEE Transactions on Electromagnetic Compatibility, Vol. 50, No. 4, November 2008.

Electrical Fast Transient (EFT) ISO 7637 Source

When de-energized, inductive loads such as relays, switch contactors, and heavy-duty motors produce bursts of narrow high-frequency transients on the power distribution system. The EFT source replicates the effect of an EFT event.

The EFT source is available in the Schematic Editor via the Component Libraries. It is implemented via a .SUBCKT instance. It does not have a netlist form. The EFT_ISO7637 source models the ISO7637 standard. It is is only implemented for 12V systems.

The EFT_ISO7637 source has the following parameters:

PulseType – Sets the type of pulse (default is Pulse-2a-37V)

R – Repeat ESD discharge pulse(s). Set to '0' to enable. (default is *nan*)

Ri – Sets the internal resistance (default is 0.05 Ohm)

Td – sets the time delay (default is 0.01s)

> **Note:** Td (time delay) differs from t_d (pulse duration, which is shown in the following figure).

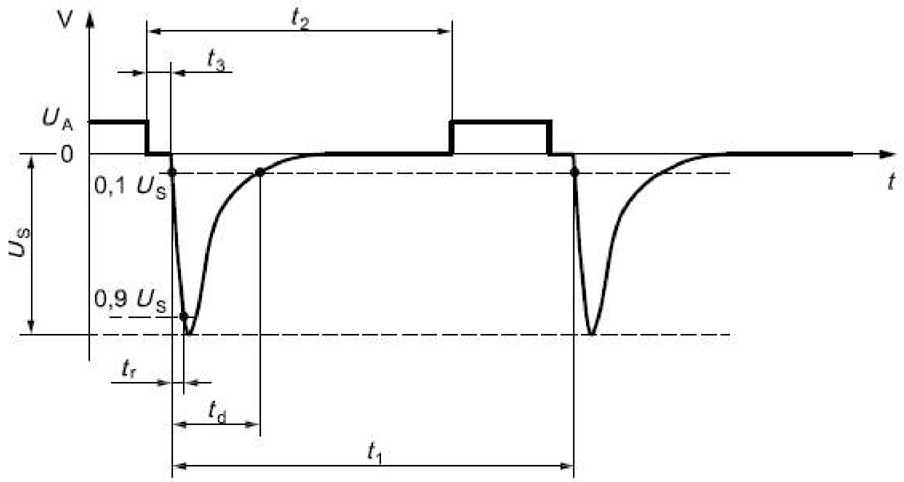
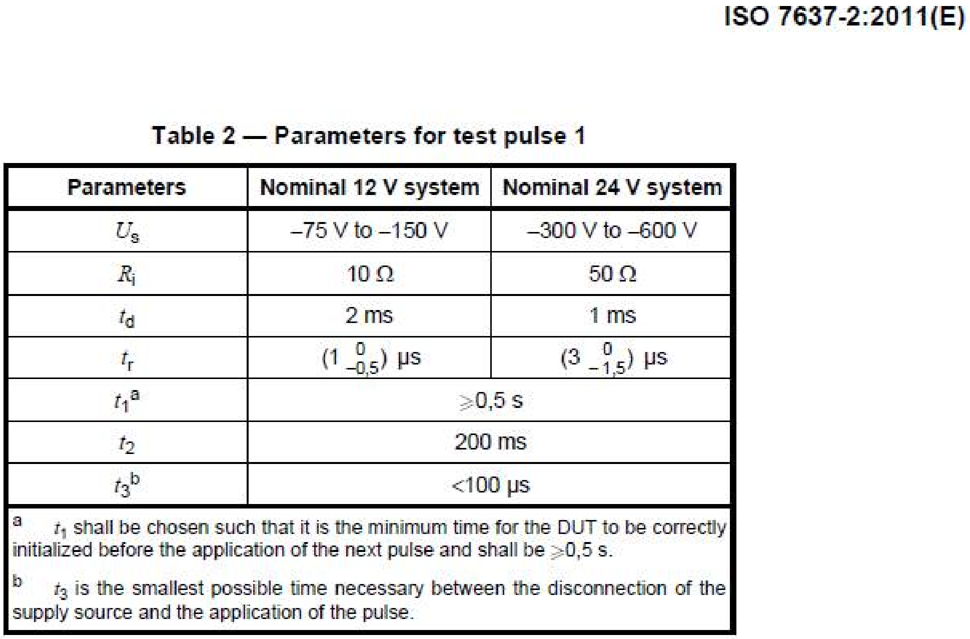


Figure 5 — Test pulse 1



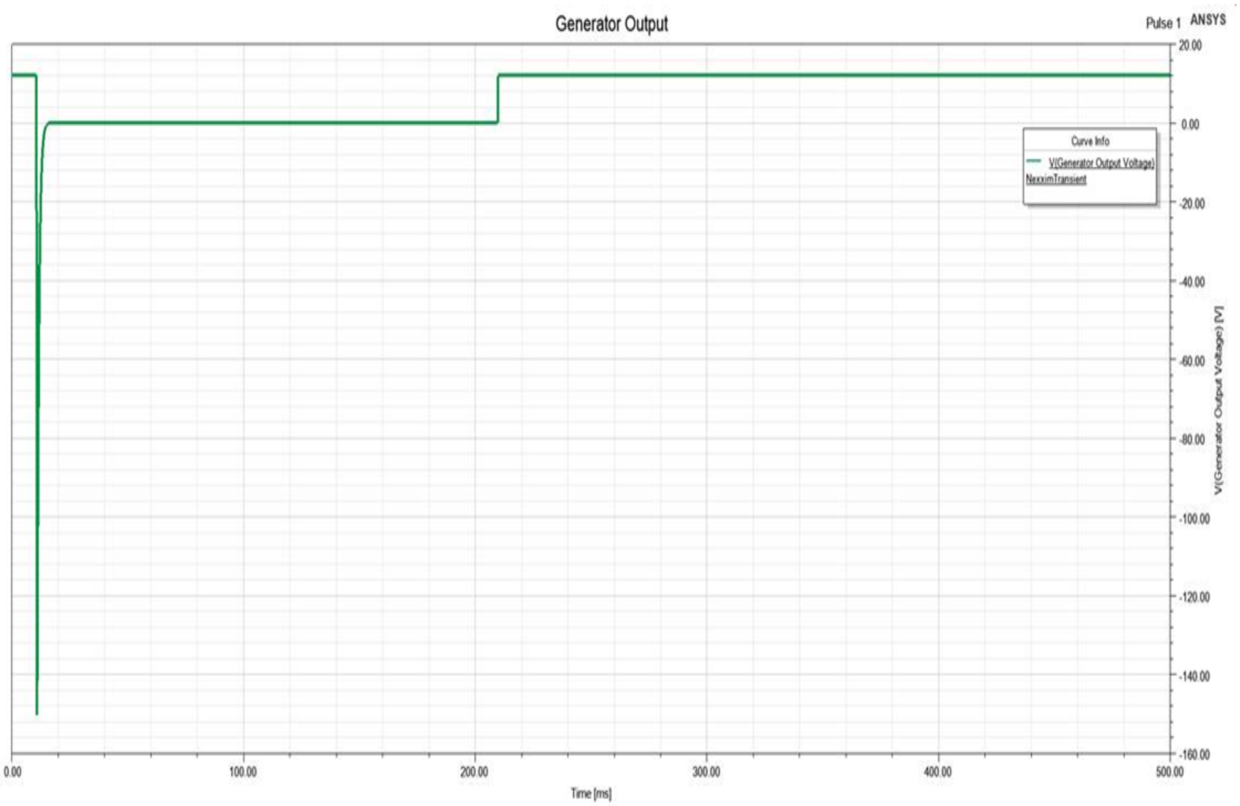
ISO 7637-2:2011(E)

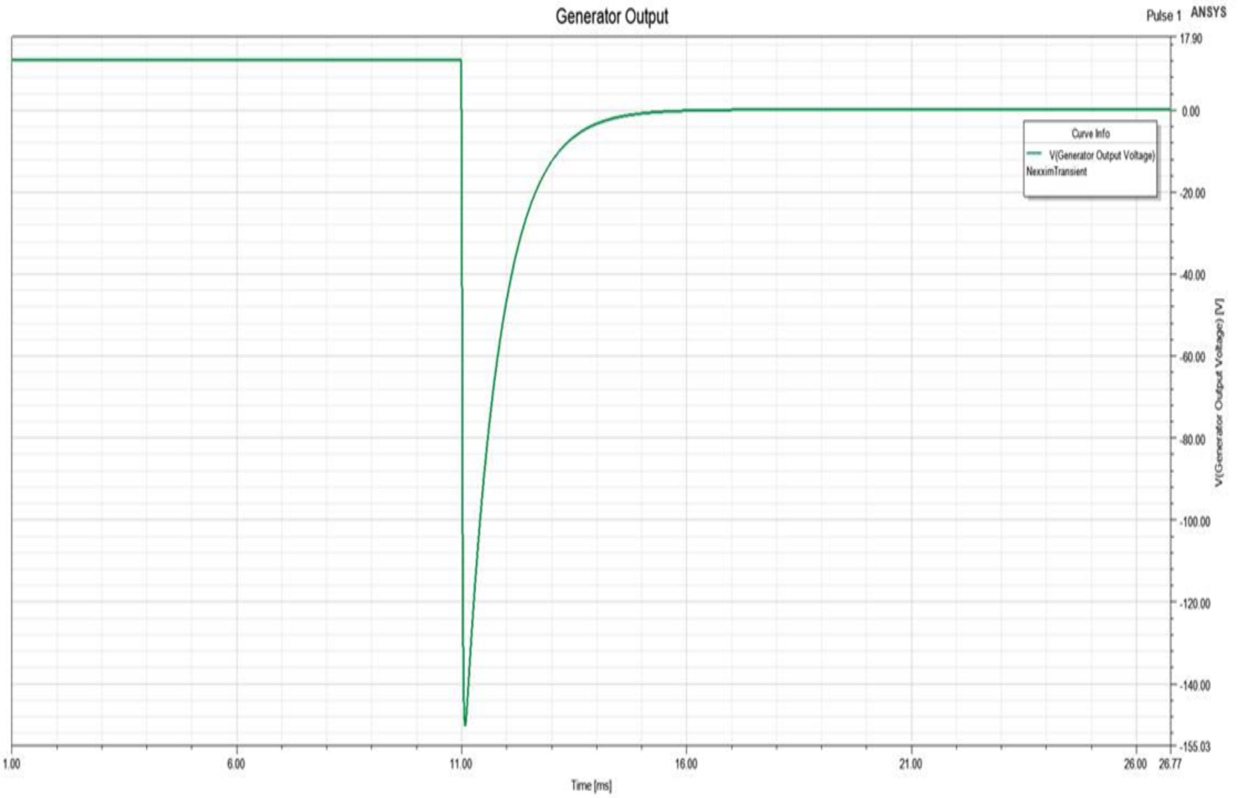
Table 2 — Parameters for test pulse 1

Parameters	Nominal 12 V system	Nominal 24 V system
U_s	–75 V to –150 V	–300 V to –600 V
R_i	10 Ω	50 Ω
t_d	2 ms	1 ms
t_r	$(1\,^{0}_{-0,5})$ µs	$(3\,^{0}_{-1,5})$ µs
t_1[a]	⩾0,5 s	
t_2	200 ms	
t_3[b]	<100 µs	

[a] t_1 shall be chosen such that it is the minimum time for the DUT to be correctly initialized before the application of the next pulse and shall be ⩾0,5 s.

[b] t_3 is the smallest possible time necessary between the disconnection of the supply source and the application of the pulse.


Generator Output
Pulse 1
ANSYS
Curve Info
V(Generator Output Voltage)
NexximTransient
20.00
0.00
-20.00
-40.00
-60.00
-80.00
-100.00
-120.00
-140.00
-160.00
V(Generator Output Voltage) [V]
0.00
100.00
200.00
300.00
400.00
500.00
Time [ms]


Generator Output
Pulse 1
ANSYS
Curve Info
V(Generator Output Voltage)
NexximTransient
17.90
0.00
-20.00
-40.00
-60.00
-80.00
-100.00
-120.00
-140.00
-155.03
V(Generator Output Voltage) [V]
1.00
6.00
11.00
16.00
21.00
26.00
26.77
Time [ms]

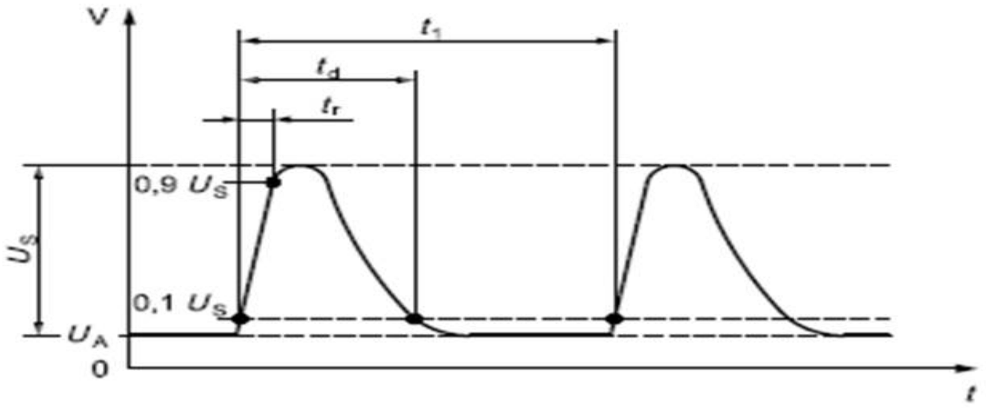
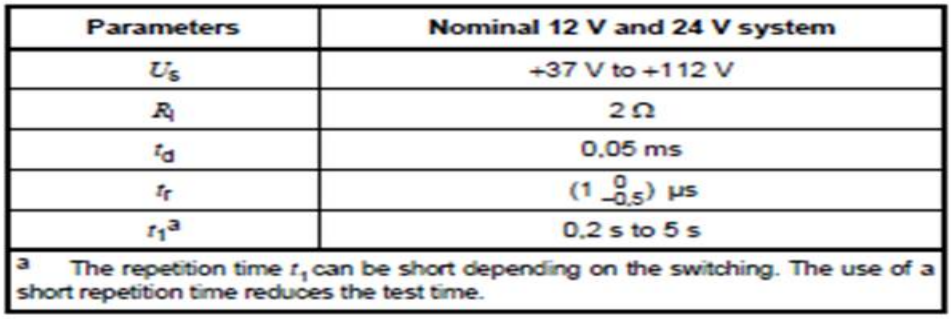


Figure 6 — Test pulse 2a

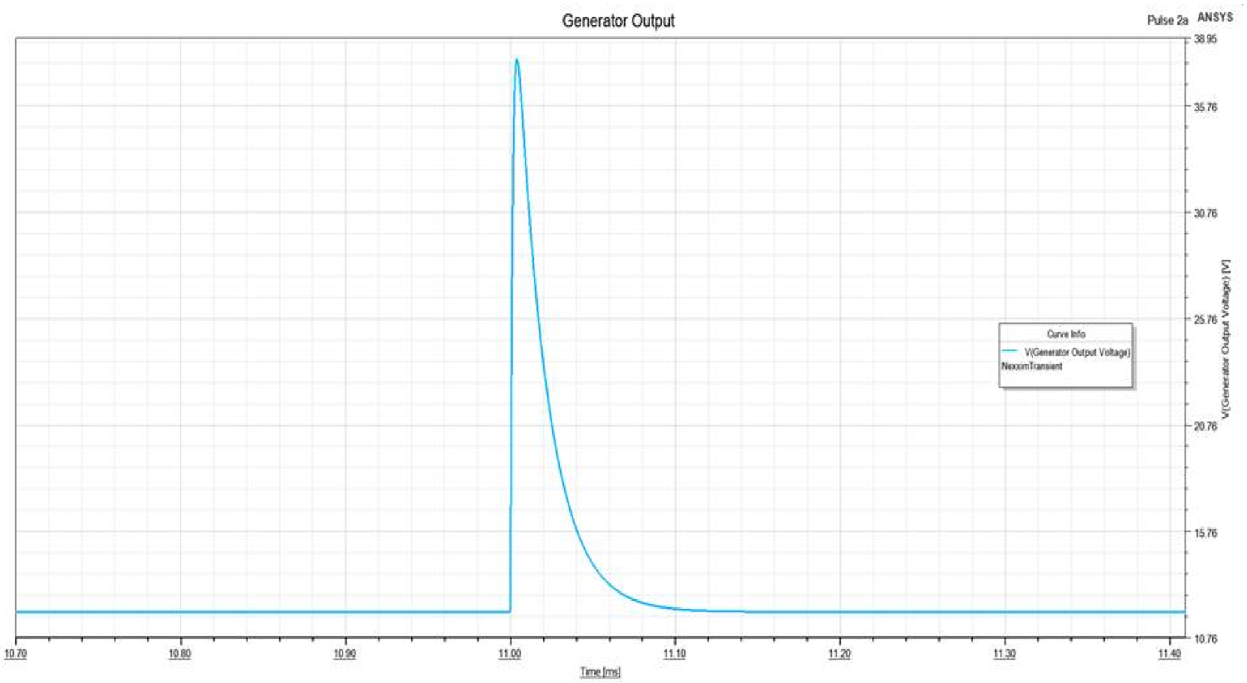
11(E)

Table 3 — Parameters for test pulse 2a



Parameters	Nominal 12 V and 24 V system
U_S	+37 V to +112 V
R_i	2 Ω
t_d	0,05 ms
t_r	$(1\,^{0}_{-0{,}5})$ µs
t_1[a]	0,2 s to 5 s

[a] The repetition time t_1 can be short depending on the switching. The use of a short repetition time reduces the test time.


Generator Output
Pulse 2a
ANSYS
38.95
35.76
30.76
25.76
20.76
15.76
10.76
V(Generator Output Voltage) [V]
Curve Info
V(Generator Output Voltage)
NexximTransient
10.70
10.80
10.90
11.00
11.10
11.20
11.30
11.40
Time [ms]

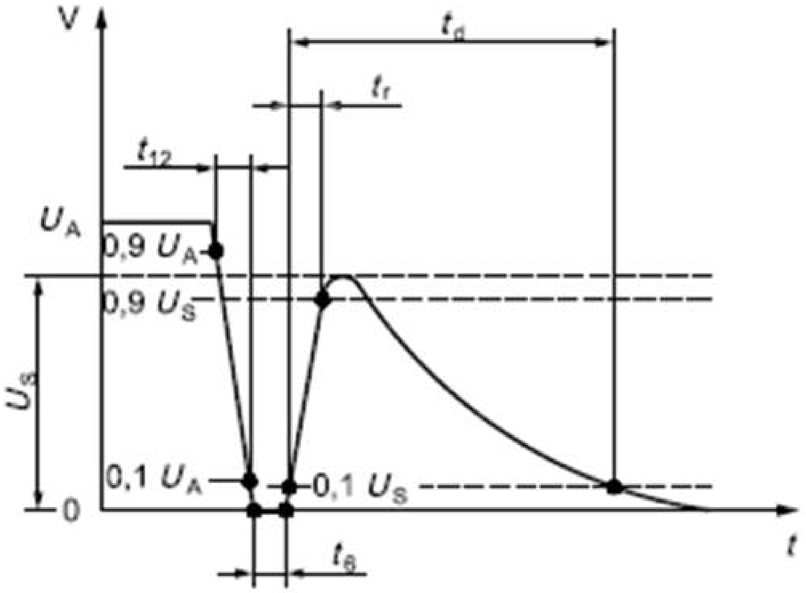
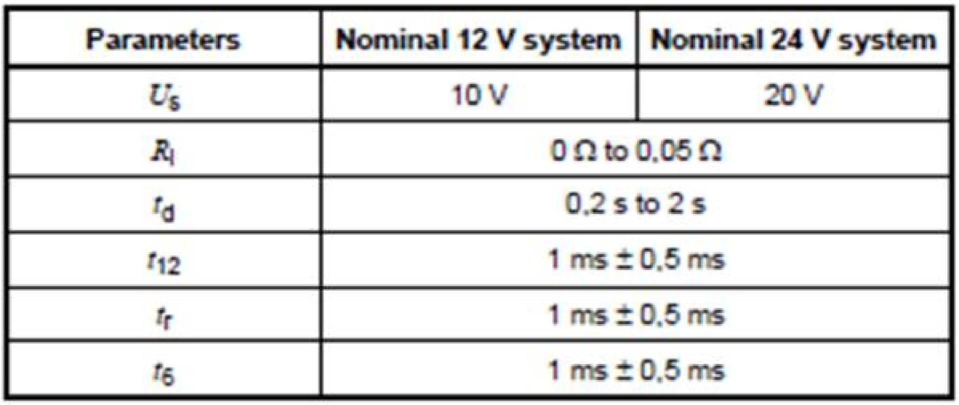
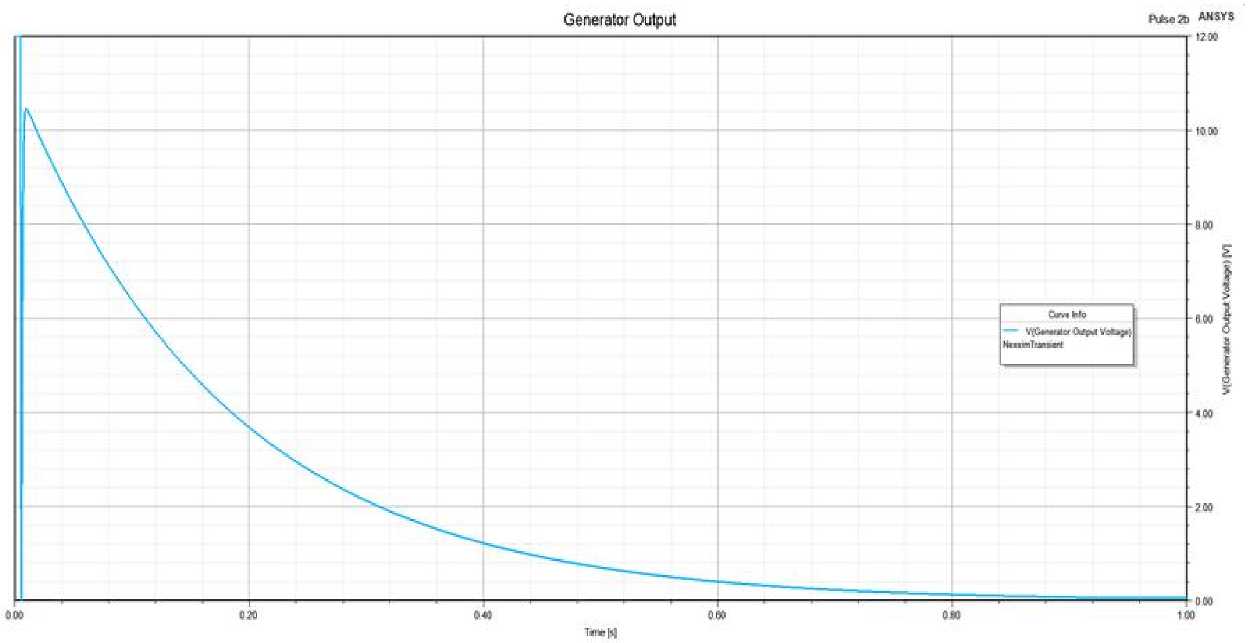


Figure 7 — Test pulse 2b

Table 4 — Parameters for test pulse 2b



Parameters	Nominal 12 V system	Nominal 24 V system
U_s	10 V	20 V
R_i	0 Ω to 0,05 Ω	
t_d	0,2 s to 2 s	
t_{12}	1 ms ± 0,5 ms	
t_r	1 ms ± 0,5 ms	
t_6	1 ms ± 0,5 ms	


Generator Output
Pulse 2b
ANSYS
12.00
10.00
8.00
6.00
4.00
2.00
0.00
V(Generator Output Voltage) [V]
Curve Info
V(Generator Output Voltage)
NexximTransient
0.00
0.20
0.40
0.60
0.80
1.00
Time [s]

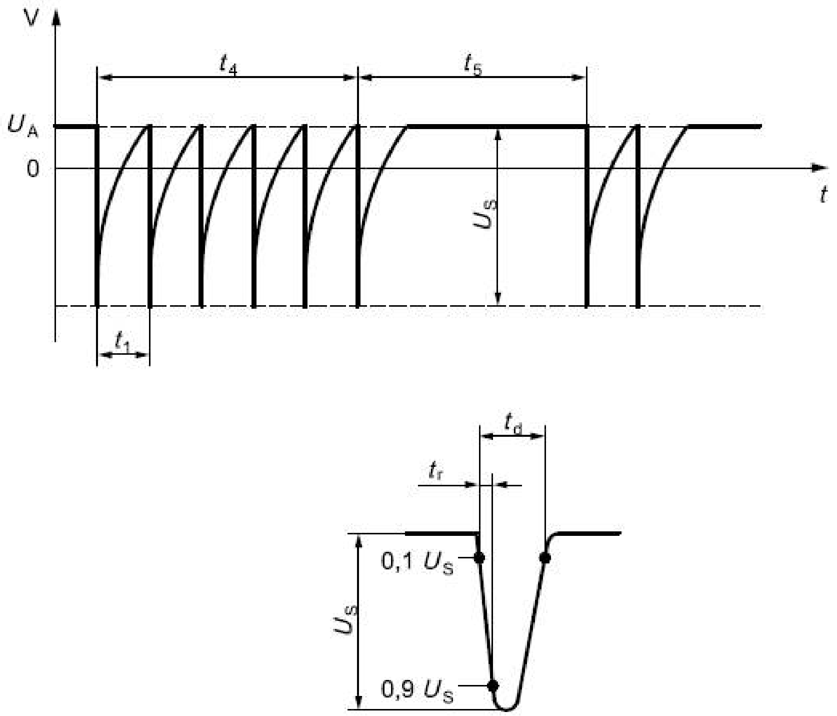
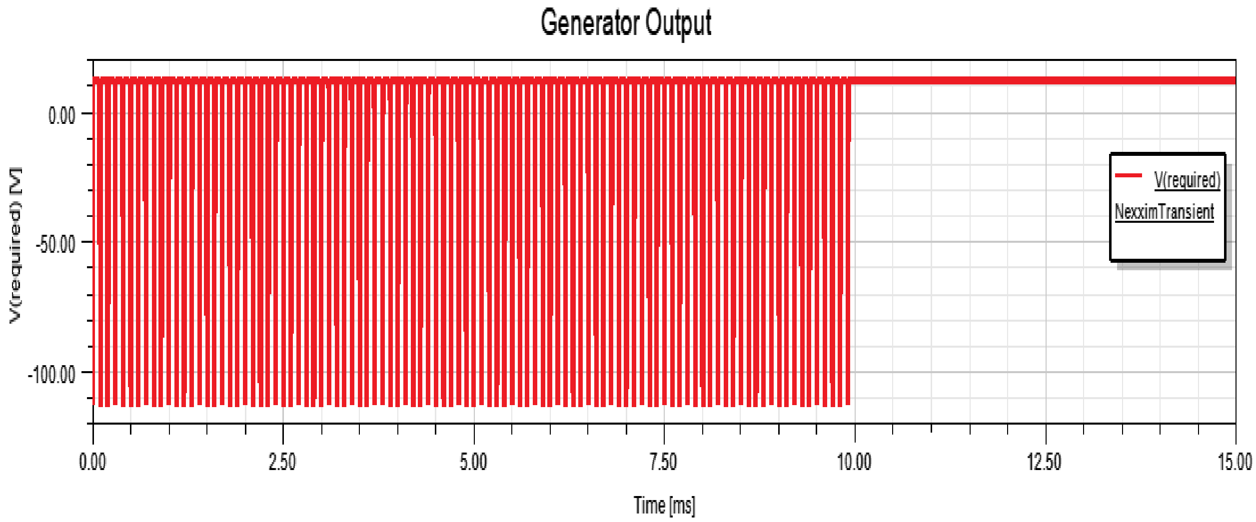
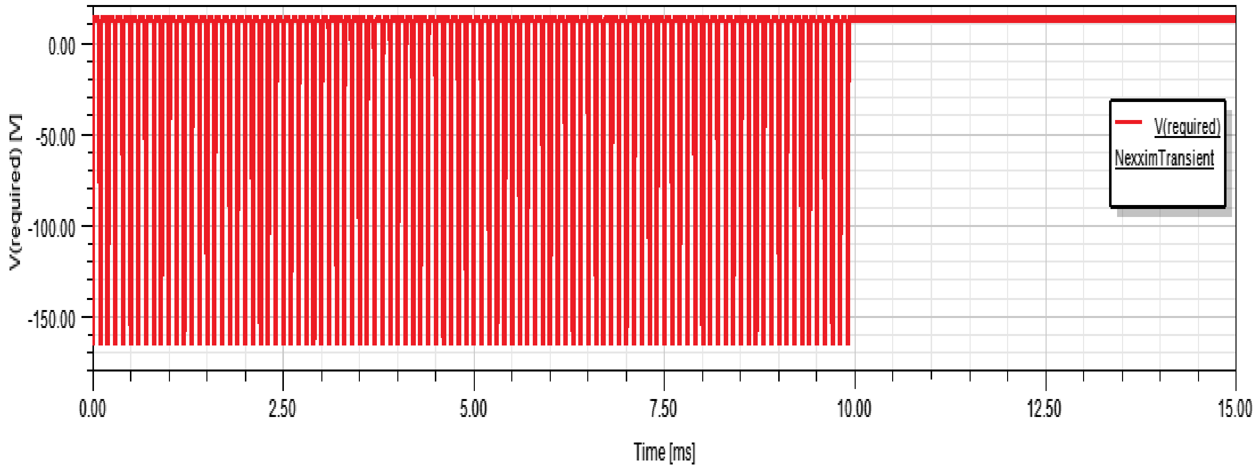


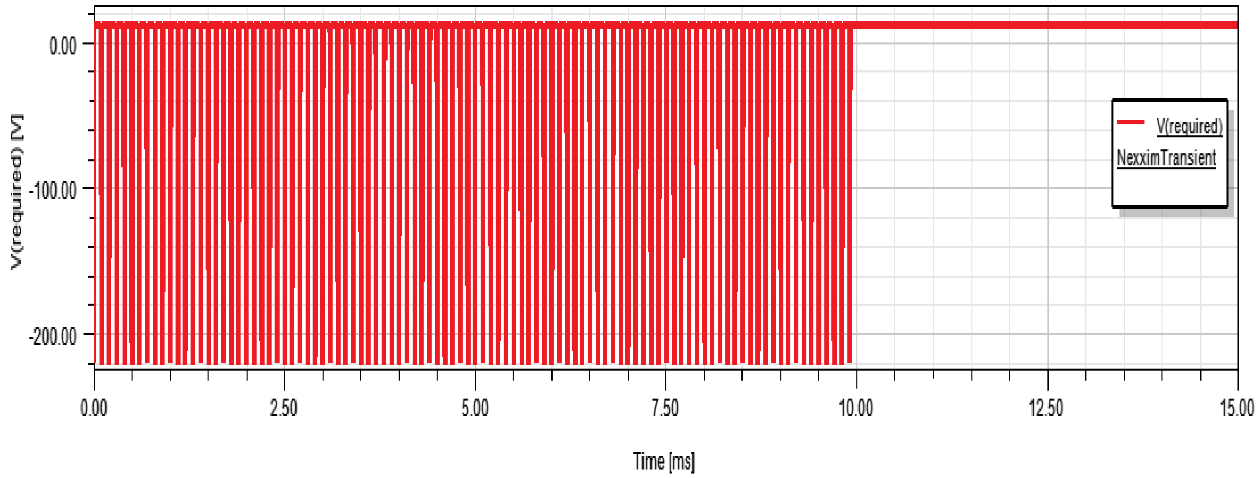
Figure 8 — Test pulse 3a

Table 5 — Parameters for test pulse 3a

Parameters	Nominal 12 V system	Nominal 24 V system
U_s	–112 V to –220 V	–150 V to –300 V
R_i	50 Ω	
t_d	150 ns ± 45 ns	
t_r	5 ns ± 1,5 ns	
t_1	100 µs	
t_4	10 ms	
t_5	90 ms	


Generator Output
V(required) [V]
0.00
-50.00
-100.00
Time [ms]
0.00
2.50
5.00
7.50
10.00
12.50
15.00
V(required)
NexximTransient


V(required) [V]
0.00
-50.00
-100.00
-150.00
Time [ms]
0.00
2.50
5.00
7.50
10.00
12.50
15.00
V(required)
NexximTransient


V(required) [V]
0.00
-100.00
-200.00
Time [ms]
0.00
2.50
5.00
7.50
10.00
12.50
15.00
V(required)
NexximTransient

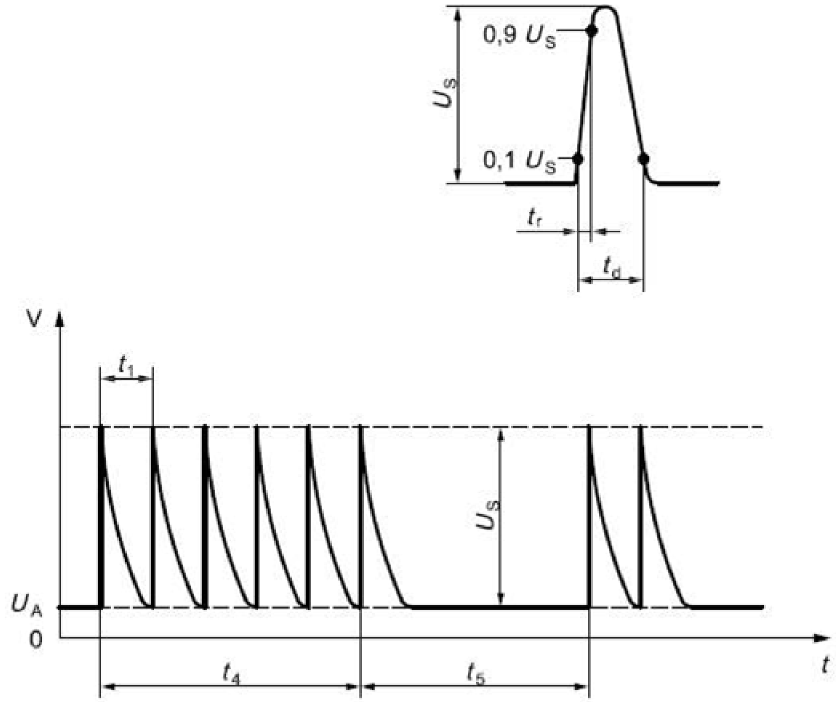
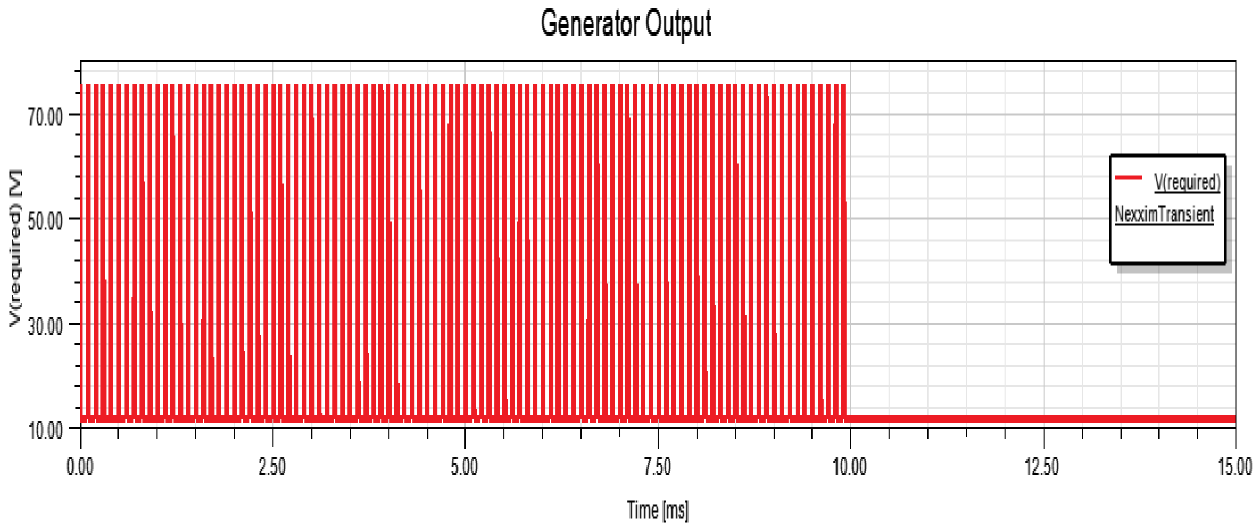
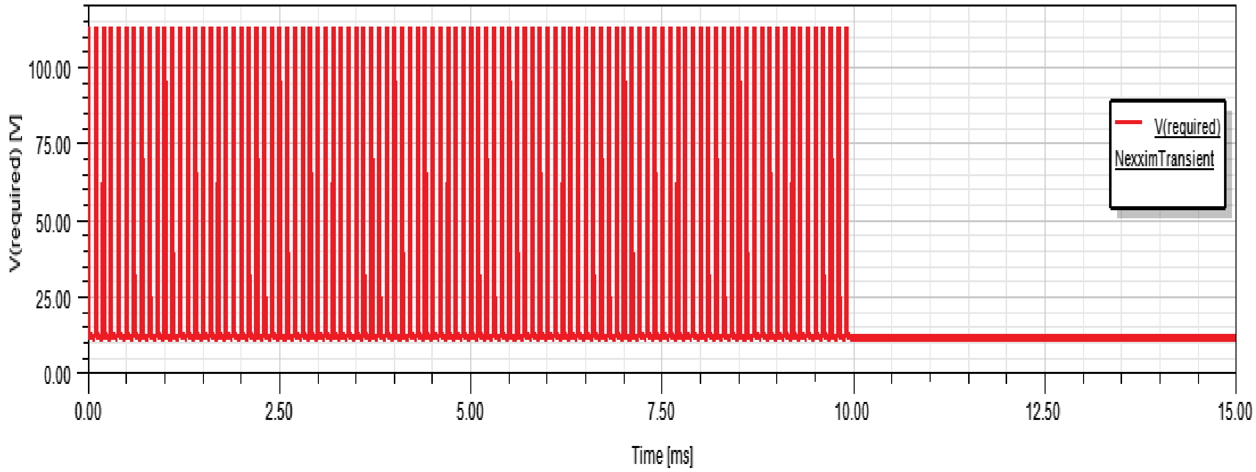


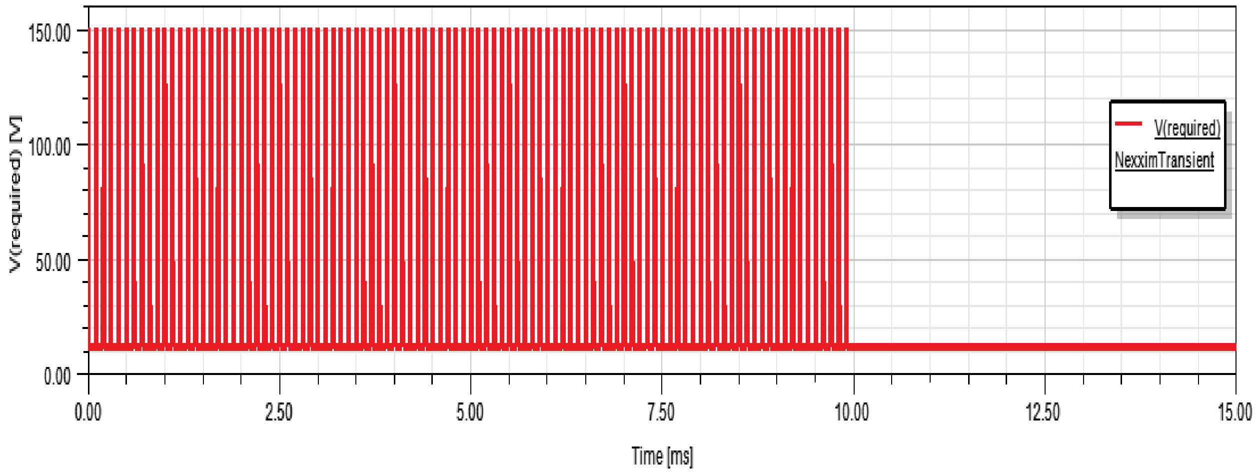
Figure 9 — Test pulse 3b

Table 6 — Parameters for test pulse 3b

Parameters	Nominal 12 V system	Nominal 24 V system
U_s	+75 V to +150 V	+150 V to +300 V
R_i	50 Ω	
t_d	150 ns ± 45 ns	
t_r	5 ns ± 1,5 ns	
t_1	100 µs	
t_4	10 ms	
t_5	90 ms	


Generator Output
V(required) [V]
70.00
50.00
30.00
10.00
0.00
2.50
5.00
7.50
10.00
12.50
15.00
Time [ms]
V(required)
NexximTransient


V(required) [V]
100.00
75.00
50.00
25.00
0.00
2.50
5.00
7.50
10.00
12.50
15.00
Time [ms]
V(required)
NexximTransient


V(required) [V]
150.00
100.00
50.00
0.00
2.50
5.00
7.50
10.00
12.50
15.00
Time [ms]
V(required)
NexximTransient

Electrostatic Discharge (ESD) Source

Electrostatic discharge (ESD) occurs when there is a sudden flow of electricity between two electrically charged objects caused by contact, an electrical short, or dielectric breakdown.

The ESD source replicates the effect of an ESD event. The ESD_HMM source models the IEC61000-4-2 Human-Metal Model standard.

The ESD source is available in the Schematic Editor via the Component Libraries. It is implemented via a .SUBCKT instance. It does not have a netlist form.

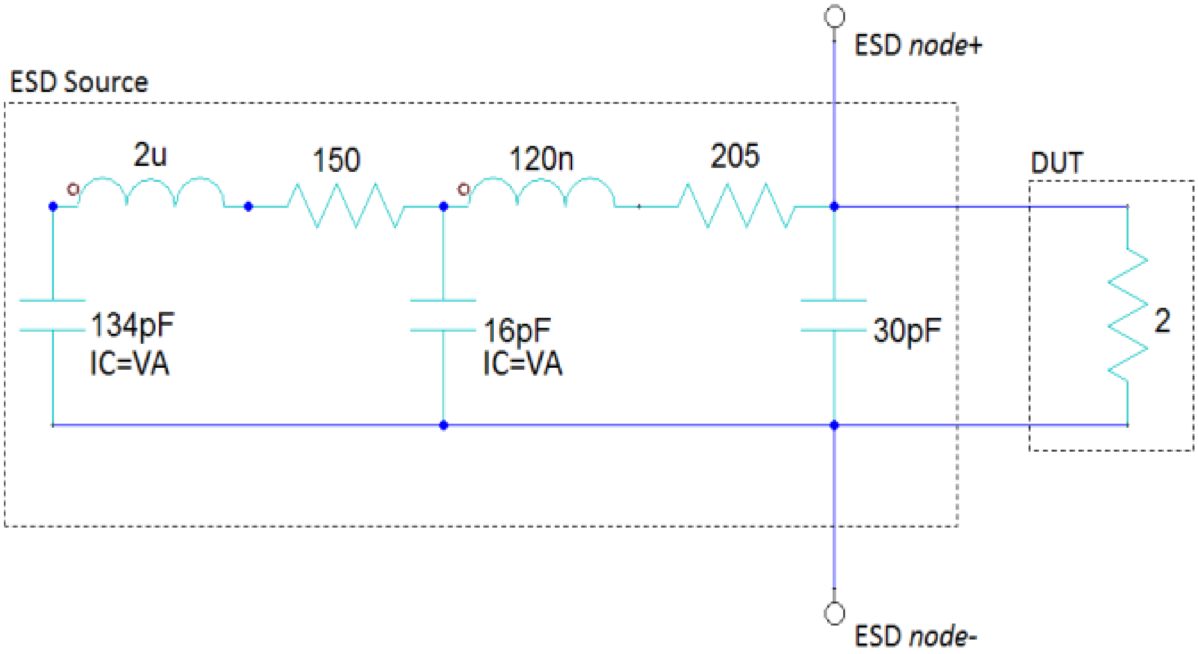
The ESD source has one parameter:

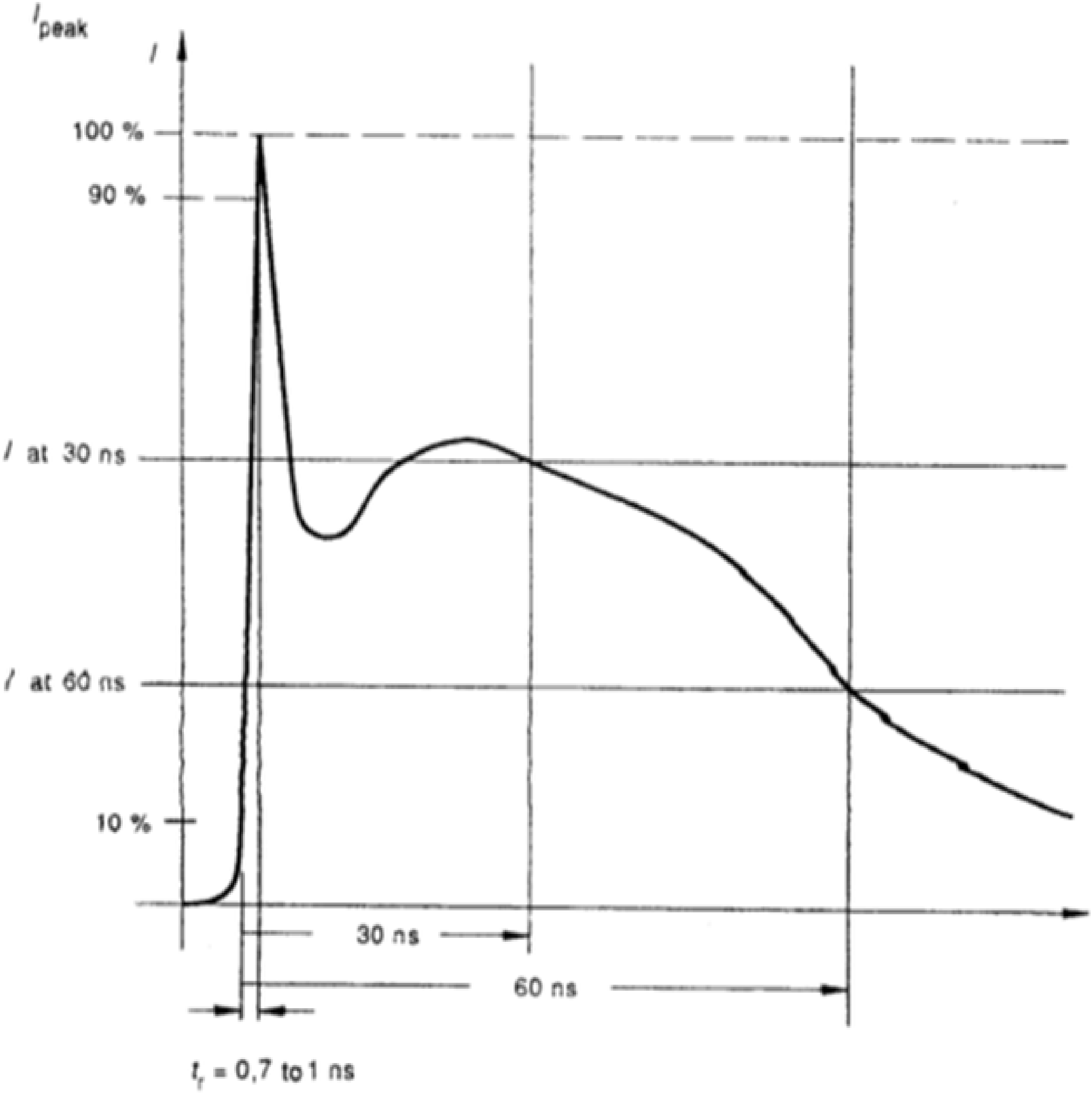
VA – Sets the initial capacitor voltage on the metal tool and the human body

Td – Sets the time delay before ESD discharge begins.

R – Repeat ESD discharge pulse(s). Set to '0' to enable. (default is *nan*)

ESD_Out is the output node connected to the DUT and *Gnd*. It is the grounded node of the source.


ESD Source
2u
150
120n
205
134pF
IC=VA
16pF
IC=VA
30pF
ESD node+
ESD node-
DUT
2


I_{peak}
I
100 %
90 %
I at 30 ns
I at 60 ns
10 %
30 ns
60 ns
t_r = 0,7 to 1 ns

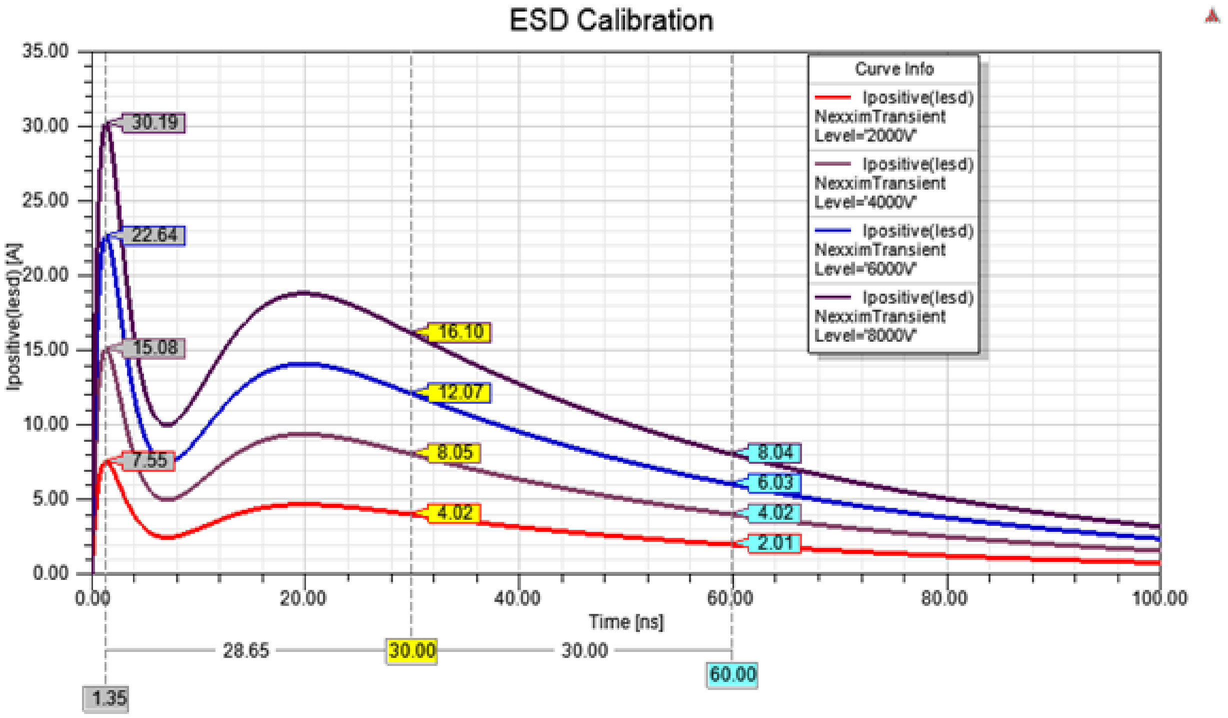


Figure: Simulation model results of calibration circuit (2Ω load).

Voltage (KV)	Peak Current (A) ±10%		Rise time (ns)		Current at 30ns (A) ±30%		Current at 60ns (A) ±30%	
	Standard	Model	Standard	Model	Standard	Model	Standard	Model
2	7.5	7.55	0.7-1	0.74	4	4.02	2	2.01
4	15	15.08	0.7-1	0.74	8	8.05	4	4.02
6	22.5	22.64	0.7-1	0.74	12	12.07	6	6.03
8	30	30.19	0.7-1	0.74	16	16.1	8	8.04

Electrostatic Discharge (ESD) Human-Metal Model (HMM) Source with Delay

Electrostatic discharge (ESD) occurs when there is a sudden flow of electricity between two electrically charged objects caused by contact, an electrical short, or dielectric breakdown.

The ESD source with delay replicates the effect of an ESD event. The ESD_HMM_Delay source models the IEC61000-4-2 Human-Metal Model standard.

The ESD source with delay is available in the Schematic Editor via the Component Libraries. It is implemented via a .SUBCKT instance. It does not have a netlist form.

The ESD source with delay has two parameters:

VA – Sets the initial capacitor voltage on the metal tool and the human body

Td – Sets the time delay before ESD discharge begins.

R – Repeat ESD discharge pulse(s). Set to '0' to enable. (default is *nan*)

ESD_Out is the output node connected to the DUT and *Gnd*. It is the grounded node of the source.

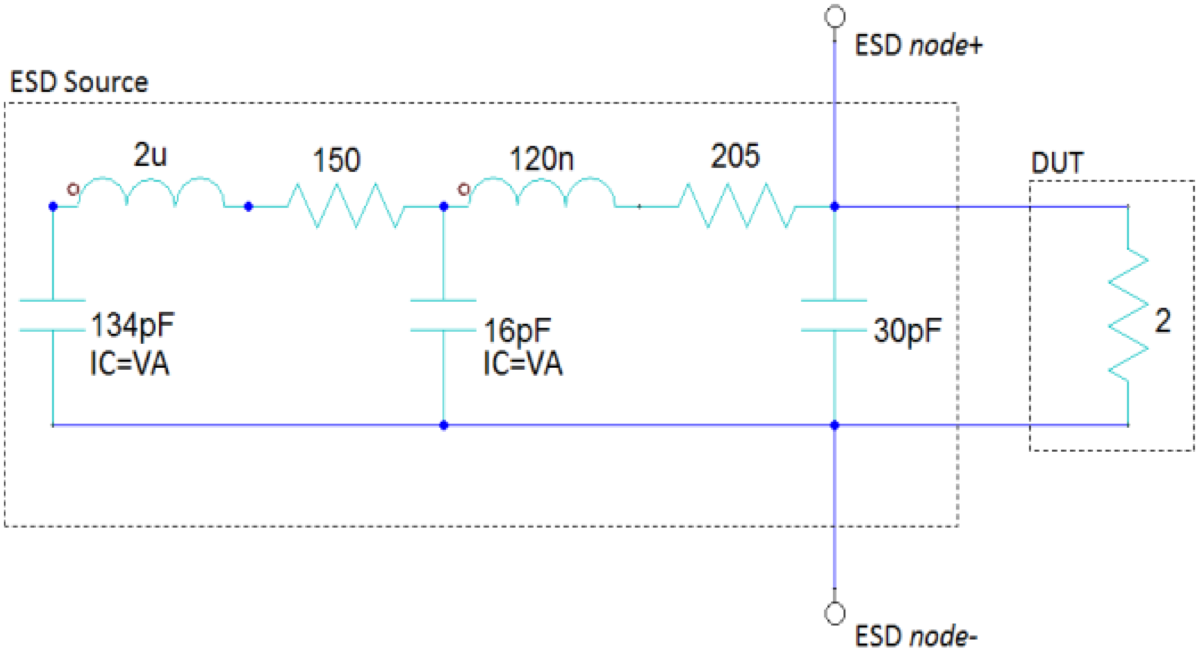


Figure 8-1 Internal Circuit of ESD_HMM_Delay: Human Metal Model (HMM) IEC61000-4-2

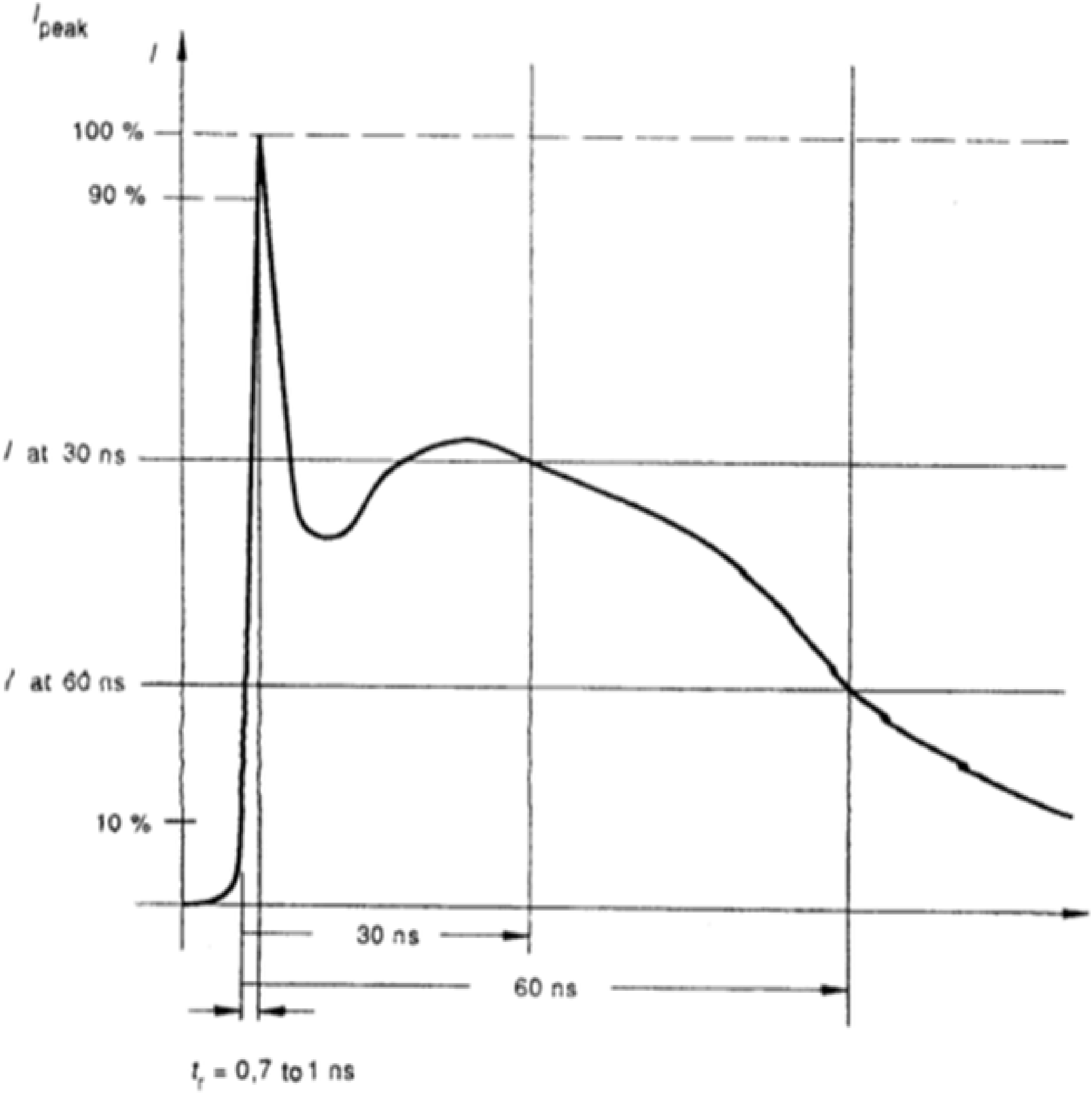


Figure 8-2 IEC61000-4-2 ESD Waveform Specification

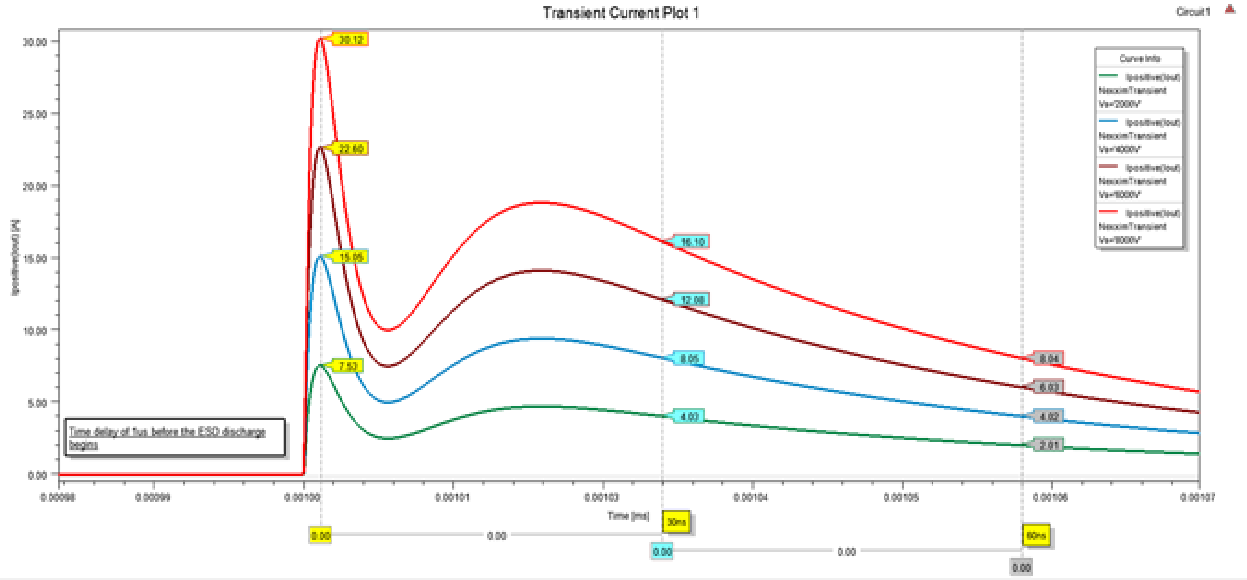


Figure 8-3 Simulation model results of calibration circuit (2Ω load)

Voltage (KV)	Peak Current (A) ±10%		Rise time (ns)		Current at 30ns (A) ±30%		Current at 60ns (A) ±30%	
	Standard	Model	Standard	Model	Standard	Model	Standard	Model
2	7.5	7.52	0.7-1	0.76	4	4.03	2	2.01
4	15	15.06	0.7-1	0.76	8	8.05	4	4.02
6	22.5	22.60	0.7-1	0.74	12	12.08	6	6.03
8	30	30.11	0.7-1	0.75	16	16.10	8	8.04

Simulation model results vs Standard specification for calibration test circuit.

Electrostatic Discharge (ESD) ISO 10605 Source for Automotive Electronic Modules and Vehicles

Electrostatic discharge (ESD) occurs when there is a sudden flow of electricity between two electrically charged objects caused by contact, an electrical short, or dielectric breakdown.

The ESD ISO 10605 source for automotive electronic modules and vehicles replicates the effect of an ESD event and models the ISO 10605 International Standard for road vehicles.

The ESD source is available in the Schematic Editor via the Component Libraries. It is implemented via a .SUBCKT instance. It does not have a netlist form.

The ESD source has two parameters:

VA – Sets the initial capacitor voltage on the metal tool and the human body

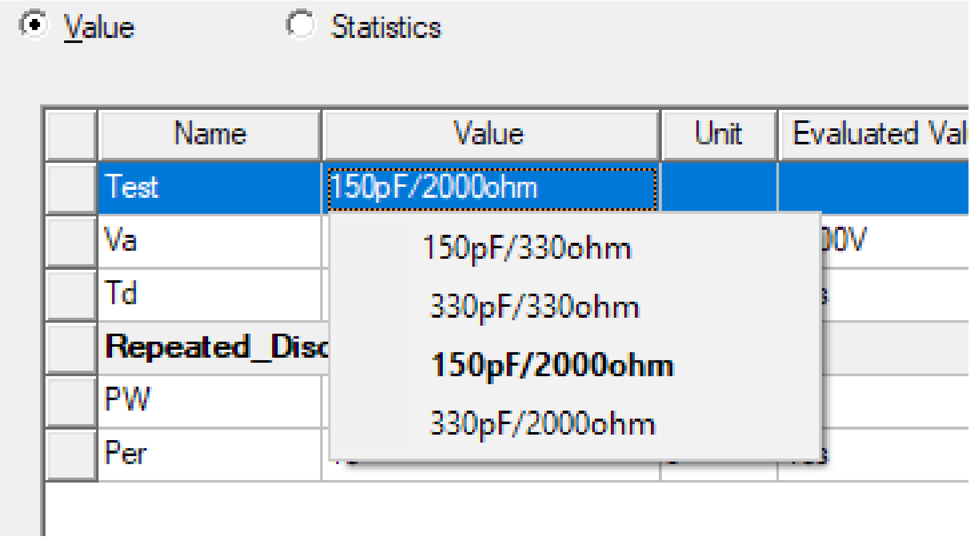
Td – Sets the time delay before ESD discharge begins.

PW – Sets length of time that ESD is discharged (in seconds).

Per – Sets the length of recharge between subsequent ESD discharges (in 10s intervals).

ESD_Out is the output node connected to the DUT and *Gnd*. It is the grounded node of the source.

As Shown in Electronics Desktop



● Value ○ Statistics

	Name	Value	Unit	Evaluated Val
	Test	150pF/2000ohm		
	Va			
	Td			
	Repeated_Disc			
	PW			
	Per			

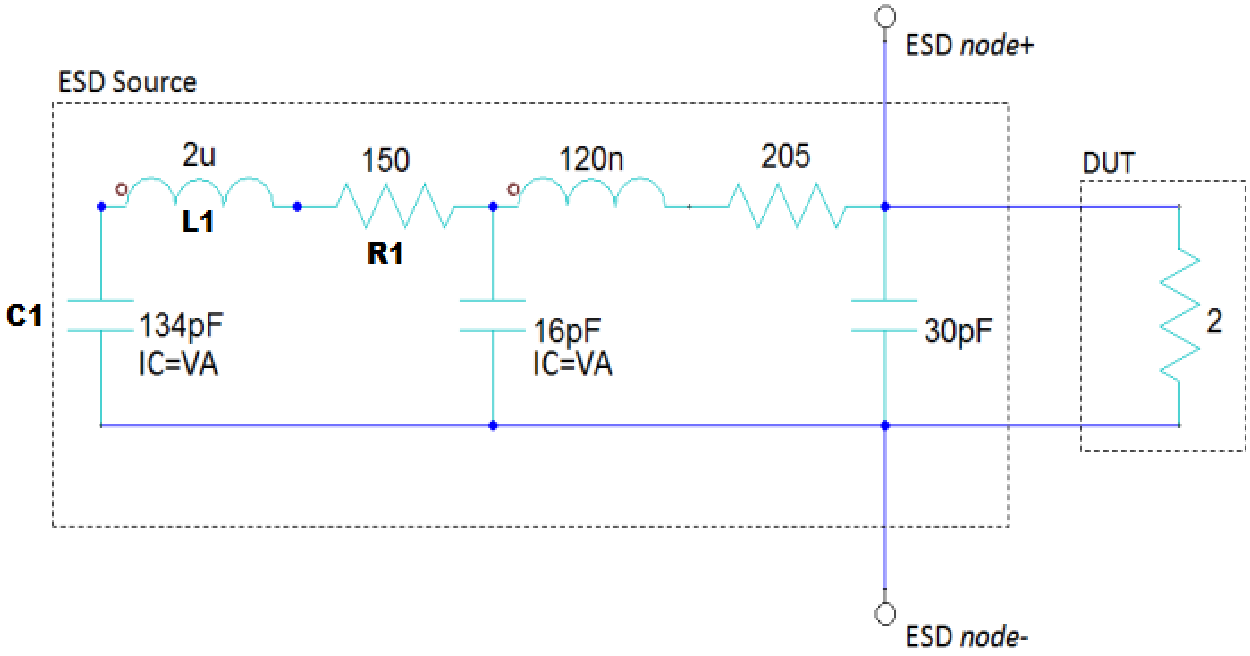
150pf/330ohm – c1=1.34e-10, R1=150, and L1=2e-6

330pf/330ohm – c1=3.54e-10, R1=130, and L1=2e-6

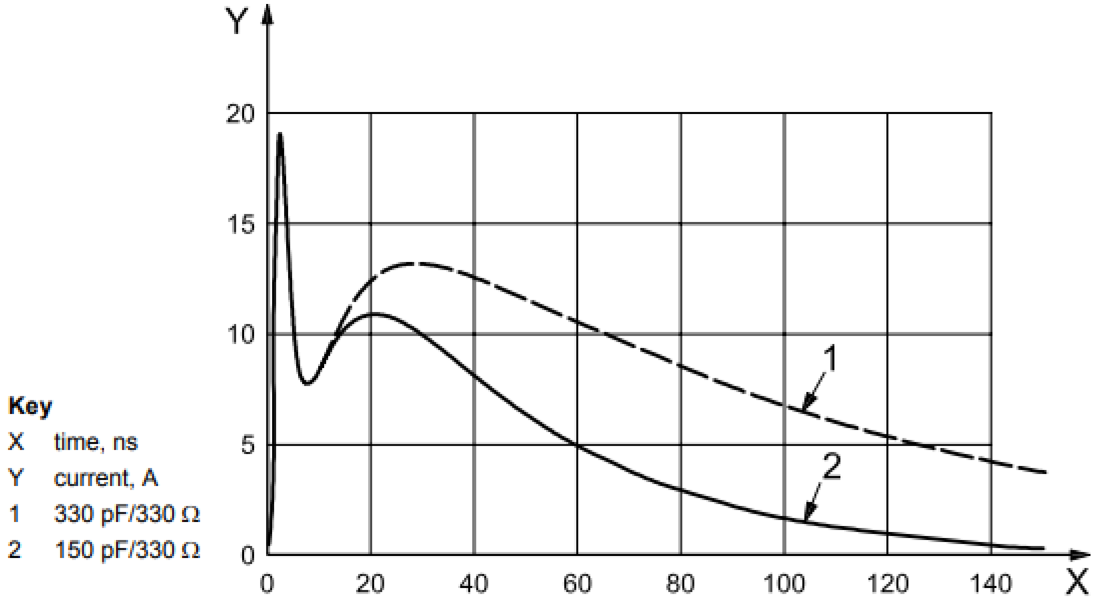
150pf/2kohm – c1=1.44e-10, R1=1850, and L1=10e-6

330pf/2kohm – c1=3.28e-10, R1=1850, and L1=10e-6

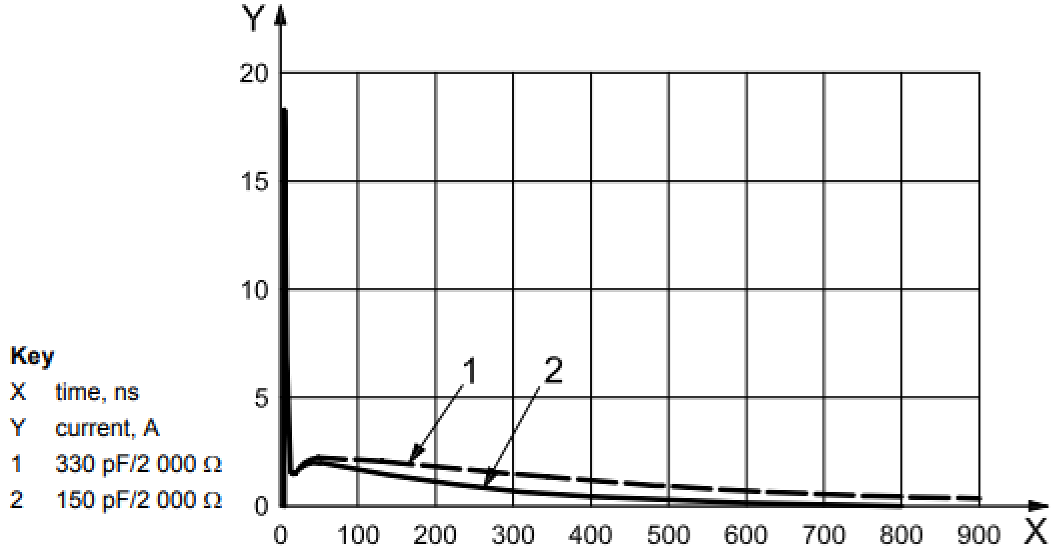
Positions in the circuit shown below


ESD node+
ESD Source
2u
L1
150
R1
120n
205
DUT
C1
134pF
IC=VA
16pF
IC=VA
30pF
2
ESD node-

From ISO 10605 International Standard

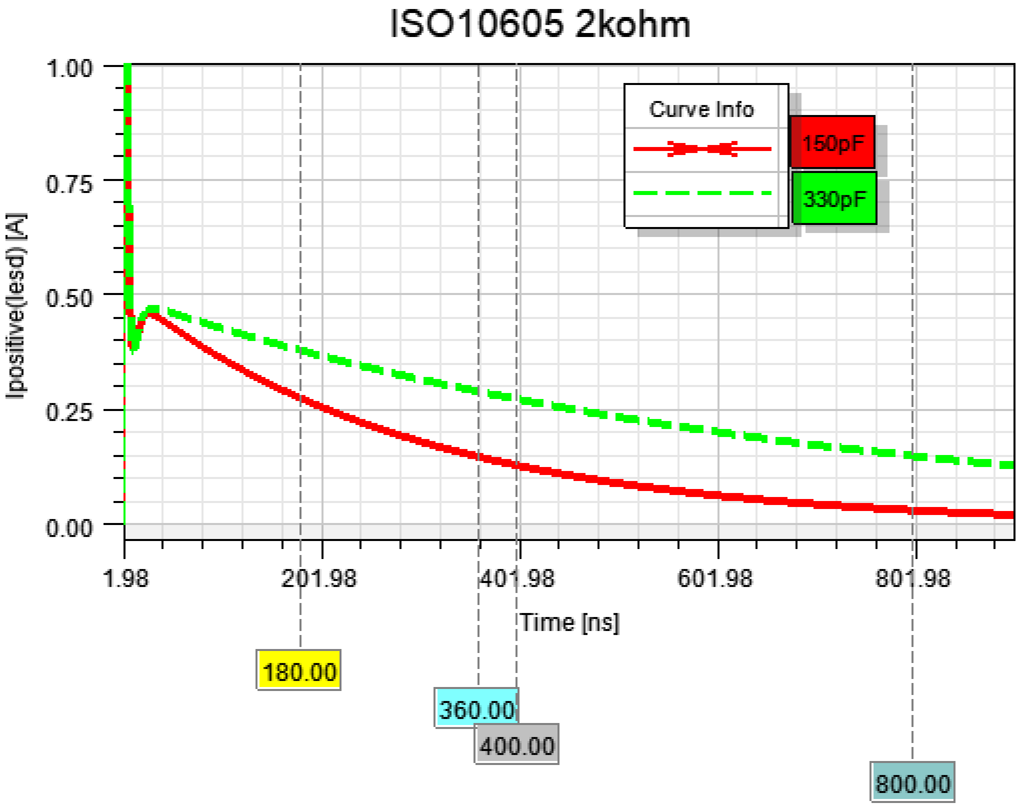


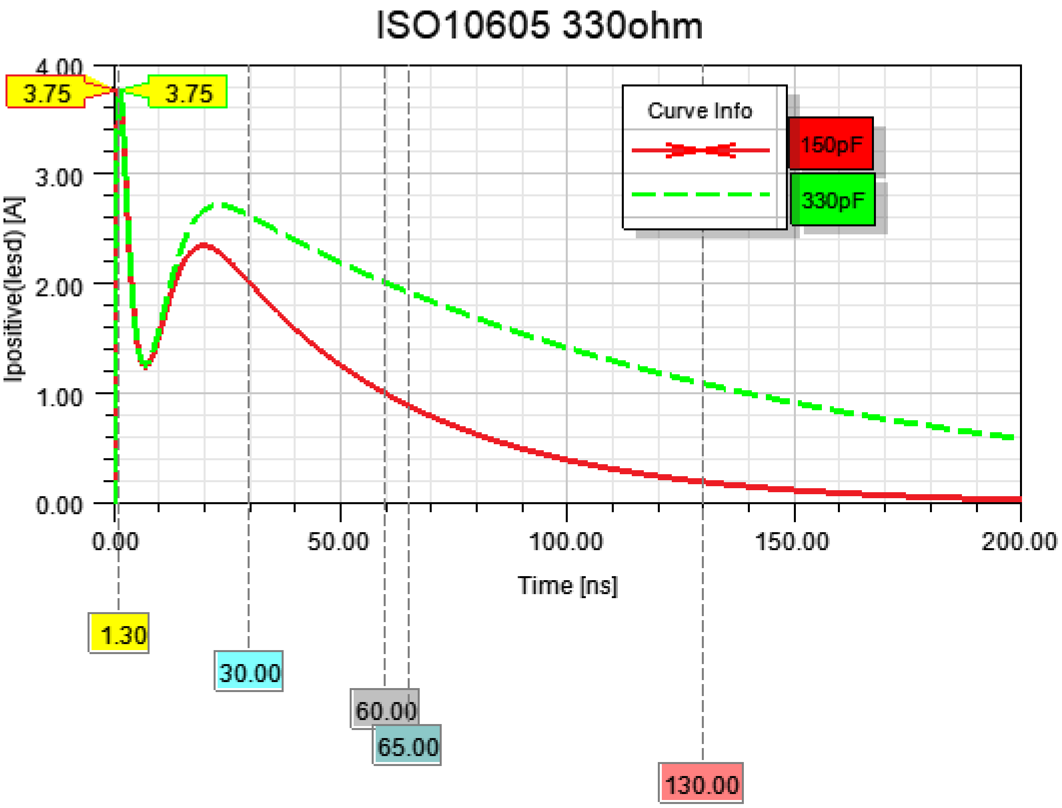
a) **For 150 pF/330 pF, 330 Ω and 5 kV**

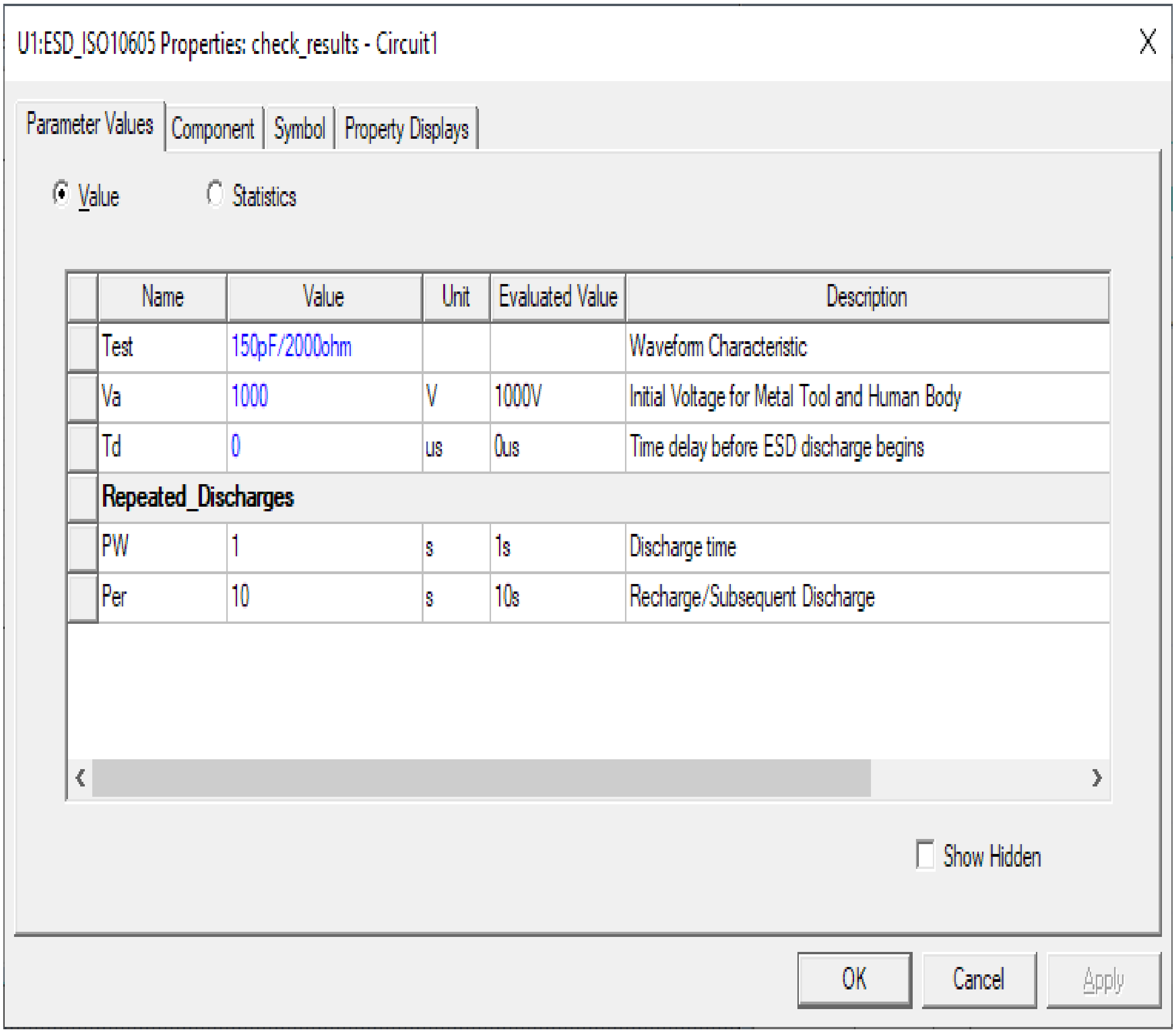


b) **For 150 pF/330 pF, 2 kΩ and 5 kV**

Simulated Results in Electronics Desktop




ISO10605 330ohm
Curve Info
150pF
330pF
3.75
3.75
Ipositive(Iesd) [A]
4.00
3.00
2.00
1.00
0.00
0.00
50.00
100.00
150.00
200.00
Time [ns]
1.30
30.00
60.00
65.00
130.00



Name	Value	Unit	Evaluated Value	Description
Test	150pF/2000ohm			Waveform Characteristic
Va	1000	V	1000V	Initial Voltage for Metal Tool and Human Body
Td	0	us	0us	Time delay before ESD discharge begins
Repeated_Discharges				
PW	1	s	1s	Discharge time
Per	10	s	10s	Recharge/Subsequent Discharge

> **Note:** When an external ESD generator supplies power (AC or DC) or is controlled by a separate unit and the cables are not bundled with the ESD generator discharge return cable, uncontrolled current can flow through the cables.

Electrostatic Discharge (ESD) Human-Body Model (HBM) Source with Delay

Electrostatic discharge (ESD) occurs when there is a sudden flow of electricity between two electrically charged objects caused by contact, an electrical short, or dielectric breakdown.

The ESD source with delay replicates the effect of an ESD event. The ESD_HBM_Delay source models the AEC Q101-001/AEC-Q100-002/JEDEC JS-001 Human Body Model standard.

The ESD source with delay is available in the Schematic Editor via the Component Libraries. It is implemented via a .SUBCKT instance. It does not have a netlist form.

The ESD source with delay has two parameters:

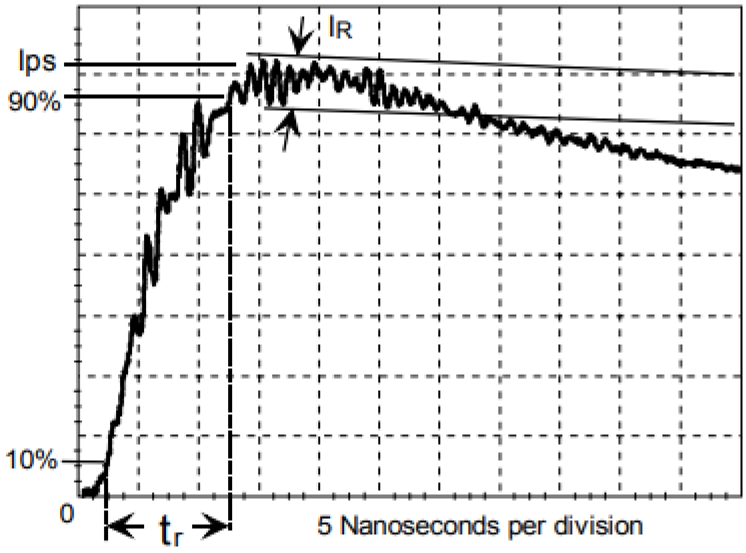
VA – Sets the initial capacitor voltage on the metal tool and the human body

Td – Sets the time delay before ESD discharge begins.

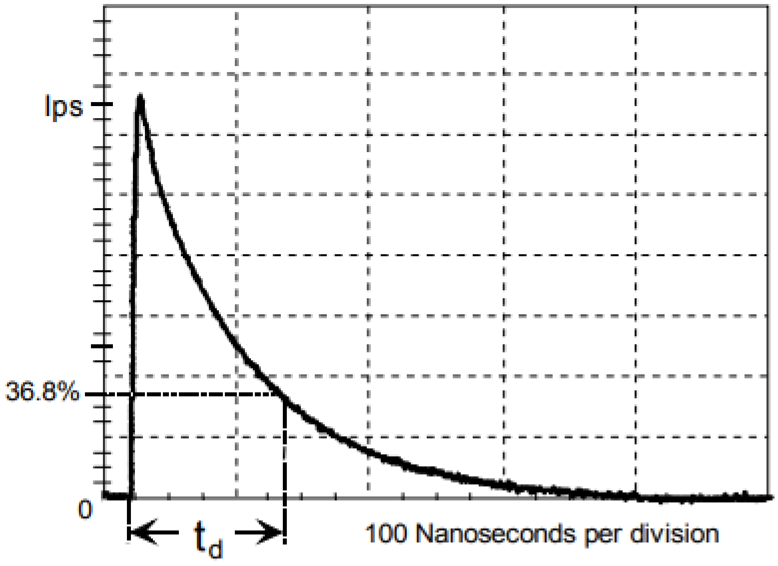
R – Repeat ESD discharge pulse(s). Set to '0' to enable. (default is *nan*)

ESD_Out is the output node connected to the DUT and *Gnd*. It is the grounded node of the source.

From AEC Q101-001 Human Body Model Standard

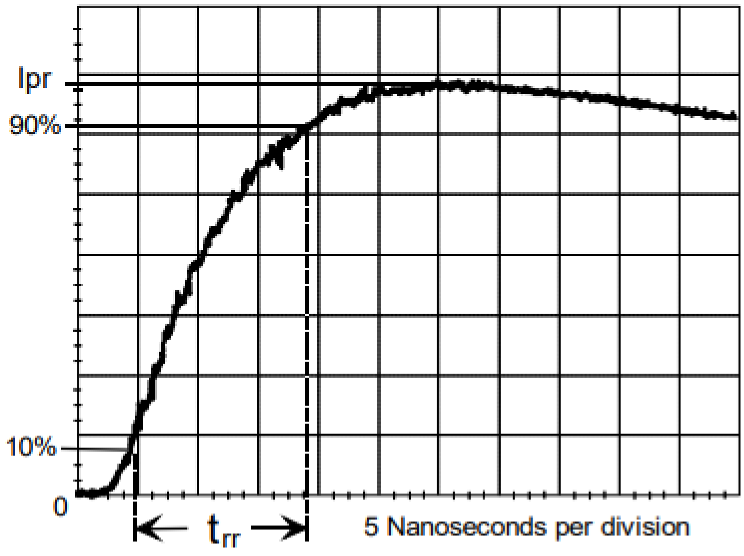


(a) Pulse rise time, (t_r)



(b) Pulse decay time, (t_d)

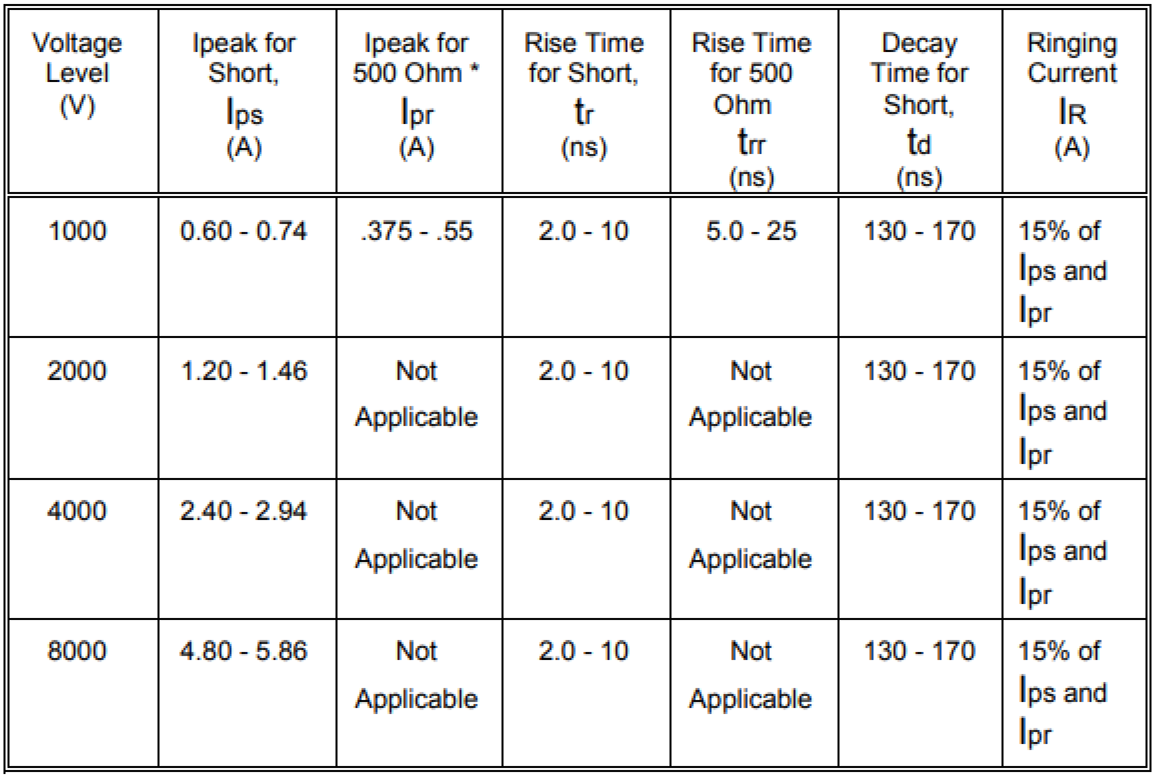
HBM Current Waveform through a Shorting Wire



(a) Pulse rise time, (t_{rr})

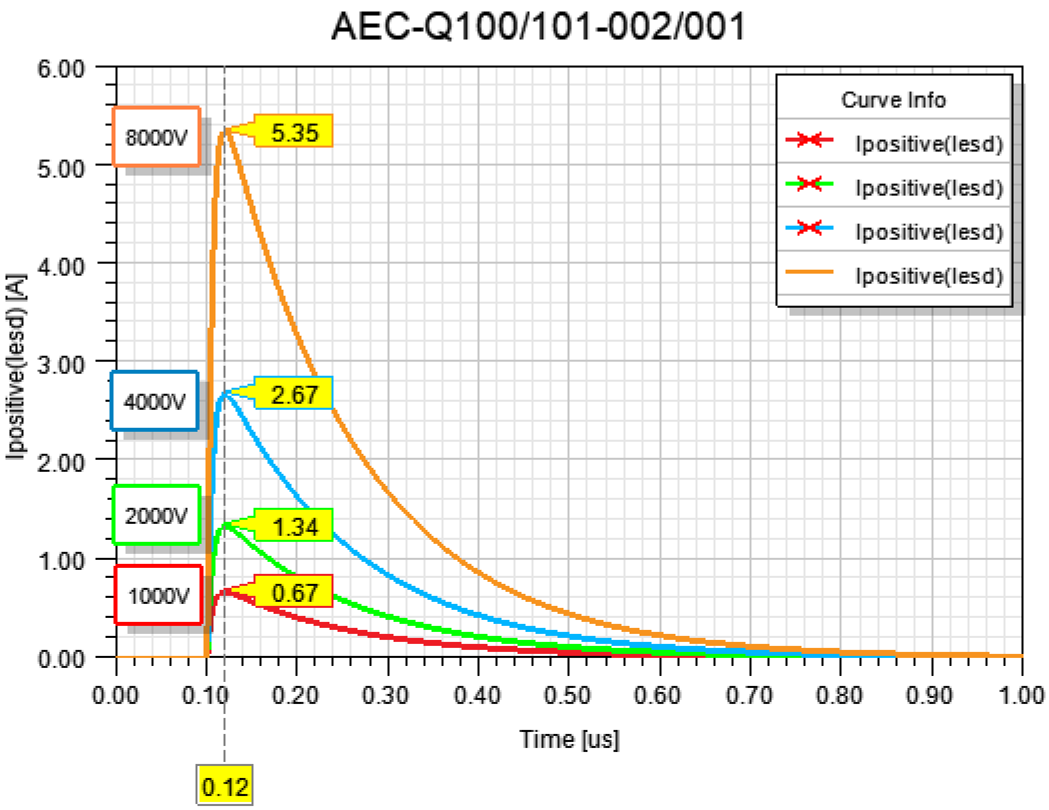
HBM Current Waveform through a 500 ohm Resistor

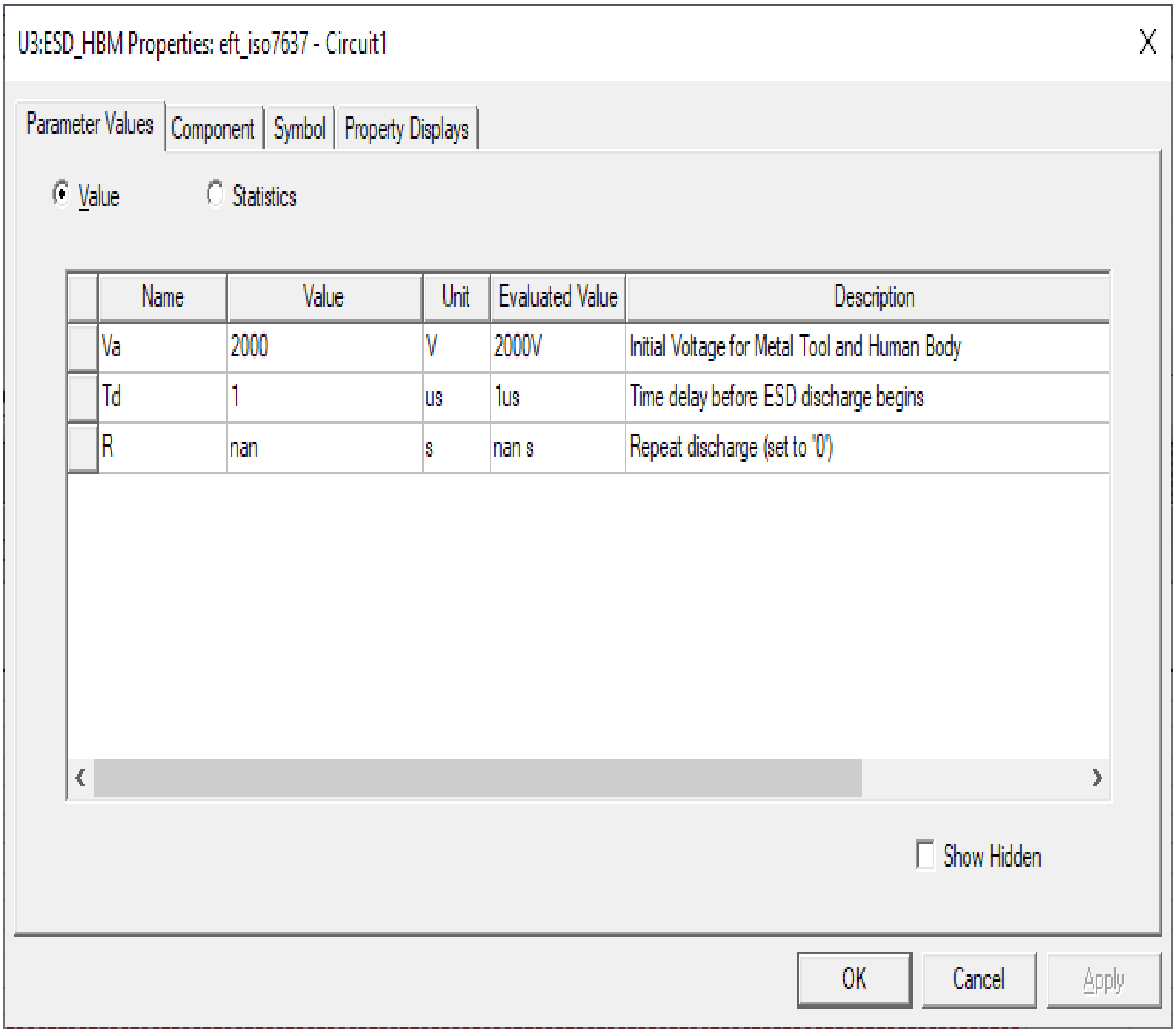
> **Note:** The 500 ohm load is only used during equipment qualification.



Voltage Level (V)	Ipeak for Short, I_{ps} (A)	Ipeak for 500 Ohm * I_{pr} (A)	Rise Time for Short, t_r (ns)	Rise Time for 500 Ohm t_{rr} (ns)	Decay Time for Short, t_d (ns)	Ringing Current I_R (A)
1000	0.60 - 0.74	.375 - .55	2.0 - 10	5.0 - 25	130 - 170	15% of I_{ps} and I_{pr}
2000	1.20 - 1.46	Not Applicable	2.0 - 10	Not Applicable	130 - 170	15% of I_{ps} and I_{pr}
4000	2.40 - 2.94	Not Applicable	2.0 - 10	Not Applicable	130 - 170	15% of I_{ps} and I_{pr}
8000	4.80 - 5.86	Not Applicable	2.0 - 10	Not Applicable	130 - 170	15% of I_{ps} and I_{pr}

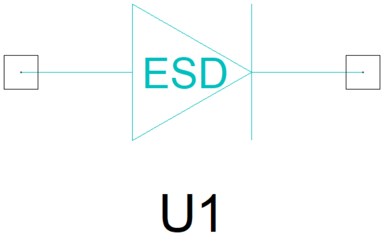
Simulated Results in Electronics Desktop





Name	Value	Unit	Evaluated Value	Description
Va	2000	V	2000V	Initial Voltage for Metal Tool and Human Body
Td	1	us	1us	Time delay before ESD discharge begins
R	nan	s	nan s	Repeat discharge (set to '0')

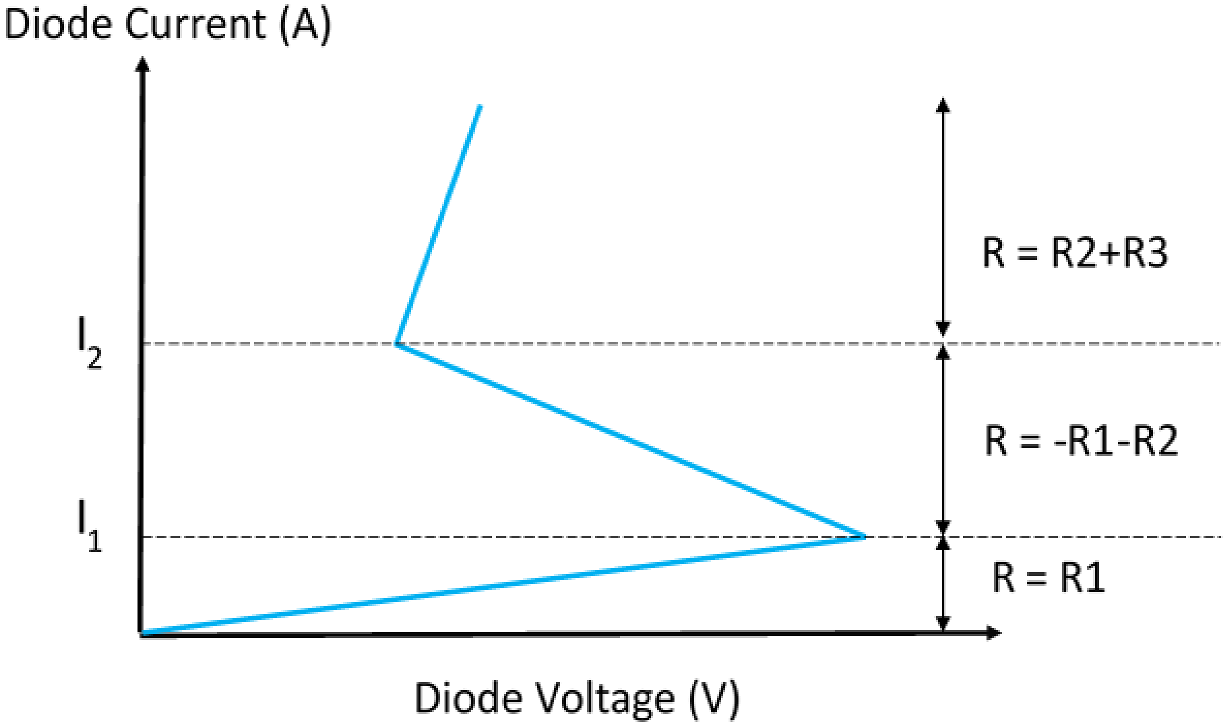
ESD Diode: Snapback Diode Model



The Snapback Diode model provides a simplified behavioral model of a transient voltage suppressor diode for ESD simulations. The model is built using idealized SPICE diode models, ideal current sources, and resistors.[1]

Table: Snapback Diode Model Parameters

Parameter	**Description**	**Default Value [Unit]**
I1	First breakdown threshold	0.008 [A]
I2	Second breakdown threshold	0.14 [A]
R1	Initial positive resistance	1000 [Ohm]
R2	Determines negative resistance region	50 [Ohm]
R3	Determines final positive resistance	1 [Ohm]



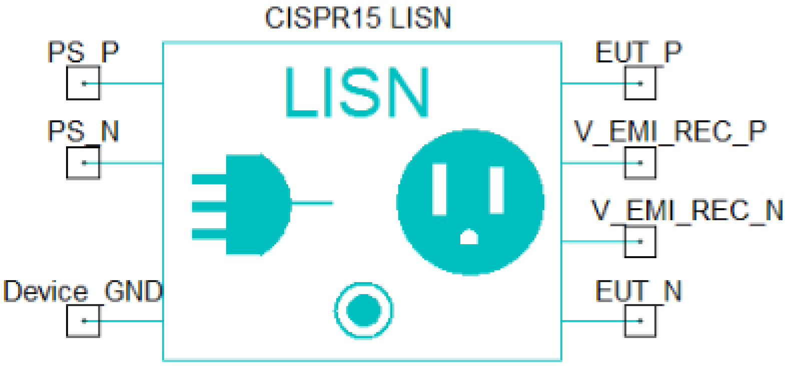
References

[1] Santoro, R.P., "Piecewise-linear modeling of I-V characteristics with SPICE," in Education, IEEE Transactions on , vol.38, no.2, pp.107-117, May 1995

Line Impedance Stabilization Networks (LISNs)

The Line Impedance Stabilization Network, or LISN as it is commonly called, is used for the measurement of conducted emissions on power lines.

The LISN sub-library represents the line impedance stabilization networks that are defined by various standards. All parameters follow the values given by the standards. The LISN sub-library contains the following list of components.



CISPR15_LISN: This model represents the 50 Ohm, 50 uH + 5 Ohm LISN circuit originated with VDE conducted emissions testing. It is also the LISN required for CISPR 15 testing of Luminaries. Compare to CISPR 16, it includes additional inductors and capacitors for filtering and has an operating frequency of 9 kHz - 30 MHz. In the symbol, pins PS_P and PS_N are the differential pins for the power supply connection, EUT_P and EUT_N are the differential pins for the unit under test, and V_EMI_REC_P and V_EMI_REC_N are the differential pins for the EMI Receiver Voltage (measurement ports for noise voltage).

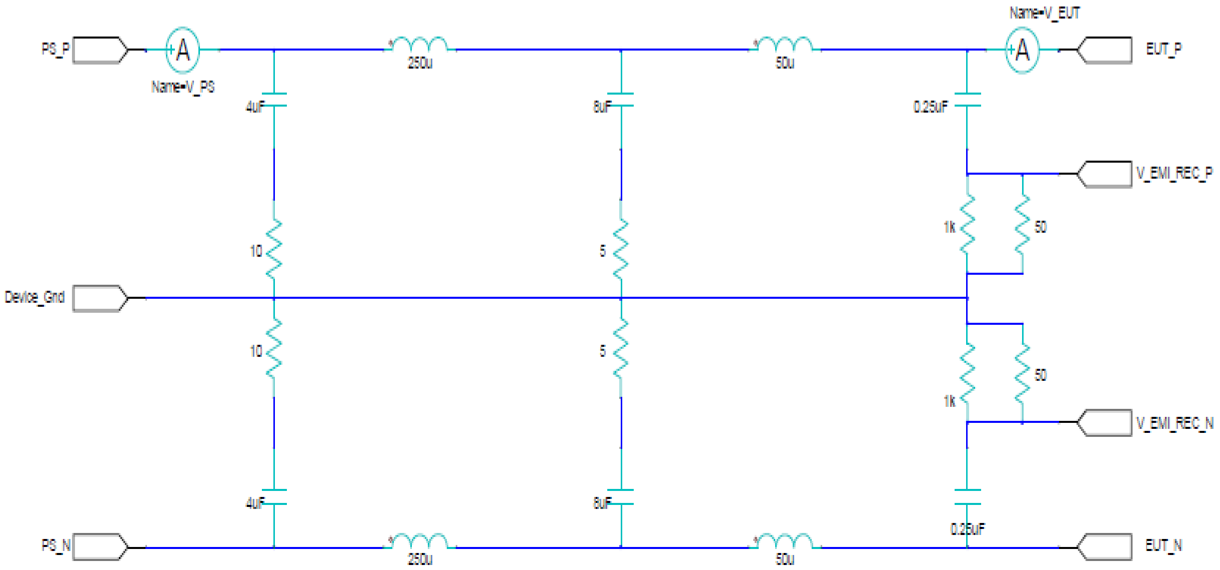
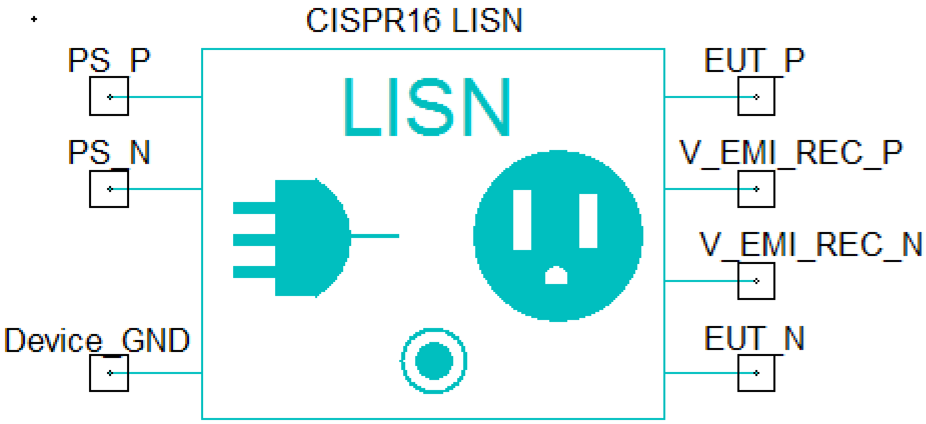


Figure: Schematic representation of the CISPR15_LISN



CISPR16_LISN: This model represents the 50 Ohm, 50 uH LISN circuit defined in CISPR 16-1-2. 2006. It has an operating frequency of 10kHz to 100MHz. In the symbol, pins PS_P and PS_N are the differential pins for the power supply connection, EUT_P and EUT_N are the differential pins for the unit under test, and V_EMI_REC_P and V_EMI_REC_N are the differential pins for the EMI Receiver Voltage (measurement ports for noise voltage).

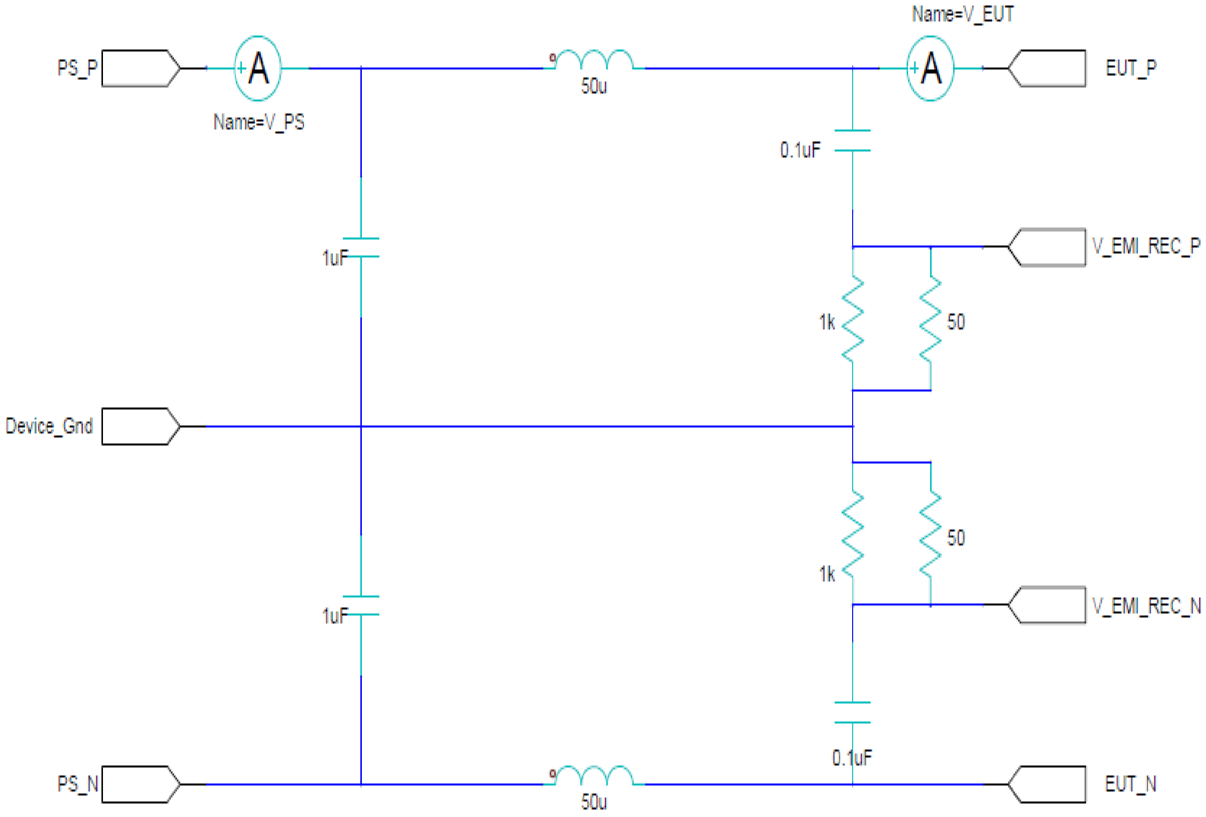


Figure: Schematic representation of the CISPR16_LISN

CISPR25_LISN: This model represents the LISN for use with frequency range from 0.1 MHz to 100 MHz, defined by standard CISPR-25 E.2, version 2008, with a 50 Ohm load included on the measurement. The EMI receiver voltage is provided instead of a measurement port. It has an operating frequency of 10kHz to 108MHz. In the symbol, pins PS_P is the pin for the power supply connection, EUT_Pis the pin for the unit under test, and V_EMIis the pin for the EMI Receiver Voltage (measurement ports for noise voltage).

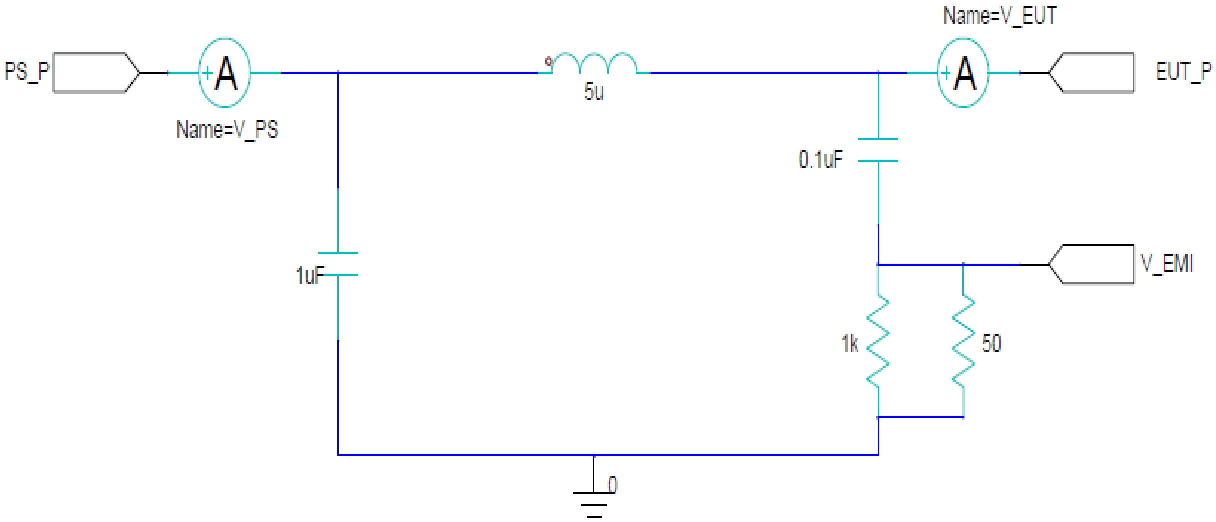
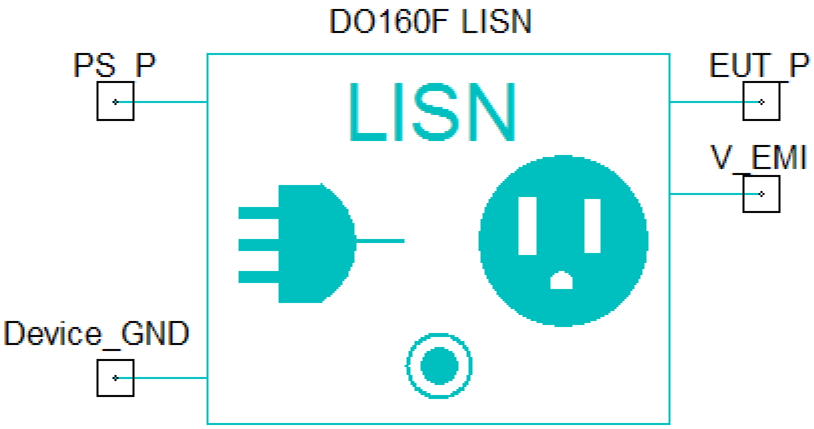


Figure: Schematic representation of the CISPR25_LISN



DO160F_LISN: This model represents the LISN for use with frequency range from 15 KHz to 400 MHz, defined by standard RTCA DO-160F. In the symbol, pins PS_P is the pin for the power supply connection, EUT_Pis the pin for the unit under test, and V_EMIis the pin for the EMI Receiver Voltage (measurement ports for noise voltage).

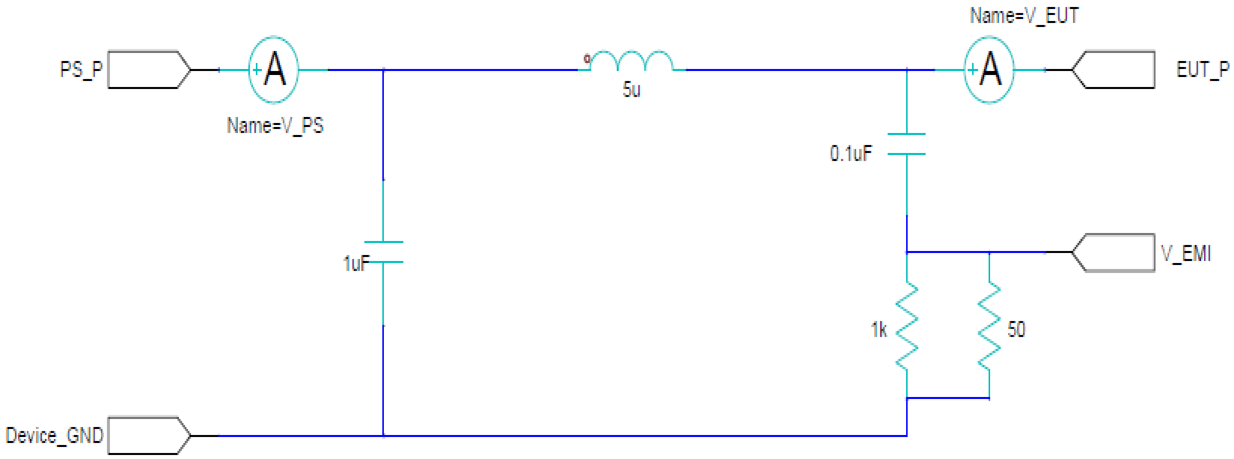
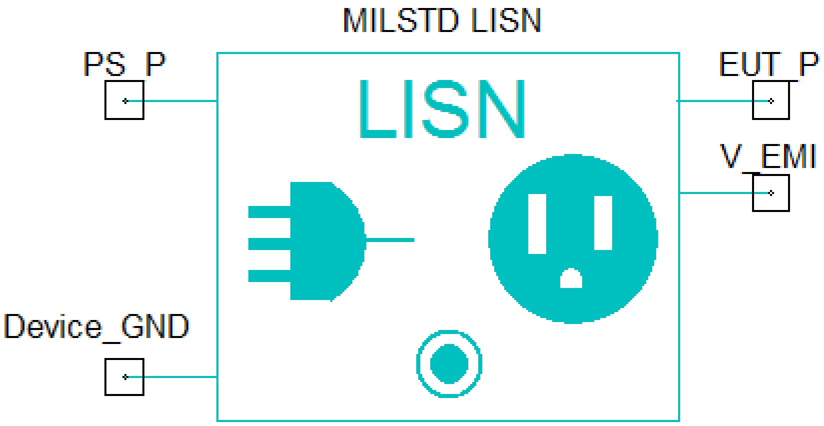


Figure: Schematic representation of the DO160F_LISN



MILSTD461F_LISN: This model represents the LISN for use with frequency range from 10 KHz to 10 MHz, defined by standard MIL-STD 461F Annex A-2. In the symbol, pins PS_P is the pin for the power supply connection, EUT_Pis the pin for the unit under test, and V_EMIis the pin for the EMI Receiver Voltage (measurement ports for noise voltage).

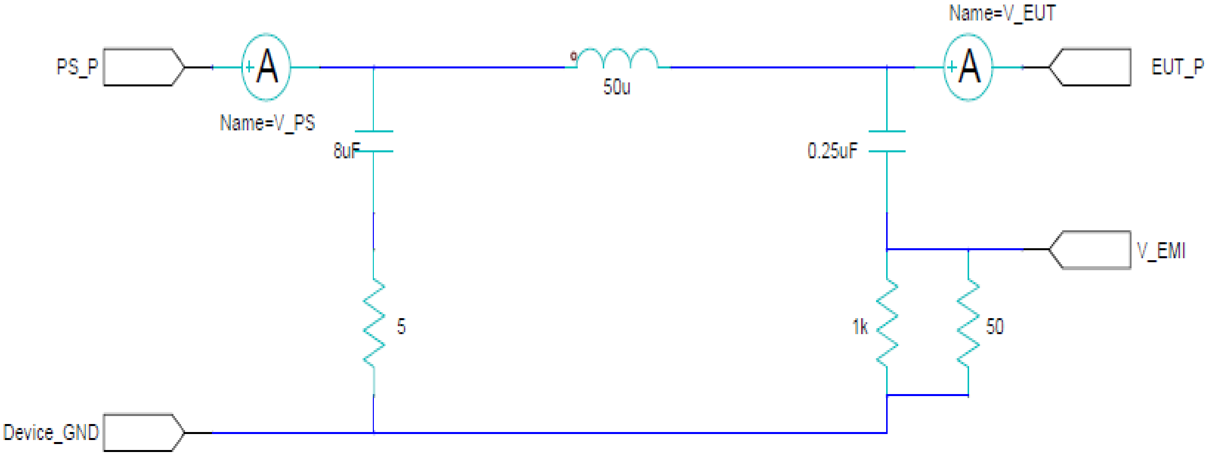
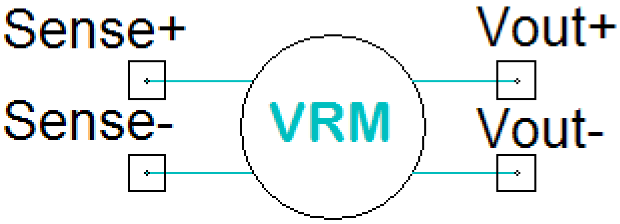


Figure 8-4 Figure: Schematic representation of the MILSTD461F_LISN

Voltage Regulator Module (VRM) Source with Remote Sense Line



A voltage regulator generates a fixed output voltage of a preset magnitude that attempts to remain constant regardless of changes to its input voltage or load conditions, taking current from a higher supply voltage and delivering it to loads at lower voltage.

The VRM source replicates the behavior of a VRM.

The VRM source is available in the Schematic Editor. It is implemented via a .SUBCKT instance. It does not have a netlist form.

The VRM source has three parameters:

VREF – Sets the reference voltage (default is 1.1V).

ILOAD – Sets the load current (default is 10A).

REG – Sets the load regulation specification (default is 0.001, or 0.1%).

Sense+ is the positive side of the remote sense line.

Sense- is the negative side of the sense line, typically grounded.

Vout+ is the positive side of the output.

Vout- is the negative side of the output, typically grounded.

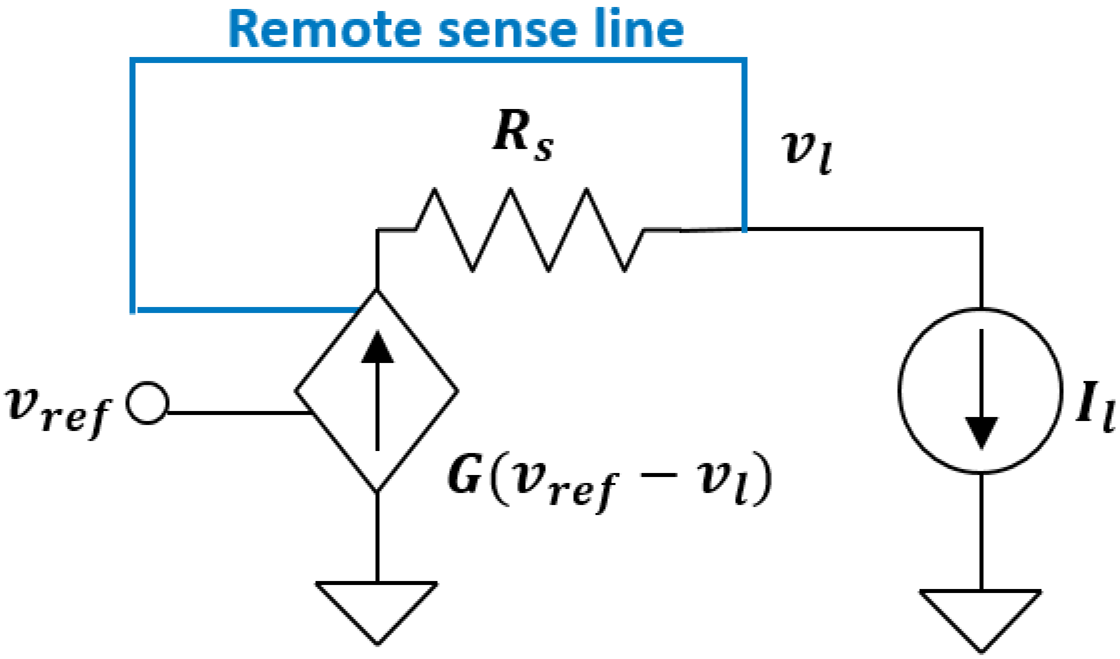


Figure: Schematic representation of the VRM Source

In this formulation,

$V_l = V_{ref} - I_l/G$,

where:

- V_l is the output voltage
- I_l is the load current
- V_{ref} is the reference voltag
- G is the factor by which output current increases/decreases per changes in output voltage

G is calculated on the parameters supplied:

G = (Load Current) / (V_{ref} x Load Regulation Spec)

Voltage Regulator Module (VRM) Source with Hard Current Limit

A voltage regulator generates a fixed output voltage of a preset magnitude that attempts to remain constant regardless of changes to its input voltage or load conditions, taking current from a higher supply voltage and delivering it to loads at lower voltage. The VRM with hard current limit functions to limit the output current using a controlled source with a PWL table.

The VRM source replicates the behavior of a Linear Regulator VRM.

The VRM source is available in the Schematic Editor. It is implemented via a .SUBCKT instance. It does not have a netlist form.

The VRM source has two parameters:

VREF – Sets the reference voltage (default is 1V).

ILOAD – Sets the hard current limit (default is 1A).

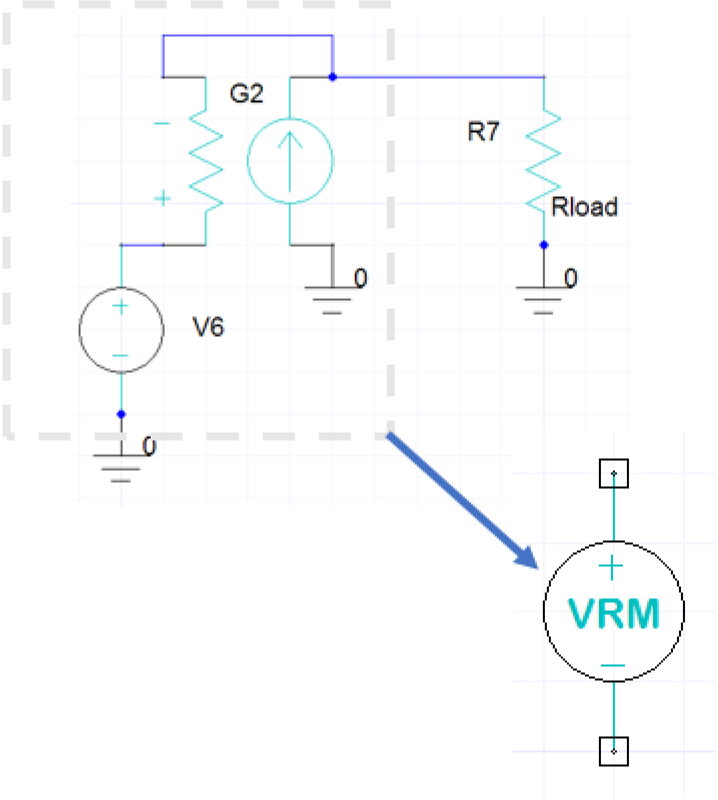


Figure: Schematic representation of the VRM Source

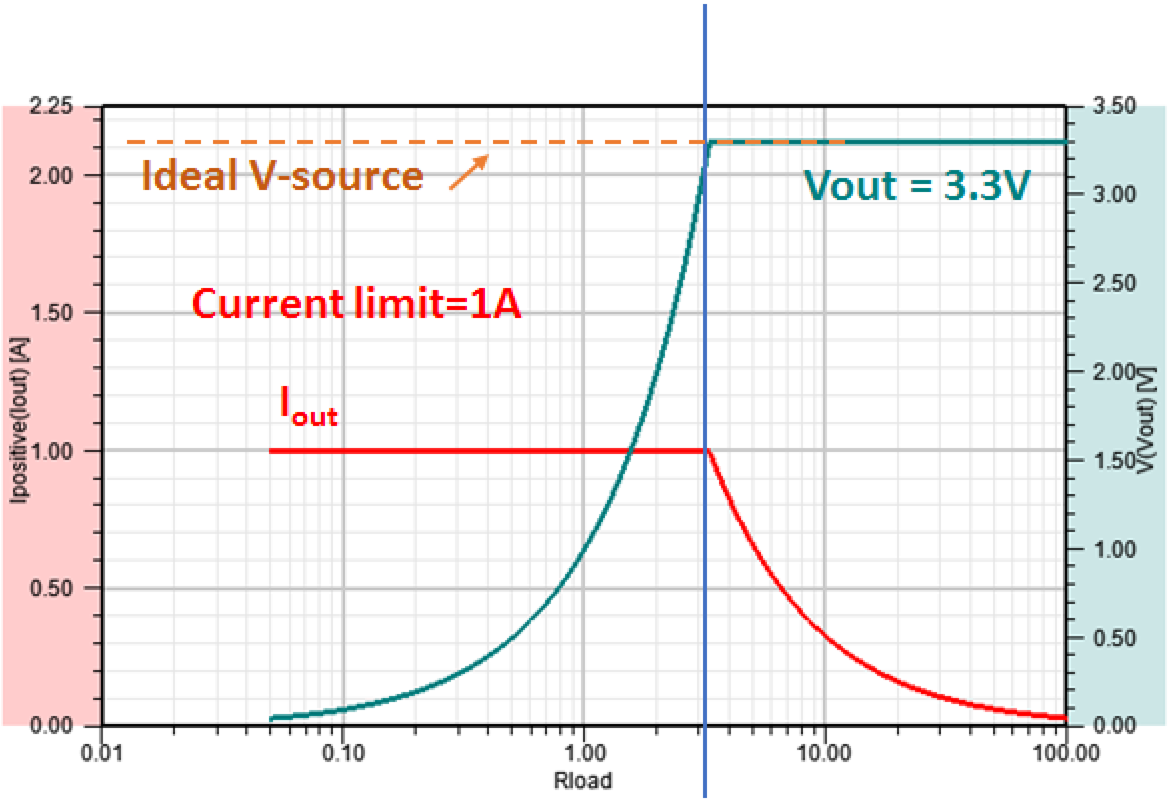


Figure: Current and Voltage characteristics versus load resistance

Lightning and Surge Sources

Lightning source can broadly be categorized into two main types:

- Indirect lightning EMP
- Direct Lightning Surge

For EMC tools, limit to the indirect lightning EMP as that allows us to measure the susceptibility of a device under test.

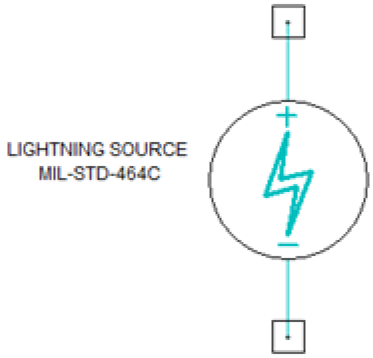
The component gives an option to choose between different types of lightning/surge standards based on the field of application. You could choose on the following standards:

- MIL-STD-464C
- IEC 62305-1
- IEEE C62.41

MIL-STD-464C

MIL-STD-464C is the Department of Defense standard for EMI

This standard establishes electromagnetic environmental effects (E3) interface requirements and verification criteria for airborne, sea, space, and ground systems, including associated ordnance. Unintentional intelligence-bearing signals which, if intercepted and analyzed, disclose the national security information transmitted, received, handled, or otherwise processed by any classified information processing system.



The MIL-STD-464C source has two parameters:

Current component - Allows you to choose between the type of waveform based on the lightning stroke

Delay Time 'T_delay' - Time before the component turns on

Mathematical representation:

$$I = Io \times \left[\left(e^{-\alpha t}\right) - \left(e^{-\beta t}\right)\right]$$

The following figure provides aspects of the lightning environment that are relevant for protection against direct effects.

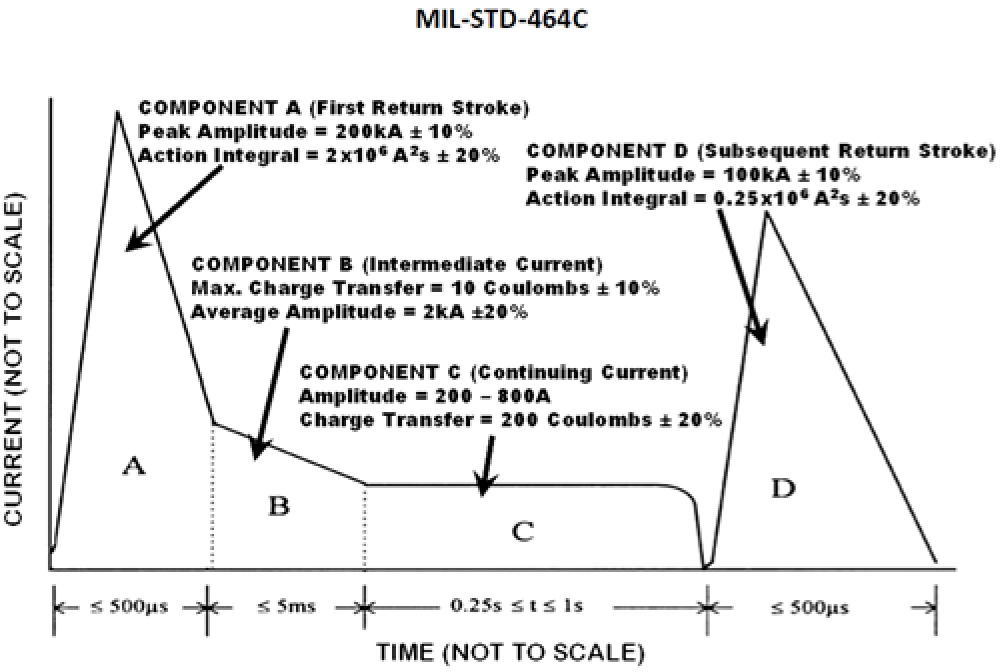
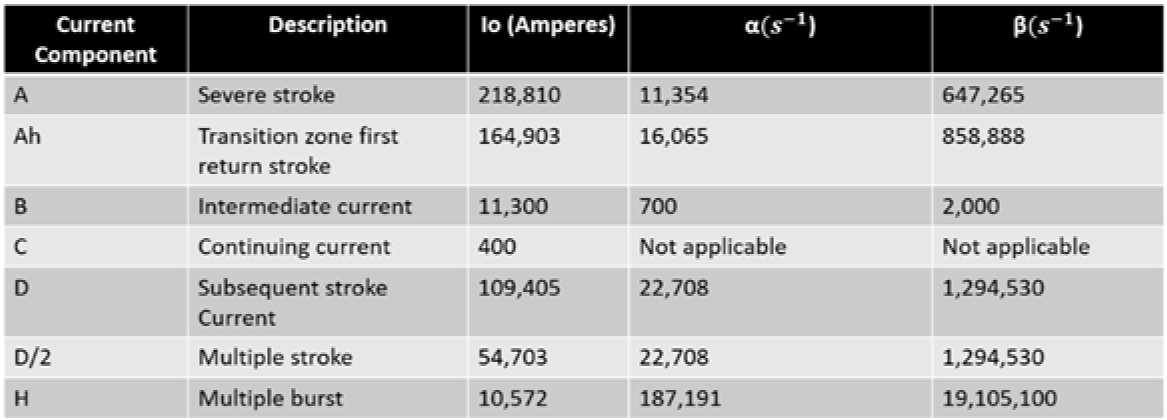


Figure 8-5 Waveforms defined in MIL-STD-464C



Current Component	Description	Io (Amperes)	$\alpha(s^{-1})$	$\beta(s^{-1})$
A	Severe stroke	218,810	11,354	647,265
Ah	Transition zone first return stroke	164,903	16,065	858,888
B	Intermediate current	11,300	700	2,000
C	Continuing current	400	Not applicable	Not applicable
D	Subsequent stroke Current	109,405	22,708	1,294,530
D/2	Multiple stroke	54,703	22,708	1,294,530
H	Multiple burst	10,572	187,191	19,105,100

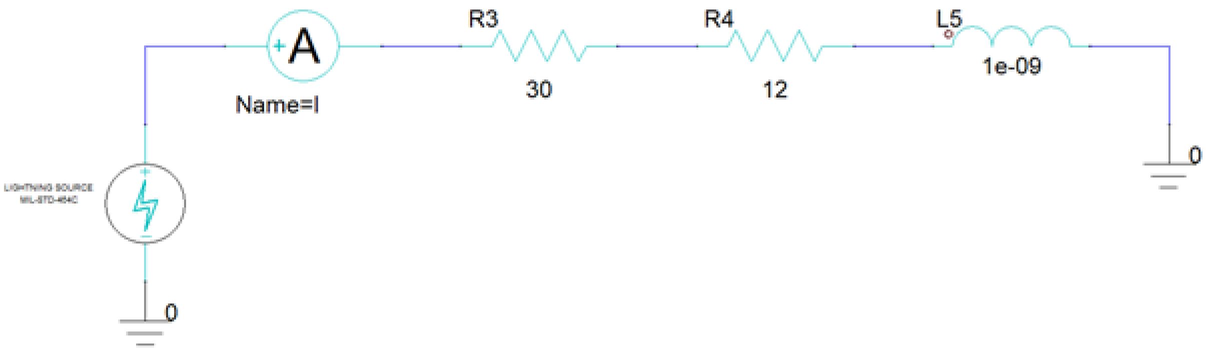


Figure 8-6 Test circuit for MIL-STD-464C

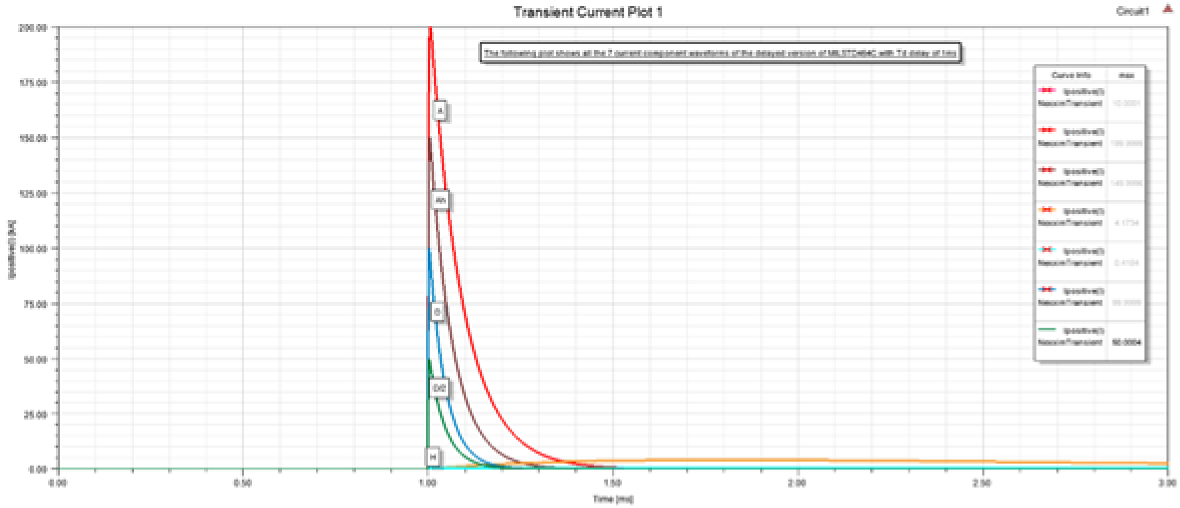
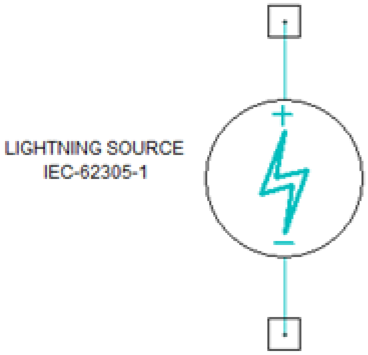


Figure 8-7 Output of test circuit for MIL-STD-464C

IEC 62305-1



The IEC 62305-1 source has four parameters:

Ioff - Offset current

Impulse type - First positive, first negative, or subsequent negative.

Protection Level - It is a number related to a set of lightning parameters

'Tdelay' - Time before the component turns on

IEC 62305 provides general principles to be followed for protection of structures against lightning, including their installations and contents, and persons.

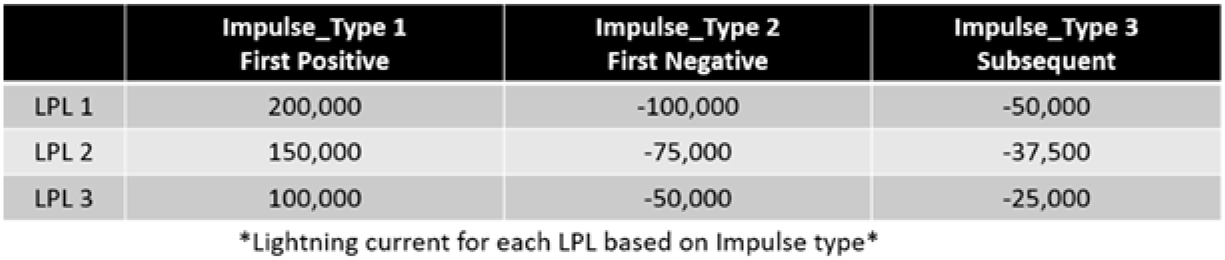
Mathematical representation of IEC 62305-1:

$$I = I\text{off} + \left(\frac{I\max}{k1} \times \left(\frac{\left(\frac{t}{t1}\right)^{10}}{1+\left(\frac{t}{t1}\right)^{10}} \right) \times e^{-\frac{t}{t2}} \right)$$

Lightning protection level LPL: It is a number related to a set of lightning parameters. Each level has a fixed set of maximum and minimum lightning current parameters. The lightning protection levels are:

LPL 1, LPL 2, LPL 3 or LPL4.

LPL 1 offers the highest protection level, with LPL 3 or 4 offering the lowest level



	Impulse_Type 1 First Positive	Impulse_Type 2 First Negative	Impulse_Type 3 Subsequent
LPL 1	200,000	-100,000	-50,000
LPL 2	150,000	-75,000	-37,500
LPL 3	100,000	-50,000	-25,000

Lightning current for each LPL based on Impulse type

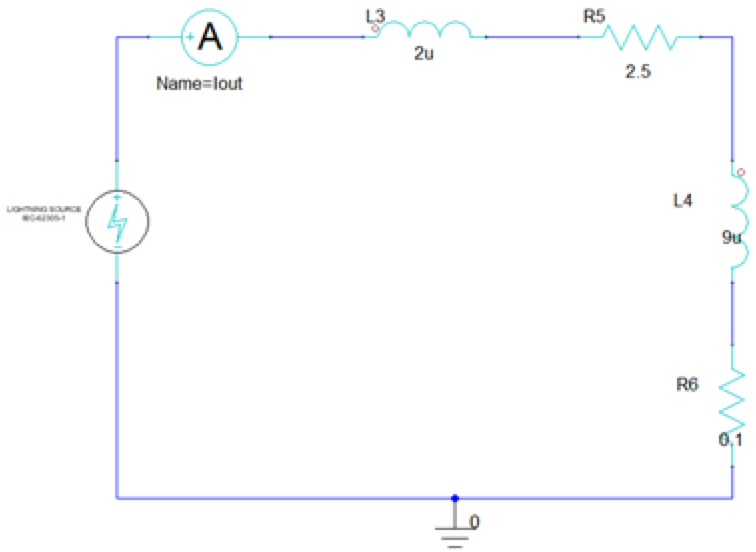


Figure 8-8 Test circuit for IEC 62305-1

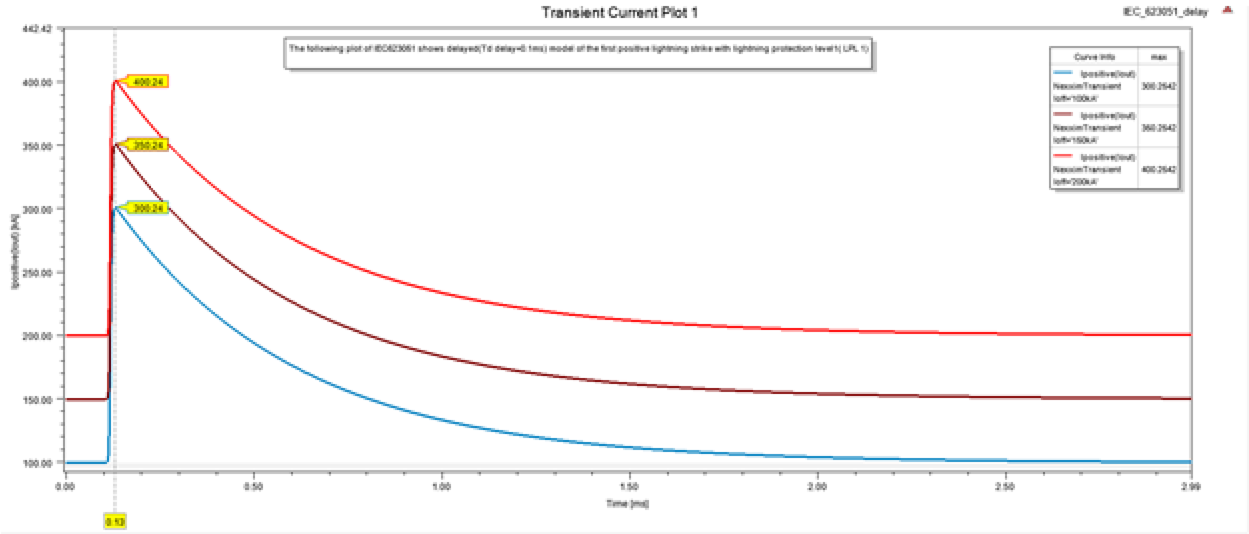
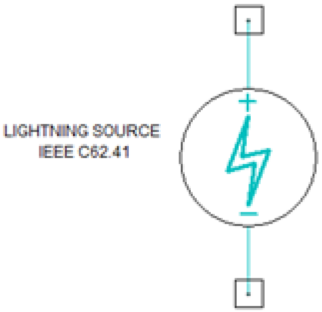


Figure 8-9 Output of test circuit for IEC62305-1

IEEE C62.41



The IEEE C62.41 source has five parameters:

Vpk - Peak voltage 200kV (default)

Rise time ‘t1’ - Rise Time (10% - 90%) 0.533us (default)

Fall time ‘t2’ - Fall Time (100% - 50%) 9.788 us(default).

Angular acceleration ‘w’ - 225000 rad_per_sec^2.

Delay Time ‘Tdelay’ - Time before the component turns on

ANSI/IEEE C62.41 defines the three exposure levels that characterize the rate of surge occurrence versus voltage level at an unprotected site as follows:

Low: Geographic locations where lightning activity is known to be low, and little load switching is anticipated.

Medium: Geographic locations where medium to high lightning activity is expected, significant load switching is anticipated, or both.

High: Geographic locations where surges greater than those defined as low or medium are expected.

Mathematical expression:

$$V = A \times Vpk \times \left(1 - e^{-\frac{t}{t1}}\right) \times \left(e^{-\frac{t}{t2}}\right) \times (\cos \omega t)$$

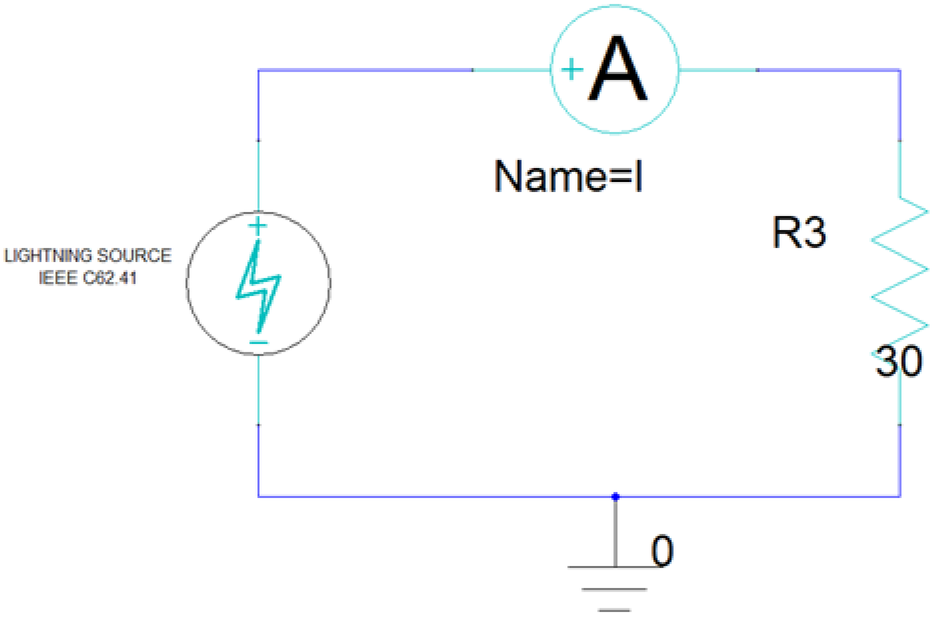


Figure 8-10 Test circuit for IEEE C62.41

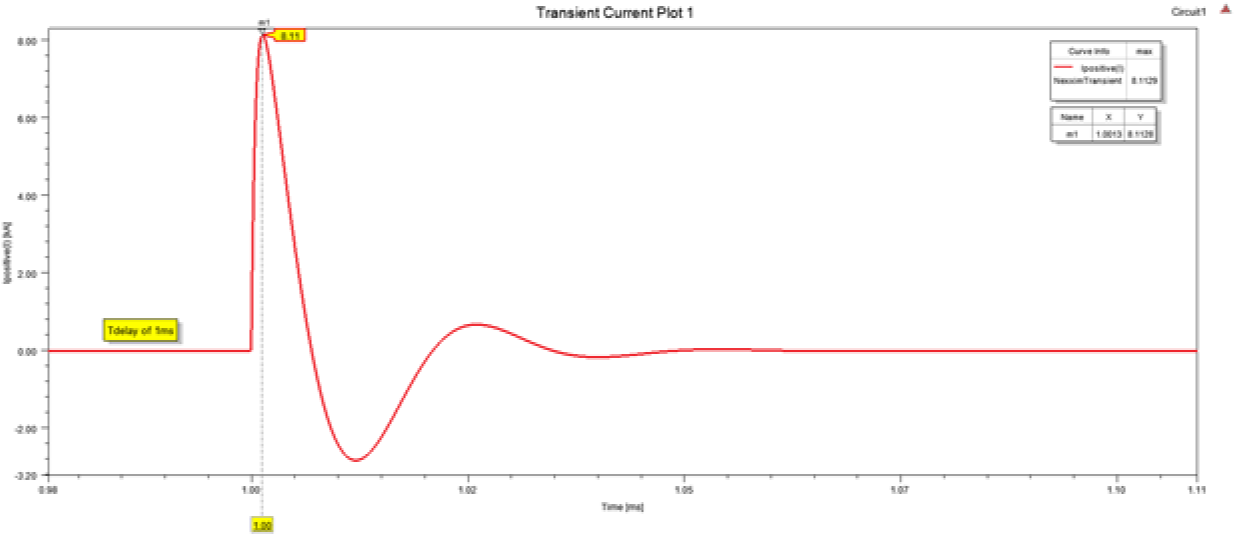


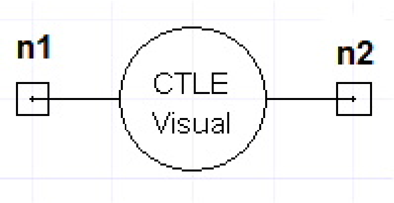
Figure 8-11 Output of test circuit for IEEE C62.41

9 - Equalizers

This topic describes the following equalizer elements:

"CTLE Visualization" below

CTLE Visualization



CTLE Visualization Instance Netlist Syntax

The Continuous-Time Linear Equalization (CTLE) visualization element allows you to preview the waveform generated for a given CTLE setting during QuickEye or VerifEye analysis. The syntax for a CTLE visualization instance is:

```
ACTLExxxxn2 n2ref n1 n1ref internal p1=val p2=val z=val
gain=val file="file_reference" reltol=val   tf_num=val
numerator=[a0 ...] denominator=[b0 ...] poles=[pole1 ... ]
zeros=[zero1 ... ] ac_gain=val
```

```
COMPONENT=ctle
```

n1 is the input node, *n2* is the output node of the equalizer. *n1ref* and *n2ref* are the reference nodes for the input and output, respectively, and are typically grounded (node 0). The **internal** node is required, and should not be connected to any signal or ground. The entry **COMPONENT=ctle** identifies the device.

Refer to *Continuous Time Linear Equalization* in the QuickEye and VerifEye Technical Notes for details.

Table 1: CTLE Visualization Instance Parameters

Parameter	Description	Unit	Default
p1	CTLE pole 1 frequency. (Enables p1, p2, z, and gain as CTLE data source. See Note 1.)	Hz	0
p2	CTLE pole 2 frequency	Hz	0

Parameter	Description	Unit	Default
z	CTLE zero pole frequency	Hz	0
gain	DC Gain	dB	0
file	File name for the CTLE transfer function data. (Enables CTLE file, reltol, and tf_num as CTLE data source. See Note 1.)	None	None
reltol	Target fitting error for the fit of the transfer function data	None	1e-2
tf_num	Select one transfer function from a file containing multiple transfer functions. With the default value of 0, Nexxim tries each transfer function on the file, selecting the one that yields the maximum eye height. If **tf_num** is less than zero or greater than the number of functions in the file, an error occurs.	None	0
numerator	Vector of coefficients for the numerator of the rational polynomial. (Enables numerator and denominator as CTLE data source. See Note 1.)	None	None
denominator	Vector of coefficients for the denominator of the rational polynomial. (Order of the denominator must be >= the order of the numerator.)	None	None
poles	Vector of pole frequencies. (Enables poles, zeros, gain, and ac_gain as CTLE data source. See Note 1.)	Hz	None
zeros	Vector of zero frequencies (number of zero frequencies must be less than the number of pole frequencies)	Hz	None
ac_gain	High-frequency peak gain (maximum value of transfer function)	dB	0

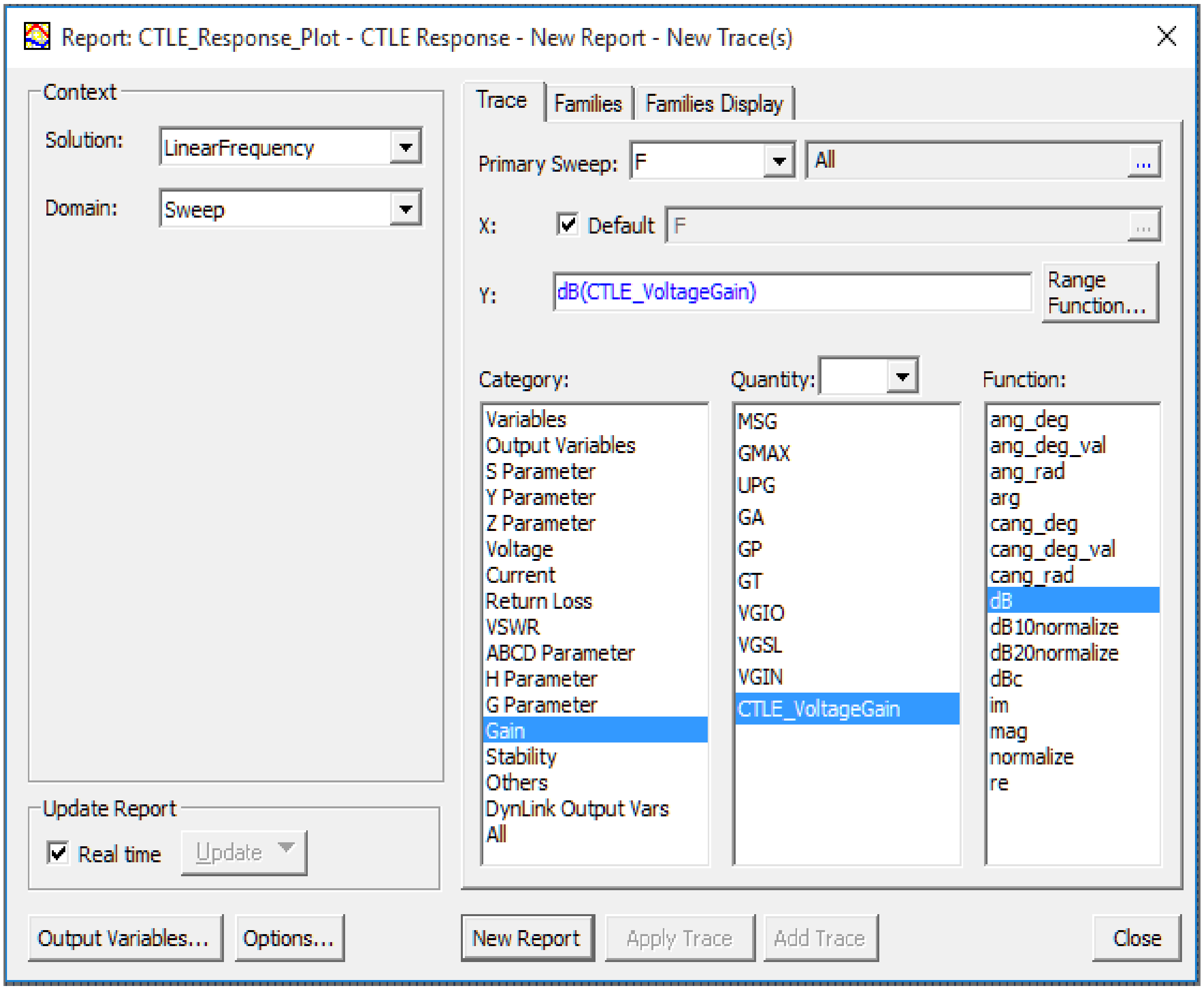
CTLE Visualization Element Netlist Example

```
ACTLE1 out 0 in 0 internal p1=1950000000 p2=5000000000
z=650000000 gain=-3.5175 COMPONENT=ctle
```

Notes

1. If there are multiple sources of CTLE data present in the netlist, the order of precedence is:
   (**file**, **reltol**, **tf_num**) > (**numerator**, **denominator**) > (**poles**, **zeros**, **gain**, **ac_gain**) > (**p1**, **p2**, **z**, **gain**)
2. The defaults for the legacy instance parameters **p1**, **p2**, and **z** indicate that they are not set. For example: for USB3.1, Gen1, and long channel, they should be set to **p1** =1.95GHz, **p2** =5GHz, and **z** =650MHz. Also set **gain** =-3.5175dB.

3. Set up and run a linear network analysis (LNA) for the frequency range of interest.
4. Create a standard rectangular report from the **LNA** Solution, **Sweep** domain, using **Gain** as the **Category**, **CTLE_VoltageGain** as the **Quantity**, **dB** as the **Function**, and **All** Frequencies as the **Primary Sweep**.



Report: CTLE_Response_Plot - CTLE Response - New Report - New Trace(s)

Context

Solution: LinearFrequency

Domain: Sweep

Primary Sweep: F All

X: ☑ Default F

Y: dB(CTLE_VoltageGain)

Category: Gain

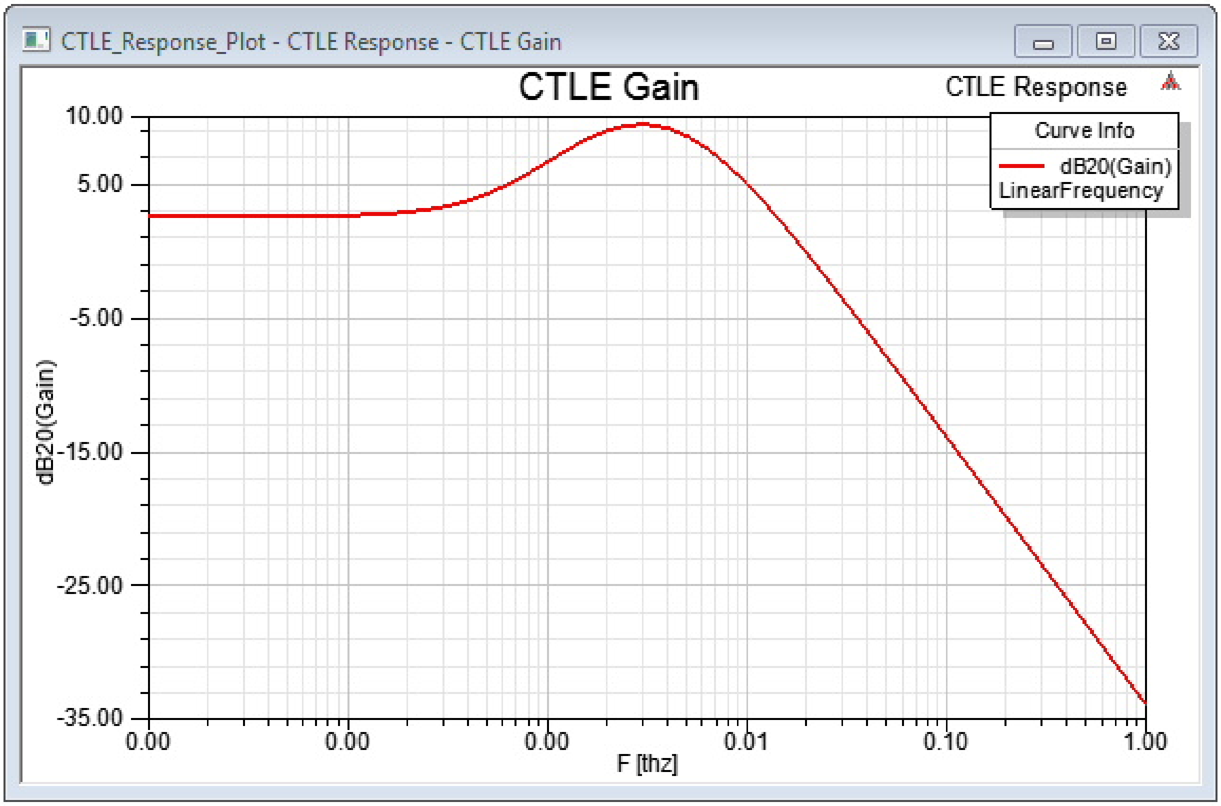
Quantity: CTLE_VoltageGain

Function: dB

Update Report

☑ Real time

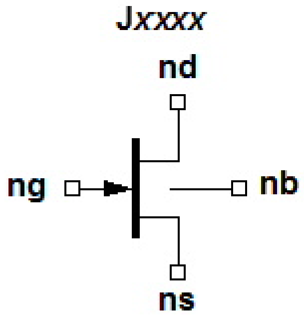
When the report opens, click horizontal axis (Frequency), open the axis properties window **Scaling** tab and select **Log** scaling.


CTLE_Response_Plot - CTLE Response - CTLE Gain
CTLE Gain
CTLE Response
Curve Info
dB20(Gain)
LinearFrequency
10.00
5.00
-5.00
-15.00
-25.00
-35.00
dB20(Gain)
0.00
0.00
0.00
0.01
0.10
1.00
F [thz]

10 - FETs (JFETs and MESFETs)

This topic describes the JFETs, MESFETs, GaAsFETs, and HEMTs:

JFET Instance, SPICE Model (Level 1)



SPICE JFET Instance Netlist Syntax

The netlist syntax for a SPICE model JFET Level 1 instance is:

```
Jxxxx nd ng ns [nb] modelname
[area_specification]
[M= val] [DTEMP= val]
```

nd is the drain node, *ng* is the gate node, *ns* is the source node and *nb* is the base or substrate node of the transistor. The *modelname* is the name of a JFET Level 1 model defined in a .MODEL statement elsewhere in the netlist.

The *area_specification* is one of the following entries:

```
[[AREA=]area]
```

or

`[`**`W=`**_`width`_`] [`**`L=`**_`length`_`]`

Table 32: JFET/MESFET Instance Parameters

Instance Parameter	Description	Unit	Default
AREA	Area factor	None	1.0
DTEMP	Difference between transistor and circuit temperatures	°C	0
L	FET gate length	Meter	0.0
M	Multiplier to simulate multiple devices in parallel	None	1.0
W	FET gate width	Meter	0.0

SPICE JFET Instance Netlist Example

```
J1 11 22 33 44 jfet1 AREA=0.97
```

JFET Model (Level 1)

The .MODEL statement for the Level 1 JFET has the netlist syntax.

`.MODEL`_`modelname`_ **`NJF`** `[`**`LEVEL=1`**`] [`_`modelparameter=val`_`] ...`

or

`.MODEL`_`modelname`_ **`PJF`** `[`**`LEVEL=1`**`] [`_`modelparameter=val`_`] ...`

The entry **NJF** selects the N-channel JFET, while **PJF** selects the P-channel JFET.

Table 33: Level 1 and Level 2 JFET Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	1 selects the Basic SPICE JFET model	None	1 (default if LEVEL parameter is omitted)
ACM	Gate area calculation method	None	0
AF	Flicker noise exponent	None	1.0
ALIGN	Correction for gate misalignment	Meter	0.0

ALPHA (**ALFA**, **ALPHA1**)	Saturation factor	Volt^{-1}	2.0
AREA	Area factor	None	1.0
BETA	Transconductance (gain)	Amp/Volt^{2}	1.0e-4
BEX	Temperature exponent to correct for low field mobility	None	0.0
CAPOP	Capacitor model selector	None	0
CAPDS (**CDS**)	Drain-source capacitance	Farad	0.0
CGD	Zero-bias gate-drain junction capacitance	ACM = 0 : Farad ACM = 1 : Farad/Meter^{2}	0.0
CGS	Zero-bias gate-source junction capacitance	ACM = 0 : Farad ACM = 1 : Farad/Meter^{2}	0.0
CRAT	Source ratio of gate capacitance	None	0.666
CTD	Temperature coefficient for gate-drain junction capacitance	$°\text{C}^{-1}$	0.0
CTS	Temperature coefficient for gate-drain junction capacitance	$°\text{C}^{-1}$	0.0
DCAP	Capacitance equation selector	None	2
EG	Energy gap for gate-drain and gate-source diodes at 0 °K.	electron-Volt	1.11
FC	Coefficient for PB in forward-bias capacitance calculations	None	0.5
GAMDS (**GAMMA**, **GAMA**)	Lowering coefficient for drain voltage-induced threshold voltage	None	0.0
GAP1	1st bandgap correction factor	electron-Volt/°K	7.02e-4
GAP2	2nd bandgap correction factor	°K	1108.0
GCAP	Zero-bias gate capacitance	ACM = 0 : Farad ACM = 1 :	Not used if not provided

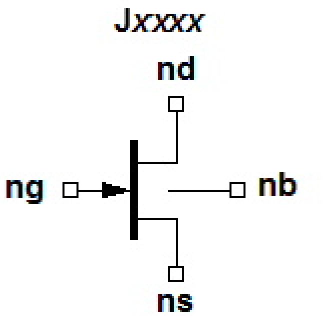
		Farad/Meter^2	
GDSNOI	Channel noise coefficient (NLEV = 3)	None	1.0
HDIF	Distance of heavily-doped (low resistance) region from source or drain contact to lightly-doped region	Meter	0.0
IS	Gate junction saturation current.	ACM = 0: Amp ACM = 1: Amp/Meter^2	1.0e-14
KF (**KF4**)	Flicker noise coefficient	None	0.0
L	FET gate length	Meter	0.0
LAMBDA (**LAMB**)	Channel length modulation factor	Volt^{-1}	0.0
LDEL	Difference between drawn length and actual or optical device length	Meter	0.0
LDIF	Distance of lightly-doped region from heavily-doped region to transistor edge	Meter	0.0
MJ	Grading coefficient for gate-drain and gate-source diodes	None	0.50
N	Emission coefficient for gate-drain and gate-source diodes	None	1.0
NG	Gate subthreshold factor	Volt^{-1}	0.0
NLEV	Noise equation selector	None	2
PB	Gate junction potential	Volt	0.8
RD	Drain ohmic resistance	Ohm	0.0
RG (**RG2**)	Gate ohmic resistance	Ohm	0.0
RS	Source ohmic resistance	Ohm	0.0
RSH	Sheet resistance of heavily-doped region	Ohm/square	0.0
RSHG	Gate sheet resistance	Ohm/square	0.0
RSHL	Sheet resistance of lightly-doped region	Ohm/square	0.0
TCV (**VTOTC**, **AVT0**)	Temperature compensation coefficient for threshold voltage VTO	°K^{-1}	0.0
TLEV	Temperature equation selector for junction diodes	None	0.0
TLEVC	Temperature equation selector for junction	None	0.0

	capacitances and potential		
TNOM (**TREF**)	Nominal circuit temperature	°C	25.0
TPB	Temperature coefficient for gate junction potential PB	Volt/°K	0.0
TRD (**TRD1**, **ARD**)	Temperature coefficient for drain resistance RD	°K^{-1}	0.0
TRG (**TRG1**, **ARG**)	Temperature coefficient for gate resistance RG	°K^{-1}	0.0
TRS (**TRS1**, **ARS**)	Temperature coefficient for source resistance RS	°K^{-1}	0.0
TT	Transit time	Second	0.0
VTO (**VT0**, **VPO**)	Threshold voltage.	Volt	-2.0
W	FET gate width	Meter	0.0
WDEL	Difference between drawn width and actual or optical device width	Meter	0.0
XTI	Saturation current temperature exponent	None	3.0

SPICE JFET Model Netlist Example

```
J1 11 22 33 44 jfet1 AREA=0.97

.MODEL jfet1 NJF LEVEL=1

+ BETA=626e-6 LAMBDA=45e-3

+ VTO=-2.33 IS=0.5e-9

+ N=1.2 CGS=1e-15 CGD=1e-15

+ TT=1.0e-14 MJ=0.5 PB=0.7 FC=0.5

+ CAPOP=1
```

JFET Instance, Modified SPICE Model (Level 2)



Modified SPICE JFET Instance Netlist Syntax

The netlist syntax for a modified SPICE JFET Level 2 instance is:

J*xxxx nd ng ns* [*nb*] *modelname*
[*area_specification*] [**M=** val] [**DTEMP=** val]

nd is the drain node, *ng* is the gate node, *ns* is the source node and *nb* is the base or substrate node of the transistor. The *modelname* is the name of a Level 2 JFET model defined in a .MODEL statement elsewhere in the netlist.

The *area_specification* is one of the following entries:

[[**AREA=**]*area*] or [**W=***width*] [**L=***length*]

Levels 1, 2, 3, 7, 8, and 9 of JFETs, MESFETs and GaAsFETs use the same instance parameters. See "JFET Instance, SPICE Model (Level 1)" on page 10-2.

Modified SPICE JFET Instance Netlist Example

```
J1 11 22 33 44 jfet2 AREA=0.97
```

Modified SPICE JFET Model (Level 2)

The .MODEL statement for the Level 2 JFET is:

.MODEL*modelname* **NJF LEVEL=2** [*modelparameter***=***val*] ...

or

.MODEL*modelname* **PJF LEVEL=2** [*modelparameter***=***val*] ...

The Level 2 JFET uses the model parameters listed in the module for the Level 1 JFET (see "JFET Model (Level 1)" on page 10-3.)

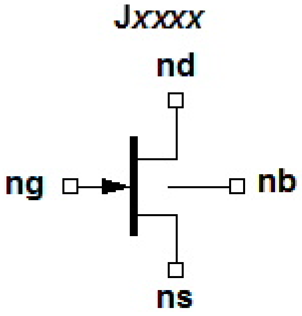
Table 34: Level 2 JFET Additional Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	2 is required to select the Modified SPICE JFET model	None	1 (default if LEVEL parameter is omitted)
LAM1	Channel length modulation gate voltage parameter	Volt^{-1}	0.0

Modified SPICE JFET Model Netlist Example

```
.MODEL njf NJF level=2

+ beta=626e-6 lambda=45e-3 lam1=.01

+ vto=-2.33 is=0.5e-9

+ n=1.2 rd=0  rs=0
```

MESFET Instance, Curtice Model (Level 3, SAT 0)



Curtice MESFET Instance Netlist Syntax

The syntax for a Curtice model MESFET instance is:

```
Jxxxx nd ng ns [nb] modelname
[area_specification] [M=val] [DTEMP=val]
```

nd is the drain node, *ng* is the gate node, *ns* is the source node and *nb* is the base or substrate node of the transistor. The *modelname* is the name of a Curtice model MESFET (Level 3, SAT 0) defined in a .MODEL statement elsewhere in the netlist.

The *area_specification* is one of the following entries:

`[[AREA=]area]`

or

`[W=width] [L=length]`

Levels 1, 2, 3, 7, 8, and 9 of JFETs, MESFETs and GaAsFETs use the same instance parameters. See "JFET Instance, SPICE Model (Level 1)" on page 10-2.

Curtice MESFET Netlist Examples

```
J2 12 VCC 0 mesfet3
```

MESFET, Curtice Model

The .MODEL statement for the Curtice model MESFET is:

`.MODELmodelname NJF LEVEL=3 [SAT=0] [modelparameter=val] ...`

or

`.MODELmodelname PJF LEVEL=3 [SAT=0] [modelparameter=val] ...`

LEVEL=3 specifies a MESFET model. The **SAT=0** parameter specifies the Curtice MESFET model.

The Level 3 MESFET models use all the Level 1 and Level 2 model parameters listed in the module for the "JFET Model (Level 1)" on page 10-3.

Table 35: Level 3 MESFET Additional Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	3 is required to select one of several MESFET models (see SAT parameter)	None	1 (default if LEVEL parameter is omitted)
SAT	Saturation factor (MESFET model selector) 0 = Standard Curtice model 1 = Curtice model with tanh coefficient 2 = Statz cubic approximation to Curtice model with gate field degradation 3 = Variable saturation model or Triquint extended (TOM) model	None	0

A	Active layer thickness Aeff = A × SCALM	Meter	0.5e-6
ACM	0 = SPICE method 1 = physical basis (required for Triquint TOM features)	None	0
AF	Flicker noise exponent	None	1.0
ALIGN	Correction for gate misalignment	Meter	0.0
ALPHA (**ALFA**, **ALPHA1**)	Saturation factor	Volt^{-1}	2.0
AREA	Area factor	None	1.0
BETA	Transconductance (gain)	Amp/Volt^{2}	1.0e-4
CAPOP	Capacitor model 0 = SPICE depletion capacitor model 1 = Statz charge-conserving symmetric capacitor model (Level 3 only) 2 = Modified Statz model	None	0
CAPDS (**CDS**)	Drain-source capacitance	Farad	0.0
CGD	Zero-bias gate-drain junction capacitance	ACM = 0 : Farad ACM = 1 : Farad/Meter^{2}	0.0
CGS	Zero-bias gate-source junction capacitance	ACM = 0 : Farad ACM = 1 : Farad/Meter^{2}	0.0
CRAT	Source ratio of gate capacitance	None	0.666
D	Semiconductor dielectric constant Silicon: 11.7 Gallium arsenide: 10.9	None	11.7
DCAP	Capacitance equation selector	None	2
DGAM	Dispersion model feedback coefficient	None	0.0
FC	Coefficient for PB in forward-bias capacitance calculations,	None	0.5

	CAPOP = 0 or 2		
GAMDS (**GAMMA**, **GAMA**)	Lowering coefficient for drain voltage-induced threshold voltage	None	0.0
GCAP	Zero-bias gate capacitance	ACM = 0 : Farad ACM = 1 : Farad/Meter^2	Not used if not provided
GDSNOI	Channel noise coefficient (NLEV = 3)	None	1.0
HDIF	Distance of heavily-doped (low resistance) region from source or drain contact to lightly-doped region	Meter	0.0
IS	Gate junction saturation current.	ACM = 0: Amp ACM = 1: Amp/Meter^2	1.0e-14
K1	Threshold voltage sensitivity to bulk node	Volt$^{1/2}$	0.0
KF	Flicker noise coefficient	None	0.0
L	FET gate length	Meter	0.0
LAMBDA (**LAMB**)	Channel length modulation factor Must be 0 for Triquint TOM model compatibility.	Volt^{-1}	0.0
LAM1	Channel length modulation gate voltage parameter	Volt^{-1}	0.0
LDEL	Difference between drawn length and actual or optical device length	Meter	0.0
LDIF	Distance of lightly-doped region from heavily-doped region to transistor edge	Meter	0.0
MJ	Grading coefficient for gate-drain and gate-source diodes (CAPOP = 0 or 2) Step junction: 0.50 Linear graded junction: 0.33	None	0.50
N	Emission coefficient for gate-drain and gate-source diodes	None	1.0
NCHAN	Effective channel dopant concentration	atom/cm^3	1.552e+22
ND	Drain subthreshold factor	Volt^{-1}	0.0

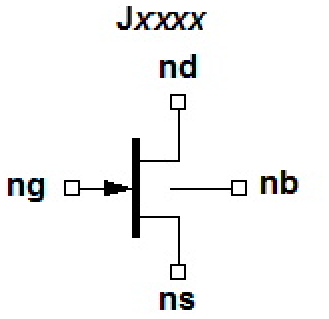
NG	Gate subthreshold factor	Volt^{-1}	0.0
NLEV	Noise equation selector	None	2
PB	Gate junction potential	Volt	0.8
RD	Drain ohmic resistance	Ohm	0.0
RG (**RG2**)	Gate ohmic resistance	Ohm	0.0
RS	Source ohmic resistance	Ohm	0.0
RSH	Sheet resistance of heavily-doped region	Ohm/square	0.0
RSHG	Gate sheet resistance	Ohm/square	0.0
SATEXP	Drain voltage exponent	None	3.0
TNOM	Nominal circuit temperature	°C	25
TT	Transit time	Second	0.0
UCRIT	Critical field for mobility degradation Must be 0 for Triquint TOM model compatibility.	Volt/cm	0.0
VBI	Gate diode built-in voltage	Volt	1.0
VGEXP (**Q**)	Gate voltage exponent	None	2.0
VP	Pinch-off voltage	Volt	Calculated
VTO	Threshold voltage. If VTO is nonzero, it overrides the internal calculation. Negative VTO denotes a depletion transistor (for both NJF and PJF), while positive VTO denotes an enhancement transistor.	Volt	Calculated
W	FET gate width	Meter	0.0
WDEL	Difference between drawn width and actual or optical device width	Meter	0.0

Curtice MESFET Model Netlist Example

```
.MODEL mesfet3 NJF LEVEL=3 SAT=0

.model njf NJF level=3 sat=3

+ beta=626e-6 lambda=0 k1=0.02 delta=0

+ vto=-2.33 is=0.5e-9 tt=1.0e-14 capds = 1e-14

+ n=1.2 cgs=1e-15 cgd=1e-15 satexp=3.2

+ gamds=1e-4 ucrit=1e-2 q=2.5 alpha=2.5  rg=10
```

```
+ m=0.5 pb=0.7 fc=0.5 capop=1
```

MESFET Instance, Modified Curtice Model (Level 3, SAT 1)



Modified Curtice MESFET Instance Netlist Syntax

The syntax for a modified Curtice model MESFET instance is:

J*xxxx nd ng ns* [*nb*] *modelname*
[*area_specification*]
[**M=***val*] [**DTEMP=***val*]

nd is the drain node, *ng* is the gate node, *ns* is the source node and *nb* is the base or substrate node of the transistor. The *modelname* is the name of a Modified Curtice model MESFET (Level 3, SAT 1) defined in a .MODEL statement elsewhere in the netlist.

The *area_specification* is one of the following entries:

[[**AREA=**]*area*]

or

[**W=***width*] [**L=***length*]

Levels 1, 2, 3, 7, 8, and 9 of JFETs, MESFETs and GaAsFETs use the same instance parameters. See "JFET Instance, SPICE Model (Level 1)" on page 10-2.

Modified Curtice MESFET Instance Netlist Example

```
J2 12 VCC 0 mesfet3
```

MESFET, Modified Curtice Model

The .MODEL statement for the Modified Curtice model MESFET is:

`.MODELmodelname NJF LEVEL=3 SAT=1 [modelparameter=val] ...`

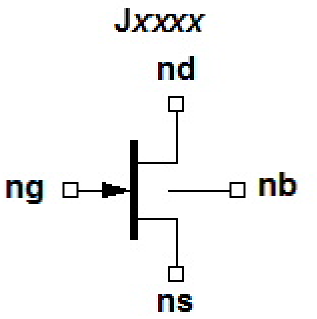
or

`.MODELmodelname PJF LEVEL=3 SAT=1 [modelparameter=val] ...`

LEVEL=3 specifies a MESFET model. The **SAT=1** parameter specifies the Modified Curtice MESFET model.

The Level 3 MESFET models use all the Level 1 and Level 2 model parameters listed in the module for the "JFET Model (Level 1)" on page 10-3. The module "MESFET, Curtice Model" on page 10-9 lists the additional model parameters that apply to all Level 3 MESFET models.

MESFET Instance, Statz Model (Level 3, SAT 2)



Statz MESFET Instance Netlist Syntax

The syntax for a Statz model MESFET instance is:

```
Jxxxx nd ng ns [nb] modelname
[area_specification] [M=val] [DTEMP=val]
```

nd is the drain node, *ng* is the gate node, *ns* is the source node and *nb* is the base or substrate node of the transistor. The *modelname* is the name of a Statz model MESFET (Level 3, SAT 2) defined in a .MODEL statement elsewhere in the netlist.

The *area_specification* is one of the following entries:

`[[AREA=]area]`

or

```
[W=width] [L=length]
```

Levels 1, 2, 3, 7, 8, and 9 of JFETs, MESFETs and GaAsFETs use the same instance parameters. See "JFET Instance, SPICE Model (Level 1)" on page 10-2.

Statz MESFET Netlist Example

```
J2 12 VCC 0 mesfet3
```

Statz MESFET Model

The .MODEL statement for the Statz model MESFET is:

```
.MODELmodelname NJF LEVEL=3 SAT=2 [modelparameter=]val] ...
```

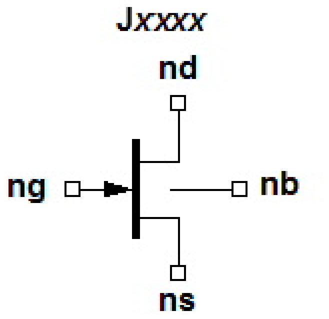
or

```
.MODELmodelname PJF LEVEL=3 SAT=2 [modelparameter=]val] ...
```

LEVEL=3, **SAT=2** parameter combination specifies the Statz MESFET model.

The Level 3 MESFET models use all the Level 1 and Level 2 model parameters listed in the module for the "JFET Model (Level 1)" on page 10-3. The module "MESFET, Curtice Model" on page 10-9 lists the additional model parameters that apply to all Level 3 MESFET models.

MESFET Instance, Triquint Extended (TOM1) Model (Level 3, SAT 3)



TOM1 MESFET Instance Netlist Syntax

The syntax for a TOM1 MESFET instance is:

```
Jxxxx nd ng ns [nb] modelname
[area_specification][M=val] [DTEMP=val]
```

nd is the drain node, *ng* is the gate node, *ns* is the source node and *nb* is the base or substrate node of the transistor. The *modelname* is the name of a Triquint Extended (TOM1) model MESFET (Level 3, SAT 3) defined in a .MODEL statement elsewhere in the netlist.

The *area_specification* is one of the following entries:

```
[[AREA=]area]
```

or

```
[W=width] [L=length]
```

Levels 1, 2, 3, 7, 8, and 9 of JFETs, MESFETs and GaAsFETs use the same instance parameters. See "JFET Instance, SPICE Model (Level 1)" on page 10-2.

TOM1 MESFET Netlist Example

```
J2 12 VCC 0 mesfet3
```

Level 3 Triquint Extended MESFET (TOM) Model

The .MODEL statement for the Level 3 Triquint extended MESFET (TOM) model specifies values for one or more model parameters.

```
.MODELmodelname NJF LEVEL=3 SAT=3 ACM=1
TOM_extended_parameter=val
[modelparameter=]val] ...
```

or

```
.MODELmodelname PJF LEVEL=3 SAT=3 ACM=1
TOM_extended_parameter=val
[modelparameter=]val] ...
```

In addition to **LEVEL=3** and **SAT=3**, the .MODEL statement must specify a value for at least one of the Triquint extended model parameters **BETATCE**, **DELTA**, or **CAPDS**. In addition, the area calculation method parameter **ACM** must be 1 to enable some TOM features. Aliases are provided for a few Level 3 parameters for compatibility with the original TOM model.

The Level 3 MESFET models use all the Level 1 and Level 2 model parameters listed in the module for the "JFET Model (Level 1)" on page 10-3. The module "MESFET, Curtice Model" on page 10-9 lists the additional model parameters that apply to all Level 3 MESFET models.

Table 36: TOM MESFET (SAT=3) Model Parameters

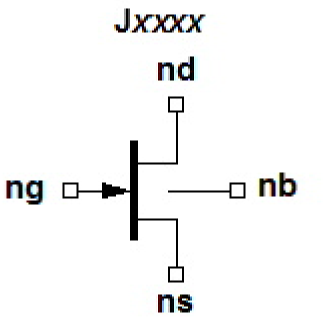
Model Parameter	Description	Unit	Default
LEVEL	3 is required to select one of several MESFET models (see SAT parameter)	None	1 (default if LEVEL parameter is omitted)
NJF	Selects N-channel MESFET	None	None
PJF	Selects P-channel MESFET	None	None
SAT	Saturation factor (MESFET model selector) 3 is required to select the Variable saturation model or Triquint extended (TOM) model	None	0
BETATCE (**ABET**)	Temperature coefficient for BETA When BETATCE is nonzero, BETA(temp) = BETA(TNOM+273.15) × 1.01 (BETATCE × (temp-TNOM+273.15))	$^{\circ}C^{-1}$	0.0
CAPDS (**CDS**)	Drain-source capacitance	Farad	0.0
DELTA	Ids feedback parameter.	None	0.0
GAMDS (**GAMMA**, **GAMA**)	Lowering coefficient for drain voltage-induced threshold voltage	None	0.0
MJ	Grading coefficient for gate-drain and gate-source diodes (CAPOP = 0 or 2) Step junction: 0.50 Linear graded junction: 0.33	None	0.50

TOM1 MESFET Model Netlist Example

```
.MODEL tqmesfet NJF LEVEL=3 SAT=3 BETATCE=1.0

.model njf NJF level=3 sat=3    vto=-3

+ beta=626e-6 lambda=0 k1=0.02

+ is=0.5e-9 tt=1.0e-14  rg=100

+ n=1.2  cgs=1e-15  cgd=1e-15

+ gamds=1e-4 ucrit=1e-2 vgexp=2.2 alpha=2.5

+ m=0.5  pb=0.7   fc=0.5   capop=1
```

```
+ n=5.0   rd=0    rs=0   satexp=3.2
*+ ng=1   nd=1
```

MESFET Instance, Triquint TOM3 Model (Level 7)



TOM3 MESFET Netlist Syntax

The syntax for a Level 7 Triquint TOM3 model MESFET instance is:

J*xxxx nd ng ns* [*nb*] *modelname*
[*area_specification*] [**M=***val*] [**DTEMP=***val*]

nd is the drain node, *ng* is the gate node, *ns* is the source node and *nb* is the base or substrate node of the transistor. The *modelname* is the name of a TOM3 Level 7 MESFET model defined in a .MODEL statement elsewhere in the netlist.

The *area_specification* is one of the following entries:

[[**AREA=**]*area*]

or

[**W=***width*] [**L=***length*]

Levels 1, 2, 3, 7, 8, and 9 of JFETs, MESFETs and GaAsFETs use the same instance parameters. See "JFET Instance, SPICE Model (Level 1)" on page 10-2.

TOM3 MESFET Instance Netlist Examples

```
J2 12 VCC 0 mesfet7
```

TOM3 MESFET Model (Level 7)

The .MODEL statement for the Level 7 Triquint TOM3 MESFET models is:

`.MODELmodelname NJF LEVEL=7 [modelparameter=]val] ...`

or

`.MODELmodelname PJF LEVEL=7 [modelparameter=]val] ...`

LEVEL=7 specifies the TOM3 MESFET model.

Table 37: Level 7 TOM3 MESFET Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	7 is required to select the Triquint TOM3 MESFET model	None	1 (default if LEVEL parameter is omitted)
ACM	0 = SPICE method 1 = physical basis (required for Triquint TOM features)	None	0
AF	Flicker noise exponent	None	1.0
ALIGN	Correction for gate misalignment	Meter	0.0
ALPHA (**ALPHA1**, **ALFA**)	Saturation factor	Volt^{-1}	2.0
ALPHATCE	ALPHA temperature coefficient (exponential)	°K-1	0.0
AREA	Area factor	None	1.0
BETA	Transconductance (gain) parameter	$\mathrm{Amp/Volt}^{-Q}$	0.1
BETATCE (**ABET**)	Linear temperature coefficient for BETA	$°\mathrm{K}^{-1}$	0.0
CAPDS (**CDS**)	Drain-source capacitance	Farad	1.0e-12
CAPOP	Capacitor model selector	None	0
CDSC	Dispersion model capacitance	Farad	1.0e-18
CGD	Zero-bias gate-drain junction capacitance	Farad	0.0
CGDTCE	Linear temperature coefficient for CGD	$°\mathrm{K}^{-1}$	0.0

CGS	Zero-bias gate-source junction capacitance	Farad	0.0
CGSTCE	Linear temperature coefficient for CGS	°K^{-1}	0.0
DCAP	Capacitance equation selector	None	2
DGAM	Dispersion model feedback coefficient	None	0.0
DELTA	Ids feedback parameter.	None	0.0
EG	Barrier height at 0 °K.	Volt	1.11
FC	Coefficient for PB in forward-bias capacitance calculations	None	0.5
GAMMA (**GAMDS**, **GAMA**)	Lowering coefficient for drain voltage-induced threshold voltage	None	0.0
GAMMATC (**AGAM**)	Linear temperature coefficient for GAMMA	°K^{-1}	0.0
GDSNOI	Channel noise coefficient (NLEV = 3)	None	1.0
HDIF	Distance of heavily-doped (low resistance) region from source or drain contact to lightly-doped region	Meter	0.0
ILK	Leakage diode current parameter	Amp	0.0
IS	Forward gate diode saturation current.	Amp	1.0e-14
K (**KAPP**)	Knee-function parameter	None	2
KF (**KF4**)	Flicker noise coefficient	None	0.0
K1	Threshold voltage sensitivity to bulk node	Volt$^{\frac{1}{2}}$	0.0
L	FET gate length	Meter	0.0
LAMBDA (**LAMB**)	Channel length modulation factor	Volt^{-1}	0.0
LAM1	Channel length modulation gate voltage parameter	Volt^{-1}	0.0
LDEL	Difference between drawn length and actual or optical device length	Meter	0.0
LDIF	Distance of lightly-doped region from heavily-doped region to transistor edge	Meter	0.0
MJ	Grading coefficient for gate-drain and gate-source diodes (CAPOP = 0 or 2) Step junction: 0.50	None	0.50

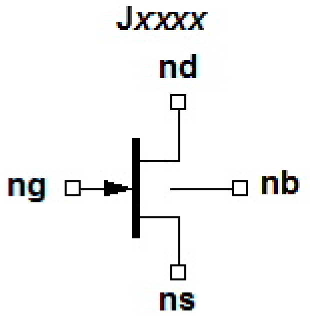
	Linear graded junction: 0.33		
MST	Subthreshold slope-drain parameter	Volt^{-1}	0.0
MSTTC (**AMST**)	Linear temperature coefficient for MST	Volt^{-1}°K^{-1}	0.0
N	Forward gate diode ideality factor	None	1.0
ND	Drain subthreshold factor	Volt^{-1}	0.0
NG	Gate subthreshold factor	Volt^{-1}	0.0
NLEV	Noise equation selector	None	2
PB	Gate junction potential	Volt	0.8
PLK	Leakage diode potential parameter	Volt	1.0
QGAD	Charge parameter	Volt^{-1}	1.0
QGAG	Charge parameter	Volt^{-1}	1.0
QGCL	Charge parameter	Farad	2.0e-16
QGDH	Sidewall capacitance	Farad	0.0
QGG0	Charge parameter	Farad	0.0
QGGB	Charge parameter	Amp^{-1}Volt^{-1}	100
QGI0	Charge parameter	Amp	1.0e-6
QGQH	Charge parameter	Farad-Volt	-2.0e-16
QGQL	Charge parameter	Farad-Volt	5.0e-16
QGSH	Sidewall capacitance	Farad	1.0e-16
RD	Drain ohmic resistance	Ohm	0.0
RG (**RG2**)	Gate ohmic resistance	Ohm	0.0
RS	Source ohmic resistance	Ohm	0.0
RSH	Sheet resistance of heavily-doped region	Ohm/square	0.0
RSHG	Gate sheet resistance	Ohm/square	0.0
TNOM (**TREF**)	Nominal temperature	°C	25.00
TT	Transit time	Second	0.0
TUGD	Dispersion model time constant	Second	1.0e-9
VBI	Gate diode built-in voltage	Volt	1.0
VBITC	Linear temperature coefficient of VBI	Volt/°K	0.0
VGEXP (**Q**)	Gate voltage exponent	None	2.0
VST	Subthreshold slope	Volt	1.0

VTO (**VT0**, **VPO**)	Threshold voltage. Negative VTO denotes a depletion transistor (for both NJF and PJF), while positive VTO denotes an enhancement transistor.	Volt	-2.0
VTOTC (**TCV**, **AVT0**)	Temperature compensation coefficient for threshold voltage VTO	°K^{-1}	0.0
VSTTC (**AVST**)	Linear temperature coefficient for VST	Volt	0.0
W	FET gate width	Meter	0.0
WDEL	Difference between drawn width and actual or optical device width	Meter	0.0
XTI	Diode saturation current temperature exponent	None	3.0

TOM3 Model Netlist Example

```
.MODEL mesfet7 NJF LEVEL=7

+ beta=626e-6 lambda=0 ilk =.5e-5

+ vto=-2.33   is=0.0e-9 tt=1.0e-14

+ n=2.0  cgs=1e-15  cgd=1e-15

+ gamds=1e-4 ucrit=1e-2 vgexp=2.2 alpha=2.5

+ m=0.5  pb=0.7   fc=0.5   capop=1

+ rd=0   rs=0   satexp=3.2
```

MESFET Instance, Materka Model (Level 8)



Materka MESFET Instance Netlist Syntax

The syntax for the HSPICE-compatible Level 8 Materka model MESFET instance is:

J*xxxx nd ng ns* [*nb*] *modelname*
[*area_specification*] [**M=***val*] [**DTEMP=***val*]

nd is the drain node, *ng* is the gate node, *ns* is the source node and *nb* is the base or substrate node of the transistor. The *modelname* is the name of a Level 8 MESFET model defined in a .MODEL statement elsewhere in the netlist.

The *area_specification* is one of the following entries:

[[**AREA=**]*area*]

or

[**W=***width*] [**L=***length*]

Levels 1, 2, 3, 7, 8, and 9 of JFETs, MESFETs and GaAsFETs use the same instance parameters. See "JFET Instance, SPICE Model (Level 1)" on page 10-2.

Materka MESFET Instance Netlist Examples

```
J2 12 VCC 0 mesfet8
```

MESFET Materka Model (Level 8)

The .MODEL statement for the Level 8 Materka MESFET models specifies values for one or more model parameters.

.MODEL*modelname* **NJF LEVEL=8** [*modelparameter***=***val*] ...

or

.MODEL*modelname* **PJF LEVEL=8** [*modelparameter***=***val*] ...

LEVEL=8 specifies the Materka MESFET model.

Table 38: Level 8 Materka MESFET Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	8 is required to select the Materka MESFET model	None	1 (default if LEVEL parameter is omitted)

ACM	0 = SPICE method 1 = physical basis (required for Triquint TOM features)	None	0
AF	Flicker noise exponent	None	1.0
ALIGN	Correction for gate misalignment	Meter	0.0
ALPHA (**ALFA**, **ALPHA1**)	Saturation factor	Volt^{-1}	2.0
AREA	Area factor	None	1.0
BETA	Transconductance (gain) parameter	Amp/Volt^{-Q}	1.0e-4
CAPDS (**CDS**)	Drain-source capacitance	Farad	0.0
CAPOP	Capacitor model selector	None	0
CGD	Zero-bias gate-drain junction capacitance	Farad	0.0
CGS	Zero-bias gate-source junction capacitance	Farad	0.0
CRAT	Source ratio of gate capacitance	None	0.666
DCAP	Capacitance equation selector	None	2
FC	Coefficient for PB in forward-bias capacitance calculations	None	0.5
GAMMA (**GAMDS**, **GAMA**)	Voltage slope parameter of pinch-off voltage	Volt^{-1}	0.0
GCAP	Zero-bias gate capacitance	ACM = 0 : Farad ACM = 1 : Farad/Meter^2	Not used if not provided
GDSNOI	Channel noise coefficient (NLEV = 3)	None	1.0
HDIF	Distance of heavily-doped (low resistance) region from source or drain contact to lightly-doped region	Meter	0.0
IDSS	Drain saturation current for VGS = 0	Amp	0.1
IDSSTCE	Idss temperature exponent	None	0.0
IS	Forward gate diode saturation current.	Amp	1.0e-14
KF (**KF4**)	Flicker noise coefficient	None	0.0
K1	Threshold voltage sensitivity to bulk node	Volt$^{1/2}$	0.0

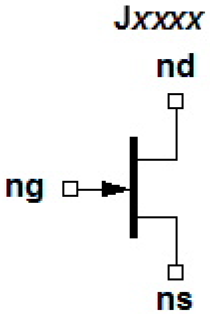
L	FET gate length	Meter	0.0
LAMBDA (**LAMB**)	Channel length modulation factor	Volt^{-1}	0.0
LAM1	Channel length modulation gate voltage parameter	Volt^{-1}	0.0
LDEL	Difference between drawn length and actual or optical device length	Meter	0.0
LDIF	Distance of lightly-doped region from heavily-doped region to transistor edge	Meter	0.0
MJ	Grading coefficient for gate-drain and gate-source diodes (CAPOP = 0 or 2) Step junction: 0.50 Linear graded junction: 0.33	None	0.50
N	Emission coefficient for gate-drain and gate-source diodes	None	1.0
ND	Drain subthreshold factor	Volt^{-1}	0.0
NG	Gate subthreshold factor	Volt^{-1}	0.0
NLEV	Noise equation selector	None	2
PB	Gate junction potential	Volt	0.8
RD	Drain ohmic resistance	Ohm	0.0
RG (**RG2**)	Gate ohmic resistance	Ohm	0.0
RS	Source ohmic resistance	Ohm	0.0
RSH	Sheet resistance of heavily-doped region	Ohm/square	0.0
RSHG	Gate sheet resistance	Ohm/square	0.0
TNOM (**TREF**)	Nominal temperature	°C	25.0
VBI	Gate diode built-in voltage	Volt	1.0
VGSS	Gate-source voltage for simulating enhancement mode FET with Vgss>Vp0	Volt	0.0
VTO (**VT0**, **VPO**)	Threshold voltage. Negative VTO denotes a depletion transistor (for both NJF and PJF), while positive VTO denotes an enhancement transistor.	Volt	-2.0

W	FET gate width	Meter	0.0
WDEL	Difference between drawn width and actual or optical device width	Meter	0.0

Materka MESFET Model Netlist Example

```
.MODEL mesfet8 NJF LEVEL=8

+ idss=0.0649003 alpha1=1.5 gamma=-0.0306278

+ vto=.210228   is=5e-20

+ cgs=1e-15  cgd=2e-16   pb=0.8   fc=0.5 kf=0

+ rd=1.85195   rs=0.899101  rg=5 af=1
```

GaAsFET Instance, Curtice3 Model (Level 9)



Curtice3 GaAsFET Instance Netlist Syntax

The syntax for a Level 9 Curtice3 model GaAsFET instance is:

J*xxxx nd ng ns* [*nb*] *modelname*
[**AREA=** val] [**M=***val*] [**TEMP=***val*] [**DTEMP=***val*]

nd is the drain node, *ng* is the gate node, *ns* is the source node and *nb* is the base or substrate node of the transistor. The *modelname* is the name of a Level 8 MESFET model defined in a .MODEL statement elsewhere in the netlist.

Levels 1, 2, 3, 7, 8, and 9 of JFETs, MESFETs and GaAsFETs use the same instance parameters. See "JFET Instance, SPICE Model (Level 1)" on page 10-2..

Table 39: Level 9 Curtice3 GaAsFET Instance Parameters

Model	Description	Unit	Default

Parameter			
AREA	Area multiplier	None	1.0
M	Multiplier for parallel devices	None	1.0
TEMP	Device temperature	°C	None
DTEMP	Difference between device temperature and circuit temperature	°C	None

Curtice3 GaAsFET Instance Netlist Examples

```
J2 12 VCC 0 gaasfet9
```

GaAsFET Curtice3 Model (Level 9)

The .MODEL statement for the Level 9 Curtice3 Cubic GaAsFET models specifies values for one or more model parameters.

.MODEL*modelname* **NJF LEVEL=9** [*modelparameter***=***val*] ...

or

.MODEL*modelname* **PJF LEVEL=9** [*modelparameter***=***val*] ...

LEVEL=9 specifies the Curtice3 GaAsFET model.

Table 40: Level 9 Curtice3 GaAsFET Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	9 is required to select the Curtice3 GaAsFET model	None	1 (default if LEVEL parameter is omitted)
BETATCE	Beta temperature coefficient for TriQuint model		0.0
CDS	Drain to source capacitance	Farad	0.0
CGD	Zero-bias gate-drain junction capacitance	Farad	0.0
CGS	Zero-bias gate-source junction capacitance	Farad	0.0
EG	Energy gap for gate-to-drain and gate-to-source diodes at 0.0K	e-V	1.11
FC	Coefficient for forward-bias depletion capacitance formulas‘		0.5

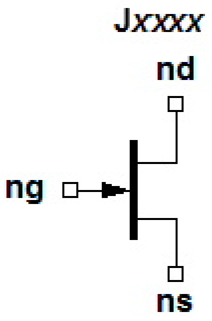
IS	Leakage saturation current	Ampere	1.0e-14
N	Gate diode emission coefficient	None	1.0
RD	Drain ohmic resistance	Ohm	0.0
RG	Gate ohmic resistance	Ohm	0.0
RS	Source ohmic resistance	Ohm	0.0
VTOTC	Temperature compensation coefficient for VTO		0.0
TNOM	Nominal circuit temperature	°C	25.0
VBI	Built-in gate diode voltage	Volt	0.85
VTO	Threshold voltage	Volt	Not used if not defined
XTI	Saturation current temperature coefficient		3.0
IDSMOD	IDS model selector	None	2.0
TAU	Transit time under the gate	Second	0.0
IDSTC	Ids temperature coefficient		0.0
RF	Gate-source effective forward-bias resistance	Ohm	0.0
GSCAP	Gate-source capacitance model selector 0=None, 1=Linear, 2=Junction, 3=Stazt charge, 5=Statz cap	None	1
RGD	Gate-drain resistance	Ohm	0.0
GDCAP	Gate-drain capacitance model selector 0=None, 1=Linear, 2=Junction, 3=Stazt charge, 5=Statz cap	None	1
LG	Gate inductance	Henry	0.0
LD	Drain inductance	Henry	0.0
LS	Source inductance	Henry	0.0
CRF	With RDS, models frequency-dependent output conductance		0.0
GSFWD	0=None, 1=Linear, 2=Diode		1.0
GSREV	0=None, 1=Linear, 2=Diode		1.0
GDFWD	0=None, 1=Linear, 2=Diode		1.0
GDREV	0=None, 1=Linear, 2=Diode		1.0
R1	Approximate breakdown resistance	Ohm	0.0
R2	Resistance relating breakdown voltage to channel current	Ohm	0.0
VBR	Gate-drain junction reverse bias breakdown voltage (gate-source junction reverse bias breakdown	Volt	1e100

	voltage with Vds<0)		
VJR	Breakdown junction potential	Volt	0.025
IR	Gate reverse saturation current	Ampere	1.0e-14
IMAX	Explosion current	Ampere	1.0
IMELT		Ampere	1.0
FNC	Flicker noise corner frequency	Hz	0.0
R	Gate noise coefficient		0.5
P	Drain noise coefficient		1.0
C	Gate-drain noise correlation coefficient	None	0.9
BETA2	Coefficient for pinch-off change with respect to Vds		1.0e-4
RDS0	DC conductance at Vgs=0		0.0
VOUT0	Output voltage at which A0, A1, A2, and A3 are evaluated	Volt	0.0
VDSDC	Vds at RDSO measured bias	Volt	0.0
GAMMA	Current saturation		2.0
A0	Cubic polynomial Ids equation coefficient 1		0.0
A1	Cubic polynomial Ids equation coefficient 2		0.0
A2	Cubic polynomial Ids equation coefficient 3		0.0
A3	Cubic polynomial Ids equation coefficient 4		0.0
RIN	Channel resistance	Ohm	0.0
A5	Time delay proportionality constant for Vds		0.0
KF	Flicker noise coefficient		0.0
AF	Flicker noise exponent		1.0
FFE	Flicker noise exponent		1.0
RDS	Additional output resistance for RF operation	Ohm	0.0

Curtice 3 GaAsFETFET Model Netlist Example

```
.MODEL gaasfet9 NJF LEVEL=9
```

MESFET Instance, EEHEMT Model (Level 15)



EEHEMT Instance Netlist Syntax

The syntax for a Level 15 High-Energy Mobility Transistor (EEHEMT) instance is:

```
Jxxxx nd ng ns [nb] modelname
[UGW=val] [M=val] [N=val]
```

nd is the drain node, *ng* is the gate node, and *ns* is the source node of the transistor. The *modelname* is the name of a Level 15 EEHEMT model defined in a .MODEL statement elsewhere in the netlist.

Table 41: Level 2 JFET Model Parameters

Model Parameter	Description	Unit	Default
UGW	Instance gate width	Meter	10e-6
N	Number of instances (gate fingers)	None	1.0
M	Number of parallel transistor instances	None	1.0

> **Note:** The instance parameter UGW overrides the model parameter UGW in setting the gate width.
>
> The instance parameter N sets the number of instances, and does not override the model parameter N (gate diode emission coefficient).

EEHEMT Instance Netlist Examples

```
J15 12 VCC 0 eehemt15
```

EEHEMT Model (Level 15)

The .MODEL statement for the Level 15 High-Energy Mobility Transistor (EEHEMT) model specifies values for one or more model parameters.

```
.MODELmodelname NJF LEVEL=15 [modelparameter=val] ...
```

or

```
.MODELmodelname PJF LEVEL=15 [modelparameter=val] ...
```

LEVEL=15 specifies the EEHEMT model.

Table 42: Level 15 EEHEMT Basic Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	15 is required to select the EEHEMT model	None	1 (default if LEVEL parameter is omitted)
KMOD	Model version	None	1.0
KVER	Model version	None	1.0
ALPHA	Fitting parameter	Volt	0.5
C11o	C11 at saturation	Farad	1e-12
C11th	C11 below threshold	Farad	1e-15
C12sat	C12 at saturation	Farad	30e-15
CBS	Body-source capacitance	Farad	1e-15
CDSO	Drain-source capacitance	Farad	40e-15
CGDSAT	Gate-drain capacitance at saturation	Farad	20e-15
DELTDS	Gate charge partition parameter	Volt	0.4
DELTGM	Slope of transconductance dropoff	Siemens/Volt	0.15
DELTGMAC	AC slope of transconductance dropoff	Siemens/Volt	0.15
DELTGS	Gate charge partition parameter	Volt	0.35
GAMMA	Body effect parameter	Volt^{-1}	0.001
GAMMAAC	AC body effect parameter	Second	0.001
GDBM	Drain-to-body conductance	Siemens	35e-6
GMMAX	Maximum transconductance	Siemens	0.25
GMMAXAC	Maximum transconductance	Siemens	0.25

IDSOC	Gate diode breakdown fitting parameter	Ampere	1.0
IS	Gate diode current	Ampere	15.0e-12
KAPA	Output conductance parameter	Volt^{-1}	0.025
KAPAAC	Output conductance parameter	Volt^{-1}	0.025
KBK	Gate diode breakdown constant	None	0.008119
KDB	Drain-body current parameter	None	88.8e-15
LAMBDA	Gate charge fitting parameter	Volt^{-1}	0.035
MU	Fitting parameter	None	1.332e-10
N	Gate diode emission coefficient	None	1.5
NBR	Gate diode breakdown emission coefficient	None	5
NGF	Number of gate fingers	None	1
PEFF	Self-heating parameter	Watt	0.4
PEFFAC	Self-heating parameter	Watt	0.4
RD	Extrinsic drain resistance	Ohm	2.0
RDB	Drain-body resistance	Ohm	1.0e9
RG	Gate resistance	Ohm	2.0
RID	Intrinsic drain resistance	Ohm	0.1
RIS	Intrinsic source resistance	Ohm	6.0
RS	Extrinsic source resistance	Ohm	2.0
TAU	Delay of drain-source current	Second	8.3e-12
UGW	Unit gate width model	Meter	10e-6
VBA	Voltage defining area of operation	Volt	0.2
VBC	Voltage defining area of operation	Volt	0.44
VBR	Gate diode breakdown voltage	Volt	0.008119
VCH	Voltage at which output conductance is set by kappa	Volt	7.329
VCO	Start voltage of transconductance compression	Volt	1.3
VDELT	Not used	Volt	0.1
VDELTAC	Not used	Volt	0.1
VDSM	Fitting parameter for drain-body current	Volt	10
VDSO	Voltage at which the drain-source model collapses to a single voltage dependency in	Volt	2.0

	Vgs		
VGO	Vgs of peak transconductance	Volt	0.65
VINFL	Threshold voltage in charge model	Volt	0.44
VSAT	Saturation voltage	Volt	0.45
VTO	Threshold voltage	Volt	0.1
VTOAC	Threshold voltage in AC	Volt	0.1
VTSO	Subthreshold onset voltage	Volt	-10
VTSOAC	Subthreshold onset voltage	Volt	-10

> **Note:** The instance parameter UGW overrides the model parameter UGW in setting the gate width.
>
> The instance parameter N sets the number of instances, and does not override the model parameter N (gate diode emission coefficient).

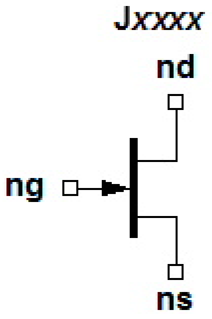
Table 43: Level 15 EEHEMT Temperature Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
RGTC	Linear temperature coefficient for RG		0.0
RDTC	Linear temperature coefficient for RD		0.0
RSTC	Linear temperature coefficient for RS		0.0
VTOTC	Linear temperature coefficient for VTO		0.0
GMMAXTC	Linear temperature coefficient for GMMAX		0.0
XTI	Saturation current temperature coefficient		3.0
VINFLTC	Linear temperature coefficient for VINFL		0.0
GAMMATC	Linear temperature coefficient for GAMMA		0.0
VTOACTC	Linear temperature coefficient for VTOAC		0.0
GMMAXACTC	Linear temperature coefficient for GMMAXAC		0.0
GAMMAACTC	Linear temperature coefficient for GAMMAAC		0.0
TNOM	Nominal temperature coefficient for RG	°C	25.0

EEHEMT Model Netlist Example

```
.MODEL eehemt15 NJF LEVEL=15
```

PSFET Instance, Parker-Skellern Model (Level 18)



PSFET Instance Netlist Syntax

The syntax for a Level 18 Parker-Skellern Model Transistor (PSFET) instance is:

```
Jxxxx nd ng ns modelname [M=val]
```

nd is the drain node, *ng* is the gate node, and *ns* is the source node of the transistor. The *modelname* is the name of a Level 18 Parker-Skellern model defined in a .MODEL statement elsewhere in the netlist.

Table 44: Level 18 PSFET Instance Parameters

Model Parameter	Description	Unit	Default
M	Number of parallel transistor instances	None	1.0

PSFET Instance Netlist Examples

```
J15 12 VCC 0 psfet18
```

Parker-Skellern PSFET Model (Level 18)

The .MODEL statement for the Level 18 Parker-Skellern PSFET Transistor model specifies values for one or more model parameters.

```
.MODELmodelname NJF LEVEL=18 [modelparameter=val] ... ]
```

or

```
.MODELmodelname PJF LEVEL=18 [modelparameter=val ... ]
```

LEVEL=18 specifies the Parker-Skellern PSFET model.

Table 45: Level 18 PSFET Basic Model Parameters

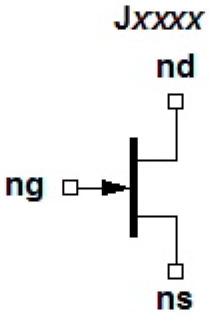
Model Parameter	Description	Unit	Default
LEVEL	18 is required to select the Parker-Skellern PSFET model	None	1 (default if LEVEL parameter is omitted)
ACGAM	Capacitance modulation parameter	None	0.0
BETA	Linear region transconductance scale factor	None	1e-4
CGD	Zero-bias gate-drain capacitance	Farad	0.0
CGS	Zero-bias gate-source capacitance	Farad	0.0
DELTA	Thermal reduction coefficient	1/Watt	0.0
FC	Forward-bias capacitance parameter	None	0.5
HFETA	High-frequency Vgs feedback parameter	None	0.0
HFE1	HFETA modulation by Vgd	1/Volt	0.0
HFE2	HFETA modulation by Vgs	1/Volt	0.0
HFGAM	High-frequency Vgd feedback parameter	None	0.0
HFG1	HFGAM modulation by Vsg	1/Volt	0.0
HFG2	HFGAM modulation by Vdg	1/Volt	0.0
IBD	Gate-junction breakdown current	Ampere	0.0
IS	Gate-junction saturation current	Ampere	1.0e-14
LFGAM	Low-frequency Vgd feedback parameter	None	0.0
LFG1	LFGAM modulation by Vsg	1/Volt	0.0
LFG2	LFGAM modulation by Vdg	1/Volt	0.0
MVST	Subthreshold modulation	1/Volt	0.0
N	Gate-junction ideality factor	None	1.0
P	Linear region power law exponent	None	2.0
Q	Saturated region power law exponent	None	2.0
RS	Source ohmic resistance	Ohm	0.0
RD	Drain ohmic resistance	Ohm	0.0
TAUD	Relaxation time for thermal reduction	Second	0.0
TAUG	Relaxation time for gamma feedback	Second	0.0
VBD	Gate-junction breakdown potential	Volt	1.0
VBI	Gate-junction potential	Volt	1.0

VST	Subthreshold potential	Volt	0.0
VTO	Subthreshold voltage	Volt	-2.0
XC	Capacitance pinchoff reduction factor	None	0.0
XI	Saturation-knee potential factor	None	1000.0
Z	Knee transition parameter	None	0.5
RG	Gate ohmic resistance	Ohm	0.0
LG	Gate inductance	Henry	0.0
LS	Source inductance	Henry	0.0
LD	Drain inductance	Henry	0.0
CDSS	Fixed drain-source capacitance	Farad	0.0
AFAC	Gate width scale factor	None	1.0
NFING	Number of gate fingers scale factor	None	1.0
TNOM	Nominal temperature	°K	300
TEMP	Temperature	°K	300

PSFET Model Netlist Example

```
.MODEL psfet18 NJF LEVEL=18
```

GaAsFET Instance, Angelov-Chalmers Model (Level 19)



GaAsFET Instance Netlist Syntax

The syntax for a Level 19 Angelov-Chalmers Gallium Arsenide Field-Effect Transistor (GaAsFET) instance is:

J*xxxx nd ng ns modelname* **M=***val* *nd* is the drain node, *ng* is the gate node, and *ns* is the source node of the transistor. The *modelname* is the name of a Level 19 GaAsFET model defined in a .MODEL statement elsewhere in the netlist.

Parameter **M** is a multiplier for multiple parallel transistors (default 1.0).

GaAsFET Instance Netlist Example

```
J15 12 VCC 0 gaasfet15
```

GaAsFET Model, Angelov-Chalmers (Level 19)

The .MODEL statement for the Level 19 Angelov-Chalmers Gallium Arsenide Field-Effect Transistor (GaAsFET) model specifies values for one or more model parameters.

.MODEL*modelname* **NJF LEVEL=19** [*modelparameter***=***val*] ...

or

.MODEL*modelname* **PJF LEVEL=19** [*modelparameter***=***val*] ...

LEVEL=19 specifies the Angelov-Chalmers GaAsFET model.

Table 46: Level 19 GaAsFET Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	19 is required to select the Angelov-Chalmers GaAsFET model	None	1 (default if LEVEL parameter is omitted)
ALPHR	Ids calculation parameter	None	0.619601
ALPHS	Ids calculation parameter	None	1.0e-7
B1	P1 coefficient, unsaturated	None	0.505595
B2	P2 coefficient, unsaturated	None	0.536229
CDS0	Capacitance from drain to source	Farad	0.07678
CDSW	Drain-source capacitance	Henry	1.0e-19
CGD0	Capacitance from gate to drain	Farad	7.646539e-12
CGDP	Pinch-off capacitance from gate to drain	Farad	0.137838e-12
CGEXT	External gate capacitance	Farad	0.08e-12
CGS0	Capacitance from gate to source	Farad	0.5848117e-12
CGSP	Pinch-off capacitance from gate to source	Farad	0.4379102e-12
CPD	Parasitic drain capacitance	Farad	1.0e-19

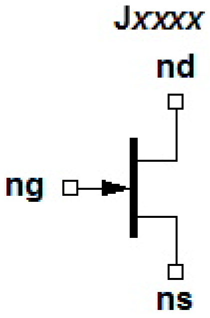
CPG	Parasitic gate capacitance	Farad	1.0e-19
CRF	Capacitance for calculating frequency-dependent output conductance	Farad	4.0e-7
CDEXT	External drain capacitance	Farad	0.13e-12
I0	Saturation current per unit area	Amp	0.00065e-3
IPK	Peak transconductance current	Amp	0.198032
L	Inductance, source to drain	Henry	1.0
LAMBDA	Modulation parameter for channel length	None	0.0193209
LD	Drain inductance	Henry	1.0e-16
LDEXT	External drain inductance	Henry	0.085e-9
LG	Gate inductance	Henry	1.0e-16
LGEXT	External gate inductance	Henry	0.09e-9
LS	Source inductance	Henry	0.007e-9
N	Emission coefficient	None	4.1
P1	Channel current polynomial coefficient	None	0.524204
P10	Capacitance polynomial coefficient	Farad	10.37095
P11	Capacitance polynomial coefficient	Farad	2.652327
P2	Channel current polynomial coefficient	None	-0.0005232
P20	Capacitance polynomial coefficient	Farad	0.331596
P21	Capacitance polynomial coefficient	Farad	-0.0024284
P3	Channel current polynomial coefficient	None	0.1411908
P30	Capacitance polynomial coefficient	Farad	-0.105783
P31	Capacitance polynomial coefficient	Farad	0.048553
P40	Capacitance polynomial coefficient	Farad	-0.875367
P41	Capacitance polynomial coefficient	Farad	0.201137
P110	Capacitance polynomial coefficient	Farad	2.822948
P111	Capacitance polynomial coefficient	Farad	1.383106
RCW			1.0e5
RD	Drain resistance	Ohm	2.0
RG	Gate resistance	Ohm	0.8
RGD	Gate-drain resistance	Ohm	0.1
RI	Gate-source resistance	Ohm	1.29

RS	Source resistance	Ohm	1.6
TAU	Time delay	Sec	0.004038e-9
VPK0	Peak voltage parameter	Volt	-1.964205
VPKS	Peak transconductance gate voltage	Volt	1.0e-7
VT	Threshold voltage	Volt	0.025
WG			1000.0

GaAsFET Model Netlist Example

```
.MODEL gaasfet15 NJF LEVEL=19
```

GaAsFET Instance, Curtice2 Model (Level 21)



Curtice2 GaAsFET Instance Netlist Syntax

The syntax for a Level 21 Curtice2 Gallium Arsenide Field-Effect Transistor instance is:

`J`*`xxxx nd ng ns modelname`* `[`**`AREA=`***`val`*`]` `[`**`TEMP=`***`val`*`]` `[`**`DTEMP=`***`val`*`]` `[`**`M=`***`val`*`]`

nd is the drain node, *ng* is the gate node, and *ns* is the source node of the transistor. The *modelname* is the name of a Level 21 GaAsFET model defined in a .MODEL statement.

Table 47: Level 21 GaAsFET Instance Parameters

Parameter	Description	Unit	Default
AREA	Area multiplier	None	1.0
M	Multiplier for multiple parallel devices	None	1.0
TEMP	Device temperature	°C	Circuit temperature

DTEMP	Temperature difference between device and circuit	°C	0.0

Curtice2 GaAsFET Instance Netlist Example

```
J15 12 VCC 0 gaasfet21 area=1.1
```

GaAsFET Model, Curtice2 (Level 21)

The .MODEL statement for the Level 21 Curtice2 Gallium Arsenide Field-Effect Transistor model specifies values for one or more model parameters.

`.MODELmodelname NJF LEVEL=21 [modelparameter=val] ...`

or

`.MODELmodelname PJF LEVEL=21 [modelparameter=val] ...`

LEVEL=21 specifies the Curtice2 GaAsFET model.

Table 48: Level 21 GaAsFET Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	21 is required to select the Curtice2 GaAsFET model	None	1 (default if LEVEL parameter is omitted)
AF	Flicker noise exponent	None	1.0
ALPHA	Saturation factor	None	2.0
BETA	Transconductance coefficient	None	1.0e-4
BETATCE	Beta temperature coefficient for Triquint models	None	0.0
CDS	Drain to source capacitance	Farad	0.0
CGD	Zero-bias gate-drain junction capacitance	Farad	0.0
CGS	Zero-bias gate-source junction capacitance	Farad	0.0
EG	Energy gap for gate-to-drain and gate-to-source diode at 0.0 K		1.11
FC	Coefficient for forward-bias depletion capacitance formulas		0.5
IS	Leakage saturation current	Amp	1.0e-14

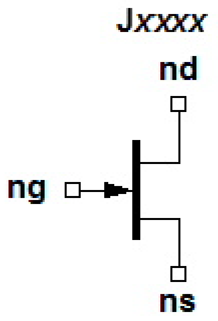
KF	Flicker noise coefficient	None	0.0
LAMBDA	Channel length modulation		0.0
N	Gate diode emission coefficient	None	1.0
RD	Drain ohmic resistance	Ohm	0.0
RG	Gate ohmic resistance	Ohm	0.0
RS	Source ohmic resistance	Ohm	0.0
VTOTC	Temperature compensation coefficient for VTO		0.0
TNOM	Nominal temperature	°C	25
VBI	Gate diode built-in voltage	Volt	0.85
VTO	Threshold voltage	Volt	-2.0
XTI	Saturation current temperature exponent		3.0
IDSMOD	IDS model	None	2.0
TAU	Transit time under the gate	Second	0.0
IDSTC	Ids temperature coefficient		0.0
RIN	Channel resistance	Ohm	0.0
RF	Gate-source effective forward-bias resistance	Ohm	0.0
GSCAP	Gate-source capacitance model 0 = None 1 = Linear 2 = Junction 3 = Statz charge 5 = Statz capacitance	None	1
RGD	Gate-drain resistance	Ohm	0.0
GDCAP	Gate-drain capacitance model 0 = None 1 = Linear 2 = Junction 3 = Statz charge 5 = Statz capacitance	None	1
LD	Drain inductance	Henry	0.0

LG	Gate inductance	Henry	0.0
LS	Source inductance	Henry	0.0
CRF	With RDS, frequency-dependent output conductance	Siemens	0.0
GSFWD		None	1.0
GSREV		None	2.0
GDFWD		None	1.0
GDREV		None	2.0
R1	Approximate breakdown resistance	Ohm	0.0
R2	Resistance relating breakdown voltage to channel current	Ohm	0.0
VBR	Gate-drain junction reverse-bias breakdown voltage (gate-source junction reverse-bias breakdown voltage with Vds<0)	Volt	1.0e100
VJR	Breakdown junction potential	Volt	0.025
IR	Gate reverse saturation current	Ampere	1.0e-14
IMAX	Explosion current	Ampere	1.0
IMELT		Ampere	1.0
FNC	Flicker noise corner frequency	Hertz	0.0
R	Gate noise coefficient		0.5
P	Gate noise coefficient		1.0
C	Gate noise coefficient		0.9
FFE	Flicker noise exponent	None	1.0
RC	Used with CRF to model frequency dependence output		0.0

Level 21 GaAsFET Model Netlist Example

```
.MODEL mesfet21 NJF LEVEL=21
```

GaAsFET Instance, Curtice2 Advanced Model (Level 22)



Curtice2 Advanced GaAsFET Instance Netlist Syntax

The syntax for a Level 22 Curtice2 Advanced Gallium Arsenide Field-Effect Transistor instance is:

`J``xxxx nd ng ns modelname [`**`AREA=`**`val] [`**`TEMP=`**`val] [`**`DTEMP=`**`val] [`**`M=`**`val]`

nd is the drain node, *ng* is the gate node, and *ns* is the source node of the transistor. The *modelname* is the name of a Level 22 GaAsFET model defined in a .MODEL statement.

Table 49: Level 22 GaAsFET Instance Parameters

Parameter	Description	Unit	Default
AREA	Area multiplier	None‘	1.0
M	Multiplier for multiple parallel devices	None	1.0
TEMP	Device temperature	°C	Circuit temperature
DTEMP	Temperature difference between device and circuit	°C	0.0

Curtice2 Advanced GaAsFET Instance Netlist Example

```
J15 12 VCC 0 gaasfet22 area=1.1
```

GaAsFET Model, Curtice2 Advanced (Level 22)

The .MODEL statement for the Level 21 Curtice2 Gallium Arsenide Field-Effect Transistor model specifies values for one or more model parameters.

`.MODEL``modelname` **`NJF LEVEL=22`** `[modelparameter`**`=`**`val] ...`

or

`.MODELmodelname PJF LEVEL=22 [modelparameter=val] ...`

LEVEL=22 specifies the Curtice2 Advanced GaAsFET model.

Table 50: Level 22 GaAsFET Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	22 is required to select the Curtice2 Advanced GaAsFET model	None	1 (default if LEVEL parameter is omitted)
ALPHA	Saturation factor	None	2.0
BETA	Transconductance coefficient	None	1.0e-4
BETATCE	Beta temperature coefficient for Triquint models	None	0.0
CDS	Drain to source capacitance	Farad	0.0
CGD	Zero-bias gate-drain junction capacitance	Farad	0.0
CGS	Zero-bias gate-source junction capacitance	Farad	0.0
EG	Energy gap for gate-to-drain and gate-to-source diode at 0.0 K		1.11
FC	Coefficient for forward-bias depletion capacitance formulas		0.5
GAMDS	Drain voltage induced threshold voltage lowering coefficient		-0.01
IS	Leakage saturation current	Amp	1.0e-14
KF	Flicker noise coefficient	None	0.0
LAMBDA	Channel length modulation		0.0
N	Gate diode emission coefficient	None	1.0
RD	Drain ohmic resistance	Ohm	0.0
RG	Gate ohmic resistance	Ohm	0.0
RS	Source ohmic resistance	Ohm	0.0
VTOTC	Temperature compensation coefficient for VTO		0.0
TNOM	Nominal temperature	°C	25
UCRIT	Critical field for mobility degradation		0.0
VBI	Gate diode built-in voltage	Volt	0.85
VGEXP	Gate voltage exponent		2.0

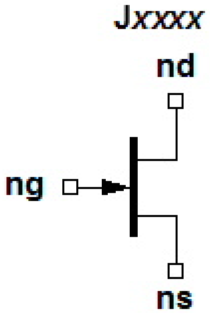
VTO	Threshold voltage	Volt	-2.0
XTI	Saturation current temperature exponent		3.0
IDSMOD	IDS model	None	2.0
TAU	Transit time under the gate	Second	0.0
IDSTC	Ids temperature coefficient		0.0
RF	Gate-source effective forward-bias resistance	Ohm	0.0
GSCAP	Gate-source capacitance model 0 = None 1 = Linear 2 = Junction 3 = Statz charge 5 = Statz capacitance	None	1
RGD	Gate-drain resistance	Ohm	0.0
GDCAP	Gate-drain capacitance model 0 = None 1 = Linear 2 = Junction 3 = Statz charge 5 = Statz capacitance	None	1
LD	Drain inductance	Henry	0.0
LG	Gate inductance	Henry	0.0
LS	Source inductance	Henry	0.0
CRF	With RDS, frequency-dependent output conductance	Siemens	0.0
GSFWD		None	1.0
GSREV		None	2.0
GDFWD		None	1.0
GDREV		None	2.0
R1	Approximate breakdown resistance	Ohm	0.0
R2	Resistance relating breakdown voltage to channel current	Ohm	0.0

VBR	Gate-drain junction reverse-bias breakdown voltage (gate-source junction reverse-bias breakdown voltage with Vds<0)	Volt	1.0e100
VJR	Breakdown junction potential	Volt	0.025
IR	Gate reverse saturation current	Ampere	1.0e-14
IMAX	Explosion current	Ampere	1.0
IMELT		Ampere	1.0
FNC	Flicker noise corner frequency	Hertz	0.0
R	Gate noise coefficient		0.5
P	Gate noise coefficient		1.0
C	Gate noise coefficient		0.9
RC	Used with CRF to model frequency dependence output		0.0
RGS	Gate-source resistance	Ohm	0.0

Level 22 GaAsFET Model Netlist Example

```
.MODEL gaasfet22 NJF LEVEL=22
```

GaAsFET Instance, Angelov-Chalmers Model (Level 23)



GaAsFET Instance Netlist Syntax

The syntax for a Level 23 Angelov-Chalmers Gallium Arsenide Field-Effect Transistor (GaAsFET) instance is:

`Jxxxx nd ng ns modelname [M=val] [SELFT=val] [TRISE=val] [TEMP=val]`

nd is the drain node, *ng* is the gate node, and *ns* is the source node of the transistor. The *modelname* is the name of a Level 23 GaAsFET model defined in a .MODEL statement elsewhere in the netlist.

Table 49: Level 22 GaAsFET Instance Parameters

Parameter	Description	Unit	Default
M	Multiplier for multiple parallel devices	None	1.0
SELFT	Flag for self-heating	None	0
TEMP	Device temperature	°C	Circuit temperature
TRISE	Temperature difference between device and tnom	°C	0.0

GaAsFET Instance Netlist Example

```
J15 12 VCC 0 gaasfet23
```

GaAsFET Model, Angelov-Chalmers (Level 23)

The .MODEL statement for the Level 23 Angelov-Chalmers Gallium Arsenide Field-Effect Transistor (GaAsFET) model specifies values for one or more model parameters.

`.MODELmodelname NJF LEVEL=23 [modelparameter=val] ...`

or

`.MODELmodelname PJF LEVEL=23 [modelparameter=valPelosi is calling for the 25] ...`

LEVEL=19 specifies the Angelov-Chalmers GaAsFET model.

Table 46: Level 23 GaAsFET Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	23 is required to select the Angelov-Chalmers GaAsFET model	None	23
AF	flicker noise exponent	None	1.0
ALPHR	Saturation parameter Alpha R	None	0.1
ALPHS	Saturation parameter Alpha	None	1.0
B1	Unsaturated coefficient B1 for P1	None	0.0
B2	Saturated coefficient B2 for P1	None	3.0

CAPMOD	Capacitance model selector: 0=linear, 1=bias-dependent capacitances, 2=charge	None	2.0
CDS	Zero-bias capacitance from drain to source	Farad	c
CGD0	Capacitance from gate to drain	Farad	0.0
CGDPE	External capacitance from gate to drain	Farad	0.0
CGDPI	Pinch-off capacitance from gate to drain	Farad	0.0
CGS0	Capacitance from gate to source	Farad	0.0
CGSPI	Pinch-off capacitance from gate to source	Farad	0.0
CRF	Capacitance for calculating frequency-dependent output conductance	Farad	0.0
CRFIN	Capacitance for frequency-dependent input conductance	Farad	0.0
CTH	Thermal capacitance	Farad	0.0
DVPKS	Delta gate voltage at peak GM	Volt	0.2
FFE	Flicker noise parameter	None	1.0
FGR	G-R frequency corner	Hertz	60.0e3
FNC	Noise corner frequency	Hertz	0.0
IDSMOD	IDS current model	None	0.0
IGMOD	Select gate diode model	None	0.0
IJ	Gate forward saturation current	Amp	0.00005
IPK0	Current for maximum transconductance	Amp	0.05
KF	Flicker noise coefficient	None	0.0
KLF	Flicker noise exponent	None	1.0e14
LAMBDA	Channel length modulation	None	0.0
LAMBDA1	Channel length modulation	None	0.0
LD	Drain ohmic inductance	Henry	0.0
LG	Gate ohmic inductance	Henry	0.0
LS	Source ohmic inductance	Henry	0.0
LSB0	Soft breakdown voltage	None	0.0
LVG	Channel length modulation coefficient	None	0.0
LW	Effective gate noise width	mm	0.1
NE	Gate p-n emission coefficient	None	0.0

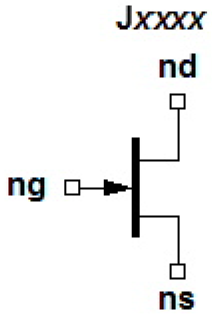
NOISEC	Gate-drain noise coefficient	None	0.9
NOISEP	Gate noise coefficient	None	1.0
NOISER	Gate noise coefficient	None	0.5
NP	Flicker noise freq exponant	None	0.3
P1	Polynomial coefficient P1 for channel current	None	1.0
P10	Polynomial coefficient for capacitance	Farad	0.0
P11	Polynomial coefficient for capacitance	Farad	1.0
P2	Polynomial coefficient P2 for channel current	None	0.0
P20	Polynomial coefficient for capacitance	Farad	0.0
P21	Polynomial coefficient for capacitance	Farad	0.2
P3	Polynomial coefficient P3 for channel current	None	0.0
P30	Polynomial coefficient for capacitance	Farad	0.0
P31	Polynomial coefficient for capacitance	Farad	0.2
P40	Polynomial coefficient for capacitance	Farad	0.0
P41	Polynomial coefficient for capacitance	Farad	1.0
P111	Polynomial coefficient for capacitance	Farad	0.0
PG	Gate current	Amps	0.0
RC	Resistance for frequency dependent output conduction	Ohm	10.0e3
RCIN	Resistance for frequency dependent input conduction	Oh	100.0e3
RCMIN	Minimum value of RC	Ohm	1.0e3
RD	Drain ohmic resistance	Ohm	0.0
RG	Gate ohmic resistance	Ohm	0.0
RGD	Gate resistance	Ohm	0.0
RI	Input resistance	Ohm	0.0
RS	Source ohmic resistance	Ohm	0.0
RTH	Thermal resistance	Ohm	0.0
TAU	Device delay	Sec	0.0
TCCGD0	Linear temperature coefficient CGD0	None	0.0
TCCGS0	Linear temperature coefficient CGS0	None	0.0
TCCRF	Linear temperature coefficient CRF	None	0.0

TCIPK0	Linear temperature coefficient TIPK for IPK	None	0.0
TCLSB0	Linear temperature coefficient LSB0	None	0.0
TCP1	Linear temperature coefficient TIPK for IPK	None	0.0
TCRC	Linear temperature coefficient RC	None	0.0
TD	Equivalent temperature	Degree Celsius	25.0
TD1	Equivalent temperature	Degree Celsius	0.1
TG	Equivalent temperature	Degree Celsius	25.0
TMN	Noise fitting coefficient	None	1.0
TNOM	Nominal temperature	Degree Celsius	25.0
VIG	Gate current	Volt	0.7
VKN	Knee voltage	Volt	0.8
VPKS	Gate voltage VPK for maximum transconductance	-0.2	1.0e-7
VSB2	Surface breakdown model parameter	None	0.0
VTR	Soft breakdown	Volt	20.0

GaAsFET Model Netlist Example

```
.MODEL gaasfet15 NJF LEVEL=23
```

MESFET Instance, Materka Model (Level 24)



Materka MESFET Instance Netlist Syntax

The syntax for a Level 24 Materka model MESFET instance is:

`J``xxxx nd ng ns modelname [`**`AREA=`**`area] [`**`M=`**`val] [`**`TJ=`**`val]`

nd is the drain node, *ng* is the gate node, and *ns* is the source node of the transistor. The *modelname* is the name of a Level 24 MESFET model defined in a .MODEL statement elsewhere in the netlist.

Table 51: Materka Level 24 MESFET Instance Parameters

Instance Parameter	Description	Unit	Default
AREA	Area factor	None	1.0
TJ	Device temperature	°C	Circuit temperature
M	Multiplier to simulate multiple devices in parallel	None	1.0

Materka MESFET Instance Netlist Example

```
J2 12 VCC 0 mesfet24
```

MESFET, Materka Model (Level 24)

The .MODEL statement for the Level 24 Materka MESFET models specifies values for one or more model parameters.

`.MODEL``modelname `**`NJF LEVEL=24`**` [modelparameter`**`=`**`val] ...`

or

`.MODEL``modelname `**`PJF LEVEL=24`**` [modelparameter`**`=`**`val] ...`

LEVEL=24 specifies the Materka MESFET model.

Table 52: Level 24 Materka MESFET Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	24 is required to select the Materka MESFET model	None	1 (default if LEVEL parameter is omitted)

AF	Flicker noise exponent	None	1.0
CDS	Drain-source capacitance	Farad	0.0
EG	Barrier height at 0°K (CAP model)	Volt	0.8
FCP	Coefficient for forward-bias depletion capacitance formulas	None	1.0
GAMA	Drain voltage-induced threshold voltage lowering coefficient	None	0.0
IDSS	Drain saturation current for Vgs=Vgss	Ampere	0.1
KFN	Flicker noise coefficient	None	0.0
RD	Drain ohmic resistance	Ohm	0.0
RG	Gate ohmic resistance	Ohm	0.0
RS	Source ohmic resistance	Ohm	0.0
TNOM	Nominal circuit temperature	°C	25.0
VP0	Threshold voltage	Volt	-2.0
XTI	Saturation current temperature exponent	None	2.0
EE (E)	Constant part of power law parameter	None	2.0
KE	Dependence of power law on Vgs	None	0.0
SL	Slope of the Vgs=0 drain characteristic in the linear region	None	0.15
KG	Drain dependence on Vgs in the linear region	None	0.0
SS	Slope of the drain characteristic in the linear region	None	0.0
T	Channel transit time delay	Second	0.0
DLVL	Model selector: 0 = Diode model, 1 = Raytheon model	None	0
IG0	Diode saturation current	Ampere	0.0
AFAG	Slope factor for diode saturation current	None	38.696
IB0	Breakdown saturation current	Ampere	0.0
AFAB	Slope factor for breakdown saturation current	None	0.0
VBC	Breakdown voltage	Volt	None
GMAX	Breakdown conductance	Siemen	0.0
K1D	Fitting parameter	None	0.0
K2D	Fitting parameter	None	0.0
K3D	Fitting parameter	None	0.0

R10	Intrinsic channel resistance for Vgs=0	Ohm	0.0
KR	Slope factor of intrinsic channel resistance	None	0.0
CLVL	Capacitance model selector: 1 = Materka model, 2 = Raytheon model	None	1
CDSD	Low-frequency trapping capacitance	Farad	0.0
RDSD	Channel trapping resistance	Ohm	None
C10	Gate-source Schottky barrier capacitance for Vgs=0	Farad	0.0
K1	Slope parameter for gate-source capacitance	None	1.25
MGS	Gate-source grading coefficient	None	0.5
C1S	Constant parasitic component of gate-source capacitance	Farad	0.0
CF0	Gate-drain feedback capacitance	Farad	0.0
KF	Slope parameter for gate-drain capacitance	None	1.25
MGD	Gate-drain grading coefficient	None	0.5
FCC	Forward-bias depletion capacitance coefficient	None	0.8
CGS0	Gate-source Schottky barrier capacitance for Vgs=0	Farad	0.0
CGD0	Gate-drain Schottky barrier capacitance for Vgs=0	Farad	0.0
VBI	Built-in barrier potential for Raytheon capacitance model	Volt	0.8
RI	Channel resistance for Raytheon capacitance model	Ohm	0.0
VMAX	Maximum voltage used for Vnew	Volt	0.5
VDELTA	Capacitance transition voltage	Volt	0.2
TMOD	Temperature model selector: 0 = quadratic, 1 = linear	None	0
AVT0	Vp0 linear temperature coefficient	None	0.0
ARI	RI linear temperature coefficient	None	0.0
ARG	RG linear temperature coefficient	None	0.0
ARD	RD linear temperature coefficient	None	0.0
ARS	RS linear temperature coefficient	None	0.0
TM	IDS linear temperature coefficient	None	0.0
TME	IDS power law temperature coefficient	None	0.0
M	Capacitance model grading coefficient (Note: This	None	0.5

	parameter M does not override the instance scaling parameter M)		
BVT0	Vp0 quadratic temperature coefficient	None	0.0
BRI	RI quadratic temperature coefficient	None	0.0
BRG	RG quadratic temperature coefficient	None	0.0
BRD	RD quadratic temperature coefficient	None	0.0
BRS	RS quadratic temperature coefficient	None	0.0
AIDS	IDSS linear temperature coefficient	None	0.0
AGAM	GAMA linear temperature coefficient	None	0.0
AEE	EE linear temperature coefficient	None	0.0
AKE	KE linear temperature coefficient	None	0.0
ASL	SL linear temperature coefficient	None	0.0
AKG	KG linear temperature coefficient	None	0.0
ASS	SS linear temperature coefficient	None	0.0
AT	T linear temperature coefficient	None	0.0
AC10	C10 linear temperature coefficient	None	0.0
ACF0	CF0 linear temperature coefficient	None	0.0
AVBC	VBC linear temperature coefficient	None	0.0
ACGS	CGS linear temperature coefficient	None	0.0
ACGD	CGD linear temperature coefficient	None	0.0
AVBI	VBI linear temperature coefficient	None	0.0
AGMX	GMAX linear temperature coefficient	None	0.0
SN	Noise analysis selector, 1=on, 0=off	None	1
RGS	Gate-source ohmic resistance for Enhanced Raytheon model	Ohm	0.0
RGD	Gate-drain ohmic resistance for Enhanced Raytheon model	Ohm	0.0

Materka MESFET Model Netlist Example

```
.MODEL mesfet24 NJF LEVEL=24

+ idss=0.0649003 alpha1=1.5 gama=-0.0306278
```

Device Equations

V_{gsi} = Intrinsic gate-source voltage

V_{dsi} = Intrinsic drain-source voltage

V_{gdi} = Intrinsic gate-drain voltage

V1 = Voltage across Cgs and Ri

V_t = Thermal voltage k TJ/q

k = Boltzmann’s constant

q = Electron charge

TJ = Analysis temperature, Kelvin

Channel Current

$$I_{ds} = IDSS\left(1 + \frac{SS \cdot V_{dsi}}{IDSS}\right)\left(1 - \frac{V_{gsi}(t-T)}{VP0 + GAMA \cdot V_{dsi}}\right)^{E + KEV_{gsi}(t-T)} \times \tanh\left(\frac{SL \cdot V_{dsi}}{IDSS(1 - KGV_{gsi}(t-T))}\right)$$

Diodes

$$I_{gs} = IG0(\exp(AFAG \cdot V_{gsi}) - 1) - IB0 \cdot \exp(-AFAB \cdot (V_{gsi} + VBC))$$

$$I_{gdc} = IG0(\exp(AFAG \cdot V_{gdi}) - 1)$$

When DLVL = DIOD

$$I_{gd} = I_{gdc} - IB0\exp(-AFAB(V_{gdi} + VBC))$$

When DLVL = RAY

$$I_{gd} = I_{gdc} - \frac{GMAX}{4} \cdot (\tanh(K1D(V_{gsi} - K2D)) - 1) \times (V_{gdi} + VBC - \sqrt{(V_{gdi} + VBC)^2 + K3D})$$

Channel Resistance

When KR*V_{gsi} < 1.0

$$R_i = R10(1 - (KR \cdot V_{gsi}))$$

When KR*V_{gsi} >= 1.0

$R_i = 0$

Materka Capacitance Model (CLVL=MAT)

When K1V_{gsi} < FCC

$$C_{gs} = C10(1 - K1V_{gsi})^{-MGS} + C1S$$

When K1V_{gsi} >= FCC

$$C_{gs} = C10(1 - FCC)^{-MGS} + C1S$$

When K1V_{gdi} < FCC

$$C_{gd} = CF0(1 - KFV_{gdi})^{-MGD}$$

When K1V_{gdi} >= FCC

$$C_{gd} = CF0(1 - FCC)^{-MGD}$$

Raytheon Capacitance Model (CLVL=2)

Gate Charge

When V $_{new}$ > V $_{max}$

$$Q_g = C_{gs} \cdot \left(2 \times VBI \cdot \left(1 - \sqrt{1 - \frac{V_{max}}{VBI}} \right) + \frac{V_{new} - V_{max}}{\sqrt{1 - \frac{V_{max}}{VBI}}} \right) + C_{gd} \times V_{eff2}$$

$$Q_{gs} = C_{gs} \cdot \left(2 \times VBI \cdot \left(1 - \sqrt{1 - \frac{V_{max}}{VBI}} \right) + \frac{V_{new} - V_{max}}{\sqrt{1 - \frac{V_{max}}{VBI}}} \right)$$

When V $_{new}$ <= V $_{max}$

$$Q_g = C_{gs} \cdot 2 \times VBI \cdot \left(1 - \sqrt{1 - \frac{V_{max}}{VBI}} \right) + C_{gd} \times V_{eff2}$$

$$Q_{gs} = C_{gs} \cdot 2 \times VBI \cdot \left(1 - \sqrt{1 - \frac{V_{new}}{VBI}} \right) \quad Q_{gd} = C_{gd} \times V_{eff2}$$

Where:

$$V_{max} = Min(FC \times V_{bi}, V_{max})$$

$$V_{new} = \frac{1}{2} \cdot \left\{ V_{eff1} + V_{to} + \sqrt{(V_{eff1} - V_{to})^2 + VDELTA^2} \right\}$$

$$V_{eff1} = \frac{1}{2} \cdot \left\{ V_{gsi} + V_{gdi} + \sqrt{(V_{gsi} - V_{gdi})^2 + \left(\frac{1}{SL}\right)^2} \right\}$$

$$V_{eff2} = \frac{1}{2} \cdot \left\{ V_{gsi} + V_{gdi} - \sqrt{(V_{gsi} - V_{gdi})^2 + \left(\frac{1}{SL}\right)^2} \right\}$$

Temperature Effects

For all TMOD:

$$RD(TJ) = \frac{RD \cdot (1 + (BRD \cdot \Delta t + ARD) \cdot \Delta t)}{AREA / M}$$

$$RG(TJ) = \frac{RG \cdot (1 + (BRG \cdot \Delta t + ARG) \cdot \Delta t)}{AREA / M}$$

$$RS(TJ) = \frac{RS \cdot (1 + (BRS \cdot \Delta t + ARS) \cdot \Delta t)}{AREA / M}$$

$$RI(TJ) = RI \cdot (1 + (BRI \cdot \Delta t + ARI) \cdot \Delta t)$$

Quadratic Model, TMOD=0

Define:

$\Delta t = TJ - TNOM$

$$tn = \frac{TJ}{TNOM} \, TAU(TJ) = t \cdot (1 + AT \cdot \Delta t)$$

$$IDSS(TJ) = IDSS \cdot (1 + AIDS \cdot \Delta t)$$

$$VP0(TJ) = VP0(1 + tm \cdot \Delta t)$$

$$R10(TJ) = R10 \cdot (1 + ARI \cdot \Delta t)$$

$$GAMA(TJ) = GAMA \cdot (1 + AGAM \cdot \Delta t)$$

$$E(TJ) = EE \cdot (1 + AEE \cdot \Delta t)$$

$$KE(TJ) = KE \cdot (1 + AKE \cdot \Delta t)$$

$$SL(TJ) = SL \cdot (1 + ASL \cdot \Delta t)$$

$$KG(TJ) = KG \cdot (1 + AKG \cdot \Delta t)$$

$$SS(TJ) = SS \cdot (1 + ASS \cdot \Delta t)$$

$$VBC(TJ) = VBC \cdot (1 + AVBC \cdot \Delta t)$$

$$I_{ds}(TJ) = I_{ds}(1 + TM\Delta t)^{TME}$$

$$I_{sat}(TJ) = I_{sat} \cdot \exp[(tn - 1)\alpha EG(TJ)] \cdot tn^{XTI\alpha V_{\ast}}$$

Where I_{sat} = IG0 or IB0 and α = ADAG or AFAB for the forward diode and breakdown efffects, respectively.

$$EG(TJ) = EG - \frac{0.000702TJ^2}{TJ + 1108} \quad V_{bi}(TJ) = V_{bi}\Delta t - 3\Delta t\ln(tn) + tnEG(TNOM) - EG(TJ)$$

Where V_{bi} is 1/K1 or 1/KF.

$$C_j(TJ) = C_j\left(1 + M\left(0.0004\Delta t + 1 - \frac{V_{bi}(TJ)}{V_{bi}}\right)\right)$$

Where C_j is C10 or CF0.

$$R(TJ) = R(1 + AR\Delta t + BR\Delta t^2)$$

Where R is R10, RG, RD, or RS; AR and BR are the linear and quadratic temperature coefficients for the respective resistances.

Materka Model, TMOD=0, CLVL=1

$$C10(TJ) = C10 \cdot (1 + AC10 \cdot \Delta t)$$

$$CF0(TJ) = CF0 \cdot (1 + ACF0 \cdot \Delta t)$$

Raytheon Model, TMOD=0, CLVL=2

$$VBI(TJ) = VBI \cdot (1 + AVBI \cdot \Delta t)$$

$$CGS0(TJ) = CGS0 \cdot (1 + ACGS \cdot \Delta t)$$

$$CGD0(TJ) = CGD0 \cdot (1 + ACGD \cdot \Delta t)$$

$$VMAX(TJ) = VMAX \cdot (1 + AVMAX \cdot \Delta t)$$

Linear Model, TMOD=1

This model for the temperature dependence modifies diode saturation current using a physics-based equation and modifies several of the model coefficients using a linear function of Δt. The model is an extension of the paper by Anholt and Swirhun [2].

$$I_{sat}(TJ) = I_{sat} \cdot \exp((tn - 1)\alpha EG(TJ)) \cdot tn^{XT\alpha V_{\text{[illegible]}}}$$

Where I_{sat} = IG0 or IB0 and α = ADAG or AFAB for the forward diode and breakdown efffects, respectively.

$$EG(TJ) = EG - \frac{0.000702\,TJ^2}{TJ + 1108} \quad P(TJ) = P(1 + AP\Delta t)$$

Where P is a parameter (e.g., RG, RD, or C10) and AP is the temperature linear coefficient of that parameter (e.g., ARG, ARD, or AC10).

The Linear temperature coefficient for VMAX is calculated as:

$$\frac{VBI \cdot AVBI}{VMAX} \quad IDSS(TJ) = IDSS \cdot (1 + TM \cdot \Delta t)^{TME}$$

$$VP0(TJ) = VP0 \cdot (1 + (AVT0 + BVT0 \cdot \Delta t) \cdot \Delta t)$$

$$R10(TJ) = R10 \cdot (1 + (ARI + BRI \cdot \Delta t) \cdot \Delta t)$$

Materka Model, TMOD=1, CLVL=1:

$$C10(TJ) = C10 \cdot \left(1 + M \cdot \left(1 + 4 \cdot 10^{-4} \cdot \Delta t - \frac{VBI(TJ)}{AUX}\right)\right)$$

$$K1(TJ) = \frac{1}{\frac{tn}{K1} - 3 \times VT \times \log(tn) + EG(TJ) - EG(TNOM) \times tn}$$

$$CF0(TJ) = CF0 \cdot \left(1 + M \cdot \left(1 + 4 \cdot 10^{-4} \cdot \Delta t - \frac{VBI(TJ)}{AUX}\right)\right)$$

$$KF(TJ) = \frac{1}{\frac{tn}{KF} - (3 \cdot VT \cdot \ln(tn))} + EG(TJ) - (EG(TNOM) \cdot tn)$$

Raytheon Model TMOD=1, CLVL=2:

$$VBI(TJ) = VBI \cdot tn - 3 \cdot VT \cdot \ln(tn) + EG(TJ) - EG(TNOM) \cdot tn$$

$$CGS0(TJ) = CGS0 \cdot \left(1 + M \cdot \left(1 + 4 \cdot 10^{-4} \cdot \Delta t - \frac{VBI(TJ)}{VBI}\right)\right)$$

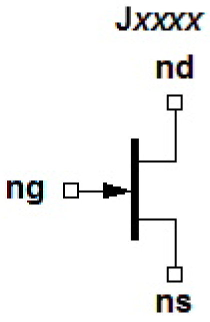
$$CGD0(TJ) = CGD0 \cdot \left(1 + M \cdot \left(1 + 4 \cdot 10^{-4} \cdot \Delta t - \frac{VBI(TJ)}{VBI}\right)\right)$$

$$VMAX(TJ) = VMAX \cdot (1 + AT \cdot \Delta t)$$

References

1. A. Materka and T. Kacprzak, “Computer calculation of large-signal GaAs FET amplifier characteristics,” IEEE Transactions on Microwave Theory Tech., Vol. MTT-33, No. 2, pp. 129-135 Feb. 1985.
2. R.E. Anholt and S. E. Swirhun, “Experimental Investigation of the Temperature Dependence of GaAs FET Equivalent Circuits,” IEEE Trans. on ED, vol. 39, no. 9, pp. 2029-2036, Sept. 1992.

MESFET Instance, Statz Model (Level 25)



Statz MESFET Instance Netlist Syntax

The syntax for a Statz model MESFET instance is:

J*xxx nd ng ns modname* [**AREA=***area*] [**M=***val*] [**TEMP=***val*][**DTEMP=***val*]

nd is the drain node, *ng* is the gate node, and *ns* is the source node of the transistor. *Modname* is the name of a Statz model MESFET (Level 25) defined in a .MODEL statement.

Table 53: Materka Level 25 MESFET Instance Parameters

Instance Parameter	Description	Unit	Default
AREA	Area factor	None	1.0
TEMP	Device temperature	°C	Circuit temp
DTEMP (**TRISE**)	Difference between device temperature and circuit temperature	°C	0.0
M	Multiplier to simulate multiple devices in parallel	None	1.0

Statz MESFET Netlist Examples

```
J2 12 VCC 0 mesfet25
```

Statz MESFET Model

The .MODEL statement for the Statz model MESFET is:

.MODEL*modelname* **NJF LEVEL=25** [*modelparameter***=***val*] **...**

or

`.MODELmodelname PJF LEVEL=25 [modelparameter=val] ...`

LEVEL=25 specifies the Statz MESFET Level 25 model.

Table 54: Materka Level 25 MESFET Model Parameters

Model Parameter	Description	Unit	Default
AF	Flicker noise exponent	None	1.0
ALPHA	Saturation factor	None	2.0
B	Ids-Igs characteristics factor	None	0.0
BETA	Transconductance coefficient	None	1.0e-4
BETATCE	Beta temperature coefficient for Triquint model	None	0.0
CDS	Drain-source capacitance	Farad	0.0
CGD	Gate-drain capacitance	Farad	0.0
CGS	Gate-source capacitance	Farad	0.0
DELTA1	Capacitance saturation transition voltage	Volt	0.3
DELTA2	Capacitance saturation transition voltage	Volt	0.2
EG	Energy gap for gate-drain and gate-source diodes at 0°K	Volt	1.11
FC	Coefficient for forward-bias depletion capacitance formulas	None	0.5
IS	Leakage saturation current	Ampere	1.0e-14
KF	Flicker noise coefficient. Reasonable values are from 1e-19 to 1e-25.	None	0.0
LAMBDA	Channel length modulation factor	None	0.0
N	Gate diode emission coefficient	None	1.0
RD	Drain ohmic resistance	Ohm	0.0
RG	Gate ohmic resistance	Ohm	0.0
RS	Source ohmic reisitance	Ohm	0.0
VTOTC	Temperature compensation coefficient for VTO	None	0.0
TNOM	Nominal circuit temperature	°C	25.0
TQM	Junction capacitance temperature coefficient	None	0.2
VBI	Built-in gate diode voltage	Volt	0.85
VMAX	Maximum junction voltage before capacitance limiting	Volt	0.5
VTO	Threshold voltage	Volt	-2.0

XTI	Saturation current temperature exponent	None	3.0
IDSMOD	IDS Model	None	3.0
TAU	Transit time under the gate	Second	0.0
IDSTC	IDS temperature coefficient	None	0.0
RIN	Channel resistance	Ohm	0.0
GSCAP	Gate-source capacitance model selector: 0=None, 1=Linear, 2=Junction, 3=Statz Charge, 5= Statz Capacitance	None	1
RGD	Gate-drain resistance	Ohm	0.0
GDCAP	Gate-drain capacitance model selector: 0=None, 1=Linear, 2=Junction, 3=Statz Charge, 5= Statz Capacitance	None	1
LG	Gate inductance	Henry	0.0
LD	Drain inductance	Henry	0.0
LS	Source inductance	Henry	0.0
CRF	With RC, frequency-dependent output capacitance	Farad	0.0
GSFWD	Forward Igs model selector: 0=None, 1=Linear, 2=Diode	None	1
GSREV	Reverse Igs model selector: 0=None, 1=Linear, 2=Diode	None	0
GDFWD	Forward Igd model selector: 0=None, 1=Linear, 2=Diode	None	0
GDREV	Reverse Igd model selector: 0=None, 1=Linear, 2=Diode	None	1
VBR	Gate-drain junction reverse bias breakdown voltage	Volt	1.0e100
VJR	Breakdown junction potential	Volt	0.025
IR	Gate reverse saturation current	Ampere	1.0e-14
IMAX	Explosion current	Ampere	1.6
IMELT	Diode limiting current	Ampere	1.6
FNC	Flicker noise corner frequency	Hertz	0.0
R	Gate noise coefficient	None	0.5
P	Drain noise coefficient	None	1.0
C	Gate-drain noise correlation coefficient	None	0.9
FFE	Flicker noise exponent	None	1.0
RC	Frequency-dependent resistance	Ohm	0.0

11 - Grounded Coplanar Waveguide Elements

This topic describes the grounded coplanar waveguide distributed elements available in Nexxim.

General Components

Bends

Coupled Lines

Couplers

Inductors

Open Stubs

Resistors

"Thin Film Resistor" on page 11-28

Shorted Stubs

"Shorted Stub, Physical Length " on page 11-35

"Shorted Stub, Physical Length with Reference " on page 11-36

"Shorted Stub, Electrical Length " on page 11-38

"Shorted Stub, Electrical Length with Reference " on page 11-39

Transmission Lines

"Tapered Line " on page 11-41

"Transmission Line, Physical Length " on page 11-42

"Transmission Line, Physical Length with Reference " on page 11-44

"Transmission Line, Electrical Length " on page 11-45

"Transmission Line, Electrical Length with Reference " on page 11-47

This topic also describes the Grounded Coplanar Waveguide substrate type.

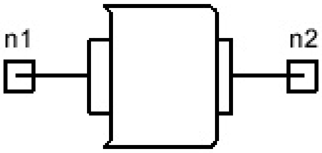
"Selecting None for the Initial Substrate " on page 11-48

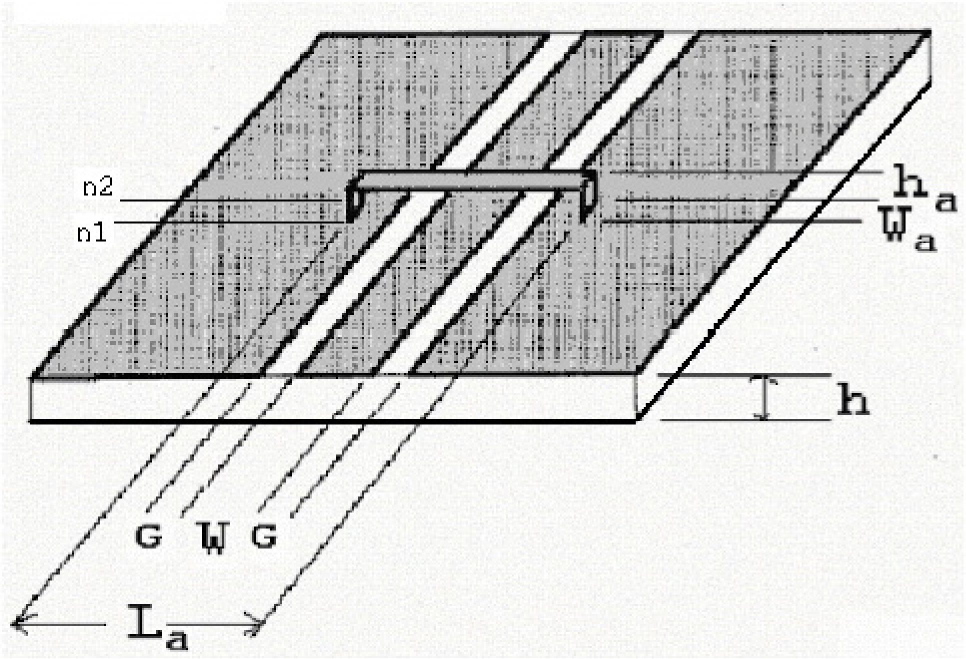
"Creating a Custom Grounded Coplanar Waveguide Substrate " on page 11-49

"Selecting a Grounded Coplanar Waveguide Substrate at the Component Level " on page 11-50

"Grounded Coplanar Waveguide Substrate Model " on page 11-51

Air Bridge, Rectangular Cross Section





Netlist Form

An instance of a grounded coplanar waveguide air bridge with rectangular cross-section has the following Nexxim netlist syntax:

```
Axxx n1 n2 [W=val] [G=val] [HA=val] [WA=val] [LA=val]
+ COMPONENT=gcpwbridge SUBSTRATE=substrate_name
```

n1 and *n2* are the nodes connected to the bridge. The entry **COMPONENT=gcpwbridge** identifies the element.

The **SUBSTRATE=***substrate_name* is the grounded coplanar waveguide substrate model name selected for the design (see "Grounded Coplanar Waveguide Substrate Model " on page 11-51 for details).

Table 24: Air Bridge Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Width of slots	Meter	1.0e-3
HA	Height of air bridge above conductor plane	Meter	3.0e-6
WA	Width of air bridge	Meter	10.0e-6
LA	Length of air bridge	Meter	3.5e-3

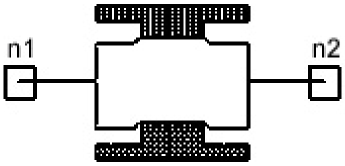
Netlist Example

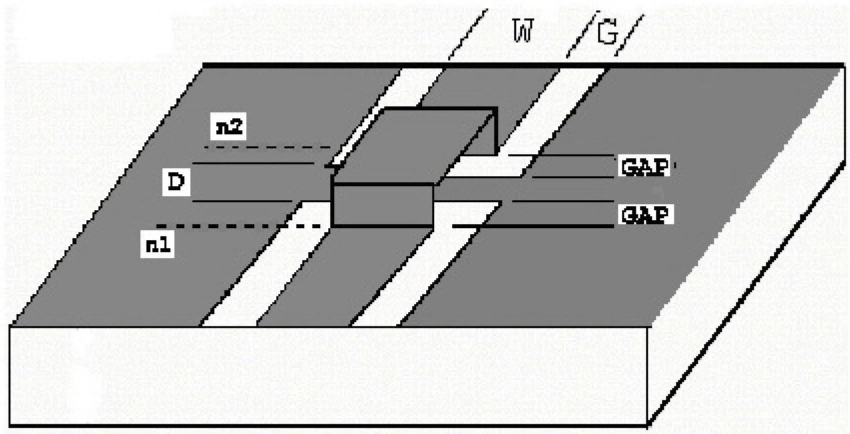
```
Ajumper1 1 2 W=0.3e-3 G=0.5e-3 HA=2.0e-6 WA=5.0e-6 LA=2.0e-3
+ COMPONENT=gcpwbridge SUBSTRATE=GCPW1
```

where GCPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB GCPW1 GCPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Air Bridge, Cross Over





Netlist Form

An instance of a grounded coplanar waveguide air bridge cross over has the following Nexxim netlist syntax:

```
Axxx n1 n2 [W=val] [G=val] [HA=val] [GAP=val] [D=val]
+ COMPONENT=gcpw_crossbridge SUBSTRATE=substrate_name
```

n1 and *n2* are the nodes connected to the bridge. The entry **COMPONENT=gcpw_crossbridge** identifies the element.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Grounded Coplanar Waveguide Substrate Model " on page 11-51 for details).

Table 25: Air Bridge Cross Over Instance Parameters

Parameter	Description	Units	Default
W	Width of crossover bridge	Meter	1.0e-3
G	Width of gaps	Meter	1.0e-3
HA	Height of air bridge above conductor plane	Meter	3.0e-3
GAP	Width of open-end gap	Meter	1.0e-3
D	Distance of separation	Meter	3.0e-3

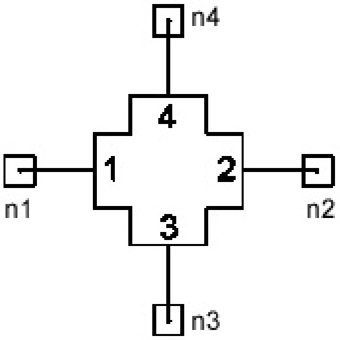
Netlist Example

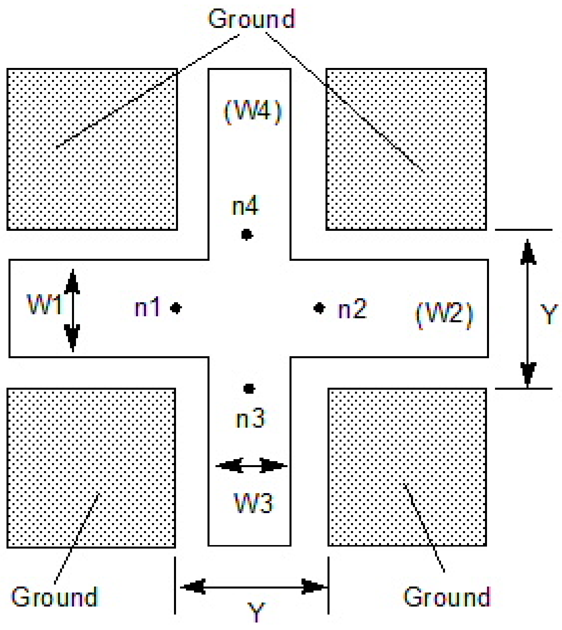
```
Ajumper1 1 2 W=0.3e-3 G=0.5e-3 HA=2.0e-3 GAP=0.5e-3 D=2.0e-3
+ COMPONENT=cpw_crossbridge SUBSTRATE=GCPW1
```

where GCPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB GCPW1 GCPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Cross





Netlist Format

An instance of a symmetric grounded coplanar waveguide cross has the following netlist syntax:

```
Axxx n1 n2 n3 n4 [W1=val] [W3=val][Y=val]
+ COMPONENT=gcpwcross SUBSTRATE=substrate_name
```

n1, *n2*, *n3*, and *n4* are the names of the nodes attached to the cross.

The implementation of the grounded coplanar waveguide grounded cross element requires the element to be symmetric. Only widths W1 and W3 are specified, with W2=W1 and W4=W3.

The entry **COMPONENT=gcpwcross** identifies the element as a grounded coplanar waveguide cross element.

The **SUBSTRATE=***substrate_name* is the grounded coplanar waveguide substrate model name selected for the design (see "Grounded Coplanar Waveguide Substrate Model " on page 11-51 for details).

Table 26: Grounded Coplanar Waveguide Cross Instance Parameters

Parameter	Description	Units	Default
Y	Ground-to-ground spacing at all ports. Must be greater than both W1 and W3.	Meter	3e-3
W1	Conductor width at ports 1 and 2	Meter	1e-3

W3	Conductor width at ports 3 and 4	Meter	1e-3

Netlist Example

```
A23 Port1 Port2 Port3 Port4 W1=4.0e-004 W3=2.0e-4 Y=6.0e-4
+ COMPONENT=GCPWCROSS   SUBSTRATE=GCPW1
```

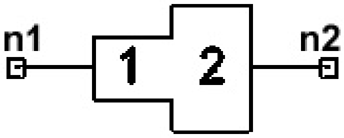
where GCPW1, the selected layout technology or substrate type, has a definition such as:

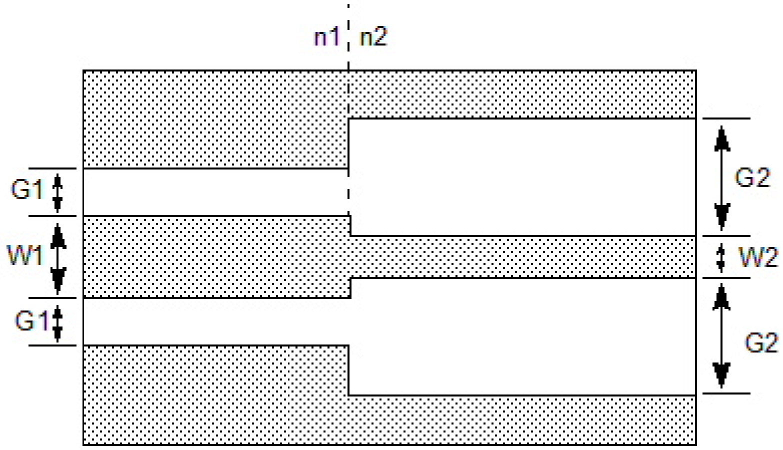
```
.SUB GCPW1 GCPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. The ground-to-ground distance Y is the same at all ports.
2. W1 = W2 and W3 = W4.
3. For accurate results, the substrate definition should specify:
   2 < ER <14
   H > Y
   0.1 < W*n*/Y <0.9, where W*n* is the conductor width at any port.
4. The coplanar mode is assumed to exist only. Parasitic effects due to air bridges are not considered by this model.

Step





Netlist Format

An instance of a grounded coplanar waveguide step has the following netlist syntax:

```
Axxx n1 n2 [W1=val] [P=val]
+ COMPONENT=gcpwstep SUBSTRATE=substrate_name
```

n1 and *n2* are the names of the nodes attached to the step. The entry **COMPONENT=gcpwstep** identifies the element as a grounded coplanar waveguide step.

The **SUBSTRATE=***substrate_name* is the grounded coplanar waveguide substrate model name selected for the design (see "Grounded Coplanar Waveguide Substrate Model " on page 11-51 for details).

Table 27: Grounded Coplanar Waveguide Step Instance Parameters

Parameter	Description	Units	Default
W1	Conductor width of line connected to node 1	Meter	1.5e-3
G1	Slot width of line connected to node 1	Meter	1e-3
W2	Conductor width of line connected to node 2	Meter	1e-3
G2	Gap width of line connected to node 2	Meter	1.5e-3

Netlist Example

```
A5 Port1 Port2 W1=0.75e-3 G1=1.1e-3 W2=0.5e-3 G2=1.3e-3
COMPONENT=gcpwstep SUBSTRATE=GCPW1
```

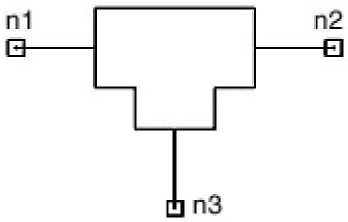
where GCPW1, the selected layout technology or substrate type, has a definition such as:

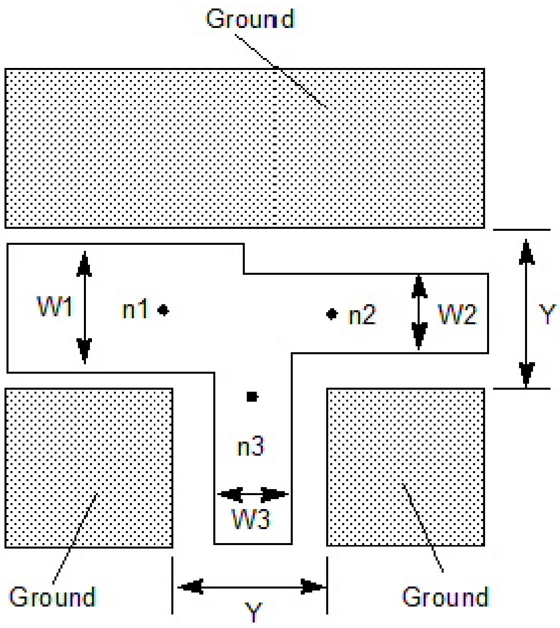
```
.SUB GCPW1 GCPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. The model computes the equivalent T-network of the GCPW step, which consists of two series inductors and a shunt capacitor.
2. For accurate results, the substrate definition should specify:
   $H > W1 + 2×G1$
   $H > W2 + 2×G2$
   $0.1 < k1 < 0.9$, where $k1 = W1/(W1 + 2×G1)$
   $0.1 < k2 < 0.9$, where $k2 = W2/(W2 + 2×G2)$
3. When G2>G1, W1>W2. When G2<G1, W1<W2.

Tee





Netlist Format

An instance of a grounded coplanar waveguide tee has the following netlist syntax:

```
Axxx n1 n2 n3 [W1=val] [W3=val][Y=val] COMPONENT=gcpwtee
SUBSTRATE=substrate_name
```

n1, *n2*, and *n3* are the names of the nodes attached to the tee.

The entry **COMPONENT=gcpwtee** identifies the element as a grounded coplanar waveguide tee element.

The **SUBSTRATE=***substrate_name* is the grounded coplanar waveguide substrate model name selected for the design (see "Grounded Coplanar Waveguide Substrate Model " on page 11-51 for details).

Table 28: Grounded Coplanar Waveguide Tee Instance Parameters

Parameter	Description	Units	Default
Y	Ground-to-ground spacing at all ports. Must be greater than W1, W2, and W3.	Meter	4e-3
W1	Conductor width at port 1	Meter	1e-3
W2	Conductor width at port 2	Meter	1e-3
W3	Conductor width at port 3	Meter	1e-3

Netlist Example

```
A23 Port1 Port2 Port3 W1=4.0e-4 W2=3.0e-4 W3=2.0e-4 Y=6.0e-4
+ COMPONENT=GCPWTEE SUBSTRATE=GCPW1
```

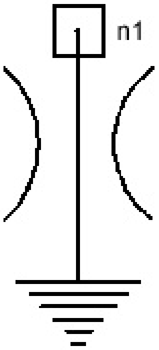
where GCPW1, the selected layout technology or substrate type, has a definition such as:

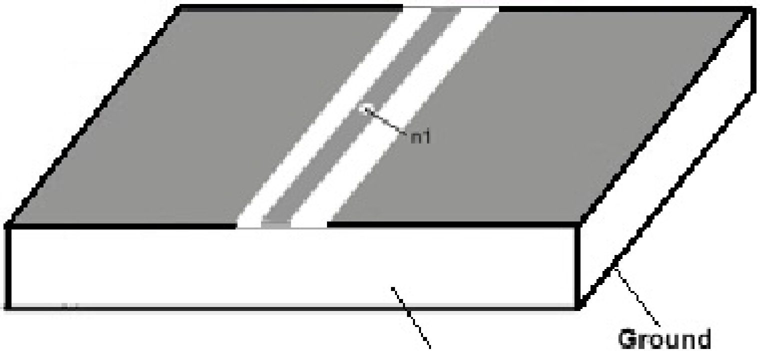
```
.SUB GCPW1 GCPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

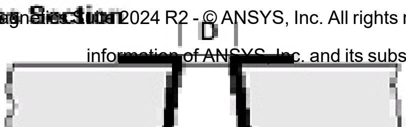
1. The lines connected to nodes n1 and n2 are collinear, with conductor widths W1 and W2. The perpendicular line is connected to node n3 and has center conductor width W3. The ground-to-ground distance Y is the same for all ports.
2. For accurate results, the substrate definition should specify:
   H > Y
   0.1 < W*n*/Y <0.9, where W*n* is the conductor width at any port.
3. The coplanar mode is assumed to exist only. Parasitic effects due to air bridges are not considered by this model.

Via Hole





Cross Section



Netlist Format

An instance of a grounded coplanar waveguide via hole has the following netlist syntax:

A*xxx n1* **D=***val* **DG=***val* **COMPONENT=gcpw_viahole**
SUBSTRATE=*substrate_name*

n1 is the name of the node attached to the via.

The entry **COMPONENT=gcpw_viahole** identifies the element as a grounded coplanar waveguide via hole.

The **SUBSTRATE=***substrate_name* is the grounded coplanar waveguide substrate model name selected for the design (see "Grounded Coplanar Waveguide Substrate Model " on page 11-51 for details).

Table 29: Grounded Coplanar Waveguide Via Hole Instance Parameters

Parameter	Description	Units	Default
D	Diameter of via hole	Meter	1e-3
DG	Diameter of via hole on ground plane	Meter	D

Netlist Example

```
A23 Port1 D=3.0e-4 DG=5.0e-4
+ COMPONENT=gcpw_viahole   SUBSTRATE=GCPW1
```

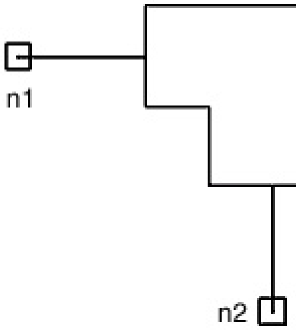
where GCPW1, the selected layout technology or substrate type, has a definition such as:

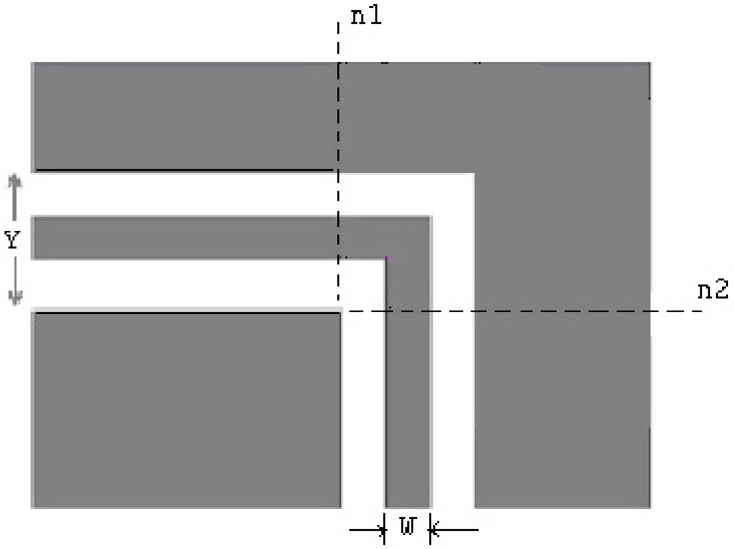
```
.SUB GCPW1 GCPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. Conditions for ±2% accuracy of the no radiation loss model:
   $ER \geq 1.0$
   $H << \lambda$, where λ is the wavelength

Unmitered Bend, Distance Between Ground Planes





Netlist Format

An instance of a grounded coplanar waveguide unmitered bend, ground plane distance, has the following netlist syntax:

`Axxx n1 n2 [W=val] [Y=val]`

`COMPONENT=gcpw_bend_ground_plane_distance SUBSTRATE=substrate_name`

n1 and *n2* are the names of the nodes attached to the bend. The entry **COMPONENT=gcpw_bend_ground_plane_distance** identifies the element as a grounded coplanar waveguide unmitered bend, ground plane distance specified.

The **SUBSTRATE=***substrate_name* is the grounded coplanar waveguide substrate model name selected for the design (see "Grounded Coplanar Waveguide Substrate Model " on page 11-51 for details).

Table 30: Grounded Coplanar Waveguide Unmitered Bend, Ground Plane Distance Instance Parameters

Parameter	Description	Units	Default
W	Center conductor width	Meter	1.0e-3
Y	Distance between ground planes	Meter	3.0e-3

Netlist Example

```
A5 Port1 Port2 W=0.75e-3 Y=2.1e-3
+ COMPONENT=cpw_bend_ground_plane_distance SUBSTRATE=GCPW1
```

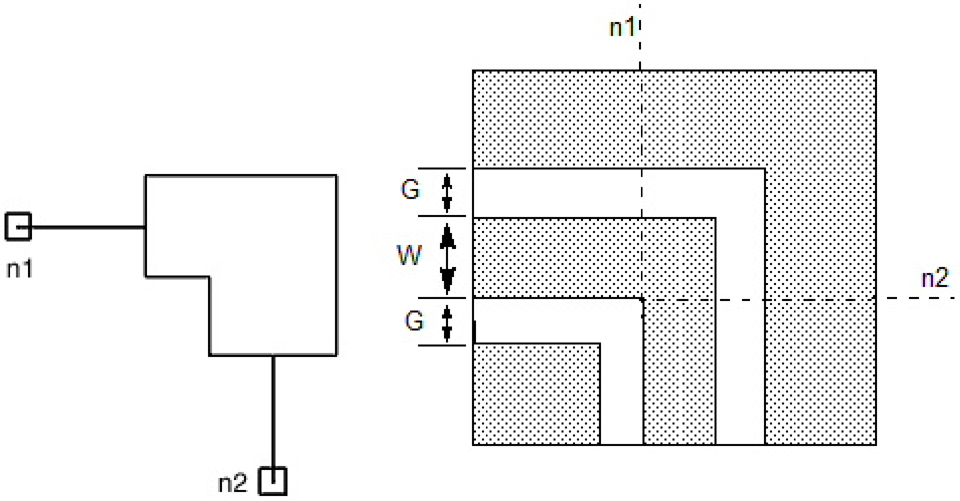
where GCPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB GCPW1 GCPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. Reference planes coincide with the inside vertex of the corner, as shown in the figure.
2. For accurate results, the substrate definition should specify:
   H > Y
   0.1 < W/Y < 0.9
3. The coplanar mode is assumed to exist only. The CPW Air Bridge can be used if parasitic effects due to air bridges can be considered.

Unmitered Bend, Gap Width



Netlist Format

An instance of a grounded coplanar waveguide unmitered bend, gap width, has the following netlist syntax:

```
Axxx n1 n2 [W=val] [G=val]
+COMPONENT=gcpw_unmitered_bend SUBSTRATE=substrate_name
```

n1 and *n2* are the names of the nodes attached to the bend. The entry **COMPONENT=gcpw_unmitered_bend** identifies the element as a grounded coplanar waveguide unmitered bend, gap width specified.

The **SUBSTRATE=***substrate_name* is the grounded coplanar waveguide substrate model name selected for the design (see "Grounded Coplanar Waveguide Substrate Model " on page 11-51 for details).

Table 31: Grounded Coplanar Waveguide Unmitered Bend, Gap Widthm Instance Parameters

Parameter	Description	Units	Default
W1	Center conductor width	Meter	1.0e-3
G	Gap width	Meter	1.0e-3

Netlist Example

```
A5 Port1 Port2 W=0.75e-3 G=1.1e-3
+ COMPONENT=gcpw_unmitered_bend SUBSTRATE=GCPW1
```

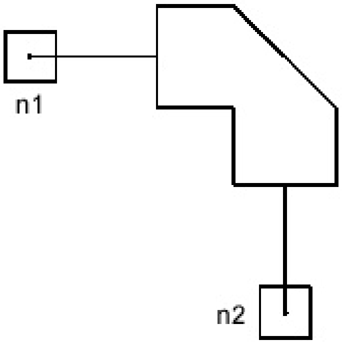
where GCPW1, the selected layout technology or substrate type, has a definition such as:

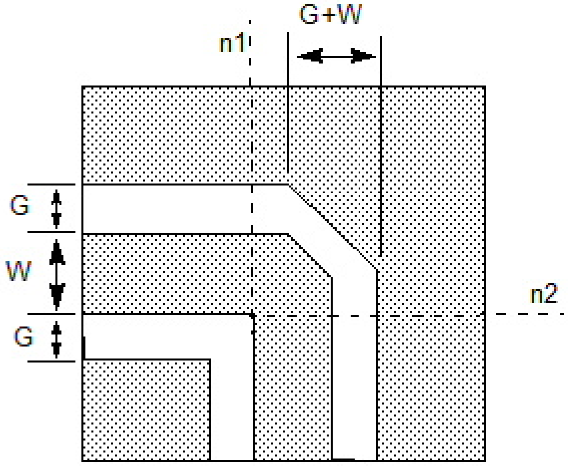
```
.SUB GCPW1 GCPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. Reference planes coincide with the inside vertex of the corner, as shown in the figure.
2. For accurate results, the substrate definition should specify:
   $H > W + 2×G$
   $0.1 < W/(W1 + 2×G) < 0.9$
3. The coplanar mode is assumed to exist only. Parasitic effects due to air bridges are not considered by this model.

Mitered Bend





Netlist Format

An instance of a grounded coplanar waveguide mitered bend has the following netlist syntax:

```
Axxx n1 n2 [W=val] [G=val]
+ COMPONENT=gcpw_mitered_bend SUBSTRATE=substrate_name
```

n1 and *n2* are the names of the nodes attached to the bend. The entry **COMPONENT=gcpw_mitered_bend** identifies the element as a grounded coplanar waveguide unmitered bend.

The **SUBSTRATE=***substrate_name* is the grounded coplanar waveguide substrate model name selected for the design (see "Grounded Coplanar Waveguide Substrate Model " on page 11-51 for details).

Table 32: Grounded Coplanar Waveguide Mitered Bend Instance Parameters

Parameter	Description	Units	Default

W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3

Netlist Example

```
A5 Port1 Port2 W=0.75e-3 G=1.1e-3 COMPONENT=gcpw_mitered_bend
SUBSTRATE=GCPW1
```

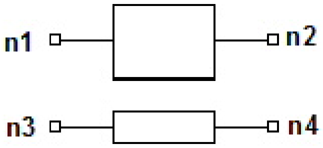
where GCPW1, the selected layout technology or substrate type, has a definition such as:

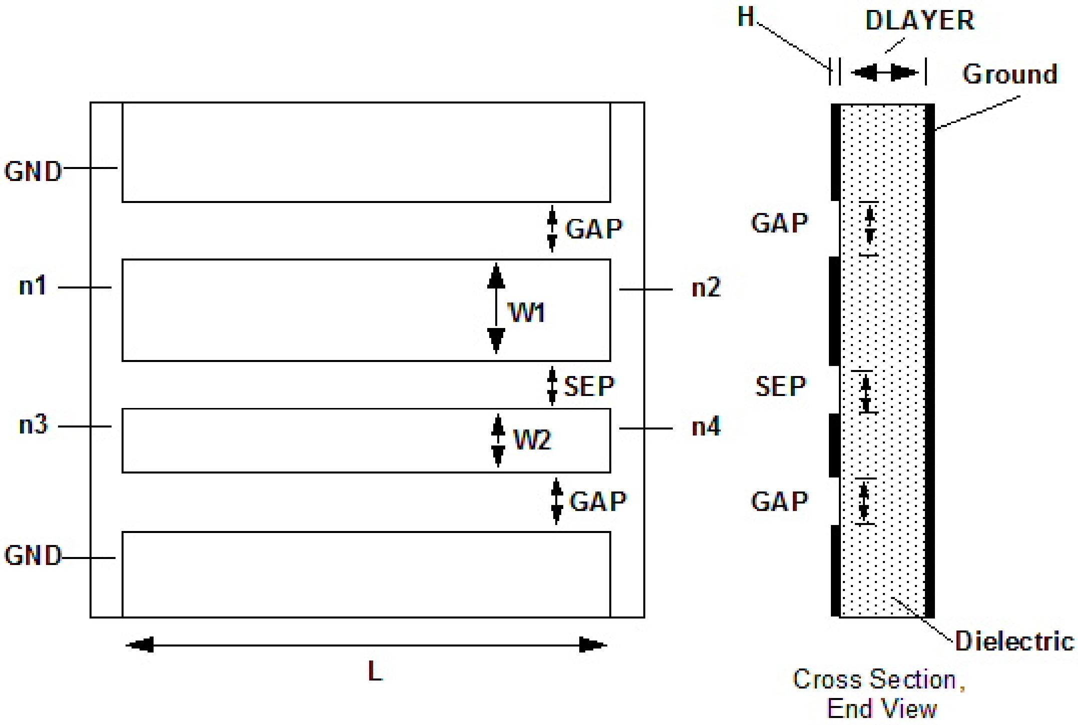
```
.SUB GCPW1 GCPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. Reference planes coincide with the inside vertex of the corner, as shown in the figure.
2. For accurate results, the substrate definition should specify:
   H > W + 2×G
   0.1 < W/(W1 + 2×G) < 0.9
3. The coplanar mode is assumed to exist only. Parasitic effects due to air bridges are not considered by this model.

Coupled Lines, Asymmetric, Physical Length, Field Solver





Netlist Form

A GCPW asymmetric coupled line, physical length, field solver instance has the following netlist syntax:

```
Wxxx n1 n2 0 n3 n4 0 [L=length] N=2 FSmodel=modelname
.MATERIAL material METAL CONDUCTIVITY=conductivity
.MATERIAL dielectric DIELECTRIC ER=er LOSSTANGENT=losstangent
.SHAPE RECT1 RECTANGLE WIDTH=w1 HEIGHT=h
.SHAPE RECT2 RECTANGLE WIDTH=w2 HEIGHT=h
.SHAPE RECT3 RECTANGLE WIDTH='5*(w1+w2)' HEIGHT=h
.LAYERSTACK STACK1
+ LAYER=(material,h)
+ LAYER=(dielectric,dlayer)
.MODEL modelname W MODELTYPE=Fieldsolver
+ LAYERSTACK=STACK1
+ CONDUCTOR=(SHAPE=RECT3, ORIGIN=('-gap-5*(w1+w2)',dlayer+h)
+ MATERIAL=conductor, TYPE=REFERENCE)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=(0,dlayer+h)
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT2, ORIGIN=('w1+sep',dlayer+h)
+ MATERIAL=conductor, TYPE=SIGNAL)
```

```
+ CONDUCTOR=(SHAPE=RECT3, ORIGIN=('w1+sep+w2+gap', dlayer+h)
+ MATERIAL=conductor, TYPE=REFERENCE)
```

n1 and *n3* are the names of the input nodes. *n2* and *n4* are the corresponding output nodes. The entry **N=2** is required.

The entry **FSmodel=***modelname* identifies the field solver coplanar waveguide model.

Table 33: Asymmetric Coupled Line, Physical Length, Field Solver Instance Parameters

Parameter	Description	Units	Default
L	Physical length	Meter	1e-3
N	Number of lines (must be 2)	None	2
material	Conductor material	None	cond1
conductivity	Conductivity of conductor material		57.6e6
dielectric	Dielectric material	None	diel1
er	Dielectric constant		2.2
losstangent	Dielectric loss tangent		0
w1	Width of first conductor	Meter	1e-3
w2	Width of second conductor	Meter	1e-3
gap	Gap width between outer conductors and grounds	Meter	1e-3
sep	Spacing between conductors	Meter	1e-3

> **Note:**
>
> The default values for the coupled line are the ones assigned when placing a component from the Component library in a schematic. There are NO defaults for netlist designs; all values must be specified.

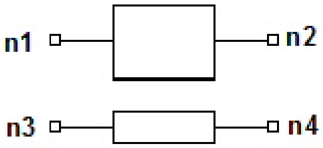
Netlist Example

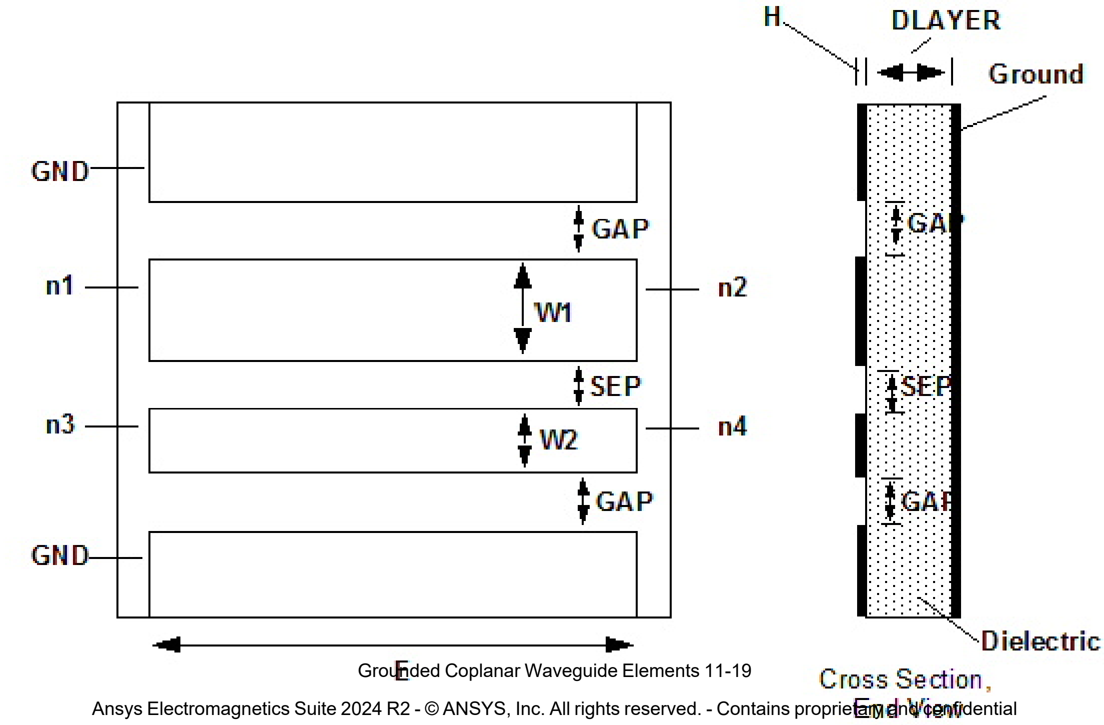
```
W3 Port1 Port2 0 net_1911 net_2 0 N=2 L=0.002 FSmodel=GCPW1
```

```
.MATERIAL COPPER METAL CONDUCTIVITY=58000000
.MATERIAL dielectric1 DIELECTRIC ER=4.4 LOSSTANGENT=0.02
.SHAPE RECT1 RECTANGLE WIDTH=0.001 HEIGHT=0.002
.SHAPE RECT2 RECTANGLE WIDTH=0.002 HEIGHT=0.002
.SHAPE RECT3 RECTANGLE WIDTH='5*(w1+w2)' HEIGHT=0.002
.LAYERSTACK STACK1
```

```
.LAYERSTACK STACK1
+ LAYER=(COPPER,0.002)
+ LAYER=(dielectric1,0.010)
.MODEL CPW1 W MODELTYPE=Fieldsolver
+ LAYERSTACK=STACK1
+ CONDUCTOR=(SHAPE=RECT3,
+ ORIGIN=('-.005-5*(.001+.002)',.010+.002)
+ MATERIAL=conductor, TYPE=REFERENCE)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=(0,.010+.002)
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT2, ORIGIN=('.001+.003',.010+.002)
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT3,
+ ORIGIN=('.001+.003+.002+.005', .010+.002)
+ MATERIAL=conductor, TYPE=REFERENCE)
```

Coupled Lines, Asymmetric, Electrical Length, Field Solver





Netlist Form

An asymmetric coupled line, electrical length, field solver instance has the following netlist syntax:

```
Wxxx n1 n2 0 n3 n4 0

+ L= '(E*3e8)/(360*F*SQRT(ER))' // Convert to physical length
+ N=2 FSmodel=modelname

.MATERIAL material METAL CONDUCTIVITY=conductivity
.MATERIAL dielectric DIELECTRIC ER=er LOSSTANGENT=losstangent
.SHAPE RECT1 RECTANGLE WIDTH=w1 HEIGHT=h
.SHAPE RECT2 RECTANGLE WIDTH=w2 HEIGHT=h
.SHAPE RECT3 RECTANGLE WIDTH='5*(w1+w2)' HEIGHT=h
.LAYERSTACK STACK1
+ LAYER=(material,h)
+ LAYER=(dielectric,dlayer)
.MODEL modelname W MODELTYPE=Fieldsolver
+ LAYERSTACK=STACK1
+ CONDUCTOR=(SHAPE=RECT3, ORIGIN=('-gap-5*(w1+w2)',dlayer+h)
+ MATERIAL=conductor, TYPE=REFERENCE)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=(0,dlayer+h)
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT2, ORIGIN=('w1+sep',dlayer+h)
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT3, ORIGIN=('w1+sep+w2+gap', dlayer+h)
+ MATERIAL=conductor, TYPE=REFERENCE)
```

n1 and *n3* are the names of the input nodes. *n2* and *n4* are the corresponding output nodes. The entry **N=2** is required.

The entry **FSmodel=***modelname* links the field solver coplanar waveguide instance to the model code.

Table 34: Asymmetric Coupled Line, Electrical Length, Field Solver Instance Parameters

Parameter	Description	Units	Default
E	Electrical length	Degree	45
F	Reference frequency for electrical length	Hertz	1e9
N	Number of lines (must be 2)	None	2
material	Conductor material	None	cond1
conductivity	Conductivity of conductor material		57.6e6

dielectric	Dielectric material	None	diel1
er	Dielectric constant		2.2
losstangent	Dielectric loss tangent		0
w1	Width of first conductor	Meter	1e-3
w2	Width of second conductor	Meter	1e-3
gap	Gap width between outer conductors and grounds	Meter	1e-3
sep	Spacing between conductors	Meter	1e-3

> **Note:**
>
> The default values for the coupled line are the ones assigned when placing a component from the Component library in a schematic. There are NO defaults for netlist designs; all values must be specified.

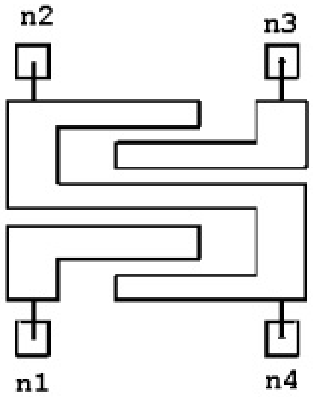
Netlist Example

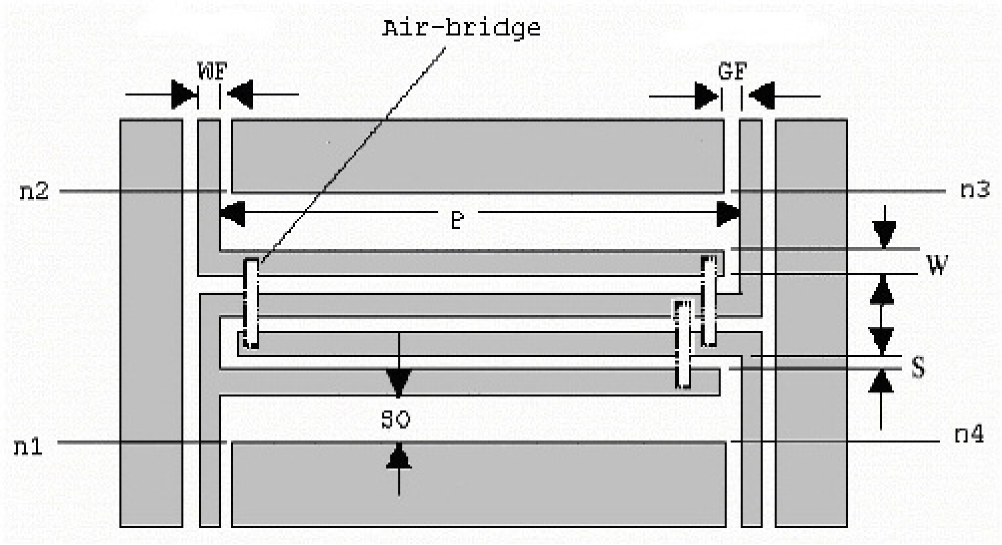
```
W3 Port1 Port2 0 net_1911 net_2 0 N=2
+ L=’(45*3e8)/(360*1e9*SQRT(4.4)
+ FSmodel=GCPW1
```

```
.MATERIAL COPPER METAL CONDUCTIVITY=58000000
.MATERIAL dielectric1 DIELECTRIC ER=4.4 LOSSTANGENT=0.02
.SHAPE RECT1 RECTANGLE WIDTH=0.001 HEIGHT=0.002
.SHAPE RECT2 RECTANGLE WIDTH=0.002 HEIGHT=0.002
.SHAPE RECT3 RECTANGLE WIDTH='5*(.001+.002)' HEIGHT=0.002
.LAYERSTACK STACK1
+ LAYER=(COPPER,0.002)
+ LAYER=(dielectric1,0.010)
.MODEL GCPW1 W MODELTYPE=Fieldsolver
+ LAYERSTACK=STACK1
+ CONDUCTOR=(SHAPE=RECT3,
+ ORIGIN=('-.005-5*(.001+.002)',.010+.002)
+ MATERIAL=conductor, TYPE=REFERENCE)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=(0,.010+.002)
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT2, ORIGIN=('.001+.003',.010+.002)
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT3,
+ ORIGIN=('.001+.003+.002+.005', .010+.002)
```

```
+ MATERIAL=conductor, TYPE=REFERENCE)
```

Lange Coupler, Physical Length





Netlist Format

A Lange coupler, physical length instance has the following netlist format:

`AGCPWLANG``xxx n1 n2 n3 n4` **`N=4 W=`**`val` **`S=`**`val` **`P=`**`val`

```
WF=val GF=val WA=val HA=val SO=val
+ COMPONENT=gcpwlange_physical SUBSTRATE=substrate_name
```

n1, *n2*, *n3*, and *n4* are the names of the nodes attached to the coupler. The entry **COMPONENT=gcpwlange_physical** identifies the element.

The **SUBSTRATE=***substrate_name* is the grounded coplanar waveguide substrate model name selected for the design (see "Grounded Coplanar Waveguide Substrate Model " on page 11-51 for details).

Table 35: Lange Coupler, Physical Length Instance Parameters

Parameter	Description	Unit	Default
N	Number of lines. Must be 4.	None	4
W	Conductor width	Meter	1e-3
S	Conductor spacing	Meter	1e-3
P	Physical length	Meter	10e-3
WF	Center conductor width of feeding lines	Meter	0.5e-3
GF	Slot width of feeding lines	Meter	0.5e-3
WA	Width of air bridges	Meter	0.1e-3
HA	Height of air bridges	Meter	0.1e-3
SO	Distance to ground plane	Meter	1e-3

Netlist Example

```
AGCPWLANG1 Port1 Port2 Port3 Port4 N=4 W=1e-3 S=.2e-3 P=10e-3
+ COMPONENT=gcpwlange_physical SUBSTRATE=GCPW1
```

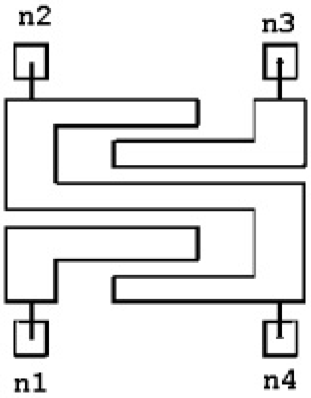
where GCPW1, the selected layout technology or substrate type, has a definition such as:

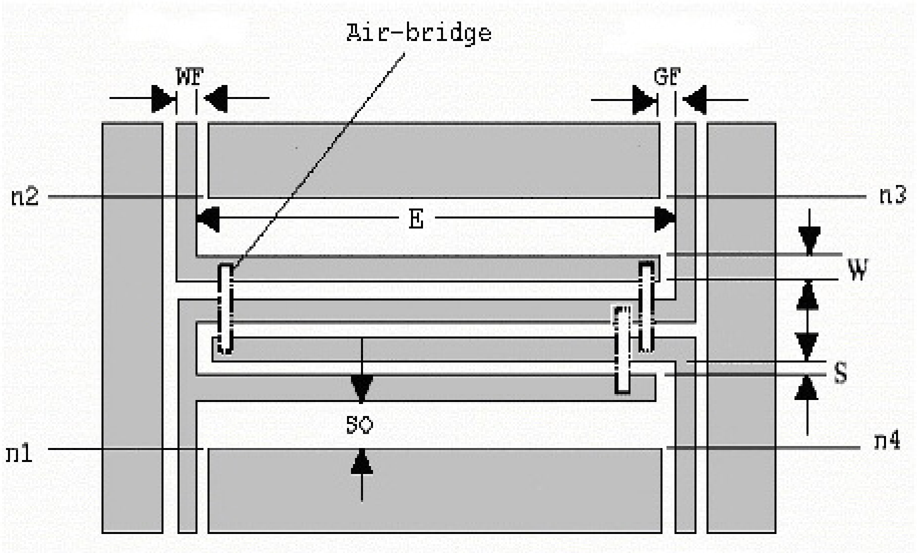
```
.SUB GCPW1 GCPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. The conductor width of all fingers is W. The diatance between all fingers is S.
2. The number of fingers, N, must be 4.
3. Port 1 is the input port, port 2 is the coupled port, port 3 is the through port, and port 4 is the isolated port.
4. The length of air bridges used to approximate their parasitic effects, is 2*(W+S).

Lange Coupler, Electrical Length





Netlist Format

A Lange coupler, electrical length instance has the following netlist format:

AGCPWLANGE*xxx n1 n2 n3 n4* **N=4 W=***val* **S=***val* **E=***val* **F=***val* **WF=***val* **GF=***val* **WA=***val* **HA=***val* **SO=***val* **COMPONENT=gcpwlange_electrical SUBSTRATE=***substrate_name* *n1*, *n2*, *n3*, and *n4* are the names of the nodes attached to the coupler. The entry **COMPONENT=gcpwlange_electrical** identifies the element.

The **SUBSTRATE=***substrate_name* is the grounded coplanar waveguide substrate model name selected for the design (see "Grounded Coplanar Waveguide Substrate Model " on page 11-51 for details).

Table 36: Lange Coupler, Electrical Length Instance Parameters

Parameter	Description	Unit	Default
N	Number of lines. Must be 4.	None	4
W	Conductor width	Meter	1e-3
S	Conductor spacing	Meter	1e-3
E	Physical length	Degree	90
F	Frequency at which E is taken	Hz	1e9
WF	Center conductor width of feeding lines	Meter	0.5e-3
GF	Slot width of feeding lines	Meter	0.5e-3
WA	Width of air bridges	Meter	0.1e-3
HA	Height of air bridges	Meter	0.1e-3
SO	Distance to ground plane	Meter	1e-3

Netlist Example

```
AGCPWLANGE1 Port1 Port2 Port3 Port4 N=4 W=1e-3 S=.2e-3 E=75
+ COMPONENT=gcpwlange_electrical SUBSTRATE=GCPW1
```

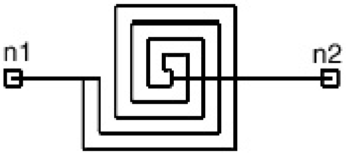
where GCPW1, the selected layout technology or substrate type, has a definition such as:

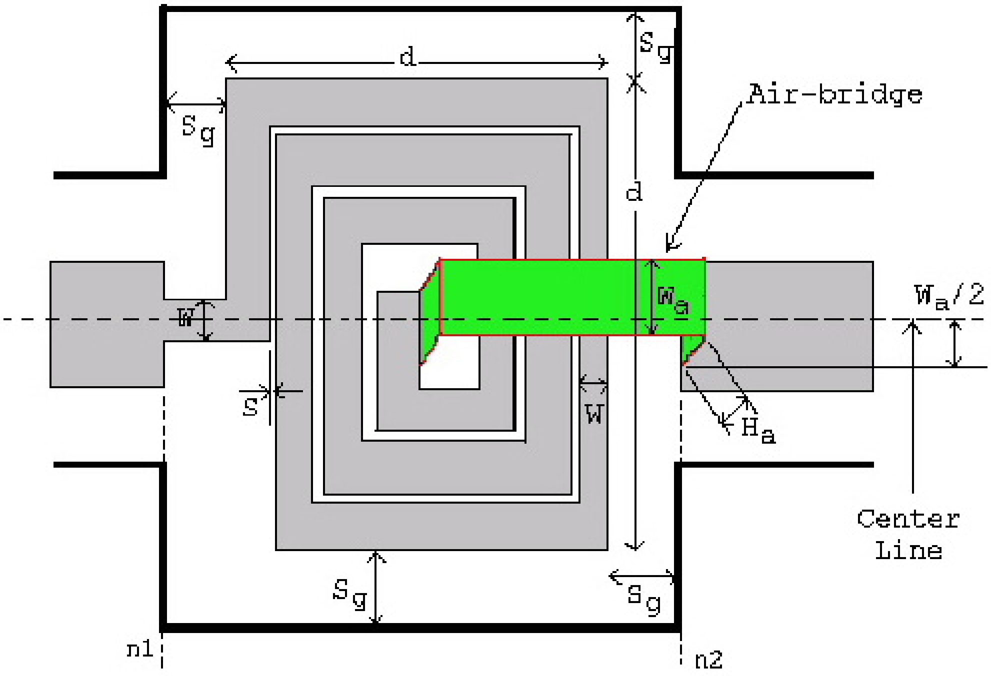
```
.SUB GCPW1 GCPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. The conductor width of all fingers is W. The diatance between all fingers is S.
2. The number of fingers, N, must be 4.
3. Port 1 is the input port, port 2 is the coupled port, port 3 is the through port, and port 4 is the isolated port.
4. The length of air bridges used to approximate their parasitic effects, is 2*(W+S).

Rectangular Inductor





Netlist Format

An instance of a grounded coplanar waveguide rectangular inductor has the following netlist syntax:

A*xxx n1* **N=***val* **D=***val* **W=***val* **S=***val*] **HA=***val* **WA=***val* **SG=***val* **T=***val*]

RB=*val* **COMPONENT=gcpwreci SUBSTRATE=***substrate_name* *n1* is the name of the node attached to the rectangular inductor. The entry **COMPONENT=gcpwreci** identifies the element as a grounded coplanar waveguide open stub, physical length.

The **SUBSTRATE=***substrate_name* is the grounded coplanar waveguide substrate model name selected for the design (see "Grounded Coplanar Waveguide Substrate Model " on page 11-51 for details).

Table 37: Grounded Coplanar Waveguide Rectangular Inductor Instance Parameters

Parameter	Description	Units	Default
N	Number of turns	None	5.5
D	Spiral outer dimension	Meter	10e-3
W	Conductor width	Meter	0.5e-3
S	Spacing between turns	Meter	0.2e-3
HA	Height of air bridge	Meter	3.0e-6
WA	Width of air bridge	Meter	10e-6
SG	Distance to ground plane	Meter	0.5e-6
T	Conductor thickness	Meter	Substrate Metallization
RB	Bulk resistivity	μ-Ohm/cm	Substrate Metallization

Netlist Example

```
A2 Port1 Port2 D=6e-3 N=3 W=0.3e-3 S=0.3e-3 HA=0.11e-3
WA=0.21e-3 SG=2e-3 COMPONENT=gcpwreci SUBSTRATE=GCPW1
```

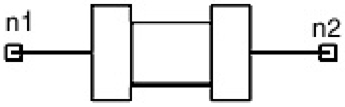
where GCPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB GCPW1 GCPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. This model is not recommended beyond the first resonant frequency.
2. The model is restricted to a square GCPW spiral.
3. An error occurs if the size of the inductor cannot accomodate the specified number of turns.
4. The number of turns N has to be an integer multiple of half a turn, i.e., 0.5, 1, 1.5, …

Thin Film Resistor



Netlist Format

An instance of a grounded coplanar waveguide thin film resistor has the following netlist syntax:

AGCPWTFR*xxx n1 n2* **W=***val* **G=***val* **P=***val* **RB=***val* **T=***val*
COMPONENT=gcpw_thinfilm_rb SUBSTRATE=*substrate_name*

n1 and *n2* are is the names of the nodes attached to the resistor. The entry **COMPONENT=gcpw_thinfilm_rb** identifies the element.

The **SUBSTRATE=***substrate_name* is the grounded coplanar waveguide substrate model name selected for the design (see "Grounded Coplanar Waveguide Substrate Model " on page 11-51 for details).

Table 38: Grounded Coplanar Waveguide Thin-Film Resistor Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3
P	Physical length	Meter	1.0e-3
RB	Bulk resistivity	μohm-cm	300
T	Thickness of thin-film resistor	Meter	1e-3

Netlist Example

```
AGCPWTFR5 net1 net5 W=0.75e-3 G=1.1e-3 P=2.5e-3 T=1.75e-4
+ COMPONENT=gcpw_thinfilm_rb SUBSTRATE=GCPW1
```

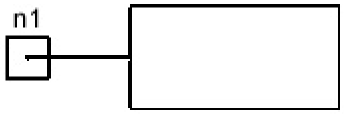
where GCPW1, the selected layout technology or substrate type, has a definition such as:

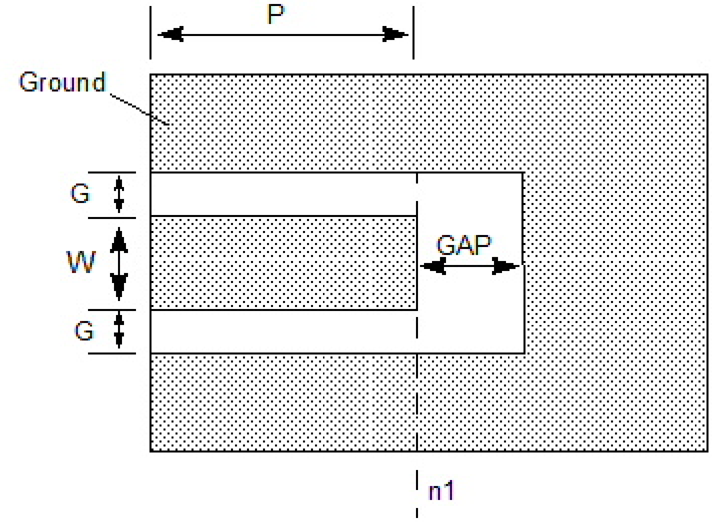
```
.SUB GCPW1 GCPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. A lossy transmission line is used to model the TFR section. Distributed effects are thus taken into consideration.
2. The user needs to define the GCPW steps, if any. They are not included in the TFR model.

Open Stub, Physical Length





Netlist Format

An instance of a grounded coplanar waveguide open stub, physical length has the following netlist syntax:

```
Axxx n1 [W=val] [G=val] [P=val] [GAP=val]
+ COMPONENT=gcpw_open_stub_physical SUBSTRATE=substrate_name
```

n1 is the name of the node attached to the open stub. The entry **COMPONENT=gcpw_open_stub_physical** identifies the element as a grounded coplanar waveguide open stub, physical length.

The **SUBSTRATE=***substrate_name* is the grounded coplanar waveguide substrate model name selected for the design (see "Grounded Coplanar Waveguide Substrate Model " on page 11-51 for details).

Table 39: Grounded Coplanar Waveguide Open Stub, Physical Length Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3
P	Physical length	Meter	5.0e-3
GAP	Gap width at end of CPW line	Meter	1.0e-3

Netlist Example

```
A5 Port1 W=0.75e-3 G=1.1e-3 P=2.5e-3 GAP=1.75e-3
COMPONENT=gcpw_open_stub_physical SUBSTRATE=GCPW1
```

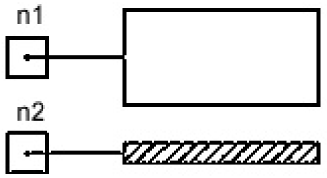
where GCPW1, the selected layout technology or substrate type, has a definition such as:

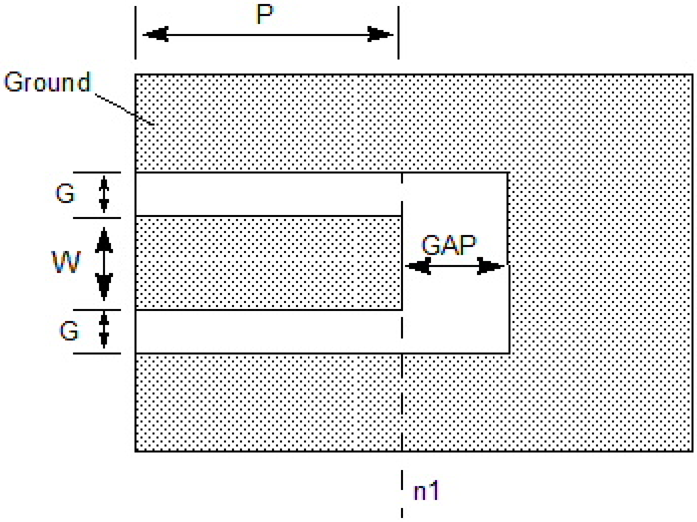
```
.SUB GCPW1 GCPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. The substrate thickness must be larger than (W + 2*G), so the effect of the lower ground plane is negligible.
2. The physical model using physical length includes the open end length correction.
3. The GCPWOST model is equivalent to a transmission line followed by an open model. This is also true in the case of negative length specifications which are used for de-embedding.

Open Stub, Physical Length with Reference





Netlist Format

An instance of a grounded coplanar waveguide open stub, physical length with reference has the following netlist syntax:

```
Axxx n1 n2 [W=val] [G=val] [P=val] [GAP=val]

COMPONENT=gcpw_open_stub_physical SUBSTRATE=substrate_name
```

n1 is the name of the node attached to the open stub. *n2* is the reference node. The entry **COMPONENT=gcpw_open_stub_physical** identifies the element as a grounded coplanar waveguide open stub, physical length.

The **SUBSTRATE=***substrate_name* is the grounded coplanar waveguide substrate model name selected for the design (see "Grounded Coplanar Waveguide Substrate Model " on page 11-51 for details).

Table 40: Grounded Coplanar Waveguide Open Stub, Physical Length with Reference Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3
P	Physical length	Meter	5.0e-3
GAP	Gap width at end of CPW line	Meter	1.0e-3

Netlist Example

```
A5 Port1 Port2 W=0.75e-3 G=1.1e-3 P=2.5e-3 GAP=1.75e-3
COMPONENT=gcpw_open_stub_physical SUBSTRATE=GCPW1
```

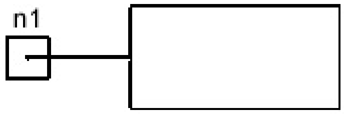
where GCPW1, the selected layout technology or substrate type, has a definition such as:

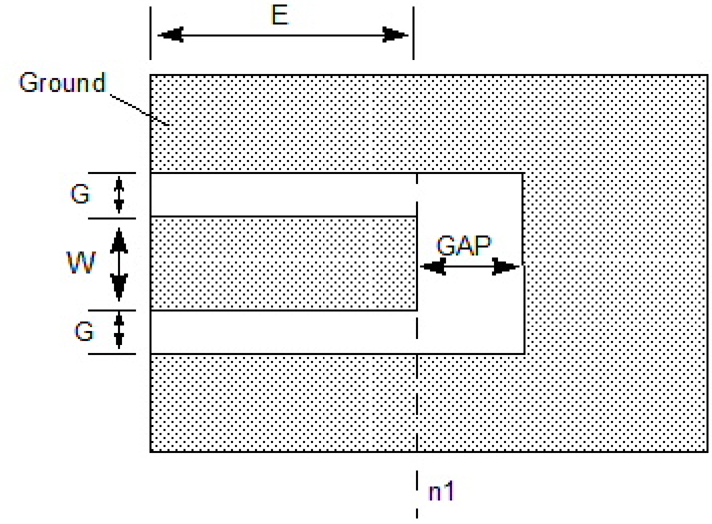
```
.SUB GCPW1 GCPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. The substrate thickness must be larger than (W + 2*G), so the effect of the lower ground plane is negligible.
2. The physical model using physical length includes the open end length correction.
3. The GCPWOST model is equivalent to a transmission line followed by an open model. This is also true in the case of negative length specifications which are used for de-embedding.

Open Stub, Electrical Length





Netlist Format

An instance of a grounded coplanar waveguide open stub, electrical length has the following netlist syntax:

A*xxx n1* [**W=***val*] [**G=***val*] [**GAP=***val*] [**E=***val*] [**F=***val*]
+ **COMPONENT=gcpw_open_stub_e SUBSTRATE=***substrate_name*

n1 is the name of the node attached to the open stub. The entry **COMPONENT=gcpw_open_stub_e** identifies the element as a grounded coplanar waveguide open stub, electrical length.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Grounded Coplanar Waveguide Substrate Model " on page 11-51 for details).

Table 41: Grounded Coplanar Waveguide Open Stub, Electrical Length Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3
GAP	Gap width at end of CPW line	Meter	1.0e-3
E	Electrical length	Degree	45
F	Reference frequency for E	Hz	1.0e9

Netlist Example

```
A5 Port1 W=0.75e-3 G=1.1e-3 GAP=1.75e-3 E=50 F=2.0e9
COMPONENT=gcpw_open_stub_e SUBSTRATE=GCPW1
```

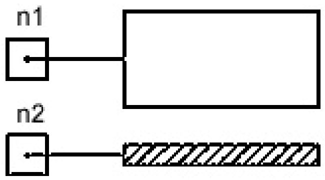
where GCPW1, the selected layout technology or substrate type, has a definition such as:

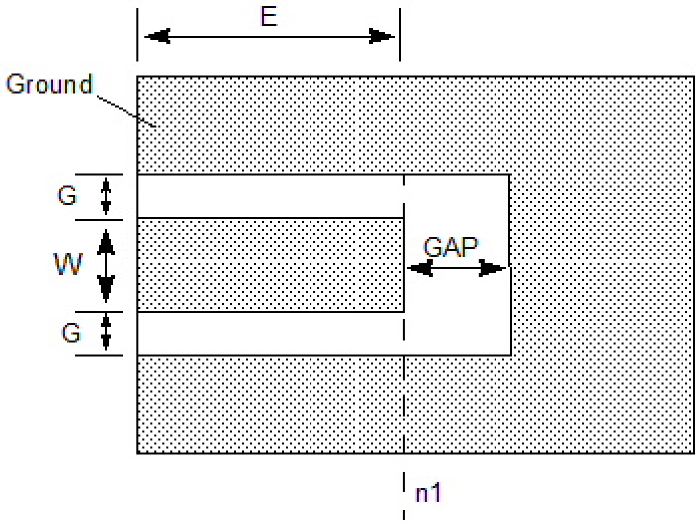
```
.SUB GCPW1 GCPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. The substrate thickness must be larger than (W + 2*G), so the effect of the lower ground plane is negligible.
2. The physical model using physical length includes the open end length correction.
3. The GCPWOSTE model is equivalent to a transmission line followed by an open model. This is also true in the case of negative length specifications which are used for de-embedding.

Open Stub, Electrical Length with Reference





Netlist Format

An instance of a grounded coplanar waveguide open stub, electrical length with reference has the following netlist syntax:

```
Axxx n1 n2 [W=val] [G=val] [GAP=val] [E=val] [F=val]
+ COMPONENT=gcpw_open_stub_e SUBSTRATE=substrate_name
```

n1 is the name of the node attached to the open stub. *n2* is the reference node. The entry **COMPONENT=gcpw_open_stub_e** identifies the element as a grounded coplanar waveguide open stub, electrical length.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Grounded Coplanar Waveguide Substrate Model " on page 11-51 for details).

Table 42: Grounded Coplanar Waveguide Open Stub, Electrical Length with Reference Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3
GAP	Gap width at end of CPW line	Meter	1.0e-3
E	Electrical length	Degree	45
F	Reference frequency for E	Hertz	1.0e9

Netlist Example

```
A5 Port1 Port2 W=0.75e-3 G=1.1e-3 GAP=2.5e-3 E=50 F=2.0e9
COMPONENT=gcpw_open_stub_e SUBSTRATE=GCPW1
```

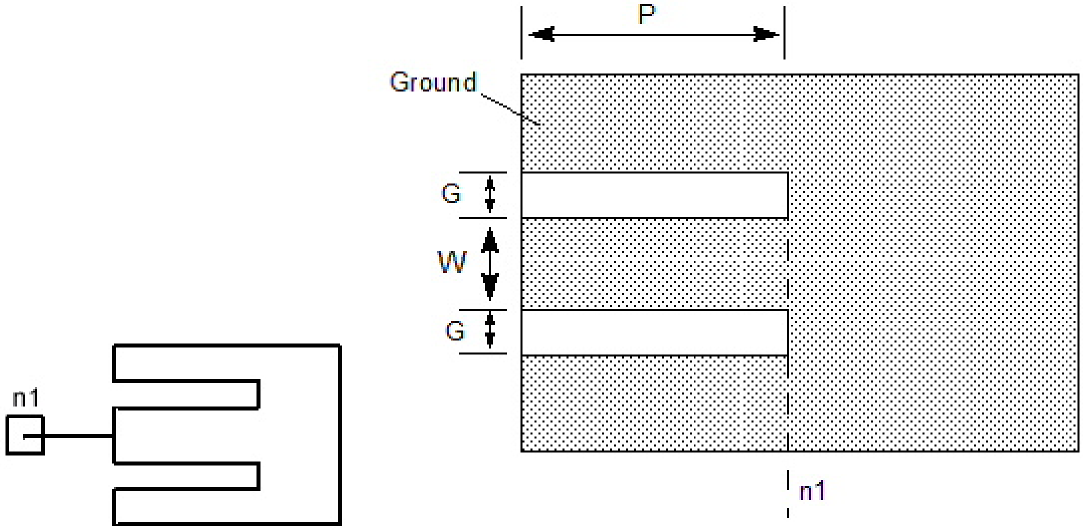
where CPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB GCPW1 GCPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. The substrate thickness must be larger than (W + 2*G), so the effect of the lower ground plane is negligible.
2. The physical model using physical length includes the open end length correction.
3. The GCPWOSTE model is equivalent to a transmission line followed by an open model. This is also true in the case of negative length specifications which are used for de-embedding.

Shorted Stub, Physical Length



Netlist Format

An instance of a grounded coplanar waveguide shorted stub, physical length has the following netlist syntax:

```
Axxx n1 [W=val] [G=val] [P=val]
+ COMPONENT=gcpw_short_stub_physical SUBSTRATE=substrate_name
```

n1 is the name of the node attached to the shorted stub. The entry **COMPONENT=gcpw_short_stub_physical** identifies the element as a grounded coplanar waveguide shorted stub, physical length.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Grounded Coplanar Waveguide Substrate Model " on page 11-51 for details).

Table 43: Grounded Coplanar Waveguide Shorted Stub, Physical Length Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3
P	Physical length	Meter	1.0e-3

Netlist Example

```
A5 Port1 W=0.75e-3 G=1.1e-3 P=2.5e-3
COMPONENT=gcpw_short_stub_physical SUBSTRATE=GCPW1
```

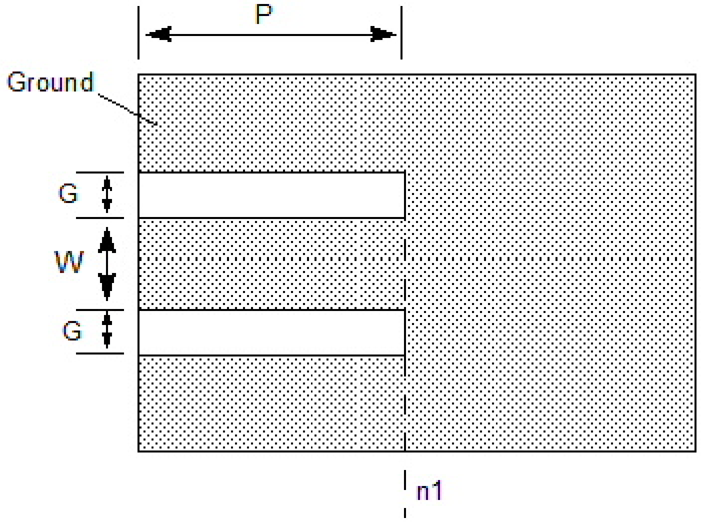
where GCPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB GCPW1 GCPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. The substrate thickness must be larger than (W + 2*G), so the effect of the lower ground plane is negligible.
2. This model includes the short end length correction.

Shorted Stub, Physical Length with Reference



Netlist Format

An instance of a grounded coplanar waveguide shorted stub, physical length with reference has the following netlist syntax:

```
Axxx n1 n2 [W=val] [G=val] [P=val]
+ COMPONENT=gcpw_short_stub_physical SUBSTRATE=substrate_name
```

n1 is the name of the node attached to the open stub. *n2* is the reference node. The entry **COMPONENT=gcpw_short_stub_physical** identifies the element as a grounded coplanar waveguide shorted stub, physical length.

The **SUBSTRATE=***substrate_name* is the grounded coplanar waveguide substrate model name selected for the design (see "Grounded Coplanar Waveguide Substrate Model " on page 11-51 for details).

Table 44: Grounded Coplanar Waveguide Shorted Stub, Physical Length with Reference Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3
P	Physical length	Meter	1.0e-3

Netlist Example

```
A5 Port1 Port2 W=0.75e-3 G=1.1e-3 P=2.5e-3
COMPONENT=gcpw_short_stub_physical SUBSTRATE=GCPW1
```

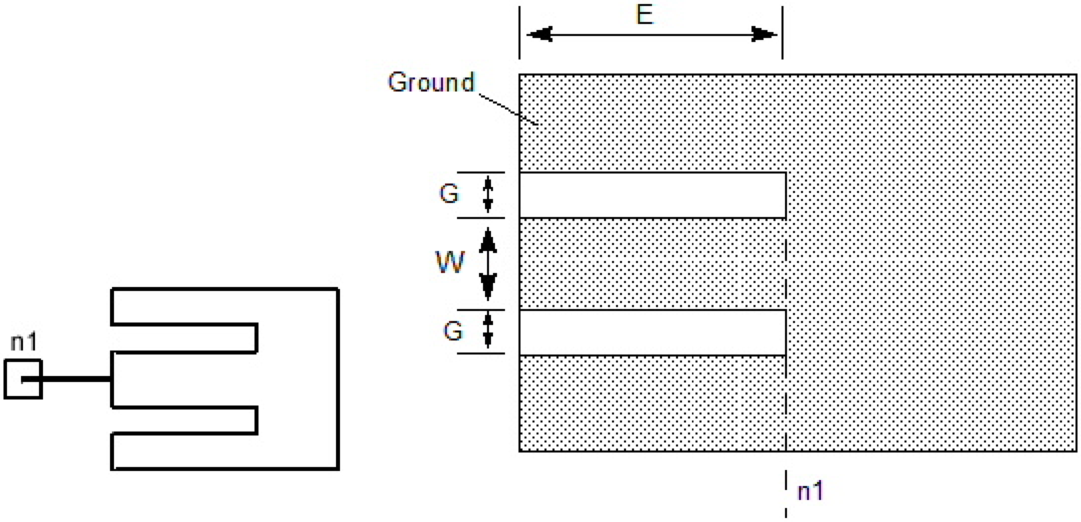
where GCPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB GCPW1 GCPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. The substrate thickness must be larger than (W + 2*G), so the effect of the lower ground plane is negligible.
2. This model includes the short end length correction.

Shorted Stub, Electrical Length



Netlist Format

An instance of a grounded coplanar waveguide shorted stub, electrical length has the following netlist syntax:

A*xxx n1* [**W=***val*] [**G=***val*] [**E=***val*] [**F=***val*]

COMPONENT=gcpw_short_stub_electrical SUBSTRATE=*substrate_name* *n1* is the name of the node attached to the shorted stub. The entry **COMPONENT=gcpw_ short_stub_electrical** identifies the element as a grounded coplanar waveguide shorted stub, electrical length.

The **SUBSTRATE=***substrate_name* is the grounded coplanar waveguide substrate model name selected for the design (see "Grounded Coplanar Waveguide Substrate Model " on page 11-51 for details).

Table 45: Grounded Coplanar Waveguide Shorted Stub, Electrical Length Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3
E	Electrical length	Degree	45
F	Reference frequency for E	Hz	1.0e9

Netlist Example

```
A5 Port1 W=0.75e-3 G=1.1e-3 E=50 F=2.039
COMPONENT=gcpw_short_stub_electrical SUBSTRATE=GCPW1
```

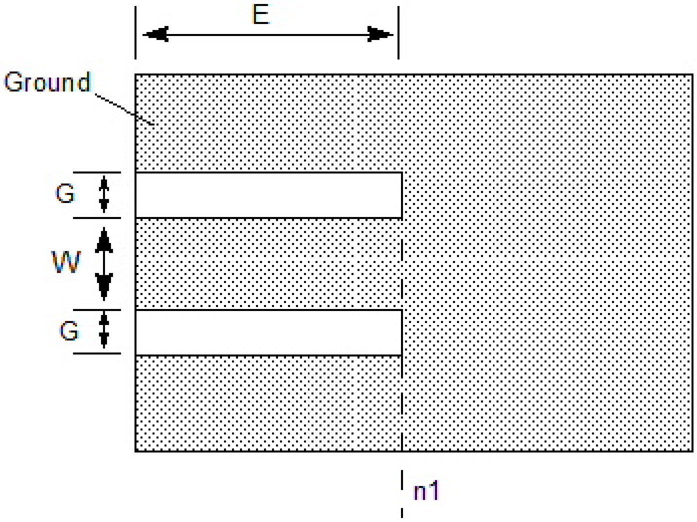
where GCPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB GCPW1 GCPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. The substrate thickness must be larger than (W + 2*G), so the effect of the lower ground plane is negligible.
2. This model includes the short end length correction.

Shorted Stub, Electrical Length with Reference



Netlist Format

An instance of a grounded coplanar waveguide shorted stub, electrical length with reference has the following netlist syntax:

```
Axxx n1 n2 [W=val] [G=val] [E=val] [F=val]
+ COMPONENT=gcpw_short_stub_electrical SUBSTRATE=substrate_name
```

n1 is the name of the node attached to the shorted stub. *n2* is the reference node. The entry **COMPONENT=gcpw_short_stub_electrical** identifies the element as a grounded coplanar waveguide shorted stub, electrical length.

The **SUBSTRATE=***substrate_name* is the grounded coplanar waveguide substrate model name selected for the design (see "Grounded Coplanar Waveguide Substrate Model " on page 11-51 for details).

Table 46: Grounded Coplanar Waveguide Shorted Stub, Electrical Length with Reference Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3
E	Electrical length	Degree	45
F	Reference frequency for E	Hertz	1.0e9

Netlist Example

```
A5 Port1 Port2 W=0.75e-3 G=1.1e-3 E=50 F=.0e9
COMPONENT=gcpw_short_stub_electrical SUBSTRATE=GCPW1
```

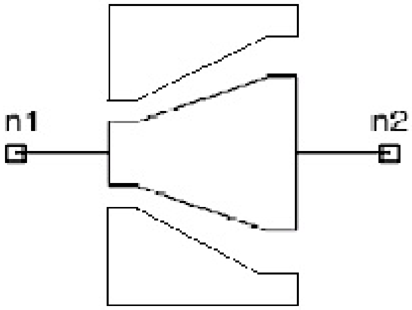
where GCPW1, the selected layout technology or substrate type, has a definition such as:

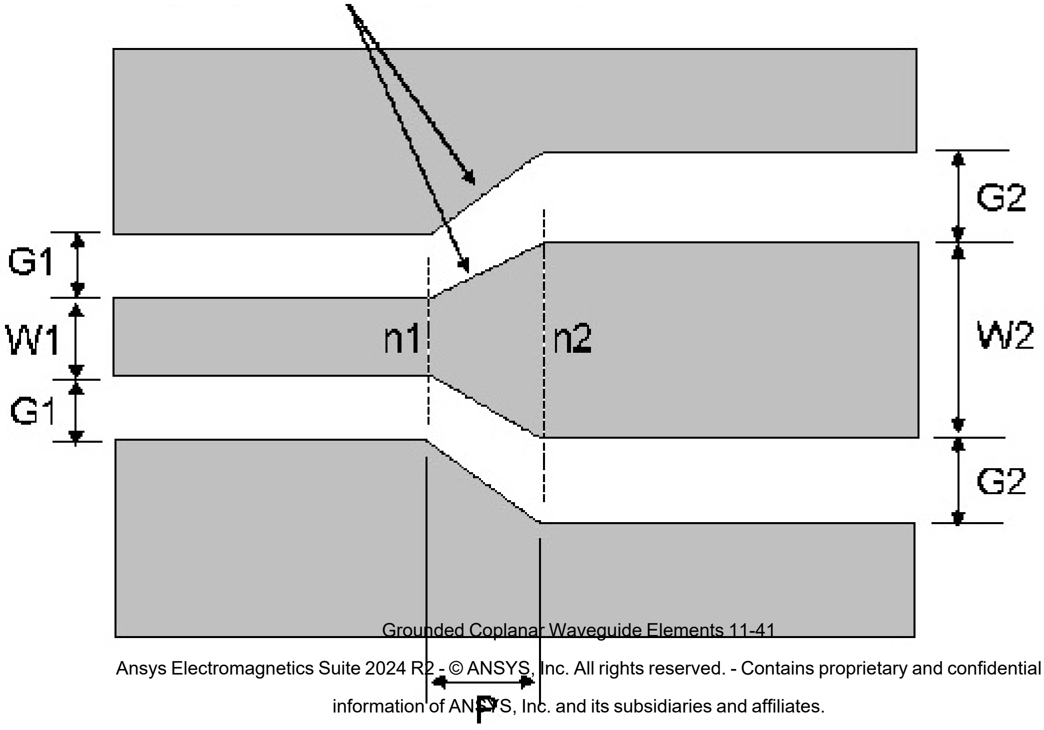
```
.SUB GCPW1 GCPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. The substrate thickness must be larger than (W + 2*G), so the effect of the lower ground plane is negligible.
2. This model includes the short end length correction.

Tapered Line





Netlist Format

An instance of a grounded coplanar waveguide tapered line has the following netlist syntax:

```
Axxx n1 n2 [W1=val] [W2=val] [G1=val] [G2=val] [P=val]
[TAPER="LINWIDTH"|"EXPWIDTH"]
+ COMPONENT=gcpw_tapered_line SUBSTRATE=substrate_name
```

n1 and *n2* are the names of the nodes attached to the transmission line. The entry **COMPONENT=gcpw_tapered_line** identifies the element as a grounded coplanar waveguide transmission line, physical length.

The **SUBSTRATE=***substrate_name* is the grounded coplanar waveguide substrate model name selected for the design (see "Grounded Coplanar Waveguide Substrate Model " on page 11-51 for details).

Table 47: Grounded Coplanar Waveguide Tapered Line Instance Parameters

Parameter	Description	Units	Default
W1	Width of node 1 conductor	Meter	1.0e-3
W2	Width of node 2 conductor	Meter	2.0e-3
G1	Slot width at node 1	Meter	0.5e-3
G2	Slot width at node 2	Meter	0.75e-3
P	Physical length	Meter	1.0e-2

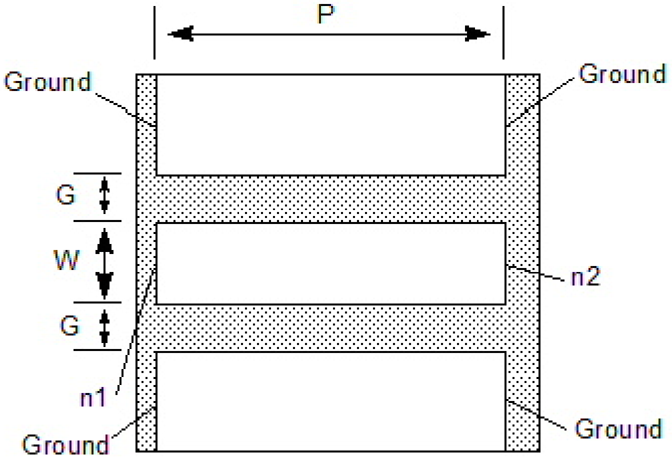
Netlist Example

```
A5 Port1 Port2 W1=0.75e-3 W2=1.5e-3 G1=1.1e-3 G2=2.1e-3 P=2e-2
+ COMPONENT=gcpw_tapered_line SUBSTRATE=GCPW1
```

where GCPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB GCPW1 GCPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Transmission Line, Physical Length



Netlist Format

An instance of a grounded coplanar waveguide transmission line, physical length has the following netlist syntax:

```
Axxx n1 n2 [W=val] [G=val] [P=val]
+ COMPONENT=gcpwtrl SUBSTRATE=substrate_name
```

n1 and *n2* are the names of the nodes attached to the transmission line. The entry **COMPONENT=gcpwtrl** identifies the element as a grounded coplanar waveguide transmission line, physical length.

The **SUBSTRATE=***substrate_name* is the grounded coplanar waveguide substrate model name selected for the design (see "Grounded Coplanar Waveguide Substrate Model " on page 11-51 for details).

Table 48: Grounded Coplanar Waveguide Transmission Line, Physical Length Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3
P	Physical length	Meter	1.0e-2

Netlist Example

```
A5 Port1 Port2 W=0.75e-3 G=1.1e-3 P=2e-2 COMPONENT=gcpwtrl
SUBSTRATE=GCPW1
```

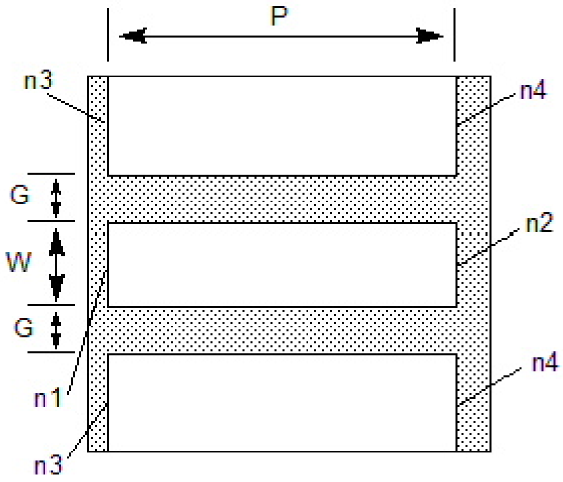
where GCPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB GCPW1 GCPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. Conformal mapping technique is used in the analysis, in which quasi-TEM behavior is assumed. Dispersion is not included in the model.

Transmission Line, Physical Length with Reference



Netlist Format

An instance of a grounded coplanar waveguide transmission line, physical length with reference has the following netlist syntax:

```
Axxx n1 n2 n3 n4 [W=val] [G=val]
+ COMPONENT=gcpwtrl SUBSTRATE=substrate_name
```

n1 and *n2* are the names of the nodes attached to the transmission line. *n3* and *n4* are the reference nodes. The entry **COMPONENT=gcpwtrl** identifies the element as a grounded coplanar waveguide transmission line, physical length.

The **SUBSTRATE=***substrate_name* is the grounded coplanar waveguide substrate model name selected for the design (see "Grounded Coplanar Waveguide Substrate Model " on page 11-51 for details).

Table 49: Grounded Coplanar Waveguide Transmission Line, Physical Length with Reference Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3
P	Physical length	Meter	1.0e-2

Netlist Example

```
A5 Port1 Port2 Port3 Port4 W=0.75e-3 G=1.1e-3 P=2e-2
COMPONENT=gcpwtrl SUBSTRATE=GCPW1
```

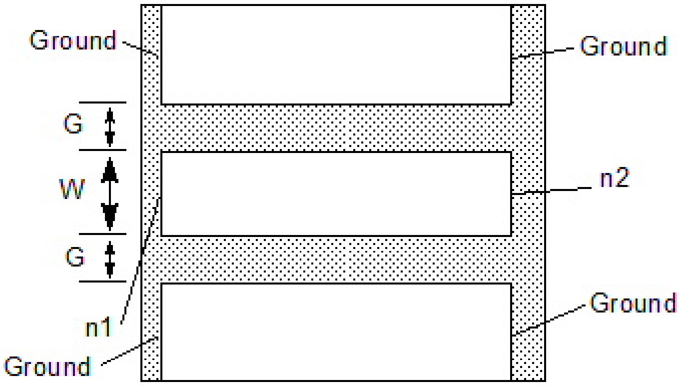
where GCPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB GCPW1 GCPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. Conformal mapping technique is used in the analysis, in which quasi-TEM behavior is assumed. Dispersion is not included in the model.

Transmission Line, Electrical Length



Netlist Format

An instance of a coplanar waveguide transmission line, electrical length has the following netlist syntax:

```
Axxx n1 n2 [W=val] [E=val] [F=val] [G=val]
+ COMPONENT=gcpwtrl_e SUBSTRATE=substrate_name
```

n1 and *n2* are the names of the nodes attached to the bend. The entry **COMPONENT=gcpwtrl_e** identifies the element as a grounded coplanar waveguide transmission line, electrical length.

The **SUBSTRATE=***substrate_name* is the grounded coplanar waveguide substrate model name selected for the design (see "Grounded Coplanar Waveguide Substrate Model " on page 11-51 for details).

Table 50: Grounded Coplanar Waveguide Transmission Line, Electrical Length Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3
E	Electrical length	Degree	45
F	Reference frequency for electrical length	Hertz	1e9

Netlist Example

```
A5 Port1 Port2 W=0.75e-3 G=1.1e-3 F=2e9 COMPONENT=gcpwtrl_e
SUBSTRATE=GCPW1
```

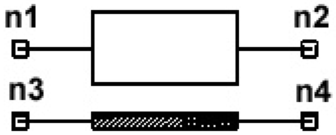
where GCPW1, the selected layout technology or substrate type, has a definition such as:

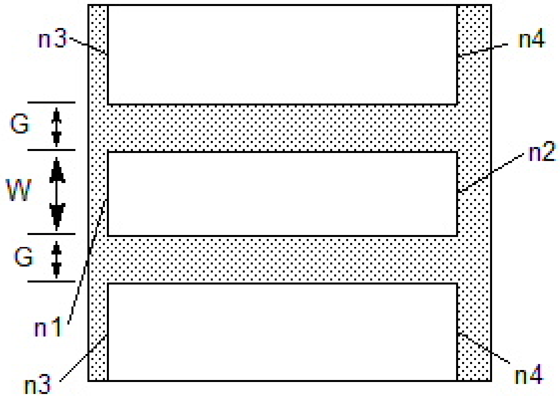
```
.SUB GCPW1 GCPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. Conformal mapping technique is used in the analysis, in which quasi-TEM behavior is assumed. Dispersion is not included in the model.

Transmission Line, Electrical Length with Reference





Netlist Format

An instance of a grounded coplanar waveguide transmission line, electrical length with reference has the following netlist syntax:

A*xxx n1 n2 n3 n4* [**W=***val*] [**E=***val*] [**F=***val*] [**G=***val*]
+ **COMPONENT=gcpwtrl_e SUBSTRATE=***substrate_name*

n1 and *n2* are the names of the nodes attached to the bend. *n3* and *n4* are the reference nodes. The entry **COMPONENT=gcpwtrl_e** identifies the element as a coplanar waveguide transmission line, electrical length.

The **SUBSTRATE=***substrate_name* is the coplanar waveguide substrate model name selected for the design (see "Grounded Coplanar Waveguide Substrate Model " on page 11-51 for details).

Table 51: Grounded Coplanar Waveguide Transmission Line, Electrical Length with Reference Instance Parameters

Parameter	Description	Units	Default
W	Width of center conductor	Meter	1.0e-3
G	Slot gap width	Meter	1.0e-3
E	Electrical length	Degree	45
F	Reference frequency for electrical length	Hertz	1e9

Netlist Example

```
A5 Port1 Port2 Port3 Port4 W=0.75e-3 G=1.1e-3 F=2e9
+ COMPONENT=gcpwtrl_e SUBSTRATE=GCPW1
```

where GCPW1, the selected layout technology or substrate type, has a definition such as:

```
.SUB GCPW1 GCPW(
+ H=0.001524 Er=4.4 TAND=0.02 HU=2.54E-4
+ MET1=1.724137931034483 T1=2.54e-5 RGH=0)
```

Notes

1. Conformal mapping technique is used in the analysis, in which quasi-TEM behavior is assumed. Dispersion is not included in the model.

Selecting None for the Initial Substrate

For Nexxim designs that are created with the **Schematic Editor**, the initial selection of a global substrate type is made on the **Choose Layout Technology** window that appears when you select Insert Nexxim Circuit Design on the Project menu.

However, no grounded coplanar waveguide substrates are available in the **Choose Layout Technology** window.

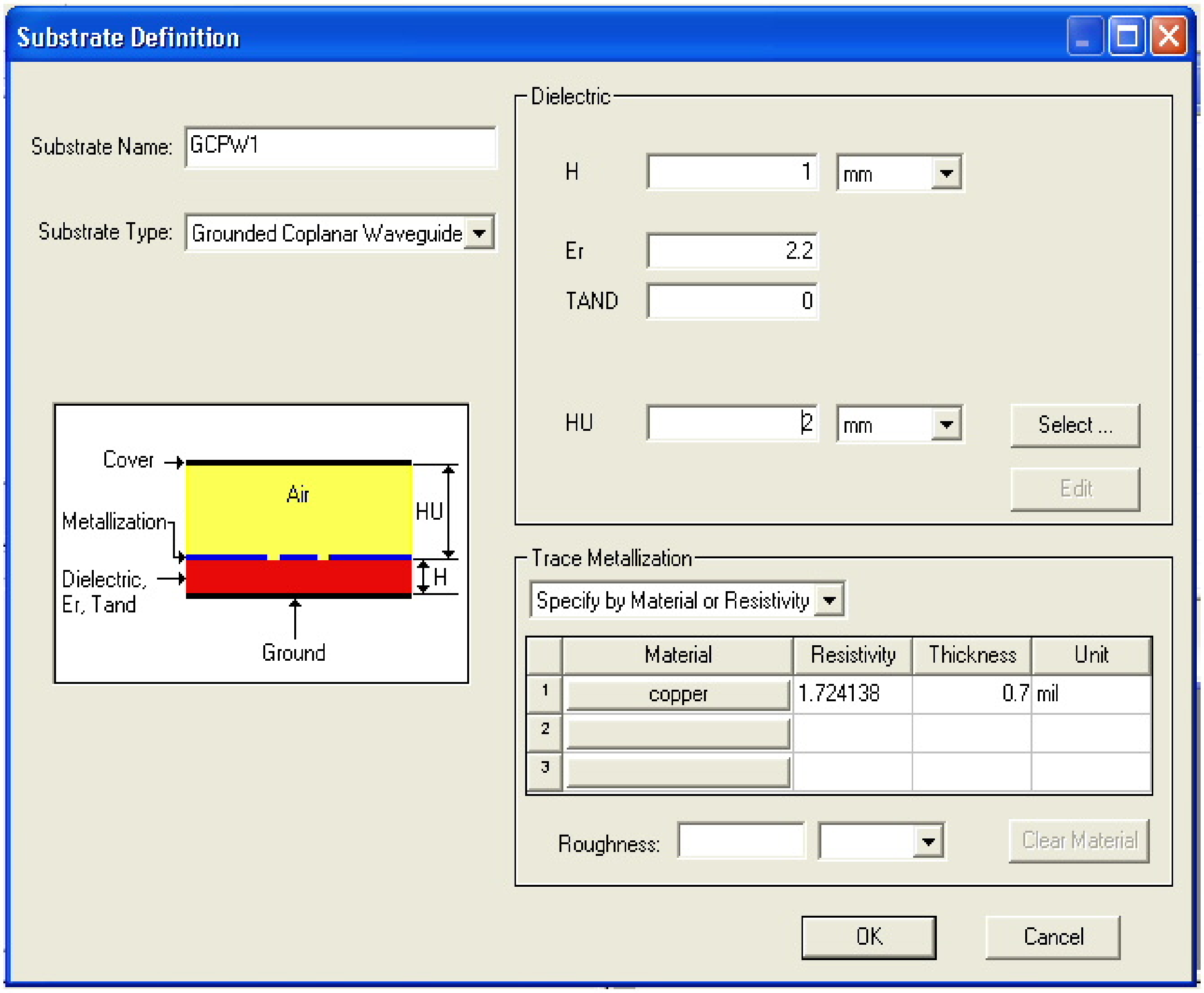
If you wish to use a grounded coplanar waveguide substrate, you must create it as a custom substrate type.

In the **Choose Layout Technology** window, click **None**. The schematic design opens, but no substrate type is applied to instances of distributed elements until you create a custom substrate type.

"Creating a Custom Grounded Coplanar Waveguide Substrate " below for details.

Creating a Custom Grounded Coplanar Waveguide Substrate

To create a grounded coplanar waveguide substrate definition, open the Nexxim design icon (e.g., “Nexxim1”), then right-click the **Data** field and select **Add Substrate Definition** to open the **Substrate Definition** window. Specify the name of your new substrate (the following example uses the name “GCPW1”).



Substrate Name: GCPW1

Substrate Type: Grounded Coplanar Waveguide

H: 1 mm

Er: 2.2

TAND: 0

HU: 2 mm

Specify by Material or Resistivity

	Material	Resistivity	Thickness	Unit
1	copper	1.724138	0.7	mil
2				
3				

Roughness:

Select **GroundedCoplanar Waveguide** as the **Substrate Type**. Complete the specifications for the **Dielectric** and the **Trace Metallization**.

(see the "Grounded Coplanar Waveguide Substrate Model " on the facing page help topic for guidelines on defining grounded coplanar waveguide substrates.

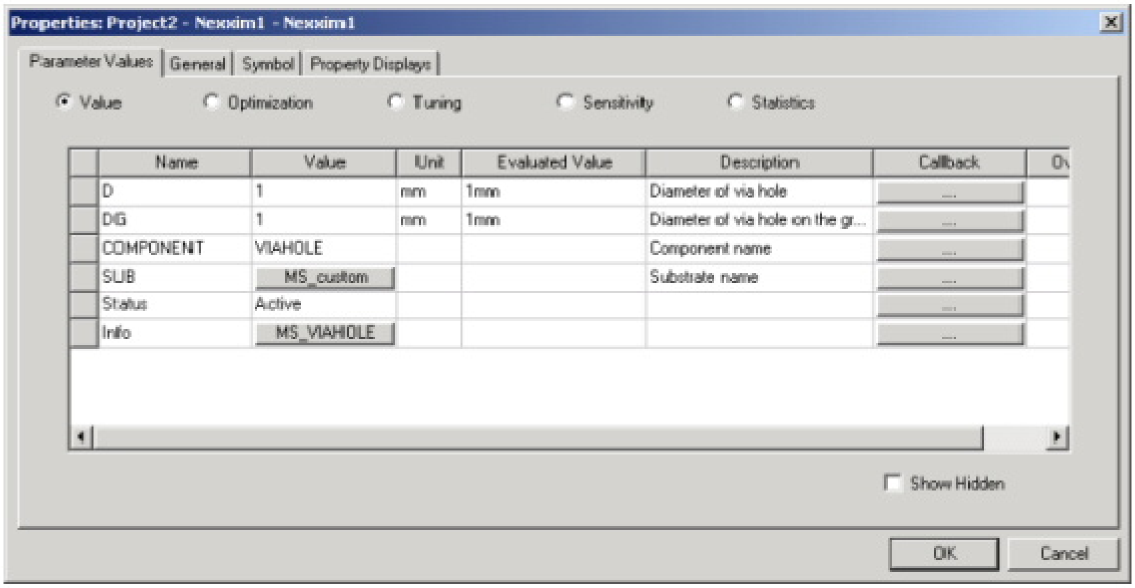
When the substrate definition is complete, click **OK**.

If you selected **None** for the global substrate type in the **Choose Layout Technology** window, the custom grounded coplanar waveguide substrate becomes the global substrate type.

When an element is instantiated , it includes a **SUBSTRATE=***substrate_name* entry in its netlist syntax. **Electronics Desktop** automatically inserts the global *substrate_name* into the internal netlist entry for the instantiated element.

Selecting a Grounded Coplanar Waveguide Substrate at the Component Level

To specify a custom substrate type, or to change to a different predefined substrate type, you must make the assignment individually for each component. Double-click the distributed element to open the **Properties** window:



● Value ○ Optimization ○ Tuning ○ Sensitivity ○ Statistics

Name	Value	Unit	Evaluated Value	Description	Callback	Ov
D	1	mm	1mm	Diameter of via hole	...	
DIG	1	mm	1mm	Diameter of via hole on the gr...	...	
COMPONENT	VIAHOLE			Component name	...	
SUB	MS_custom			Substrate name	...	
Status	Active				...	
Info	MS_VIAHOLE				...	

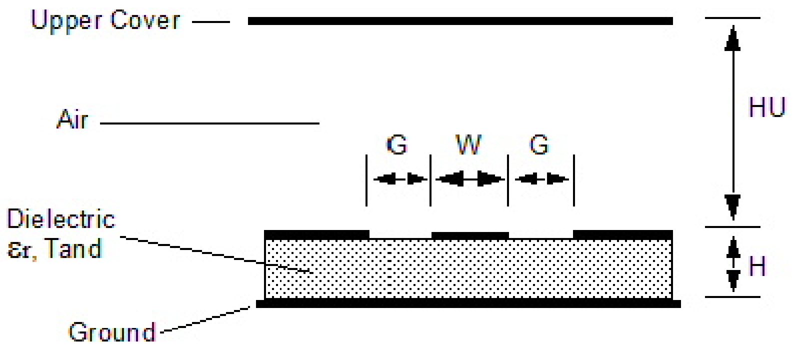
☐ Show Hidden

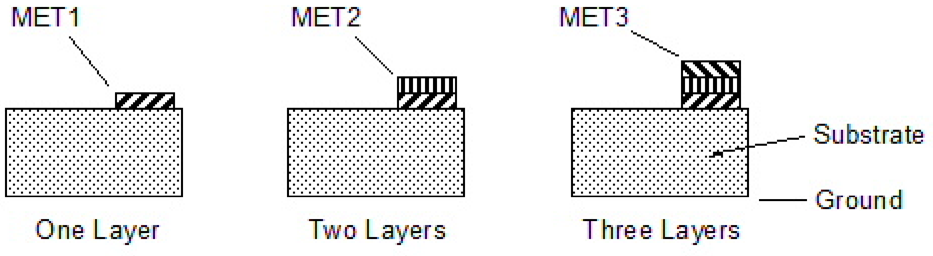
The **SUB** property identifies the substrate that is currently applied to the element. In the example above, a custom substrate type named “MS_custom”appears as the value of the **SUB** property.

To change to a grounded coplanar waveguide substrate, click in the **SUB** Value field and select the grounded coplanar waveguide substrate name as the value of the **SUB** property. Then click **OK**.

> **Note:** All distributed elements in a given design must use the same substrate type.

Grounded Coplanar Waveguide Substrate Model





Metallization

Defining a Grounded Coplanar Waveguide Model

To add a grounded coplanar waveguide substrate model to a new Nexxim design, you must define the substrate model. To add a new substrate definition to an existing design, expand the **Project** icon, the **Design** icon. Right-click the **Data** icon and select **Add Substrate Definition** to open the **Substrate Definition** window. Add the substrate name and parameters as appropriate, then click **OK**. A substrate added in this manner requires you to specify the metallization parameters explicitly.

To edit the definition of a substrate, expand the **Project** icon, the **Design** icon, the **Data** icon. Click on the icon for the substrate you wish to edit to open the **Substrate Definition** window. Add or modify the substrate parameters as appropriate, then click **OK**.

Grounded Coplanar Waveguide Substrate Model Netlist Format

The Grounded Coplanar Waveguide substrate model has the following netlist format:

```
.SUBsubstrate_name CPW ( [H=val] [HU=val] [ER=val] [TAND=val]
[MET1=val] [T1=val] [MET2=val] [T2=val] [MET3=val] [T3=val]
[RGH=val])
```

The *substrate_name* is the name for the substrate type used in distributed elements that refer to this substrate definition. The entry **CPW** is required to identify the Coplanar Waveguide substrate type. The **CPW** identifier must immediately follow the *substrate_name*.

Inside the parentheses, the labeled parameters may be entered in any order.

Table 52: Grounded Coplanar Waveguide Substrate Parameters

Parameter	Description	Unit	Default
H	Thickness of dielectric	Meter	1e-3
HU	Spacing between top of dielectric and upper cover	Meter	0.0
ER	Dielectric constant of substrate, $1 \le ER \le 128$	None	4.5
TAND	Dielectric loss tangent, [0,0.1]	None	0.0
MET1, **MET2**, **MET3**	Resistivity of metal layer 1, 2, 3	μOhm-cm	0.0
T1, **T2**, **T3**	Thickness of metal layer 1, 2, 3	Meter	0.0
RGH	RMS surface roughness	Meter	0.0

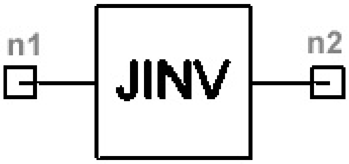
Grounded Coplanar Waveguide Substrate Model Netlist Example

```
.SUB GCPW1 GCPW(
+ H=0.001524 HU=0.003 Er=4.4 TAND=0.02
+ MET1=1.724137931034483 T1=2.5400e-005
+ RGH=0)
```

12 - Lumped Elements General

This topic describes the following general-purpose lumped elements:

Admittance Inverter



Netlist Syntax

The syntax for the admittance inverter instance is:

```
Axxxx n1 n2 [JINV=val] COMPONENT=admittance_inverter
```

n1 is the positive node and *n2* is the negative node of the inverter.

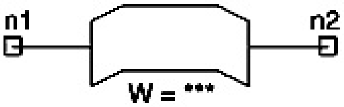
Parameter **JINV** is the inverter constant. The default is 0.02.

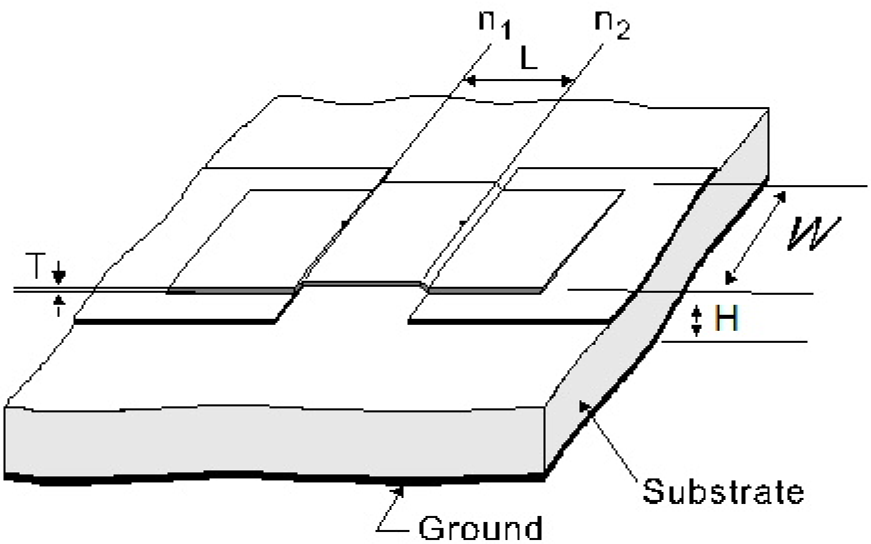
The entry **COMPONENT=admittance_inverter** identifies the element.

Ideal Admittance Inverter Netlist Example

```
Aadinv 1 2 L=0.02 COMPONENT=admittance_inverter
```

Air Bridge, Rectangular Cross Section





Netlist Form

An instance of an air bridge with rectangular cross-section (and no substrate) has the following Nexxim netlist syntax:

```
Axxx n1 n2 [W=val] [T=val] [L=val] [R=val] [H=val]
COMPONENT=jump
```

n1 and *n2* are the nodes connected to the air bridge. The entry **COMPONENT=jump** identifies the element.

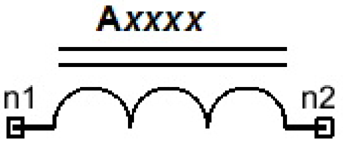
Table 29: Air Bridge Instance Parameters

Parameter	Description	Units	Default
W	Width of jumper wire	Meter	0.5e-3
T	Thickness of jumper wire	Meter	0.1e-3
L	Length of jumper wire	Meter	1.0e-3
R	Resistivity of the wire	μOhm/cm	0.0
H	Height of jumper wire above ground plane	Meter	1.0e-3

Netlist Example

Ajumper1 1 2 W=0.3e-3 T=0.05e-3 L=0.8e-3 H=2.86e-3
+ COMPONENT=jump

Ideal Choke



Ideal Choke Instance Netlist Syntax

An ideal choke is equivalent to an open circuit at AC, and a short circuit at DC. The parameter **L** controls the AC impedance, $Z=2j\pi \times f \times L$. The ideal choke is sometimes referred to as a “DC Through.”

The syntax for the ideal choke instance is:

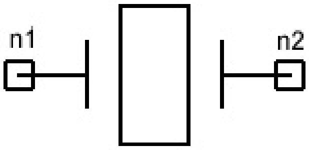
A*xxxx n1 n2* [**L=***val*] **COMPONENT=ideal_choke**

n1 is the positive node and *n2* is the negative node of the capacitor. The inductance defaults to 100,000 Henry. The entry **COMPONENT=ideal_choke** is required to identify the element.

Ideal Choke Netlist Example

```
Achoke 1 2 L=50000 COMPONENT=ideal_choke
```

Crystal, Q, Parallel Resonance



Netlist Form

An instance of an crystal , Q specified, parallel resonance, has the following Nexxim netlist syntax:

A*xxx n1 n2* **C=***val* **FP=***val* [**Q=***val*] [**CO=***val*] [**CL=***val*] [**TC=***val*] [**MODE=***val*] [**TEMP=***val*] [**F1=***val*] [**F2=***val*] **COMPONENT=crystalqp**

n1 and *n2* are the nodes connected to the crystal. The entry **COMPONENT=crystalqp** identifies the element.

Table 30: Crystal, Q, Parallel Resonance Instance Parameters

Parameter	Description	Units	Default
C	Motional capacitance	Farad	0.0
FP	Parallel overtone frequency	Hz	0.0
CO	Static capacitance	Farad	0.0
CL	Load capacitance	Farad	0.0
Q	Quality factor at resonant frequency FP	None	0.0
MODE	Overtone (odd number)	None	1
TC	Temperature coeffficient in PPM	None	0.0
TEMP	Device temperature	Celsius	25.0

F1	Lower resonant frequency limit	Hz	10
F2	Upper resonant frequency limit	Hz	1e12

Netlist Example

```
Acryqp1 port1 port2 C=9.5e-27 FP=27e6 CO=2.3e-12 CL=1.8e-11
+ Q=83000 F1=25e6 F2=75e6 COMPONENT=crystalqp
```

Notes

1. ESR is the equivalent series resistance for the crystal and can be calculated from *Q* factor (specified at resonant frequency **FP**) and the motional capacitance **C** as

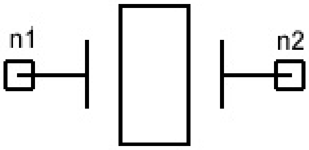
   ESR=1.0/(2π×**FP** ×**Q** ×**C**).

2. **L** is the crystal's motional inductance and can be calculated from motional capacitance **C** and resonant frequency **FP**.
3. **F1** and **F2** specify the frequency range for crystal device. The motional capacitance and the *Q* of the crystal falls in the manufacture specified value in this frequency range.
4. **TC** is defined in PPM (parts per million). For example, a crystal has nominal value of **FP** at 298 K. At temperature **TEMP**, the resulting value of the series-self resonance frequency, *Fp*, is calculated as
   Fp = **FP** ×[1+(**TEMP** –298)×**TC** ×1.0e–6]
5. **MODE** is used to specify the crystal's overtone mode and must be an odd positive integer. Setting **MODE** to a value greater than 1 results in series self-resonances at **FP** and at **FP** /**MODE**. For example, setting **FP** equal to 222 MHz and **MODE** equal to 5 results in series resonances at 222 MHz (the fifth-overtone resonance) and 222/5 MHz, or 44.4 MHz (the fundamental resonance).
6. The load capacitance, **CL**, is an external capacitance that sets a point on the reactance curve at which the crystal resonates. **CL** comprises a combination of the circuit's discrete load capacitance, stray board capacitance, and capacitance from the operation of the Miller effect in active devices. When an oscillator presents some amount of load capacitance to a crystal, the crystal is said to be *parallel-resonant*, and a value of load capacitance, **CL**, must be specified. If the circuit does not exhibit capacitive loading, the crystal is said to be *series-resonant*, and no value of load capacitance is specified. A quartz crystal's parallel-resonance operating frequency **FL** is based on:

$$FL = FP\left(\frac{C}{2(CL + CO) + 1}\right)$$

where **FP** is the series-resonance frequency, **CL** is the crystal load capacitance, **CO** is the crystal shunt capacitance, and **C** is the crystal motional capacitance.

Crystal, Q, Series Resonance (CRYQS)



Netlist Form

An instance of an crystal , Q specified, series resonance, has the following Nexxim netlist syntax:

```
Axxx n1 n2 C=val FS=val [Q=val] [CO=val] [TC=val]
[MODE=val] [TEMP=val] [F1=val] [F2=val] COMPONENT=crystalqs
```

n1 and *n2* are the nodes connected to the crystal. The entry **COMPONENT=crystalqs** identifies the element.

Table 31: Crystal, Q, Series Resonance Instance Parameters

Parameter	Description	Units	Default
C	Motional capacitance	Farad	0.0
FS	Series overtone frequency	Hz	0.0
CO	Static capacitance	Farad	0.0
Q	Quality factor at resonant frequency FS	None	0.0
MODE	Overtone (odd number)	None	1
TC	Temperature coeffficient in PPM	None	0.0
TEMP	Device temperature	Celsius	25.0
F1	Lower resonant frequency limit	Hz	10
F2	Upper resonant frequency limit	Hz	1e12

Netlist Example

```
Acryqs1 1 2 C=0.3e-12 Q=132000 FS=273.75e6 MODE=3 TC=50
+ TEMP=50 COMPONENT=crystalqs
```

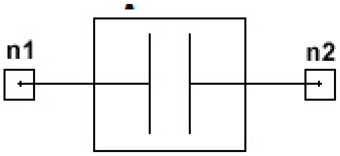
Notes

1. ESR is the equivalent series resistance for the crystal and can be calculated from *Q* factor (specified at resonant frequency **FS**) and the motional capacitance **C** as

ESR=1.0/(2π×**FS** ×**Q** ×**C**).

2. **L** is the crystal's motional inductance and can be calculated from motional capacitance **C** and resonant frequency **FS**.
3. **F1** and **F2** specify the frequency range for crystal device. The motional capacitance and the *Q* of the crystal falls in the manufacture specified value in this frequency range.
4. **TC** is defined in PPM (parts per million). For example, a crystal has nominal value of **FS** at 298 K. At temperature **TEMP**, the resulting value of the series-self resonance frequency, *Fs*, is calculated as
   Fs = **FS** ×[1+(**TEMP** -298)×**TC** ×1.0e–6]
5. **MODE** is used to specify the crystal's overtone mode and must be an odd positive integer. Setting **MODE** to a value greater than 1 results in series self-resonances at **FS** and at **FS** /**MODE**. For example, setting **FS** equal to 222 MHz and **MODE** equal to 5 results in series resonances at 222 MHz (the fifth-overtone resonance) and 222/5 MHz, or 44.4 MHz (the fundamental resonance).

DC Block for Bias



DC Block Instance Netlist Syntax

The DC Block device is equivalent to a short circuit at AC, and an open circuit at DC.

The syntax for a DC block device instance is:

A*xxxx n1 n2* [**C=***val*] **COMPONENT=dc_block**

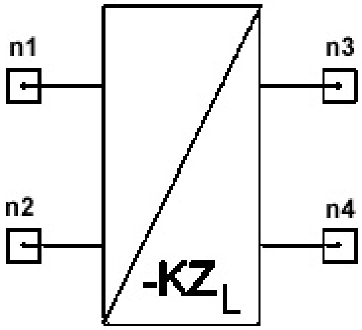
n1 is the positive node and *n2* is the negative node of the DC block. The current is assumed to flow from *n1* through the capacitor to *n2*. The entry **COMPONENT=dc_block** is required to identify the element.

The capacitance **C** defaults to 100,000 Farad.

DC Block Device Netlist Example

```
Ablock1 3 4 C=500000
```

Negative Impedance Converter



Netlist Form

An instance of a negative impedance converter (NIC) has the following Nexxim netlist syntax:

A*xxx n1 n2 n3 n4* [**TYPE=V**|**I**] [**K1=***val*] [**K2=***val*] **COMPONENT=negative_impedance_converter**

n1, *n2*, *n3*, and *n4* are the nodes connected to the converter. The entry **COMPONENT=negative_impedance_converter** identifies the element.

Table 32: Negative Impedance Converter Instance Parameters

Parameter	Description	Units	Default
TYPE	**V** = Voltage, **I** = Current	None	V
K1	Voltage transfer ratio	None	1
K2	Current transfer ratio	None	1

Netlist Example

```
AnicI 1 2 0 0 Type=I K1=1.5 K2=1
+ COMPONENT=negative_impedance_converter
```

Notes

1. Absolute values are used for computations. A positive value is used even if K1 and K2 are negative.
2. Values of exactly zero are not allowed for either K1 or K2. If a zero value is supplied or is implied through omission, a value of 1.0e-9 is assigned.
3. For option V:

```
V1 = -|K1|*V2
```

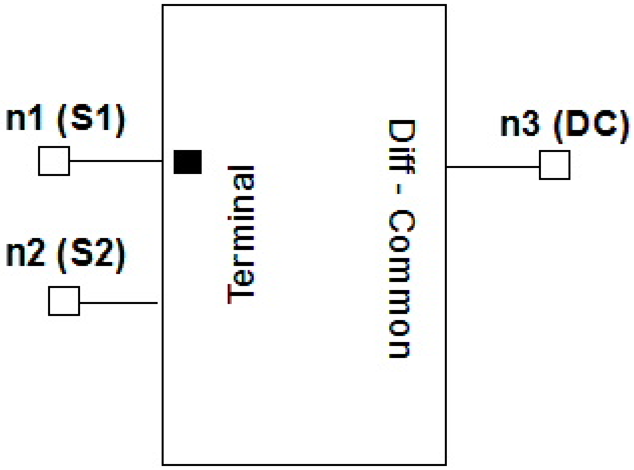
```
I1 = -|K2|*I2
```

4. For option I:

```
V1 = |K1|*V2
```

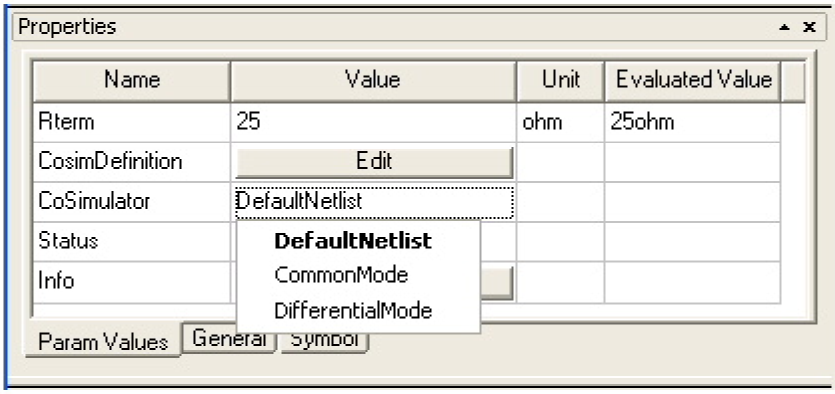
```
I1 = |K2|*I2
```

Terminal to Differential or Common Mode Converter



Selecting Differential or Common Mode Conversion

This component is available for Nexxim schematic designs. Select the component (**SnglNd2DorC**) on the **lumped_general** category of Nexxim components. In the Property window, click CoSimulator property to display a menu:



Name	Value	Unit	Evaluated Value
Rterm	25	ohm	25ohm
CosimDefinition	Edit		
CoSimulator	DefaultNetlist		
Status			
Info			

DefaultNetlist or **DifferentialMode** returns the differential mode on the D terminal.

CommonMode returns the common mode on the C terminal.

Netlist Form

The netlist generated by this component depends on the CoSimulator selection.

With **DefaultNetlist** or **DifferentialMode** selected, the terminal to differential pair converter has the following three-line Nexxim netlist syntax:

```
AxxxAn3 0n1 inet_1 N=2 COMPONENT=transformer1x1

AxxxBn3 0 inet_1n2 N=2 COMPONENT=transformer1x1

Rxxx inet_1 0Rterm
```

With **CommonMode** selected, the terminal to common mode converter has the following three-line Nexxim netlist syntax:

```
AxxxA inet_1 0n3 n2 N=2 COMPONENT=transformer1x1

AxxxB inet_1 0n1 n3 N=2 COMPONENT=transformer1x1

Rxxx inet_1 0Rterm
```

n1 (S1), *n2* (S2), and *n3* (D or C) are the nodes connected to the mode converter. The entry **COMPONENT=transformer1x1** identifies the underlying transformers (see **Notes**).

Table 33: Diff or Common Mode Converter Instance Parameters

Parameter	Description	Units	Default
CoSimulator	Select Mode: DifferentialMode, CommonMode, or DefaultNetlist (same as DifferentialMode)	None	DefaultNetlist

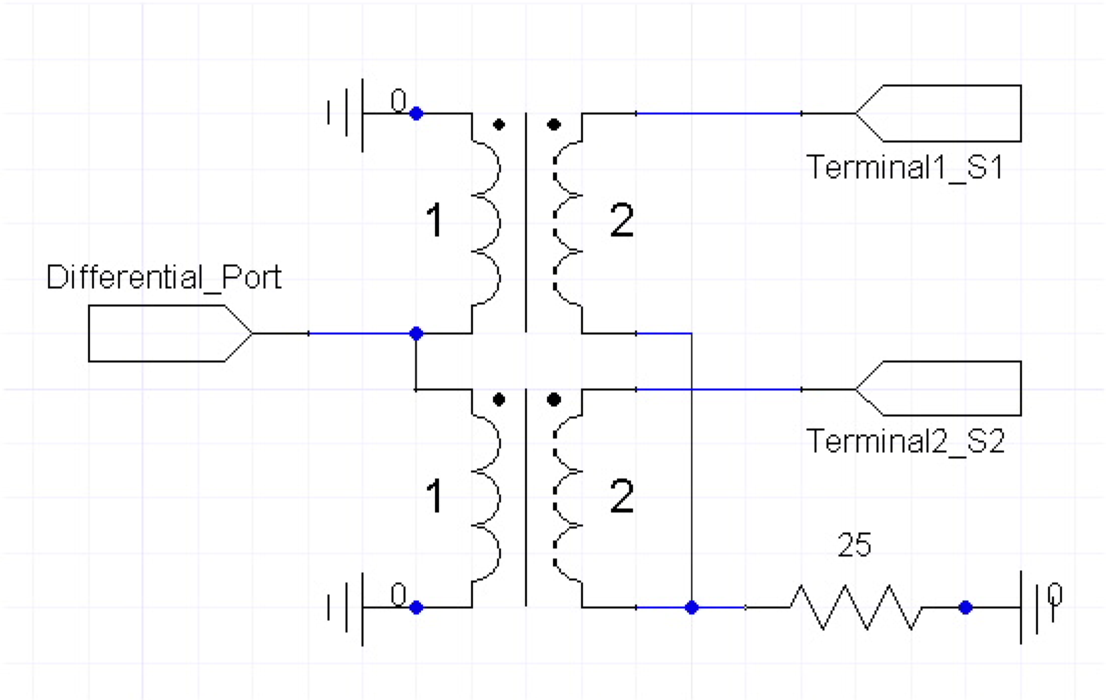
Rterm	Alternate mode termination impedance	Ohm	25

Netlist Example

```
A2481A net3 0 net1 inet_1 N=2 COMPONENT=transformer1x1

A2481B net3 0 inet_1 net2 N=2 COMPONENT=transformer1x1

R2481 inet_1 0 25
```

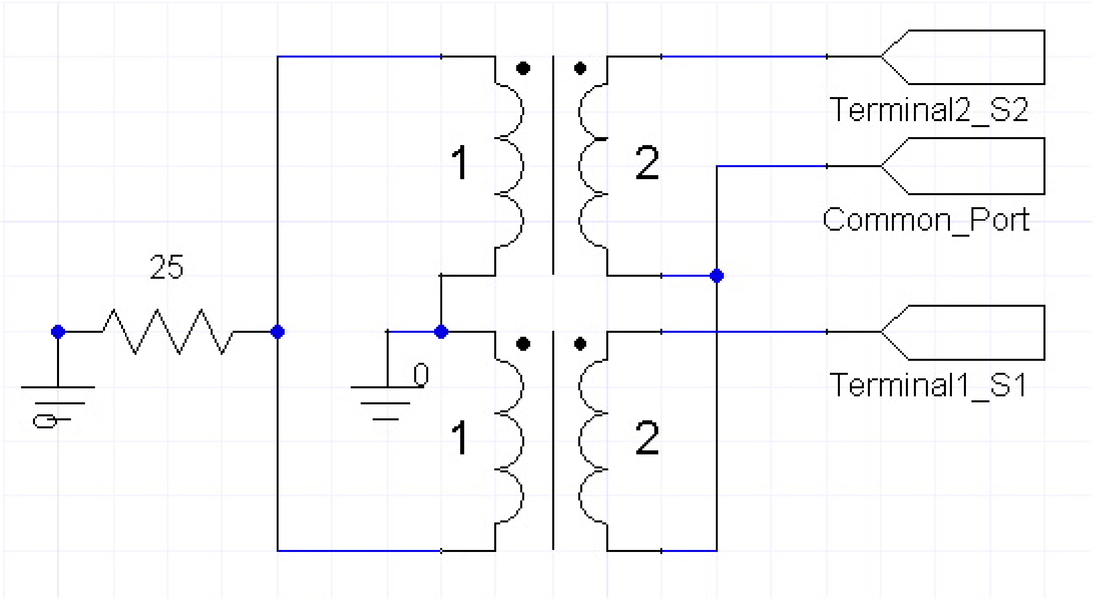
Notes

1. The mode converter incorporates two ideal transformers and a resistor. The single-ended terminals (S1 and S2) are converted to either a differential or a common mode terminal (D or C).
2. The equivalent circuit to extract the differential mode is shown in the following figure. Both transformers have 2:1 coupling ratios.

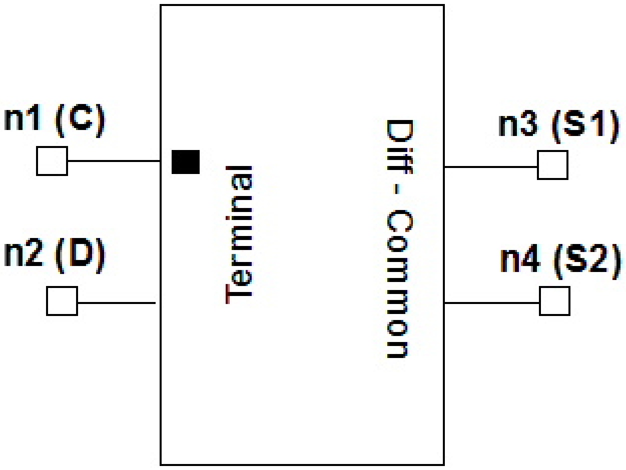


3. The equivalent circuit to extract the common mode is shown in the following figure. Both

transformers have 2:1 coupling ratios.



Terminal to Differential and Common Mode Converter



Netlist Form

This component is available for Nexxim schematic designs. Select the component (**SnglNd2DandC**) on the **lumped_general** category of Nexxim components. The netlist generated by the terminal to differential and common mode converter has the following two-line Nexxim netlist syntax:

A*xxx***A***n2* **0***n3 n1* **N=2 COMPONENT=transformer1x1**

A*xxx***B***n2* **0***n1 n4* **N=2 COMPONENT=transformer1x1**

n1 (C), *n2* (D), *n3* (S1) and *n4* (S2) are the nodes connected to the mode converter. The entry **COMPONENT=transformer1x1** identifies underlying transformers.

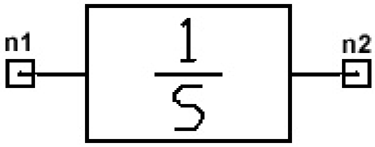
Netlist Example

```
A2485A net2 0 net3 net1 N=2 COMPONENT=transformer1x1

A2485B net2 0 net1 net4 N=2 COMPONENT=transformer1x1
```

Notes

1. This mode converter incorporates two ideal transformers. The single-ended terminals (S1 and S2) are converted to both differential and common mode terminals (D and C). The user must supply appropriate terminations.

Integrator



Netlist Form

An instance of a 1/s integrator has the following Nexxim netlist syntax:

A*xxx n1 n2* **COMPONENT=ideal_integrator**

n1 and *n2* are the nodes connected to the integrator. The entry **COMPONENT=ideal_integrator** identifies the element.

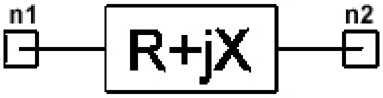
Netlist Example

```
A21 11 0 COMPONENT=ideal_integrator
```

Notes

1. The output is calculated as H(s)=1/s, where $s=j2\pi f$ and f is the operating frequency.

Ideal Impedance



Netlist Form

An instance of an ideal impedance has the following Nexxim netlist syntax:

A*xxx n1 n2* **RZ=***val* **IZ=***val* **COMPONENT=impedance**

n1 and *n2* are the nodes connected to the impedance. The entry **COMPONENT=impedance** identifies the element.

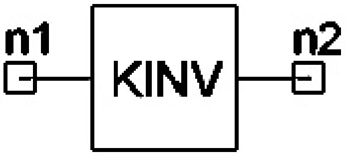
Table 34: Ideal Impedance Instance Parameters

Parameter	Description	Units	Default
RZ	Real part of impedance	Ohm	50
IZ	Imaginary part of impedance	Ohm	0

Netlist Example

```
A11 1 2 RZ=100 IZ=-0.1 COMPONENT=impedance
```

Impedance Inverter



Netlist Syntax

The syntax for the impedance inverter instance is:

A*xxxx n1 n2* [**KINV=***val*] **COMPONENT=impedance_inverter**

n1 is the positive node and *n2* is the negative node of the inverter.

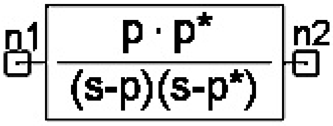
Parameter **KINV** is the inverter constant. The default is50.

The entry **COMPONENT=impedance_inverter** identifies the element.

Impedance Inverter Netlist Example

```
Aadinv 1 2 KINV=50.0 COMPONENT=impedance_inverter
```

Complex Conjugate Pole Pair



Netlist Form

An instance of a complex conjugate pole pair has the following Nexxim netlist syntax:

`A``xxx n1 n2` **`REAL=`**`val` **`IMAG=`**`val` **`COMPONENT=complex_pole_pair`**

n1 and *n2* are the nodes connected to the complex conjugate pole pair. The entry **COMPONENT=complex_pole_pair** identifies the element.

Table 35: Complex Conjugate Pole Pair Instance Parameters

Parameter	Description	Units	Default
REAL	Real part of complex pole	None	Required
IMAG	Imaginary part of complex pole	None	Required

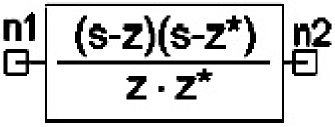
Netlist Example

Acpole1 1 2 Real=3.1415 IMAG=0.1 COMPONENT=complex_pole_pair

Notes

1. The complex conjugate pole pair is supported for frequency-domain analyses only.
2. The Output is calculated by H(s) = P•P*/((s-P)•(s-P*))
   P = Real+jImag
   S = j2πF
   F = Operating frequency

Complex Conjugate Zero Pair



Netlist Form

An instance of a complex conjugate zero pair has the following Nexxim netlist syntax:

A*xxx n1 n2* **REAL=***val* **IMAG=***val* **COMPONENT=complex_zero_pair**

n1 and *n2* are the nodes connected to the complex conjugate zero pair. The entry **COMPONENT=complex_zero_pair** identifies the element.

Table 36: Complex Conjugate Zero Pair Instance Parameters

Parameter	Description	Units	Default
REAL	Real part of complex zero	None	Required
IMAG	Imaginary part of complex zero	None	Required

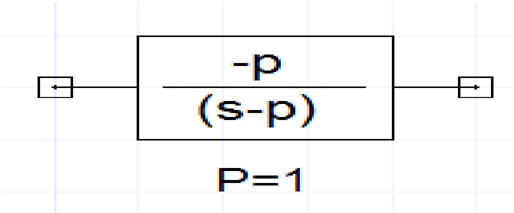
Netlist Example

Acpole1 1 2 Real=3.1415 IMAG=0.1 COMPONENT=complex_zero_pair

Notes

1. The complex conjugate zero pair is supported for frequency-domain analyses only.
2. The Output is calculated by H(s) = (s - Z)•(s - Z*) / (Z •Z*)
   Z = Real+jImag
   s = j2πF
   F = Operating frequency

Real Pole



Netlist Form

An instance of a real pole has the following Nexxim netlist syntax:

`A`*`xxx n1 n2`* **`P=`***`val`* **`COMPONENT=real_pole`**

n1 and *n2* are the nodes connected to the real pole. Parameter **P** is the value of the real pole. The entry **COMPONENT=real_pole** identifies the element.

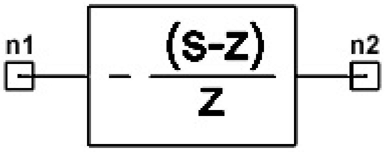
Netlist Example

```
Arpole1 1 2 P=3.1415 COMPONENT=real_pole
```

Notes

1. The real pole is supported for frequency-domain analyses only.
2. The output is calculated by H(s) = -P / (s - P)
   s = j2πf
   F = Operating frequency

Real Zero



Netlist Form

An instance of a real zero component has the following Nexxim netlist syntax:

`A`*`xxx n1 n2`* **`Z=`***`val`* **`COMPONENT=real_zero`**

n1 and *n2* are the nodes connected to the real zero. Parameter **Z** is the real zero value. The entry **COMPONENT=real_zero** identifies the element.

Netlist Example

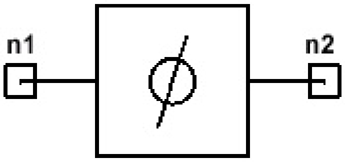
```
Arzero1 1 2 Z=3.1415 COMPONENT=real_zero
```

Notes

1. The real zero is supported for frequency-domain analyses only.

2. The output is calculated by H(s) = -(s - Z) / Z
   S = j2πf
   F = operating frequency

Phase Shifter



Netlist Form

An instance of a phase shifter has the following Nexxim netlist syntax:

A*xxx n1 n2* **P=***val* **R0=***val* **COMPONENT=phase_shifter**

n1 and *n2* are the nodes connected to the phase shifter. The entry **COMPONENT=phase_shifter** identifies the element.

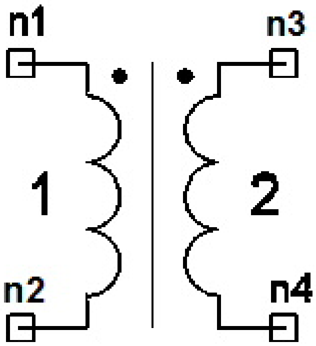
Table 37: Phase Shifter Instance Parameters

Parameter	Description	Units	Default
P	Phase shift	Degree	0
R0	Reference characteristic impedance	Ohm	50

Netlist Example

Ashift 1 2 P=45 R0=55 COMPONENT=phase_shifter

Transformer, 1 x 1 coils



Netlist Form

An instance of a 1x1 transformer has the following Nexxim netlist syntax:

`Axxx n1 n2 n3 n4 N=val COMPONENT=transformer_1x1`

n1 and *n3* are the nodes connected to the input transformer. *n2* and *n4* are the nodes connected to the output transformer. The entry **COMPONENT=transformer_1x1** identifies the element.

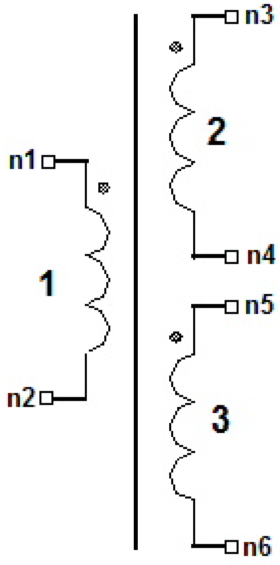
Table 38: Transformer, 1x1 Instance Parameters

Parameter	Description	Units	Default
N	Turn ratio of coil 2 to coil 1	None	1

Netlist Example

Atrf1x1 1 2 3 4 N=3 COMPONENT=transformer_1x1

Transformer, 1 x 2 coils



Netlist Form

An instance of a 1x2 transformer has the following Nexxim netlist syntax:

A*xxx n1 n2 n3 n4 n5 n6* **N1=***val* **N2=***val* **COMPONENT=transformer_1x2**

n1 and *n4* are the nodes connected to the input transformer. *n2*, *n5*, *n3*, and *n6* are the nodes connected to the output transformers. The entry **COMPONENT=transformer_1x2** identifies the element.

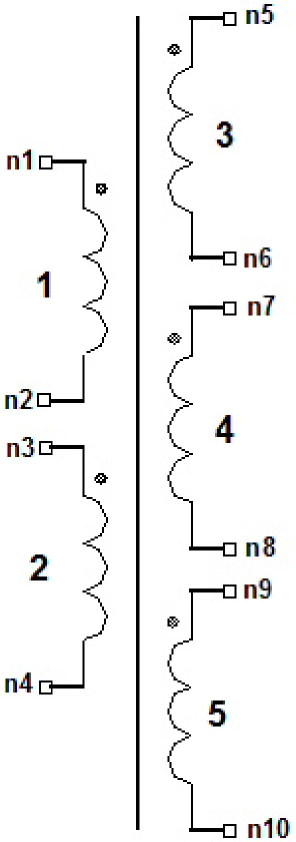
Table 39: Transformer, 1x2 Instance Parameters

Parameter	Description	Units	Default
N1	Turn ratio of coil 2 to coil 1	None	1
N2	Turn ratio of coil 3 to coil 1	None	1

Netlist Example

```
Atrf1x2 1 2 3 4 5 6 N1=3 N2=5 COMPONENT=transformer_1x2
```

Transformer, M x N coils



Netlist Form

An instance of a transformer with M input coils and N output coils (M=2, N=3 in the illustration above) has the following Nexxim netlist syntax:

```
Axxx n1 [... n2M] n2M+1 [... n2M+2N]   M=num_inputs N=num_outputs
K=[k12 ... k1M k1(M+1) ... k1N] COMPONENT=transformer_MxN
```

n1 through *n2M* are the nodes connected to the input transformers. *n2M+1* through *n2M+2N* are the nodes connected to the output transformers. The entry **COMPONENT=transformer_MxN** identifies the element.

Table 40: Transformer, MxN Instance Parameters

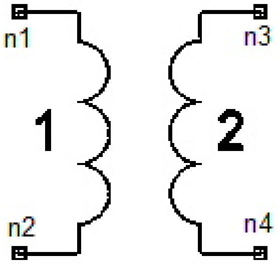
Parameter	Description	Units	Default
M	Number of input coils	None	1
N	Number of output coils	None	1
K	Vector of coil ratios	None	Vector of all 1’s

k12	Turn ratio of coil 2 to coil 1	None	1
k1M	Turn ratio of last input coil M to coil 1	None	1
k1(M+1)	Turn ratio of first output coil to coil 1	None	1
k1N	Turn ratio of last output coil N to coil 1	None	1

Netlist Example

```
Atrf2x3 in1 in2 in3 in4 out1 out2 out3 out4 out5 out6 M=2 N=3
+ K=[2.2 3.3 4.4 5.5 ] COMPONENT=transformer_MxN
```

Transformer, Impedance Model



Netlist Form

An instance of a transformer, impedance model, has the following Nexxim netlist syntax:

A*xxx n1 n2 n3 n4* **R1=***val* **R2=***val* **COMPONENT=trfnc**

n1 through *n4* are the nodes connected to the transformers. **COMPONENT=trfnc** identifies the element.

Table 41: Transformer, Impedance Model Instance Parameters

Parameter	Description	Units	Default
R1	Impedance seen from coil 1 when R2 is connected to coil 2	Ohm	50
R2	Impedance seen from coil 2 when R1 is connected to coil 1	Ohm	50

Netlist Example

```
Atrfnc 1 2 3 4 R1=50 R2=12.5
```

Notes

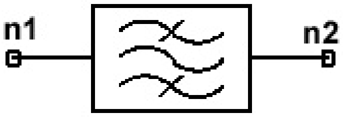
1. The relative polarity can be reversed by entering a negative value for R1 or R2.
2. The turns ratio N is related to the impedance levels R1 and R2 through:

$$N = \left|\frac{R1}{R2}\right|^{1/2}$$

13 - Nexxim Filters

This section contains descriptions of the following filters available for Nexxim designs:

Bessel-Thompson Band Pass Filter



Netlist Form

An instance of a Bessel-Thompson band pass filter has the following Nexxim netlist syntax:

```
Axxx n1 n2 [N=val] [FL=val] [FU=val] [R1=val] [R2=val] [IL=val]
COMPONENT=bessel_bandpass_filter
```

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=bessel_bandpass_filter** is required.

Table 14: Bessel-Thompson Band Pass Filter Instance Parameters

Parameter	Description	Units	Default
N	Order of filter	None	3
FL	Lower cutoff frequency (3dB)	Hz	1e9
FU	Upper cutoff frequency (3dB)	Hz	2e9
R1	Reference resistance for node 1	Ohm	50
R2	Reference resistance for node 2	Ohm	50
IL	Insertion loss in dB	dB	0

Netlist Example

```
A22 1 2 N=5 FL=80e6 FU=100e6 IL=0.5
+ COMPONENT=bessel_bandpass_filter
```

Notes

1. Bessel-Thompson filters are derived from a maximally-flat delay criterion (the first *N* derivatives of the delay are zero at the origin). As a result, they exhibit very good group delay characteristics, at the cost of poor attenuation performance in the stopband.
2. The transfer function of the Bessel filter (low-pass prototype) is given by [see Reference 1]:

$$H(j\omega) = \frac{B_n(j\omega)}{b_0}$$

where $B_n(j\omega)$ is the Nth-order Bessel polynomial, and $b_0 = B_n(0)$.

3. The normalized low-pass prototype filter is designed for a cutoff frequency ω_c=1. To change the response of the filter to a band-reject, a frequency transformation is required, where ω is substituted by {Reference 3]:

$$\omega \leftarrow \frac{\omega}{\omega_H - \omega_L}\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)^{-1}$$

where ω_0 is the geometric mean of the edge frequencies, ω_L and ω_H, of the stopband:

$$\omega_0 = \sqrt{\omega_L \cdot \omega_H}$$

4. The range for N (order of filter) is from 1 to 15. Orders higher than 15 cannot be simulated.

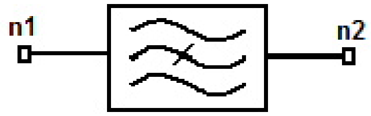
References

[1] *Approximation Methods for Electronic Filter Design*, Richard W. Daniels, McGraw-Hill, Inc.

[2] *Handbook of Filter Synthesis*, Anatol I. Zvered, John Wiley & Sons, Inc. 1967.

[3] *Microwave Engineering*, 2nd Ed. David M. Pozar, John Wiley & Sons, Inc. 1998.

Bessel-Thompson Band Reject Filter



Netlist Syntax

An instance of a Bessel-Thompson band reject filter has the following Nexxim netlist syntax:

```
Axxx n1 n2 [N=val] [FL=val] [FU=val] [R1=val] [R2=val] [IL=val]
COMPONENT=bessel_bandreject_filter
```

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=bessel_bandreject_filter** is required.

Table 15: Bessel-Thompson Band Reject Filter Instance Parameters

Parameter	Description	Units	Default
N	Order of filter	None	3
FL	Lower cutoff frequency (3dB)	Hz	1e9
FU	Upper cutoff frequency (3dB)	Hz	2e9
R1	Reference resistance for node 1	Ohm	50
R2	Reference resistance for node 2	Ohm	50
IL	Insertion loss in dB	dB	0

Netlist Example

```
A22 1 2 N=5 FL=80e6 FU=100e6 IL=0.5
+ COMPONENT=bessel_bandreject_filter
```

Notes

1. Bessel-Thompson filters are derived from a maximally-flat delay criterion (the first *N* derivatives of the delay are zero at the origin). As a result, they exhibit very good group delay characteristics, at the cost of poor attenuation performance in the stopband.
2. The transfer function of the Bessel filter (low-pass prototype) is given by [see Reference 1]:

$$H(j\omega) = \frac{B_n(j\omega)}{b_0}$$

where $B_n(j\omega)$ is the Nth-order Bessel polynomial, and $b_0 = B_n(0)$.

3. The normalized low-pass prototype filter is designed for a cutoff frequency ω_c=1. To change the response of the filter to a bandpass, a frequency transformation is required, where ω is substituted by {Reference 3]:

$$\omega \leftarrow \frac{\omega}{\omega_H - \omega_L}\left(\frac{\omega}{\omega_0} - \frac{\omega_0}{\omega}\right)$$

where ω_0 is the geometric mean of the edge frequencies, ω_L and ω_H, of the passband:

$$\omega_0 = \sqrt{\omega_L \cdot \omega_H}$$

4. The range for N (order of filter) is from 1 to 15. Orders higher than 15 cannot be simulated.

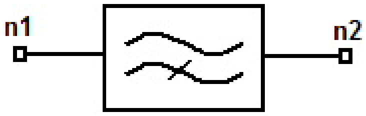
References

[1] *Approximation Methods for Electronic Filter Design*, Richard W. Daniels, McGraw-Hill, Inc.

[2] *Handbook of Filter Synthesis*, Anatol I. Zvered, John Wiley & Sons, Inc. 1967.

[3] *Microwave Engineering*, 2nd Ed. David M. Pozar, John Wiley & Sons, Inc. 1998.

Bessel-Thompson High Pass Filter



Netlist Syntax

An instance of a Bessel-Thompson high pass filter has the following Nexxim netlist syntax:

A_xxx n1 n2_ [**N=**_val_] [**FC=**_val_] [**R1=**_val_] [**R2=**_val_] [**IL=**_val_]
COMPONENT=bessel_highpass_filter

_n1_ and _n2_ are the nodes connected to the filter. The entry **COMPONENT=bessel_highpass_filter** is required.

Table 16: Bessel-Thompson High Pass Filter Instance Parameters

Parameter	Description	Units	Default
N	Order of filter	None	3
FC	Cutoff frequency (3dB)	Hz	1e9
R1	Reference resistance for node 1	Ohm	50
R2	Reference resistance for node 2	Ohm	50
IL	Insertion loss in dB	dB	0

Netlist Example

```
A22 1 2 N=5 FL=80e6 FU=100e6 IL=0.5
+ COMPONENT=bessel_highpass_filter
```

Notes

1. Bessel-Thompson filters are derived from a maximally-flat delay criterion (the first _N_ derivatives of the delay are zero at the origin). As a result, they exhibit very good group delay characteristics, at the cost of poor attenuation performance in the stopband.
2. The transfer function of the Bessel filter (low-pass prototype) is given by [see Reference 1]:

$$H(j\omega) = \frac{B_n(j\omega)}{b_0}$$

where $B_n(j\omega)$ is the Nth-order Bessel polynomial, and $b_0 = B_n(0)$.

3. The normalized low-pass prototype filter is designed for a cutoff frequency ω_c=1. To change the cutoff frequency from unity to ω_c, the frequency dependence of the transfer function must be scaled by ω_c, so ω is substituted by {Reference 3]:

$$\omega \leftarrow \frac{\omega_c}{\omega}$$

4. The range for N (order of filter) is from 1 to 15. Orders higher than 15 cannot be simulated.

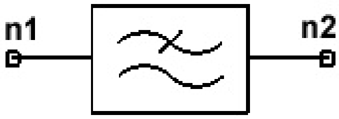
References

[1] *Approximation Methods for Electronic Filter Design*, Richard W. Daniels, McGraw-Hill, Inc.

[2] *Handbook of Filter Synthesis*, Anatol I. Zvered, John Wiley & Sons, Inc. 1967.

[3] *Microwave Engineering*, 2nd Ed. David M. Pozar, John Wiley & Sons, Inc. 1998.

Bessel-Thompson Low Pass Filter



Netlist Syntax

An instance of a Bessel-Thompson low pass filter has the following Nexxim netlist syntax:

```
Axxx n1 n2 [N=val] [FC=val] [R1=val] [R2=val] [IL=val]
COMPONENT=bessel_lowpass_filter
```

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=bessel_lowpass_filter** is required.

Table 17: Bessel-Thompson Low Pass Filter Instance Parameters

Parameter	Description	Units	Default
N	Order of filter	None	3

FC	Cutoff frequency (3dB)	Hz	1e9
R1	Reference resistance for node 1	Ohm	50
R2	Reference resistance for node 2	Ohm	50
IL	Insertion loss in dB	dB	0

Netlist Example

```
A22 1 2 N=5 FL=80e6 FU=100e6 IL=0.5
+ COMPONENT=bessel_lowpass_filter
```

Notes

1. Bessel-Thompson filters are derived from a maximally-flat delay criterion (the first *N* derivatives of the delay are zero at the origin). As a result, they exhibit very good group delay characteristics, at the cost of poor attenuation performance in the stopband.
2. The transfer function of the Bessel filter (low-pass prototype) is given by [see Reference 1]:

$$H(j\omega) = \frac{B_n(j\omega)}{b_0}$$

where $B_n(j\omega)$ is the Nth-order Bessel polynomial, and $b_0 = B_n(0)$.

3. The normalized low-pass prototype filter is designed for a cutoff frequency $\omega_c=1$. To change the cutoff frequency from unity toω_c, the frequency dependence of the transfer function must be scaled by $1/\omega_c$, so ω is substituted by {Reference 3]:

$$\omega \leftarrow \frac{\omega}{\omega_c}$$

4. The range for N (order of filter) is from 1 to 15. Orders higher than 15 cannot be simulated.

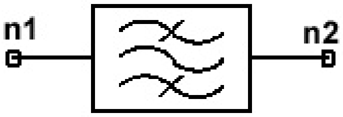
References

[1] *Approximation Methods for Electronic Filter Design*, Richard W. Daniels, McGraw-Hill, Inc.

[2] *Handbook of Filter Synthesis*, Anatol I. Zvered, John Wiley & Sons, Inc. 1967.

[3] *Microwave Engineering*, 2nd Ed. David M. Pozar, John Wiley & Sons, Inc. 1998.

Butterworth Band Pass Filter



An instance of a Butterworth band pass filter has the following Nexxim netlist syntax:

```
Axxx n1 n2 [N=val] [FL=val] [FU=val] [ATT=val] [QU=val]
[RRE=val] [IL=val] COMPONENT=butterworth_band_pass_filter
```

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=butterworth_band_pass_filter** is required.

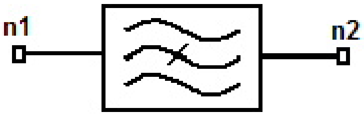
Table 18: Butterworth Band Pass Filter Instance Parameters

Parameter	Description	Units	Default
N	Order of filter	None	3
FL	Lower cutoff frequency	Hz	1e9
FU	Upper cutoff frequency	Hz	2e9
ATT	Attenuation at cutoff	dB	3
QU	Unloaded *Q* for each resonator	None	1e36
RRE	Reference resistance	Ohm	50
IL	Insertion loss	dB	0

Netlist Example

```
A22 1 2 N=5 FL=80e6 FU=100e6 ATT=3 QU=2e36 RRE=50 IL=0
+ COMPONENT=butterworth_band_pass_filter
```

Butterworth Band Reject Filter



Netlist Syntax

An instance of a Butterworth band reject filter has the following Nexxim netlist syntax:

```
Axxx n1 n2 [N=val] [FL=val] [FU=val] [ATT=val] [QU=val]
[RRE=val] [IL=val] COMPONENT=butterworth_band_reject_filter
```

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=butterworth_band_reject_filter** is required.

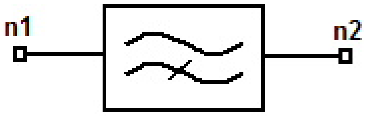
Table 19: Butterworth Band Reject Filter Instance Parameters

Parameter	Description	Units	Default
N	Order of filter	None	3
FL	Lower cutoff frequency	Hz	1e9
FU	Upper cutoff frequency	Hz	2e9
ATT	Attenuation at cutoff	dB	3
QU	Unloaded *Q* for each resonator	None	1e36
RRE	Reference resistance	Ohm	50
IL	Insertion loss	dB	0

Netlist Example

```
A22 1 2 N=5 FL=80e6 FU=100e6 ATT=3 QU=2e36 RRE=50 IL=0
+ COMPONENT=butterworth_band_reject_filter
```

Butterworth High Pass Filter



Netlist Syntax

An instance of a Butterworth high pass filter has the following Nexxim netlist syntax:

A*xxx n1 n2* [**N=***val*] [**FC=***val*] [**ATT=***val*] [**QU=***val*] [**RRE=***val*] [**IL=***val*] **COMPONENT=butterworth_high_pass_filter**

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=butterworth_high_pass_filter** is required.

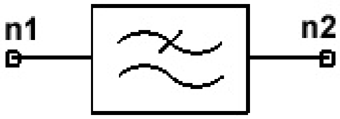
Table 20: Butterworth High Pass Filter Instance Parameters

Parameter	Description	Units	Default
N	Order of filter	None	3
FC	Cutoff frequency	Hz	1e9
ATT	Attenuation at cutoff	dB	3
QU	Unloaded *Q* for each resonator	None	1e36
RRE	Reference resistance	Ohm	50
IL	Insertion loss	dB	0

Netlist Example

```
A22 1 2 N=5 FC=80e6 ATT=3 QU=2e36 RRE=50 IL=0
+ COMPONENT=butterworth_high_pass_filter
```

Butterworth Low Pass Filter



Netlist Syntax

An instance of a Butterworth low pass filter has the following Nexxim netlist syntax:

A*xxx n1 n2* [**N=***val*] [**FC=***val*] [**ATT=***val*] [**QU=***val*] [**RRE=***val*] [**IL=***val*] **COMPONENT=butterworth_low_pass_filter**

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=butterworth_low_pass_filter** is required.

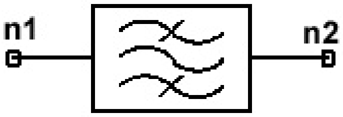
Table 21: Butterworth Low Pass Filter Instance Parameters

Parameter	Description	Units	Default
N	Order of filter	None	3
FC	Cutoff frequency	Hz	1e9
ATT	Attenuation at cutoff	dB	3
QU	Unloaded *Q* for each resonator	None	1e36
RRE	Reference resistance	Ohm	50
IL	Insertion loss	dB	0

Netlist Example

```
A22 1 2 N=5 FC=100e6 ATT=3 QU=2e36 RRE=50 IL=0
+ COMPONENT=butterworth_low_pass_filter
```

Chebyshev Band Pass Filter



Netlist Form

An instance of a Chebyshev band pass filter has the following Nexxim netlist syntax:

```
Axxx n1 n2 [N=val] [FL=val] [FU=val] [RIP=val] [QU=val]
[RRE=val] [IL=val] COMPONENT=chebyshev_band_pass_filter
```

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=chebyshev_band_pass_filter** is required.

Table 22: Chebyshev Band Pass Filter Instance Parameters

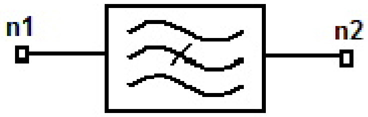
Parameter	Description	Units	Default
N	Order of filter	None	3

FL	Lower cutoff frequency	Hz	1e9
FU	Upper cutoff frequency	Hz	2e9
RIP	Maximum inband ripple	dB	0.05
QU	Unloaded *Q* for each resonator	None	1e36
RRE	Reference resistance	Ohm	50
IL	Insertion loss	dB	0

Netlist Example

```
A22 1 2 N=5 FL=80e6 FU=100e6 RIP=0.07 QU=2e36 RRE=50 IL=0
+ COMPONENT=chebyshev_band_pass_filter
```

Chebyshev Band Reject Filter



Netlist Syntax

An instance of a Chebyshev band reject filter has the following Nexxim netlist syntax:

```
Axxx n1 n2 [N=val] [FL=val] [FU=val] [RIP=val] [QU=val]
[RRE=val] [IL=val] COMPONENT=chebyshev_band_reject_filter
```

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=chebyshev_band_reject_filter** is required.

Table 23: Chebyshev Band Reject Filter Instance Parameters

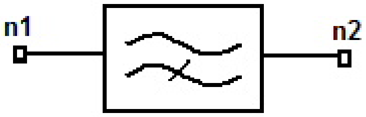
Parameter	Description	Units	Default
N	Order of filter	None	3
FL	Lower cutoff frequency	Hz	1e9
FU	Upper cutoff frequency	Hz	2e9

RIP	Maximum inband ripple	dB	0.05
QU	Unloaded *Q* for each resonator	None	1e36
RRE	Reference resistance	Ohm	50
IL	Insertion loss	dB	0

Netlist Example

```
A22 1 2 N=5 FL=80e6 FU=100e6 RIP=0.07 QU=2e36 RRE=50 IL=0
+ COMPONENT=chebyshev_band_reject_filter
```

Chebyshev High Pass Filter



Netlist Syntax

An instance of a Chebyshev high pass filter has the following Nexxim netlist syntax:

```
Axxx n1 n2 [N=val] [FC=val] [RIP=val] [QU=val] [RRE=val]
[IL=val] COMPONENT=chebyshev_high_pass_filter
```

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=chebyshev_high_pass_filter** is required.

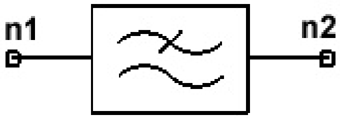
Table 24: Chebyshev High Pass Filter Instance Parameters

Parameter	**Description**	**Units**	**Default**
N	Order of filter	None	3
FC	Cutoff frequency	Hz	1e9
RIP	Maximum inband ripple	dB	0.05
QU	Unloaded *Q* for each resonator	None	1e36
RRE	Reference resistance	Ohm	50
IL	Insertion loss	dB	0

Netlist Example

```
A22 1 2 N=5 FC=80e6 RIP=0.07 QU=1e36 RRE=50 IL=0
+ COMPONENT=chebyshev_high_pass_filter
```

Chebyshev Low Pass Filter



Netlist Syntax

An instance of a Chebyshev low pass filter has the following Nexxim netlist syntax:

A*xxx n1 n2* [**N=***val*] [**FC=***val*] [**RIP=***val*] [**QU=***val*] [**RRE=***val*] [**IL=***val*] **COMPONENT=chebyshev_low_pass_filter**

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=chebyshev_low_pass_filter** is required.

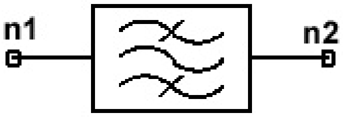
Table 25: Chebyshev Low Pass Filter Instance Parameters

Parameter	Description	Units	Default
N	Order of filter	None	3
FC	Cutoff frequency	Hz	1e9
RIP	Maximum inband ripple	dB	0.05
QU	Unloaded *Q* for each resonator	None	1e36
RRE	Reference resistance	Ohm	50
IL	Insertion loss	dB	0

Netlist Example

```
A22 1 2 N=5 FC=80e6 RIP=0.07 QU=2e36 RRE=50 IL=0
+ COMPONENT=chebyshev_low_pass_filter
```

Elliptic Band Pass Filter



Netlist Syntax

An instance of an elliptic band pass filter has three netlist variants:

A*xxx n1 n2* **N=***val* [**AMAX=***val*] [**AMIN=***val*] [**FA=***val*] [**FB=***val*] [**R1=***val*] [**R2=***val*] [**IL=***val*] **COMPONENT=elliptic_bandpass_filter**

A*xxx n1 n2* **KP=***val* [**AMAX=***val*] [**AMIN=***val*] [**FA=***val*] [**FB=***val*] [**R1=***val*] [**R2=***val*] [**IL=***val*] **COMPONENT=elliptic_bandpass_filter**

A*xxx n1 n2* **FL=***val* **FH=***val* [**AMAX=***val*] [**AMIN=***val*] [**FA=***val*] [**FB=***val*] [**R1=***val*] [**R2=***val*] [**IL=***val*] **COMPONENT=elliptic_bandpass_filter**

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=elliptic_bandpass_filter** is required.

Table 26: Elliptic Band Pass Filter Instance Parameters

Parameter	Description	Units	Default
AMAX	Maximum fluctuation in the pass band	dB	0.1
AMIN	Minimum fluctuation in the stop band	dB	40
FA	Lower pass band edge	Hz	1e9
FB	Upper pass band edge	Hz	2e9
N	Order of filter, 2 < N < 15	None	0
KP	Steepness of descent (sharpness of filter)	None	0.0
FL	Lower stop band edge	Hz	0
FH	Upper stop band edge	Hz	0
R1	Reference resistance for node 1	Ohm	50

R2	Reference resistance for node 2	Ohm	50
IL	Insertion loss in dB	dB	0

Netlist Example

```
A22 1 2 N=5 AMAX=.05 AMIN=40 FA=0.5e9 FB=3e9
+ COMPONENT=elliptic_bandpass_filter
```

Notes

1. The elliptic filter model represents three separate components: ELBPF_N, ELBPF_KP, and ELBPF_FS. The parameters N, KP, and FL &FH are mutually exclusive in the syntax.
2. The elliptic filter has equal loss maxima in the pass band and equal loss minima in the stop band. The elliptic filter provides a sharp transition region for the lowest possible order.
3. The magnitude of the transfer function of the elliptic filter (low-pass prototype) is equal to the inverse of the loss:

$$|H(j\omega)|^2 = \frac{1}{1+\varepsilon^2 \cdot R_n^{\,2}(\omega, L)}$$

where:

$R_n(\omega, IL)$ is the Nth-order Chebychev rational function,

$\varepsilon = 10^{0.1AMIN}$,

$\omega = 2\pi f$,

$$L^2 = \frac{10^{0.1 \cdot AMIN} - 1}{10^{0.1 \cdot AMAX} - 1}$$

$$\omega \leftarrow \left[\frac{\omega_B - \omega_A}{2} \cdot \left[\pm\omega + \sqrt{\omega^2 + \frac{4\omega_A\omega_B}{(\omega_B - \omega_A)^2}}\right]\right]^{-1}$$

4. The first netlist variant specifies the order of the filter, N. The order defines the number of reactive elements needed to implement the filter. The range for N (order of filter) is from 2

to 15. Orders higher than 15 cannot be simulated.

5. The second netlist variant specifies the sharpness of the filter, KP. The order of the filter is then calculated on the value of KP.
6. The third netlist variant specifies one or both stop band edges, FH and FL. The required order of the filter is calculated on the edge information.

6A. When only FH or FL is given, the edge frequencies are calculated to define a geometrically symmetrical filter:

$$f_A \cdot f_B = f_L \cdot f_H$$

6B. When both FH and FL are given such that $f_A \cdot f_B < f_L \cdot f_H$, a new upper stop band edge and a new upper pass band edge are defined:

$$f_{B,new} = \frac{\sqrt{f_A \cdot f_B \cdot f_L \cdot f_H}}{f_A}$$

$$f_{H,new} = \frac{\sqrt{f_A \cdot f_B \cdot f_L \cdot f_H}}{f_L}$$

6C. When both FH and FL are given such that $f_A \cdot f_B > f_L \cdot f_H$, a new lower stop band edge and a new lower pass band edge are defined:

$$f_{A,new} = \frac{\sqrt{f_A \cdot f_B \cdot f_L \cdot f_H}}{f_B}$$

$$f_{L,new} = \frac{\sqrt{f_A \cdot f_B \cdot f_L \cdot f_H}}{f_H}$$

6D. After the edge calculations, the normalized low-pass model poles are calculated for

$f_C = 1$and $f_S = (f_H - f_L)/(f_B - f_A)$, where f_C is the pass band cutoff frequency and f_S is the stopband edge frequency.

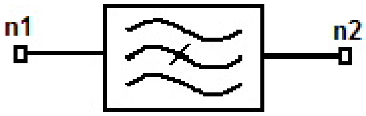
(see the elliptic lowpass filter description).

References

[1] *Approximation Methods for Electronic Filter Design*, Richard W. Daniels, McGraw-Hill, Inc.

[2] *Handbook of Filter Synthesis*, Anatol I. Zvered, John Wiley & Sons, Inc. 1967.

Elliptic Band Reject Filter



Netlist Syntax

An instance of an elliptic band reject filter has three netlist variants:

A*xxx n1 n2* **N=***val* [**AMAX=***val*] [**AMIN=***val*] [**FA=***val*] [**FB=***val*] [**R1=***val*] [**R2=***val*] [**IL=***val*] **COMPONENT=elliptic_bandreject_filter**

A*xxx n1 n2* **KP=***val* [**AMAX=***val*] [**AMIN=***val*] [**FA=***val*] [**FB=***val*] [**R1=***val*] [**R2=***val*] [**IL=***val*] **COMPONENT=elliptic_bandreject_filter**

A*xxx n1 n2* **FL=***val* **FH=***val* [**AMAX=***val*] [**AMIN=***val*] [**FA=***val*] [**FB=***val*] [**R1=***val*] [**R2=***val*] [**IL=***val*] **COMPONENT=elliptic_bandreject_filter**

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=elliptic_bandreject_filter** is required.

Table 27: Elliptic Band Reject Filter Instance Parameters

Parameter	Description	Units	Default
AMAX	Maximum fluctuation in the pass band	dB	0.1
AMIN	Minimum fluctuation in the stop band	dB	40
FA	Lower pass band edge	Hz	1e9
FB	Upper pass band edge	Hz	2e9
N	Order of filter, 2 < N < 15	None	0
KP	Steepness of descent (sharpness of filter)	None	0.0
FL	Lower stop band edge	Hz	0
FH	Upper stop band edge	Hz	0
R1	Reference resistance for node 1	Ohm	50
R2	Reference resistance for node 2	Ohm	50
IL	Insertion loss in dB	dB	0

Netlist Example

```
A22 1 2 KP=0.1 AMAX=0.5 AMIN=45 FA=0.5e9 FB=3e9
+ COMPONENT=elliptic_bandreject_filter
```

Notes

1. The elliptic filter model represents three separate components: ELBRF_N, ELBRF_KP, and ELBRF_FS. The parameters N, KP, and FL &FH are mutually exclusive in the syntax.
2. The elliptic filter has equal loss maxima in the pass band and equal loss minima in the stop band. The elliptic filter provides a sharp transition region for the lowest possible order.
3. The magnitude of the transfer function of the elliptic filter is equal to:

$$|H(j\omega)|^2 = \frac{1}{1+\varepsilon^2 \cdot R_n^{\,2}(\omega, L)}$$

where:

$R_n(\omega, IL)$ is the Nth-order Chebychev rational function,

$\varepsilon = 10^{0.1AMIN}$,

and ω = 2πf.

4. The loss in dB is the inverse of the transfer function:

$$A(f) = 10\log[1 + \varepsilon^2 \cdot R_n^{\;2}(\omega, IL)]$$

$R_n(\omega, IL)$ is the Nth-order Chebychev rational function,

$\varepsilon = 10^{0.1AMIN}$,

and ω = 2πf.

$$L^2 = \frac{10^{0.1 \cdot AMIN} - 1}{10^{0.1 \cdot AMAX} - 1}$$

5. The first netlist variant specifies the order of the filter, N. The order defines the number of reactive elements needed to implement the filter. The range for N (order of filter) is from 2 to 15. Orders higher than 15 cannot be simulated.
6. The second netlist variant specifies the sharpness of the filter, KP. The order of the filter is then calculated on the value of KP.
7. The third netlist variant specifies one or both stop band edges, FH and FL. The required order of the filter is calculated on the edge information.

7A. When only FH or FL is given, the edge frequencies are calculated to define a geometrically symmetrical filter:

$$f_A \cdot f_B = f_L \cdot f_H$$

7B. When both FH and FL are given such that $f_A \cdot f_B < f_L \cdot f_H$, a new upper stop band edge and a new upper pass band edge are defined:

$$f_{B,new} = \frac{\sqrt{f_A \cdot f_B \cdot f_L \cdot f_H}}{f_A}$$

$$f_{H,new} = \frac{\sqrt{f_A \cdot f_B \cdot f_L \cdot f_H}}{f_L}$$

7C. When both FH and FL are given such that $f_A \cdot f_B > f_L \cdot f_H$, a new lower stop band edge and a new lower pass band edge are defined:

$$f_{A,new} = \frac{\sqrt{f_A \cdot f_B \cdot f_L \cdot f_H}}{f_B}$$

$$f_{L,new} = \frac{\sqrt{f_A \cdot f_B \cdot f_L \cdot f_H}}{f_H}$$

7D. After the edge calculations, the normalized low-pass model poles are calculated for

$f_C = 1$and $f_S = (f_H - f_L)/(f_B - f_A)$, where f_C is the pass band cutoff frequency and f_S is the stopband edge frequency.

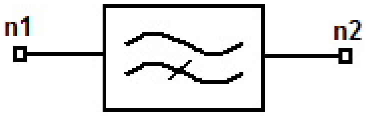
(see the elliptic lowpass filter description).

References

[1] *Approximation Methods for Electronic Filter Design*, Richard W. Daniels, McGraw-Hill, Inc.

[2] *Handbook of Filter Synthesis*, Anatol I. Zvered, John Wiley & Sons, Inc. 1967.

Elliptic High Pass Filter



Netlist Syntax

An instance of an elliptic high pass filter has three netlist variants:

```
Axxx n1 n2 N=val [AMAX=val] [AMIN=val] FC=val [R1=val] [R2=val]
[IL=val] COMPONENT=elliptic_highpass_filter
```

```
Axxx n1 n2 KP=val [AMAX=val] [AMIN=val] FC=val [R1=val]
[R2=val] [IL=val] COMPONENT=elliptic_highpass_filter
```

```
Axxx n1 n2 FS=val [AMAX=val] [AMIN=val] [R1=val] [R2=val]
[IL=val] COMPONENT=elliptic_highpass_filter
```

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=elliptic_highpass_filter** is required.

Table 28: Elliptic High Pass Filter Instance Parameters

Parameter	Description	Units	Default
AMAX	Maximum fluctuation in the pass band	dB	0.1
AMIN	Minimum fluctuation in the stop band	dB	40
FC	Cutoff frequency	Hz	1e9
FS	Stopband edge frequency	Hz	0
N	Order of filter, 2 < N < 15	None	0
KP	Steepness of descent (sharpness of filter)	None	0.0
R1	Reference resistance for node 1	Ohm	50
R2	Reference resistance for node 2	Ohm	50
IL	Insertion loss in dB	dB	0

Netlist Example

```
A22 1 2 N=5 FS=1e9 FH=4e9 AMAX=0.5 AMIN=45
+ COMPONENT=elliptic_highpass_filter
```

Notes

1. The elliptic filter model represents three separate components: ELHPF_N, ELHPF_KP, and ELHPF_FS. The parameters N, KP, and FS are mutually exclusive in the syntax.
2. The elliptic filter has equal loss maxima in the pass band and equal loss minima in the stop band. The elliptic filter provides a sharp transition region for the lowest possible order.
3. The magnitude of the transfer function of the elliptic filter (high-pass prototype) is equal to:

$$|H(j\omega)|^2 = \frac{1}{1 + \varepsilon^2 \cdot R_n^2\left(-\frac{f_c}{f}, L\right)}$$

where:

$R_n(\omega, IL)$ is the Nth-order Chebychev rational function,

$\varepsilon = 10^{0.1AMIN}$,

$\omega = 2\pi f$,

$$L^2 = \frac{10^{0.1 \cdot AMIN} - 1}{10^{0.1 \cdot AMAX} - 1}$$

4. The loss in dB is the inverse of the transfer function:

$$A(f) = 10\log\left[1 + \varepsilon^2 \cdot R_n^{\,2}\left(-\frac{f_c}{f}, L\right)\right]$$

where:

R_n is the Nth-order Chebychev rational function, $\varepsilon = 10^{0.1AMIN}$,

$$L^2 = \frac{10^{0.1 \cdot AMIN} - 1}{10^{0.1 \cdot AMAX} - 1}$$

A normalized band pass filter is designed for ω_C=1. A frequency transformation is performed for the band reject filter:

$$\omega \leftarrow \frac{\omega_c}{\omega}$$

5. The first netlist variant specifies AMAX, AMIN, FC, and N. The order of the filter determines the sharpness. The order defines the number of reactive elements needed to implement the filter. The range for N (order of filter) is from 2 to 15. Orders higher than 15 cannot be simulated.

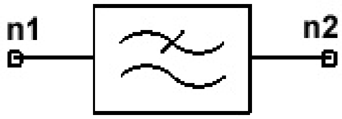
6. The second netlist variant specifies AMAX, AMIN, FC, and KP. The order of the filter is then calculated on the value of the given parameters.
7. The third netlist variant specifies AMAX, AMIN, FC, and FS. The required order of the filter is calculated from the parameters given.

References

[1] *Approximation Methods for Electronic Filter Design*, Richard W. Daniels, McGraw-Hill, Inc.

[2] *Handbook of Filter Synthesis*, Anatol I. Zvered, John Wiley & Sons, Inc. 1967.

Elliptic Low Pass Filter



Netlist Syntax

An instance of an elliptic low pass filter has three netlist variants:

A*xxx n1 n2* **N=***val* [**AMAX=***val*] [**AMIN=***val*] **FC=***val* [**R1=***val*] [**R2=***val*] [**IL=***val*] **COMPONENT=elliptic_lowpass_filter**

A*xxx n1 n2* **KP=***val* [**AMAX=***val*] [**AMIN=***val*] **FC=***val* [**R1=***val*] [**R2=***val*] [**IL=***val*] **COMPONENT=elliptic_lowpass_filter**

A*xxx n1 n2* **FS=***val* [**AMAX=***val*] [**AMIN=***val*] [**R1=***val*] [**R2=***val*] [**IL=***val*] **COMPONENT=elliptic_lowpass_filter**

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=elliptic_lowpass_filter** is required.

Table 29: Elliptic Low Pass Filter Instance Parameters

Parameter	Description	Units	Default
AMAX	Maximum fluctuation in the pass band	dB	0.1
AMIN	Minimum fluctuation in the stop band	dB	40
FC	Cutoff frequency	Hz	1e9

FS	Stopband edge frequency	Hz	0
N	Order of filter, 2 < N < 15	None	0
KP	Steepness of descent (sharpness of filter)	None	0.0
R1	Reference resistance for node 1	Ohm	50
R2	Reference resistance for node 2	Ohm	50
IL	Insertion loss in dB	dB	0

Netlist Example

```
A22 1 2 N=5 FC=1e9 AMAX=0.5 AMIN=45
+ COMPONENT=elliptic_lowpass_filter
```

Notes

1. The elliptic filter model represents three separate components: ELHPF_N, ELHPF_KP, and ELHPF_FS. The parameters N, KP, and FS are mutually exclusive in the syntax.
2. The elliptic filter has equal loss maxima in the pass band and equal loss minima in the stop band. The elliptic filter provides a sharp transition region for the lowest possible order.
3. The magnitude of the transfer function of the elliptic filter (high-pass prototype) is equal to:

$$|H(j\omega)|^2 = \frac{1}{1+\varepsilon^2 \cdot R_n^2\left(\frac{f}{f_c}, L\right)}$$

where:

$R_n(\omega, IL)$ is the Nth-order Chebychev rational function,

$\varepsilon = 10^{0.1AMIN}$,

$\omega = 2\pi f$,

$$L^2 = \frac{10^{0.1 \cdot AMIN} - 1}{10^{0.1 \cdot AMAX} - 1}$$

4. The loss in dB is the inverse of the transfer function:

$$A(f) = 10\log\left[1+\varepsilon^2 \cdot R_n^2\left(\frac{f}{f_c}, L\right)\right]$$

where:

R_n is the Nth-order Chebychev rational function,

$\varepsilon = 10^{0.1AMIN}$,

$$L^2 = \frac{10^{0.1 \cdot AMIN} - 1}{10^{0.1 \cdot AMAX} - 1}$$

A normalized band pass filter is designed for ω_C=1. A frequency transformation is performed for the band reject filter:

$$\omega \leftarrow \frac{\omega}{\omega_c}$$

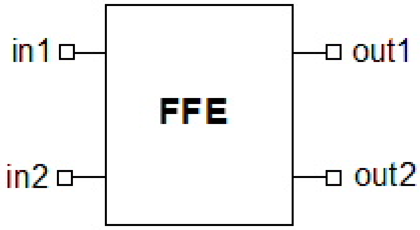
5. The first netlist variant specifies AMAX, AMIN, FC, and N. The order of the filter determines the sharpness. The order defines the number of reactive elements needed to implement the filter. The range for N (order of filter) is from 2 to 15. Orders higher than 15 cannot be simulated.
6. The second netlist variant specifies AMAX, AMIN, FC, and KP. The order of the filter is then calculated on the value of the given parameters.
7. The third netlist variant specifies AMAX, AMIN, FC, and FS. The required order of the filter is calculated from the parameters given.

References

[1] *Approximation Methods for Electronic Filter Design*, Richard W. Daniels, McGraw-Hill, Inc.

[2] *Handbook of Filter Synthesis*, Anatol I. Zvered, John Wiley & Sons, Inc. 1967.

Feed-Forward Equalizer (FFE)



Netlist Syntax

The feed-forward equalizer can be used for transient analysis of a communication channel. The implementation is similar to the QuickEye/VerifEye equalization. An instance of a feed-forward equalizer has the netlist syntax:

A*xxx in1 in2 out1 out2* **UI=***val* **FFE_TAPS=***Number_of_Taps*
NORMALIZE_FFE=1|0 COMPONENT=tx_deemphasis FFE_LOCS=[*Tap1_Loc Tap2_Loc ...***]**
FFE_WEIGHTS=[*Tap1_Weight Tap2_Weight ...***]**

in1 and *out1* are the single-ended input and output. *in2* and *out2* are the differential input and output. For single-ended transmission, the differential nodes may be grounded. The entry **COMPONENT=tx_deemphasis** is required.

Table 30: Feed-Forward Equalizer Instance Parameters

Parameter	Description	Units	Default
UI	Duration of unit interval	Second	None
FFE_TAPS	Number of FFE taps	None	0
FFE_LOCS	Positive or negative offsets from the tap at location 0. There must always be a tap at location 0 itself. Negative locations become precursor taps, positive locations become postcursors.	None	None
FFE_ WEIGHTS	FFE weights for the taps with settings in FFE_LOCS	None	None
NORMALIZE_ FFE	1=Normalize, 0=No normalization	None	1

Netlist Example

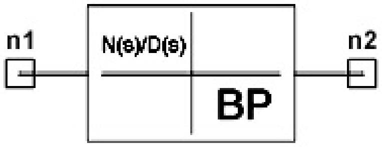
```
AFFE1 bits 0 post_eq 0 ui=2e-9 ffe_taps=3
+ ffe_locs=[0 1 2] // All taps are postcursors
+ ffe_weights=[1.25 -0.2 -0.05]
+ normalize_ffe=1 component=tx_deemphasis
```

```
AFFE2 bitsplus bitsminus post_eq_plus post_eq_minus ui=2e-9
+ ffe_taps=5 normalize_ffe=1 component=tx_deemphasis
+ ffe_locs=[-2 -1 0 1 2] // Taps 1 and 2 are precursors
+ ffe_weights=[.04 -.17 1.25 -0.2 -0.05]
```

Notes

1. A FFE tap has a number, a location, and a weight.
2. The tap numbers are consecutive, starting with Tap1. The highest tap number is given by FFE_TAPS.
3. A tap location is the positive or negative offset of that tap from location 0. The tap with location 0 is applied at the time of the current bit in the data stream. There must always be a tap at location 0. Taps with positive locations (including location 0) become postcursor taps. Taps with negative locations become precursors.
4. The tap weights are the deemphasis factors used in the equalization.

Polynomial Band Pass Filter



Netlist Syntax

An instance of a polynomial band pass filter has the following Nexxim netlist syntax:

A*xxx n1 n2* [**FC=***val*] [**BW=***val*] [**GF=***val*] [**R1=***val*] [**X1=***val*] [**R2=***val*] [**X2=***val*] **NUMER=[***a0 a1* **...] DENOM=[***b0 b1* **...]** **COMPONENT=polynomial_bandpass_filter**

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=polynomial_ bandpass_filter** is required.

Table 31: Polynomial Band Pass Filter Instance Parameters

Parameter	Description	Units	Default
FC	Center frequency	Hz	0
BW	Bandwidth (3dB)	Hz	0
GF	Gain factor	None	1.0
R1	Resistive part of reference impedance at node 1	Ohm	50
X1	Reactive part of reference impedance at node 1	Ohm	0
R2	Resistive part of reference impedance at node 2	Ohm	50
X2	Reactive part of reference impedance at node 2	Ohm	0

a0 ... aN	Coefficients of the numerator polynomial	None	None
b0 ... bD	Coefficients of the denominator polynomial	None	None

Netlist Example

To specify the following transfer function (where coefficient a_1=0):

$$H(s) = \frac{1 + 2s^2}{1 + s + 3s^2}$$

The netlist specifies:

```
A22 1 2 FC=80e6 BW=101e4 NUMER=[1 0 2] DENOM=[1 1 3]
+ COMPONENT=polynomial_bandpass_filter
```

Notes

1. The element is specified using a transfer function given as the ratio of two polynomials in the complex variable *s*. The bold brackets for the **NUMER** and **DENOM** entries are required.

   The function of the device is expressed as:

GAIN × H(s)

   The transfer function H(s) is specified by giving the coefficients:

$$H(s) = \frac{a_0 + a_1 s + a_2 s^2 + \ldots}{b_0 + b_1 s + b_2 s^2 + \ldots}$$

$$S = \frac{j(F/F_0 - F_0/F)}{(F_H/F_0 - F_0/F_H)}$$

   where *F* = the analysis frequency and *j*=sqrt(-1)

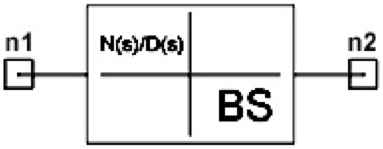
$$F_0 = \sqrt{F_L F_H}$$

$$F_L = \left(F_C - \frac{BW}{2}\right)$$

$$F_H = F_C + \frac{BW}{2}$$

2. The first coefficients in both numerator and denominator (a_0 and b_0) are constants, which must be specified even if they are zero. Thus, leading zeros are significant. In addition, intermediate zero-valued coefficients must be explicitly supplied in order to have the non-zero coefficients applied to the correct powers of *s*.
3. Trailing zeros are not significant, and are automatically removed.
4. Both numerator and denominator must contain at least one non-zero value..

Polynomial Band Reject Filter



Netlist Syntax

An instance of a polynomial band reject filter has the following Nexxim netlist syntax:

```
Axxx n1 n2 [FC=val] [BW=val] [GF=val] [R1=val] [X1=val]
[R2=val] [X2=val] NUMER=[a0 a1 ...] DENOM=[b0 b1 ...]
COMPONENT=polynomial_bandreject_filter
```

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=polynomial_bandreject_filter** is required.

Table 32: Polynomial Band Reject Filter Instance Parameters

Parameter	Description	Units	Default
FC	Center frequency	Hz	0
BW	Bandwidth (3dB)	Hz	0
GF	Gain factor	None	1.0
R1	Resistive part of reference impedance at node 1	Ohm	50
X1	Reactive part of reference impedance at node 1	Ohm	0
R2	Resistive part of reference impedance at node 2	Ohm	50
X2	Reactive part of reference impedance at node 2	Ohm	0
a0 ... aN	Coefficients of the numerator polynomial	None	None
b0 ... bD	Coefficients of the denominator polynomial	None	None

To specify the following transfer function (where coefficient a_1=0):

$$H(s) = \frac{1 + 2s^2}{1 + s + 3s^2}$$

The netlist specifies:

```
A22 1 2 FC=80e6 BW=101e4 NUMER=[1 0 2] DENOM=[1 1 3]
+ COMPONENT=polynomial_bandreject_filter
```

Notes

1. The element is specified using a transfer function given as the ratio of two polynomials in the complex variable *s*. The bold brackets for the **NUMER** and **DENOM** entries are required.

The function of the device is expressed as:

GAIN × H(s)

The transfer function H(s) is specified by giving the coefficients:

$$H(s) = \frac{a_0 + a_1 s + a_2 s^2 + \ldots}{b_0 + b_1 s + b_2 s^2 + \ldots}$$

$$S = \frac{j(F/F_0 - F_0/F)}{(F_H/F_0 - F_0/F_H)}$$

where *F* = the analysis frequency and *j*=sqrt(-1)

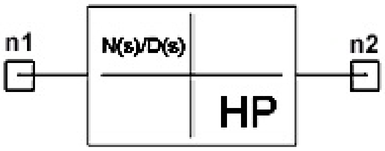
$$F_0 = \sqrt{F_L F_H}$$

$$F_L = \left(F_C - \frac{BW}{2}\right)$$

$$F_H = F_C + \frac{BW}{2}$$

2. The first coefficients in both numerator and denominator (a_0 and b_0) are constants, which must be specified even if they are zero. Thus, leading zeros are significant. In addition, intermediate zero-valued coefficients must be explicitly supplied in order to have the non-zero coefficients applied to the correct powers of *s*.
3. Trailing zeros are not significant, and are automatically removed.
4. Both numerator and denominator must contain at least one non-zero value..

Polynomial High Pass Filter



Netlist Syntax

An instance of a polynomial high pass filter has the following Nexxim netlist syntax:

```
Axxx n1 n2 [FC=val] [GF=val] [R1=val] [X1=val] [R2=val]
[X2=val] NUMER=[a0 a1 ...] DENOM=[b0 b1 ...]
COMPONENT=polynomial_highpass_filter
```

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=polynomial_highpass_filter** is required.

Table 33: Polynomial High Pass Filter Instance Parameters

Parameter	Description	Units	Default
FC	3dB cutoff frequency	Hz	0
GF	Gain factor	None	1.0
R1	Resistive part of reference impedance at node 1	Ohm	50
X1	Reactive part of reference impedance at node 1	Ohm	0
R2	Resistive part of reference impedance at node 2	Ohm	50
X2	Reactive part of reference impedance at node 2	Ohm	0
a0 ... aN	Coefficients of the numerator polynomial	None	None
b0 ... bD	Coefficients of the denominator polynomial	None	None

Netlist Example

To specify the following transfer function (where coefficient a_1=0):

$$H(s) = \frac{1 + 2s^2}{1 + s + 3s^2}$$

The netlist specifies:

```
A22 1 2 FC=80e6 BW=101e4 NUMER=[1 0 2] DENOM=[1 1 3]
+ COMPONENT=polynomial_highpass_filter
```

Notes

1. The element is specified using a transfer function given as the ratio of two polynomials in the complex variable *s*. The bold brackets for the **NUMER** and **DENOM** entries are required.

   The function of the device is expressed as:

GAIN × H(s)

   The transfer function H(s) is specified by giving the coefficients:

$$H(s) = \frac{a_0 + a_1 s + a_2 s^2 + \dots}{b_0 + b_1 s + b_2 s^2 + \dots}$$

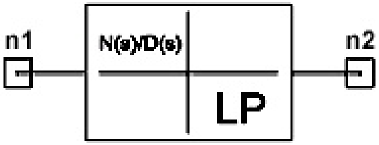
$$S = \frac{-jF_C}{F}$$

   where *F* = the analysis frequency and *j*=sqrt(-1)

2. The first coefficients in both numerator and denominator (a_0 and b_0) are constants, which must be specified even if they are zero. Thus, leading zeros are significant. In addition, intermediate zero-valued coefficients must be explicitly supplied in order to have the non-zero coefficients applied to the correct powers of *s*.

3. Trailing zeros are not significant, and are automatically removed.
4. Both numerator and denominator must contain at least one non-zero value.

Polynomial Low Pass Filter



Netlist Syntax

An instance of a polynomial low pass filter has the following Nexxim netlist syntax:

```
Axxx n1 n2 [FC=val] [GF=val] [R1=val] [X1=val] [R2=val]
[X2=val] NUMER=[a0 a1 ...] DENOM=[b0 b1 ...]
COMPONENT=polynomial_lowpass_filter
```

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=polynomial_lowpass_filter** is required.

Table 34: Polynomial Low Pass Filter Instance Parameters

Parameter	Description	Units	Default
FC	3dB cutoff frequency	Hz	0
GF	Gain factor	None	1.0
R1	Resistive part of reference impedance at node 1	Ohm	50
X1	Reactive part of reference impedance at node 1	Ohm	0
R2	Resistive part of reference impedance at node 2	Ohm	50
X2	Reactive part of reference impedance at node 2	Ohm	0
a0* ... *aN	Coefficients of the numerator polynomial	None	None
b0* ... *bD	Coefficients of the denominator polynomial	None	None

Netlist Example

To specify the following transfer function (where coefficient a_1=0):

$$H(s) = \frac{1 + 2s^2}{1 + s + 3s^2}$$

The netlist specifies:

```
A22 1 2 FC=80e6 BW=101e4 NUMER=[1 0 2] DENOM=[1 1 3]
+ COMPONENT=polynomial_lowpass_filter
```

Notes

1. The element is specified using a transfer function given as the ratio of two polynomials in the complex variable s. The bold brackets for the **NUMER** and **DENOM** entries are required.

The function of the device is expressed as:

GAIN × H(s)

The transfer function H(s) is specified by giving the coefficients:

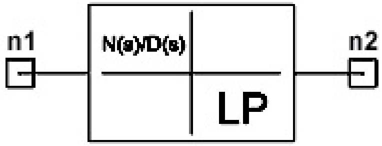
$$H(s) = \frac{a_0 + a_1 s + a_2 s^2 + \ldots}{b_0 + b_1 s + b_2 s^2 + \ldots}$$

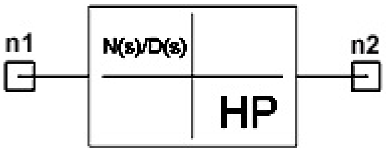
$$S = \frac{jF}{F_C}$$

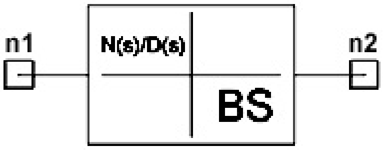
where *F* = the analysis frequency and *j*=sqrt(-1)

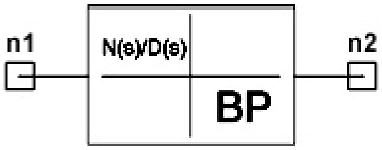
2. The first coefficients in both numerator and denominator (a_0 and b_0) are constants, which must be specified even if they are zero. Thus, leading zeros are significant. In addition, intermediate zero-valued coefficients must be explicitly supplied in order to have the non-zero coefficients applied to the correct powers of *s*.
3. Trailing zeros are not significant, and are automatically removed.
4. Both numerator and denominator must contain at least one non-zero value.

Polynomial Filter, Causal









Netlist Syntax

An instance of a polynomial low pass filter has the following Nexxim netlist syntax:

```
Axxx n1 n2 FILTER_TYPE=1|2|3|4 [FC=val] [GF=val] [BW=val]
NUMER=[a0 a1 ...] DENOM=[b0 b1 ...]
COMPONENT=polynomial_filter_causal
```

n1 and *n2* are the nodes connected to the filter. The parameter **FILTER_TYPE** selects the passband. The entry **COMPONENT=polynomial_filter_causal** is required.

Table 35: Polynomial Low Pass Filter Instance Parameters

Parameter	Description	Units	Default
FILTER_ TYPE	Passband selector: 1=HIGHPASS, 2=LOWPASS, 3=BANDREJECT, 4=BANDPASS	None	None
FC	3dB cutoff frequency	Hz	1e9
GF	Gain factor	None	1.0
BW	3dB Bandwidth	Hz	1e9
a0 ... aN	Coefficients of the numerator polynomial	None	None
b0 ... bD	Coefficients of the denominator polynomial	None	None

Netlist Example

To specify the following transfer function (where coefficient a_1=0):

$$H(s) = \frac{1 + 2s^2}{1 + s + 3s^2}$$

The netlist specifies:

```
A22 1 2 FILTER_TYPE=4 FC=80e6 BW=101e4
+ NUMER=[1 0 2] DENOM=[1 1 3]
+ COMPONENT=polynomial_filter_causal
```

Notes

1. The element is specified using a transfer function given as the ratio of two polynomials in the complex variable *s*. The bold brackets for the **NUMER** and **DENOM** entries are required.

   The function of the device is expressed as:

GAIN × H(s)

   The transfer function H(s) is specified by giving the coefficients:

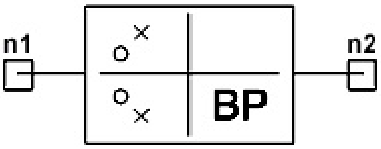
$$H(s) = \frac{a_0 + a_1 s + a_2 s^2 + \ldots}{b_0 + b_1 s + b_2 s^2 + \ldots}$$

$$S = \frac{jF}{F_C}$$

   where *F* = the analysis frequency and *j*=sqrt(-1)

2. The first coefficients in both numerator and denominator (a_0 and b_0) are constants, which must be specified even if they are zero. Thus, leading zeros are significant. In addition, intermediate zero-valued coefficients must be explicitly supplied in order to have the non-zero coefficients applied to the correct powers of *s*.
3. Trailing zeros are not significant, and are automatically removed.
4. Both numerator and denominator must contain at least one non-zero value.

Pole Zero Band Pass Filter



Netlist Syntax

An instance of a pole-zero band pass filter has the following Nexxim netlist syntax:

```
Axxx n1 n2 [FC=val] [BW=val] [GF=val] [R1=val] [X1=val]
[R2=val] [X2=val] POLES=[rp1 ip1 ...] ZEROS=[rz1 iz1 ...]
COMPONENT=polezero_bandpass_filter
```

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=polezero_bandpass_filter** is required.

Table 36: Pole-Zero Band Pass Filter Instance Parameters

Parameter	Description	Units	Default
FC	Center frequency	Hz	0
BW	Bandwidth (3dB)	Hz	0
GF	Gain factor	None	1.0
R1	Resistive part of reference impedance at node 1	Ohm	50
X1	Reactive part of reference impedance at node 1	Ohm	0
R2	Resistive part of reference impedance at node 2	Ohm	50
X2	Reactive part of reference impedance at node 2	Ohm	0
rp1, ip1 ... rpN, ipN	Real and imaginary parts of the poles	None	None
rz1, iz1 ... rzN, izN	Real and imaginary parts of the zeros	None	None

Netlist Example

```
A22 1 2 FC=80e6 BW=101e4 POLES=[.1 -1.03 .2 .003]
+ ZEROS=[.05 -1.7] + COMPONENT=polezero_bandpass_filter
```

Notes

1. The element is specified using a transfer function given as the ratio of two expressions in the complex variable *s*. The bold brackets for the **POLES** and **ZEROS** entries are required.

The function of the device is expressed as:

GAIN x H(s)

The transfer function H(s) is specified by giving the coefficients:

$$H(s) = \frac{(S - zero1)(S - zero2)\ldots}{(S - pole1)(S - pole2)\ldots}$$

$$S = \frac{j(F/F_0 - F_0/F)}{(F_H/F_0 - F_0/F_H)}$$

where *F* = the analysis frequency and *j*=sqrt(-1)

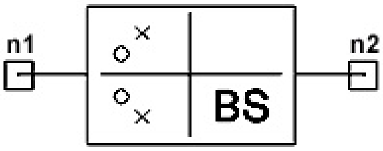
$$F_0 = \sqrt{F_L F_H}$$

$$F_L = \left(F_C - \frac{BW}{2}\right)$$

$$F_H = F_C + \frac{BW}{2}$$

2. The first coefficients in both numerator and denominator (a_0 and b_0) are constants, which must be specified even if they are zero. Thus, leading zeros are significant. In addition, intermediate zero-valued coefficients must be explicitly supplied in order to have the non-zero coefficients applied to the correct powers of *s*.
3. Trailing zeros are not significant, and are automatically removed.
4. At least one non-zero pole value must be supplied.

Pole Zero Band Reject Filter



Netlist Syntax

An instance of a pole-zero band reject filter has the following Nexxim netlist syntax:

```
Axxx n1 n2 [FC=val] [BW=val] [GF=val] [R1=val] [X1=val]
[R2=val] [X2=val] POLES=[rp1 ip1 ...] ZEROS=[rz1 iz1 ...]
COMPONENT=polezero_bandreject_filter
```

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=polezero_bandreject_filter** is required.

Table 37: Pole-Zero Band Reject Filter Instance Parameters

Parameter	Description	Units	Default
FC	Center frequency	Hz	0
BW	Bandwidth (3dB)	Hz	0
GF	Gain factor	None	1.0
R1	Resistive part of reference impedance at node 1	Ohm	50
X1	Reactive part of reference impedance at node 1	Ohm	0
R2	Resistive part of reference impedance at node 2	Ohm	50

X2	Reactive part of reference impedance at node 2	Ohm	0
rp1, ip1 ... rpN, ipN	Real and imaginary parts of the poles	None	None
rz1, iz1 ... rzN, izN	Real and imaginary parts of the zeros	None	None

Netlist Example

```
A22 1 2 FC=80e6 BW=101e4 POLES=[.1 -1.03 .2 .003]
+ ZEROS=[.05 -1.7] + COMPONENT=polezero_bandreject_filter
```

Notes

1. The element is specified using a transfer function given as the ratio of two expressions in the complex variable *s*. The bold brackets for the **POLES** and **ZEROS** entries are required.

The function of the device is expressed as:

GAIN × H(s)

The transfer function H(s) is specified by giving the coefficients:

$$H(s) = \frac{(S - zero1)(S - zero2)\ldots}{(S - pole1)(S - pole2)\ldots}$$

$$S = \frac{j(F_0/F_L - F_L/F_0)}{(F/F_0 - F_0/F)}$$

where *F* = the analysis frequency and j=sqrt(-1)

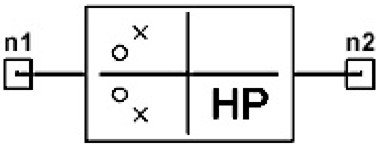
$$F_0 = \sqrt{F_L F_H}$$

$$F_L = \left(F_C - \frac{BW}{2}\right)$$

$$F_H = F_C + \frac{BW}{2}$$

2. The first coefficients in both numerator and denominator (a_0 and b0) are constants, which must be specified even if they are zero. Thus, leading zeros are significant. In addition, intermediate zero-valued coefficients must be explicitly supplied in order to have the non-zero coefficients applied to the correct powers of *s*.
3. Trailing zeros are not significant, and are automatically removed.
4. At least one non-zero pole value must be supplied.

Pole Zero High Pass Filter



Netlist Syntax

An instance of a pole-zero high pass filter has the following Nexxim netlist syntax:

```
Axxx n1 n2 [FC=val][GF=val] [R1=val] [X1=val] [R2=val] [X2=val]
POLES=[rp1 ip1 ...] ZEROS=[rz1 iz1 ...]
COMPONENT=polezero_highpass_filter
```

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=polezero_highpass_filter** is required.

Table 38: Pole-Zero High Pass Filter Instance Parameters

Parameter	Description	Units	Default
FC	3dB cutoff frequency	Hz	0
GF	Gain factor	None	1.0
R1	Resistive part of reference impedance at node 1	Ohm	50
X1	Reactive part of reference impedance at node 1	Ohm	0
R2	Resistive part of reference impedance at node 2	Ohm	50
X2	Reactive part of reference impedance at node 2	Ohm	0
rp1, ip1 ... rpN, ipN	Real and imaginary parts of the poles	None	None
rz1, iz1 ... rzN, izN	Real and imaginary parts of the zeros	None	None

Netlist Example

```
A22 1 2 FC=80e6 BW=101e4 POLES=[.1 -1.03 .2 .003]
+ ZEROS=[.05 -1.7] + COMPONENT=polezero_highpass_filter
```

Notes

1. The element is specified using a transfer function given as the ratio of two expressions in the complex variable *s*. The bold brackets for the **POLES** and **ZEROS** entries are required.

The function of the device is expressed as:

GAIN × H(s)

The transfer function H(s) is specified by giving the coefficients:

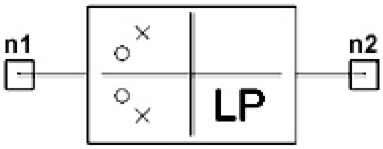
$$H(s) = \frac{(S-zero1)(S-zero2)\ldots}{(S-pole1)(S-pole2)\ldots}$$

$$S = \frac{-jF_C}{F}$$

where *F* = the analysis frequency and *j*=sqrt(-1)

2. The first coefficients in both numerator and denominator (a_0 and b_0) are constants, which must be specified even if they are zero. Thus, leading zeros are significant. In addition, intermediate zero-valued coefficients must be explicitly supplied in order to have the non-zero coefficients applied to the correct powers of *s*.
3. Trailing zeros are not significant, and are automatically removed.
4. At least one non-zero pole value must be supplied.

Pole Zero Low Pass Filter



Netlist Syntax

An instance of a pole-zero low pass filter has the following Nexxim netlist syntax:

```
Axxx n1 n2 [FC=val][GF=val] [R1=val] [X1=val] [R2=val] [X2=val]
POLES=[rp1 ip1 ...] ZEROS=[rz1 iz1 ...]
COMPONENT=polezero_lowpass_filter
```

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=polezero_lowpass_filter** is required.

Table 39: Pole-Zero Low Pass Filter Instance Parameters

Parameter	Description	Units	Default
FC	3dB cutoff frequency	Hz	0
GF	Gain factor	None	1.0
R1	Resistive part of reference impedance at node 1	Ohm	50
X1	Reactive part of reference impedance at node 1	Ohm	0
R2	Resistive part of reference impedance at node 2	Ohm	50
X2	Reactive part of reference impedance at node 2	Ohm	0

rp1, ip1 ... rpN, ipN	Real and imaginary parts of the poles	None	None
rz1, iz1 ... rzN, izN	Real and imaginary parts of the zeros	None	None

Netlist Example

A22 1 2 FC=80e6 BW=101e4 POLES=[.1 -1.03 .2 .003]
+ ZEROS=[.05 -1.7] + COMPONENT=polezero_lowpass_filter

Notes

1. The element is specified using a transfer function given as the ratio of two expressions in the complex variable *s*. The bold brackets for the **POLES** and **ZEROS** entries are required.

The function of the device is expressed as:

GAIN × H(s)

The transfer function H(s) is specified by giving the coefficients:

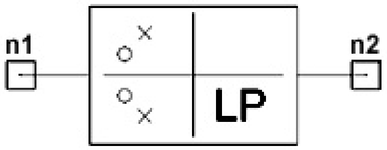
$$H(s) = \frac{(S-zero1)(S-zero2)\ldots}{(S-pole1)(S-pole2)\ldots}$$

$$S = \frac{-jF}{F_C}$$

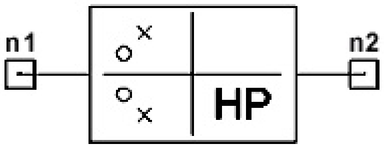
where *F* = the analysis frequency and *j*=sqrt(-1)

2. The first coefficients in both numerator and denominator (a_0 and b_0) are constants, which must be specified even if they are zero. Thus, leading zeros are significant. In addition, intermediate zero-valued coefficients must be explicitly supplied in order to have the non-zero coefficients applied to the correct powers of *s*.
3. Trailing zeros are not significant, and are automatically removed.
4. At least one non-zero pole value must be supplied.

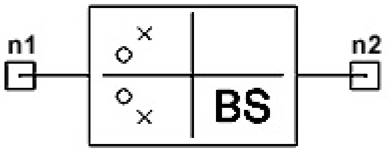
Pole Zero Filter, Causal



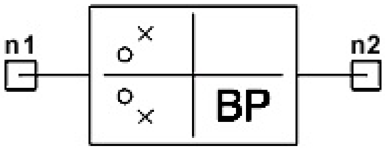
filter_type=1



filter_type=2



filter_type=3



filter_type=4

Netlist Syntax

An instance of a pole-zero causal filter has the following Nexxim netlist syntax:

```
Axxx n1 n2 filter_type=1|2|3|4 [FC=val][GF=val] [BW=val]

POLES=[rp1 ip1 ...] ZEROS=[rz1 iz1 ...]
COMPONENT=polezero_filter_causal
```

n1 and *n2* are the nodes connected to the filter. The parameter **filter_type** selects the passband. The entry **COMPONENT=polezero_filter_causal** is required.

Table 40: Pole-Zero Causal Filter Instance Parameters

Parameter	Description	Units	Default
FILTER_TYPE	Passband selector 1=LOWPASS, 2=HIGHPASS, 3=BANDREJECT, 4=BANDPASS	None	None
FC	3dB cutoff frequency	Hz	1e9
GF	Gain factor	None	1.0
BW	3dB bandwidth	Hz	1e9
rp1, ip1 ... rpN, ipN	Real and imaginary parts of the poles	None	None
rz1, iz1 ... rzN, izN	Real and imaginary parts of the zeros	None	None

Netlist Example

```
A22 1 2 filter_type=4 FC=80e6 BW=101e4 POLES=[.1 -1.03 .2 .003]
+ ZEROS=[.05 -1.7] + COMPONENT=polezero_filter_causal
```

Notes

1. The element is specified using a transfer function given as the ratio of two expressions in the complex variable *s*. The bold brackets for the **POLES** and **ZEROS** entries are required.

The function of the device is expressed as:

GAIN × H(s)

The transfer function H(s) is specified by giving the coefficients:

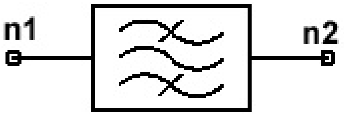
$$H(s) = \frac{(S-zero1)(S-zero2)\ldots}{(S-pole1)(S-pole2)\ldots}$$

$$S = \frac{-jF}{F_C}$$

where *F* = the analysis frequency and *j*=sqrt(-1)

2. The first coefficients in both numerator and denominator (a_0 and b_0) are constants, which must be specified even if they are zero. Thus, leading zeros are significant. In addition, intermediate zero-valued coefficients must be explicitly supplied in order to have the non-zero coefficients applied to the correct powers of *s*.
3. Trailing zeros are not significant, and are automatically removed.
4. At least one non-zero pole value must be supplied.

Raised Cosine Band Pass Filter



Netlist Syntax

An instance of a raised cosine band pass filter has the following Nexxim netlist syntax:

`A`*`xxx n1 n2`* `[`**`FL=`***`val`*`] [`**`FU=`***`val`*`] [`**`E=`***`val`*`] [`**`B=`***`val`*`] [`**`R1=`***`val`*`] [`**`R2=`***`val`*`]`
`[`**`IL=`***`val`*`]` **`COMPONENT=raised_cosine_band_pass_filter`**

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=raised_cosine_band_pass_filter** is required.

Table 41: Raised Cosine Band Pass Filter Instance Parameters

Parameter	Description	Units	Default
FL	Lower cutoff frequency	Hz	1e9
FU	Upper cutoff frequency	Hz	2e9
E	Exponential parameter	None	0.5
B	Rolloff factor	None	0.25
R1	Reference resistance for node 1	Ohm	50
R2	Reference resistance for node 2	Ohm	50
IL	Insertion loss	dB	0

Netlist Example

```
A22 1 2 FL=80e6 FU=100e6 E=0.5 B=0.25 R1=50 R2=50 IL=0
+ COMPONENT=raised_cosine_band_pass_filter
```

Notes

1. The raised cosine frequency characteristic is given by:

$$X_{rc}(f) = T \qquad \left(0 \le |f| \le \frac{1-\beta}{2T}\right)$$

$$X_{rc}(f) = \frac{T}{2}\left\{1 + \cos\left[\frac{\pi T}{\beta}\left(|f| - \frac{1-\beta}{2T}\right)\right]\right\} \qquad \left(\frac{1-\beta}{2T} \le |f| \le \frac{1+\beta}{2T}\right)$$

$$X_{rc}(f) = 0 \qquad \left(|f| > \frac{1+\beta}{2T}\right)$$

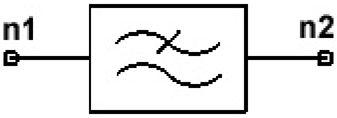
where T is the symbol interval and β (parameter **B**) is the rolloff factor, which takes values ranging from 0 to 1.

2. The bandwidth occupied by the signal beyond the Nyquist frequency 1/2T is called the excess bandwidth and is usually expressed as a percentage of the Nyquist frequency. For example, when B=0.5, the excess bandwidth is 50%, and when B=1.0, the excess bandwidth is 100%.
3. The exponential parameter E raises the transfer function to the power E: $H_{FRC}(j\omega)=(H_{RC}(j\omega))^{E}$. The default value E=0.5 is typically used in a cascade of identical transmit and receive filters.
4. At DC, the filter is implemented as a short circuit.

References

1. J. G. Proakis, *Digital Communications*, McGraw-Hill, 1989

Raised Cosine Low Pass Filter



Netlist Syntax

An instance of a raised cosine low pass filter has the following Nexxim netlist syntax:

A*xxx n1 n2* [**FC=***val*] [**E=***val*] [**B=***val*] [**R1=***val*] [**R2=***val*] [**IL=***val*]
COMPONENT=raised_cosine_low_pass_filter

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=raised_cosine_low_pass_filter** is required.

Table 42: Raised Cosine Low Pass Filter Instance Parameters

Parameter	Description	Units	Default
FC	Cutoff frequency	Hz	1e9
E	Exponential parameter	None	0.5
B	Rolloff factor	None	0.25
R1	Reference resistance for node 1	Ohm	50
R2	Reference resistance for node 2	Ohm	50
IL	Insertion loss	dB	0

Netlist Example

```
A22 1 2 FC=80e6 E=0.5 B=0.25 R1=50 R2=50 IL=0
+ COMPONENT=raised_cosine_low_pass_filter
```

Notes

1. The raised cosine frequency characteristic is given by:

$$X_{rc}(f) = T \qquad \left(0 \le |f| \le \frac{1-\beta}{2T}\right)$$

$$X_{rc}(f) = \frac{T}{2}\left\{1 + \cos\left[\frac{\pi T}{\beta}\left(|f| - \frac{1-\beta}{2T}\right)\right]\right\} \qquad \left(\frac{1-\beta}{2T} \le |f| \le \frac{1+\beta}{2T}\right)$$

$$X_{rc}(f) = 0 \qquad \left(|f| > \frac{1+\beta}{2T}\right)$$

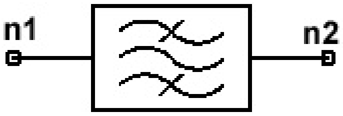
where T is the symbol interval and β (parameter **B**) is the rolloff factor, which takes values ranging from 0 to 1.

2. The bandwidth occupied by the signal beyond the Nyquist frequency 1/2T is called the excess bandwidth and is usually expressed as a percentage of the Nyquist frequency. For example, when B=0.5, the excess bandwidth is 50%, and when B=1.0, the excess bandwidth is 100%.
3. The exponential parameter E raises the transfer function to the power E: $H_{FRC}(j\omega)=(H_{RC}(j\omega))^{E}$. The default value E=0.5 is typically used in a cascade of identical transmit and receive filters.
4. At DC, the filter is implemented as a short circuit.

Reference

1. G. Proakis, *Digital Communications*, McGraw-Hill, 1989

Root Raised Cosine Band Pass Filter



Netlist Syntax

An instance of a root raised cosine band pass filter has the following Nexxim netlist syntax:

```
Axxx n1 n2 [FL=val] [FU=val] [E=val] [B=val] [R1=val] [R2=val]
[IL=val] COMPONENT=root_raised_cosine_band_pass_filter
```

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=root_raised_cosine_band_pass_filter** is required.

Table 43: Root Raised Cosine Band Pass Filter Instance Parameters

Parameter	Description	Units	Default
FL	Lower cutoff frequency	Hz	1e9
FU	Upper cutoff frequency	Hz	2e9
E	Exponential parameter	None	0.5
B	Rolloff factor	None	0.25

R1	Reference resistance for node 1	Ohm	50
R2	Reference resistance for node 2	Ohm	50
IL	Insertion loss	dB	0

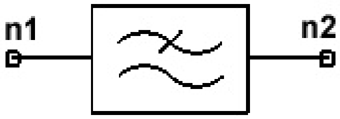
Netlist Example

```
A22 1 2 FL=80e6 FU=100e6 E=0.5 B=0.25 R1=50 R2=50 IL=0
+ COMPONENT=root_raised_cosine_band_pass_filter
```

Note

1. The impulse response of a root raised cosine filter convolved with itself is approximately equal to the impulse response of a raised cosine filter.

Root Raised Cosine Low Pass Filter



Netlist Syntax

An instance of a root raised cosine low pass filter has the following Nexxim netlist syntax:

```
Axxx n1 n2 [FC=val] [E=val] [B=val] [R1=val] [R2=val] [IL=val]
COMPONENT=root_raised_cosine_low_pass_filter
```

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=root_raised_cosine_low_pass_filter** is required.

Table 44: Root Raised Cosine Low Pass Filter Instance Parameters

Parameter	Description	Units	Default
FC	Cutoff frequency	Hz	1e9
E	Exponential parameter	None	0.5
B	Rolloff factor	None	0.25
R1	Reference resistance for node 1	Ohm	50
R2	Reference resistance for node 2	Ohm	50

IL	Insertion loss	dB	0

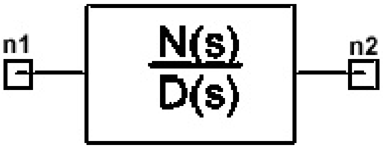
Netlist Example

```
A22 1 2 FC=80e6 E=0.5 B=0.25 R1=50 R2=50 IL=0
+ COMPONENT=root_raised_cosine_low_pass_filter
```

Note

1. The impulse response of a root raised cosine filter convolved with itself is approximately equal to the impulse response of a raised cosine filter.

Transfer Function, S-Domain, Polynomial



Netlist Syntax

An instance of a polynomial transfer function filter has the following Nexxim netlist syntax:

```
Axxx n1 n2 [GF=val] [R1=val] [X1=val] [R2=val] [X2=val]
NUMER=[a0 a1 ...] DENOM=[b0 b1 ...]
COMPONENT=tranfun_polynomial_filter
```

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=tranfun_polynomial_filter** is required.

Table 45: Polynomial Transfer Function Filter Instance Parameters

Parameter	Description	Units	Default
GF	Gain factor	None	1.0
R1	Resistive part of reference impedance at node 1	Ohm	50
X1	Reactive part of reference impedance at node 1	Ohm	0
R2	Resistive part of reference impedance at node 2	Ohm	50
X2	Reactive part of reference impedance at node 2	Ohm	0

a0 ... aN	Coefficients of the numerator polynomial	None	None
b0 ... bD	Coefficients of the denominator polynomial	None	None

Netlist Example

To specify the following transfer function (where coefficient a_1=0):

$$H(s) = \frac{1 + 2s^2}{1 + s + 3s^2}$$

The netlist specifies:

```
A22 1 2 NUMER=[1 0 2] DENOM=[1 1 3]
+ COMPONENT=tranfun_polynomial_filter
```

Notes

1. The element is specified using a transfer function given as the ratio of two polynomials in the complex variable *s*. The bold brackets for the **NUMER** and **DENOM** entries are required.

   The function of the device is expressed as:

GAIN × H(s)

   The transfer function H(s) is specified by giving the coefficients:

$$H(s) = \frac{a_0 + a_1 s + a_2 s^2 + \ldots}{b_0 + b_1 s + b_2 s^2 + \ldots}$$

$$S = j2\pi F$$

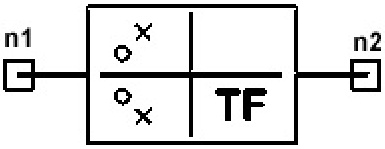
   where *F* = the analysis frequency and *j*=sqrt(-1)

2. The first coefficients in both numerator and denominator (a_0 and b_0) are constants, which must be specified even if they are zero. Thus, leading zeros are significant. In addition, intermediate zero-valued coefficients must be explicitly supplied in order to have the non-

zero coefficients applied to the correct powers of *s*.

3. Trailing zeros are not significant, and are automatically removed.
4. Both numerator and denominator must contain at least one non-zero value.

Transfer Function, S-Domain, Pole Zero



Netlist Syntax

An instance of a pole-zero transfer function filter has the following Nexxim netlist syntax:

```
Axxx n1 n2 [GF=val] [R1=val] [X1=val] [R2=val] [X2=val]
POLES=[rp1 ip1 ...] ZEROS=[rz1 iz1 ...]
COMPONENT=tranfun_polezero_filter
```

n1 and *n2* are the nodes connected to the filter. The entry **COMPONENT=tranfun_polezero_filter** is required.

Table 46: Pole-Zero Transfer Function Filter Instance Parameters

Parameter	Description	Units	Default
GF	Gain factor	None	1.0
R1	Resistive part of reference impedance at node 1	Ohm	50
X1	Reactive part of reference impedance at node 1	Ohm	0
R2	Resistive part of reference impedance at node 2	Ohm	50
X2	Reactive part of reference impedance at node 2	Ohm	0
rp1, ip1 ... rpN, ipN	Real and imaginary parts of the poles	None	None
rz1, iz1 ... rzN, izN	Real and imaginary parts of the zeros	None	None

Netlist Example

```
A22 1 2 POLES=[.1 -1.03 .2 .003] ZEROS=[.05 -1.7]
+ COMPONENT=tranfun_polezero_filter
```

Notes

1. The element is specified using a transfer function given as the ratio of two expressions in the complex variable *s*. The bold brackets for the **POLES** and **ZEROS** entries are required.

The function of the device is expressed as:

GAIN × H(s)

The transfer function H(s) is specified by giving the coefficients:

$$H(s) = \frac{(S-zero1)(S-zero2)\ldots}{(S-pole1)(S-pole2)\ldots}$$

$$S = j2\pi F$$

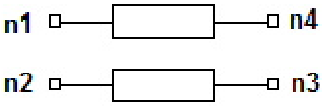
where *F* = the analysis frequency and *j*=sqrt(-1)

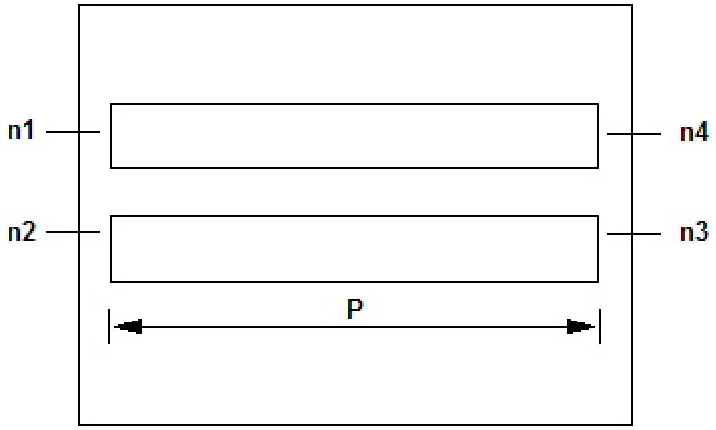
2. The first coefficients in both numerator and denominator (a_0 and b_0) are constants, which must be specified even if they are zero. Thus, leading zeros are significant. In addition, intermediate zero-valued coefficients must be explicitly supplied in order to have the non-zero coefficients applied to the correct powers of *s*.
3. Trailing zeros are not significant, and are automatically removed.
4. At least one non-zero pole value must be supplied.

14 - Nexxim Ideal Distributed

This topic describes the following ideal distributed elements:

Coupled Lines, Physical Length





Netlist Form

An ideal coupled line, physical length instance has the following netlist syntax:

```
Axxx n1 n4 n2 n3 [P=val] [ZE=val] [ZO=val]
[KE=val] [KO=val] [AE=val] [AO=val] [F=val]
COMPONENT=cpl
```

n1 and *n2* are the names of the input nodes. *n4* and *n3* are the corresponding output nodes. The entry **COMPONENT=cpl** identifies the element as an ideal coupled line, physical length.

Table 34: Ideal Coupled Line, Physical Length, Instance Parameters

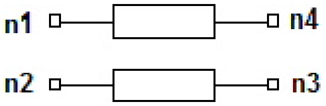
Parameter	Description	Units	Default
P	Physical length	Meter	1e-2
ZE	Even mode impedance	Ohm	50
ZO	Odd mode impedance (the second character is the letter **O**, not the numeral zero)	Ohm	50
KE	Even mode effective dielectric constant		1
KO	Odd mode effective dielectric constant (the second character is the letter **O**, not the numeral zero)		1
AE	Even mode attenuation	dB/m	0.0
AO	Odd mode attenuation (the second character is the letter **O**, not the numeral zero)	dB/m	0.0

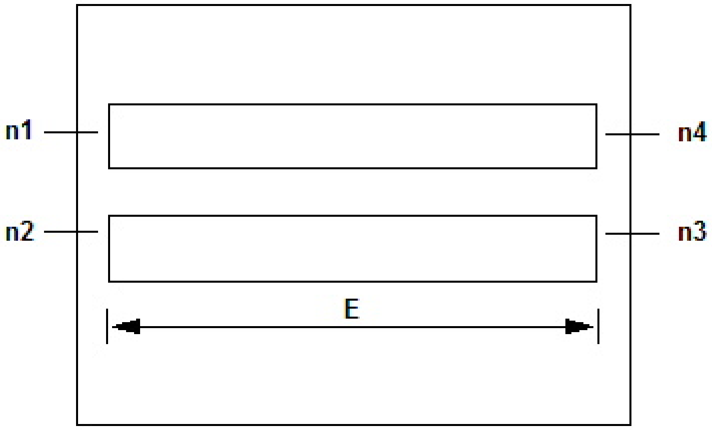
F	Reference frequency for AE and AO	Hertz	1e9

Netlist Example

```
A3 Port1 Port4 net_27 0 P=0.015
+ KE=1.12 KO=1.01 AE=0.1 F=1.25e9
+ COMPONENT=cpl
```

Coupled Lines, Electrical Length





Netlist Form

An ideal coupled line, electrical length instance has the following netlist syntax:

A*xxx n1 n4 n2 n3* [**E=***val*] [**ZE=***val*] [**ZO=***val*]
[**AE=***val*] [**AO=***val*] [**F=***val*] **COMPONENT=cple**

n1 and *n2* are the names of the input nodes. *n4* and *n3* are the corresponding output nodes. The entry **COMPONENT=cple** identifies the element as an ideal coupled line, electrical length.

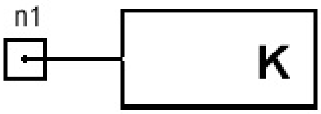
Table 35: Ideal Coupled Line, Electrical Length, Instance Parameters

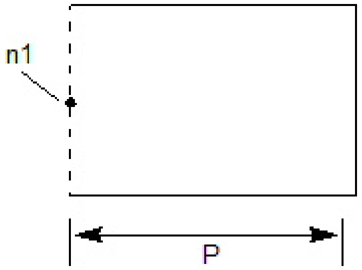
Parameter	Description	Units	Default
E	Electrical length	Degree	45
ZE	Even mode impedance	Ohm	50
ZO	Odd mode impedance (the second character is the letter **O**, not the numeral zero)	Ohm	50
AE	Even mode attenuation	dB/m	0.0
AO	Odd mode attenuation (the second character is the letter **O**, not the numeral zero)	dB/m	0.0
F	Reference frequency for AE and AO	Hertz	1e9

Netlist Example

```
A3 Port1 Port4 net_27 0 E=55
+ AE=0.1 F=1.25e9 COMPONENT=cple
```

Open Stub, Physical Length





Netlist Form

An instance of an ideal open stub with physical length has the following netlist syntax:

A*xxx n1* **P=***val* **Z=***val* **K=***val* **A=***val* **F=***val*
COMPONENT=ideal_open_stub_physical

n1 is the name of the node attached to the open stub. The entry **COMPONENT=ideal_open_stub_physical** identifies the element as an ideal open stub with physical length.

Table 36: Ideal Open Stub with Physical Length, Instance Parameters

Parameter	Description	Units	Default
P	Physical length	Meter	0.01
Z	Characteristic impedance	Ohm	50.0
K	Effective dielectric constant		1.0
F	Reference frequency	Hz	1.0e9
A	Attenuation constant at reference frequency	dB/m	0.0

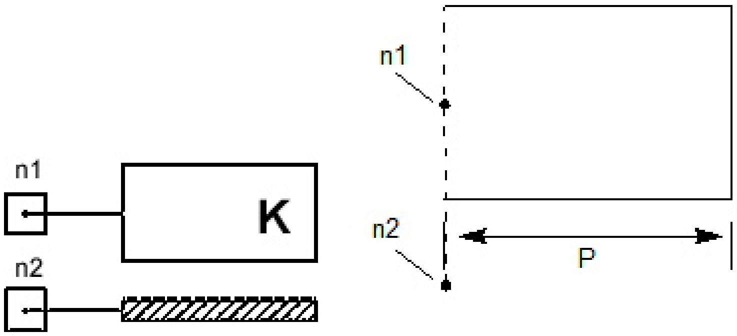
Netlist Example

```
A99 Port1 P=10e-3 COMPONENT=ideal_open_stub_physical
```

Notes

1. The physical model using physical length includes the open end length correction.
2. The open stub model is equivalent to a transmission line model followed by an open model. This is also true in the case of negative length specifications, which are used for deembedding purposes. Note that in the latter case, the open stub model is equivalent to the transmission line model with a negative length terminated by an open.

Open Stub, Physical Length with Reference



Netlist Form

An instance of an ideal open stub, physical length with reference node has the following netlist syntax:

```
Axxx n1 n2 P=val Z=val K=val A=val F=val
COMPONENT=ideal_open_stub_physical
```

n1 is the name of the node attached to the open stub. *n2* is the name of the reference node. The entry **COMPONENT=ideal_open_stub_physical** identifies the element as an ideal open stub, physical length (with or without a reference node).

Table 37: Ideal Open Stub, Physical Length with Reference, Instance Parameters

Parameter	Description	Units	Default
P	Physical length	Meter	0.01
Z	Characteristic impedance	Ohm	50.0
K	Effective dielectric constant		1.0
F	Reference frequency	Hz	1.0e9
A	Attenuation constant at reference frequency	dB/m	0.0

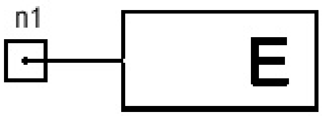
Netlist Example

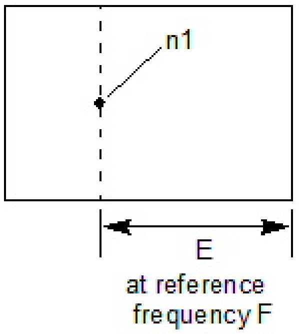
```
A44 Port1 Port3 P=10e-3 COMPONENT=ideal_open_stub_physical
```

Notes

1. The physical model using physical length includes the open end length correction.
2. The open stub model is equivalent to a transmission line model followed by an open model. This is also true in the case of negative length specifications, which are used for deembedding purposes. Note that in the latter case, the open stub model is equivalent to the transmission line model with a negative length terminated by an open.

Open Stub, Electrical Length





Netlist Format

An instance of an ideal open stub with electrical length has the following netlist syntax:

```
Axxx n1 Z=val E=val A=val F=val
COMPONENT=ideal_open_stub_electrical
```

n1 is the name of the node attached to the open stub. A reference node of ground (node 0) is automatically supplied, and is not shown in the netlist. The entry **COMPONENT=ideal_open_stub_electrical** identifies the element as an ideal open stub with electrical length.

Table 38: Ideal Open Stub with Electrical Length, Instance Parameters

Parameter	Description	Units	Default
Z	Characteristic impedance	Ohm	50.0
E	Electrical length at reference frequency	Degree	45
A	Attenuation constant at reference frequency	dB/m	0.0
F	Reference frequency for E	Hz	1e9

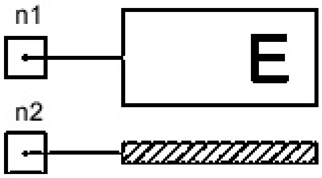
Netlist Example

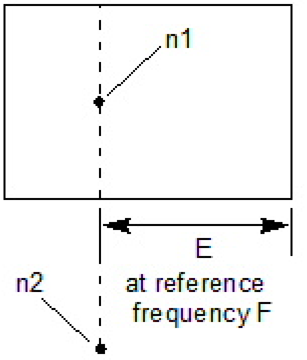
```
A44 Port1 E=45 F=1.0e9 COMPONENT=ideal_open_stub_electrical
```

Notes

1. The open stub, electrical length model is equivalent to a transmission line model followed by an open model. This is also true in the case of negative length specifications, which are used for deembedding purposes. Note that in the latter case, the open stub model is equivalent to the transmission line model with a negative length terminated by an open.

Open Stub, Electrical Length with Reference





Netlist Format

An instance of an ideal open stub, electrical length with reference has the following netlist syntax:

```
Axxx n1 n2 Z=val E=val A=val F=val
COMPONENT=ideal_open_stub_electrical
```

n1 is the name of the node attached to the open stub. *n2* is the name of the reference node. The entry **COMPONENT=ideal_open_stub_electrical** identifies the element as an ideal open stub, electrical length, with or without a reference node.

Table 39: Ideal Open Stub with Electrical Length, Instance Parameters

Parameter	Description	Units	Default
Z	Characteristic impedance	Ohm	50.0
E	Electrical length at reference frequency	Degree	45
A	Attenuation constant at reference frequency	dB/m	0.0
F	Reference frequency for E	Hz	1e9

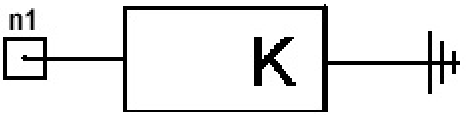
Netlist Example

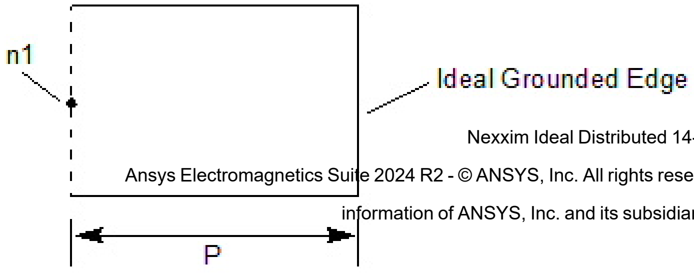
```
A44 Port1 Port2 E=45 F=1.0e9
COMPONENT=ideal_open_stub_electrical
```

Notes

1. The open stub, electrical length model is equivalent to a transmission line model followed by an open model. This is also true in the case of negative length specifications, which are used for deembedding purposes. Note that in the latter case, the open stub model is equivalent to the transmission line model with a negative length terminated by an open.

Shorted Stub, Physical Length





Netlist Form

An instance of an ideal shorted stub with physical length has the following netlist syntax:

A*xxx n1* **Z=***val* **K=***val* **P=***val* **A=***val* **F=***val*
COMPONENT=ideal_shorted_stub_physical

n1 is the name of the node attached to the shorted stub. The entry **COMPONENT=ideal_shorted_stub_physical** identifies the element as an ideal shorted stub, physical length.

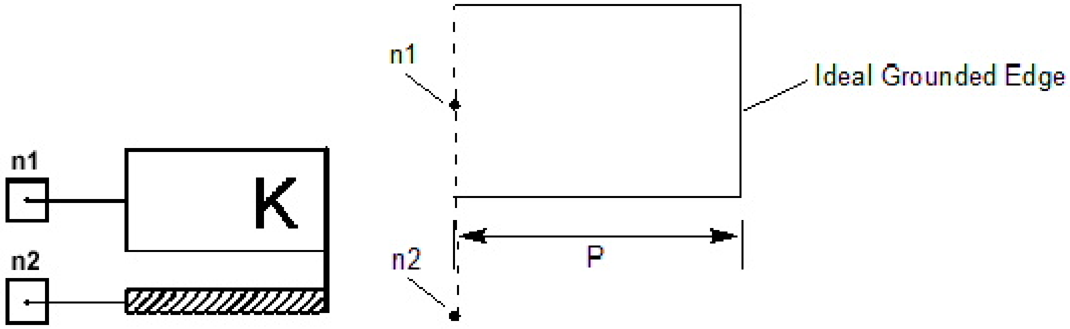
Table 40: Ideal Shorted Stub, Physical Length, Instance Parameters

Parameter	Description	Units	Default
P	Physical length	Meter	0.01
Z	Characteristic impedance	Ohm	50.0
K	Effective dielectric constant		1.0
F	Reference frequency	Hz	1.0e9
A	Attenuation constant at reference frequency	dB/m	0.0

Netlist Example

```
A44 Port1 P=10e-3 COMPONENT=ideal_shorted_stub_physical
```

Shorted Stub, Physical Length with Reference



Netlist Form

An instance of an ideal shorted stub, physical length with reference node has the following netlist syntax:

```
Axxx n1 n2 Z=val K=val P=val A=val F=val
COMPONENT=ideal_shorted_stub_physical
```

n1 is the name of the node attached to the shorted stub. *n2* is the reference node. The entry **COMPONENT=ideal_shorted_stub_physical** identifies the element as an ideal shorted stub, physical length with or without a reference node.

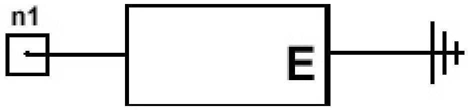
Table 41: Ideal Shorted Stub, Physical Length with Reference, Instance Parameters

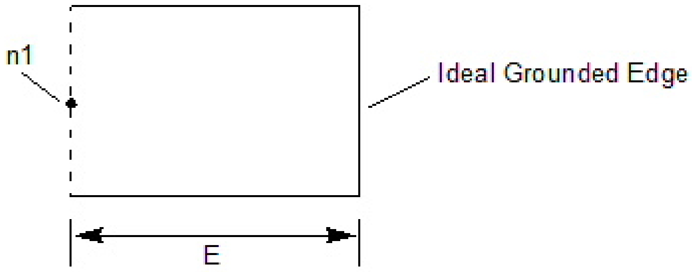
Parameter	Description	Units	Default
P	Physical length	Meter	0.01
Z	Characteristic impedance	Ohm	50.0
K	Effective dielectric constant		1.0
F	Reference frequency	Hz	1.0e9
A	Attenuation constant at reference frequency	dB/m	0.0

Netlist Example

```
A44 Port1 Port3 P=10e-3 COMPONENT=ideal_shorted_stub_physical
```

Shorted Stub, Electrical Length





Netlist Format

An instance of an ideal shorted stub with electrical length has the following netlist syntax:

A*xxx n1* **Z=***val* **E=***val* **A=***val* **F=***val*
COMPONENT=ideal_shorted_stub_electrical

n1 is the name of the node attached to the shorted stub. A reference node of ground (node 0) is automatically supplied, and is not shown in the netlist. The entry **COMPONENT=ideal_shorted_stub_electrical** identifies the element as an ideal shorted stub with electrical length.

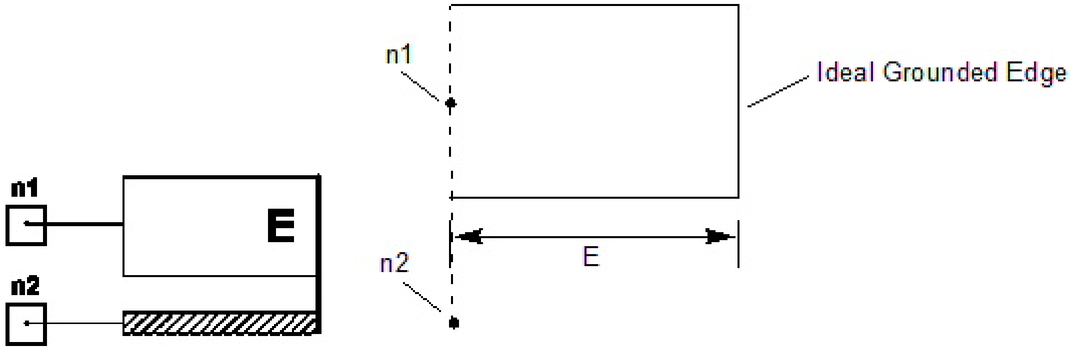
Table 42: Ideal Shorted Stub with Electrical Length, Instance Parameters

Parameter	Description	Units	Default
Z	Characteristic impedance	Ohm	50.0
E	Electrical length at reference frequency	Degree	45
A	Attenuation at reference frequency	dB/m	0.0
F	Reference frequency	Hz	1e9

Netlist Example

```
A44 Port1 E=45 F=1.0e9 COMPONENT=ideal_shorted_stub_electrical
```

Shorted Stub, Electrical Length with Reference



Netlist Format

An instance of an ideal shorted stub, electrical length with reference has the following netlist syntax:

A*xxx n1 n2* **Z=***val* **E=***val* **A=***val* **F=***val*
COMPONENT=ideal_shorted_stub_electrical

n1 is the name of the node attached to the shorted stub. *n2* is the reference node. The entry **COMPONENT=ideal_shorted_stub_electrical** identifies the element as an ideal shorted stub, electrical length with or without a reference node.

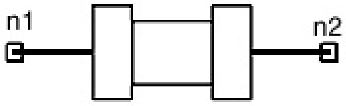
Table 43: Ideal Shorted Stub, Electrical Length with Reference, Instance Parameters

Parameter	Description	Units	Default
Z	Characteristic impedance	Ohm	50.0
E	Electrical length at reference frequency	Degree	45
A	Attenuation at reference frequency	dB/m	0.0
F	Reference frequency	Hz	1e9

Netlist Example

```
A44 Port1 Port 2 E=45 F=1.0e9
COMPONENT=ideal_shorted_stub_electrical
```

Thin-Film Resistor, Bulk Resistivity



Netlist Form

An instance of a thin-film resistor with bulk resistivity specified has the following Nexxim netlist syntax:

A*xxx n1 n2* **W=***val* **P=***val* **RB=***val* **T=***val* **COMPONENT=thinfilm_rb**

n1 and *n2* are the nodes connected to the resistor. The entry **COMPONENT=thinfilm_rb** identifies the element.

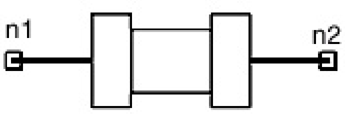
Table 44: Thin-Film Resistor, Bulk Resistivity Instance Parameters

Parameter	Description	Units	Default
W	Wire width	Meter	1e-3
P	Wire length	Meter	10e-3
RB	Bulk resistivity	µOhm-cm	1e-20
T	Thickness of thin-film resistor	Meter	1e-3

Netlist Example

```
Atfrb1 sigin sigout W=1mm P=15mm T=0.1mm COMPONENT=thinfilm_rb
```

Thin-Film Resistor, Surface Resistivity



Netlist Form

An instance of a thin-film resistor with surface resistivity specified has the following Nexxim netlist syntax:

`A`*`xxx n1 n2`* `W=`*`val`* `P=`*`val`* `RS=`*`val`* `COMPONENT=thinfilm_rs`

n1 and *n2* are the nodes connected to the resistor. The entry **COMPONENT=thinfilm_rs** identifies the element.

Table 45: Thin-Film Resistor, Surface Resistivity Instance Parameters

Parameter	Description	Units	Default
W	Wire width	Meter	1e-3
P	Wire length	Meter	10e-3
RS	Surface resistivity	µOhm-cm	0.0

Netlist Example

```
Atfrs1 sigin sigout W=1mm P=15mm COMPONENT=thinfilm_rs
```

Transmission Line, Electrical Length

Netlist Form

An instance of a transmission line with electrical length has the following Nexxim netlist syntax:

A*xxx n1 n2* **E=***val* **Z=***val* **F=***val* [**A=***val*]   **COMPONENT=trle**

n1 and *n2* are the nodes connected to the transmission line. The entry **COMPONENT=trle** identifies the element as a transmission line, electrical length.

Table 46: Transmission Line, Electrical Length Instance Parameters

Parameter	Description	Units	Default
E	Electrical length at reference frequency	Degree	45
Z	Reference characteristic impedance	Ohm	50
F	Reference frequency	Hz	1e9
A	Attenuation at reference frequency	dB/m	0.0

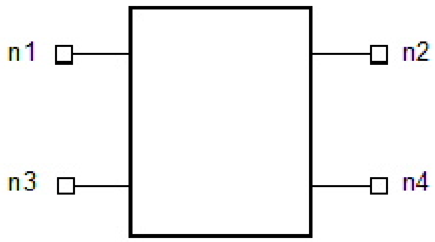
Netlist Example

```
Atrle1 trin trout E=55 Z=65 F=2e9 COMPONENT=trle
```

Notes

1. A lossless line is assumed unless parameter A is assigned a non-zero value. Attenuation is then scaled in inverse proportion to the square root of the frequency.

Transmission Line, Electrical Length with Reference



Netlist Form

An instance of a transmission line with electrical length and reference nodes has the following Nexxim netlist syntax:

```
Axxx n1 n2 n3 n4 E=val Z=val F=val [A=val]    COMPONENT=trle
```

n1 and *n2* are the nodes connected to the transmission line. *n3* and *n4* are the reference nodes. The entry **COMPONENT=trle** identifies the element as a transmission line, electrical length.

Table 47: Transmission Line, Electrical Length with Reference Instance Parameters

Parameter	Description	Units	Default
E	Electrical length at reference frequency	Degree	45
Z	Reference characteristic impedance	Ohm	50
F	Reference frequency	Hz	1e9
A	Attenuation at reference frequency	dB/m	0.0

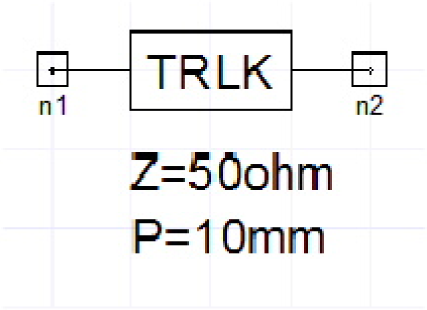
Netlist Example

```
Atrlk1 trin trout refin refout E=55 Z=65 F=2e9 COMPONENT=trle
```

Notes

1. A lossless line is assumed unless parameter A is assigned a non-zero value. Attenuation is then scaled in inverse proportion to the square root of the frequency.

Transmission Line, Physical Length



Netlist Form

An instance of a transmission line with physical length has the following Nexxim netlist syntax:

```
Axxx n1 n2 P=val Z=val F=val K=val [A=val]
[TAND=val] [MUR=val][SIGMA=val] [ENFORCE_CAUSALITY=val]
COMPONENT=trlk
```

n1 and *n2* are the nodes connected to the transmission line. The entry **COMPONENT=trlk** identifies the element as a transmission line, physical length.

Table 48: Transmission Line, Physical Length Instance Parameters

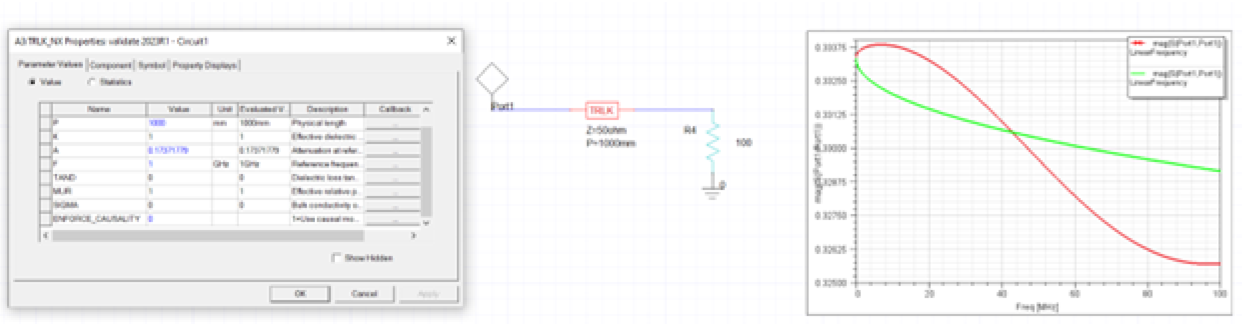
Parameter	Description	Units	Default
P	Physical length at reference frequency F	Meter	10e-3
Z	Reference characteristic impedance (Z>0)	Ohm	50
K	Dielectric constant (K>=1)		1.0
F	Reference frequency (F>=0)	Hz	1e9
A	Attenuation at reference frequency F (A>=0)	dB/Meter	0.0
TAND	Dielectric loss tangent (TanD>=0.0)	None	0.0
MUR	Effective relative permeability of the dielectric (Mur>=1.0)	None	1.0
SIGMA	Bulk conductivity of the dielectric (Sigma>=0.0)	Mho/meter	0.0
ENFORCE_ CAUSALITY	1=Use causal model, 0=Use noncausal model. -1 = Causal model for Transient, noncausal model for LNA	None	-1

Netlist Example

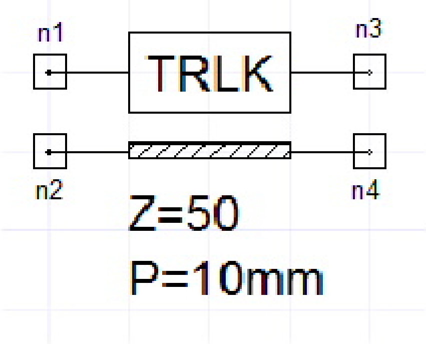
```
Atrlk2 trin trout P=2e-3 Z=65 K=1.1 F=2e9 COMPONENT=trlk
```

Notes

1. A lossless line is assumed unless parameter A is assigned a non-zero value. Attenuation is then scaled in inverse proportion to the square root of the frequency.
2. The causality is enforced by default for both time domain and frequency domain analysis in the TRLK component for which the simulation is going through W element model.
3. When users choose **ENFORCE_CAUSALITY** to be zero using the property window, the TRLK will use a non-causal model, which is more ideal, to do the time domain and frequency domain analysis. The following snapshot illustrates the difference of result with ENFORCE_CAUSALITY=1 (red) and with ENFORCE_CAUSALITY=0 (green) for a simple 1 port TRLK frequency domain analysis



Transmission Line, Physical Length with Reference



Netlist Form

An instance of a transmission line with physical length and reference nodes has the following Nexxim netlist syntax:

```
Axxx n1 n2 n3 n4 P=val Z=val K=val F=val [A=val]
[TAND=val] [MUR=val][SIGMA=val] [ENFORCE_CAUSALITY=val]
COMPONENT=trlk
```

n1 and *n3* are the nodes connected to the transmission line. *n2* and *n4* are the corresponding reference nodes. The entry **COMPONENT=trlk** identifies the element as a transmission line, physical length.

Table 49: Transmission Line, Physical Length with Reference Instance Parameters

Parameter	Description	Units	Default
P	Physical length at reference frequency F	Meter	10e-3
Z	Reference characteristic impedance (Z>0)	Ohm	50
K	Dielectric constant (K>=1)		1.0
F	Reference frequency (F>=0)	Hz	1e9
A	Attenuation at reference frequency F (A>=0)	dB/Meter	0.0
TAND	Dielectric loss tangent (TanD>=0.0)	None	0.0
MUR	Effective relative permeability of the dielectric (Mur>=1.0)	None	1.0
SIGMA	Bulk conductivity of the dielectric (Sigma>=0.0)	Mho/meter	0.0
ENFORCE_ CAUSALITY	1=Use causal model, 0=Use noncausal model. -1 = Causal model for Transient, noncausal model for LNA	None	-1

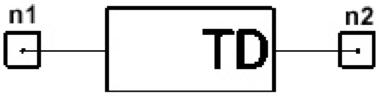
Netlist Example

```
Atrlk1 trin trout refin refout P=0.055 Z=65 F=2e9 A=0.2
COMPONENT=trlk
```

Notes

1. A lossless line is assumed unless parameter A is assigned a non-zero value. Attenuation is then scaled in inverse proportion to the square root of the frequency.

Transmission Line with Delay



Netlist Form

An instance of a transmission line with delay has the following Nexxim netlist syntax:

A*xxx n1 n2* **TD=***val* **Z0=***val* **COMPONENT=trl_td**

n1 and *n2* are the nodes connected to the transmission line. The entry **COMPONENT=trl_td** identifies the element as a transmission line with delay.

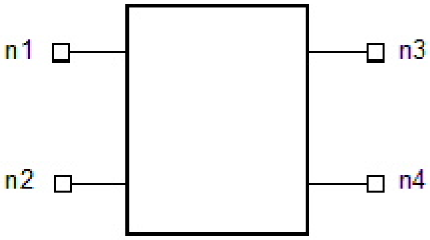
Table 50: Transmission Line with Delay Instance Parameters

Parameter	Description	Units	Default
Z	Reference characteristic impedance	Ohm	50
TD	Time delay	Second	0.0

Netlist Example

```
Atrltd1 trin trout TD=0.001 Z=65 COMPONENT=trl_td
```

Transmission Line, Delay with Reference



Netlist Form

An instance of a transmission line with electrical length and reference nodes has the following Nexxim netlist syntax:

A*xxx n1 n2 n3 n4* **TD=***val* **Z0=***val* **COMPONENT=trl_td**

n1 and *n3* are the nodes connected to the transmission line. *n2* and *n4* are the reference nodes. The entry **COMPONENT=trl_td** identifies the element as a transmission line with delay.

Table 51: Transmission Line, Delay with Reference Instance Parameters

Parameter	Description	Units	Default
TD	Time delay	Second	0.0
Z0	Reference characteristic impedance	Ohm	50

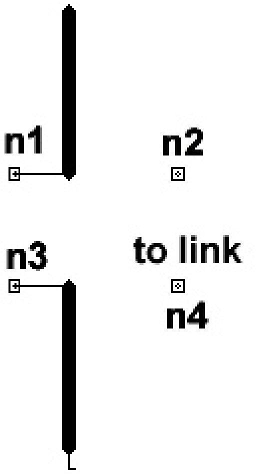
Netlist Example

```
Atrltd2 trin refin trout refout TD=0.001 Z0=65 COMPONENT=trl_td
```

15 - Nexxim Ideal Microwave

This topic describes the following ideal microwave elements:

Antenna, Dipole



Netlist Form

An instance of a dipole antenna has the following Nexxim netlist syntax:

A*xxx n1 n2 n3 n4* [**L=***val*] [**LD=***val*] [**R0=***val*] **COMPONENT=anted**

n1 and *n3* are the nodes connected to the antenna. *n2* and *n4* are the nodes to be connected to the LINK element for 2-port operation. The entry **COMPONENT=anted** identifies the element as an dipole antenna.

Table 19: Dipole Antenna Instance Parameters

Parameter	Description	Units	Default
L	Length of the antenna	Meter	5.0e-3
LD	Ratio of antenna length to diameter	None	3.0
R0	Reference characteristic impedance	Ohm	50

Netlist Example

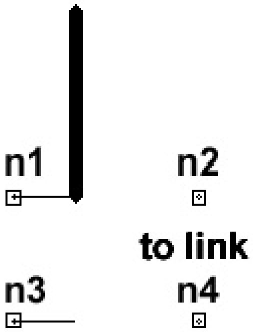
```
Aanted1 sigout1 sigout2 L=6e-3 COMPONENT=anted
```

Notes

1. For main beam calculations, the simulation frequency in MHz should be less than 900/L (meter) for the dipole antenna.
2. The calculated gain is the maximum antenna gain in the main beam direction.

3. When used as a 1-port or a 2-port, the input impedance is calculated across nodes 1 and 3. When used as a 2-port, the second port should be connected to a LINK element for proper analysis.
4. The **R0** parameter can be used to modify the antenna calculation of reference impedance for non-50-Ohm systems. **R0** is used to convert the antenna's S-parameters (computed for a 50-Ohm system) to the Y-parameters used by the linear analysis.

Antenna, Monopole



Netlist Form

An instance of a monopole antenna has the following Nexxim netlist syntax:

A*xxx n1 n2 n3 n4* [**L=***val*] [**LD=***val*] [**R0=***val*] **COMPONENT=antem**

n1 and *n3* are the nodes connected to the antenna. *n2* and *n4* are the nodes to be connected to the LINK element for 2-port operation. The entry **COMPONENT=antem** identifies the element as a monopole antenna.

Table 20: Monopole Antenna Instance Parameters

Parameter	Description	Units	Default
L	Length of the antenna	Meter	5.0e-3
LR	Ratio of antenna length to radius	None	3.0
R0	Reference characteristic impedance	Ohm	50

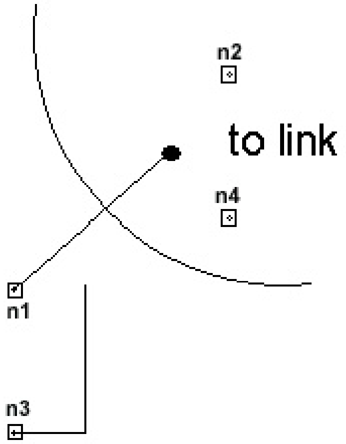
Netlist Example

```
Aanted1 sigout1 sigout2 L=4e-3 COMPONENT=antem
```

Notes

1. For main beam calculations, the simulation frequency in MHz should be less than 450/L (meter) for the dipole antenna.
2. The calculated gain is the maximum antenna gain in the main beam direction.
3. When used as a 1-port or a 2-port, the input impedance is calculated across nodes 1 and 3. When used as a 2-port, the second port should be connected to a LINK element for proper analysis.
4. The **R0** parameter can be used to modify the antenna calculation of reference impedance for non-50-Ohm systems. **R0** is used to convert the antenna’s S-parameters (computed for a 50-Ohm system) to the Y-parameters used by the linear analysis.

Antenna, Parabolic



Netlist Form

An instance of a parabolic antenna has the following Nexxim netlist syntax:

```
Axxx n1 n2 n3 n4 D=val [R0=val] COMPONENT=antep
```

n1 and *n3* are the nodes connected to the antenna. *n2* and *n4* are the nodes to be connected to the LINK element for 2-port operation. The entry **COMPONENT=antep** identifies the element as a parabolic antenna.

Table 21: Parabolic Antenna Instance Parameters

Parameter	Description	Units	Default
D	Diameter of the antenna	Meter	1.0
R0	Reference characteristic impedance	Ohm	50

Netlist Example

```
Aantep1 sigout1 sigout2 D1.15 COMPONENT=antep
```

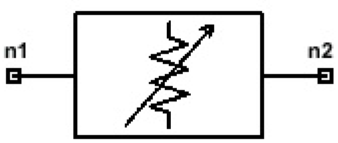
Notes

1. The gain of the parabolic antenna is calculated as $(\pi D/\lambda)^2$, where λ is the wavelength. This gain is the maximum antenna gain in the main beam direction.
2. When used as a 1-port or a 2-port, the input impedance is presented by **R0** across nodes 1 and 3. When used as a 2-port, the 2nd port should be connected to the LINK element for proper analysis (see **Note** 3).
3. The **R0** parameter can be used to modify the antenna calculation reference impedance for non 50-Ohm systems. **R0** is used to convert the antenna's S-parameters, which are computed for a 50-Ohm system, to the Y-parameters used by the linear analysis.

References

1. C. A. Balanis, *Antenna Theory: Analysis and Design, Harper & Row Publishers*, Section 7.3, 1982

Attenuator



Netlist Form

An instance of an attenuator has the following Nexxim netlist syntax:

A*xxx n1 n2* [**A=***val*] [**R0=***val*] **COMPONENT=attenuator**

n1 and *n2* are the nodes connected to the attenuator. The entry **COMPONENT=attenuator** identifies the element as an attenuator.

Table 22: Attenuator Instance Parameters

Parameter	Description	Units	Default
A	Attenuation	dB	3.0
R0	Reference characteristic impedance	Ohm	50

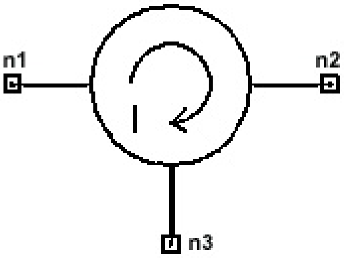
Netlist Example

```
Aattn1 attin attout A=2.75 COMPONENT=attenuator
```

Notes

1. 20 log |S21| = 20 log |S12| = -ATTENUATION
2. The phase of all four S-parameters is zero degrees.

Circulator



Netlist Form

An instance of a three-port circulator has the following Nexxim netlist syntax:

```
Axxx n1 n2 n3 [RL=val] [PRL=val] [IS=val] [PIS=val]
[IL=val] [PIL=val] [R=val] [X=val] COMPONENT=circulator
```

n1, *n2*, and *n3* are the nodes connected to the circulator. The entry **COMPONENT=circulator** identifies the element as a circulator.

Table 23: Circulator Instance Parameters

Parameter	Description	Units	Default
RL	Magnitude of the return loss for all ports	dB	370
PRL	Phase of the return loss for all ports	Degree	180
IS	Magnitude of the isolation for all reverse paths	dB	370
PIS	Phase of the isolation for all reverse paths	Degree	0
IL	Magnitude of the insertion loss for all forward paths	dB	0
PIL	Phase of the insertion loss for all forward paths	Degree	0
R (R0)	Resistive part of the reference characteristic impedance	Ohm	50
X	Inductive part of the reference characteristic impedance	Ohm	0

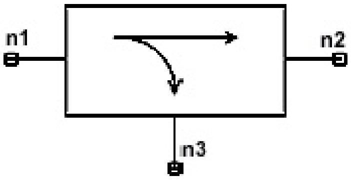
Netlist Example

```
Acirc1 11 21 13 COMPONENT=circulator
```

Notes

1. S21 = S32 = S13 =1.
2. All other S parameters are 0.

Directional Coupler, 3-Port



Netlist Form

An instance of a three-port directional coupler has the following Nexxim netlist syntax:

A*xxx n1 n2 n3* [**COUP=***val*] [**LOSS=***val*] [**DIRECTIVITY=***val*] [**VSWR1=***val*] [**VSWR2=***val*] [**VSWR3=***val*] [**ZREF=***val*] **COMPONENT=coupler3**

n1, *n2*, and *n3* are the nodes connected to the coupler. The entry **COMPONENT=coupler3** identifies the element as a 3-port directional coupler.

Table 24: Three-Port Directional Coupler Instance Parameters

Parameter	Description	Units	Default
COUP	Coupling factor	dB	20
LOSS	Main arm insertion loss	dB	3
DIRECTIVITY	Directivity (ratio of coupled power to isolated power)	dB	100
VSWR1	Voltage standing wave ratio at port 1	dB	1
VSWR2	Voltage standing wave ratio at port 2	dB	1
VSWR3	Voltage standing wave ratio at port 3	dB	1
ZREF (R0)	Reference Impedance	Ohm	50

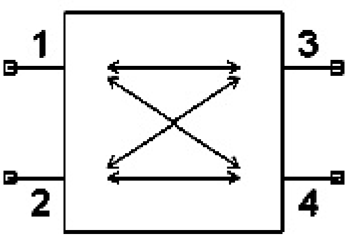
Netlist Example

```
Acoup3 11 21 13 COUPL=30 COMPONENT=coupler
```

Notes

1. 20 log |S21| = 20 log |S12| = -LOSS
2. 20 log |S23| = 20 log |S32| = DIRECTIVITY
3. 20 log |S31| = 20 log |S13| = -COUP
4. |S11| = (VSWR1 -1)/(VSWR1 + 1), where VSWR1 is the voltage standing wave ratio at port 1.
5. |S22| = (VSWR2 -1)/(VSWR2 + 1), where VSWR2 is the voltage standing wave ratio at port 2.
6. |S33| = (VSWR3 -1)/(VSWR3 + 1), where VSWR3 is the voltage standing wave ratio at port 2.
7. The phase of all S-parameters is zero degrees.

Directional Coupler, 4-Port



Netlist Form

An instance of a 4-port directional coupler has the following Nexxim netlist syntax:

A*xxx n1 n2 n3 n4* [**COUPLING=***val*] [**LOSS=***val*] [**DIRECTIVITY=***val*] [**VSWRM=***val*] [**VSWRC=***val*] [**ZREF=***val*] **COMPONENT=coupler4**

n1, *n2*, *n3* and *n4* are the nodes connected to the coupler. The entry **COMPONENT=coupler4** identifies the element as a 4-port directional coupler.

Table 25: Four-Port Directional Coupler Instance Parameters

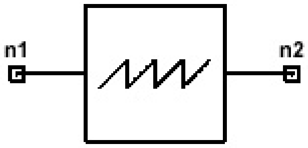
Parameter	Description	Units	Default
COUPLING	Coupling factor	dB	20
LOSS	Main arm insertion loss	dB	3

DIRECTIVITY	Directivity (ratio of coupled power to isolated power)	dB	100
VSWRM	Voltage standing wave ratio of the main arm	dB	1
VSWRC	Voltage standing wave ratio of the coupled arm	dB	1
ZREF (R0)	Reference Impedance	Ohm	50

Netlist Example

```
Acoup4 11 21 13 44 COUPLING=25 COMPONENT=coupler4
```

Free Space Path Loss



Netlist Form

An instance of a microwave link has the following Nexxim netlist syntax:

`A``xxx n1 n2` **`P=`**`val` **`R0=`**`val` **`COMPONENT=link`**

n1 and *n2* are the nodes connected to the link. The entry **COMPONENT=link** identifies the element as a free space path loss element.

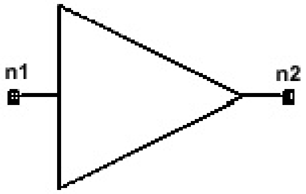
Table 26: Link Instance Parameters

Parameter	Description	Units	Default
P	Physical length of link	Meter	1000
RO	Termination resistance of the link	Ohm	50

Netlist Example

```
Aattn1 txout rxin P=2000 COMPONENT=link
```

Ideal Gain/Loss Model



Netlist Form

An instance of an ideal gain/loss model has the following Nexxim netlist syntax:

```
Axxx n1 n2 [GAIN=val] [LFC=val] [HFC=val] [HROF=val]
[ISWR=val] [OSWR=val] [INPUT_PHASE=val] [OUTPUT_PHASE=val]
[PG=val]
[BEL=val] [FMIN=val] [MGO=val] [PGO=val] [RN=val]
[RO=val] COMPONENT=gain_loss
```

n1 and *n2* are the nodes connected to the gain/loss model. The entry **COMPONENT=gain_loss** identifies the element as an ideal gain/loss model.

Table 27: Ideal Gain/Loss Model Instance Parameters

Parameter	Description	Units	Default
GAIN	Gain or loss (MS21)	dB	0
LFC	Low frequency cutoff	Hz	0
LROF	Low frequency roll-off slope	None	0
HFC	High frequency cutoff	Hz	0
HROF	High frequency roll-off factor	None	0
ISWR	Input standing wave ratio	None	1
OSWR	Output standing wave ratio	None	1
INPUT_PHASE	Input reflection phase	Degree	0
OUTPUT_PHASE	Output reflection phase	Degree	0
PG	Input-to-output phase delay	Degree	0
BEL	Band edge limit	dB	-3
FMIN	Minimum noise figure	dB	0
MGO	Magnitude of optimum noise figure reflection coefficient	None	0
PGO	Phase of optimum noise figure reflection coefficient	Degree	0

RN	Real equivalent normalized noise resistance	Ohm	0
RO (R0)	Reference impedance	Ohm	50

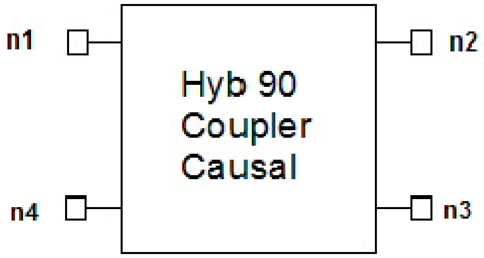
Netlist Example

```
Again2 11 21 GAIN=3 COMPONENT=gain_loss
```

Notes

1. This component may be used as an amplifier, a filter, or an attenuator.
2. The formulation is ideal with S12=0.
3. The GAIN element computes the noise properties when the noise parameters FMIN, MGO, PGO, and RN are specified.

Hybrid Coupler, 90-Degree, Causal Model



Netlist Form

The 90-degree hybrid coupler with causal model supports both time domain and frequency domain analyses, but see Note 1 for limitations. An instance of a 90-degree hybrid coupler with causal model has the following netlist syntax:

A*xxx n1 n2 n3 n4* **CP=***val* **F0=***val* [**RO=***val*] **COMPONENT=hyb90_causal**

n1, *n2*, *n3* and *n4* are the nodes connected to the coupler. The entry **COMPONENT=hyb90_causal** identifies the element as a 90-degree hybrid coupler, causal model.

Table 28: 90-Degree Hybrid Coupler, Causal Model Instance Parameters

Parameter	Description	Units	Default
CP	Coupling factor (must be a positive number)	dB	3.0104

F0 (FO)	Center frequency	Hertz	None
R0 (RO)	Reference impedance	Ohm	50

Netlist Example

```
A87 11 21 13 44 CP=2.7 F0=1e9 COMPONENT=hyb90
```

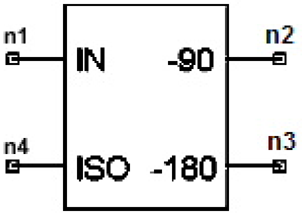
Notes

1. The causal model coupler supports both time domain and frequency domain analyses.
2. The following table details the operation of the 90 degree couplers. In this table,$\alpha=10^{-0.05CP}$ in dB, A and B are voltages presented at the pins.

Table 29: Hybrid 90-Degree Coupler Operation

Operation	**n1**	**n2**	**n3**	**n4**
Splitter with 90 ° phase shift (#1)	**A**	**0**	$A\sqrt{1-\alpha^2}\angle{-90}$	$\alpha A\angle{-180}$
Splitter with 90 ° phase shift (#2)	**0**	**A**	$\alpha A\angle{-180}$	$A\sqrt{1-\alpha^2}\angle{-90}$
Combiner	**A**	**B**	$A\sqrt{1-\alpha^2}\angle{-90}$ $+\alpha B\angle{-180}$	$\alpha A\angle(-180)$ $+B\sqrt{1-\alpha^2}\angle{-90}$

Hybrid Coupler, 90-Degree, Ideal



Netlist Form

The ideal coupler model supports frequency domain analysis only, not time domain. An instance of a 90-degree hybrid coupler has the following Nexxim netlist syntax:

```
Axxx n1 n2 n3 n4 [CP=val] [PH1=val] [PH2=val] [RO=val]
COMPONENT=hyb90
```

n1, *n2*, *n3* and *n4* are the nodes connected to the coupler. The entry **COMPONENT=hyb90** identifies the element as a 90-degree hybrid coupler.

Table 30: Ideal 90-Degree Hybrid Coupler Instance Parameters

Parameter	Description	Units	Default
CP	Coupling factor (must be a positive number)	dB	3.0104
PH1	Phase shift between port1 and port 2	Degree	-90
PH2	Phase shift between port 1 and port 3	Degree	-180
RO (RO)	Reference impedance	Ohm	50

Netlist Example

```
A87 11 21 13 44 CP=2.5 PH1=-75 PH2=-205 COMPONENT=hyb90
```

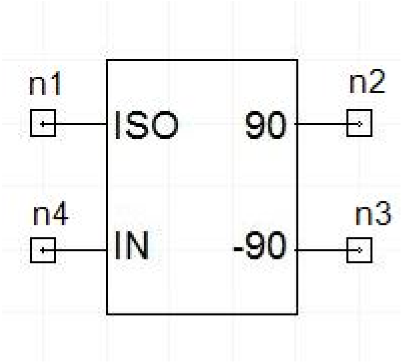
Notes

1. The ideal coupler models support frequency domain analyses only, not time domain.
2. The following table details the operation of the 90 degree couplers. In this table, $\alpha=10^{-0.05CP}$ in dB, A and B are voltages presented at the pins.

Table 31: Hybrid 90-Degree Coupler Operation

Operation	n1	n2	n3	n4
Splitter with 90 ° phase shift (#1)	**A**	**0**	$A\sqrt{1-\alpha^2}\angle -90$	$\alpha A\angle -180$
Splitter with 90 ° phase shift (#2)	**0**	**A**	$\alpha A\angle -180$	$A\sqrt{1-\alpha^2}\angle -90$
Combiner	**A**	**B**	$A\sqrt{1-\alpha^2}\angle -90$ $+\alpha B\angle -180$	$\alpha A\angle(-180)$ $+B\sqrt{1-\alpha^2}\angle -90$

Hybrid Coupler, 180-Degree, Causal Model



Netlist Form

The 180-degree hybrid coupler can function as an in-phase power splitter, as an out-of-phase power splitter, or as a power combiner. The causal model 180-degree hybrid coupler can be simulated in both frequency and time domains. See notes for limitations and operating information. The causal model coupler instance has the following netlist syntax:

`A`*`xxx n1 n2 n3 n4`* **`CP=`***`val`* **`F0=`***`val`* `[`**`RO=`***`val`*`]` **`COMPONENT=hyb180_causal`**

n1, *n2*, *n3* and *n4* are the nodes connected to the coupler. The entry **COMPONENT=hyb180_causal** is required.

Table 32: 180-Degree Hybrid Coupler Instance Parameters

Parameter	**Description**	**Units**	**Default**
CP	Coupling factor (must be a positive number)	dB	3.0104
F0 (FO)	Center frequency	Hertz	None
RO (R0)	Reference impedance	Ohm	50

Netlist Example

```
A87 11 21 13 44 F0=1e9 COMPONENT=hyb180_causal
```

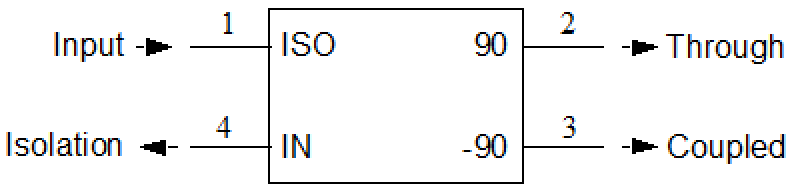
Notes

1. The causal model coupler supports both time domain and frequency domain analyses.
2. A positive value must be entered for the center frequency (F0 or FO) in order for the hybrid 180 splitter/combiner to operate. There is no default.

3. The operation of the causal model coupler is captured by the following 4-port S-matrix:

$$[S] = \frac{-j}{\sqrt{2}} \begin{bmatrix} 0 & 1 & 1 & 0 \\ 1 & 0 & 0 & -1 \\ 1 & 0 & 0 & 1 \\ 0 & -1 & 1 & 0 \end{bmatrix}$$

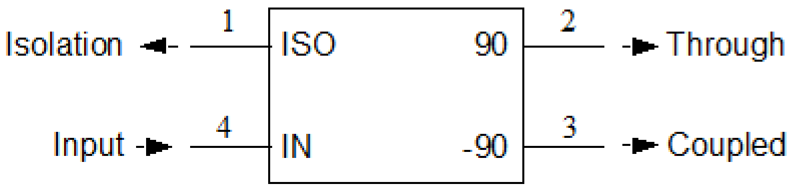
4. The columns of the S-matrix represent the various modes of operation. The in-phase power splitter mode of operation can be illustrated as follows:



In-Phase Power Splitter

The input at n1 is matched, the outputs at n2 and n3 are in phase with each other, and n4 is the isolation port. This represents column 1 of the S-matrix.

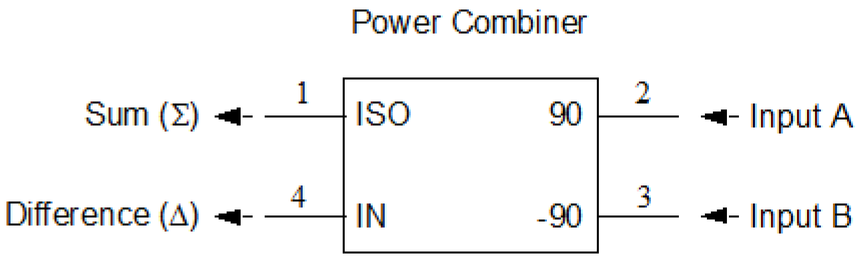
5. The out-of-phase power splitter mode of operation can be illustrated:



Out-of-Phase Power Splitter

The input at n4 is matched, the outputs at n2 and n3 are 180° out of phase, and n1 is the isolation port. This operation represents column 4 of the S-matrix.

6. The power combiner mode of operation can be illustrated:



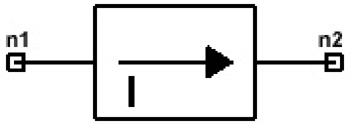
The inputs n2 and n3 are matched, n1 outputs the sum of the two input signals, n4 outputs the difference. This uses columns 2 and 3 of the S-matrix.

7. The following table summarizes the operation of the 180 degree couplers.

Hybrid 180-Degree Coupler Operation

Operation	n1	n2	n3	n4
In-phase Power Splitter	Input	Through Output (in phase with Coupled output)	Coupled Output	Isolation
Out-of-Phase Power Splitter	Isolation	Through Output (180° out of phase with Coupled output)	Coupled Output	Input
Power Combiner	Sum of A and B	Input A	Input B	Difference of A and B

Isolator



Netlist Form

An instance of an isolator has the following Nexxim netlist syntax:

```
Axxx n1 n2 [RL=val] [PRL=val] [IS=val] [PIS=val]
[IL=val] [PIL=val] [R=val] [X=val] COMPONENT=isolator
```

n1 and *n2* are the nodes connected to the isolator. The entry **COMPONENT=isolator** identifies the element as an isolator.

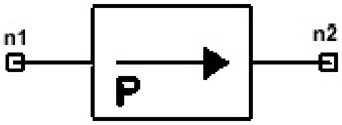
Table 34: Isolator Instance Parameters

Parameter	Description	Units	Default
RL	Magnitude of the return loss for all ports	dB	370
PRL	Phase of the return loss for all ports	Degree	180
IS	Magnitude of the isolation for all reverse paths	dB	370
PIS	Phase of the isolation for all reverse paths	Degree	0
IL	Magnitude of the insertion loss for all forward paths	dB	0
PIL	Phase of the insertion loss for all forward paths	Degree	0
R (R0)	Resistive part of the reference characteristic impedance	Ohm	50
X	Inductive part of the reference characteristic impedance	Ohm	0

Netlist Example

```
A87 11 21 COMPONENT=isolator
```

Isolator, Physical Model



Netlist Form

An instance of an isolator physical model has the following Nexxim netlist syntax:

A*xxx n1 n2* [**RL1=***val*] [**PRL1=***val*] [**IS1=***val*] [**PIS1=***val*] [**IL1=***val*] [**PIL1=***val*] [**RL2=***val*] [**PRL2=***val*] [**R=***val*] [**X=***val*] **COMPONENT=isolator_physical**

n1 and *n2* are the nodes connected to the isolator. The entry **COMPONENT=isolator_physical** identifies the element as an isolator, physical model.

Table 35: Isolator Physical Model Instance Parameters

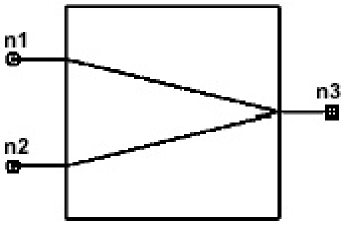
Parameter	Description	Units	Default
RL1	Magnitude of the return loss for port 1	dB	370
PRL1	Phase of the return loss for port 1	Degree	180

IS1	Magnitude of the isolation for reverse path 2-1	dB	370
PIS1	Phase of the isolation for reverse path 2-1	Degree	0
IL1	Magnitude of the insertion loss for forward path 1-2	dB	0
PIL1	Phase of the insertion loss for forward path 1-2	Degree	0
RL2	Magnitude of the return loss for port 2	dB	370
PRL2	Phase of the return loss for port 2	Degree	180
R (R0)	Resistive part of the reference characteristic impedance	Ohm	50
X	Inductive part of the reference characteristic impedance	Ohm	0

Netlist Example

```
A88 11 21 COMPONENT=isolator_physical
```

Power Combiner/Divider, 2-Way



Netlist Form

An instance of a 2-way power combiner/divider has the following Nexxim netlist syntax:

```
Axxx n1 n2 n3 [IL13=val] [PH13=val] [IL23=val] [PH23=val]
                       [RO=val] COMPONENT=power_combiner2
```

n1, *n2*, and *n3* are the nodes connected to the combiner/divider. The entry **COMPONENT=power_combiner2** identifies the element as a 2-way power combiner/divider .

Table 36: Two-Way Power Combiner/Divider Instance Parameters

Parameter	Description	Units	Default
IL13	Insertion loss between port 1 and port 3	dB	3.0104
PH13	Phase shift between port1 and port 3	Degree	-90

IL14	Insertion loss between port 2 and port 3	dB	3.0104
PH23	Phase shift between port 2 and port 3	Degree	-90
RO (R0)	Reference characteristic impedance	Ohm	50

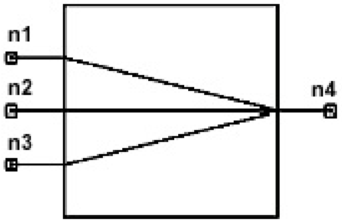
Netlist Example

```
A87 11 22 33 COMPONENT=power_combiner2
```

Notes

1. |S13| = |S23| = |S31| = |S32| = -3dB
2. S11 = S22 = S33 = S21 = S12 = 0
3. The phases of all S-parameters are zero degrees.
4. All the parameters are assumed to be constant.

Power Combiner/Divider, 3-Way



Netlist Form

An instance of a 3-way power combiner/divider has the following Nexxim netlist syntax:

A*xxx n1 n2 n3 n4* [**IL13=***val*] [**PH13=***val*] [**IL23=***val*] [**PH23=***val*] [**RO=***val*] **COMPONENT=power_combiner3**

n1, *n2*, *n3* and *n4* are the nodes connected to the combiner/divider. The entry **COMPONENT=power_combiner3** identifies the element as a 3-way power combiner/divider .

Table 37: Three-Way Power Combiner/Divider Instance Parameters

Parameter	Description	Units	Default
IL14	Insertion loss between port 1 and port 4	dB	4.7713
PH14	Phase shift between port1 and port 3	Degree	-90

IL24	Insertion loss between port 2 and port 4	dB	4.7713
PH24	Phase shift between port 2 and port 4	Degree	-90
IL34	Insertion loss between port 3 and port 4	dB	4.7713
PH34	Phase shift between port 3 and port 4	Degree	-90
RO (R0)	Reference characteristic impedance	Ohm	50

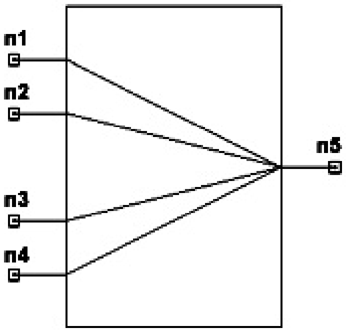
Netlist Example

```
A87 11 22 33 44 COMPONENT=power_combiner3
```

Notes

1. All the parameters are assumed to be constant.

Power Combiner/Divider, 4-Way



Netlist Form

An instance of a 4-way power combiner/divider has the following Nexxim netlist syntax:

```
Axxx n1 n2 n3 n4 n5 [IL=val] [RO=val]
COMPONENT=power_combiner_n
```

n1 through *n5* are the nodes connected to the combiner/divider. The entry **COMPONENT=power_combiner_n** is required.

Table 38: Four-Way Power Combiner/Divider Instance Parameters

Parameter	Description	Units	Default

IL	Insertion loss	dB	10
RO (R0)	Reference characteristic impedance	Ohm	50

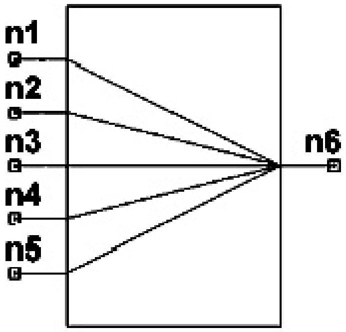
Netlist Example

`A87 11 22 33 44 55 COMPONENT=power_combiner_n`

Notes

1. All non-transmission S-parameters are zero.
2. The phases of all s-parameters are zero.
3. All the parameters are assumed to be constant.

Power Combiner/Divider, 5-Way



Netlist Form

An instance of a 5-way power combiner/divider has the following Nexxim netlist syntax:

A*xxx n1 n2 n3 n4 n5 n6* [**IL=***val*] [**RO=***val*]
COMPONENT=power_combiner_n

n1 through *n6* are the nodes connected to the combiner/divider. The entry **COMPONENT=power_combiner_n** is required.

Table 39: Five-Way Power Combiner/Divider Instance Parameters

Parameter	Description	Units	Default
IL	Insertion loss	dB	10
RO (R0)	Reference characteristic impedance	Ohm	50

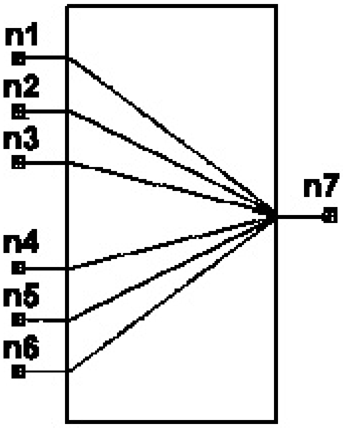
Netlist Example

```
A87 11 22 133 44 55 66 COMPONENT=power_combiner_n
```

Notes

1. All non-transmission S-parameters are zero.
2. The phases of all S-parameters are zero.
3. All the parameters are assumed to be constant.

Power Combiner/Divider, 6-Way



Netlist Form

An instance of a 3-way power combiner/divider has the following Nexxim netlist syntax:

A*xxx n1 n2 n3 n4 n5 n6 n7* [**IL=***val*] [**RO=***val*]
COMPONENT=power_combiner_n

n1 through *n7* are the nodes connected to the combiner/divider. The entry **COMPONENT=power_combiner_n** is required.

Table 40: Six-Way Power Combiner/Divider Instance Parameters

Parameter	Description	Units	Default
IL	Insertion loss	dB	10
RO (R0)	Reference characteristic impedance	Ohm	50

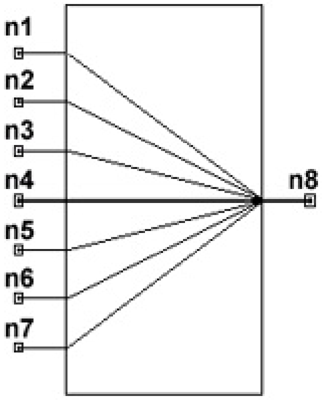
Netlist Example

```
A87 11 22 33 44 55 66 77 COMPONENT=power_combiner_n
```

Notes

1. All non-transmission S-parameters are zero.
2. The phases of all S-parameters are zero.
3. All the parameters are assumed to be constant.

Power Combiner/Divider, 7-Way



Netlist Form

An instance of a 7-way power combiner/divider has the following Nexxim netlist syntax:

A*xxx n1 n2 n3 n4 n5 n6 n7 n8* [**IL=***val*][**RO=***val*]
COMPONENT=power_combiner_n

n1 through *n8* are the nodes connected to the combiner/divider. The entry **COMPONENT=power_combiner_n** is required.

Table 41: Seven-Way Power Combiner/Divider Instance Parameters

Parameter	Description	Units	Default
IL	Insertion loss	dB	10
RO (R0)	Reference characteristic impedance	Ohm	50

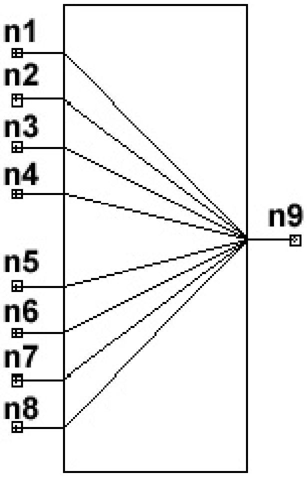
Netlist Example

```
A87 11 22 33 44 55 66 77 88 N=7 COMPONENT=power_combiner_n
```

Notes

1. All non-transmission S-parameters are zero.
2. The phases of all S-parameters are zero.
3. All the parameters are assumed to be constant.

Power Combiner/Divider, 8-Way



Netlist Form

An instance of an 8-way power combiner/divider has the following Nexxim netlist syntax:

A*xxx n1 n2 n3 n4 n5 n6 n7 n8 n9* [**IL=***val*] [**RO=***val*]
COMPONENT=power_combiner_n

n1 through *n9* are the nodes connected to the combiner/divider. The entry **COMPONENT=power_combiner_n** is required.

Table 42: Eight-Way Power Combiner/Divider Instance Parameters

Parameter	Description	Units	Default
IL	Insertion loss	dB	10

RO (R0)	Reference characteristic impedance	Ohm	50

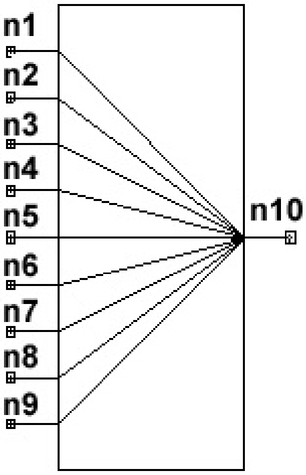
Netlist Example

```
A87 11 22 33 44 55 66 77 88 99 COMPONENT=power_combiner_n
```

Notes

1. All non-transmission S-parameters are zero.
2. The phases of all S-parameters are zero.
3. All the parameters are assumed to be constant.

Power Combiner/Divider, 9-Way



Netlist Form

An instance of a 9-way power combiner/divider has the following Nexxim netlist syntax:

A*xxx n1 n2 n3 n4 n5 n6 n7 n8 n9 n10* [**IL=***val*][**RO=***val*]
COMPONENT=power_combiner_n

n1 through *n10* are the nodes connected to the combiner/divider. The entry **COMPONENT=power_combiner_n** is required.

Table 43: Nine-Way Power Combiner/Divider Instance Parameters

Parameter	Description	Units	Default
IL	Insertion loss	dB	10
RO (R0)	Reference characteristic impedance	Ohm	50

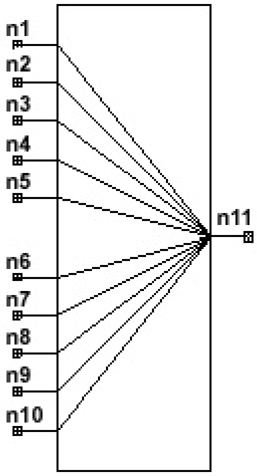
Netlist Example

```
A87 11 22 33 44 55 66 77 88 99 110 COMPONENT=power_combiner_n
```

Notes

1. All non-transmission S-parameters are zero.
2. The phases of all S-parameters are zero.
3. All the parameters are assumed to be constant.

Power Combiner/Divider, 10-Way



Netlist Form

An instance of a 10-way power combiner/divider has the following Nexxim netlist syntax:

A*xxx n1 n2 n3 n4 n5 n6 n7 n8 n9 n10 n11* [**IL=***val*] [**RO=***val*] **COMPONENT=power_combiner_n**

n1 through *n11* are the nodes connected to the combiner/divider. The entry **COMPONENT=power_combiner_n** is required.

Table 44: Ten-Way Power Combiner/Divider Instance Parameters

Parameter	Description	Units	Default
IL	Insertion loss	dB	10
RO (R0)	Reference characteristic impedance	Ohm	50

Netlist Example

```
A87 11 21 33 44 55 66 77 88 99 110 211
+ COMPONENT=power_combiner_n
```

Notes

1. All non-transmission S-parameters are zero.
2. The phases of all S-parameters are zero.
3. All the parameters are assumed to be constant.

16 - IBIS Buffer Elements

This topic describes IBIS buffer elements as used with Nexxim device models.

"Series Buffer" below

"Series Switch Buffer" on the next page

"IBIS Buffer Conventions " on page 16-5

TYP Parameter Values for All IBIS Buffers

Series Buffer

IBIS Series Buffer Symbol

Netlist Syntax

```
B_SERIESxxxnode1 node2
+ file='filename' model='model_name'
+ buffer=15|series

+ [typ=typ|min|max|fast|slow]
+ [interpol=1|2]
+ [nowarn]
+ [all_sm=0|1]
```

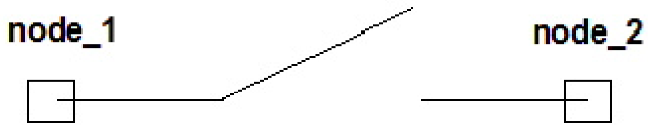
Node1 is the input, *node2* is the output.

Table 37: IBIS Series Buffer Instance Parameters

Parameter	Description	Units	Default
FILE	Name of IBIS file	None	None
MODEL	Name of model in IBIS file. The model type must match the	None	None

	instance type.		
BUFFER	Code or token for buffer type. Must be **15** or **series_buffer** for the Series Buffer type	None	None
TYP	Parameter range: **typ** =midrange of all values **min** =minimum of all values **max** =maximum of all values **fast** =maxima and minima selected to produce the fastest transitions. **slow** =maxima and minima selected to produce the slowest transitions. See "TYP Parameter Values for All IBIS Buffers" on page 16-4 for **fast** and **slow** settings.	None	**typ**
INTERPOL	Interpolation: 1=linear, 2=spline This parameter is ignored when ALL_SM=1.	None	1
NOWARN	When present, disable parser warnings.	None	Warnings enabled
ALL_SM	Series MOSFET: 0=use first table only, 1=use all tables. If ALL_SM=1 and more than one table exists, parameter INTERPOL is ignored and Nexxim uses a fixed method for processing the multi-table data	None	0

Series Switch Buffer



IBIS Series Switch Buffer Symbol

Netlist Syntax

```
B_SERIES_SWxxxnode1 node2
+ file='filename' model='model_name'
+ buffer=16|series_switch
+ [typ=typ|min|max|fast|slow]
+ [ss_state=on|off]
+ [interpol=1|2]
+ [nowarn]
+ [all_sm=0|1]
```

Node1 is the input, *node2* is the output.

Table 38: IBIS Series Switch Instance Parameters

Parameter	Description	Units	Default
FILE	Name of IBIS file	None	None
MODEL	Name of model in IBIS file. The model type must match the instance type.	None	None
BUFFER	Code or token for buffer type. Must be **16** or **series_switch** for the Series Switch type	None	None
TYP	Parameter range: **typ** =midrange of all values **min** =minimum of all values **max** =maximum of all values **fast** =maxima and minima selected to produce the fastest transitions. **slow** =maxima and minima selected to produce the slowest transitions. See "TYP Parameter Values for All IBIS Buffers" on the next page for **fast** and **slow** settings.	None	**typ**
SS_STATE	Switch setting, **on** or **off**.	None	**on**
INTERPOL	Interpolation: 1=linear, 2=spline This parameter is ignored when ALL_SM=1.	None	1
NOWARN	When present, disable parser warnings.	None	Warnings enabled

ALL_SM	Series MOSFET: 0=use first table only, 1=use all tables. If ALL_SM=1 and more than one table exists, parameter INTERPOL is ignored and Nexxim uses a fixed method for processing the multi-table data	None	0

v

TYP Parameter Values for All IBIS Buffers

The following table lists the effects on IBIS buffer parameters when the **TYP** parameter is set to **Fast** or **Slow**. In general, the **Fast** setting sets maxima and minima to provide the fastest transitions, while the **Slow** setting seeks to provide the slowest transitions.

Table 40: Effects of TYP=Fast or TYP=Slow

IBIS Buffer Parameter	**TYP Setting**	
	Fast	**Slow**
C_comp	Min	Max
Cac	Min	Max
GND Clamp Reference	Min	Max
Pulldown Reference	Min	Max
R Series	Min	Max
L Series	Min	Max
Rl Series	Min	Max
C Series	Min	Max
Lc Series	Min	Max
Rc Series	Min	Max
Temperature Range	Max	Min
Voltage Range	Max	Min
Pullup Reference	Max	Min
POWER Clamp Reference	Max	Min
Rgnd	Max	Min
Rpower	Max	Min
Pulldown	Max	Min

IBIS Buffer Parameter	**TYP Setting**	
	Fast	**Slow**
Pullup	Max	Min
GND Clamp	Max	Min
POWER Clamp	Max	Min
Ramp	Max	Min
Rising Waveform	Max	Min
Falling Waveform	Max	Min
Series Current	Max	Min
Series MOSFET	Max	Min
V_fixture	Max	Min

IBIS Buffer Conventions

This topic provides details on the conventions that should be followed to produce a correct simulation with the IBIS buffer elements.

Power Parameter

All active IBIS components contains some combination of pullup, pulldown, power clamp, and ground clamp nodes. These components also have a configuration parameter **power**. By default, **power** is set to “**on**,” so the component automatically drives the nodes using internal voltage sources set to the voltages specified in the IBIS model. When **power** is set to “**on**,” the user should **NOT** connect any of these nodes to voltage sources or to ground. Connecting external voltage sources or grounds when **power** is set to “**on** ” generates warning messages about parallel supplies, and may cause problems with simulation.

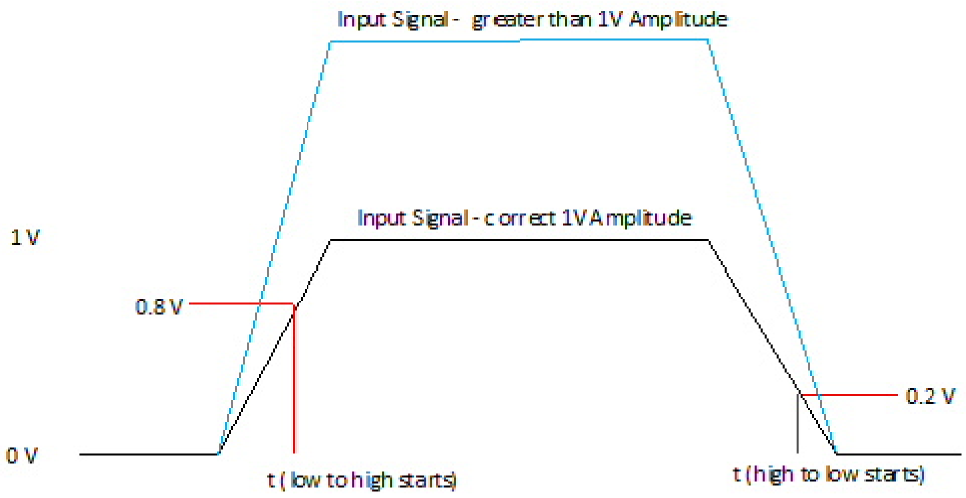
To use external sources and grounds, set the **power** parameter to “**off**.” With this setting, Nexxim expects all pullup, pulldown, power clamp, and ground clamp nodes to have the correct external voltages connected.

Digital Nodes

All digital nodes on IBIS components expect a voltage range of 0V to 1V.

Input Nodes

Digital input nodes for drivers (output, I/O, etc.) use fixed thresholds of 0.2V and 0.8V to trigger changes in state from high to low and low to high, respectively. (See the following figure.



Any voltage supply may be connected to these nodes, but the expected values are 0V for low or off and 1V for high or on. Because the transition trigger thresholds are fixed, duty cycle distortion (DCD) occurs if a high amplitude other than 1Vis used (blue trace in diagram). The amount of DCD is negligible if the transitions themselves are very fast relative to the overall pulse width. Using a high amplitude of less than 0.8V results in no output transitions occurring.

For initial transient values, and for DC analysis, a single fixed input threshold of 0.5V is used. If the input signal is above 0.5V, the output is placed in the high state. Otherwise, the output is placed in the low state.

These descriptions of the relationships between input voltage and output state for the Input buffer nodes assume that **Polarity** parameter in the IBIS model is set to “Non-Inverting”. The relationships are appropriately inverted if the IBIS buffer model has **Polarity** defined as “Inverting.”

Output Nodes

The digital output nodes of receivers provide a waveform that switches between 0V and 1V. These transitions depend on the input signal and on the values of **Vinl**, **Vinh**, and **Polarity** set in the IBIS model.

If the output is in the low state (0V) and the input signal becomes greater than **Vinh**, the output transitions to high (1V). If the output state is high (1V) and the input signal becomes less than **Vinl**, the output transitions to low (0V).

For initial transient values, and for DC analysis, the buffers use a single fixed threshold equal to the average of **Vinl** and **Vinh** [(**Vinh** + **Vinl**)/2]. If the input signal is above this threshold, the output is placed in the high state (1V). Otherwise, the output is placed in the low state (0V).

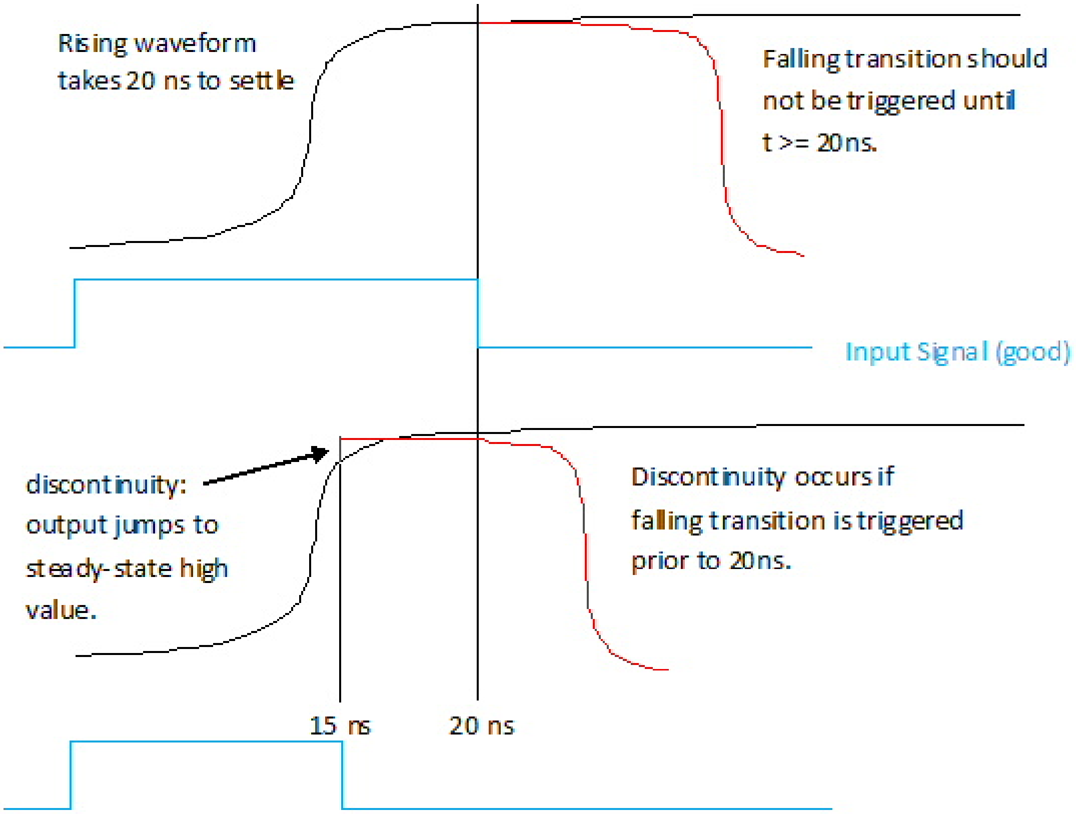
These descriptions of the relationships between input voltage and output state for the Output buffer nodes assume that **Polarity** parameter in the IBIS model is set to “Non-Inverting”. The relationships are appropriately inverted if the IBIS buffer model has **Polarity** defined as “Inverting.”

Enable Nodes

A single fixed threshold of 0.5V is used for Enable nodes. If the Enable pin is higher than 0.5V, the enable state is considered high. Other wise, the enable state is considered low. The behavior of the component then depends on whether the IBIS buffer model has its **Enable** parameter set to “Active-High” or “Active-Low.”

Avoid Overclocking Drivers

Be careful to ensure that the frequency of the input signal does not exceed the capabilities of the IBIS model. The frequency of the input signal must consider the time required for the output to settle. Whenever a transition from high to low or from low to high is triggered by the input signal, the output jumps immediately to the steady-state voltage value from which the next transition starts. However, the actual waveform requires a settling time period to reach the steady-state high or low voltage. If the input then changes state too soon, the next transition occurs before the initial transition has settled to its steady-state value. This can lead to discontinuities and other unexpected simulation results.



For example, if the IBIS model takes 20ns to complete a rising transition, the input signal should stay in the high state (1V) for at least 20ns after a low-to-high-transition. If instead the input goes back to low after only 15ns, the behavior at the high-to-low transition creates a discontinuity in the output signal. Since the initial rising transition has not completed at 15ns, the output has not settled at the steady state from which the falling transition is to occur. The too-early falling transition causes the output to jump discontinuously to the high value.

Buffer Import vs. Pin Import (pkg_selector)

IBIS devices are created using either “Buffer Import” or “Pin Import.” A buffer import captures the behavior of a given model in an IBIS file. A Pin Import captures the behavior of a given pin on a component defined in the IBIS file. A device created via Pin Import contains the behavior of the model associated with the pin, and it also contains information about the parasitic package model specified for that pin. A device created with a Pin Import has functionality similar to one created via Buffer Import, but with an additional parameter **pkg_selector**.

The **pkg_selector** parameter is used to select the appropriate packaging model. When **pkg_selector** is set to “Package,” the default package model for that component is used. When **pkg_selector** is set to “Pin,” the pin-specific package model is used if it exists, otherwise the default package model for that component is used. . When **pkg_selector** is set to “None,” no package model is used, and the device behavior is identical to one created with a Buffer Import of the same model.

17 - Independent Sources

AMI Transmitter

This topic includes descriptions of the following AMI Analysis transmitter:

AMI Transmitter

Current Sources

This topic includes descriptions of the following independent current sources:

Current Source, DC

Current Source, Pulse

Current Source, Piecewise Linear

Current Source, Sinusoidal

Current Source, AM (Netlist Only)

Current Source, Exponential (Netlist Only)

Current Source, Piecewise Linear, MSINC and ASPEC Compatible (Netlist Only)

Current Source, Single Frequency FM (Netlist Only)

Current Source, Frequency Dependent

Eye Sources

This topic includes descriptions of the following Eye Analysis sources:

Eye Source

Eye External Step Response Source

Noise Sources

This topic includes descriptions of the following independent noise sources:

Noise Source, Current, 2-Branch

Noise Source, Current, N-Branch (Netlist Only)

Shot Noise Source, Current

Shot Noise Source, Voltage

White Noise Source, Current

White Noise Source, Voltage

Voltage Sources

This topic includes descriptions of the following independent voltage sources:

Voltage Source, Clock with Jitter

Voltage Source, CPM Modulated

Voltage Source, DC

Voltage Source, IQ Modulated

Voltage Source, Linear Feedback Shift Register

Voltage Source, PSK Modulated

Voltage Source, Pulse

Voltage Source, Piecewise Linear

Voltage Source, QAM Modulated

Voltage Source, Random Bit Generator

Voltage Source, Digital Random Bit Generator

Voltage Source, Digital Random Bit Generator with Jitter

Voltage Source, Gaussian Pulse TDR

Voltage Source, Gaussian Random Bit Generator with Jitter

Voltage Source, Sinusoidal

Voltage Source, Spread Spectrum Clock

Voltage Source, AM (Netlist Only)

Voltage Source, Exponential (Netlist Only)

Voltage Source, Piecewise Linear, MSINC and ASPEC Compatible (Netlist Only)

Voltage Source, Single Frequency FM (Netlist Only)

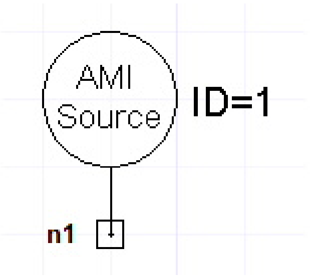
Voltage Source, Frequency Dependent

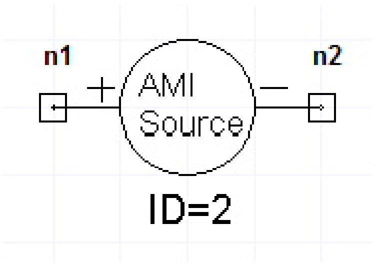
Port Power Sources

Port Power Source, Sinusoidal (Netlist Only)

- In a schematic design, a power source is a special kind of interface port. See *Port Power Source* in the main help topics for details.

AMI Source (Transmitter)





> **Note:** The AMI source can be used to simulate an AMI transmitter, when only an IBIS AMI Receiver model has been imported. See *IBIS and IBIS AMI Library Support* in the Circuit Design help topics..

AMI Source Netlist Format

The AMI Source implements the user’s AMI transmitter model in an Algorithmic Modeling Interface simulation. Single-ended and differential versions are available.

The netlist syntax for the AMI Source is:

```
AAMISOURCExxxx n1 [n2] COMPONENT=AMI_SOURCE

 + LIBRARY='file-reference'

 + PARAMETERS_FILE='file-reference'

+ PROBE_NAME='name'

+ BITLIST=#bitlist

+ BITFILE='file-reference'

 + RANDOM_BIT_COUNT=val RANDOM_SEED=val
```

```
+ REPEAT_COUNT=val HOLD_LAST_BIT=val

+ VLOW=val VHIGH=val TRISE=val TFALL=val

+ PHASE_DELAY=val

+ UI=val BPS=val

+ STEP_RESP_NUM_UI=val

+ DCD=val DCD_TIME=val TXRJ=val TXPJ=val TXUJ=val

+ PRBS_NO=val

+ PRBS_SEED=val

+ PRBS_INVERT=val

+ PRBS_BITLENGTH=val

+ DO_ENCODING=val

+ DELAY=val
```

n1 is the node connected to the single-ended source. *n1* and *n2* are the positive and negative nodes connected to the differential source. The differential AMI source must be connected between two signal lines. Neither node should be directly grounded. See **Notes** for details. The entry **COMPONENT=AMI_SOURCE** is required.

Table 1: AMI Source Parameters

Parameter	Description	Unit	Default
LIBRARY	AMI shared library file	None	None
PARAMETERS_FILE	AMI parameters file	None	None
PROBE_NAME	Name of the AMI probe that is the primary receiver on the channel with this source (other AMI Sources and Probes are treated as crosstalk.)	None	None
BITLIST	Sequence of ones and zeros	None	None
BITFILE	File containing bit list	None	None
RANDOM_BIT_	Number of random bits to generate	None	0

Parameter	**Description**	**Unit**	**Default**
COUNT			
RANDOM_SEED	Seed for RANDOM_BIT_COUNT	None	None
REPEAT_ COUNT	Number of times to repeat the random bit count. Total bits in sequence= (REPEAT_COUNT+1) times the number of bits in the chosen bit pattern. REPEAT_COUNT must be a non-negative integer. See Note 6 in this topic.	None	0
HOLD_LAST_ BIT	Controls behavior when end of bit sequence occurs before simulation ends. 1=Run sequence, then hold last bit of sequence until end of simulation. 0=Continue to repeat sequence until end of simulation. See Note 6 in this topic.	None	0
VLOW	Logic low voltage level	Volt	0
VHIGH	Logic high voltage level	Volt	1
TRISE	Low-to-high rise time	Second	1e-10
TFALL	High-to-low fall time	Second	TRISE
BPS	Specify number of bits per second instead of duration of unit interval. See Note 1 in this topic.	1/Second	1e9
UI	Specify duration of the unit interval instead of the BPS. If both UI and BPS properties are present in the netlist, the UI value is used. See Note 1 in this topic.	Second	1e-9
DCD	Duty cycle distortion as a fraction of UI, 0.0 <= DCD <= 1.0). If both **DCD** and **DCD_TIME** are present in the netlist, **DCD** (fraction of UI) is used and **DCD_ TIME** is ignored.	None	0
DCD_TIME	Duty cycle distortion as an absolute time. If both **DCD** and **DCD_TIME** are present in the netlist, **DCD** (fraction of UI) is used and **DCD_TIME** is	Second	0

Parameter	Description	Unit	Default
	ignored.		
TXRJ	Transmit Gaussian random jitter (standard deviation)	Second	0
TXPJ	Transmit periodic random jitter (amplitude)	Second	0
TXUJ	Transmit uniform random jitter (amplitude)	Second	0
PHASE_DELAY	Phase delay of the source	Second	0.0
STEP_RESP_ NUM_UI	Number of unit intervals to run step response from	None	
PRBS_NO	Size of pseudorandom bit pattern. May be any integer from 2 to 31. Nexxim randomly runs through all combinations of that many bits.	None	
PRBS_SEED	Random seed for pseudorandom bit pattern	None	0
PRBS_INVERT	1=invert pseudorandom bit output, 0=no inversion	None	0
PRBS_ BITLENGTH	Total number of PRBS bits to generate	None	2^PRBS_ NO
DO_ENCODING	0=no encoding 1=perform 8b10b encoding 2=perform 64b66b encoding 3=perform 128b130b encoding 4=perform128b132b encoding	None	0
DELAY	Delay offset for transition	Second	0

AMI Source Netlist Example

```
AAMISOURCE3 Port1 Port2 COMPONENT=AMI_SOURCE
+ LIBRARY='AMI_library_1'
+ PARAMETERS_FILE='Project1_parameters'
+ BITLIST=#101010101010000011111010101010100000001111
+ REPEAT_COUNT=1000
```

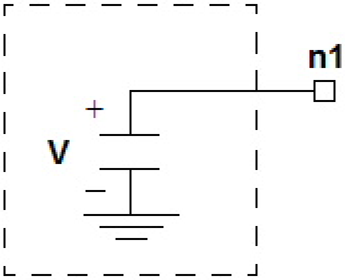
To run examples of AMI analysis, see *AMI Analysis Example* in the Nexxim Design Examples topic.

Notes

1. The Unit Interval and the bit rate are inversely related. The **BPS** and **UI** parameters are mutually exclusive. If the netlist contains both properties, the **UI** value is used.

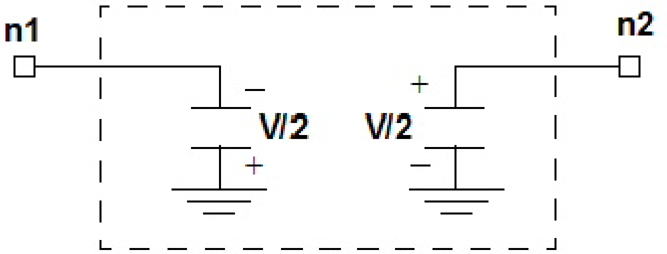
   When an AMI Source is instantiated in a schematic, the Properties window uses two artificial properties to ensure that only one of the two parameters is netlisted:

   - **UIorBPS**: Select between **UnitInterval** and **BitsPerSecond**. For **UnitInterval**, only the UI property is netlisted. For **BitsPerSecond**, only the BPS property is netlisted.
   - **UIorBPSValue**: UI time in seconds, or BPS number of bits per second.
2. The Single-Ended AMI source has the generalized internal structure shown in the following figure.



   The internal voltage source amplitude is set by VHIGH and VLOW. The source is grounded internally.

3. The Differential AMI source has the generalized internal structure in the following figure:

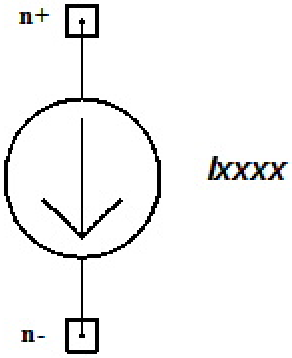


   Each of the two nodes is driven with half the voltage amplitude of the single-ended source and opposite polarity. The output is symmetrical in that the average of the two outputs is close to zero. The series resistance is also divided equally between the two nodes. Both sources are internally grounded.

4. The Single-Ended AMI source connects to a signal line. The line should not be directly grounded. The corresponding AMI probe should connect to the same signal line without any direct ground connection.

5. The Differential AMI source connects to two signal lines. Neither node should be grounded. The corresponding Differential AMI probe should connect to the same two signal lines without direct grounding.
6. **End of Simulation:** With transient analysis, the end of simulation is set by the stop time. For AMI analysis, simulation ends when the longest bit sequence (including any REPEAT_COUNT) is completed.

Current Source, DC



DC Current Source Netlist Format

The format for specifying a DC current source is:

I*xxxx n+ n-* [**DC=** dc_*current*] [**M=***val*] [**AC***acmag acphase*] [**NOISEVEC=[***f1*,*psd1*,... *fn*,*psdn***]**]

n+ is the positive node and *n-* is the negative node of the current source. The **DC** value in Amperes is used for the DC operating point (default 0.0). The parameter **M** allows the netlist to specify multiple current sources in parallel (default 1.0).

The **AC** parameter specifies the AC magnitude and phase to be applied during a small-signal AC analysis. The default for *acmag* is 1 Amp, the default for *acphase* is 0 degrees.

Table 2: DC Current Source Parameters

Parameter	Description	Unit	Default
acmag	Magnitude for AC analysis	Amp	1.0
acphase	Phase for AC analysis	Degree	0.0
DC	DC current value	Amp	0.0
M	Multiplier for simulating multiple parallel current sources	None	1.0
NOISEVEC	List of shot noise frequencies (f1...fn) and corresponding	Hertz,	None

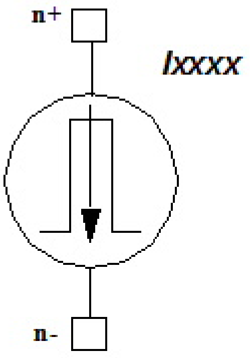
	noise power spectral densities (psd1...psdn), in pairs. The sequence of frequencies must be monotonically non-decreasing.	Volt ^{2}/Hertz	

Note: Units shown above are for users entering netlists directly. When using the UI to enter values, SI units are assumed unless specific units are shown. In particular, for angles, a unitless number entered into the Property value is interpreted as radians. Users are encouraged to enter explicit units (e.g., "45deg") if there is any uncertainty.

DC Current Source Netlist Example

```
I5 34 27 DC=1e-2
```

Current Source, Pulsed



Pulsed Current Source Netlist Format

The format for a trapezoidal pulsed current source is:

```
Ixxxx n+ n- PULSE (i1 i2 td tr tf pw per )

 [M=val] [ACacmag acphase] [TONE=tone_val]
[NOISEVEC=[f1,psd1,... fn,psdn]]
```

n+ and *n-* are the positive and negative nodes. The parameters after the **PULSE** keyword must be enclosed in parentheses. Note that all parameters are required to be present in the order given.

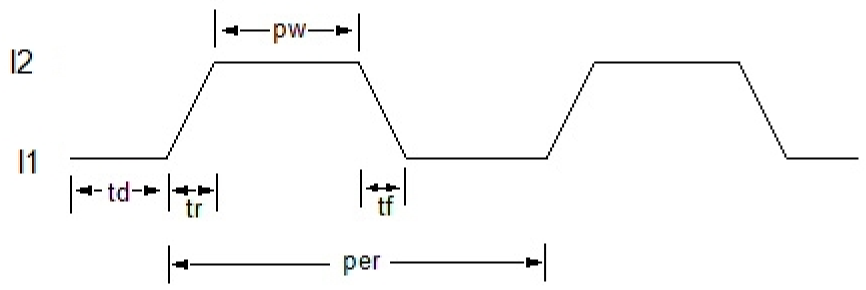
Table 3: Pulsed Current Source Parameters

Parameter	Description	Unit	Default

acmag	Magnitude for AC analysis	Amp	1.0
acphase	Phase for AC analysis	Degree	0.0
M	Multiplier for simulating multiple parallel current sources	None	1.0
NOISEVEC	List of shot noise frequencies (f1...fn) and corresponding noise power spectral densities (psd1...psdn), in pairs. The sequence of frequencies must be monotonically non-decreasing.	Hertz, Volt ^{2}/Hertz	None
i1	Initial current value	Amp	0.0
i2	Pulsed current value	Amp	0.0
td	(Positive) delay time to start of up-ramp	Second	0.0
tr	Rise time from V1 to V2	Second	0.0
tf	Fall time from V2 to V1	Second	0.0
pw	Pulse width (V2 hold time)	Second	1.0e100
per	Period of repetition for trapezoidal pulse	Second	1.5e100
TONE	Frequency to use for harmonic balance analysis, should be a submultiple of or equal to the driving frequency and should also be included in the HB solution setup	Hertz	0.0

Note: Units shown above are for users entering netlists directly. When using the UI to enter values, SI units are assumed unless specific units are shown. In particular, for angles, a unitless number entered into the Property value is interpreted as radians. Users are encouraged to enter explicit units (e.g., "45deg") if there is any uncertainty.

The **PULSE** current source repeats the current waveform each period until the STOPTIME of the transient analysis is reached in the following figure.



> **Note:**
>
> If **pw** is negative, **per** and **pw** are both set to infinity.
>
> If **per** is less than (**tf** +**tr** +**pw**), **per** is set to (**tf** +**tr** +**pw**).

The **AC** parameter specifies the AC magnitude and phase to be applied during a small-signal AC analysis. The default for *acmag* is 1 Amp, the default for *acphase* is 0 degrees.

For harmonic balance (HB) analysis, the test tones must be submultiples or equal to the frequencies of the actual voltage or current inputs to the circuit. To ensure that the appropriate HB frequency is used with a **SIN**, **PWL**, or **PULSE** source, qualify the source by adding a **TONE** =*tone_val* entry at the end of the instance statement. The *tone_val* is then used in a subsequent HB statement.

The **TONE** keyword is needed with a **SIN** voltage or current source only when the driving frequency of the source differs on the frequency at which the harmonic balance is to run. For example, to analyze a circuit driven by a single 1-KHz AC current source using harmonic balance at a test tone of 1 KHz over the first 31 harmonics, the netlist is:

```
I1 1 0 SIN(0 1000 0 0)
```

```
.HB TONES=1000 MAXK=31
```

However, to specify a 1000-Hz tone for harmonic balance while driving the circuit with a 2000-Hz sinusoidal current, the voltage source statement should include the **TONE** specification:

```
I1 1 0 SIN(0 2000 0 0) TONE=1000
```

```
.HB TONES=1000 MAXK=31
```

The **TONE** entry is *required* with any **PWL** or **PULSE** source. For example, to analyze a mixer driven by sources at 1 MHz and 27 kHz over the first four harmonics of a **PWL** source and the first two harmonics of a **PULSE** source, the netlist syntax is:

```
I23 20 0 PWL(0 0 0.1e-6 2.0 0.5e-6 5.0 1.0e-6 0 R) TONE=1.0e6
```

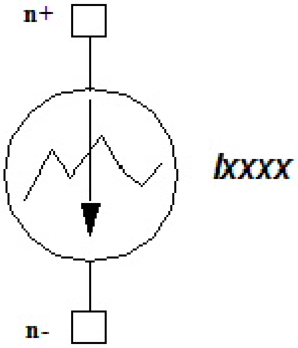
```
I1 1 0 PULSE (0 5 0 5e-3 5e-3 27e-3 27.0e3) TONE=27.0e3
```

```
.HB TONES=(1.0e+6, 27.0e+3) MAXK=(4, 2)
```

Pulsed Current Source Netlist Example

```
I23 23 53 PULSE (0 .05 10ns 5ns 5ns 20ns 40ns)
```

Current Source, Piecewise Linear



Piecewise Linear Current Source Netlist Format

The netlist format for a piecewise linear current source is:

```
Ixxxx n+ n- [DC=val] PWL (t1 v1 [t2 v2... tN vN]
) [M=val] [ACacmag acphase]
[TONE=tone_val] [PWLFILE=file_reference][R [=repeattime]] [TD=delay]
[NOISEVEC=[f1,psd1,... fn,psdn]]
```

n+ and *n-* are the positive and negative nodes. The parentheses around the parameters after the **PWL** keyword are required. The first time-value pair (*t1v1*) is required, while subsequent pairs are optional.

> **Note:**
>
> The time points *t1* ... *tN* must be given in STRICTLY INCREASING order. Two points may not refer to the same time.

Table 4: Piecewise Linear Current Source Parameters

Parameter	Description	Unit	Default
acmag	Magnitude for AC analysis	Amp	1.0
acphase	Phase for AC analysis	Degree	0.0
DC	DC current	Amp	0.0
M	Multiplier for simulating multiple parallel current sources	None	1.0
NOISEVEC	List of shot noise frequencies (f1...fn) and corresponding noise power spectral densities (psd1...psdn), in pairs. The sequence of frequencies must be	Hertz, Volt ^{2}/Hertz	None

	monotonically non-decreasing.		
t1 ... tN	Time points	Second	0.0
v1 ... vN	Current values at corresponding time points	Amp	0.0
PWLFILE (**PWL_FILE**)	Reference to file containing the time point and current values	None	None
R	Repeat the segment of the waveform that begins at *repeattime* and ends at *timeN*. *Repeattime* must be less than *timeN*. If R is entered with no *repeattime,* repeats from 0.0 seconds to *timeN.* If R is not present, no repeats are performed.	Second	None
TD	Time delay to start of first PWL waveform, and start of first repeat	Second	0.0
TONE	Frequency to use for harmonic balance analysis, should be a submultiple of or equal to the driving frequency and should also be included in the HB solution setup	Hertz	0.0

Note: Units shown above are for users entering netlists directly. When using the UI to enter values, SI units are assumed unless specific units are shown. In particular, for angles, a unitless number entered into the Property value is interpreted as radians. Users are encouraged to enter explicit units (e.g., "45deg") if there is any uncertainty.

Piecewise Linear Current Source Netlist Example

```
Ipwl 23 53 PWL (0 0 10ns 0.05 15ns 1.5e-2 20ns 1.0e-2 30ns 0
+ R TD=5ns)
```

Notes

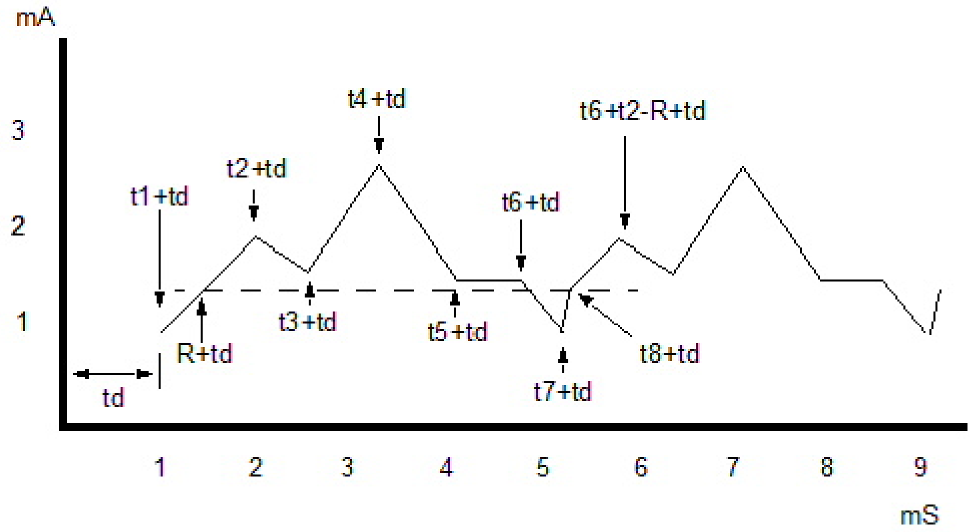
1. The time delay specified by **TD=***delay* is applied to the start of the PWL waveform, so the wave starts at (*time1* + *delay*).
2. The repeat specified by **R=***repeattime* repeats the portion of the PWL waveform that lies between *repeattime* and *timeN*. The *repeattime* must be greater than or equal to 0.0 seconds, and less than *timeN*. The repeat begins at time *tN* , subject to any delay. The *delay* is applied to the *repeattime* and to the PWL waveform, so the repeating segment is the portion of the PWL waveform between (*repeattime* + *delay*) and (*timeN* + *delay*). The repeating wave starts at the PWL value that occurred at *repeattime* in the original wave, interpolated if necessary.

> **Note:**
>
> The transition on the PWL value vN at time tN to the (possibly interpolated) value at the start of the repeat can create a discontinuity in the output, especially if the transition is "instantaneous," that is, occurring with no time difference between the two values. Care should be taken to avoid such a discontinuity, or to ensure that it is very small if it cannot be avoided. Discontinuous current or voltage jumps larger than a minimum value can create a timestep problem for transient analysis.

3. Here is an example using eight time points plus a time delay, with a repeat time (R) that occurs between time points, so interpolation is required.

```
I2 1 0 PWL(

+ 0.0    1.0e-3 $ t1 v1

+ 1.0e-3 2.0e-3 $ t2 v2

+ 1.6e-3 1.6e-3 $ t3 v3

+ 2.3e-3 2.7e-3 $ t4 v4

+ 3.1e-3 1.6e-3 $ t5 v5

+ 3.7e-3 1.6e-3 $ t6 v6

+ 4.2e-3 1.0e-3 $ t7 v7

+ 4.3e-3 1.4e-3 $ t8 v8

+ ) R=0.4e-3 TD=1.0e-3
```

Note the use of time point *t8* to avoid an "instantaneous" jump in output where the repeat begins. If t8 is omitted, the output changes on the level at *t7* to the (interpolated) value at the start of the repeat with no time difference between the two values. Such a sudden discontinuity can cause a timestep-too-small failure in transient analysis. The following figure illustrates this example, showing one repeat.



4. The **AC** parameter specifies the AC magnitude and phase to be applied during a small-signal AC analysis. The default for *acmag* is 1 Amp, the default for *acphase* is 0 degrees.
5. For harmonic balance (HB) analysis, the test tones must be submultiples or equal to the frequencies of the actual voltage or current inputs to the circuit. To ensure that the appropriate HB frequency is used with a **SIN**, **PWL**, or **PULSE** source, qualify the source by adding a **TONE** =*tone_val* entry at the end of the instance statement. The *tone_val* is then used in a subsequent HB statement.
6. The **TONE** entry is *required* with any **PWL** or **PULSE** source. For example, to analyze a mixer driven by sources at 1 MHz and 27 kHz over the first four harmonics of a **PWL** source and the first two harmonics of a **PULSE** source, the netlist syntax is:

```
I23 20 0 PWL(0 0 0.1e-6 2.0 0.5e-6 5.0 1.0e-6 0 R) TONE=1.0e6
```

```
I1 1 0 PULSE (0 5 0 5e-3 5e-3 27e-3 27.0e3) TONE=27.0e3
```

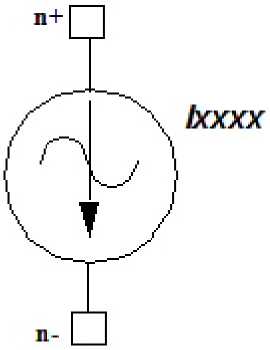
```
.HB TONES=(1.0e+6, 27.0e+3) MAXK=(4, 2)
```

7. The parameter **PWLFILE =***file_reference* refers to an external file containing the PWL data. See *File References* in the Nexxim Netlist File Format topic for details. Nexxim also supports the keyword **PWL_FILE** in place of the keyword **PWLFILE**.

The format of the PWL data file is:

```
t1 v1 [t2 v2 ...]
```

Current Source, Sinusoidal



Sinusoidal Current Source Netlist Format

The format for a damped sinusoidal current source is:

I*xxxx n+ n-* [**DC=***val*] **SIN (***io ia* [*freq* [*td* [*alpha* [*theta*]]]] **)**

[**M=***val*] [**AC***acmag acphase*] [**TONE=***tone_val*]
[**NOISEVEC=[***f1*,*psd1*,... *fn*,*psdn***]**]

n+ and *n-* are the positive and negative nodes. The parameters after the **SIN** keyword must be enclosed in parentheses. Parameters are positional and must be entered in the order given. To guarantee that a given parameter is interpreted correctly, all parameters to the left of it must be present.

Table 5: Sinusoidal Current Source Parameters

Parameter	Description	Unit	Default
acmag	Magnitude for AC analysis	Amp	1.0
acphase	Phase for AC analysis	Degree	0.0
DC	DC current	Amp	0.0
Io	Current offset from zero Amps	Amp	0.0
Ia	Peak current amplitude	Amp	0.0
freq	Frequency	Hz	1.0
td	Delay to start of sine wave	Second	0.0
alpha	Damping factor	Second^{-}	0.0

		1	
theta	Phase delay	Degree	0.0
M	Multiplier for simulating multiple parallel current sources	None	1.0
NOISEVEC	List of shot noise frequencies (f1...fn) and corresponding noise power spectral densities (psd1...psdn), in pairs. The sequence of frequencies must be monotonically non-decreasing.	Hertz, Volt ^{2}/Hertz	None
TONE	Frequency to use for harmonic balance analysis, should be a submultiple of or equal to the driving frequency and should also be included in the HB solution setup	Hertz	0.0

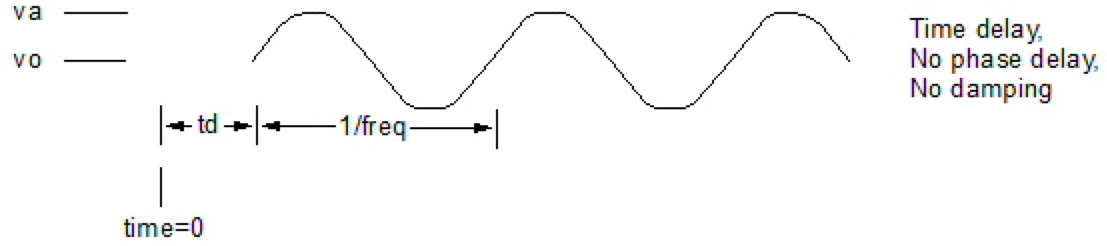
Note: Units shown above are for users entering netlists directly. When using the UI to enter values, SI units are assumed unless specific units are shown. In particular, for angles, a unitless number entered into the Property value is interpreted as radians. Users are encouraged to enter explicit units (e.g., "45deg") if there is any uncertainty.

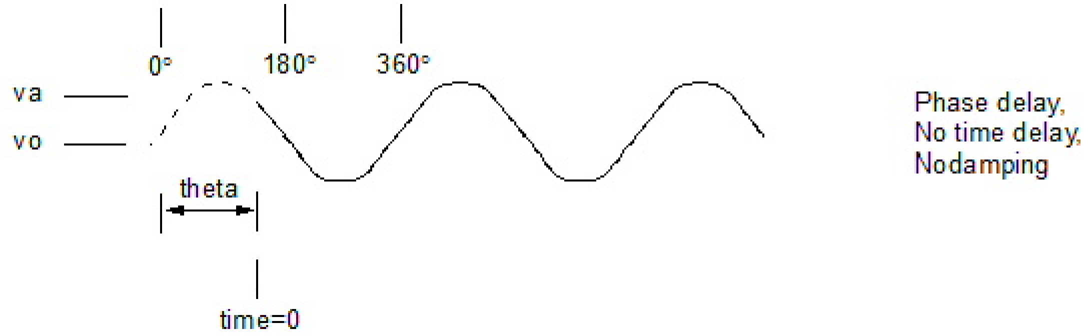
Sinusoidal Current Source Netlist Example

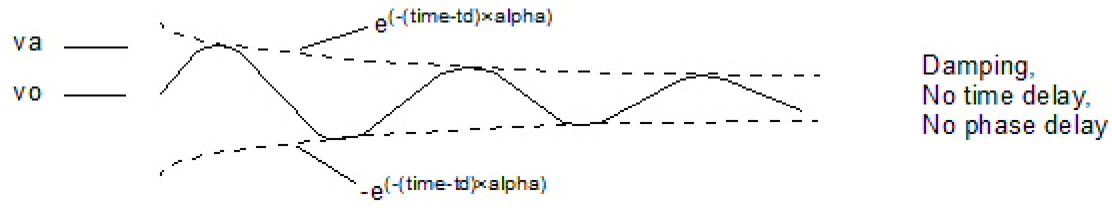
```
I23 15 21 SIN (0 1 100e+3 1e-12 1e-2 20)
```

Notes

1. The vo parameter overrides the DC parameter in all analyses except DC analysis.
2. The following figures show sinusoidal outputs with time delay, phase delay, and damping.







3. The **AC** parameter specifies the AC magnitude and phase to be applied during a small-signal AC analysis. The default for *acmag* is 1 Amp, the default for *acphase* is 0 degrees.
4. For harmonic balance (HB) analysis, the test tones must be submultiples or equal to the frequencies of the actual voltage or current inputs to the circuit. To ensure that the appropriate HB frequency is used with a **SIN**, **PWL**, or **PULSE** source, qualify the source by adding a **TONE** =*tone_val* entry at the end of the instance statement. The *tone_val* is then used in a subsequent HB statement.
5. The **TONE** keyword is needed with a **SIN** voltage or current source only when the driving frequency of the source differs on the frequency at which the harmonic balance is to run.

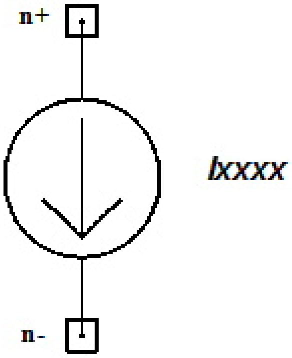
For example, to analyze a circuit driven by a single 1-KHz sinusoidal current source using harmonic balance at a test tone of 1 KHz over the first 31 harmonics, the netlist is:

```
I1 1 0 SIN(0 1000 0 0)

.HB TONES=1000 MAXK=31
```

However, to specify a 1000-Hz tone for harmonic balance while driving the circuit with a 2000-Hz sinusoidal current, the voltage source statement should include the **TONE** specification:

```
I1 1 0 SIN(0 2000 0 0) TONE=1000

.HB TONES=1000 MAXK=31
```

Current Source, AM (Netlist Only)



AM Current Source Netlist Format

The format to include an amplitude-modulated, time-varying (AM) current source is:

I*xxxx n+ n-* **AM (***sa oc fm fc* [*td*]**)**

n+ is the positive node and *n-* is the negative node of the current source. Parameters in parentheses are positional. The first four parameters must be present in the order given.

> **Note:** The AM current source is available for use in netlists, but is not supported in the Components window of the **Schematic Editor**.

Table 6: AM Current Source Parameters

Parameter	Description	Unit	Default

fc	Carrier frequency	Hertz	0.0
fm	Modulation frequency	Hertz	1/TSTOP
oc	Offset constant applied to the modulation amplitude	None	0.0
sa	Signal amplitude	Amp	0.0
td	Propagation delay before the start of the signal	Second	0.0

AM Current Source Netlist Example

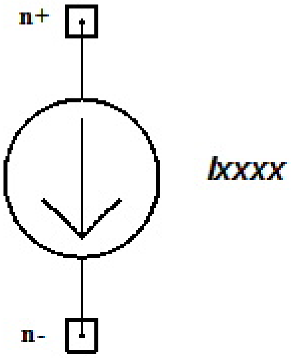
```
* AM Current Source netlist example
* To visualize the interaction of sa (signal amplitude)
* and                             oc (offset constant)
* swap the next two lines by moving the comment mark (*),
* analyze, create reports

* I1 1 0 AM (80  0   5e6  1e9  0)

  I1 1 0 AM (20  4   5e6  1e9  0)

R1 1 0 1

.TRAN 1e-10 1e-6

.PRINT tran V(1)

.END
```

Notes

1. The AM current source output is calculated as follows:

$$output = sa \times oc + \sin[2\pi \times fm \times (time - td)]\} \times \sin[2\pi \times fc \times (time - td)]$$

Current Source, Exponential (Netlist Only)



Exponential Current Source Netlist Format

The format for specifying an exponential current source is:

I*xxxx n+ n-* **EXP (***v1 v2* [*td1* [*td2* [*t1* [t2]]]]**)**

n+ is the positive node and *n-* is the negative node of the current source. Parameters in parentheses are positional. The first two (*v1* and *v2*) are required. The remainder (*td1*, *td2*, *t1*, and *t2*) can be omitted, but the parameters must be entered in the order given. To guarantee that a given parameter is interpreted correctly, all parameters to the left of it must be present.

> **Note:** The exponential current source is available for use in netlists, but is not supported in the Components window of the **Electronics Desktop Schematic Editor**.

Table 7: Exponential Current Source Parameters

Parameter	Description	Unit	Default
v1	Initial current value	Amp	0.0
v2	Maximum current value	Amp	0.0
td1	(Positive) delay time to start of exponential rise	Second	0.0
td2	Delay time to start of exponential fall	Second	td1+TSTEP (*step* argument on TRAN statement)
t1	Rise time constant	Second	TSTEP
t2	Fall time constant	Second	TSTEP

Exponential Current Source Netlist Example

```
.TITLE IEXP TEST

I1 1 0 EXP(-4 -1 5ns 30ns 80ns 40ns)

R1 1 0 1

.TRAN 0.5ns 200ns

.PRINT tran I(R1)

.END
```

Notes

1. From time = 0 to time = td1:

Output = v1

From time=td1 to time = td2:

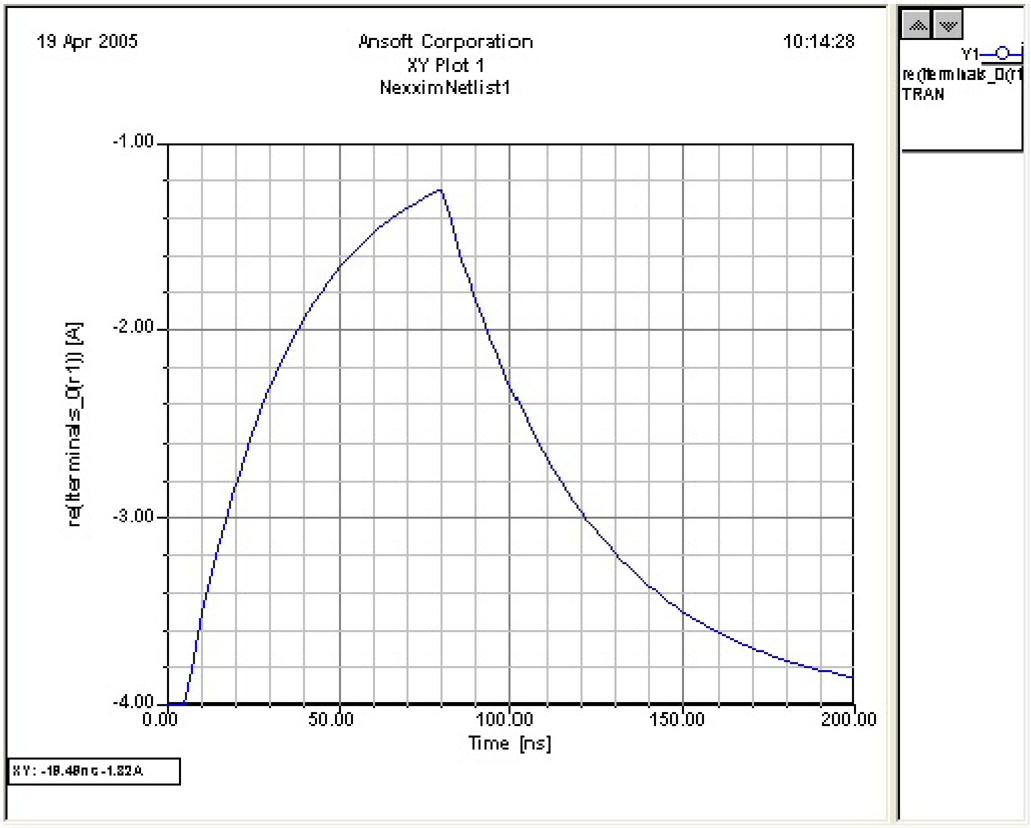
Output = v1+(v2-v1)×(1.0-EXP[-(time-td1)/t1]

From time = td2 to time = tstop:

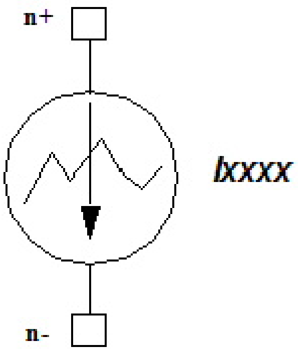
Output = v1+(v2-v1)×(1.0-EXP[-(time-td1)/t1])-(v2-v1)×(1.0-EXP[-(time-td2)/t2])

2. The *td2*, *t1*, and *t2* parameters take their default values on the *step* argument on the transient analysis TRAN statement (see *Transient Analysis Netlist Format*). Therefore, when a circuit containing an exponential current source is to be analyzed with a tool other than transient analysis, the *td2*, *t1*, and *t2* parameters must be given explicit values.
3. The exponential current source exhibits an 'overshoot' when the first time period is small relative to the first decay constant.

Here is the resulting waveform:



Current Source, Piecewise Linear, MSINC and ASPEC Compatible (Netlist Only)



> **Note:**
>
> The MSINC- and ASPEC-compatible syntax for the piecewise linear current source is available for use in netlists, but is not supported in the Components window of the **Schematic Editor**. It is provided to support third-party netlists.

Piecewise Linear Current Source MSINC and ASPEC Netlist Format

The MSINC and ASPEC compatible netlist format for a piecewise linear current source is:

```
Ixxxx n+ n- PL [(]v1 t1 [v2 t2... vN tN]
```

```
[R [=repeattime]] [TD=delay][)]
```

n+ and *n-* are the positive and negative nodes. The parentheses around the parameters after the **PL** keyword are optional. The first value-time pair (*v1t1*) is required, while subsequent pairs are optional.

> **Note:**
>
> The time points t1 ... tN must be given in STRICTLY INCREASING order. Two points may not refer to the same time.

Table 8: MSINC and ASPEC Syntax Piecewise Linear Current Source Parameters

Parameter	Description	Unit	Default
t1 ... tN	Timepoints	Second	0.0

v1 ... vN	Current values at corresponding timepoints	Amp	0.0
R	Repeat the segment of the waveform that begins at *repeattime* and ends at *timeN*. *Repeattime* must be less than *timeN*. If R is entered with no *repeattime,* repeats from 0.0 seconds to *timeN.*	Second	None
TD	Time delay to start of first PWL waveform, and start of first repeat	Second	0.0

MSINC and ASPEC Compatible Piecewise Linear Current Source Netlist Example

```
Ipl 23 53 PL (0 0  0.05 10ns 1.5e-2 15ns 1.0e-2 20ns 0 30ns
+ R TD=5ns)
```

Notes

1. The time delay specified by **TD=***delay* is applied to the start of the PL waveform, so the wave starts at (*time1* + *delay*).
2. The repeat specified by **R=***repeattime* repeats the portion of the PL waveform that lies between *repeattime* and *timeN*. The *repeattime* must be greater than or equal to 0.0 seconds, and less than *timeN*. The repeat begins at time *tN* , subject to any delay. The *delay* is applied to the *repeattime* and to the PL waveform, so the repeating segment is the portion of the PL waveform between (*repeattime* + *delay*) and (*timeN* + *delay*). The repeating wave starts at the PL value that occurred at *repeattime* in the original wave, interpolated if necessary.

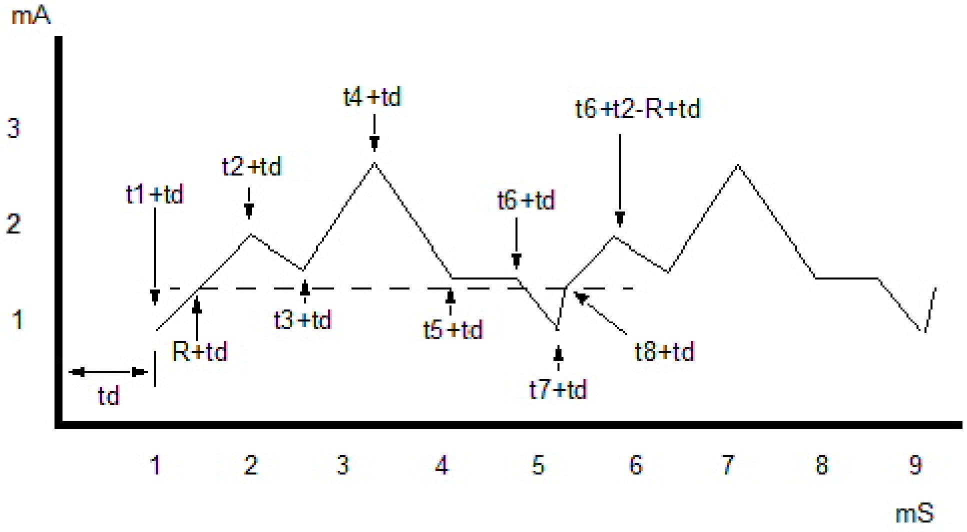
> **Note:**
>
> The transition on the PL value vN at time tN to the (possibly interpolated) value at the start of the repeat can create a discontinuity in the output, especially if the transition is “instantaneous,” that is, occurring with no time difference between the two values. Care should be taken to avoid such a discontinuity, or to ensure that it is very small if it cannot be avoided. Discontinuous current or voltage jumps larger than a minimum value can create a timestep problem for transient analysis.

3. Here is an example using eight time points plus a time delay, with a repeat time (R) that occurs between time points, so interpolation is required.

```
I2 1 0 PL(

+ 1.0e-3 0.0     $ v1 t1

+ 2.0e-3 1.0e-3 $ v2 t2

+ 1.6e-3 2.6e-3 $ v3 t3
```

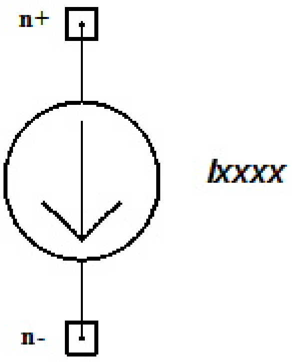
```
+ 2.7e-3 3.3e-3 $ v4 t4

+ 1.6e-3 4.1e-3 $ v5 t5

+ 1.6e-3 4.7e-3 $ v6 t6

+ 1.0e-3 5.2e-3 $ v7 t7

+ 0.4e-3 5.3e-3 $ v8 t8

+ ) R=0.4e-3 TD=1.0e-3
```

Note the use of time point *t8* to avoid an “instantaneous” jump in output where the repeat begins. If *t8* is omitted, the output changes on the level at *t7* to the (interpolated) value at the start of the repeat with no time difference between the two values. Such a sudden discontinuity can cause a timestep-too-small failure in transient analysis. The following figure illustrates this example, showing one repeat.



Current Source, Single-Frequency FM (Netlist Only)

at



Single-Frequency FM Current Source Netlist Format

The format for a single-frequency-modulated current source is:

```
Ixxxx n+ n- SFFM (vo va [fc [mdi [fs] ] ] )
```

n+ and *n*- are the positive and negative nodes, as for the DC current source. The unlabeled parameters in parentheses are positional. Parameters *vo* and va are required. Parameters *fc*, *mdi*, and *fs* can be omitted, but the parameters must be entered in the order shown. To guarantee that a given parameter is interpreted correctly, all parameters to the left of it must be present.

> **Note:** The SFFM current source is available for use in netlists, but is not supported in the Components window of the **Electronics Desktop Schematic Editor**.

Table 9: SFFM Current Source Parameters

Entry	Description	Unit	Default
vo	Output current offset from zero Amps	Amp	0.0
va	RMS output current amplitude	Amp	0.0
fc	Carrier frequency	Hertz	1/TSTOP entry on the .TRAN statement
mdi	Modulation index	Second	0.0
fs	Source frequency	Hertz	1/TSTOP entry on the .TRAN statement

SFFM Current Source Equation

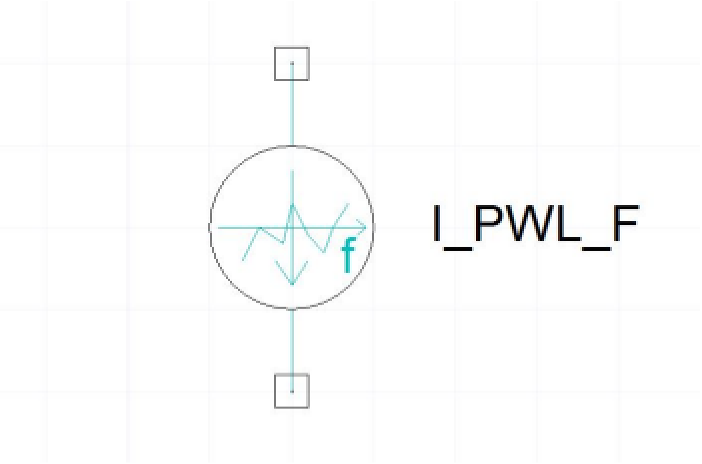
The shape of the SFFM current waveform is given by the equation:

output = $vo + va \times \sin[(2\pi \times fc \times time) + mdi \times \sin(2\pi \times fs \times time)]$

SFFM Current Source Netlist Example

```
I1 15 21 SFFM (0 1e-6 20K 5 1K)
```

Frequency Dependent Current Source



There are several applications that can make use of Frequency dependent sources. One application is in the Electromagnetic Interference (EMI) workflow (e.g., simulating cable harness radiated emissions or simulating locomotive and automotive applications). Such applications thereby motivate the need for a frequency dependent voltage/current source in the EMI workflow; one that enables extracting radiated emissions on the cable.

Amplitude Modulation (AM) based signaling and Pulse Width Modulation (PWM) allow for the capture of emissions. This is accomplished by taking into consideration the radiated emission on the cable and its impact upon the load resonances. Emission capture can be further supported by the use of frequency dependent voltage/current source components. Note, however, that the I_PWL_F component discussed herein, is only supported with frequency domain simulations.

UI support for the frequency dependent current source is available via:

- Magnitude-Angle (MA) formats with appropriate units
- A Real-Imaginary (RI) table

- For the set of “AC” or “LNA” frequencies outside of the data rang, keep the first, if it is in the low-frequency region, and the last data frequency samples if it is outside of the data frequency range. For all the frequencies in between, perform a Piecewise Linear (PWL) interpolation of the available data samples. For an example, please see Frequency Dependent Voltage Source.

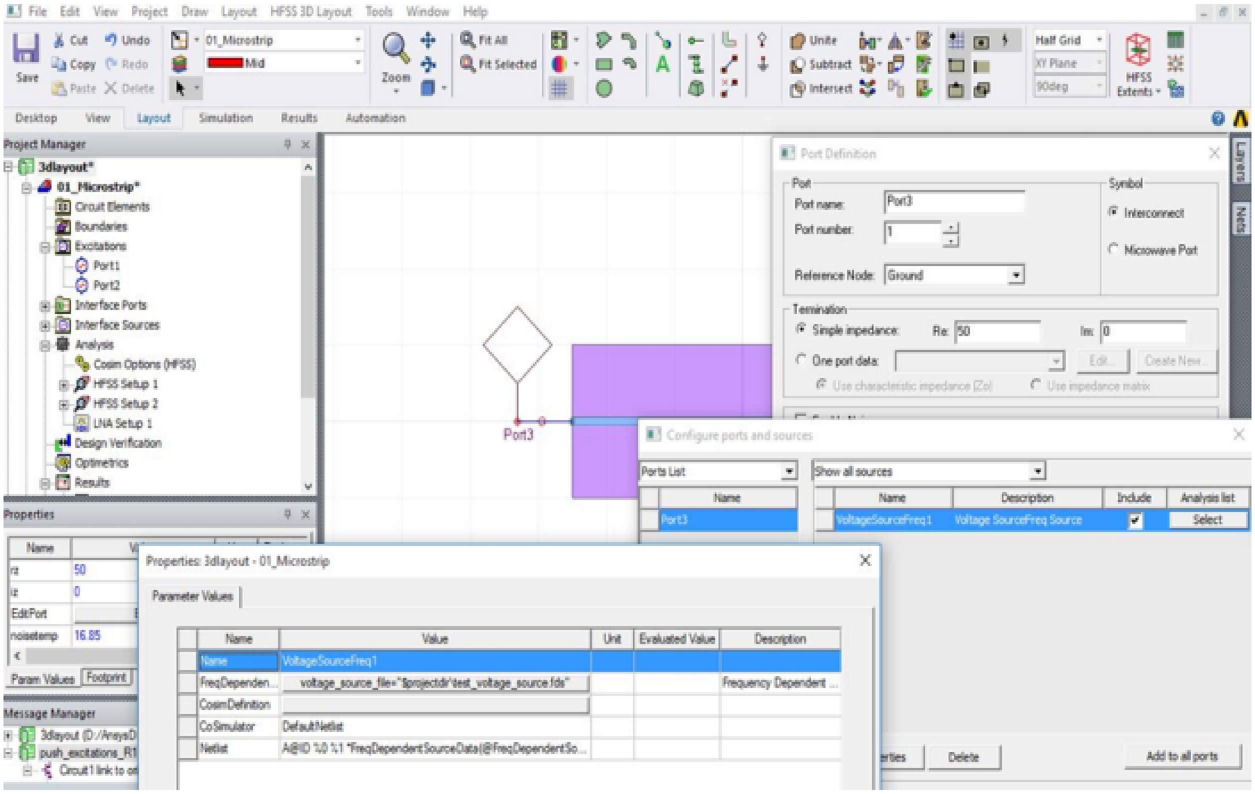
  For example, let’s say the frequency samples provided are freqs = [1 2 3 4] vreal = [0.1 -0.25 0.5 1] vimag=[0 -.25 0.5 1] and the “LNA” set up list of frequencies are 10 frequency samples linearly spaced from 0 to 5 — i.e., [0 0.5556 1.1111 1.6667 2.2222 2.7778 3.3333 3.8889 4.4444 5.0000]. Then, at DC real value of the voltage is set to 0.1, at frequency 0.5556 Hz it is set to 0.1 also and at frequencies [1.1111 1.6667 2.2222 2.7778 3.3333 3.8889] Hz the real value of the voltage source is linearly interpolated to [0.0611 -0.1333 -0.0834 0.3334 0.6666 0.9445], at 4.4444 and 5.0000 Hz the real value of the voltage is set to 1. A similar approach is taken for the imaginary part of the voltage. A warning message is also issued to let the user know when the “LNA” list of frequencies are outside of the available data range.
- When the tabulated data with “MA” (Magnitude/Angle) option is chosen, the user can enter the angle as a default in units of degrees. However, the unit of the angle in the netlist should be in radians.
- If there are duplicate frequency samples or when the frequency samples are not monotonic, the Solver corrects by skipping the samples that are non-monotonic or duplicate.
- If there are negative frequency samples in the data, an error message is issued and the simulation bails out.
- If there is a mismatch on the size of the data provided, an error message is issued and the simulation bails out.

Frequency dependent voltage/current source files are similar, and following is an example of a source file.

```
! Frequency dependent voltage source file
[Complex format] RI
[Number of frequencies] 1000
[Number of transfer functions] 1
[Data]
0.000000000000000e+00, 1.022787268227175e+00, -5.208574999256144e-17
5.005005005005004e+07, 1.053263711781395e+00, 7.758778994286877e-02
1.001001001001001e+08, 1.094513424576236e+00, 1.173421540714190e-01
1.501501501501502e+08, 1.131347607481765e+00, 1.431207641636222e-01
2.002002002002002e+08, 1.166136328385828e+00, 1.616330271227035e-01
2.502502502502503e+08, 1.199842750216311e+00, 1.750255055755736e-01
3.003003003003003e+08, 1.232944784710391e+00, 1.844110909415259e-01
3.503503503503503e+08, 1.265723285675800e+00, 1.904360324517109e-01
4.004004004004003e+08, 1.298344719578414e+00, 1.935087026784736e-01
4.504504504504505e+08, 1.330909940111871e+00, 1.939049136787713e-01
5.005005005005005e+08, 1.363480756574756e+00, 1.918172013516176e-01
5.505505505505506e+08, 1.396092974554894e+00, 1.873813132374444e-01
6.006006006006006e+08, 1.428763223646690e+00, 1.806928237317852e-01
6.506506506506506e+08, 1.461493266586956e+00, 1.718183806626403e-01
7.007007007007006e+08, 1.494273138430252e+00, 1.608034081764624e-01
7.507507507507508e+08, 1.527083498234942e+00, 1.476773350132686e-01
8.008008008008007e+08, 1.559897313159492e+00, 1.324571368814465e-01
8.508508508508508e+08, 1.592680974859775e+00, 1.151497839148079e-01
9.009009009009010e+08, 1.625394970936337e+00, 9.575400772812666e-02
9.509509509509509e+08, 1.657994240601652e+00, 7.426165532452513e-02
1.001001001001001e+09, 1.690428328765114e+00, 5.065878686061404e-02
1.051051051051051e+09, 1.722641425582628e+00, 2.492659959303357e-02
1.101101101101101e+09, 1.754572348243892e+00, -2.957785483639553e-03
1.151151151151151e+09, 1.786154493977223e+00, -3.302066253544392e-02
1.201201201201201e+09, 1.817315770523136e+00, -6.529120395725592e-02
1.251251251251251e+09, 1.847978493433314e+00, -9.980104738091944e-02
1.301301301301301e+09, 1.878059228473630e+00, -1.365840018085054e-01
1.351351351351351e+09, 1.907468551992742e+00, -1.756758602670627e-01
1.401401401401401e+09, 1.936110702365197e+00, -2.171142974733384e-01
1.451451451451451e+09, 1.963883101670582e+00, -2.609388232397690e-01
1.501501501501502e+09, 1.990675738523413e+00, -3.071907588002359e-01
1.551551551551552e+09, 2.016370419194792e+00, -3.559132081925685e-01
1.601601601601601e+09, 2.040839910935018e+00, -4.071510158787224e-01
1.651651651651652e+09, 2.063947009695972e+00, -4.609507405306048e-01
1.701701701701702e+09, 2.085543547525322e+00, -5.173607350480878e-01
1.751751751751752e+09, 2.105469288114430e+00, -5.764314932957259e-01
1.801801801801802e+09, 2.123550519682482e+00, -6.382164663518241e-01
1.851851851851852e+09, 2.139597957742090e+00, -7.027734887529041e-01
1.901901901901902e+09, 2.153403447970470e+00, -7.701667095943957e-01
1.951951951951952e+09, 2.164735239650003e+00, -8.404686135356756e-01
2.002002002002002e+09, 2.173332567227145e+00, -9.137621797256200e-01
2.052052052052052e+09, 2.178900589872246e+00, -9.901463879007639e-01
2.102102102102102e+09, 2.181100087368592e+00, -1.069753365527252e+00
2.152152152152152e+09, 2.179512775959131e+00, -1.152773452234992e+00
```

For more information, see CTLE Transfer Function from a File.

3D Layout Support



Port Definition

Port name: Port3

Port number: 1

Reference Node: Ground

Symbol: ● Interconnect ○ Microwave Port

Termination: ● Simple impedance: Re: 50 Im: 0

Configure ports and sources

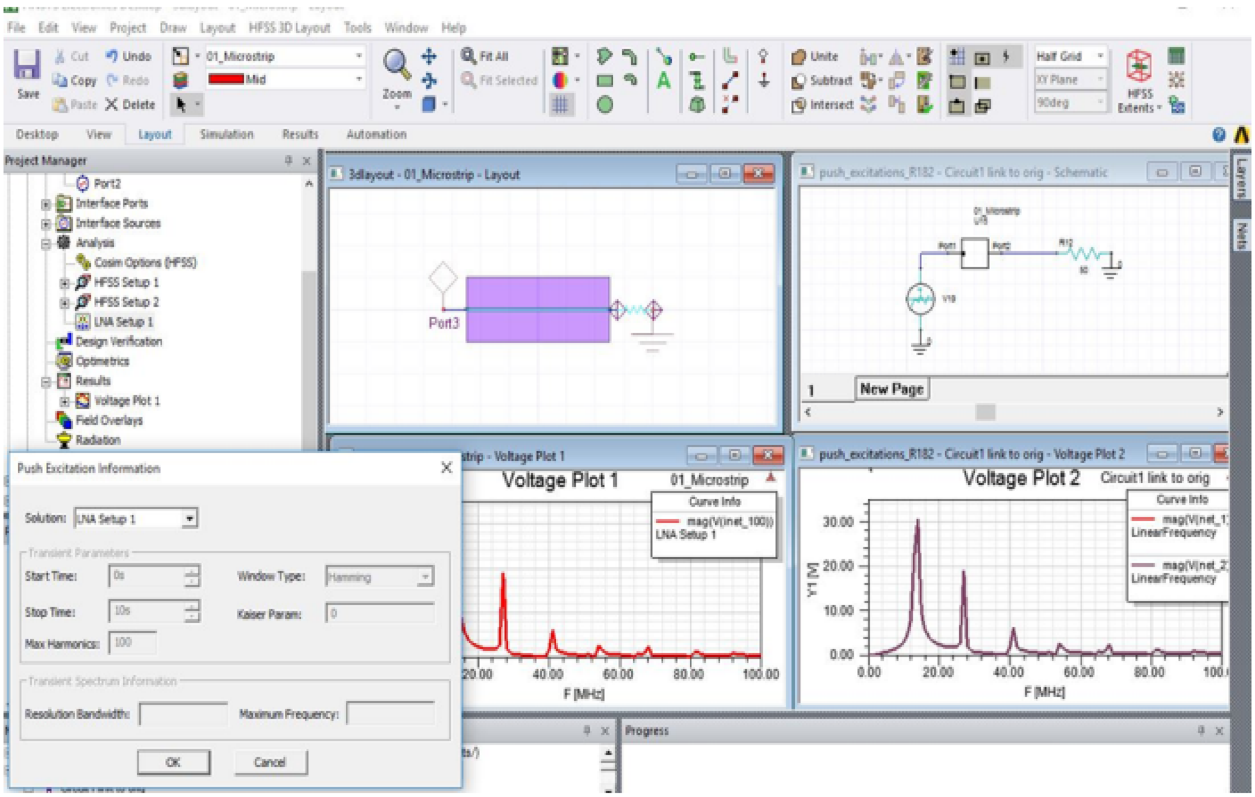
Name
Port3

Name	Description	Include	Analysis list
VoltageSourceFreq1	Voltage SourceFreq Source	☑	Select

Properties: 3dlayout - 01_Microstrip

Name	Value	Unit	Evaluated Value	Description
Name	VoltageSourceFreq1			
FreqDependen...	voltage_source_file="$projectdir\test_voltage_source.fds"			Frequency Dependent ...
CosimDefinition				
CoSimulator	DefaultNetlist			
Netlist	A@ID %0 %1 "FreqDependentSourceData(@FreqDependentSo...			

Push Excitation with Dynamic Link



Push Excitation Information

Solution: LNA Setup 1

Transient Parameters

Start Time: 0s

Stop Time: 10s

Max Harmonics: 100

Window Type: Hamming

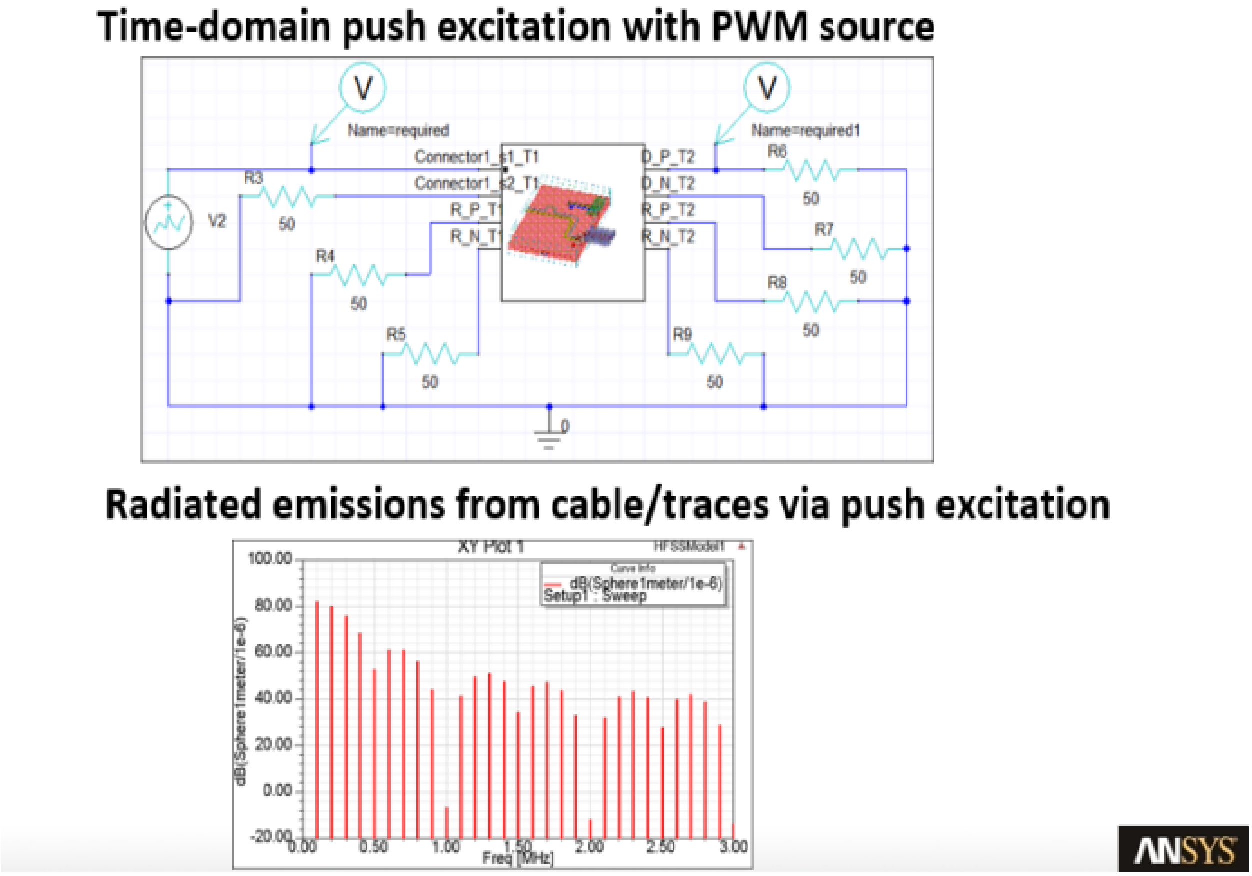
Kaiser Param: 0

Transient Spectrum Information

Resolution Bandwidth:

Maximum Frequency:

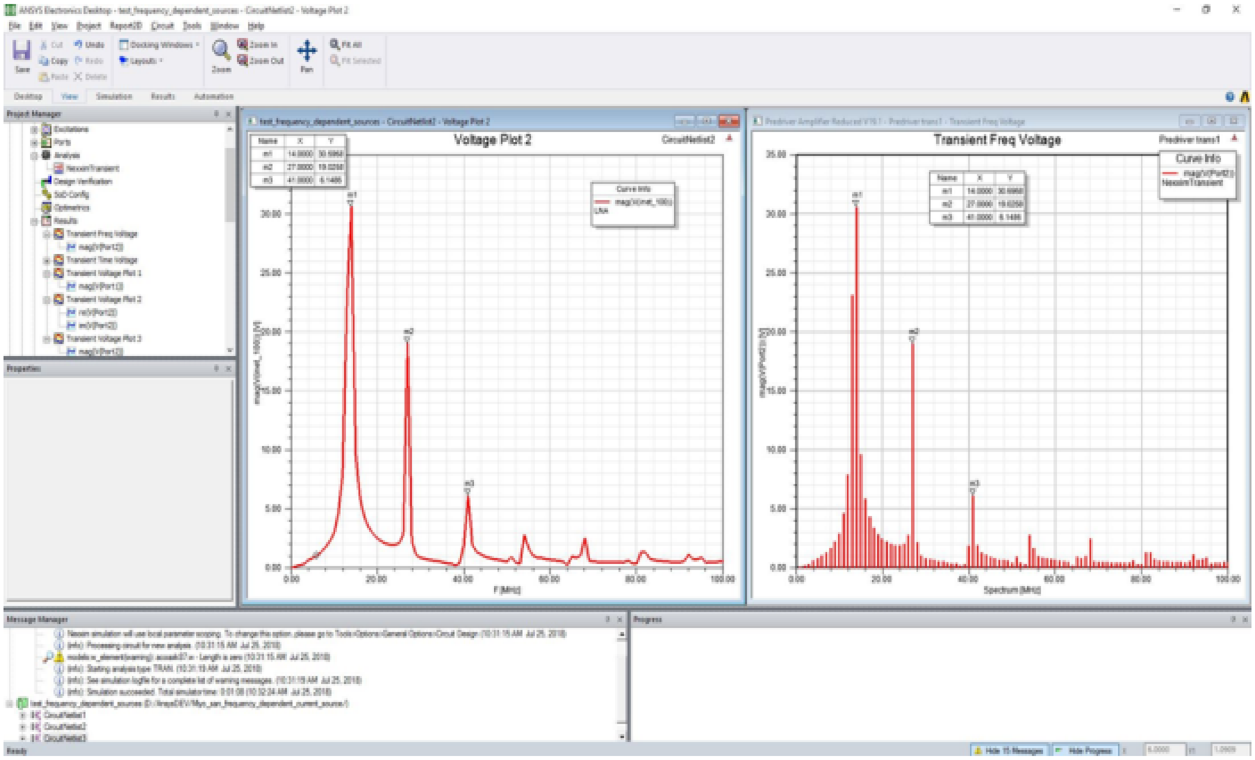
EMI Setup with Dynamic Link and Push Excitation



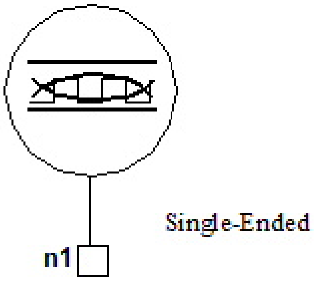
Time-domain push excitation with PWM source

Radiated emissions from cable/traces via push excitation

Voltage Spectrum Used to Build the Frequency Dependent Voltage Source



Eye Source



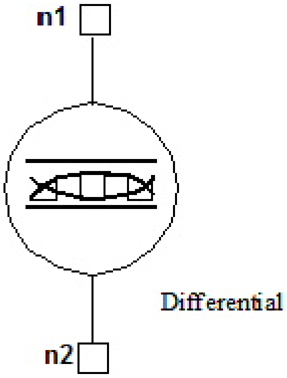


Table 10: Eye Source Parameters

Parameter	Description	Unit	Default
RESISTANCE	Impedance added in series with Eye Source	Ohm	50
BITLIST	Sequence of ones and zeros	None	None

Parameter	Description	Unit	Default
BITFILE	File containing bit list	None	None
RANDOM_BIT_COUNT	Number of random bits to generate	None	0
RANDOM_SEED	Seed for RANDOM_BIT_COUNT. Multiple sources with **random_seed=-1** receive multiple seeds 1000, 1001, ...1000+N (seeds are the same from run to run). Multiple sources with **random_seed=-2** receive multiple seeds derived on the time clock (seeds are different on each run).	None	1000
REPEAT_COUNT	Number of times to repeat the random bit sequence. Total bits in sequence = (REPEAT_COUNT+1) times the number of bits in the chosen bit pattern. REPEAT_COUNT must be a non-negative integer.	None	0
HOLD_LAST_BIT	Controls behavior when end of bit sequence occurs before simulation ends. 1=Run sequence, then hold last bit of sequence until end of simulation. 0=Continue to repeat sequence until end of simulation.	None	0
VLOW	Logic low voltage level	Volt	Single: 0 Diff: -1
VHIGH	Logic high voltage level	Volt	1
TRISE	Low-to-high rise time (see Note 8)	Second	1e-10
TFALL	High-to-low fall time (see Note 8)	Second	1e-10
MODULATION	Selects **NRZ** or **PAM4**, controlling the number of voltage levels and the corresponding number of bits per transmitted symbol. **NRZ** uses 2 voltage levels, one bit per symbol. **PAM4** uses 4 voltage levels, two bits per symbol. PAM-4 modulation with the Eye Source is supported for QuickEye, VerifEye, and Transient analyses.		
CODING	Valid for **MODULATION=PAM4** only. In the component Properties window, this property is labeled **coding_PAM4_only** as a reminder.	None	Gray

Parameter	Description	Unit	Default
	Mapping that defines how digital bits are sent as analog waveforms. In PAM-4, two bits ("00"/"01"/ "10"/"11") are transmitted at a time. With **CODING=Gray**, "00" is transmitted as "vlow," "01" as "vlow + (vhigh-vlow)/3," "11" as (vhigh - (vhigh-vlow)/3), "10" as "vhigh". With **CODING=Linear**, these voltage levels (smallest to largest) represent transmit bits "00," "01,"10," and "11," respectively. The **CODING** parameter is ignored when **MODULATION=NRZ**. In NRZ, one bit ('0' or '1') is transmitted at a time; '0' is transmitted as "vlow," and 1 as "vhigh."		
BPS	Specify number of bits per second instead of duration of unit interval. See Note 1 in this topic.	1/Second	1e9
UI	Specify duration of the unit interval instead of the BPS. If both UI and BPS properties are present in the netlist, the UI value is used. See Note 1 in this topic.	Second	1e-9
DCD	Duty cycle distortion as a fraction of UI, 0.0 <= DCD <= 1.0. If both **DCD** and **DCD_TIME** are present in the netlist, **DCD** (fraction of UI) is used and **DCD_TIME** is ignored. See Note 2 in this topic.	None	0
DCD_TIME	Duty cycle distortion as an absolute time. If both **DCD** and **DCD_TIME** are present in the netlist, **DCD** (fraction of UI) is used and **DCD_TIME** is ignored. See Note 2 in this topic.	Second	0
TXRJ	List of transmit random jitter values (standard deviations) enclosed in brackets	Second	0
TXPJ	List of transmit periodic random jitter values (amplitudes) enclosed in brackets	Second	0
TXUJ	List of transmit uniform random jitter values (amplitudes) enclosed in brackets	Second	0
TXCJ	File containing jitter probability density function data. Two-column data specifies times in seconds and corresponding PDF values.	None	None
FFE_TAPS	Number of FFE taps	None	0
FFE_LOCS	Bit locations of FFE taps	None	None

Parameter	Description	Unit	Default
FFE_WEIGHTS	FFE weights	None	None
NORMALIZE_ FFE	1=Normalize, 0=No normalization	None	
FFE_ COMPUTE_ PROBE	Name of the associated eye probe	None	None
PHASE_DELAY	Phase delay of the source	Second	0.0
STEP_RESP_ NUM_UI	Number of unit intervals to run step response from	None	
PRBS_NO	Size of pseudorandom bit pattern. May be any integer from 2 to 31. Nexxim randomly runs through all combinations of that many bits.	None	
PRBS_SEED	Seed (starting bit) for pseudorandom bit pattern	None	0
PRBS_INVERT	1=invert pseudorandom bit output, 0=no inversion	None	0
PRBS_ BITLENGTH	Total number of PRBS bits to generate	None	2^PRBS_ NO
DO_ENCODING	0=no encoding 1=perform 8b10b encoding 2=perform 64b66b encoding 3=perform 128b130b encoding 4=perform128b132b encoding Note: **DO_ENCODING** is valid only when **MODULATION=NRZ**. **DO_ENCODING** is ignored when **MODULATION=PAM4**.	None	0
FFE_FILE	Netlist Only. Used when there are technical limitations on the values that tap weights can take. References a file with a list of allowable FFE weights, one per line, in order from most negative to most positive. When FFE_FILE is present, the FFE algorithm optimizes using only tap weights on the list. As with the standard algorithm, the sum of the absolute values of the weights used is never greater than one.	None	None
Spread Spectrum Parameters (in a window, active when Enable			

Parameter	Description	Unit	Default
SSC is checked, unavailable otherwise):			
Modulation profile (ss_ profile)	Modulation profile: **triangular** or **sinusoidal**	None	triangular
Spread type (ss_spread)	Displacement of spread relative to **fc**: **center**, **up**, or **down**	None	down
Modulation frequency (ss_ freq)	Modulation rate (frequency)	Hz	33kHz
Spread rate (%) (ss_d)	Spreading rate (percent of **fc**)	None	0.5%

Eye Source Netlist Format

An eye source is placed in a schematic to perform VerifEye analysis, Quick Eye analysis, or Transient analysis.

n1 is the node connected to the single-ended source. *n2* is the second node on a differential source. The differential Eye source must be connected to two signal lines. Neither node should be directly grounded. See **Notes** for details. The entry **COMPONENT=EYE_SOURCE** is required.

The netlist syntax for the Eye Source is:

```
AEYESOURCExxxx n1 [n2] COMPONENT=EYE_SOURCE
+ RESISTANCE=val
+ BITLIST=#bitlist
+ BITFILE='file-reference'
+ RANDOM_BIT_COUNT=val RANDOM_SEED=val
+ REPEAT_COUNT=val HOLD_LAST_BIT=val
+ VLOW=val VHIGH=val TRISE=val TFALL=val
+ MODULATION=NRZ|PAM4 CODING=GRAY|LINEAR
+ UI=val BPS=val
+ STEP_RESP_NUM_UI=val
+ DCD=val DCD_TIME=val
+ TXRJ=[val ... ] TXPJ=[val ...] TXUJ=[val ...]
+ TXCJ='file-reference'
+ FFE_TAPS=val
+ FFE_LOCS=[locations ]
+ FFE_WEIGHTS=[weights ]
+ NORMALIZE_FFE= val
```

```
+ FFE_COMPUTE_PROBE='probe_name'
+ PHASE_DELAY=val
+ PRBS_NO=val
+ PRBS_SEED=val
+ PRBS_INVERT=val
+ PRBS_BITLENGTH=val
+ DO_ENCODING=val
+ FFE_FILE='file-reference' // Netlist Only
+ ss_freq=valss_profile='modulation_profile'
+ ss_spread='modulation_spread' ss_d=val
```

Eye Source Netlist Example

```
AEYESOURCE3 Port1 COMPONENT=EYE_SOURCE RESISTANCE=50
+ BITLIST=#1010101010100000111110101010101000001111
+ REPEAT_COUNT=1000
```

Notes

1. The Unit Interval is the duration of one symbol. The Unit Interval (seconds per symbol) is the ratio between the symbol size (bits per symbol) and the bit rate (bits per second).

   UI = BitsPerSymbol/BitsPerSecond

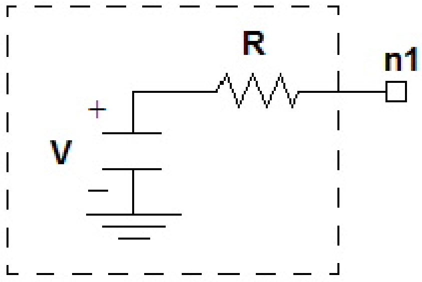
   The **BPS** and **UI** parameters are mutually exclusive. If the netlist contains both properties, the **UI** value is used.

   When an EYE Source is instantiated in a schematic, the Properties window uses two artificial properties to ensure that only one of the two UI/BPS parameters is netlisted:

   - **UIorBPS**: Select between **UnitInterval** and **BitsPerSecond**. For **UnitInterval**, only the UI property is netlisted. For **BitsPerSecond**, only the BPS property is netlisted.
   - **UIorBPSValue**: UI time in seconds, or BPS number of bits per second.
2. The Duty Cycle Distortion may be entered as a fraction of the UI (**DCD** parameter) or as an absolute time (**DCD_TIME** parameter). The **DCD** and **DCD_TIME** parameters are mutually exclusive. If the netlist contains both properties, the DCD value is used.

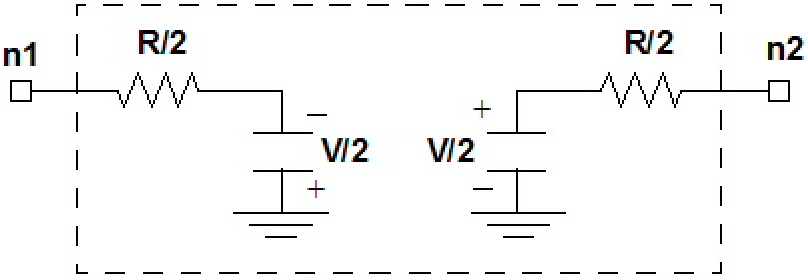
   When an EYE Source is instantiated in a schematic, the Properties window uses two artificial properties to ensure that only one of the two parameters is netlisted:

   - **DCDFractionorTime**: Select between **Fraction** (the default) and **Time**. For **Fraction**, only the **DCD** property is netlisted. For **Time**, only the **DCD_TIME** property is netlisted.
   - **DCD**: Fraction from 0.0 to 1.0, or Time in seconds (use explicit units such as **ps** to set the time value).
3. The Single-Ended Eye source has the generalized internal structure shown in the following figure.



The internal voltage source amplitude is set by VHIGH and VLOW. The source is grounded internally. The series resistance is set by the RESISTANCE parameter.

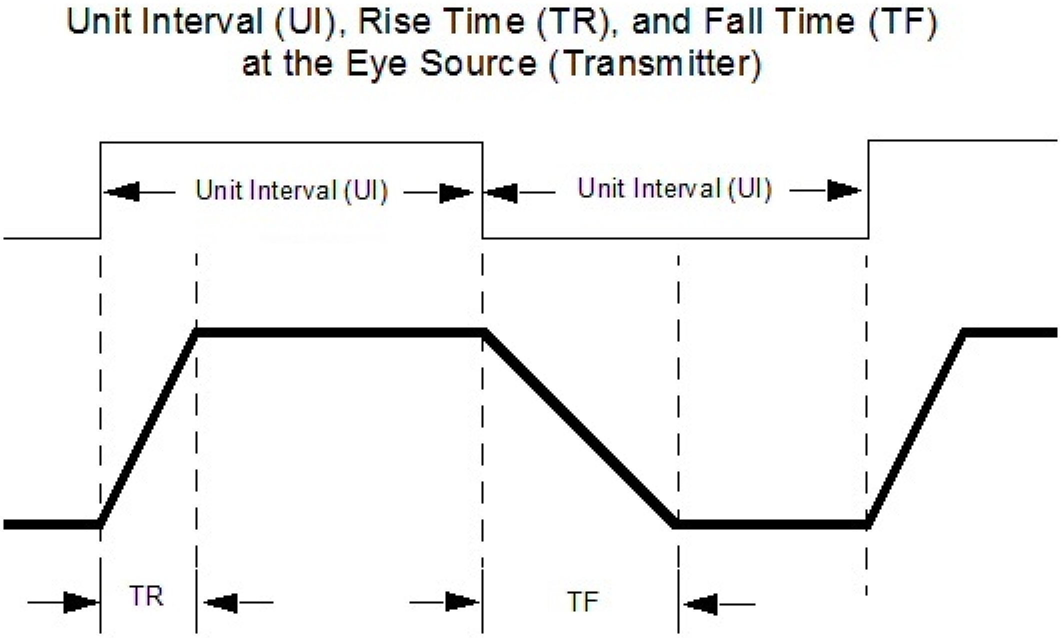
4. The Differential Eye source has the generalized internal structure shown in the following figure.



Each of the two nodes is driven with half the voltage amplitude of the single-ended source and opposite polarity. The output is symmetrical in that the average of the two outputs is close to zero. The series resistance is also divided equally between the two nodes. Both sources are internally grounded.

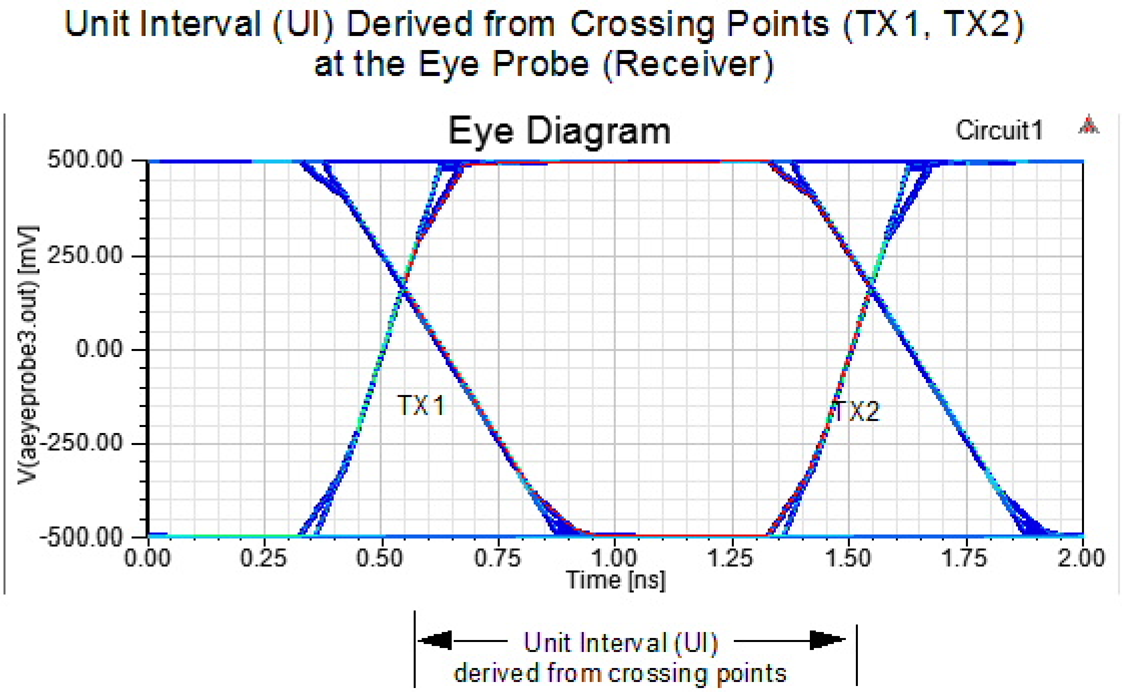
5. The Single-Ended Eye source connects to a signal line. The line should not be directly grounded. The corresponding Eye probe should also connect to the signal line without any direct ground connection.
6. The Differential Eye source connects to two signal lines. Neither node should be grounded. The corresponding Differential Eye probe should connect to the same two signal lines without direct grounding.
7. To visualize the relationships among the Eye Source parameters and how they affect the eye diagram at the output, here are two diagrams. Both of these diagrams are for MODULATION=NRZ, where each symbol is one bit, and the Unit Interval (UI) is the inverse of the Bit Rate (BPS).

The first diagram illustrates the Unit Interval, Rise Time, and Fall Time at the (NRZ) Eye Source or transmitter end.



- The upper part of the diagram illustrates an idealized clock. In this example, transitions begin on both rising and falling edges of the clock, so the Unit Interval (UI) is one-half of the clock period. For NRZ, the Bit rate (BPS) is the inverse of the UI time.
- The lower portion of the diagram illustrates the clocked output of a “1” followed by a “0.” In this example, the Rise time (TR) is smaller than the Fall time (TF). The diagram illustrates that the rising transition and falling transition begin at the same time relative to the clock edges, but the two transitions end at different times within their Unit Intervals.

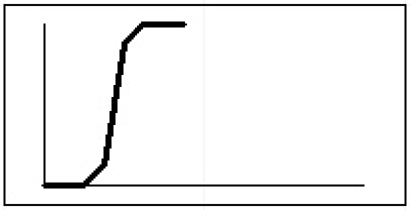
The second diagram illustrates an Eye Diagram generated from an NRZ bit stream using unequal rise time and fall time, similar to the TR and TF in the previous diagram. However, the receiver does not “know” anything about the UI, TR, or TF specified at the Eye Source.



- To generate the Eye Diagram, the UI must be specified on the Report window. In this example, the UI=1ns. The Report generator uses the specified UI to fold the data into the Eye diagram.
- The times and voltages at the crossing points of the rising and falling transitions are identified on the time/voltage data. The Eye Measurements facility uses the average times of the crossing points TX1 and TX2 to reconstruct the UI and calculate the measurement values. See *Eye Measurements* in the Reports topic for details.
- In the Eye Diagram above, note that the rising and falling edges do not cross at 0V (halfway between VHI=0.5V and VLO=-0.5V), because the rise time and fall time are not equal.

8. For more information on the Eye Source equalization and jitter parameters, see the *Quick Eye and VerifEye Technical Notes*.
9. For more information on the Spread Spectrum, see *Voltage Source, Spread Spectrum Clock* and *Add an Eye Source to a Schematic*.
10. **End of Simulation:** With transient analysis, the end of simulation is set by the stop time. For QuickEye analysis, simulation ends when the longest bit sequence (including any REPEAT_COUNT) is completed.

Eye External Step Response (ESR) Source



ESR Source Netlist Format

An Eye External Step Response source is inserted in a schematic to allow the user to specify the rising and falling step responses for QuickEye and VerifEye via data files. The netlist syntax is:

```
AESRxxxx COMPONENT=external_step_response

 + SOURCE_NAME='Eye Source'

 + PROBE_NAME='Eye Probe'

 + STEP_RESPONSE_FILE_RISE='file-reference'

 + STEP_RESPONSE_FILE_FALL='file-reference'
```

The ESR does not connect physically to the circuit. The ESR represents one set of step responses between one source and one probe, which must be specified. At least one of the step response files must be specified. If only one file is specified, symmetry is assumed. The data files use a two-column format: time voltage. Linear interpolation is used between time points. The entry **COMPONENT=external_step_response** identifies the component.

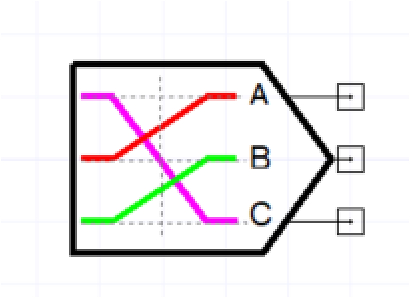
Table 11: ESR Source Parameters

Parameter	Description	Unit	Default
SOURCE_NAME	Name of the Eye Source for this ESR	None	Required
PROBE_NAME	Name of the Eye Probe for this ESR	None	Required
STEP_RESPONSE_FILE_RISE	Name of the file with the rise time step response	None	None
STEP_RESPONSE_FILE_FALL	Name of the file with the fall time step response	None	None

ESR Source Netlist Example

```
AESR3 COMPONENT=external_step_response
+ SOURCE_NAME='EYE_Source1'
+ PPROBE_NAME='EYE_Probe1'
+ STEP_RESPONSE_FILE_RISE='rising_SR.txt'
+ STEP_RESPONSE_FILE_FALL='falling_SR.txt'
```

MIPI-CPHY Transmitter



MIPI-CPHY Transmitter Parameters

Parameter	Description	Unit	Default
SIGNAL			
-Wire Signal Profile			
VLOW[1]	Low voltage level output of a wire node	Volt	0
VMID[1]	Mid voltage level output of a wire or node	Volt	0.5
VHIGH[1]	High voltage level output of a wire or node	Volt	1
TRISE_LH[2]	Rise time from VLOW to VHIGH	Sec	1e-10
TRISE_LM[2]	Rise time from VLOW to VMID	Sec	5e-11
TRISE_MH[2]	Rise time from VMID to VHIGH	Sec	5e-11
TFALL_HL[2]	Fall time from VHIGH to VLOW	Sec	1e-10
TFALL_HM[2]	Fall time from VHIGH to VMID	Sec	5e-11
TFALL_ML[2]	Fall time from VMID to VLOW	Sec	5e-11
DELAYA	Time Delay of signal on wire A	Sec	0
DELAYB	Time Delay of signal on wire B	Sec	0
DELAYC	Time Delay of signal on wire C	Sec	0
UIORDATARATE[3]	Select UI (time interval per symbol) or Data Rate	None	UnitInterval
UIORDATARATEVALUE[3]	Value of Unit Interval(sec) or Data Rate	Sec	1e-9

Parameter	Description	Unit	Default
	(symbols/sec)		
-Wire State Pattern			
RANDOM_STATE_COUNT	Number of randomly generated wire states	None	2.5e5
RANDOM_SEED[4]	Integer random seed for wire state sequence generation	None	1
REPEAT_COUNT[5]	Number of times to repeat wire state pattern	None	0
HOLD_LATE_STATE[6]	Hold last wire state sequence generation	None	Not checked
-Output Impedance			
RESISTANCE	Single-ended output impedance of each wire	Ohm	50
Jitter			
DCDFRACTIONORTIME[7]	Select Duty cycle distortion given as a fraction (of UI) or absolution time (sec)	None	Fraction
DCD[7]	Duty cycle distortion fraction (of UI) or absolution time (sec)		
TXRJ	Gaussian random jitter value (standard deviation)	Sec	0
TXPJ	Periodic random jitter value (amplitude)	Sec	0
TXUJ	Uniform random jitter value (amplitude)	Sec	0
EQUALIZATION			
FFE_data[8]	Enable and define TxEq parameters	NA	NA

Changing any of the parameter values and hitting **Enter**, will result in the **Override** box being checked. When **Override** box is checked, the set value for a parameter is enforced in simulation. Uncheck the box, its default value will be recovered.

Notes:

1. A MIPI-CPHY transmitter is composed of three single-ended nodes or lines/wires A, B and C. The three lines together form a single MIPI-CPHY lane. Each line transmits three-level signals: VLOW, VMID and VHIGH. At any unit interval, no two lines can take the same signal level. The combination of signal levels of wire A, B and C at a given UI is called a wire state. There are only six valid wire states as listed below:

Wire States

	Signal Level		
Wire State	**Wire A**	**Wire B**	**Wire C**
+x	VHIGH	VLOW	VMID
+y	VMID	VHIGH	VLOW
+z	VLOW	VMID	VHIGH
-x	VLOW	VHIGH	VMID
-y	VMID	VLOW	VHIGH
-z	VHIGH	VMID	VLOW

2. Due to three-level output from each node, there are three rise times and three fall times. It is assumed that rise or fall time between VLOW and VHIGH is not smaller than rise or fall time between VLOW and VMID, or VMID and VHIGH. Confirm that 'Override' boxes are checked if set values should be enforced.

3. The Unit Interval (UI) is the duration of one symbol. Data rate = 1/UI (symbols/sec).

4. Random seed determines random wire state sequence for transmission. A non-negative seed value controls the generated sequence. A negative seed value will be replaced by a value dependent upon time() and clock() in C++, hence the sequence can be different for each simulation even if the (negative) seed value is unchanged.

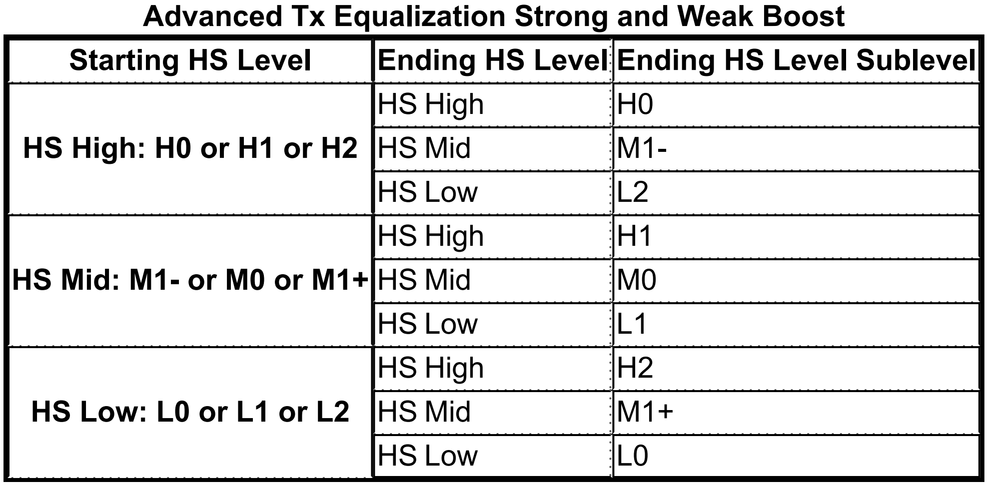
5. With transient analysis, the end of simulation is defined by the transient ‘stop’ time. REPEAT_COUNT sets the number of times to repeat the random wire state pattern. Total number of wire states = total number of symbols transmitted = (REPEAT_COUNT+1) * RANDOM_STATE_COUNT. REPEAT_COUNT must be a non-negative integer. When total number of wire states * UI is not equal to the transient ‘stop’ time, the randomly generated wire state pattern is repeated *by default* until and only up to the end of simulation ‘stop’ time.

6. When the box is checked, the last wire state (or the last transmitted symbol) of the randomly generated wire state pattern will be held and repeated until the end of simulation. By default, the box is not checked and the random wire state sequence will be repeated from the beginning until the end of simulation time is reached.

7. The Duty Cycle Distortion may be entered as a fraction of the UI or as an absolute time. When **Fraction** is selected, the value of DCD is given as a fraction of the UI. If **Time** is chosen, DCD is the absolute time of Duty Cycle Distortion.

8. Advanced equalization in Tx helps MIPI C-PHY system performance at high data rates with ISI and jitter noise. When Advanced TxEq is enabled, each of the Tx wires can output 9 voltage levels: VH0, VH1, VH2 (sublevels for VHIGH), VM1-, VM0, VM1+ (sublevels for VMID), and VL2, VL1, VL0 (sublevels for VLOW). Transition rules for FFE boost are given

in MIPI C-PHY specification v2.1 as follows:



Advanced Tx Equalization Strong and Weak Boost

Starting HS Level	Ending HS Level	Ending HS Level Sublevel
HS High: H0 or H1 or H2	HS High	H0
	HS Mid	M1-
	HS Low	L2
HS Mid: M1- or M0 or M1+	HS High	H1
	HS Mid	M0
	HS Low	L1
HS Low: L0 or L1 or L2	HS High	H2
	HS Mid	M1+
	HS Low	L0

The sublevel magnitudes with respect to the main signal levels are defined by following EQ values in dB following MIPI CPHY specification v2.1:

$$EQ_{M1+} = -20 \cdot \log\left(\frac{V_{H2} - V_{M1+}}{V_{H2} - V_{M0}}\right)$$

$$EQ_{M1-} = -20 \cdot \log\left(\frac{V_{M1-} - V_{L2}}{V_{M0} - V_{L2}}\right)$$

$$EQ_{H1} = -20 \cdot \log\left(\frac{V_{H1} - V_{M0}}{V_{H2} - V_{M0}}\right)$$

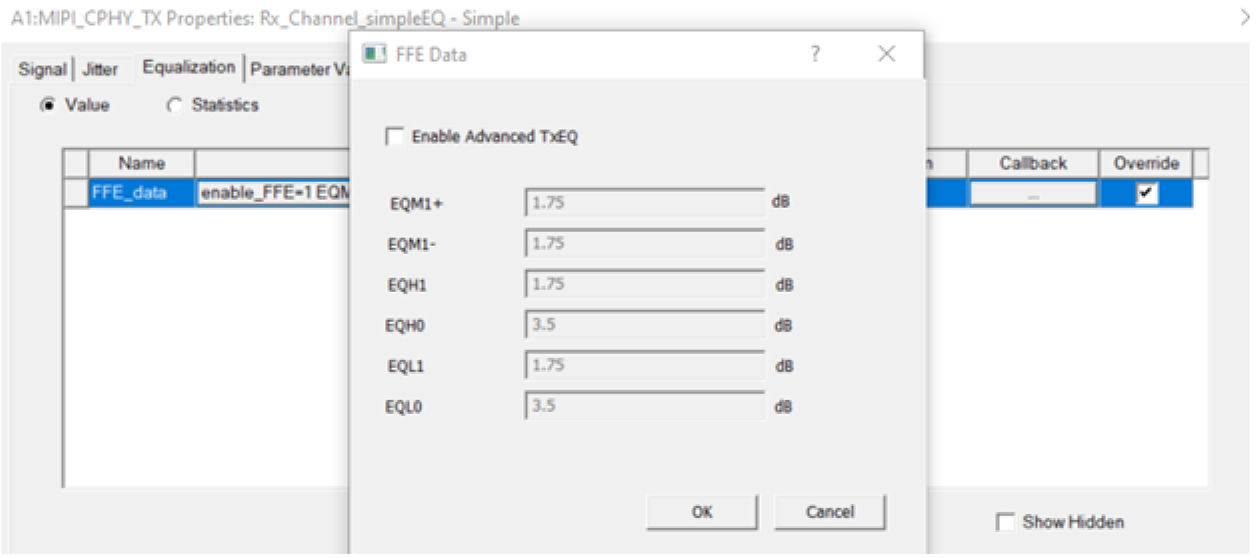
$$EQ_{H0} = -20 \cdot \log\left(\frac{V_{H0} - V_{M0}}{V_{H2} - V_{M0}}\right)$$

$$EQ_{L1} = -20 \cdot \log\left(\frac{V_{M0} - V_{L1}}{V_{M0} - V_{L2}}\right)$$

$$EQ_{L0} = -20 \cdot \log\left(\frac{V_{M0} - V_{L0}}{V_{M0} - V_{L2}}\right)$$

These EQ values can be adjusted based on channel condition and data rate to improve performance.

Click the **Value** field for the **FFE_data** to open the FFE Data dialog.



● Value ○ Statistics

FFE_data enable_FFE=1 EQM

☐ Enable Advanced TxEQ

EQM1+ 1.75 dB
EQM1- 1.75 dB
EQH1 1.75 dB
EQH0 3.5 dB
EQL1 1.75 dB
EQL0 3.5 dB

☐ Show Hidden

Check **Enable Advanced TxEQ** to make the FFE Data fields editable.

FFE Data Fields

Parameters	Description	Unit	Default
EQM1+	dB value to define VMID sublevel VM1+	dB	1.75
EQM1-	dB value to define VMID sublevel VM1-	dB	1.75
EQH1	dB value to define VHIGH sublevel VH1	dB	1.75
EQH0	dB value to define VMID sublevel VH0	dB	3.5
EQL1	dB value to define VMID sublevel VL1	dB	1.75
EQL0	dB value to define VMID sublevel VL0	dB	3.5

MIPI-CPHY Transmitter Netlist Format

AMIPHI_CPHY_TXxx net_1 net_2 net_3 COMPONENT=MIPI_CPHY_TRANSMITTER

+RESISTANCE=*val*

+TRISE_LM=*val* TRISE_MH=*val* TRISE_LH=*val* TFALL_ML=*val* TFALL_HM=*val* TFALL_HL=*val* +VLOW=*val* VMID=*val* VHIGH=*val*

+DELAYA=*val* DELAYB=*val* DELAYC=*val*

+UI=*val*

+TXRJ=*val* TXPJ=*val* TXUJ=*val*

+DCD=*val* (or +DCD_TIME=*val*)

+RANDOM_STATE_COUNT=*val* RANDOM_SEED=*val*

+REPEAT_COUNT=*val* HOLD_LAST_STATE=*val*

(+enable_FFE=*1* EQM1_p=*val* EQM1_m=*val* EQH1=*val* EQH0=*val* EQL1=*val* EQL0=*val*

or

+enable_FFE=*0*)

When all parameters take default values, the transmitter netlist is as follows:

AMIPHI_CPHY_TXxx net_1 net_2 net_3 COMPONENT=MIPI_CPHY_TRANSMITTER

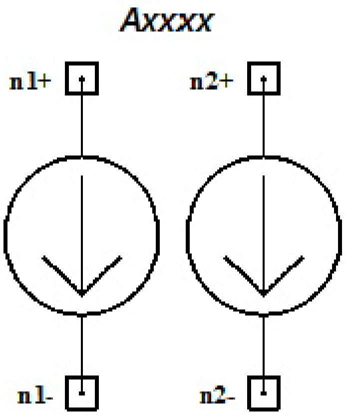
+RESISTANCE=*val*

When a parameter is altered or **Override** box next to it is checked, the parameter and its value will be listed in the netlist as shown in the following example.

MIPI-CPHY Transmitter Netlist Example

```
AMIPHI_CPHY_TX26 nA nB nC COMPONENT=MIPI_CPHY_TRANSMITTER
RESISTANCE=50 VLOW=0 VMID=0.35 VHIGH=0.7 UI=2e-09 RANDOM_STATE_
COUNT=1000 REPEAT_COUNT=25
```

Noise Source, Current, 2-Branch



Two-Branch Current Noise Source Netlist Format

The format to include a 2-branch current noise source is:

A*xxxx n1+ n2+ n1- n2-* **in1=***val* **in2=***val* **c12r=***val* **c12i=***val*
COMPONENT=inoise_source_2

n1+ and *n2+* are the positive nodes. *n1-* and *n2-* are the corresponding negative nodes.

The parameter **COMPONENT=inoise_source_2** identifies the element as a two-branch current noise source.

Table 12: Two-Branch Current Noise Source Parameters

Parameter	Description	Unit	Default
in1	First current source, RMS amplitude (must be positive or zero)	Ampere/Hz ½	0.0
in2	Second current source, RMS amplitude (must be positive or zero)	Ampere/Hz ½	0.0
c12r	Correlation coefficient, real part	None	0.0
c12i	Correlation coefficient, imaginary part	None	0.0

Two-Branch Current Noise Source Netlist Example

```
Ainsrc2 10 11 0 0 in1=1.1e-20 in2=3.0e-19
+ c12r=0.75 c12i=0.25 COMPONENT=inoise_source_2
```

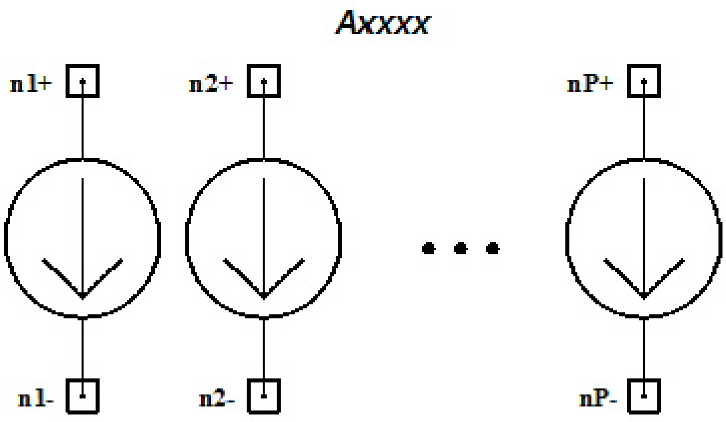
Notes

1. The noise correlation matrix is a symmetric conjugate matrix of dimension 2 ×2:

$$C = \begin{bmatrix} in1 \times in1 & (c_{12}r + jc_{12}i) \times (in1 \times in2) \\ [(c_{12}r + jc_{12}i) \times (in1 \times in2)]^* & in2 \times in2 \end{bmatrix}$$

In this matrix, the element below the diagonal is the conjugate of the corresponding element above the diagonal ($C_{21} = C_{12}^*$).

Noise Source, Current, N-Branch (Netlist Only)



> **Note:**
>
> The N-branch current noise source is available for use in netlists, but is not supported in the Components window of the **Electronics Desktop Schematic Editor**. A 2-branch current noise source is supported in Nexxim Schematics, but it uses a syntax that is similar to the syntax used in the Circuit NSRCC component.

Current Noise Source Netlist Format

The format to include a current noise source is:

```
Axxxx n1+ [n2+ ...] n1- [n2- ...]

NOISECORR_REAL=(c11r [,c12r ...])

NOISECORR_IMAG=(c12i [,c13i ...])

COMPONENT=inoise_source
```

n1+, *n2+*, etc., are the positive nodes. *n1-*, *n2-*, etc., are the corresponding negative nodes. The list of nodes (positive plus negative) must contain an even number of nodes. Using N to represent the total number of nodes in the list, the first N/2 nodes are taken to be the positive nodes.

The parameter **COMPONENT=inoise_source** identifies the element as a current noise source.

Table 13: Current Noise Source Parameters

Parameter	Description	Unit	Default

NOISECORR_REAL	List of real noise correlation coefficients	None	Required
NOISECORR_IMAG	List of imaginary noise correlation coefficients	None	Required

Current Noise Source Netlist Example

```
Ainsrc 10 11 12 0 0 0
+ NOISECORR_REAL=
+ (1.1e-20, 3.0e-19, 5.2e-20, 1.0e-18, 0.1e-18, 2.8e-19)
+ NOISECORR_IMAG=(-0.5e-20, 2.0e-20, 7.7e-19)
+ COMPONENT=inoise_source
```

Notes

1. The noise correlation matrix is a symmetric conjugate matrix of dimension P × P, where P is the number of positive nodes:

$$C = \begin{bmatrix} C_{11}r + C_{11}i & \dots & C_{1P}r + C_{1P}i \\ \dots & \dots & \dots \\ C_{P1}r + C_{P1}i & \dots & C_{PP}r + C_{PP}i \end{bmatrix}$$

In this matrix, the elements above the diagonal are the conjugates of the corresponding elements below the diagonal ($C_{jk} = C_{kj}^*$).

The noise correlation matrix is specified in two parts. The real part is specified with the **NOISECORR_REAL** parameter list and the imaginary part is specified with the **NOISECORR_IMAG** parameter list.

2. **NOISECORR_REAL Parameter**

The real noise correlation coefficients form a symmetric matrix of dimension P × P, where P is the number of positive nodes.

$$\begin{bmatrix} C_{11}r & \dots & C_{1P}r \\ \dots & \dots & \dots \\ C_{P1}r & \dots & C_{PP}r \end{bmatrix}$$

In this matrix, the diagonal elements are always positive ($C_{kk}r \geq 0$). The elements above the diagonal are equal to the corresponding elements below the diagonal ($C_{jk}r = C_{kj}r$).

For example, when P=3 the real part of the noise correlation matrix has the following elements:

$$\begin{bmatrix} C_{11}r & C_{12}r & C_{13}r \\ C_{21}r & C_{22}r & C_{23}r \\ C_{31}r & C_{32}r & C_{33}r \end{bmatrix}$$

The **NOISECORR_REAL** parameter list should specify only the elements on or above the diagonal. The entry for the matrix in this example has the form:

```
NOISECORR_REAL=(c11r, c12r, c13r, c22r, c23r, c33r)
```

3. **NOISECORR_IMAG Parameter**

The imaginary noise correlation coefficients form a matrix of dimension P × P, where P is the number of positive nodes. However, the diagonal of this matrix has all zeros:

$$\begin{bmatrix} 0 & \dots & C_{1P}i \\ \dots & 0 & \dots \\ C_{P1}i & \dots & 0 \end{bmatrix}$$

The elements below the diagonal are the negatives of the corresponding elements above the diagonal ($C_{jk}i = -C_{kj}i$)

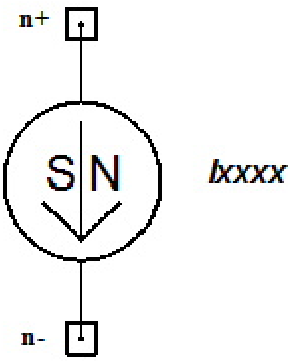
For example, when P=3 the imaginary noise correlation coefficient matrix has the following elements:

$$\begin{bmatrix} 0 & C_{12}i & C_{13}i \\ C_{21}i & 0 & C_{23}i \\ C_{31}i & C_{32}i & 0 \end{bmatrix}$$

The **NOISECORR_IMAG** parameter list should specify only the elements above the diagonal. The entry for the matrix in this example has the form:

```
NOISECORR_IMAG=(c12i, c13i, c23i)
```

Shot Noise Source, Current



Current Shot Noise Source Netlist Format

A shot noise current source is just a DC=0 current source with a **NOISEVEC** parameter:

`ISHOTNOISE``xxxx n+ n-` **`DC=0 NOISEVEC=[`**`f1,psd1,... fn,psdn`**`]`**

n+ is the positive node and *n-* is the negative node of the current source. The **NOISEVEC** parameter applies the specified power spectral density at each specified frequency.

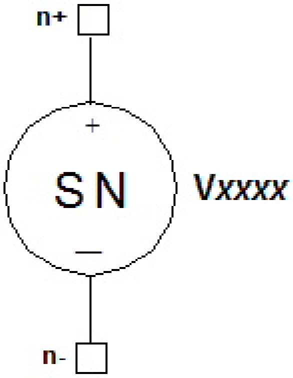
Table 14: Shot Noise Current Source Parameters

Parameter	Description	Unit	Default
NOISEVEC	List of shot noise frequencies (f1...fn) and corresponding noise power spectral densities (psd1...psdn), in pairs. The sequence of frequencies must be monotonically non-decreasing.	Hertz, Volt ^{2} /Hertz	None

Current Shot Noise Source Netlist Example

```
ISHOTNOISE32 net_1 0 DC=0 NOISEVEC=[1e6,2.7,2e6,3.4,3e6,10.37]
```

Shot Noise Source, Voltage



Voltage Shot Noise Source Netlist Format

A voltage shot noise source is just a DC=0 voltage source with a **NOISEVEC** parameter:

`VSHOTNOISE`*`xxxx n+ n-`* **`DC=0 NOISEVEC=[`***`f1,psd1,... fn,psdn`***`]`**

n+ is the positive node and *n-* is the negative node of the voltage source. The **NOISEVEC** parameter applies the specified power spectral density at each specified frequency.

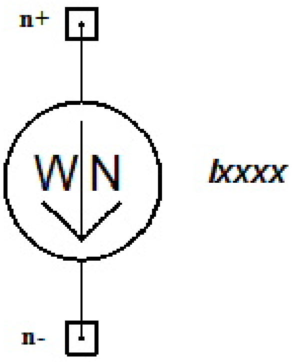
Table 15: Shot Noise Voltage Source Parameters

Parameter	Description	Unit	Default
NOISEVEC	List of shot noise frequencies (f1...fn) and corresponding noise power spectral densities (psd1...psdn), in pairs. The sequence of frequencies must be monotonically non-decreasing.	Hertz, Volt ^{2} /Hertz	None

Voltage Shot Noise Source Netlist Example

```
VSHOTNOISE32 net_1 0 DC=0 NOISEVEC=[1e6,2.7,2e6,3.4,3e6,10.37]
```

White Noise Source, Current



Current White Noise Source Netlist Format

A white noise current source is just a DC=0 current source with a special **NOISEVEC** parameter:

`IWHITENOISE`*`xxxx n+ n-`* **`DC=0 NOISEVEC=[1,`***`psd`*`,` **`1.1,`***`psd`***`]`**

n+ is the positive node and *n-* is the negative node of the current source. The **NOISEVEC** parameter applies the specified power spectral density across all frequencies.

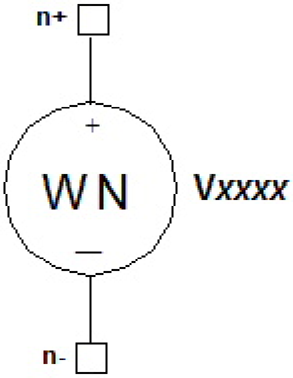
Table 16: White Noise Current Source Parameters

Parameter	Description	Unit	Default
NOISEVEC	Sets noise at all frequencies to given PSD.	Hertz, $Volt^2$/Hertz	None

Current White Noise Source Netlist Example

```
IWHITENOISE32 net_1 0 DC=0 NOISEVEC=[1,27.7, 1.1, 27.7]
```

White Noise Source, Voltage



Voltage White Noise Source Netlist Format

A voltage white noise source is just a DC=0 voltage source with a **NOISEVEC** parameter:

`VWHITENOISE`*`xxxx n+ n-`* **`DC=0 NOISEVEC=[1,`***`psd`*`,` **`1.1,`***`psd`***`]`**

n+ is the positive node and *n-* is the negative node of the voltage source. The **NOISEVEC** parameter applies the specified power spectral density across all frequencies.

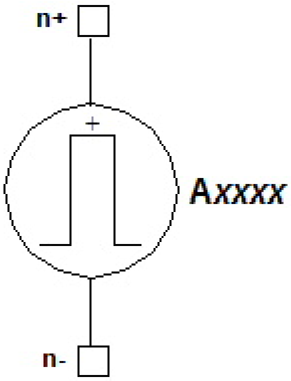
Table 17: White Noise Voltage Source Parameters

Parameter	**Description**	**Unit**	**Default**
NOISEVEC	Sets noise at all frequencies to given PSD.	Hertz, Volt^2/Hertz	None

Voltage White Noise Source Netlist Example

```
VWHITENOISE12 net_15 0 DC=0 NOISEVEC=[1,4.32, 1.1, 4.32]
```

Voltage Source, Clock with Jitter



Voltage Clock Source with Jitter Netlist Format

The format for a voltage clock source with jitter is:

A*xxxx n+ n-* [**DC=***val*] [**V1=***val*] [**V2=***val*] [**TD=***val*] [**TR=***val*] [**TF=***val*] [**PW=***val]* [**PER=***val*] [**JITTER=***val*] [**SEED=***val*] [**ROUT=***val*] [**TONE=***val*] [**NOISEVEC=[***f1*,*psd1*,... *fn*,*psdn***]**]

COMPONENT=vjitter_source

n+ and *n-* are the positive and negative nodes. The entry **COMPONENT=vjitter_source** is required.

Table 18: Voltage Clock Source with Jitter, Parameters

Parameter	Description	Unit	Default
DC	DC voltage	Volt	0.0
V1	Clock low voltage value	Volt	0.0
V2	Clock high voltage value	Volt	0.0
TD	(Positive) delay time to start of upramp	Second	0.0
TR	Risetime from V1 to V2	Second	1e-9
TF	Fall time from V2 to V1	Second	1e-9
PW	Pulse width (V2 hold time)	Second	1e100
PER	Nominal period of clock cycle	Second	1.5e100
JITTER	Standard deviation (σ) for distribution of jitter in clock period. Maximum displacement is ±3σ.	Second	0.0
SEED	Integer seed for random jitter distribution	None	0

ROUT	Output resistance for jitter calculation	Ohm	1.0
TONE	Frequency to use for harmonic balance analysis, should be a submultiple of or equal to the driving frequency and should also be included in the HB solution setup	Hertz	0.0
NOISEVEC	List of shot noise frequencies (f1...fn) and corresponding noise power spectral densities (psd1...psdn), in pairs. The sequence of frequencies must be monotonically non-decreasing.	Hertz, Volt^2/Hertz	None

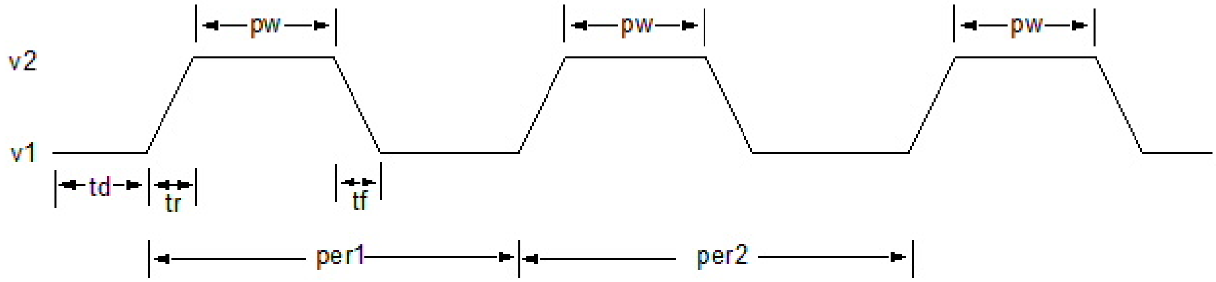
Note: Units shown above are for users entering netlists directly. When using the UI to enter values, SI units are assumed unless specific units are shown. In particular, for angles, a unitless number entered into the Property value is interpreted as radians. Users are encouraged to enter explicit units (e.g., "45deg") if there is any uncertainty.

Voltage Clock Source with Jitter Example

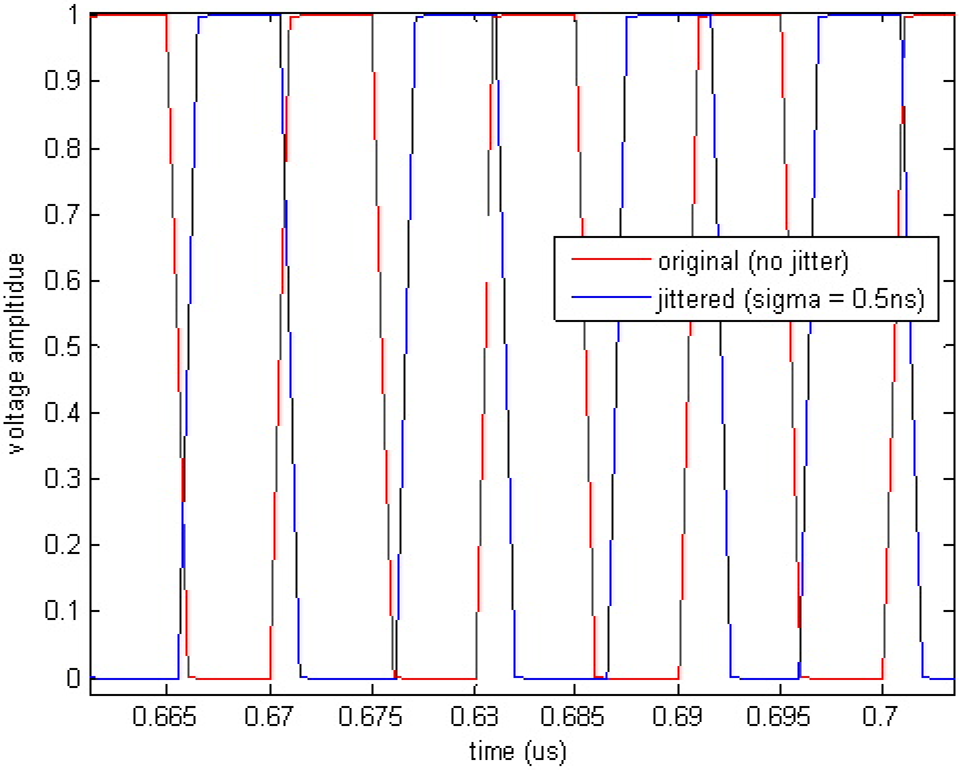
```
A11 net_1 0 v1=0 v2=1 td=0 tr=1.0e-9 tf=1.0e-9
+ pw=4.0e-9 per=10.0e-9 Rout=1.0 jitter=0.5e-9 seed=12345
+ COMPONENT=vjitter_source
```

Notes

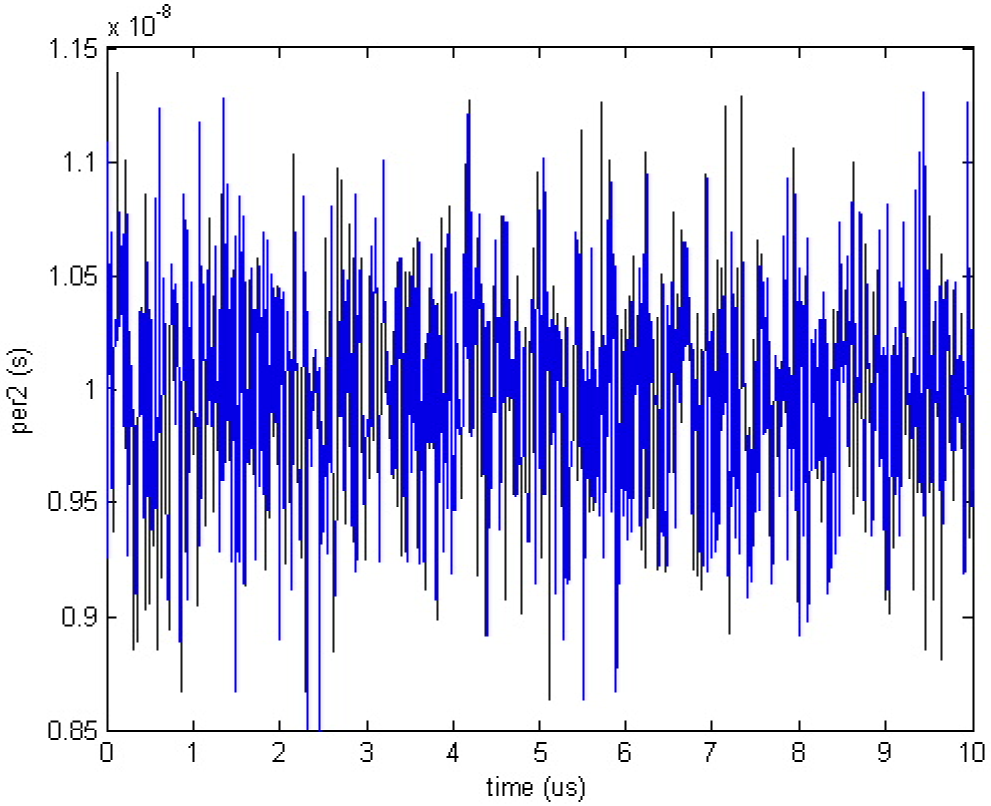
1. The voltage clock source with jitter is supported only for time domain simulations.
2. Only jitter in the overall clock period is simulated. Pulse width jitter is not calculated separately.
3. The jitter that is simulated is typical of Bounded Uncorrelated jitter (BUJ) rather than true random jitter (RJ). It simulates the jitter due to transitions on neighboring traces, and is uncorrelated with transitions on the clock itself. This device is useful for studies of crosstalk and similar effects.
4. The voltage clock source repeats the clock waveform with random variations in the period, as shown in the following figure.



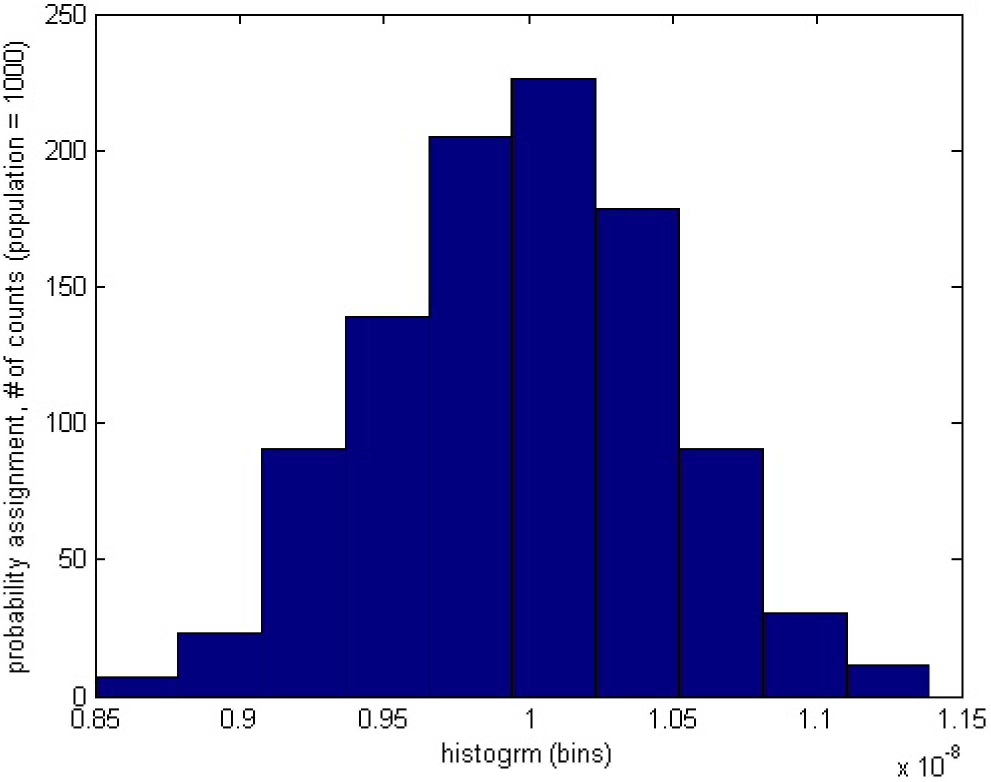
5. If **PW** is negative, **PER** and **PW** are both set to their default values.
6. If nominal period **PER** is less than (**TF** +**TR** +**PW**), **PER** is set to (**TF** +**TR** +**PW**)
7. The period is the nominal value set by the **PER** entry, summed with a jitter value that is drawn at random from a normal distribution using the **JITTER** entry as the standard deviation. The maximum jitter is plus/minus three standard deviations. The pulse width (V2 hold time) is not affected by the jitter. The optional **SEED** can be used to initialize the random number sequence.
8. The clock source is a voltage source in series with resistor **ROUT**. Output resistance **ROUT** is inserted (internally) at the output of the source. If **ROUT** is zero, the source is an ideal voltage source.
9. For harmonic balance (HB) analysis, the analyzed tones must be submultiples or equal to the frequencies of the actual voltage or current inputs to the circuit. To ensure that the appropriate HB frequency is used qualify the source by adding a **TONE** =*tone_val* entry at the end of the instance statement. The *tone_val* is then used in a subsequent HB statement.
10. Here is the time-domain simulation of this example source, showing the clock waveform with and without jitter:



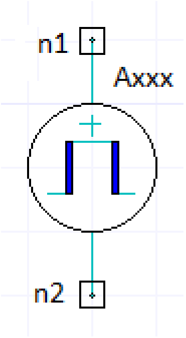
Here is a graph of the period times:



Here is a histogram of the period times:



Voltage Source, Spread Spectrum Clock



The netlist format for the spread spectrum clock source is:

Assc*xxxx n+ n-* **COMPONENT=vss_clock V1=***val* **V2=***val* **fc=***val* **trf=***val*
+ **dutycycle** =*val* **td=***val* **ss_freq=***val* **ss_profile=**'*modulation_profile*'
+ **ss_spread=**'*modulation_spread*' **ss_d=***val* [**TONE=***tone_val*]

n+ and *n-* are the positive and negative nodes. The entry **COMPONENT=vss_clock** is required.

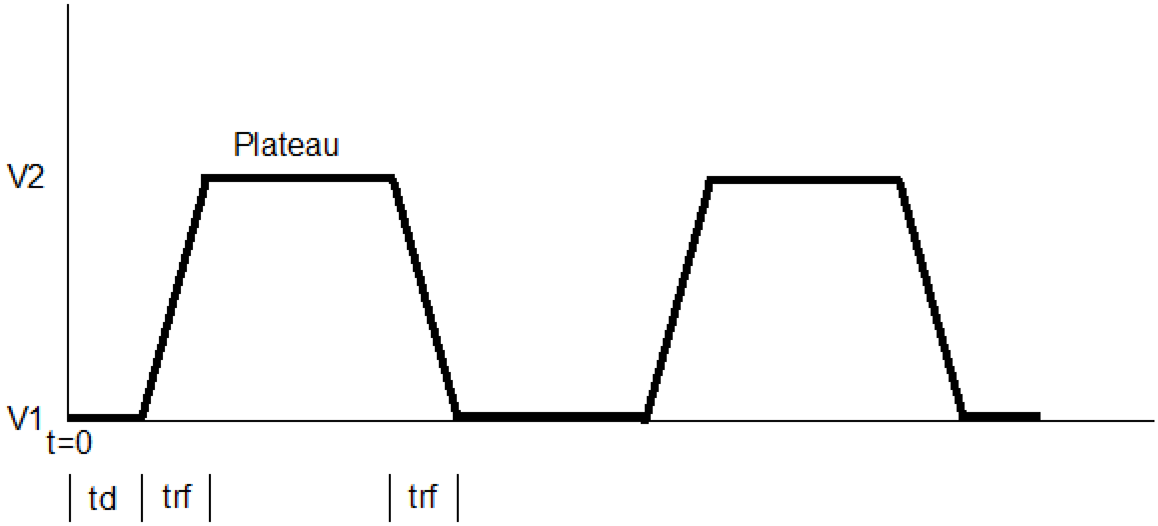
Table 18: Spread Spectrum Clock Parameters

Parameter	Description	Unit	Default
V1	Voltage at the start of simulation	Volt	0.0
V2	Voltage at the plateau	Volt	1.0
ClockFrequency (fc)	Main clock frequency	Hz	1GHz
RiseOrFallTime (trf)	Rise time and fall time of clock waveform	Second	0.1ns
DutyCycle	Duty cycle of the clock signal (percent)	None	50%
Delay time (td)	(Non-negative) delay time to start of 1st clock transition	Second	0.0
Spread Spectrum Parameters (in a window, active when Enable SSC is checked, unavailable otherwise):			
Modulation profile (ss_profile)	Modulation profile: **triangular** or **sinusoidal**	None	triangular
Spread type (ss_spread)	Displacement of spread relative to **fc**: **center**, **up**, or **down**	None	down
Modulation frequency (ss_freq)	Modulation rate (frequency)	Hz	33kHz
Spread rate (%) (ss_d)	Spreading rate (percent of **fc**)	None	0.5%
Harmonic Balance Parameter:			
tone	For Harmonic Balance only. Frequency to use for harmonic balance analysis. Should be a submultiple of or equal to the main clock frequency.See *TONE Parameter on Sources* in the Circuit Design help topics.	Hertz	0.0

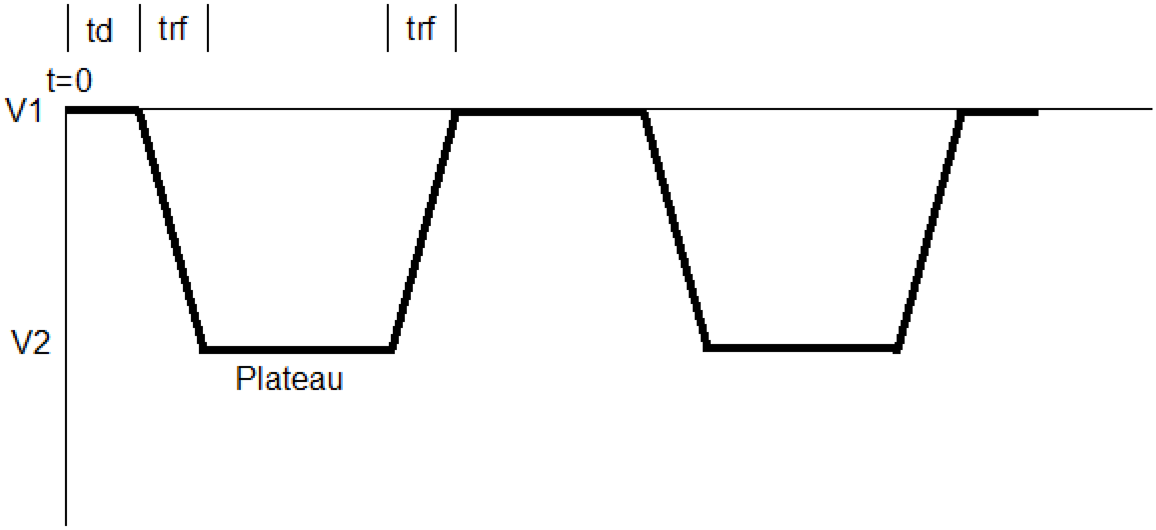
Notes

1. The spread spectrum clock (SSC) uses frequency modulation to provide improved EMI performance over the unmodulated clock.

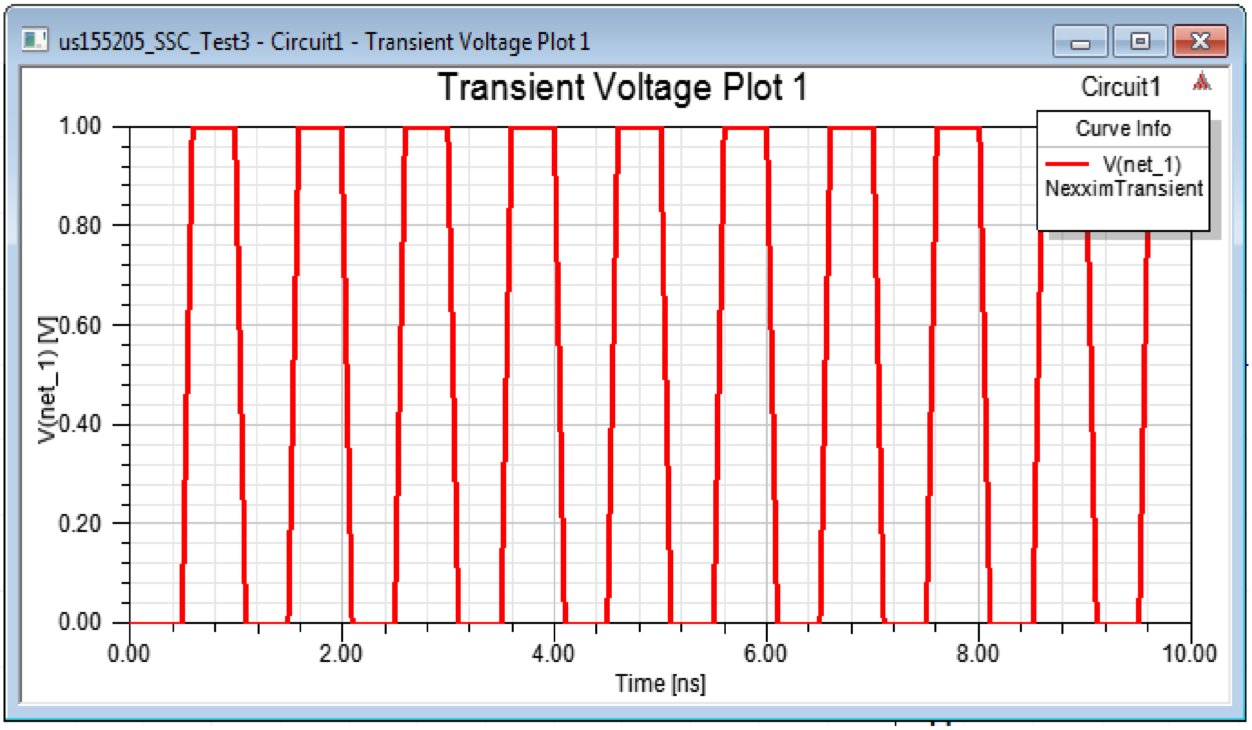
2. When the spread spectrum feature is unavailable (Enable SSC check box is not checked), the component functions as a simple digital clock with frequency **fc**, rise and fall times **trf**, **dutycycle**, and with an initial delay **td**.
3. **V1** and **V2** are the two voltage levels. When **V2** is greater than **V1**, the clock starts on a rising edge:



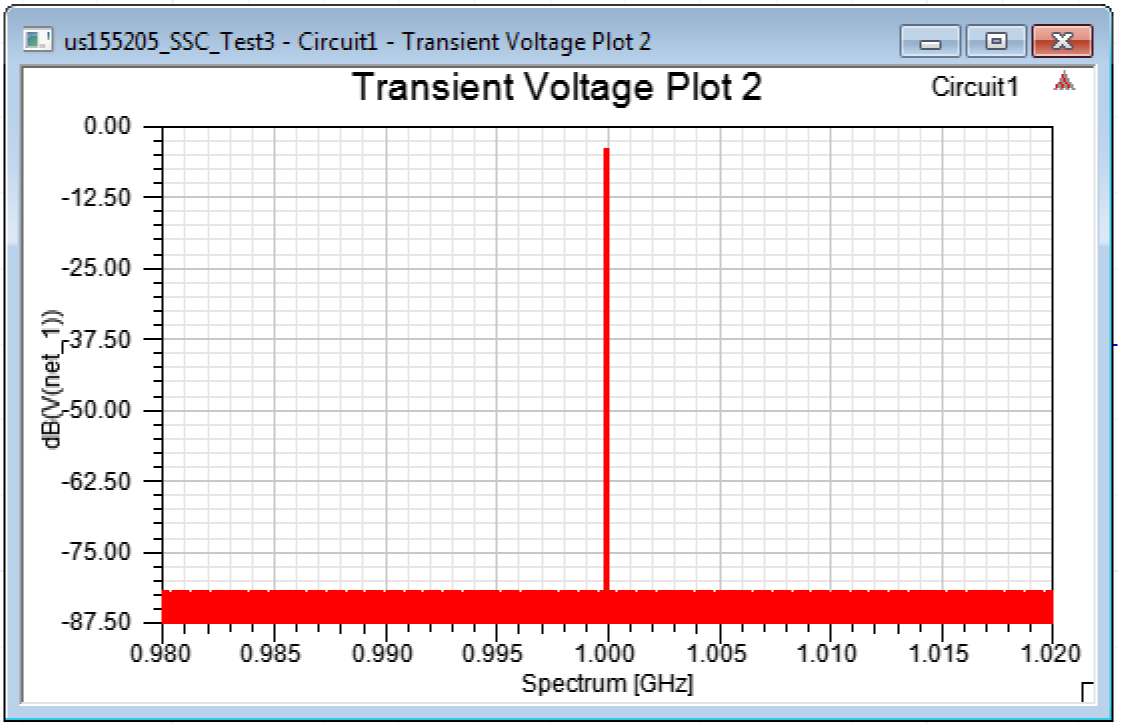
When **V2** is less than **V1**, the clock starts on a falling edge:



Here is a plot of the clock signal with V1=0V, V2=1V, td=0.5ns, trf=0.1ns, dutycycle=50, and fc=1GHz:

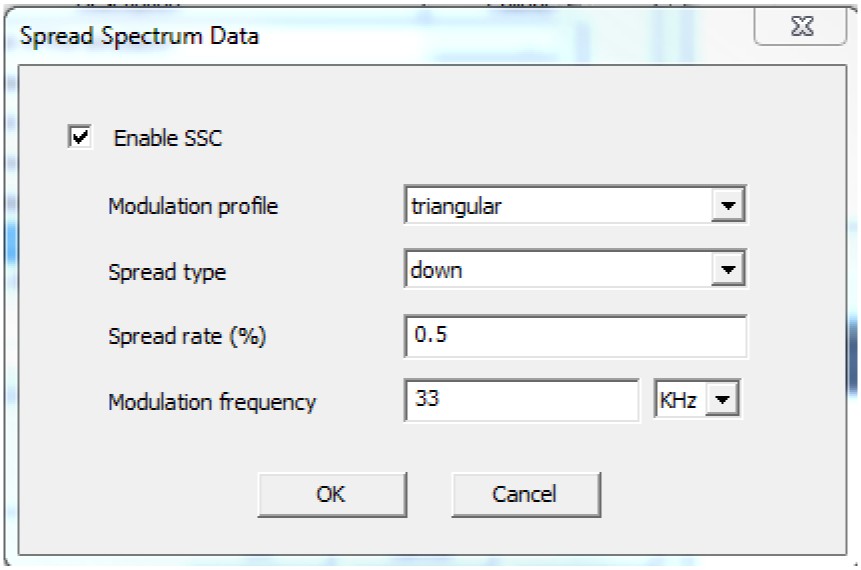


The spectrum of the clock has peaks at the main clock frequency and its harmonics. Here is a zoomed-in spectral plot of the peak at the main clock frequency (1GHz) clock signal above:



The peak has magnitude -4dB.

2. The SSC is enabled with a check box on the Spread Spectrum Data window. Click the **Value** field of the **Spread Spectrum** property to open the window:



Spread Spectrum Data

☑ Enable SSC

Modulation profile: triangular

Spread type: down

Spread rate (%): 0.5

Modulation frequency: 33 KHz

In this component, the SSC feature is enabled by default. When enabled, the SSC spreads the spectral energy to mitigate EMI.

3. The change in modulated clock frequency affects both rising and falling edges.
4. The spread type of the modulation can be Down, Center, or Up. With down-spreading, the spectral spreading lies below the main clock frequency. With center spreading, the spectral spreading is centered on the main clock frequency. With up-spreading, the spectral spreading lies above the main clock frequency.

Down:

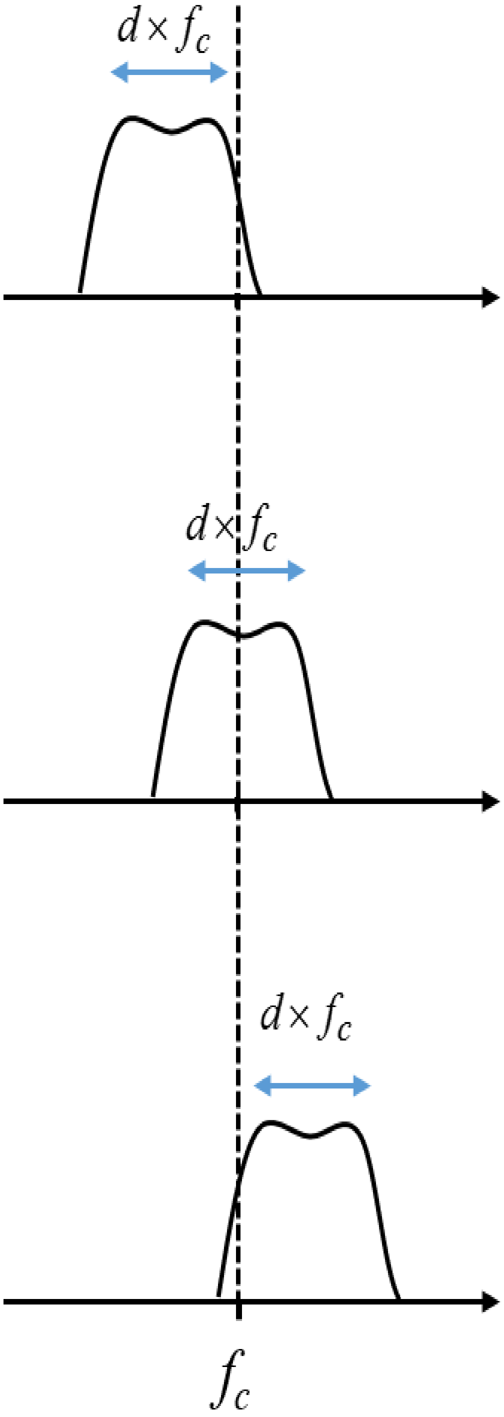
$$f_{ssc}(t) = f_c + 0.5 \times df_c\left(x_m(t) - 1\right)$$

Center:

$$f_{ssc}(t) = f_c + 0.5d \times f_c x_m(t)$$

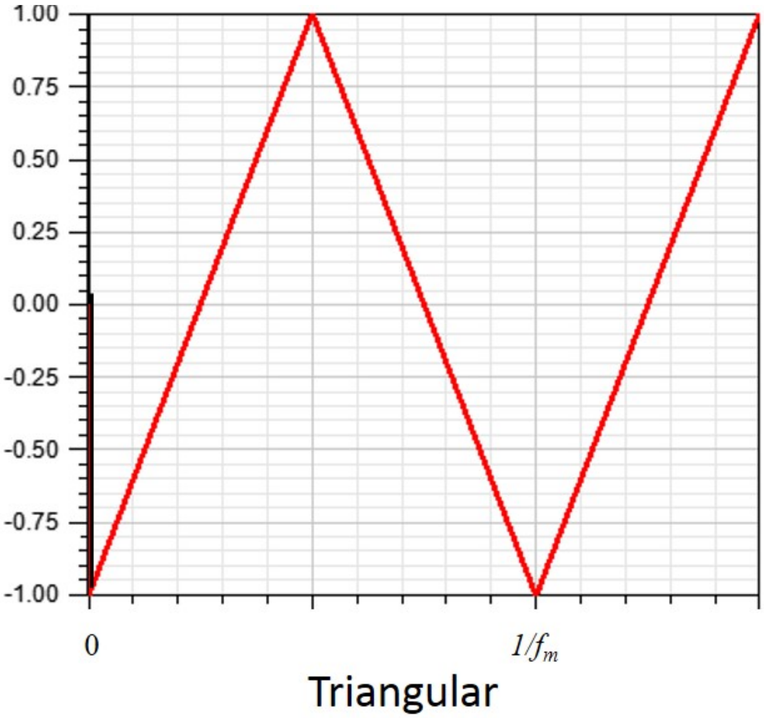
Up:

$$f_{ssc}(t) = f_c + 0.5 \times df_c\left(x_m(t) + 1\right)$$

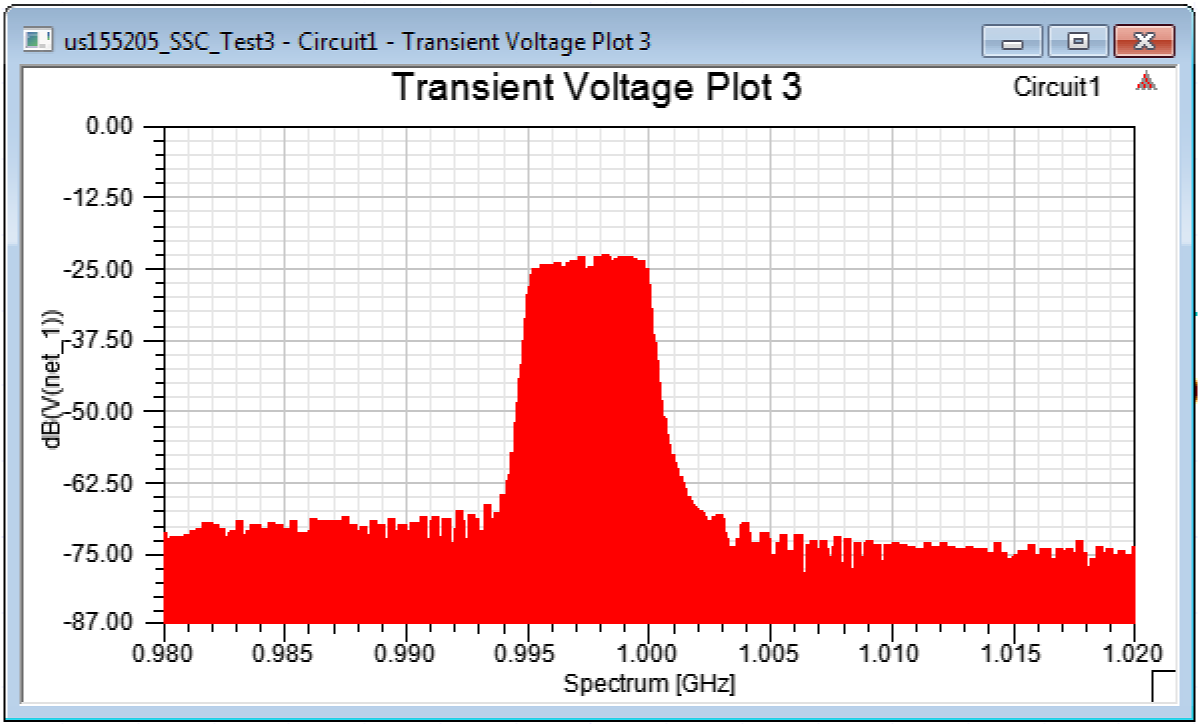


In these diagrams, $x_m(t)$ is a periodic low-frequency modulating signal with frequency *fm* varying from -1 to +1 and *d* is the spreading percent relative to f_c (divided by 100). The examples that follow all use down-spreading (the default).

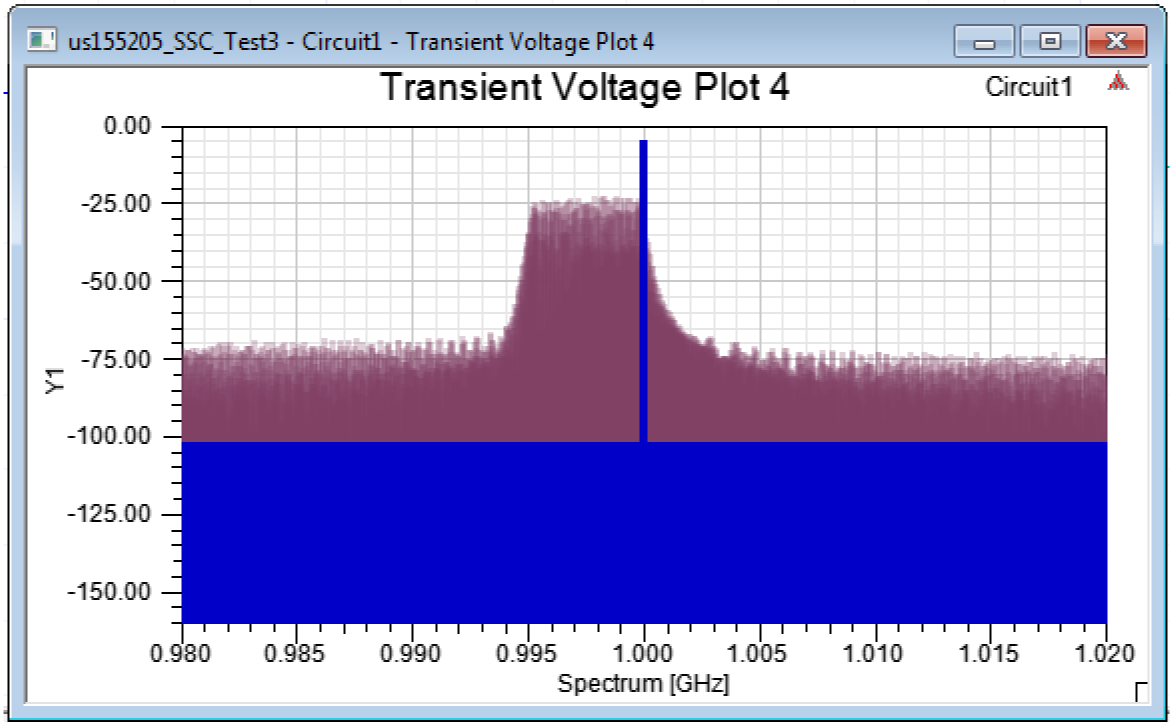
5. The modulating waveform $x_m(t)$ can be triangular or sinusoidal. Triangular is the default.



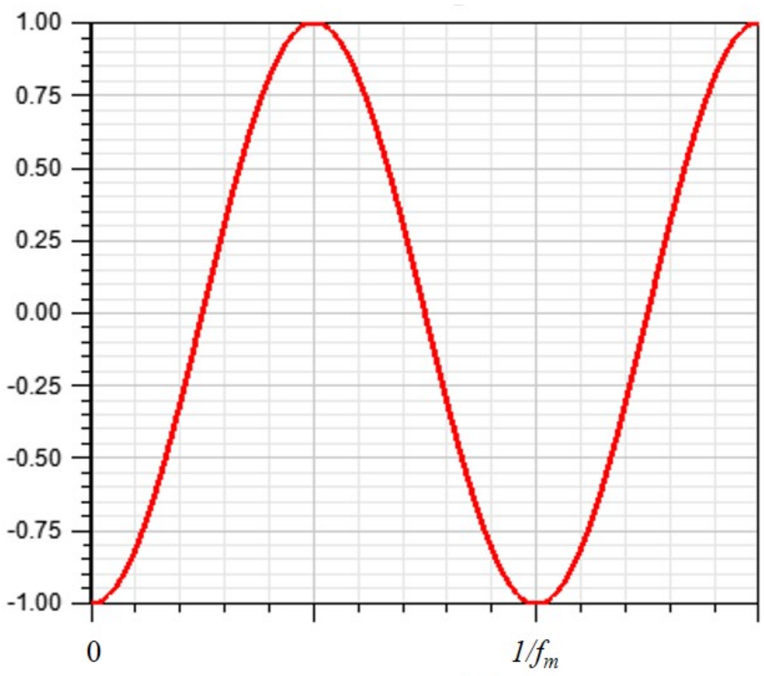
Here is the spectrum of the clock (50% duty cycle) above when triangular modulation is applied (down-spreading, spread rate 0.5%, modulation frequency 33kHz):



The magnitude of the peak now is -22.5dB. The peak value is reduced by 18.5dB with respect to the non-SSC. Here is a combined plot to show the reduction in peak value.

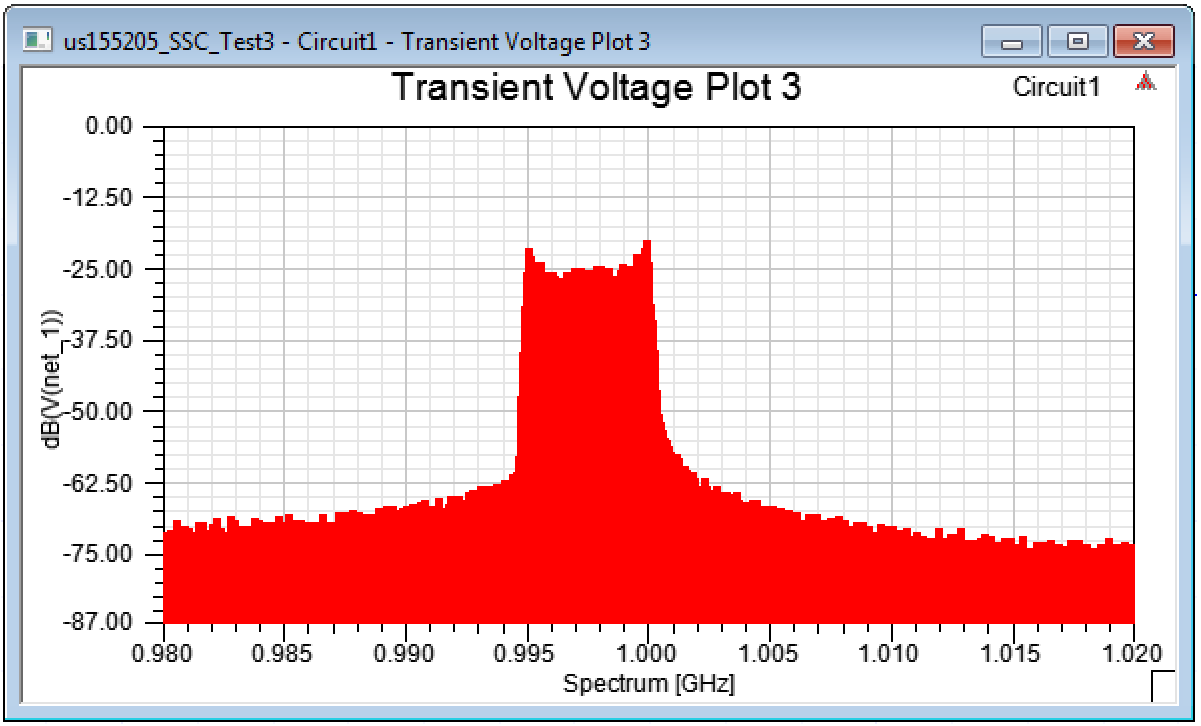


Alternatively, the modulating wave can be sinusoidal.

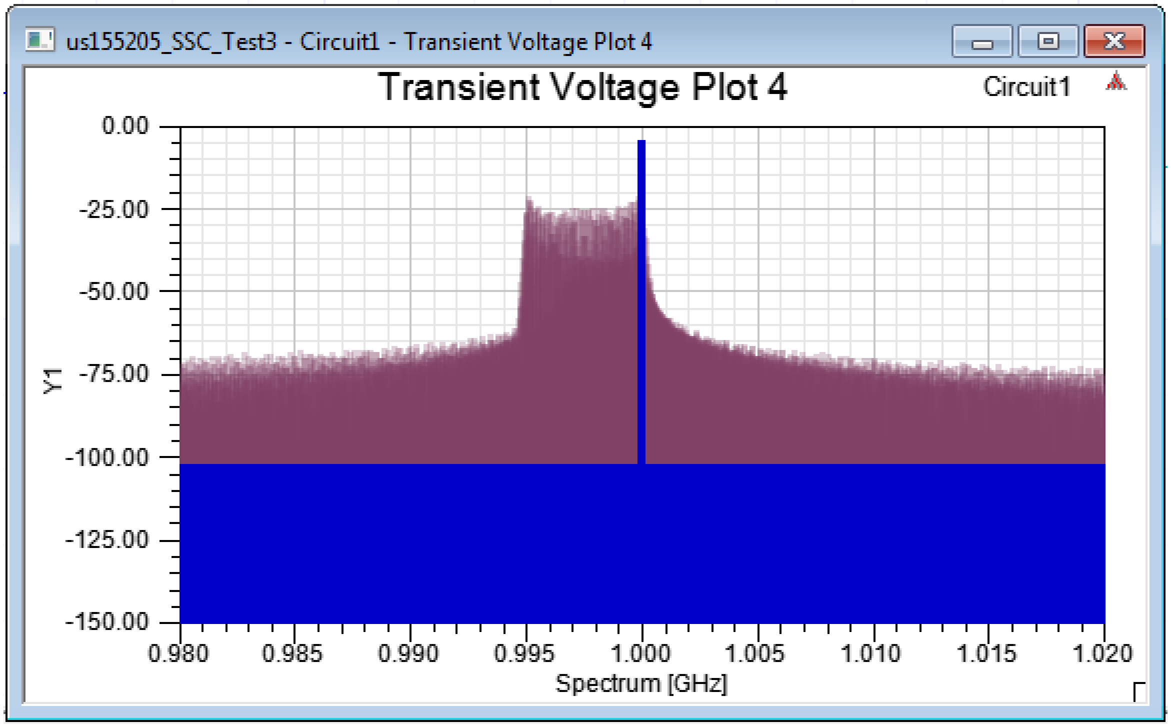


Sinusoidal

Here is the spectrum of the clock (50% duty cycle) with sinusoidal modulation (down-spreading, spread rate 0.5%, modulation frequency 33kHz):

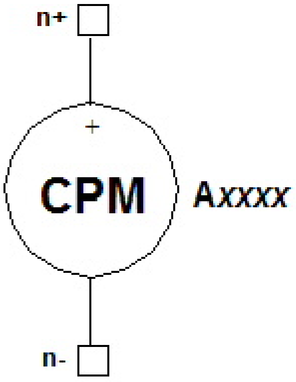


The peak magnitude is now about -20dB. The peak value is reduced by 16dB with respect to the non-SSC. Here is a combined plot to show the reduction.



6. As shown above, the triangular shows a higher reduction in peak value compared to sinusoidal. Triangular spreading is better for EMI control than sinusoidal.

Voltage Source, CPM Modulated



CPM Modulated Voltage Source Netlist Form

The netlist format for a Continuous-Phase Modulation (CPM) voltage signal generator is:

```
Axxxx n+ n- [M=val] [FB=val]

SEED=val [BITLIST=#bitlist] [BITFILE=file_reference]
[UPCHOICE=val] [UPFACTOR=val]
[V=val] [VO=val]
[FREQ_DEVIATION=val]
[ALPHA=val] [THETA=val] [TONE=val]
[FILTCHOICE=val] [NTAPS=val]
[ROLLOFF=val] [NORMALIZESCHEME=val] [BT=val]
[FC=val] [TD=val]   [NOISEVEC=[f1,psd1,... fn,psdn]]

COMPONENT=cpm_iq_source
```

n+ and *n-* are the positive and negative nodes. The brackets shown in bold are required.

The entry **COMPONENT=cpm_iq_source** is required.

The CPM modulated signal generator can be used as a source of data for Nexxim envelope analysis.

See *Nexxim Envelope Analysis* in the Circuit Design help topics for details. .

Table 19: CP-Modulated Voltage Source Parameters

Parameter	Description	Unit	Default
M	Modulation level (2=binary, 4=quaternary)	None	4
SEED	Integer seed for random pattern [Must be greater than 0.0]	None	None
BITFILE	Reference to external file with the bit values	None	None
BITLIST	Explicit list of bits to generate	None	None
FB	Data rate	Bits/Second	1.2288e6
FREQ_DEVIATION	Frequency deviation	Hertz	307.2e3
ALPHA	Damping factor	Second^{-1}	0.0
THETA	Phase delay	Degree	0.0
TD	Time delay to start of first waveform, and start of first repeat	Second	0.0
V	Output voltage	Volt	None
VO	Voltage offset	Volt	0.0
UPCHOICE	Upsampling technique.	None	1

	1 = Zero insertion 0 = Sample repeat		
UPFACTOR	Upsampling factor	None	10
TONE	Frequency to use for harmonic balance analysis. Should be the same as FC.	Hertz	0.0
FC	Carrier frequency	Hertz	1e9
FILTCHOICE	Low pass filter selector 1 = No filter 2 = Spectral raised cosine (SRC) 3 = Square root spectral raised cosine (SRRC) 4 = Rectangular (REC) 5 = Gaussian GAUSS)	None	1
NTAPS	Number of filter taps	None	31
NORMALIZESCHEME	Normalization method for tap coefficients (weights) 1 = No normalization 2 = Maximum sum (amplitude) of coefficients is 1 3 = L1 norm of coefficients is 1 4 = L2 norm of coefficients is 1	None	1
ROLLOFF	Controls the excess bandwidth parameter for SRC and SRRC filters (0< ROLLOFF <1)	None	0.35
BT	Bandwidth-time product, for FILTCHOICE=5 (GAUSS)	None	0.25
NOISEVEC	List of shot noise frequencies (f1...fn) and corresponding noise power spectral densities (psd1...psdn), in pairs. The sequence of frequencies must be monotonically non-decreasing.	Hertz, Volt^2/Hertz	None

Notes

Units shown above are for users entering netlists directly. When using the UI to enter values, SI units are assumed unless specific units are shown. In particular, for angles, a unitless number entered into the Property value is interpreted as radians. Users are encouraged to enter explicit units (e.g., "45deg") if there is any uncertainty.

When no **BITLIST** or **BITFILE** argument is supplied, the **CPM** voltage source generates a pseudorandom bit sequence, starting from a random seed value. When no **BITLIST** or **BITFILE** is present, the optional **SEED** can be used to control the bit sequence. The **SEED** must be an integer value (the maximum absolute value is the maximum size of integers on your system). Using the same **SEED** guarantees that the same sequence of bits is generated on each simulation.

When a **BITLIST** or **BITFILE** is supplied, the **CPM** source generates the specified sequence of 0 and 1 bits, and repeats the sequence until simulation terminates. When a **BITLIST** or **BITFILE** is present, any **SEED** value is ignored. If two or all three of **BITFILE**, **BITLIST**, and **SEED** are present, Nexxim uses the precedence order: **BITFILE** > **BITLIST** > **SEED**.

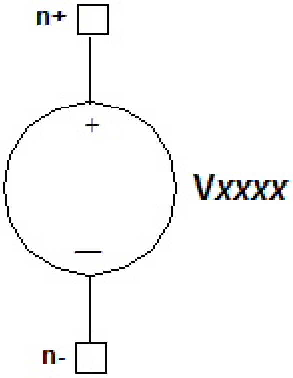
In all cases, the sequence of generated bits starts after the time delay given by **TD**, and continues until the stop time (tstop) of the transient analysis is reached.

The parameter **BITFILE =***file_reference* refers to an external file containing the data.

See *File References* in the Nexxim Netlist File Format topic for details.

For harmonic balance analysis, the test tones must be submultiples or equal to the frequencies of the actual voltage or current inputs to the circuit. To ensure that the appropriate HB frequency is used with a **VCPM** source, qualify the source by adding a **TONE** =*tone_val* entry at the end of the instance statement. The *tone_val* is then used in a subsequent HB statement.

Voltage Source, DC



DC Voltage Source Netlist Format

The format for a DC voltage source is:

V*xxxx n+ n-* [**DC=** dc_*voltage*] [**AC***acmag acphase*]
[**NOISEVEC=[***f1*,*psd1*,... *fn*,*psdn***]**]

n+ is the positive node and *n-* is the negative node of the voltage source.

The **DC** value in volts is used for the DC operating point (default is 0.0 Volts).

The **AC** parameter specifies the AC magnitude and phase to be applied during a small-signal AC analysis. The default for *acmag* is 1 Volt, the default for *acphase* is 0 degrees.

The DC voltage source implements the following equation:

output_value = **DC**

Table 20: DC Voltage Source Parameter

Parameter	Description	Unit	Default
DC	DC voltage value	Volt	0.0
acmag	Magnitude for AC analysis	Volt	1.0
acphase	Phase for AC analysis	Degree	0.0
NOISEVEC	List of shot noise frequencies (f1...fn) and corresponding noise power spectral densities (psd1...psdn), in pairs. The sequence of frequencies must be monotonically non-decreasing.	Hertz, Volt ^{2}/Hertz	None

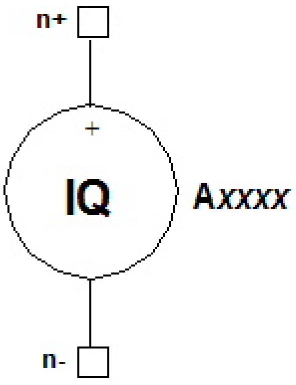
Note: Units shown above are for users entering netlists directly. When using the UI to enter values, SI units are assumed unless specific units are shown. In particular, for angles, a unitless number entered into the Property value is interpreted as radians. Users are encouraged to enter explicit units (e.g., "45deg") if there is any uncertainty.

DC Voltage Source Netlist Examples

```
V23 inplus inminus DC=0.5
```

```
VCC 34 27 5
```

Voltage Source, IQ Modulated



IQ Modulated Voltage Source Netlist Form

The netlist format for an IQ modulated voltage signal generator is:

A*xxxx n+ n-* [**DC=***val*] [**TIMES=[***t1 ...tN***]** **I_T=[** *iv1 ... ivN***]**

Q_T=[*qv1 ... qvN***]**] [**V=***val* | **VA=***val*] [**RZ=***val*] [**IZ=***val*] [**VO=***val*]
[**R** [**=***val*]] [**TD=***val*] [**FC=***val*] [**TS=***val*] [**TONE=***val*] [**ALPHA=***val*]
[**THETA=***val*] [**FILE=***file_reference*]
[**NOISEVEC=[***f1,psd1,... fn,psdn***]**] **COMPONENT=vsiq_source**

n+ and *n-* are the positive and negative nodes. The brackets shown in bold are required.

The parameter **FILE =***file_reference* refers to an external file containing the IQ data.

See *File References* in the Nexxim Netlist File Format topic for details.

The entry **COMPONENT=vsiq_source** is required.

Table 21: IQ-Modulated Voltage Source Parameters

Parameter	Description	Unit	Default
ALPHA	Damping factor	Second^{-1}	0.0
DC	DC voltage of source	Volt	0.0
TIMES=[*t1 ... tN***]**	Timepoints	Second	0.0
I_T=[*iv1 ... ivN***]**	I (in-phase) voltage values at corresponding timepoints	Volt	0.0
Q_T=[*qv1 ... qvN***]**	Q (quadrature-phase) voltage values at corresponding timepoints	Volt	0.0

FC	Carrier frequency	Hertz	1e9
TS	Sampling time, used for simulating a data file containing IQ data without time points	Second	None
FILE	Reference to file containing the timepoints and voltage values. When a file is referenced, the instance statement should not include any time points or IQ values.	None	None
R	Repeat the segment of the waveform that begins at *repeattime* and ends at *timeN*. *Repeattime* must be less than *timeN*. If R is entered with no *repeattime,* repeats from 0.0 seconds to *timeN.*	Second	None
TD	Time delay to start of first waveform, and start of first repeat	Second	0.0
TONE	Frequency to use for harmonic balance analysis. Should be equal to the carrier frequency	Hertz	0.0
VA	Carrier amplitude, power-based	Watt	None
V	Carrier amplitude, voltage-based	Volt	1.0
THETA	Phase delay	Degree	0.0
RZ	Power-based carrier impedance, real part	Ohm	50
IZ	Power-based carrier impedance, imaginary part	Ohm	0.0
VO	Carrier offset	Volt or Watt	0.0
NOISEVEC	List of shot noise frequencies (f1...fn) and corresponding noise power spectral densities (psd1...psdn), in pairs. The sequence of frequencies must be monotonically non-decreasing.	Hertz, Volt ^{2}/Hertz	None

Note: Units shown above are for users entering netlists directly. When using the UI to enter values, SI units are assumed unless specific units are shown. In particular, for angles, a unitless number entered into the Property value is interpreted as radians. Users are encouraged to enter explicit units (e.g., "45deg") if there is any uncertainty.

IQ Voltage Source Netlist Example

```
Aiqtest 23 53 FILE='C:/iqdatadirectory/iqdata.txt’ FC=2.5e9
COMPONENT=vsiq_source
```

Notes

1. If lists of times and values are present, the time points t1 ... tN must be given in STRICTLY INCREASING order. Two points may not refer to the same time.

2. If a FILE is referenced, any time and data points in the instance statement is ignored.
3. The IQ modulated signal generator can be used as a source of data for Nexxim envelope analysis.
4. The IQ modulated signal generator implements the following generalized formula:

Output(t) = [Idata(t + TD) + DC] × A_C × cos[2π × FC × (t + TD) + THETA] + OFFSET - [Qdata(t + TD) + DC] × A_C × sin[2π × FC × (t + TD) + THETA] + OFFSET

Where parameter **FC** specifies the carrier frequency, parameter **TD** specifies the time delay, parameter **THETA** specifies the phase delay, and A_C is the carrier amplitude, calculated as follows:

- When parameter **V** is specified, carrier amplitude is voltage-based. Voltage-based carrier amplitude A_C = **V** and carrier amplitude OFFSET = **VO** in volts.
- When parameter **VA** is specified and parameter **V** is not specified, carrier amplitude is power-based. Carrier amplitude A_C and carrier amplitude OFFSET are both in watts and use the formulas:
-

$$A_C = \sqrt{8VA \cdot |Z|}$$

and

$$OFFSET = \sqrt{8VO \cdot |Z|}$$

Where:

$$|Z| = \sqrt{RZ^2 + IZ^2}$$

5. The carrier value is specified either with voltage using parameters V and VO or with power using parameters VA, VO, RZ, and IZ. If neither V nor VA is present in the statement, carrier amplitude and offset are assumed to be voltage-based, and the default value of V (1.0 volt) is used. If both V and VA are present in the statement, an error occurs and simulation halts.
6. When parameter **ALPHA** is non-zero, the output is attenuated by a factor of $[e^{-(time-td)\times ALPHA}]$.
7. The IQ data file can have one of two formats. The first format supplies the time points and the corresponding I data and Q data points, with one ordered triple (*t1 iv1 qv*1) per line.

```
0.000000e+000  6.931656e-002 5.214852e-004
```

```
1.562500e-008  8.616453e-002 7.359377e-004

3.125000e-008  9.932127e-002 3.344250e-004

4.687500e-008  1.080741e-001 -7.217573e-004

6.250000e-008  1.122943e-001 -2.077420e-003

7.812500e-008  1.122116e-001 -3.040601e-003

9.375000e-008  1.083193e-001 -2.843184e-003

1.093750e-007  1.015003e-001 -1.031725e-003

1.250000e-007  9.329680e-002 2.164318e-003

1.406250e-007  8.610437e-002 5.661823e-003

1.562500e-007  8.304946e-002 7.670866e-003
```

The second format omits the time points. Each line contains the two data points (*iv1 qv1*):

```
6.931656e-002 5.214852e-004

9.932127e-002 3.344250e-004

1.080741e-001 -7.217573e-004

1.122943e-001 -2.077420e-003

1.122116e-001 -3.040601e-003

1.083193e-001 -2.843184e-003

1.015003e-001 -1.031725e-003

8.610437e-002 5.661823e-003

8.304946e-002 7.670866e-003
```

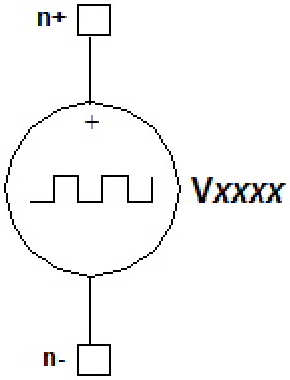
When the second format is used, the instance line must specify a value for the sampling time, **TS**. The data points is assumed to start at time 0, and each successive pair of points is simulated at times that differ by the sampling time. When the data file contains time points, the **TS** entry, if present in the instance statement, is ignored.

8. The time delay specified by **TD=***delay* is applied to the start of the IQ waveform, so the wave starts at (*time1* + *delay*).
9. The repeat specified by **R=***repeattime* repeats the portion of the IQ waveform that lies between *repeattime* and *timeN*. The *repeattime* must be greater than or equal to 0.0 seconds, and less than *timeN*. The repeat begins at *tN*, subject to any delay. The *delay* is

applied to the *repeattime* and to the PWL waveform, so the repeating segment is the portion of the PWL waveform between (*repeattime* + *delay*) and (*timeN* + *delay*). The repeating wave starts at the PWL value that occurred at *repeattime* in the original wave, interpolated if necessary.

10. For harmonic balance analysis, the test tones must be submultiples or equal to the frequencies of the actual voltage or current inputs to the circuit. To ensure that the appropriate HB frequency is used with a **VSIQ** source, qualify the source by adding a **TONE** =*tone_val* entry at the end of the instance statement. The *tone_val* is then used in a subsequent HB statement.

Voltage Source, Linear Feedback Shift Register



Linear Feedback Shift Register Voltage Source Netlist Format

The format for a linear feedback shift register voltage source is:

V*xxxx n+ n-* **RBG=5** [**VLOW=***val*] [**VHIGH=***val*] [**TDELAY=***val*]
[**TRISE=***val*] [**TFALL=***val*] [**RATE=***val*] **SEED=***val*

TAPS=[*list_of_taps***]** [**ROUT=***val*] [**TONE=***val*]

n+ and *n-* are the positive and negative nodes. The *list_of_taps* lists the feedback stages inside brackets and using spaces or commas as separators. The first tap number specifies the number of stages in the device. Subsequent taps must be entered in descending numerical order.

Nexxim also accepts the following positional syntax in externally-generated netlists:

V*xxxx n+ n-* **LFSR** [**(**] *vlow vhigh tdlay trise tfall rate seed*

[*list_of_taps***]***rout*] [**)**]

In this syntax, entries are interpreted by their position in the syntax, left to right.

> **Note:**
>
> The LFSR source is a time-domain element, suitable primarily for transient analysis simulations.

Table 22: VLFSR Voltage Source Parameters

Parameter	Description	Unit	Default
RBG	Random bit generator keyword. Must be specified as RBG=5	None	1
M	Multiplier for multiple devices in parallel.	None	1.0
RATE	Data bit rate [Must be greater than 0.0]	Bits/Second	1.0e9
ROUT	Output resistance	Ohm	0.0
SEED	Integer seed for random pattern. A SEED value greater than 0.0 must be supplied.	None	1
TAPS	Arrayed list of taps to be added to feedback chain.	None	None
TDELAY	(Positive) delay time to start of upramp [Must be greater than 0.0]	Second	0.0
TFALL	Falltime from VHIGH to VLOW [Must be greater than 0.0]	Second	0.5e-9
TONE	Frequency to use for HB or other frequency domain analysis, should be a submultiple of or equal to the driving frequency and should also be included in the any frequency-domain solution setup	Hertz	0.0
TRISE	Rise time from VHIGH to VLOW [Must be greater than 0.0]	Second	0.5e-9
VLOW	Logic low voltage value	Volt	0.0
VHIGH	Logic high voltage value	Volt	1.0

Linear Feedback Shift Register Voltage Source Netlist Examples

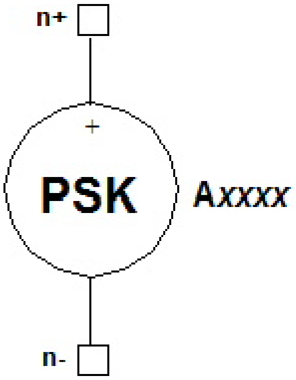
```
VLFSR1 node_43 node_53 RBG=5 VLOW=0 VHIGH=1.5
+ TDELAY=1ns TRISE=0.5ns TFALL=0.5ns RATE=1.5ns
+ TAPS=[16 15 12 9 6 3] SEED=1023 ROUT=50
```

Notes

1. If **TDELAY** is negative, an error occurs and the source is ignored.
2. If **TRISE** or **TFALL** is negative or zero, an error occurs and the source is ignored.

3. If **RATE** is negative or zero, an error occurs and the source is ignored.
4. A **SEED** value greater than 0.0 is required.
5. Units shown in the table above are for users entering netlists directly. When using the UI to enter values, SI units are assumed unless specific units are shown. In particular, for angles, a unitless number entered into the Property value is interpreted as radians. Users are encouraged to enter explicit units (e.g., "45deg") if there is any uncertainty.

Voltage Source, PSK Modulated



PSK Modulated Voltage Source Netlist Form

The netlist format for a Phase-Shift Keying (PSK) modulated voltage signal generator is:

```
Axxxx n+ n- [M=val] [FB=val]
SEED=val [BITLIST=#bitlist] [BITFILE=file_reference]
[UPCHOICE=val] [UPFACTOR=val][SYMFRAC=val]
[V=val] [VO=val]
[ALPHA=val] [THETA=val] [TONE=val]
[FILTCHOICE=val] [NTAPS=val]
[ROLLOFF=val] [NORMALIZESCHEME=val] [BT=val]
[OFFSET_PHASE=val] [FC=val] [TD=val]   [NOISEVEC=[f1,psd1,...
fn,psdn]]
COMPONENT=psk_iq_source
```

n+ and *n-* are the positive and negative nodes. The brackets shown in bold are required.

The entry **COMPONENT=psk_iq_source** is required.

The PSK modulated signal generator can be used as a source of data for Nexxim envelope analysis.

See *Nexxim Envelope Analysis* in the Circuit Design help topics for details.

Table 23: PSK-Modulated Voltage Source Parameters

Parameter	Description	Unit	Default
M	Modulation level (2=binary, 4=quaternary)	None	4
SEED	Integer seed for random pattern [Must be greater than 0.0]	None	None
BITFILE	Reference to external file with the bit values	None	None
BITLIST	Explicit list of bits to generate	None	None
FB	Data rate	Bits/Second	1.2288e6
ALPHA	Damping factor	Second^{-1}	0.0
THETA	Phase delay	Degree	0.0
TD	Time delay to start of first waveform, and start of first repeat	Second	0.0
V	Output voltage	Volt	None
VO	Voltage offset	Volt	0.0
OFFSET_PHASE	Phase offset	Radian	0.0
UPCHOICE	Upsampling technique. 1 = Zero insertion 0 = Sample repeat	None	1
UPFACTOR	Upsampling factor	None	10
SYMFRAC	Fractional symbol shift for Q channel (0<SYMFRAC<1)	None	0.0
TONE	Frequency to use for harmonic balance analysis. Should be the same as FC.	Hertz	0.0
FC	Carrier frequency	Hertz	1e9
FILTCHOICE	Low pass filter selector 1 = No filter 2 = Spectral raised cosine (SRC) 3 = Square root spectral raised cosine (SRRC) 4 = Rectangular (REC) 5 = Gaussian GAUSS)	None	1

NTAPS	Number of filter taps	None	31
NORMALIZESCHEME	Normalization method for tap coefficients (weights) 1 = No normalization 2 = Maximum sum (amplitude) of coefficients is 1 3 = L1 norm of coefficients is 1 4 = L2 norm of coefficients is 1	None	1
ROLLOFF	Controls the excess bandwidth parameter for SRC and SRRC filters (0< ROLLOFF <1)	None	0.35
BT	Bandwidth-time product, for FILTCHOICE=5 (GAUSS)	None	0.25
NOISEVEC	List of shot noise frequencies (f1...fn) and corresponding noise power spectral densities (psd1...psdn), in pairs. The sequence of frequencies must be monotonically non-decreasing.	Hertz, Volt^2/Hertz	None

PSK-Modulated Voltage Source Netlist Example

```
Apsktest 23 53 BITFILE='C:/pskdatadirectory/pskdata.txt’
FC=2.5e9 COMPONENT=psk_iq_source
```

Notes

1. When no **BITLIST** or **BITFILE** argument is supplied, the **PSK** voltage source generates a pseudorandom bit sequence, starting from a random seed value. When no **BITLIST** or **BITFILE** is present, the optional **SEED** can be used to control the bit sequence. The **SEED** must be an integer value (the maximum absolute value is the maximum size of integers on your system). Using the same **SEED** guarantees that the same sequence of bits is generated on each simulation.
2. When a **BITLIST** or **BITFILE** is supplied, the **PSK** source generates the specified sequence of 0 and 1 bits, and repeats the sequence until simulation terminates. When a **BITLIST** or **BITFILE** is present, any **SEED** value is ignored. If two or all three of **BITFILE**, **BITLIST**, and **SEED** are present, Nexxim uses the precedence order: **BITFILE** > **BITLIST** > **SEED**.
3. In all cases, the sequence of generated bits starts after the time delay given by **TD**, and

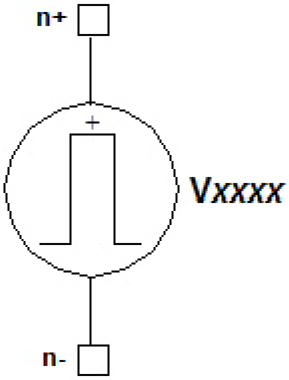
continues until the stop time (tstop) of the transient analysis is reached.

4. The parameter **BITFILE =***file_reference* refers to an external file containing the data.

See *File References* in the Nexxim Netlist File Format topic for details.

5. For harmonic balance analysis, the test tones must be submultiples or equal to the frequencies of the actual voltage or current inputs to the circuit. To ensure that the appropriate HB frequency is used with a **VPSK** source, qualify the source by adding a **TONE** =*tone_val* entry at the end of the instance statement. The *tone_val* is then used in a subsequent HB statement.
6. Units shown in the table above are for users entering netlists directly. When using the UI to enter values, SI units are assumed unless specific units are shown. In particular, for angles, a unitless number entered into the Property value is interpreted as radians. Users are encouraged to enter explicit units (e.g., "45deg") if there is any uncertainty.

Voltage Source, Pulsed



Pulsed Voltage Source Netlist Format

The format for a trapezoidal pulsed voltage source is:

```
Vxxxx n+ n- PULSE (v1 v2 [td [tr [tf [pw [per]]]]] )

 [ACacmag acphase] [TONE=tone_val]
[NOISEVEC=[f1,psd1,... fn,psdn]]
```

n+ and *n-* are the positive and negative nodes. The parameters after the **PULSE** keyword must be enclosed in parentheses. Parameters are positional and must be entered in the order given. To guarantee that a given parameter is interpreted correctly, all parameters to the left of it must be present.

Table 24: Pulsed Voltage Source Parameters

Parameter	Description	Unit	Default
v1	Initial voltage value	Volt	0.0
v2	Pulsed voltage value	Volt	0.0
td	(Positive) delay time to start of upramp	Second	0.0
tr	Risetime from V1 to V2	Second	0.0
tf	Falltime from V2 to V1	Second	0.0
pw	Pulse width (V2 hold time)	Second	1e100
per	Period of repetition for trapezoidal pulse	Second	1.5e100
acmag	Magnitude for AC analysis	Volt	1.0
acphase	Phase for AC analysis	Degree	0.0
TONE	Frequency to use for harmonic balance analysis, should be a submultiple of or equal to the driving frequency and should also be included in the HB solution setup	Hertz	0.0
NOISEVEC	List of shot noise frequencies (f1...fn) and corresponding noise power spectral densities (psd1...psdn), in pairs. The sequence of frequencies must be monotonically non-decreasing.	Hertz, Volt ^{2}/Hertz	None

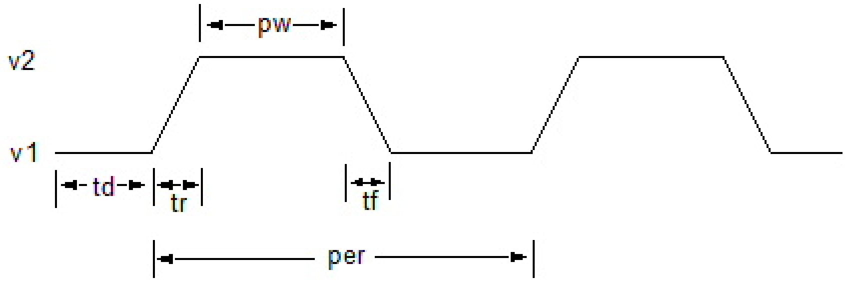
Note: Units shown above are for users entering netlists directly. When using the UI to enter values, SI units are assumed unless specific units are shown. In particular, for angles, a unitless number entered into the Property value is interpreted as radians. Users are encouraged to enter explicit units (e.g., "45deg") if there is any uncertainty.

Pulsed Voltage Source Netlist Example

```
V23 23 53 PULSE (0 5 0 5ns 5ns 20ns 40ns)
```

Notes

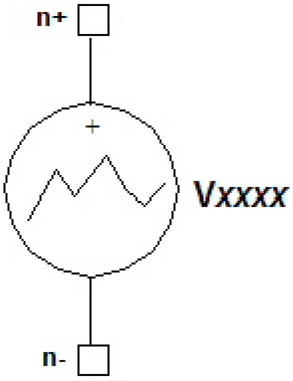
1. The **PULSE** voltage source repeats the voltage waveform each *period* until the STOPTIME of the transient analysis is reached, as shown in the following figure.



2. If **pw** is negative, **per** and **pw** are both set to infinity.
3. If **per** is less than (**tf** +**tr** +**pw**), **per** is set to (**tf** +**tr** +**pw**).
4. The **AC** parameter specifies the AC magnitude and phase to be applied during a small-signal AC analysis. The default for *acmag* is 1 Volt, the default for *acphase* is 0 degrees.
5. For harmonic balance (HB) analysis, the test tones must be submultiples or equal to the frequencies of the actual voltage or current inputs to the circuit. To ensure that the appropriate HB frequency is used with a **SIN**, **PWL**, or **PULSE** source, qualify the source by adding a **TONE** =*tone_val* entry at the end of the instance statement. The *tone_val* is then used in a subsequent HB statement.
6. The **TONE** entry is *required* with any **PWL** or **PULSE** source. For example, to analyze a mixer driven by sources at 1 MHz and 27 kHz over the first four harmonics of a **PWL** source and the first two harmonics of a **PULSE** source, the netlist syntax is:

```
V23 20 0 PWL(0 0 0.1e-6 2.0 0.5e-6 5.0 1.0e-6 0 R) TONE=1.0e6

V1 1 0 PULSE (0 5 0 5e-3 5e-3 27e-3 27.0e3) TONE=27.0e3

.HB TONES=(1.0e+6, 27.0e+3) MAXK=(4, 2)
```

Voltage Source, Piecewise Linear



Piecewise Linear Voltage Source Netlist Form

The netlist format for a piecewise linear voltage source is:

```
Vxxxx n+ n- [DC=val] PWL (t1 v1 [t2 v2... tN vN]
)
[ACacmag acphase] [TONE=tone_val]
[PWLFILE=file_reference] [R [=repeattime]] [TD=delay]
[NOISEVEC=[f1,psd1,... fn,psdn]]
```

n+ and *n-* are the positive and negative nodes. The parentheses around the parameters after the **PWL** keyword are required. The first time-value pair (*t1v1*) is required, while subsequent pairs are optional.

Table 25: Piecewise Linear Voltage Source Parameters

Parameter	Description	Unit	Default
DC	DC voltage	Volt	0.0
t1 ... tN	Timepoints	Second	0.0
v1 ... vN	Voltage values at corresponding timepoints	Volt	0.0
PWLFILE (**PWL_FILE**)	Reference to file containing the timepoint and voltage values	None	None
R	Repeat the segment of the waveform that begins at *repeattime* and ends at *timeN*. *Repeattime* must be less than *timeN*. If R is entered with no *repeattime,* repeats from 0.0 seconds to *timeN.* If R is not present, no repeats are performed.	Second	None
TD	Time delay to start of first PWL waveform, and start of first repeat	Second	0.0

acmag	Magnitude for AC analysis	Volt	1.0
acphase	Phase for AC analysis	Degree	0.0
TONE	Frequency to use for harmonic balance analysis, should be a submultiple of or equal to the driving frequency and should also be included in the HB solution setup	Hertz	0.0
NOISEVEC	List of shot noise frequencies (f1...fn) and corresponding noise power spectral densities (psd1...psdn), in pairs. The sequence of frequencies must be monotonically non-decreasing.	Hertz, Volt ^{2}/Hertz	None

Note: Units shown above are for users entering netlists directly. When using the UI to enter values, SI units are assumed unless specific units are shown. In particular, for angles, a unitless number entered into the Property value is interpreted as radians. Users are encouraged to enter explicit units (e.g., "45deg") if there is any uncertainty.

Piecewise Linear Voltage Source Netlist Example

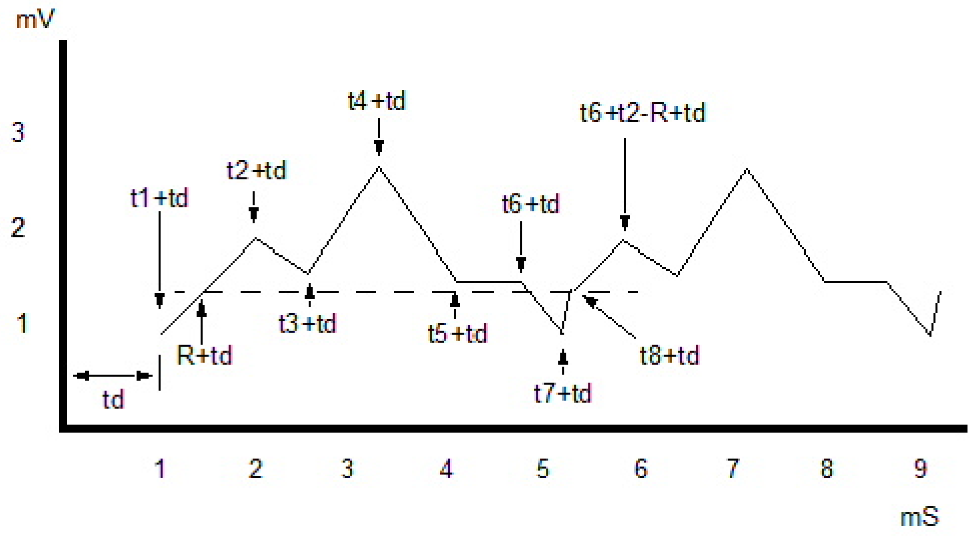
```
Vpwl 23 53 PWL (0 0 10ns 0.5 15ns 1.5 20ns 0 R TD=3e-12)
```

Notes

1. The time points t1 ... tN must be given in STRICTLY INCREASING order. Two points may not refer to the same time.
2. The time delay specified by **TD=***delay* is applied to the start of the PWL waveform, so the wave starts at (*time1* + *delay*).
3. The repeat specified by **R=***repeattime* repeats the portion of the PWL waveform that lies between *repeattime* and *timeN*. The *repeattime* must be greater than or equal to 0.0 seconds, and less than *timeN*. The repeat begins at *tN*, subject to any delay. The *delay* is applied to the *repeattime* and to the PWL waveform, so the repeating segment is the portion of the PWL waveform between (*repeattime* + *delay*) and (*timeN* + *delay*). The repeating wave starts at the PWL value that occurred at *repeattime* in the original wave, interpolated if necessary.
4. The transition on the PWL value vN at time tN to the (possibly interpolated) value at the start of the repeat can create a discontinuity in the output, especially if the transition is “instantaneous,” that is, occurring with no time difference between the two values. Care should be taken to avoid such a discontinuity, or to ensure that it is very small if it cannot be avoided. Discontinuous current or voltage jumps larger than a minimum value can create a timestep problem for transient analysis.
5. Here is an example using eight time points plus a time delay, with a repeat time (*R*) that occurs between time points, so interpolation is required.

```
V2 1 0 PWL(

+ 0.0     1.0e-3 $ t1 v1

+ 1.0e-3 2.0e-3 $ t2 v2

+ 1.6e-3 1.6e-3 $ t3 v3

+ 2.3e-3 2.7e-3 $ t4 v4

+ 3.1e-3 1.6e-3 $ t5 v5

+ 3.7e-3 1.6e-3 $ t6 v6

+ 4.2e-3 1.0e-3 $ t7 v7

+ 4.3e-3 1.4e-3 $ t8 v8

+ ) R=0.4e-3 TD=1.0e-3
```

Note the use of time point *t8* to avoid an “instantaneous” jump in output where the repeat begins. If *t8* is omitted, the output changes on the level at *t7* to the (interpolated) value at the start of the repeat with no time difference between the two values. Such a sudden discontinuity can cause a timestep-too-small failure in transient analysis. The following figure illustrates this example, showing one repeat:



6. The **AC** parameter specifies the AC magnitude and phase to be applied during a small-signal AC analysis. The default for *acmag* is 1 Volt, the default for *acphase* is 0 degrees.

7. For harmonic balance analysis, the test tones must be submultiples or equal to the frequencies of the actual voltage or current inputs to the circuit. To ensure that the appropriate HB frequency is used with a **SIN**, **PWL**, or **PULSE** source, qualify the source by adding a **TONE** =*tone_val* entry at the end of the instance statement. The *tone_val* is then used in a subsequent HB statement.
8. The **TONE** entry is *required* with any **PWL** or **PULSE** source. For example, to analyze a mixer driven by sources at 1 MHz and 27 kHz over the first four harmonics of a **PWL** source and the first two harmonics of a **PULSE** source, the netlist syntax is:

```
V23 20 0 PWL(0 0 0.1e-6 2.0 0.5e-6 5.0 1.0e-6 0 R) TONE=1.0e6

V1 1 0 PULSE (0 5 0 5e-3 5e-3 27e-3 27.0e3) TONE=27.0e3

.HB TONES=(1.0e+6, 27.0e+3) MAXK=(4, 2)
```

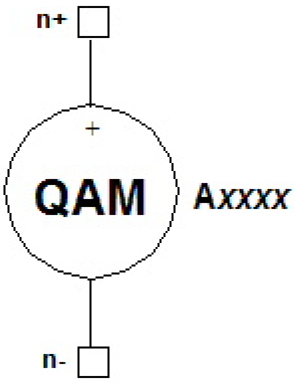
9. The parameter **PWLFILE =***file_reference* refers to an external file containing the PWL data. Nexxim also supports the keyword **PWL_FILE** in place of the keyword **PWLFILE**.

See *File References* in the Nexxim Netlist File Format topic for details.

The format of the PWL data file is:

```
t1 v1 [t2 v2 ...]
```

Voltage Source, QAM Modulated



QAM Modulated Voltage Source Netlist Form

The netlist format for a Quadrature-Amplitude modulated (QAM) voltage signal generator is:

```
Axxxx n+ n- [M=val] [FB=val] [D=val]

SEED=val [BITLIST=#bitlist] [BITFILE=file_reference]
```

```
[UPCHOICE=val] [UPFACTOR=val]
[V=val] [VO=val]
[ALPHA=val] [THETA=val] [TONE=val]
[FILTCHOICE=val] [NTAPS=val]
[ROLLOFF=val] [NORMALIZESCHEME=val] [BT=val]
[FC=val] [TD=val]   [NOISEVEC=[f1,psd1,... fn,psdn]]

COMPONENT=qam_iq_source
```

n+ and *n-* are the positive and negative nodes. The brackets shown in bold are required.

The entry **COMPONENT=qam_iq_source** is required.

The QAM modulated signal generator can be used as a source of data for Nexxim envelope analysis.

See *Nexxim Envelope Analysis* in the Circuit on-line help for details.

> **Note:**
>
> The QAM source supports only square constellations. Parameter **M** (number of constellation points) must be a power of 2.

Table 26: QAM-Modulated Voltage Source Parameters

Parameter	Description	Unit	Default
M	Number of points in constellation (2=binary, 4=quaternary) Must be a power of 2 (square constellation)	None	4
D	Spacing between constellation points	Volt	2
SEED	Integer seed for random pattern [Must be greater than 0.0]	None	None
BITFILE	Reference to external file with the bit values	None	None
BITLIST	Explicit list of bits to generate	None	None
FB	Data rate	Bits/Second	1.2288e6
ALPHA	Damping factor	Second^{-1}	0.0
THETA	Phase delay	Degree	0.0
TD	Time delay to start of first waveform, and start of first repeat	Second	0.0

V	Output voltage	Volt	None
VO	Voltage offset	Volt	0.0
UPCHOICE	Upsampling technique. 1 = Zero insertion 0 = Sample repeat	None	1
UPFACTOR	Upsampling factor	None	10
TONE	Frequency to use for harmonic balance analysis. Should be the same as FC.	Hertz	0.0
FC	Carrier frequency	Hertz	1e9
FILTCHOICE	Low pass filter selector 1 = No filter 2 = Spectral raised cosine (SRC) 3 = Square root spectral raised cosine (SRRC) 4 = Rectangular (REC) 5 = Gaussian GAUSS)	None	1
NTAPS	Number of filter taps	None	31
NORMALIZESCHEME	Normalization method for tap coefficients (weights) 1 = No normalization 2 = Maximum sum (amplitude) of coefficients is 1 3 = L1 norm of coefficients is 1 4 = L2 norm of coefficients is 1	None	1
ROLLOFF	Controls the excess bandwidth parameter for SRC and SRRC filters (0< ROLLOFF <1)	None	0.35
BT	Bandwidth-time product, for FILTCHOICE=5 (GAUSS)	None	0.25
NOISEVEC	List of shot noise frequencies (f1...fn) and corresponding noise power spectral densities (psd1...psdn), in pairs.	Hertz, Volt^2/Hertz	None

	The sequence of frequencies must be monotonically non-decreasing.		

Note: Units shown above are for users entering netlists directly. When using the UI to enter values, SI units are assumed unless specific units are shown. In particular, for angles, a unitless number entered into the Property value is interpreted as radians. Users are encouraged to enter explicit units (e.g., "45deg") if there is any uncertainty.

PSK-Modulated Voltage Source Netlist Example

```
Aqamtest 23 53 BITFILE='C:/qamdatadirectory/qamdata.txt’
FC=2.5e9 COMPONENT=qam_iq_source
```

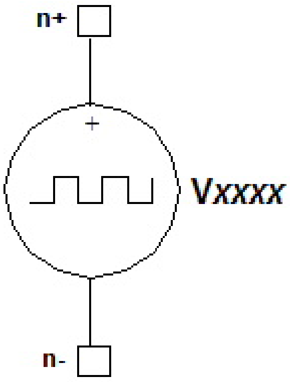
Notes

1. When no **BITLIST** or **BITFILE** argument is supplied, the **QAM** voltage source generates a pseudorandom bit sequence, starting from a random seed value. When no **BITLIST** or **BITFILE** is present, the optional **SEED** can be used to control the bit sequence. The **SEED** must be an integer value (the maximum absolute value is the maximum size of integers on your system). Using the same **SEED** guarantees that the same sequence of bits is generated on each simulation.
2. When a **BITLIST** or **BITFILE** is supplied, the **QAM** source generates the specified sequence of 0 and 1 bits, and repeats the sequence until simulation terminates. When a **BITLIST** or **BITFILE** is present, any **SEED** value is ignored. If two or all three of **BITFILE**, **BITLIST**, and **SEED** are present, Nexxim uses the precedence order: **BITFILE** > **BITLIST** > **SEED**.
3. In all cases, the sequence of generated bits starts after the time delay given by **TD**, and continues until the stop time (tstop) of the transient analysis is reached.
4. The parameters **BITFILE =***file_reference* and **NOISEVEC =***file_reference* refer to external files containing the data.

See *File References* in the Nexxim Netlist File Format topic for details.

5. For harmonic balance analysis, the test tones must be submultiples or equal to the frequencies of the actual voltage or current inputs to the circuit. To ensure that the appropriate HB frequency is used with a **QAM** source, qualify the source by adding a **TONE** =*tone_val* entry at the end of the instance statement. The *tone_val* is then used in a subsequent HB statement.

Voltage Source, Random Bit Generator



Random Bit Generator Voltage Source Netlist Format

The format for a pseudorandom bit generator voltage source (V_PRBS in the Component Manager) is:

V*xxxx n+ n-* [**DC=***val*] **RBG** [**=1**] **V1=***val* **V2=***val* [**TD=***val*] **TRF=***val* **PW=***val* [**SEED=***val*] [**BITLIST=#***bitlist*] [**BITFILE=***file_reference*] [**TONE=***val*] [**SETDC=***val*]

n+ and *n-* are the positive and negative nodes.

> **Note:**
> 1. The RBG=1 source is supported only for compatibility with earlier releases. New designs should use the "Voltage Source, Digital Random Bit Generator" on page 17-98 or the "Voltage Source, Digital Random Bit Generator with Jitter" on page 17-101.
> 2. The RBG source is a time-domain element, suitable primarily for transient analysis simulations. The RBG source can be used in harmonic balance analysis only when a BITLIST is given. See "Using the RBG Source in Harmonic Balance." on page 17-97 for details.
> 3. The BITLIST argument is ignored when a *file_reference* is supplied via the BITFILE argument.

Table 27: VRBG Voltage Source Parameters

Parameter	Description	Unit	Default
RBG	Random bit generator keyword. Can also be specified as RBG=1	None	1
BITFILE	Reference to external file with the bit values	None	None

BITLIST	Explicit list of bits to generate	None	None
DC	DC voltage	Volt	0.0
PW	Pulse width (V2 hold time) [Must be greater than 0.0]	Second	0.5e-9
SEED	Integer seed for random pattern	None	None
SETDC	Sets the t=0 voltage level	Volt	None
TD	(Positive) delay time to start of upramp [Must be greater than 0.0]	Second	0.0
TONE	Frequency to use for harmonic balance analysis, should be a submultiple of or equal to the driving frequency and should also be included in the HB solution setup	Hertz	Calculated
TRF	Rise time from V1 to V2 and fall time from V2 to V1 [Must be greater than 0.0]	Second	0.5e-9
V1	Initial voltage value	Volt	0.0
V2	Pulsed voltage value	Volt	1.0

Note: Units shown above are for users entering netlists directly. When using the UI to enter values, SI units are assumed unless specific units are shown. In particular, for angles, a unitless number entered into the Property value is interpreted as radians. Users are encouraged to enter explicit units (e.g., "45deg") if there is any uncertainty.

Bit Generator Voltage Source Netlist Examples

```
V23 23 33 RBG V1=0 V2=1.5 TD=1ns TRF=0.5ns PW=1.5ns

V43 43 53 RBG V1=0 V2=1.5 TD=1ns TRF=0.5ns PW=1.5ns SEED=1023

V83 83 93 RBG V1=0 V2=1.5 TD=1ns TRF=0.5ns PW=1.5ns

+ BITLIST=#111100001010110010010110
```

In the first example (V23), a random bit sequence is generated, starting from a random seed.

In the second example (V43), the random bit sequence starts on the given **SEED**, and is the same each time the simulation is run. In the third example, (V83), the bit sequence specified by the **BITLIST** parameter is generated.

Notes

1. The RBG=1 source is supported only for compatibility with earlier releases. New designs should use the "Voltage Source, Digital Random Bit Generator" on page 17-98 or the "Voltage Source, Digital Random Bit Generator with Jitter" on page 17-101.

2. The RBG source is a time-domain element, suitable primarily for transient analysis simulations. The RBG source can be used in harmonic balance analysis only when a BITLIST is given. See "Using the RBG Source in Harmonic Balance." below for details.
3. The BITLIST argument is ignored when a *file_reference* is supplied via the BITFILE argument.
4. When no **BITLIST** or **BITFILE** argument is supplied, the **RBG** voltage source generates a pseudorandom bit sequence, starting from a random seed value. When no **BITLIST** or **BITFILE** is present, the optional **SEED** can be used to control the bit sequence. The **SEED** must be an integer value (the maximum absolute value is the maximum size of integers on your system). Using the same **SEED** guarantees that the same sequence of bits is generated on each simulation.
5. When a **BITLIST** or **BITFILE** is supplied, the **RBG** source generates the specified sequence of 0 and 1 bits, and repeats the sequence until simulation terminates. When a **BITLIST** or **BITFILE** is present, any **SEED** value is ignored.
6. In all cases, the sequence of generated bits starts after the time delay given by **TD**, and continues until the stop time (tstop) of the transient analysis is reached. Each bit changes state with rise or fall time given by **TRF** and has the pulse width given by **PW**
7. If **TD** is negative, an error occurs and the source is ignored.
8. If **TRF** is negative or zero, an error occurs and the source is ignored.
9. If **PW** is negative or zero, an error occurs and the source is ignored.
10. DC Analysis Parameter. The **DC** parameter specifies the DC magnitude to be applied during a DC operating point analysis. The **DC** value should be the same as the initial voltage value **V1** (**DC** is made equal to **V1** if they are not equal initially).
11. The parameter **BITFILE =***file_reference* refers to an external file containing the bit data.

See *File References* in the Nexxim Netlist File Format topic for details.

The format of the VRBG data file is:

```
#bitlist
```

Where bitlist is a sequence of 1's and 0's without any whitespace.

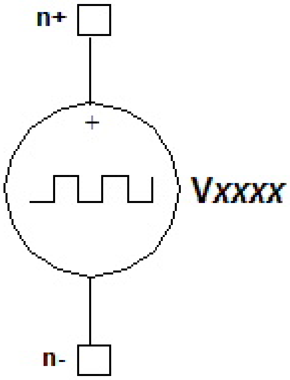
12. **Using the RBG Source in Harmonic Balance.**

The RBG source is primarily a time-domain element, best simulated with a time-domain tool such as transient analysis. The RBG source can be used with harmonic balance analysis only when an explicit **BITLIST** is provided. For harmonic balance analysis, one test tone must be a submultiple or equal to the bit-frequency of the voltage source. To ensure that the appropriate HB frequency is used with a **RBG** source, qualify the source by adding a **TONE** =*frequency* entry at the end of the instance statement. That *frequency* also appears as an argument in the .**HB** statement.

The bit-frequency for HB analysis is calculated as:

1/[(PWL + TRF) × (size of BITLIST)]

Voltage Source, Digital Random Bit Generator



Digital Random Bit Generator Voltage Source Netlist Format

The format for a pseudorandom digital bit generator voltage source is:

```
Vxxxx n+ n- RBG=2 VLO=val VHI=val [VTH=val]   [TD=val]

TR=val TF=val BITWIDTH=val [SEED=val] [DCD=val]
[BITLIST=#bitlist] [BITFILE=file_reference][TONE=val]
```

n+ and *n-* are the positive and negative nodes.

Table 28: Digital VRBG Voltage Source Parameters

Parameter	Description	Unit	Default
RBG	Random bit generator keyword. Must be specified as **RBG=2** to select the digital RBG voltage source.	None	1 (RBG source)
BITFILE	Reference to external file with the bit values	None	None
BITLIST	Explicit list of bits to generate	None	None
BITWIDTH	Duration of bit at the level of Vth [Must be greater than 0.0]	Second	1.0e-9
DCD	Duty cycle distortion (Fraction of BITWIDTH, 0 < DCD < 1)	None	0
SEED	Integer seed for random bit pattern	None	None
TD	(Positive) delay time to start of bitstream [Must be greater than or equal to 0.0]	Second	0.0
TONE	Frequency to use for harmonic balance analysis, should	Hertz	Calculated

	be a submultiple of or equal to the driving frequency and should also be included in the HB solution setup		
TR	Risetime from VLO to VHI [Must be greater than 0.0]	Second	Calculated
TF	Falltime from VHI to VLO [Must be greater than 0.0]	Second	Calculated
VLO	Logic LOW voltage value	Volt	0.0
VHI	Logic HIGH voltage value	Volt	1.0
VTH	Threshold voltage at which BITWIDTH is measured, also initial voltage	Volt	(VHI +VLO)/2

Note: Units shown above are for users entering netlists directly. When using the UI to enter values, SI units are assumed unless specific units are shown. In particular, for angles, a unitless number entered into the Property value is interpreted as radians. Users are encouraged to enter explicit units (e.g., "45deg") if there is any uncertainty.

Digital Bit Generator Voltage Source Netlist Examples

```
V23 23 33 RBG=2 VLO=0 VHI=3
```

```
V43 43 53 RBG=2 VLO=0 VHI=3 SEED=1023
```

In the first example (V23), a random bit sequence is generated starting from an internally-generated (pseudorandom) seed.

In the second example (V43), the random bit sequence starts on the given **SEED**, and is the same each time the simulation is run.

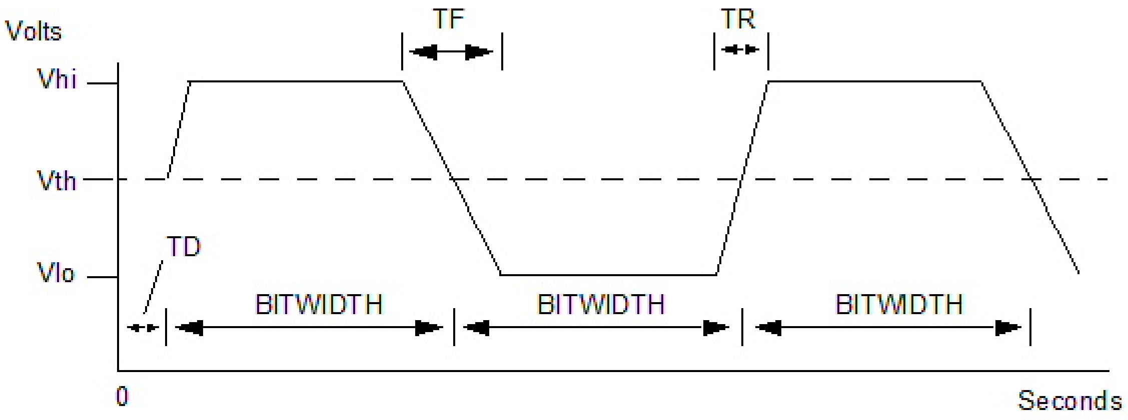
Notes

1. The RBG source is a time-domain element, suitable primarily for transient analysis simulations. The RBG source can be used in harmonic balance analysis only when a BITLIST is given. See "Using the Digital RBG Source in Harmonic Balance " on the next page for details.
2. The BITLIST argument is ignored when a *file_reference* is supplied via the BITFILE argument.
3. When no **BITLIST** or **BITFILE** argument is supplied, the **RBG** voltage source generates a pseudorandom bit sequence, starting from a random seed value. When no **BITLIST** or **BITFILE** is present, the optional **SEED** can be used to control the bit sequence. The **SEED** must be an integer value (the maximum absolute value is the maximum size of integers on your system). Using the same **SEED** guarantees that the same sequence of bits is generated on each simulation.
4. When a **BITLIST** or **BITFILE** is supplied, the **RBG** source generates the specified sequence of 0 and 1 bits, and repeats the sequence until simulation terminates. When a **BITLIST** or **BITFILE** is present, any **SEED** value is ignored.

5. In all cases, the sequence of generated bits starts after the time delay given by **TD**, and continues until the stop time (tstop) of the transient analysis is reached. Each bit changes state with rise and fall times given by **TR** and **TF**, and bit duration given by **BITWIDTH**, measured at the threshold voltage level, **VTH**.
6. The following figure illustrates the RBG operation for a source defined as:

```
V23 Port1 0 RBG=2 VLO=1 VHI=3 VTH=2 TD=0.5 TR=0.5 TF=1
+ BITWIDTH=3 BITLIST=#101
```

.



7. If **TD** is negative, an error occurs and the source is ignored.
8. If both **TR** and **TF** are omitted, **TF** and **TR** are set to **BITWIDTH** /10.
9. If **TR** is given and **TF** omitted, **TF** is set equal to **TR**.
10. If **TF** is given and **TR** omitted, **TR** is set equal to **TF**.
11. If **TR** or **TF** is negative or zero, an error occurs and the source is ignored.
12. If **PW** is negative or zero, an error occurs and the source is ignored.
13. Using an External File

The parameter **BITFILE =***file_reference* refers to an external file containing the bit data.

See *File References* in the Nexxim Netlist File Format topic for details.

The format of the VRBG data file is:

#*`bitlist`*

Where *bitlist* is a sequence of 1’s and 0’s without any whitespace.

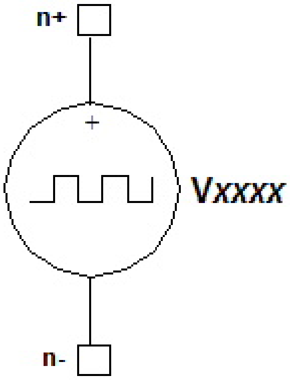
14. **Using the Digital RBG Source in Harmonic Balance**

The Digital RBG is primarily a time-domain element, best simulated with a time-domain tool such as transient analysis. The RBG source can be used with harmonic balance analysis only when an explicit **BITLIST** is provided. For harmonic balance analysis, one test tone must be a submultiple or equal to the bit-frequency of the voltage source. To ensure that the appropriate HB frequency is used with a Digital **RBG** source, qualify the source by adding a **TONE** =*frequency* entry at the end of the instance statement. That *frequency* also appears as an argument in the .**HB** statement.

The bit-frequency for HB analysis is calculated as:

1/[BITWIDTH × (number of bits in BITLIST)]

Voltage Source, Digital Random Bit Generator with Jitter



Random Bit Generator Voltage Source with Jitter Netlist Format

The format for a pseudorandom bit generator voltage source with user-definable jitter is:

```
Vxxxx n+ n- RBG=3 [VTH=val]   [TD=val] [ROUT=val]
[VLO=val] [VLOJITTER=val] [MAXVLO=val] [MINVLO=val]
[SEEDVLO=val]
[VHI=val]   [VHIJITTER=val] [MAXVHI=val] [MINVHI=val]
[SEEDVHI=val]
[BITWIDTH=val]   JITTER=val [JITTER_REPEAT=val] [MAXJITTER=val]
[SEED=val] [SEED2=val]
[TR=val]   [TRJITTER=val] [MAXTR=val] [MINTR=val] [SEEDTR=val]
[TF=val] [TFJITTER=val] [MAXTF=val] [MINTF=val] [SEEDTF=val]
[BITLIST=#bitlist] [BITFILE=file_reference]
[TAPS=[list_of_taps]] [DCD=val]
[TONE=val] [M=val]
```

n+ and *n-* are the positive and negative nodes.

Table 29: VRBG Voltage Source with Jitter Parameters

Parameter	Description	Unit	Default
RBG	Random bit generator keyword. Must be specified as **RBG=3** to select the RBG voltage source with jitter.	None	1 (RBG source without jitter)
BITFILE	Reference to external file with the bit values	None	None
BITLIST	Explicit list of bits to generate	None	None
BITWIDTH	Duration of bit at the level of Vth [Must be greater than 0.0]	Second	1.0e-9
DCD	Duty cycle distortion (Fraction of BITWIDTH, 0 < DCD < 1)	None	0
M	Multiplier for parallel sources	None	1.0
MAXJITTER	Maximum absolute jitter deviation	Second	Calculated
MAXTF	Maximum value of TF	Volt	Calculated
MAXTR	Maximum value of TR	Volt	Calculated
MINTF	Minimum value of TF	Volt	Calculated
MINTR	Minimum value of TR	Volt	Calculated
MAXVHI	Maximum value of VHI	Volt	Calculated
MAXVLO	Maximum value of VLO	Volt	Calculated
MINVHI	Minimum value of VHI	Volt	Calculated
MINVLO	Minimum value of VLO	Volt	Calculated
JITTER	Standard deviation (σ) for distribution of jitter in bit width. Maximum displacement is ±3σ.	Second	0.0
JITTER_ REPEAT	1 = Use same jitter data on each repeat of BITLIST Otherwise: Random jitter throughout transient	None	0
ROUT	Source output resistance	Ohm	0.0
SEED	Integer seed for random bit pattern	None	None
SEED2	Integer seed for random jitter in bit width	None	None
SEEDTR	Seed for random jitter in TR	None	None
SEEDTF	Seed for random jitter in TF	None	None
SEEDVHI	Seed for random jitter in VHI	None	None
SEEDVLO	Seed for random jitter in VLO	None	None

TAPS	Arrayed list of taps for a linear feedback shift register to be used as the bit source instead of **BITLIST**. The *list_of_taps* lists the feedback stages inside brackets and using spaces or commas as separators. The first tap number specifies the number of stages in the device. Subsequent taps must be entered in descending numerical order.	None	None
TD	(Positive) delay time to start of bit stream [Must be greater than or equal to 0.0]	Second	0.0
TF	Fall time from VHI to VLO [Must be greater than 0.0]	Second	Calculated
TFJITTER	Standard deviation of Gaussian distribution of jitter in VLO	Second	0.0
TONE	Frequency to use for harmonic balance analysis, should be a submultiple of or equal to the driving frequency and should also be included in the HB solution setup	Hertz	Calculated
TR	Rise time from VLO to VHI [Must be greater than 0.0]	Second	Calculated
TRJITTER	Standard deviation of Gaussian distribution of jitter in TR	Second	0.0
VLO	Logic LOW voltage value	Volt	0.0
VLOJITTER	Standard deviation of Gaussian distribution of jitter in VLO	Second	0.0
VHI	Logic HIGH voltage value	Volt	1.0
VHIJITTER	Standard deviation of Gaussian distribution of jitter in VHI	Second	0.0
VTH	Threshold voltage at which BITWIDTH is measured, also initial voltage	Volt	(VHI +VLO)/2

Note: Units shown above are for users entering netlists directly. When using the UI to enter values, SI units are assumed unless specific units are shown. In particular, for angles, a unitless number entered into the Property value is interpreted as radians. Users are encouraged to enter explicit units (e.g., "45deg") if there is any uncertainty.

Bit Generator Voltage Source with Jitter Netlist Examples

```
V23 23 33 RBG=3 VLO=0 VHI=3 JITTER=1
```

```
V43 43 53 RBG=3 VLO=0 VHI=3 JITTER=1 SEED2=1023
```

In the first example (V23), a random bit sequence is generated with random jitter starting from an internally-generated (pseudorandom) seed.

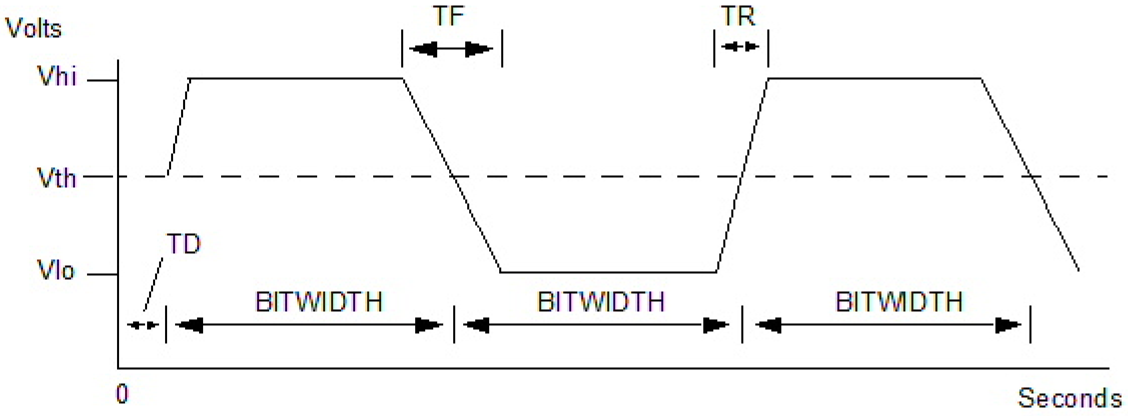
In the second example (V43), the random jitter starts on the given **SEED2**, and is the same each time the simulation is run.

Notes

1. The RBG source is a time-domain element, suitable primarily for transient analysis simulations. The RBG source can be used in harmonic balance analysis only when a BITLIST is given. See "Using the RBG Source with Jitter in Harmonic Balanc e " on the facing page for details.
2. The BITLIST argument is ignored when a *file_reference* is supplied via the BITFILE argument.
3. When no **BITLIST**, **BITFILE**, or **TAPS** entry is supplied, the **RBG** voltage source generates a pseudorandom bit sequence, starting from a random seed value. When no **BITLIST** or **BITFILE** is present, the optional **SEED** can be used to control the bit sequence. The **SEED** must be an integer value (the maximum absolute value is the maximum size of integers on your system). Using the same **SEED** guarantees that the same sequence of bits is generated on each simulation.
4. When a **BITLIST**, **BITFILE**, or **TAPS** is supplied, the **RBG** source generates the specified sequence of 0 and 1 bits, and repeats the sequence until simulation terminates. When a **BITLIST**, **BITFILE**, or **TAPS** is present, any **SEED** value is ignored.
5. In all cases, the sequence of generated bits starts after the time delay given by **TD**, and continues until the stop time (tstop) of the transient analysis is reached. Each bit changes state with rise and fall times given by **TR** and **TF**. and bit duration given by **BITWIDTH**, measured at the threshold voltage level, **VTH**.
6. When **JITTER_REPEAT** is set to 1 and a **BITLIST** is supplied, Nexxim calculates random jitter data for **BITWIDTH**, **VHI**, **VLO**, **TR**, and **TF** on the first iteration of **BITLIST**, then uses the same sets of jitter data on each subsequent repeat of **BITLIST**. This results in a periodic signal suitable for harmonic balance analysis.
7. The following figure illustrates the RBG operation for a source defined as:

```
V23 Port1 0 RBG=3 VLO=1 VHI=3 VTH=2 TD=0.5 TR=0.5 TF=1
BITWIDTH=3
BITLIST=#101
```

.



8. If **TD** is negative, an error occurs and the source is ignored.
9. If both **TR** and **TF** are omitted, **TF** and **TR** are set to **BITWIDTH** /10.
10. If **TR** is given and **TF** omitted, **TF** is set equal to **TR**.
11. If **TF** is given and **TR** omitted, **TR** is set equal to **TF**.
12. If **TR** or **TF** is negative or zero, an error occurs and the source is ignored.
13. If **BITWIDTH** is negative or zero, an error occurs and the source is ignored.
14. The **JITTER** parameter controls the random variations in bit width generated for the bit stream. The the optional **SEED2** can be used to control the bit sequence. The **SEED2** must be an integer value (the maximum absolute value is the maximum size of integers on your system). Using the same **SEED2** guarantees that the same sequence of jitter variations is generated on each simulation.
15. **Using an External File**

The parameter **BITFILE =***file_reference* refers to an external file containing the bit data.

See *File References* in the Nexxim Netlist File Format topic for details.

The format of the VRBG data file is:

```
#bitlist
```

Where bitlist is a sequence of 1’s and 0’s without any whitespace.

16. **Using the RBG Source with Jitter in Harmonic Balanc** e

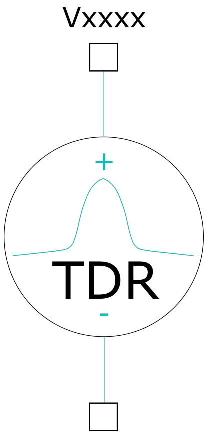
The RBG with jitter is primarily a time-domain element, best simulated with a time-domain tool such as transient analysis. The RBG source can be used with harmonic balance analysis only when an explicit **BITLIST** is provided. For harmonic balance analysis, one test tone must be a submultiple or equal to the bit-frequency of the voltage source. To ensure that the appropriate HB frequency is used with a **RBG** source, qualify the source by adding a **TONE**

=*frequency* entry at the end of the instance statement. That *frequency* also appears as an argument in the .**HB** statement.

The bit-frequency for HB analysis is calculated as:

1/[BITWIDTH ×(number of bits in BITLIST)]

Voltage Source, Gaussian Pulse TDR



The Gaussian pulse source is an independent voltage source, defined by rise time and delay time:

$$V(t) = V_{peak} \times e^{-\left\{\left(t - t_{\text{delay}}\right) \times \frac{2 \times 0.900625}{t_{\text{rise}}}\right\}^{2}}$$

A Gaussian pulse can be used as a Time Domain Reflectometry (TDR) signal source to find the impedance profile of a device under test (DUT). A Gaussian pulse is preferred over a pulse step response as the latter has aberrations such as overshoot and non-flatness, which makes interpreting the reflected signal harder as the aberrations maybe interpreted as DUT imperfections. Hence, a Gaussian pulse is preferred because it is band limited, does not contain any aberrations, and its integral is well defined.

The Gaussian pulse source is available in the **Schematic Editor**. It is implemented via a .SUBCKT instance and has no netlist form. View the component definition to access the .SUBCKT definition.

Table 32: Gaussian Pulse Voltage Source Parameters

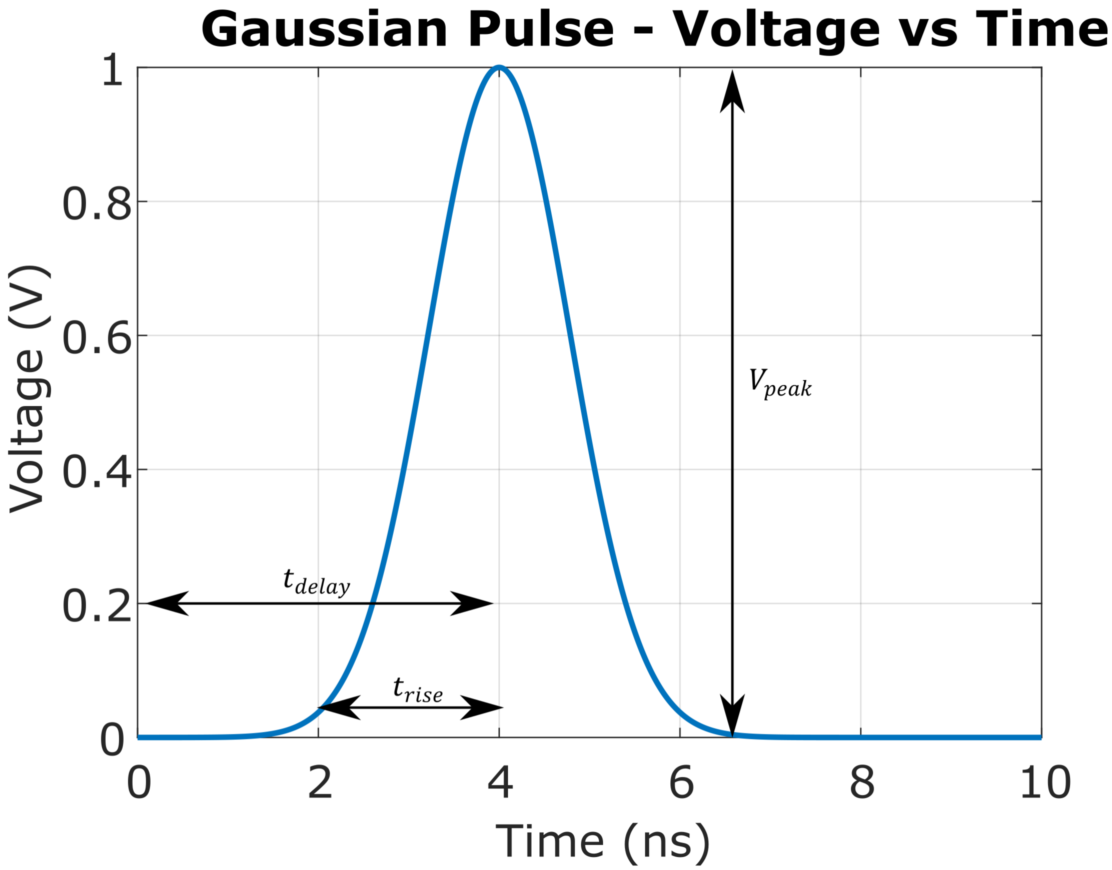
Parameter	Description	Unit	Default
t_{rise}	Rise time of the Gaussian pulse	Second	$2ns$
t_{delay}	Delay time relative to the simulation start time	Second	$2 \times t_{\text{rise}}$

V_{peak}	Peak voltage of the Gaussian pulse	Volt	$1V$

Gaussian Pulse Voltage Source Example

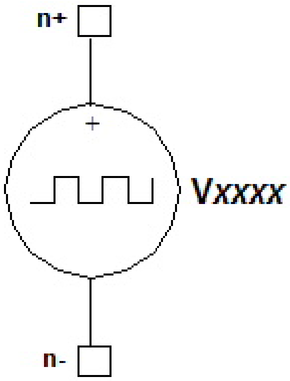
This graph shows the plot of a Gaussian pulse signal with default values:

$t_{\text{rise}} = 2ns,\ t_{\text{delay}} = 4ns,\ V_{\text{peak}} = 1V$



> **Note:** For an accurate solution, set the transient step time to much smaller than the pulse’s rise time, at least:
> $t_{\text{step}} < 0.01 \times t_{\text{rise}}$

Voltage Source, Gaussian Random Bit Generator with Jitter



Gaussian Random Bit Generator Voltage Source with Jitter Netlist Format

The format for a pseudorandom bit generator voltage source with user-definable jitter and Gaussian rising and falling edges is:

```
Vxxxx n+ n- RBG=4 [VTH=val]   [TD=val] [ROUT=val]
[VLO=val] [VHI=val]
[BITWIDTH=val]   JITTER=val [JITTER_REPEAT=val] [MAXJITTER=val]
[SEED=val] [SEED2=val] [T3=val] [T4=val]
[BITLIST=#bitlist] [BITFILE=file_reference]
[TAPS=[list_of_taps]]
[TONE=val] [M=val]
```

n+ and *n-* are the positive and negative nodes.

Table 30: Gaussian RBG Voltage Source with Jitter Parameters

Parameter	Description	Unit	Default
RBG	Random bit generator keyword. Must be specified as **RBG=4** to select the Gaussian RBG voltage source with jitter.	None	None
BITFILE	Reference to external file with the bit values	None	None
BITLIST	Explicit list of bits to generate	None	None
BITWIDTH	Duration of bit at the level of Vth [Must be greater than 0.0]	Second	1.0e-9
M	Multiplier for parallel sources	None	1.0
MAXJITTER	Maximum absolute jitter deviation	Second	Calculated
JITTER	Standard deviation (σ) for distribution of jitter in bit width. Maximum displacement is ±3σ.	Second	0.0

JITTER_ REPEAT	1 = Use same jitter data on each repeat of BITLIST Otherwise: Random jitter throughout transient	None	0
ROUT	Source output resistance	Ohm	0.0
SEED	Integer seed for random bit pattern	None	None
SEED2	Integer seed for random jitter in bit width	None	None
TAPS	Arrayed list of taps for a linear feedback shift register to be used as the bit source instead of **BITLIST**. The *list_of_taps* lists the feedback stages inside brackets and using spaces or commas as separators. The first tap number specifies the number of stages in the device. Subsequent taps must be entered in descending numerical order.	None	None
TD	(Positive) delay time to start of bitstream [Must be greater than or equal to 0.0]	Second	0.0
T3	Half the time for the pulse to rise from 25% to 75% of maximum	Second	BITWIDTH/10
T4	Half the time for the pulse to fall from 75% to 25% of maximum	Second	T3
TONE	Frequency to use for harmonic balance analysis, should be a submultiple of or equal to the driving frequency and should also be included in the HB solution setup	Hertz	Calculated
VLO	Logic LOW voltage value	Volt	0.0
VHI	Logic HIGH voltage value	Volt	1.0
VTH	Threshold voltage at which BITWIDTH is measured, also initial voltage	Volt	(VHI +VLO)/2

Note: Units shown above are for users entering netlists directly. When using the UI to enter values, SI units are assumed unless specific units are shown. In particular, for angles, a unitless number entered into the Property value is interpreted as radians. Users are encouraged to enter explicit units (e.g., "45deg") if there is any uncertainty.

Bit Generator Voltage Source with Jitter Netlist Examples

```
V23 23 33 RBG=3 VLO=0 VHI=3 JITTER=1
```

```
V43 43 53 RBG=3 VLO=0 VHI=3 JITTER=1 SEED2=1023
```

In the first example (V23), a random bit sequence is generated with random jitter starting from an internally-generated (pseudorandom) seed.

In the second example (V43), the random jitter starts on the given SEED2, and is the same each time the simulation is run.

Notes

1. The RBG source is a time-domain element, suitable primarily for transient analysis simulations. The RBG source can be used in harmonic balance analysis only when a BITLIST is given. See "Using the Gaussian RBG Source with Jitter in Harmonic Balance" on the facing page for details.
2. The BITLIST argument is ignored when a *file_reference* is supplied via the BITFILE argument.
3. **Setting 10-90 and 20-80 Rise Times**

   Parameter T3 sets the 25-75 rise/fall time, Trise(25-75).

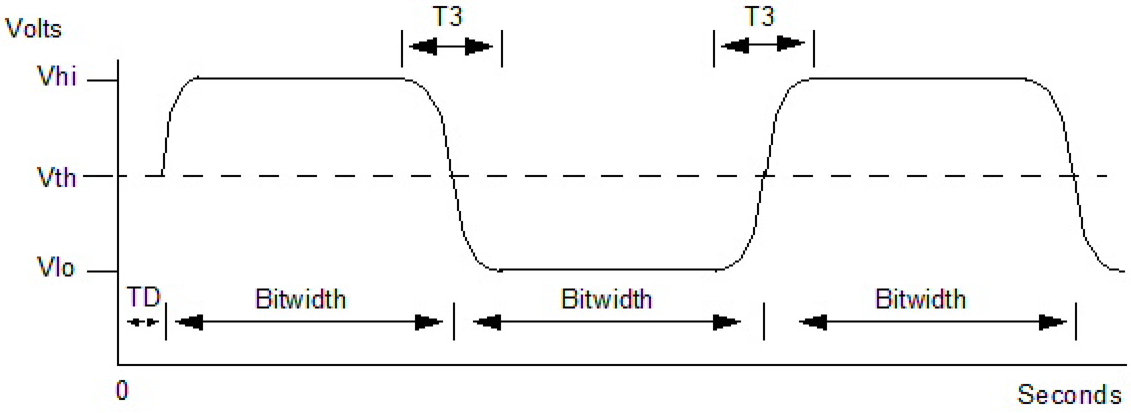
   - For a 10-90 rise time, set T3 to Trise(10-90)/3.62
   - For a 20-80 rise time, set T3 to Trise(20-80)/2.38

   For example, to specify a Trise(10-90) of 36.2ps, set T3 to 36.2/3.62=10ps. Similarly, to set a Trise(20-80) of 47.6ps, set T3 to 47.6/2.38=2ps.

4. When no **BITLIST**, **BITFILE**, or **TAPS** entry is supplied, the RBG voltage source generates a pseudorandom bit sequence, starting from a random seed value. When no BITLIST or BITFILE is present, the optional SEED can be used to control the bit sequence. The SEED must be an integer value (the maximum absolute value is the maximum size of integers on your system). Using the same SEED guarantees that the same sequence of bits is generated on each simulation.
5. When a **BITLIST**, **BITFILE**, or **TAPS** is supplied, the **RBG** source generates the specified sequence of 0 and 1 bits, and repeats the sequence until simulation terminates. When a **BITLIST**, **BITFILE**, or **TAPS** is present, any **SEED** value is ignored.
6. In all cases, the sequence of generated bits starts after the time delay given by **TD**, and continues until the stop time (tstop) of the transient analysis is reached. Each bit changes state with rise and fall times given by **TR** and **TF**. and bit duration given by **BITWIDTH**, measured at the threshold voltage level, **VTH**.
7. When **JITTER_REPEAT** is set to 1 and a **BITLIST** is supplied, Nexxim calculates random jitter data for **BITWIDTH** on the first iteration of **BITLIST**, then uses the same set of jitter data on each subsequent repeat of **BITLIST**. This results in a periodic signal suitable for harmonic balance analysis.
8. The following figure illustrates the RBG operation for a source defined as:

```
V23 Port1 0 RBG=4 VLO=1 VHI=3 VTH=2 TD=0.5 TR=0.5 TF=1
+ BITWIDTH=3 BITLIST=#101
```

.



9. If **TD** is negative, an error occurs and the source is ignored.
10. If **T3** is omitted, **T3** is set to **BITWIDTH** /10.
11. If **T3** is negative or zero, an error occurs and the source is ignored.
12. If **BITWIDTH** is negative or zero, an error occurs and the source is ignored.
13. The **JITTER** parameter controls the random variations in bitwidth generated for the bitstream. The the optional **SEED2** can be used to control the bit sequence. The **SEED2** must be an integer value (the maximum absolute value is the maximum size of integers on your system). Using the same **SEED2** guarantees that the same sequence of jitter variations is generated on each simulation.
14. **Using an External File**

    The parameter **BITFILE =***file_reference* refers to an external file containing the bit data.

    See File References in the Nexxim Netlist File Format topic for details.

    The format of the VRBG data file is:

```
#bitlist
```

    Where bitlist is a sequence of 1's and 0's without any whitespace.

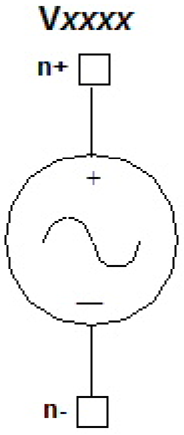
15. **Using the Gaussian RBG Source with Jitter in Harmonic Balance**

    The Gaussian RBG with jitter is primarily a time-domain element, best simulated with a time-domain tool such as transient analysis. The RBG source can be used with harmonic balance analysis only when an explicit **BITLIST** is provided. For harmonic balance analysis, one test tone must be a submultiple or equal to the bit-frequency of the voltage source. To ensure that the appropriate HB frequency is used with a **RBG** source, qualify the source by adding a **TONE** =*frequency* entry at the end of the instance statement. That *frequency* also appears as an argument in the **.HB** statement.

The bit-frequency for HB analysis is calculated as:

1/[BITWIDTH × (size of BITLIST)]

Voltage Source, Sinusoidal



Sinusoidal Voltage Source Netlist Form

The format for a damped sinusoidal voltage source is:

```
Vxxxx n+ n- [DC=val] SIN (vo va [freq [td [alpha [theta]]]] )

 [ACacmag acphase] [TONE=tone_val]
[NOISEVEC=[f1,psd1,... fn,psdn]]
```

n+ and *n-* are the positive and negative nodes. The parameters after the **SIN** keyword must be enclosed in parentheses. These six parameters are positional, and must be entered in the order given. To guarantee that a given parameter is interpreted correctly, all parameters to the left of it must be present.

Table 31: Sinusoidal Voltage Source Parameters

Parameter	Description	Unit	Default
DC	DC voltage	Volt	0.0
vo	Voltage offset from zero volts	Volt	0.0
va	Voltage amplitude	Volt	0.0
freq	Frequency	Hertz	1.0

td	Delay to start of sine wave	Second	0.0
alpha	Damping factor	Second^{-1}	0.0
theta	Phase delay	Degree	0.0
acmag	Magnitude for AC analysis	Volt	1.0
acphase	Phase for AC analysis	Degree	0.0
TONE	Frequency to use for harmonic balance analysis, should be a submultiple of or equal to the driving frequency and should also be included in the HB solution setup	Hertz	0.0
NOISEVEC	List of shot noise frequencies (f1...fn) and corresponding noise power spectral densities (psd1...psdn), in pairs. The sequence of frequencies must be monotonically non-decreasing.	Hertz, Volt^2/Hertz	None

Note: Units shown above are for users entering netlists directly. When using the UI to enter values, SI units are assumed unless specific units are shown. In particular, for angles, a unitless number entered into the Property value is interpreted as radians. Users are encouraged to enter explicit units (e.g., "45deg") if there is any uncertainty.

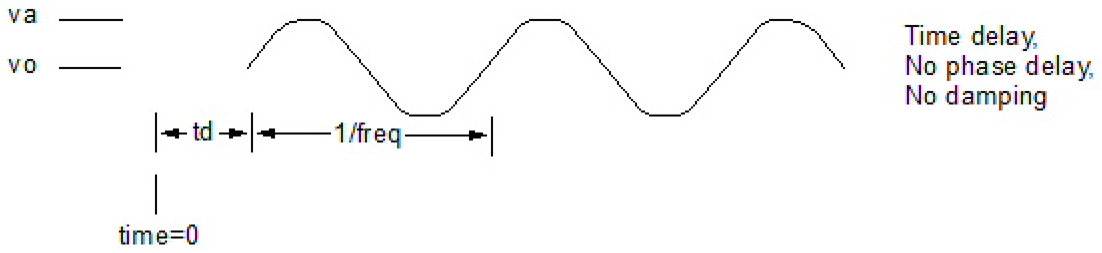
Sinusoidal Voltage Source Netlist Example

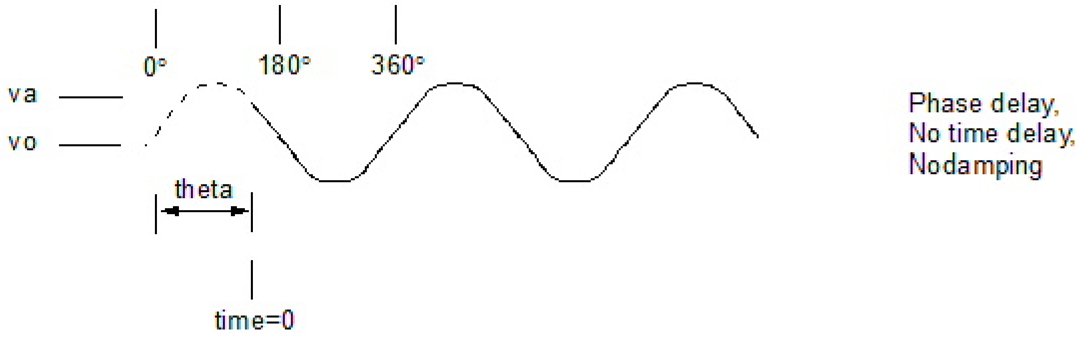
```
V23 15 21 DC=3 SIN (0 1 100e+3 1e-12 1e-4 20)
```

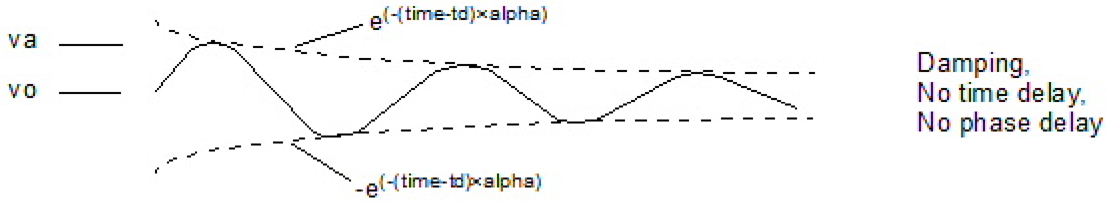
Notes

1. The **AC** parameter specifies the AC magnitude and phase to be applied during a small-signal AC analysis. The default for *acmag* is 1 Volt, the default for *acphase* is 0 degrees.
2. The *vo* parameter overrides the **DC** parameter in all analyses except DC analysis.

3. The following figures show sinusoidal outputs with time delay, phase delay, and damping.







4. For harmonic balance (HB) analysis, the test tones must be submultiples or equal to the frequencies of the actual voltage or current inputs to the circuit. To ensure that the appropriate HB frequency is used with a **SIN**, *PWL*, or **PULSE** source, qualify the source by adding a **TONE=***tone_val* parameter at the end of the instance statement. The *tone_val* is then used in a subsequent HB statement.
5. The **TONE** parameter is needed with a **SIN** voltage or current source only when the driving frequency of the source differs on the frequency at which the harmonic balance is to run. For example, to analyze a circuit driven by a single 1-KHz AC voltage source using harmonic balance at a test tone of 1 KHz over the first 31 harmonics, the netlist is:

```
V1 1 0 SIN(0 5.0 1000 0 0)
```

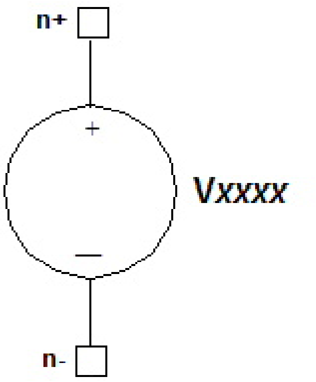
```
.HB TONES=1000 MAXK=31
```

However, to specify a 1000-Hz tone for harmonic balance while driving the circuit with a 2000-Hz sinusoidal voltage, the voltage source statement should include the **TONE** specification:

```
V1 1 0 SIN(0 5.0 2000 0 0) TONE=1000
```

```
.HB TONES=1000 MAXK=31
```

Voltage Source, AM (Netlist Only)



AM Voltage Source Netlist Format

The netlist format for amplitude-modulated, time-varying (AM) voltage source is:

V*xxxx n+ n-* **AM (***sa oc fm fc [td]***)**

n+ is the positive node and *n-* is the negative node of the voltage source. Parameters in parentheses are positional. The first four parameters must be present in the order given.

> **Note:**
>
> The AM voltage source is available for use in netlists, but is not supported in the Components window of the **Schematic Editor**.

Table 32: AM Voltage Source Parameters

Parameter	Description	Unit	Default
sa	Signal amplitude	Volt	0.0

oc	Offset constant applied to the modulation amplitude	None	0.0
fm	Modulation frequency	Hertz	1/TSTOP
fc	Carrier frequency	Hertz	0.0
td	Propagation delay before the start of the signal	Second	0.0

AM Voltage Source Netlist Example

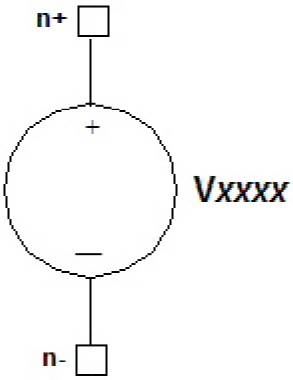
```
* AM Voltage Source netlist example
* To visualize the interaction of sa (signal amplitude)
* and                             oc (offset constant)
* swap the next two lines by moving the comment mark (*),
* analyze, create reports

* V1 1 0 AM (80  0   5e6  1e9  0)

  V1 1 0 AM (20  4   5e6  1e9  0)

R1 1 0 1

.TRAN 1e-10 1e-6

.PRINT tran V(1)

.END
```

Notes

1. The AM voltage source output is calculated as follows:

output = *sa*× {*oc* + sin[2π × *fm*× (time - *td*)]} × sin[2π × *fc*× (time - *td*)]

Voltage Source, Exponential (Netlist Only)



Exponential Voltage Source Netlist Format

The format for specifying an exponential current source is:

V*xxxx n+ n-* **EXP (***v1 v2* [*td1* [*td2* [*t1* [*t2*]]]]**)**

n+ is the positive node and *n-* is the negative node of the voltage source. Parameters in parentheses are positional. The first two (*v1* and *v2*) are required. The remainder (*td1*, *td2*, *t1*, and *t2*) can be omitted, but the parameters must be entered in the order given. To guarantee that a given parameter is interpreted correctly, all parameters to the left of it must be present.

> **Note:**
>
> The exponential voltage source is available for use in netlists, but is not supported in the Components window of the **Electronics Desktop Schematic Editor**.

Table 33: Exponential Voltage Source Parameters

Parameter	Description	Unit	Default
v1	Initial voltage value	Volt	0.0
v2	Maximum voltage value	Volt	0.0
td1	(Positive) delay time to start of exponential rise	Second	0.0
td2	Delay time to start of exponential fall	Second	td1+TSTEP (*step* argument on the TRAN statement)
t1	Rise time constant	Second	TSTEP
t2	Fall time constant	Second	TSTEP

Exponential Voltage Source Netlist Example

```
.TITLE VEXP TEST

V1 1 0 EXP(-4 -1 5ns 30ns 80ns 40ns)

R1 1 0 1

.TRAN 0.5ns 200ns

.PRINT V(1)

.END
```

Notes

1. The *td2*, *t1*, and *t2* parameters take their default values on the *step* argument on the transient analysis TRAN statement. Therefore, when a circuit containing an exponential voltage source is to be analyzed with a tool other than transient analysis, the *td2*, *t1*, and *t2* parameters must be given explicit values.
2. The exponential voltage source exhibits an 'overshoot' when the first time period is small relative to the first decay constant.
3. Exponential Voltage Source Equations:

From time = 0 to time = td1:

Output = v1

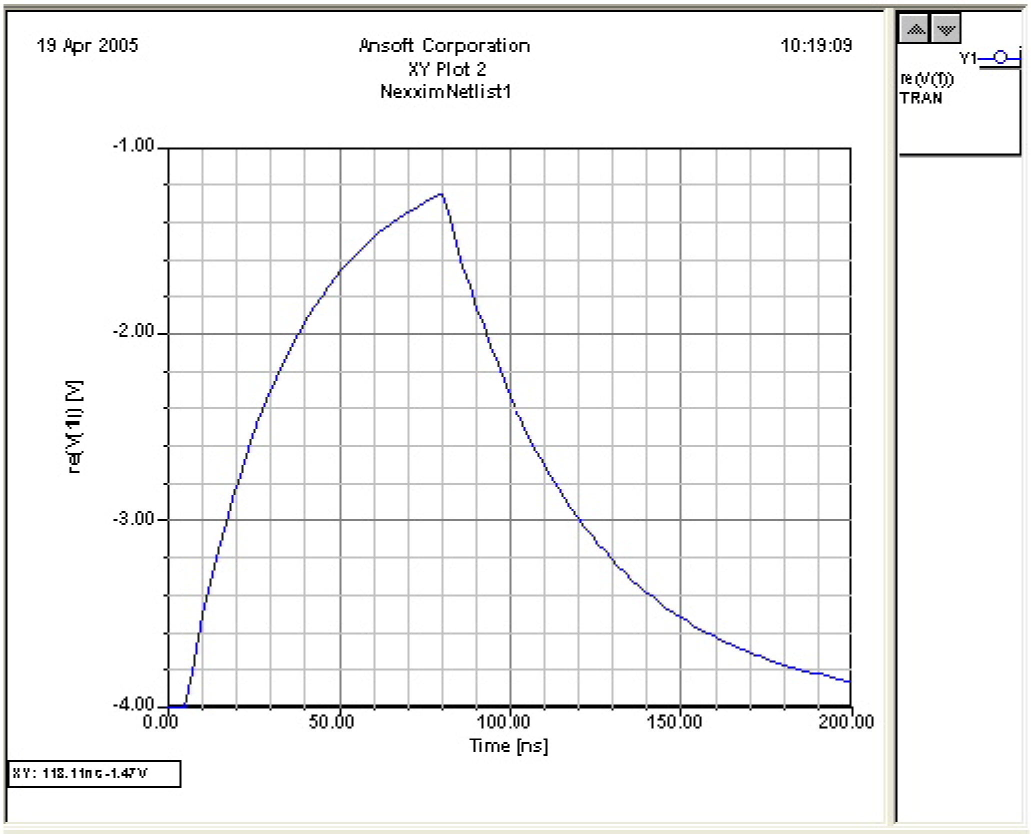
From time=td1 to time = td2:

Output = v1 + (v2 - v1) × (1.0 - EXP[-(time - td1) / t1]

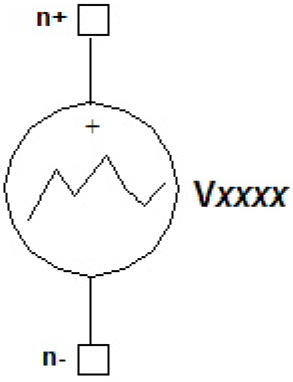
From time = td2 to time = tstop:

Output = v1 + (v2-v1) × (1.0 - EXP[-(time-td1) / t1]) - (v2 - v1) × (1.0 - EXP[-(time-td2) / t2])

4. Here is the resulting waveform:



Voltage Source, Piecewise Linear, MSINC and ASPEC Compatible (Netlist Only)



Piecewise Linear Voltage Source Netlist Form

> **Note:**
>
> The MSINC- and ASPEC-compatible syntax for the piecewise linear current source is available for use in netlists, but is not supported in the Components window of the **Electronics Desktop Schematic Editor**. It is provided to support third-party netlists.

The MSINC and ASPEC compatible netlist format for a piecewise linear current source is:

```
Vxxxx n+ n- PL [(]v1 t1 [v2 t2... vN tN]

[R= [repeattime]] [TD=delay][)]
```

n+ and *n-* are the positive and negative nodes. The parentheses around the parameters after the **PL** keyword are optional. The first value-time pair (*v1 t1*) is required, while subsequent pairs are optional.

Table 34: Piecewise Linear Voltage Source Parameters

Parameter	Description	Unit	Default
t1 ... tN	Timepoints	Second	0.0
v1 ... vN	Voltage values at corresponding time points	Volt	0.0
R	Repeat the segment of the waveform that begins at *repeattime* and ends at *timeN*. *Repeattime* must be less than *timeN*. If R is entered with no *repeattime,* repeats from 0.0 seconds to *timeN.*	Second	None

TD	Time delay to start of first PWL waveform, and start of first repeat	Second	0.0

MSINC and ASPEC Compatible PWL Voltage Source Netlist Example

```
Vpl 23 53 PL (0 0 0.5 10ns 1.5 15ns 0 20ns R TD=3e-12)
```

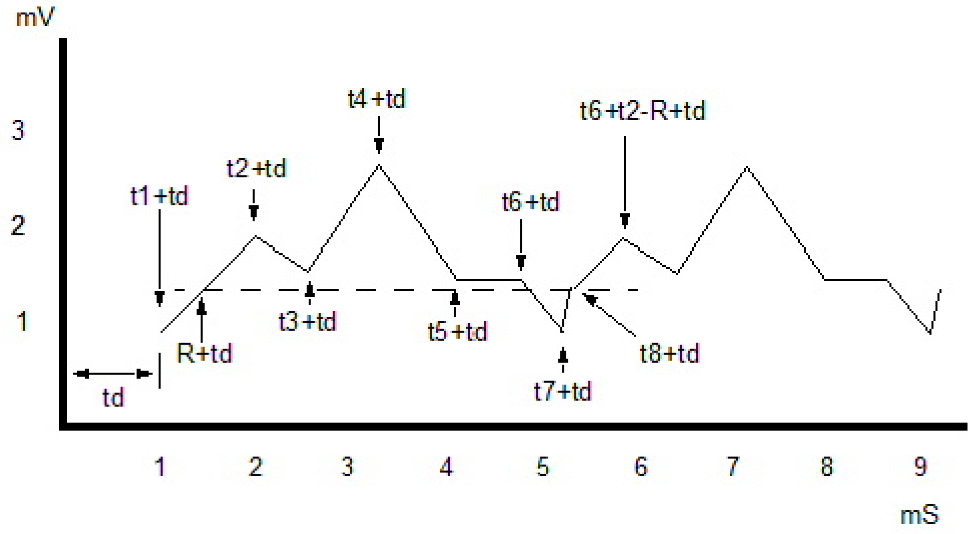
Notes

1. The time points t1 ... tN must be given in STRICTLY INCREASING order. Two points may not refer to the same time.
2. The time delay specified by **TD=***delay* is applied to the start of the PL waveform, so the wave starts at (*time1* + *delay*).
3. The repeat specified by **R=***repeattime* repeats the portion of the PL waveform that lies between *repeattime* and *timeN*. The *repeattime* must be greater than or equal to 0.0 seconds, and less than *timeN*. The repeat begins at *tN*, subject to any delay. The *delay* is applied to the *repeattime* and to the PL waveform, so the repeating segment is the portion of the PL waveform between (*repeattime* + *delay*) and (*timeN* + *delay*). The repeating wave starts at the PL value that occurred at *repeattime* in the original wave, interpolated if necessary.
4. The transition on the PL value vN at time tN to the (possibly interpolated) value at the start of the repeat can create a discontinuity in the output, especially if the transition is “instantaneous,” that is, occurring with no time difference between the two values. Care should be taken to avoid such a discontinuity, or to ensure that it is very small if it cannot be avoided. Discontinuous current or voltage jumps larger than a minimum value can create a timestep problem for transient analysis.
5. Here is an example using eight time points plus a time delay, with a repeat time (**R**) that occurs between time points, so interpolation is required.

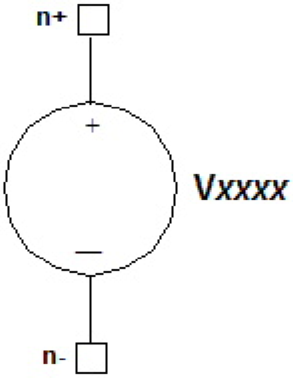
```
V2 1 0 PL(

+ 1.0e-3 0.0    $ v1 t1

+ 2.0e-3 1.0e-3 $ v2 t2

+ 1.6e-3 2.6e-3 $ v3 t3

+ 2.7e-3 3.3e-3 $ v4 t4

+ 1.6e-3 4.1e-3 $ v5 t5

+ 1.6e-3 4.7e-3 $ v6 t6

+ 1.0e-3 5.2e-3 $ v7 t7

+ 0.4e-3 5.3e-3 $ v8 t8
```

```
+ ) R=0.4e-3 TD=1.0e-3
```

Note the use of time point *t8* to avoid an “instantaneous” jump in output where the repeat begins. If *t8* is omitted, the output changes on the level at t7 to the (interpolated) value at the start of the repeat with no time difference between the two values. Such a sudden discontinuity can cause a timestep-too-small failure in transient analysis. The following figure illustrates this example, showing one repeat.



Voltage Source, Single-Frequency FM (Netlist Only)



Single-Frequency FM Voltage Source Netlist Format

The format for a single-frequency-modulated voltage source is:

V*xxxx n+ n-* **SFFM (***vo va* [*fc* [*mdi* [*fs*]]] **)**

n+ and *n-* are the positive and negative nodes, as for the DC voltage source. Parentheses around the parameters after the **SFFM** keyword are optional. The unlabeled parameters in parentheses are positional. Parameters *vo* and va are required. Parameters *fc*, *mdi*, and *fs* can be omitted, but the parameters must be entered in the order shown. To guarantee that a given parameter is interpreted correctly, all parameters to the left of it must be present.

> **Note:**
>
> The SFFM voltage source is available for use in netlists, but is not supported in the Components window of the **Electronics Desktop Schematic Editor**.

Table 35: SFFM Voltage Source Statement Entries

Entry	Description	Unit	Default
vo	Output voltage offset from zero volts	Volt	Required
va	RMS output voltage amplitude	Volt	Required
fc	Carrier frequency	Hertz	1/TSTOP entry on the .TRAN statement
mdi	Modulation index	Second	0.0
fs	Source frequency	Hertz	1/TSTOP entry on the .TRAN statement

SFFM Voltage Source Netlist Example

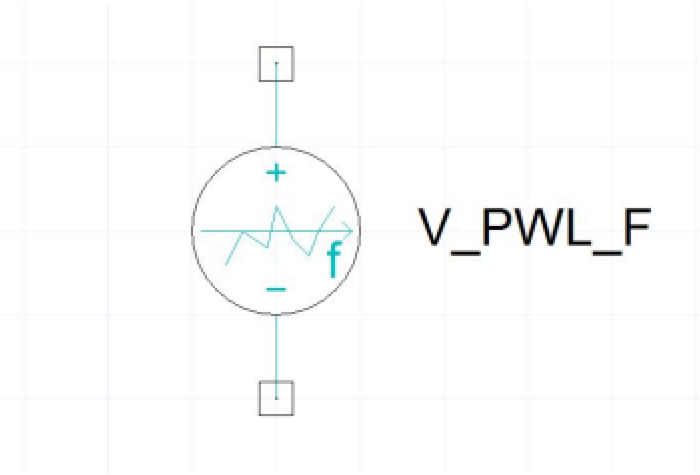
```
V1 15 21 SFFM (0 1M 20K 5 1K)
```

Notes

1. The shape of the SFFM voltage waveform is given by the equation:

$output = vo + va \times \sin[(2\pi \times fc \times time) + mdi \times \sin(2\pi \times fs \times time)]$

Frequency Dependent Voltage Source



There are several applications that can make use of Frequency dependent sources. One application is in the Electromagnetic Interference (EMI) workflow (e.g., simulating cable harness radiated emissions or simulating locomotive and automotive applications). Such applications thereby motivate the need for a frequency dependent voltage/current source in the EMI workflow; one that enables extracting radiated emissions on the cable.

Amplitude Modulation (AM) based signaling and Pulse Width Modulation (PWM) allow for the capture of emissions. This is accomplished by taking into consideration the radiated emission on the cable and its impact upon the load resonances. Emission capture can be further supported by the use of frequency dependent voltage/current source components. Note, however, that the I_PWL_F component discussed herein, is only supported with frequency domain simulations.

UI support for the frequency dependent current source is available via:

- Magnitude-Angle (MA) formats with appropriate units
- A Real-Imaginary (RI) table
- For the set of “AC” or “LNA” frequencies outside of the data range, keep the first, if it is in the low-frequency region, and the last data frequency samples if it is outside of the data frequency range. For all the frequencies in between, perform a Piecewise Linear (PWL) interpolation of the available data samples. For an example, please see Frequency Dependent Voltage Source.

  For example, let’s say the frequency samples provided are freqs = [1 2 3 4] vreal = [0.1 -0.25 0.5 1] vimag=[0 -.25 0.5 1] and the “LNA” set up list of frequencies are 10 frequency samples linearly spaced from 0 to 5 — i.e., [0 0.5556 1.1111 1.6667 2.2222 2.7778 3.3333 3.8889 4.4444 5.0000]. Then, at DC real value of the voltage is set to 0.1, at frequency 0.5556 Hz it is set to 0.1 also and at frequencies [1.1111 1.6667 2.2222 2.7778 3.3333 3.8889] Hz the real value of the voltage source is linearly interpolated to [0.0611 -0.1333 -0.0834 0.3334 0.6666 0.9445], at 4.4444 and 5.0000 Hz the real value of the voltage is set to 1. A similar approach is taken for the imaginary part of the voltage. A warning message is also issued to let the user know when the “LNA” list of frequencies are outside of the available data range.

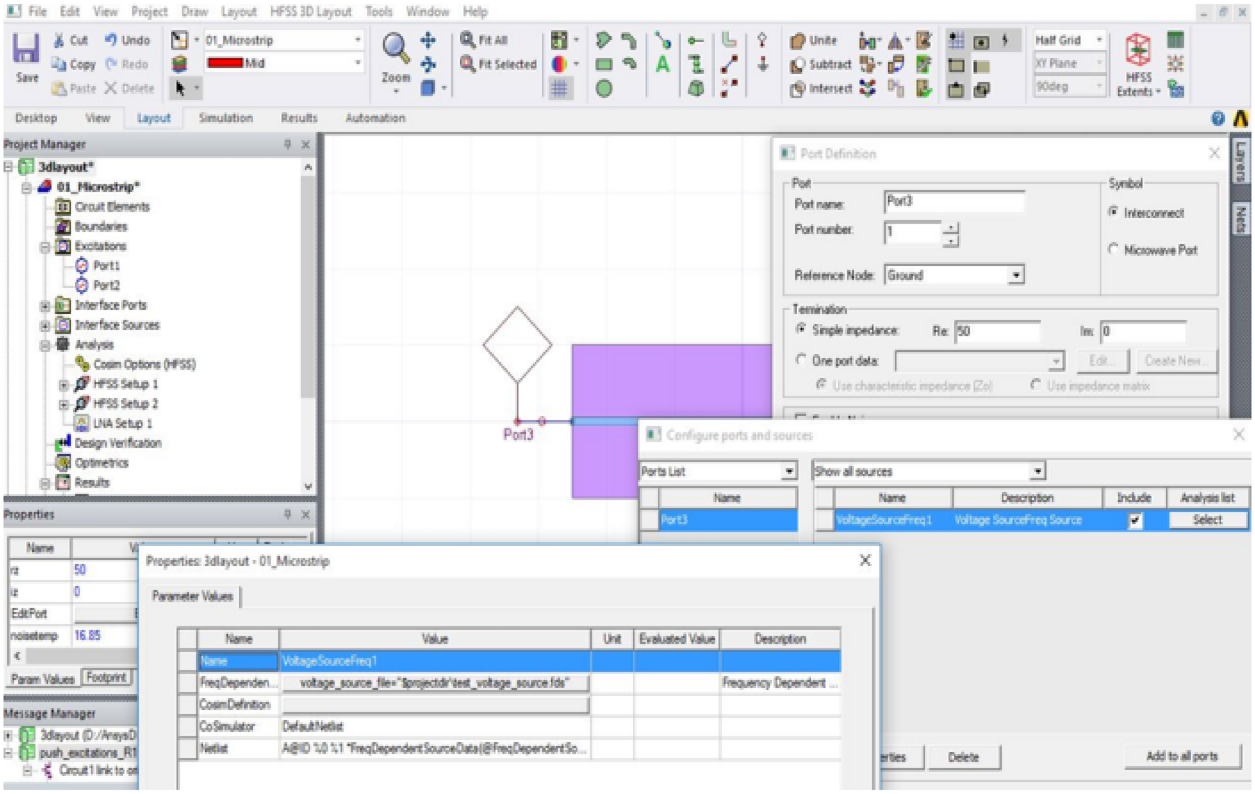
- When the tabulated data with “MA” (Magnitude/Angle) option is chosen, the user can enter the angle as a default in units of degrees. However, the unit of the angle in the netlist should be in radians.
- If there are duplicate frequency samples or when the frequency samples are not monotonic, the Solver corrects by skipping the samples that are non-monotonic or duplicate.
- If there are negative frequency samples in the data, an error message is issued and the simulation bails out.
- If there is a mismatch on the size of the data provided, an error message is issued and the simulation bails out.

Frequency dependent voltage/current source files are similar, and following is an example of a source file.

```
! Frequency dependent voltage source file
[Complex format] RI
[Number of frequencies] 1000
[Number of transfer functions] 1
[Data]
0.000000000000000e+00, 1.022787268227175e+00, -5.208574999256144e-17
5.005005005005004e+07, 1.053263711781395e+00, 7.758778994286877e-02
1.001001001001001e+08, 1.094513424576236e+00, 1.173421540714190e-01
1.501501501501502e+08, 1.131347607481765e+00, 1.431207641636222e-01
2.002002002002002e+08, 1.166136328385828e+00, 1.616330271227035e-01
2.502502502502503e+08, 1.199842750216311e+00, 1.750255055755736e-01
3.003003003003003e+08, 1.232944784710391e+00, 1.844110909415259e-01
3.503503503503503e+08, 1.265723285675800e+00, 1.904360324517109e-01
4.004004004004003e+08, 1.298344719578414e+00, 1.935087026784736e-01
4.504504504504505e+08, 1.330909940111871e+00, 1.939049136787713e-01
5.005005005005005e+08, 1.363480756574756e+00, 1.918172013516176e-01
5.505505505505506e+08, 1.396092974554894e+00, 1.873813132374444e-01
6.006006006006006e+08, 1.428763223646690e+00, 1.806928237317852e-01
6.506506506506506e+08, 1.461493266586956e+00, 1.718183806626403e-01
7.007007007007006e+08, 1.494273138430252e+00, 1.608034081764624e-01
7.507507507507508e+08, 1.527083498234942e+00, 1.476773350132686e-01
8.008008008008007e+08, 1.559897313159492e+00, 1.324571368814465e-01
8.508508508508508e+08, 1.592680974859775e+00, 1.151497839148079e-01
9.009009009009010e+08, 1.625394970936337e+00, 9.575400772812666e-02
9.509509509509509e+08, 1.657994240601652e+00, 7.426165532452513e-02
1.001001001001001e+09, 1.690428328765114e+00, 5.065878686061404e-02
1.051051051051051e+09, 1.722641425582628e+00, 2.492659959303357e-02
1.101101101101101e+09, 1.754572348243892e+00, -2.957785483639553e-03
1.151151151151151e+09, 1.786154493977223e+00, -3.302066253544392e-02
1.201201201201201e+09, 1.817315770523136e+00, -6.529120395725592e-02
1.251251251251251e+09, 1.847978493433314e+00, -9.980104738091944e-02
1.301301301301301e+09, 1.878059228473630e+00, -1.365840018085054e-01
1.351351351351351e+09, 1.907468551992742e+00, -1.756758602670627e-01
1.401401401401401e+09, 1.936110702365197e+00, -2.171142974733384e-01
1.451451451451451e+09, 1.963883101670582e+00, -2.609388232397690e-01
1.501501501501502e+09, 1.990675738523413e+00, -3.071907588002359e-01
1.551551551551552e+09, 2.016370419194792e+00, -3.559132081925685e-01
1.601601601601601e+09, 2.040839910935018e+00, -4.071510158787224e-01
1.651651651651652e+09, 2.063947009695972e+00, -4.609507405306048e-01
1.701701701701702e+09, 2.085543547525322e+00, -5.173607350480878e-01
1.751751751751752e+09, 2.105469288114430e+00, -5.764314932957259e-01
1.801801801801802e+09, 2.123550519682482e+00, -6.382164663518241e-01
1.851851851851852e+09, 2.139597957742090e+00, -7.027734887529041e-01
1.901901901901902e+09, 2.153403447970470e+00, -7.701667095943957e-01
1.951951951951952e+09, 2.164735239650003e+00, -8.404686135356756e-01
2.002002002002002e+09, 2.173332567227145e+00, -9.137621797256200e-01
2.052052052052052e+09, 2.178900589872246e+00, -9.901463879007639e-01
2.102102102102102e+09, 2.181100087368592e+00, -1.069753365527252e+00
2.152152152152152e+09, 2.179512775959131e+00, -1.152773452234992e+00
```

For more information, see CTLE Transfer Function from a File.

3D Layout Support



Properties

Name	Value
rz	50
iz	0
EditPort	
noisetemp	16.85

Port Definition

Port
Port name: Port3
Port number: 1
Reference Node: Ground

Symbol
● Interconnect
○ Microwave Port

Termination
● Simple impedance: Re: 50 Im: 0
○ One port data: Edit... Create New...
● Use characteristic impedance (Zo) ○ Use impedance matrix

Configure ports and sources

Ports List

Name
Port3

Show all sources

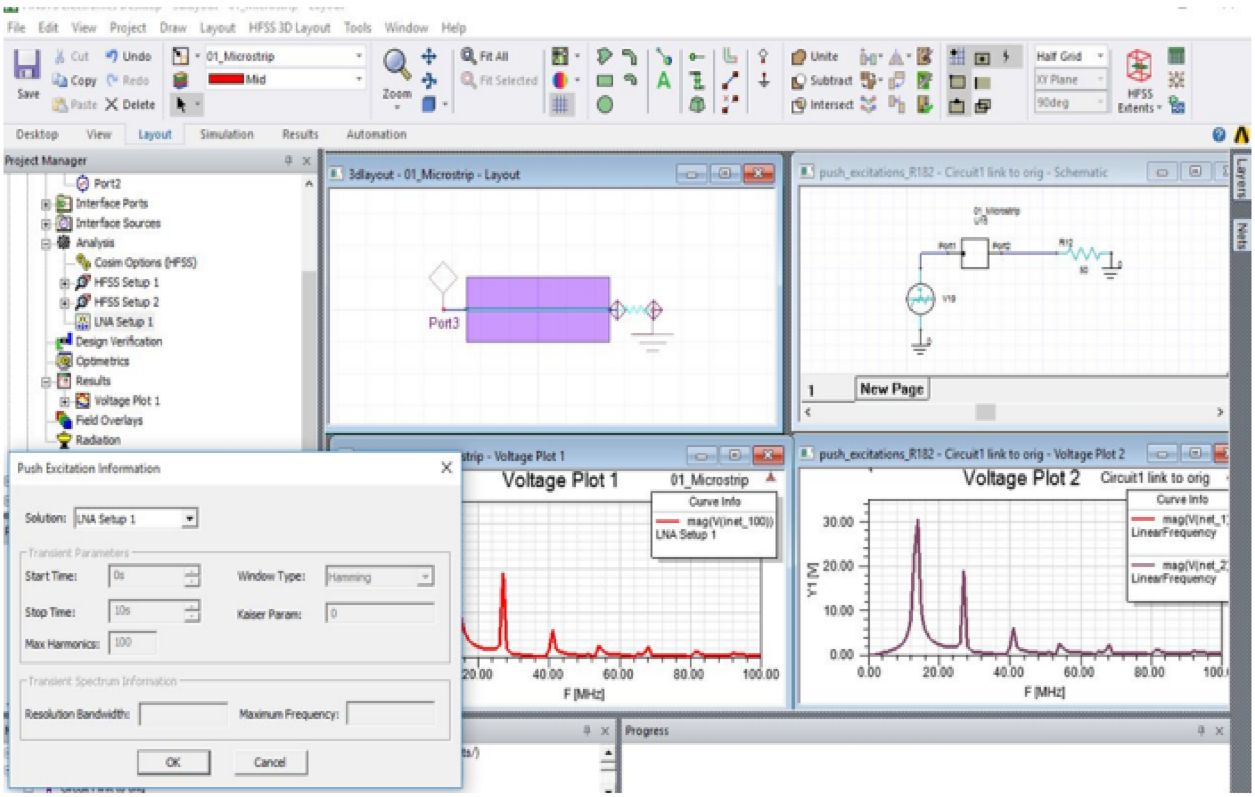
Name	Description	Include	Analysis list
VoltageSourceFreq1	Voltage SourceFreq Source	☑	Select

Properties: 3dlayout - 01_Microstrip

Parameter Values

Name	Value	Unit	Evaluated Value	Description
Name	VoltageSourceFreq1			
FreqDependen...	voltage_source_file="$projectdir\test_voltage_source.fds"			Frequency Dependent ...
CosimDefinition				
CoSimulator	DefaultNetlist			
Netlist	A@ID %0 %1 *FreqDependentSourceData(@FreqDependentSo...			

Push Excitation with Dynamic Link



Solution: LNA Setup 1

Start Time: 0s

Stop Time: 10s

Max Harmonics: 100

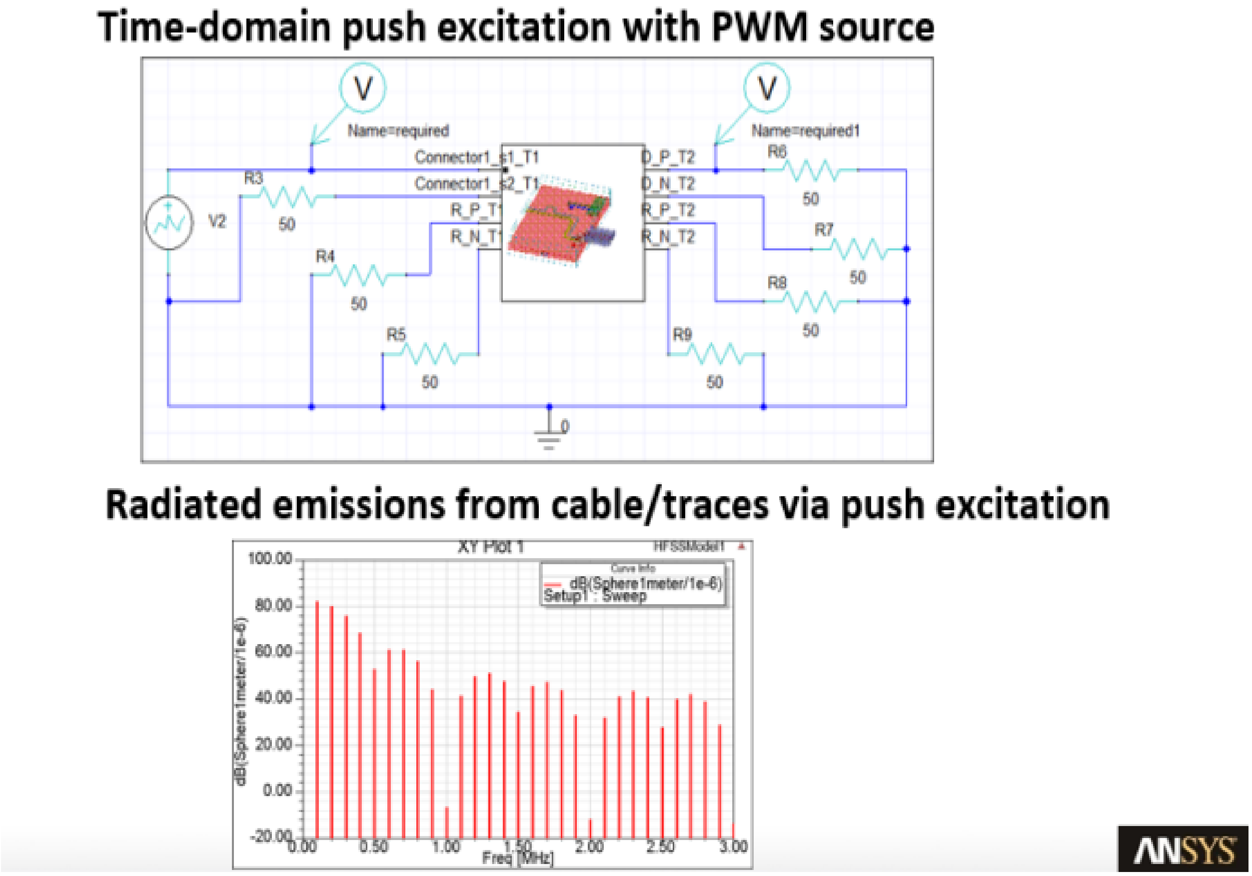
Window Type: Hamming

Kaiser Param: 0

Resolution Bandwidth:

Maximum Frequency:

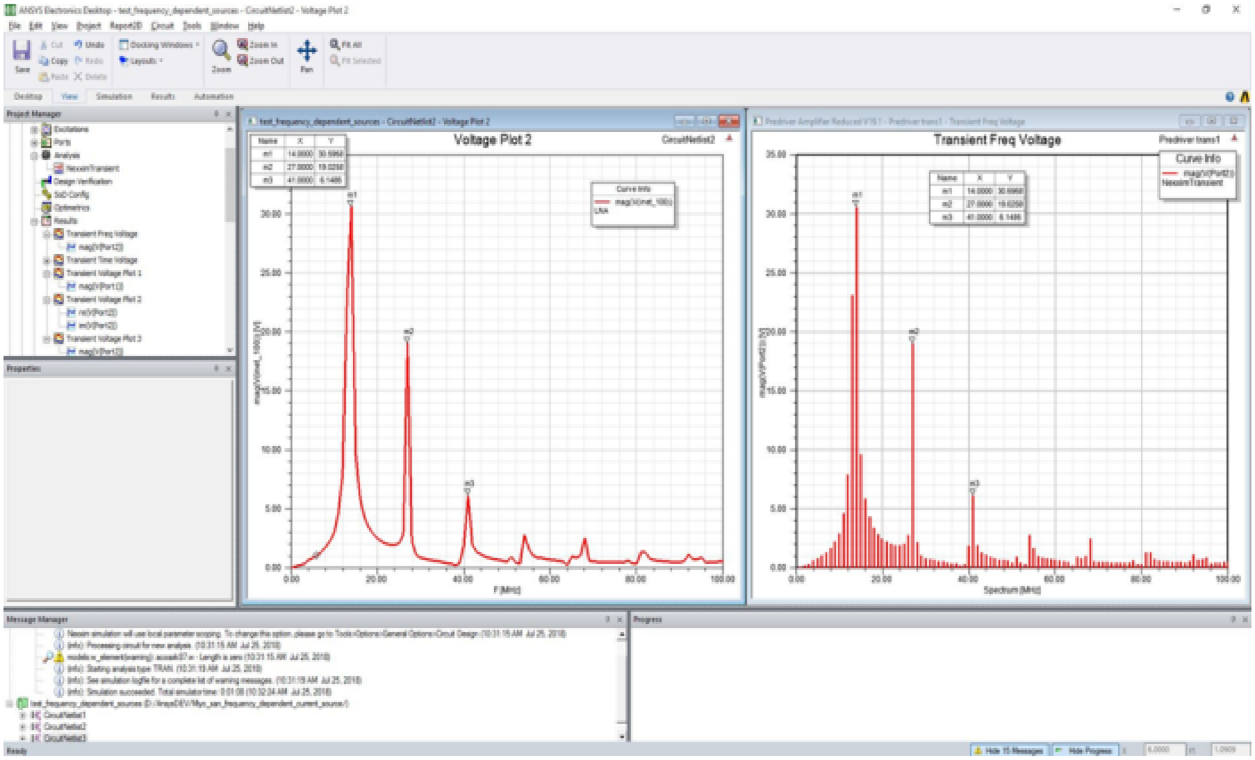
EMI Setup with Dynamic Link and Push Excitation



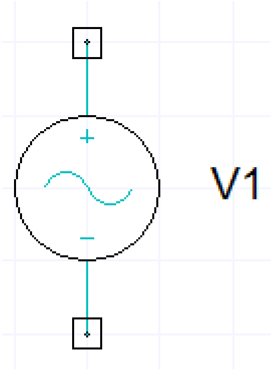
Time-domain push excitation with PWM source

Radiated emissions from cable/traces via push excitation

Voltage Spectrum Used to Build the Frequency Dependent Voltage Source



Power Source, Sinusoidal



Sinusoidal Power Source Netlist Format

The format for a sinusoidal power source is similar to that of a sinusoidal voltage source:

V*xxxx n+ n-* **POWER SIN (***vo power* [*freq* [*td* [*alpha* [*theta*]]]] **)**

[**AC***acmag acphase*] [**TONE=***tone_val*] *n+* is the positive node and *n-* the negative node to which the port source is attached. The parameters after the **SIN** keyword must be enclosed in parentheses. These six parameters are positional, and must be entered in the order given. To guarantee that a given parameter is interpreted correctly, all parameters to the left of it must be present. If the source parameters are present and *acmag* is not given a value, a sinusoidal voltage source is instantiated. The parameters other than *acmag* and *acphase* are for time domain simulation only.

Table 36: Sinusoidal Port Power Source Parameters

Parameter	Description	Unit	Default
acmag	Magnitude for AC analysis	Volt	None
acphase	Phase for AC analysis	Degree	0.0
vo	Power offset from zero watts	Watt	0.0
power	Peak power of the source above *vo*.	Watt	0.0
freq	Frequency	Hertz	1.0e9
td	Delay to start of sine wave	Second	0.0
alpha	Damping factor	1/Second	0.0
theta	Phase delay	Degree	0.0
TONE	Frequency to use for harmonic balance analysis, should be a submultiple of or equal to the driving frequency and should also be included in the HB solution setup	Hertz	0.0

Sinusoidal Power Source Netlist Example

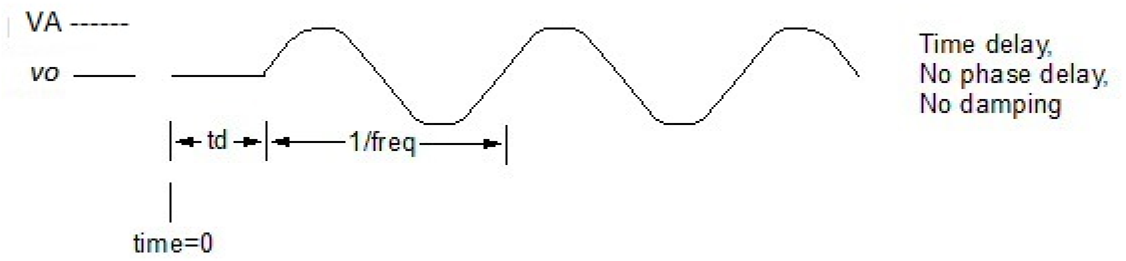
```
Vtest net_1 net_5 POWER SIN(0.0005 0.1 1e9 1e-009 0.01
'0.785*57.2957795') tone=1e9
```

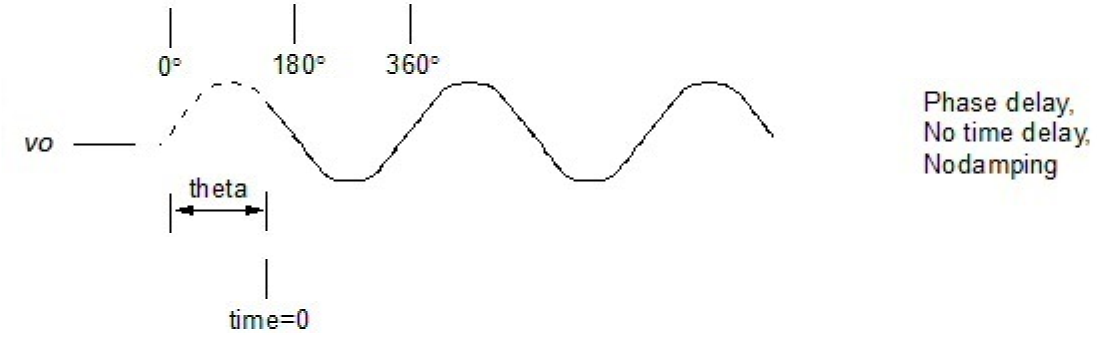
Notes

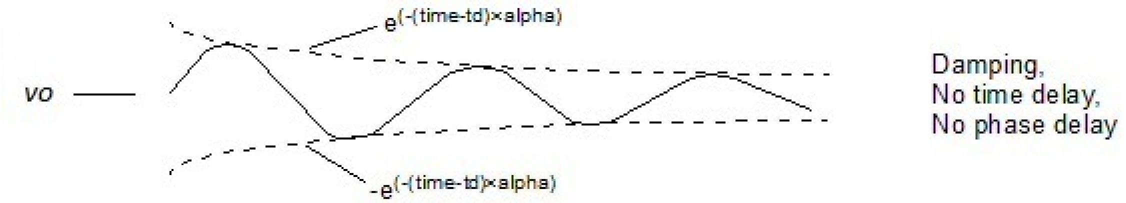
1. The **AC** parameter specifies the AC magnitude and phase to be applied during a small-signal AC analysis. There is no default for *acmag*. The default for *acphase* is 0 degrees. If *acmag* is given a value, only the *acmag* and *acphase* parameters are used, and the other parameters are ignored.
2. The following figures show sinusoidal outputs with time delay, phase delay, and damping. The amplitude of the wave is the peak voltage (*VA*) calculated on the peak power parameter (*power*) above the offset *vo* by the formula:

$$VA = \sqrt{8 \times P_{max} \times R}$$

Where *R* is a resistance defined internally to the model (based on a 50 Ohm default). This power to peak voltage conversion formula is based on maximum power delivery concepts in matched systems.







3.

3. For harmonic balance (HB) analysis, the test tones must be submultiples or equal to the frequencies of the actual voltage or current inputs to the circuit. To ensure that the appropriate HB frequency is used with a **SIN** source, qualify the source by adding a **TONE=***tone_val* parameter at the end of the instance statement. The *tone_val* is then used in a subsequent HB statement.
4. The **TONE** parameter is needed with a **SIN** source only when the driving frequency of the source differs on the frequency at which the harmonic balance is to run. For example, to analyze a circuit driven by a single 1-KHz source using harmonic balance at a test tone of 1 KHz over the first 31 harmonics, the netlist is:

```
V1 1 0 POWER SIN(0 5.0 1000 0 0)

.HB TONES=1000 MAXK=31
```

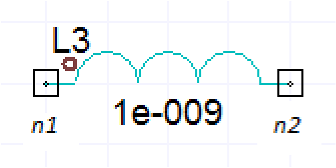
5. However, to specify a 1000-Hz tone for harmonic balance while driving the circuit with a 2000-Hz sinusoidal source, the source statement should include the **TONE** specification:

```
V1 1 0 POWER SIN(0 5.0 2000 0 0) TONE=1000

.HB TONES=1000 MAXK=31
```

18 - Inductors

This topic describes the following inductors:

Inductor



This basic inductor is available in the Schematic Editor. The basic inductor has only the inductance (>**L**) parameter. Netlist versions should use the "Inductor Device " on the next page instance.

The syntax for the basic inductor instance is:

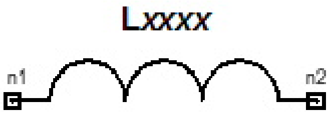
```
Lxxxx n1 n2 [[L=]val]
```

n1 is the positive node and *n2* is the negative node of the inductor. A small circle on the inductor symbol identifies the positive node. The inductance defaults to 1e-9 Henry.

An expression can be used for the inductance value. In a netlist, the Nexxim expression parser handles the expression. See *Names, Number, Constructs, and Expressions* in the Circuit Design Technical Notes for information on expressions in Nexxim. From the component Properties window in AED, an internal parser handles the expression.

In a Nexxim netlist, the expression for inductance can include the special token 'HERTZ' denoting the operating frequency. When this token is detected, Nexxim uses the "Inductor, Frequency-Dependent (Netlist Only) " on page 18-16 rather than the simple inductor. From the component Property window, use the special token 'f' (or 'F') to designate the frequency. When the **Electronics Desktop** internal parser sees 'f' or 'F' in the expression, it converts the token to 'HERTZ' and passes the expression to the netlist where it is handled by the Nexxim expression parser, and Nexxim uses the frequency-dependent inductor definition.

Inductor Device



Netlist Syntax

The general syntax for an inductor instance is:

```
Lxxxx n1 n2  [[L=]val] [TC1=val] [TC2=val] [IC=val]
[SCALE=val] [M=val] [DTEMP=val] [TNOM=val] [R=val]
[Rpar=val] [Cpar=val]
```

n1 is the positive node and *n2* is the negative node of the inductor. The current is assumed to flow from *n1* through the inductor to *n2*.

Table 35: Inductor Instance Parameters

Instance Parameter	Description	Unit	Default
DTEMP	Temperature difference between the inductor and circuit	°C	0.0
L	Inductance	Henry	0.0
M	Multiplier to simulate multiple inductors in parallel	None	1.0

R	Series resistance. To disable in PSPICE simulations, set **thev_induc** =0.	Ohm	0.0 0.001 for PSPICE simulations
SCALE	Scale factor for inductance	None	1.0
TC1	Linear temperature coefficient	°K^{-1}	0.0
TC2	Quadratic temperature coefficient	°K^{-2}	0.0
TNOM	Nominal temperature	°C	25.0
IC	Initial current through inductor	Ampere	None
Rpar	Parallel resistance. When a PSPICE import is used in a power electronics simulation, the default **Rpar** is provided if a value is not given.	mOhm	dampinductors***L** where the default for dampinductors is 1e12
Cpar	Parallel inductance	Farad	0.0

Inductor Instance Netlist Examples

```
L1 1 2 L=5PH
```

```
L2 1 2 inductor1 L=5e-12 TC1=2
```

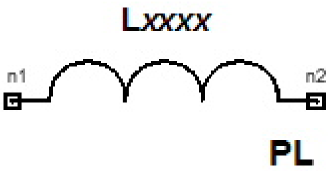
```
L3 1 2 inductor1 L=5e-12 SCALE=1.1
```

```
L4 1 2 L=1PF
```

Notes

1. The label **L=** is optional, but the presence or absence of the **L=** label affects the interpretation of other unlabeled entries in the statement. The first unlabeled value is taken to be the inductance value.
2. The syntax above shows the labels **TC1=** and **TC2=** as optional, but this option depends on the presence or absence of the inductance value, labeled or unlabeled.
3. When the inductance value is present but the inductance value does not have the **L=** label, the next two unlabeled values are taken to be **TC1**, then **TC2**. To specify a value for **TC2**, either a value for **TC1** must be given as well, or the label **TC2=** must be used.
4. When the inductance value is present with the **L=** label, the labels **TC1=** and **TC2=** are required.
5. When the option **device_cleanup=1** is in effect, a zero-valued inductor is replaced with a short circuit, and a warning is issued.

Inductor, Polynomial



The netlist can specify an inductor with an inductance defined by a polynomial function of the current across it.

Polynomial Inductor Netlist Syntax

The format for a polynomial-based inductor is:

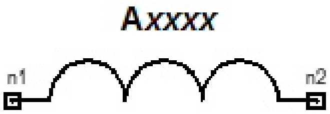
L*xxxx n1 n2* **POLY***p0 p1* ...
[*instance_parameter*=*val*] ...

The entries *p0*, *p1*, ... are the polynomial coefficients of the inductance given by L = $p0 + p1 \times I + p2 \times I^2$... , where *I* is the current through the inductor. Any other instance parameters must be labeled. See "Inductor Device " on page 18-2 for inductor instance parameters.

Polynomial Inductor Netlist Example

```
L5 2 4 POLY 1.5 1.0 0.5
```

Inductor with Q Factor



Netlist Syntax

The general syntax for an inductor with Q factor instance is:

A*xxxx n1 n2* [**L=***val*] [**Q=***val*] [**EXP=***val*] [**TC1=***val*] [**TC2=***val*]
[**M=***val*] [**DTEMP=***val*] **COMPONENT=inductor_q**

n1 is the positive node and *n2* is the negative node of the inductor. The current is assumed to flow from *n1* through the inductor to *n2*.

The parameter **COMPONENT=inductor_q** identifies the element as an inductor with Q factor.

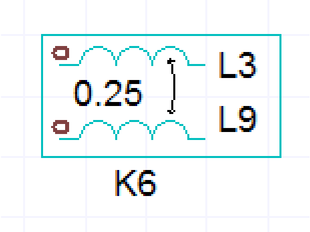
Table 36: Inductor with Q Factor Instance Parameters

Instance Parameter	Description	Unit	Default
DTEMP	Inductor and circuit temperature difference	°C	0.0
L	Inductance	Henry	10.0e-9
EXP	Q exponent 0 = constant Q 1 = constant R Other = EXP	None	0.0
F	Frequency at which Q is specified	Hertz	1.0e9
M	Divisor to simulate multiple inductors in parallel	None	1.0
Q	Quality factor	None	300.0
TC1	Linear temperature coefficient	°K^{-1}	0.0
TC2	Quadratic temperature coefficient	°K^{-2}	0.0

Inductor Instance Netlist Example

```
Aindq2 1 2 L=5e-9 Q=325 TC1=2 COMPONENT=inductor_q
```

Inductors, Coupled (K)



`Kxxxxx Lyyyy Lzzzz   [K=] val`

L*yyyy* and **L***zzzz*. *yyyy* and *zzzz* are the IDs of the two inductors defined elsewhere in the netlist. The **K=** > entry specifies the coefficient of mutual coupling, default 1e-10 (equivalent to no coupling). **K** must be in the range {-1 ≤**K** ≤ 1}, but cannot be exactly 0.0 for numerical reasons (see Note 2).

The circles on the symbol identify the positive nodes of the coupled inductors.

AMI Source Netlist Format

> **Note:** Frequency-dependent inductances are not supported in the coupled inductor model.

AMI Source Netlist Format

Coupled Inductors Netlist Example

```
L3 1 2 L=1nH

L9 3 4 L=3nH

K6 L3 L9 K=0.25
```

Notes

1. If the netlist specifies a coefficient of mutual inductance less than -1, the value changes internally to -1.0 with a warning message). See Note 7 for more on positive and negative coupling coefficients.
2. If the netlist specifies a coefficient of mutual inductance equal to 0, the value changes internally to 1e-10 (no coupling) with a warning message.
3. If the netlist specifies a coefficient of mutual inductance greater than +1, the value changes internally to +1.0 with a warning message.
4. When the netlist contains simple inductors and one or more mutual inductance couplings are also specified, Nexxim looks at all the available inductors and the corresponding mutual inductance couplings. Nexxim assigns a value of 1e-10 to any mutual inductances that are set to 0 in the netlist.
5. When the option **genK** is enabled (see Note 6), Nexxim attempts to calculate the coupling coefficients for mutual inductances that are implied by the netlist but not supplied. For example, suppose the netlist is as follows:

   ```
   L1 Port1 2 L=1.5nH
   L2 2 3 L=1.9nH
   L3 3 Port2 L=1.8nH
   L4 0 4 L=2.8nH
   L5 0 5 L=1nH

   K14 L1 L4 0.75
   K24 L2 L4 0.65
   K34 L3 L4 0.5
   K15 L1 L5 0.55
   K25 L2 L5 0.45
   K35 L3 L5 0.35
   ```

   The netlist specifies one mutual inductor joining inductors L1 and L4 (mutual inductor

K14), and a second mutual inductor joining L2 and L4 (mutual inductor K24); the netlist should also have a third mutual inductor K12 joining L1 and L2. If this mutual inductor is missing, the simulator provides the missing one with a warning message, assuming the **genK** option has its default value of 1 (enabled); see Note 6. By default, the missing mutual inductance coefficient is the maximum of the pairwise products of the applicable mutual inductance coefficients that are present. In the example above, both the L1 - L2 coupling (K12) and the L1 - L3 coupling (K13) are missing. The calculated coefficients are:

K12 = max(K14 x K24, K15 x K25) = max(0.75 x 0.65, 0.55 x 0.45) = max (0.4875, 0.2475) = 0.4875

K13 = max(K14 x K34, K15 x K35) = max(0.75 x 0.5, 0.55 x 0.35) = max(0.375, 0.1925) = 0.375

Note that the calculated value of **K** for the supplied mutual inductor coupling may not be correct for the circuit.

6. To deactivate the calculation of missing mutual inductances, uncheck (set to 0) the option **Auto-generate missing inductor couplings (genK)**. When this option is unchecked (deactivated), any mutual inductances without specific settings are set to 1e-10 (no coupling). See *Global Device Options Reference* in the Circuit Design help for details.)
7. When the coefficient of coupling **K** is positive, the input current entering the first inductor and the induced current exiting the second inductor flow from positive to negative, as if a continuous current is flowing through both inductors. When **K** is negative, the induced current exiting the second (coupled) inductor flows in the opposite direction on the input current entering the first inductor.

Chip Inductor with Dissipation Factor

Netlist Syntax

The general syntax for an inductor with dissipation factor is:

A*xxxx n1 n2* **L=***val* **DF=***val* **FDF=***val* **FRES=***val* **TC=***val* **TEMP=***val* **COMPONENT=chipindd**

n1 is the positive node and *n2* is the negative node of the inductor. The current is assumed to flow from *n1* through the inductor to *n2*.

The parameter **COMPONENT=chipindd** identifies the element as a chip inductor with dissipation factor (DF).

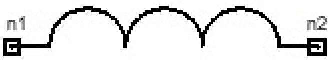
Table 37: Chip Inductor with DF Factor Instance Parameters

Instance Parameter	Description	Unit	Default
TEMP	Inductor temperature	°C	25.0
L	Inductance	Henry	10.0e-9
DF	Dissipation factor	None	0.0
FDF	Frequency at which DF is specified	Hertz	1.0e9
FRES	Self-resonant frequency	Hertz	1.0e9
TC	Temperature coefficient in PPM	None	0.0

Chip Inductor with DF Instance Netlist Example

```
Achipindd1 1 2 L=5e-9 DF=0.2 TC=2 COMPONENT=chipindd
```

Chip Inductor with Q Factor



Netlist Syntax

The general syntax for a chip inductor with Q factor is:

A*xxxx n1 n2* **L=***val* **Q=***val* **FQ=***val* **FRES=***val* **TC=***val* **TEMP=***val* **COMPONENT=chipindq**

n1 is the positive node and *n2* is the negative node of the inductor. The current is assumed to flow from *n1* through the inductor to *n2*.

The parameter **COMPONENT=chipindq** identifies the element as a chip inductor with Q factor.

Table 38: Chip Inductor with Q Factor Instance Parameters

Instance Parameter	Description	Unit	Default
TEMP	Inductor temperature	°C	25.0

L	Inductance	Henry	10.0e-9
Q	Quality factor	None	300
FQ	Frequency at which Q is specified	Hertz	1.0e9
FRES	Self-resonant frequency	Hertz	1.0e9
TC	Temperature coefficient in PPM	None	0.0

Inductor Instance Netlist Example

```
Achipindq2 1 2 L=5e-9 Q=325 TC=2 COMPONENT=chipindq
```

Notes

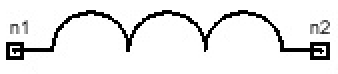
1. The model is described by the following:

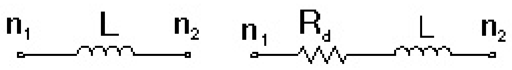
$$Q = \frac{\omega L}{R_d}$$

where $\omega = 2\pi f$, and f is the operating frequency.

2. If **Q** is not specified, the inductor is assumed to be ideal, that is, $R_d = 0$.

Chip Inductor with ESR Factor





Netlist Syntax

The general syntax for a chip inductor with effective series resistance is:

```
Axxxxx n1 n2 L=val ESR=val FESR=val FRES=val TC=val TEMP=val
COMPONENT=chipindr
```

n1 is the positive node and *n2* is the negative node of the inductor. The current is assumed to flow from *n1* through the inductor to *n2*.

The parameter **COMPONENT=chipindr** identifies the element as a chip inductor with ESR.

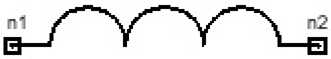
Table 39: Chip Inductor with ESR Instance Parameters

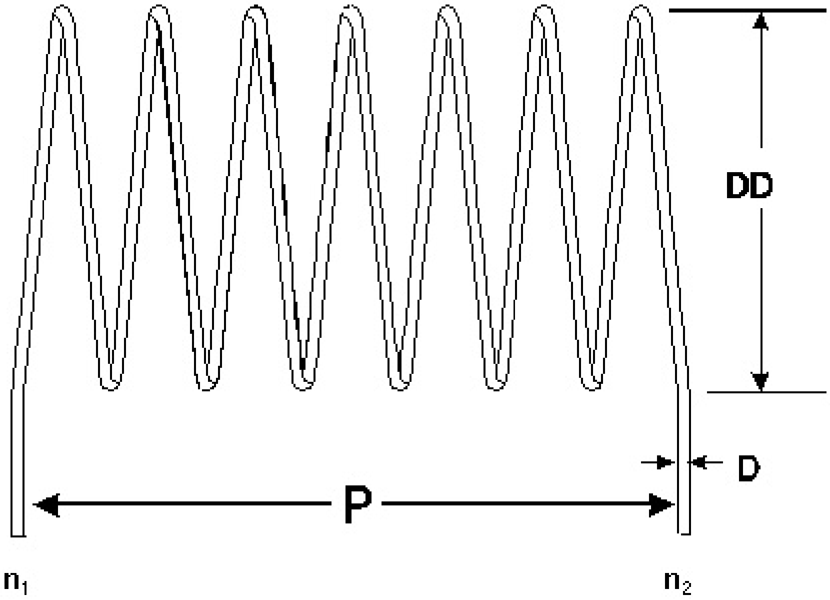
Instance Parameter	Description	Unit	Default
TEMP	Inductor temperature	°C	25.0
L	Inductance	Henry	10.0e-9
ESR	Effective series resistance	Ohm	0.0
FESR	Frequency at which ESR is specified	Hertz	1.0e9
FRES	Self-resonant frequency	Hertz	1.0e9
TC	Temperature coefficient in PPM	None	0.0

Inductor Instance Netlist Example

```
Achipindr2 1 2 L=5e-9 ESR=.01 TC=2 COMPONENT=inductor_q
```

Inductor, Solenoidal





Netlist Syntax

The general syntax for a solenoidal inductor is:

```
ASOLINDxxxx n1 n2 N=val DD=val P=val RB=val D=val
COMPONENT=solenoidal_inductor
```

n1 is the positive node and *n2* is the negative node of the inductor. The current is assumed to flow from *n1* through the inductor to *n2*.

The parameter **COMPONENT=solenoidal_inductor** identifies the element.

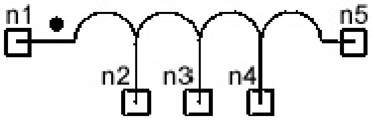
Table 40: Solenoidal Inductor Instance Parameters

Instance Parameter	Description	Unit	Default
N	Number of turns	None	None
DD	Diameter of the winding	Meter	2.54e-3
P	Length of the inductor	Meter	5.08e-3
RB	Conductor resistivity	μ-ohm/cm	1e-3
D	Diameter of the wire	Meter	2.54e-4

Inductor Instance Netlist Example

```
ASOLIND1 1 2 N=100 DD=2e-3 P=6.7e-3 RB=5e-4 D=1e-4
+ COMPONENT=solenoidal_inductor
```

Inductor, Solenoidal, N Taps



Netlist Syntax

```
ASOLINDNxxxx n1 n2 ... nN N=val DD=val P=val RB=val D=val
NT=[val1   val2 ... valN-1] COMPONENT=solenoidal_inductor_n
```

n1 is the positive node, *n2* through *nN-1* are the taps, and *nN* is the negative node of the inductor. The current is assumed to flow from *n1* through the inductor to *nN*.

The parameter **COMPONENT=solenoidal_inductor_n** identifies the element.

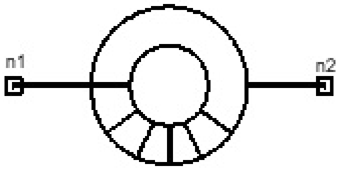
Table 41: Solenoidal Inductor, N Taps Instance Parameters

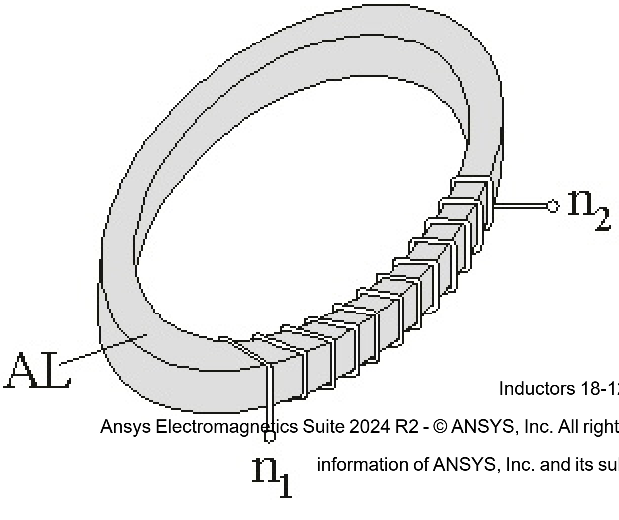
Instance Parameter	Description	Unit	Default
N	Number of taps	None	None
DD	Diameter of the core	Meter	2.54e-3
P	Physical length	Meter	5.08e-3
RB	Conductor resistivity	μ-ohm/cm	1e-3
D	Diameter of the wire	Meter	2.54e-4
NT	Number of turns for each coil section, space-separated list	None	None

Inductor Instance Netlist Example

```
ASOLINDN4 net1 net2 net3 net4 net5 N=3 DD=2e-3 P=6.7e-3 RB=5e-4
D=1e-4 NT=[100 200 300 400] + COMPONENT=solenoidal_inductor_n
```

Ideal Inductor, Toroidal





Netlist Syntax

The general syntax for an ideal toroidal inductor is:

```
Axxxx n1 n2 N=val AL=val COMPONENT=toroidal_inductor
```

n1 is the positive node and *n2* is the negative node of the inductor. The current is assumed to flow from *n1* through the inductor to *n2*.

The parameter **COMPONENT=toroidal_inductor** identifies the element as an ideal toroidal inductor.

Table 42: Ideal Toroidal Inductor Instance Parameters

Instance Parameter	Description	Unit	Default
N	Number of turns	None	None
AL	Inductance per turn	1/Henry	None

Inductor Instance Netlist Example

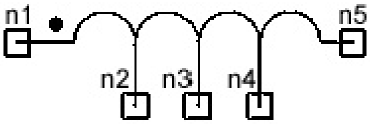
```
Atrindi1 1 2 N=100 AL=5e-9 COMPONENT=toroidal_inductor
```

Notes

1. Inductance *L*

$$L = N^2 \cdot AL$$

Ideal Inductor, Toroidal, N Taps



Netlist Syntax

The general syntax for an ideal toroidal inductor with N taps is:

```
Axxxx n1 n2 ... nN N=val AL=val NT=[val val ...]
COMPONENT=toroidal_inductor_n
```

n1 is the positive node, *n2* through *nN-1* are the taps, and *nN* is the negative node of the inductor. The current is assumed to flow from *n1* through the inductor to *nN*.

The parameter **COMPONENT=toroidal_inductor_n** identifies the element as an ideal toroidal inductor with N taps.

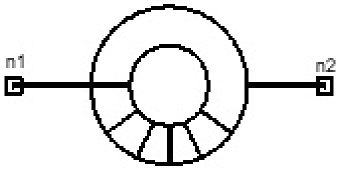
Table 43: Ideal Toroidal Inductor with N taps Instance Parameters

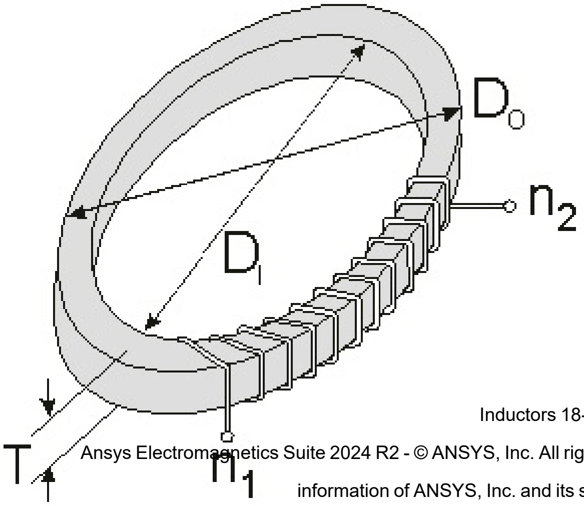
Instance Parameter	Description	Unit	Default
N	Number of taps	None	None
AL	Inductance per turn	1/Henry	None
NT	Number of turns for each coil section, space-separated list	None	None

Toroidal Inductor Instance Netlist Example

```
AtrindiT1 1 2 3 4 N=3 AL=5e-9 NT=[100 200 300]
+ COMPONENT=toroidal_inductor_n
```

Inductor, Toroidal, Physical Model





Netlist Syntax

The general syntax for a toroidal inductor, physical model is:

```
Axxxx n1 n2 N=val MU=val DO=val DI=val T=val RB=val D=val
COMPONENT=toroidal_inductor_physical
```

n1 is the positive node and *n2* is the negative node of the inductor. The current is assumed to flow from *n1* through the inductor to *n2*.

The parameter **COMPONENT=toroidal_inductor_physical** identifies the element as a toroidal inductor, physical model.

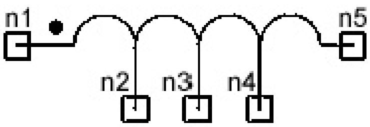
Table 44: Toroidal Inductor, Physical Model Instance Parameters

Instance Parameter	Description	Unit	Default
N	Number of turns	None	None
MU	Relative permeability of core	None	None
DO	Outer diameter of core	Meter	None
DI	Inner diameter of core	Meter	None
T	Thickness of core	Meter	None
RB	Conductor resistivity	μ-Ohm/cm	0.001
D	Diameter of wire	Meter	None

Inductor Instance Netlist Example

```
A1 Port1 Port2 N=10 MU=2 DO=5*2.54e-5 DI=3*2.54e-5
+ T=0.1*2.54e-5  RB=0.001 D=2.54e-5
+ COMPONENT=toroidal_inductor_physical
```

Inductor, Toroidal, Physical Model N Taps



Netlist Syntax

The general syntax for a toroidal inductor, physical model with N taps is:

A*xxxx n1 n2 ... nN* **N=***val* **AL=***val* **MU=***val* **DO=***val* **DI=***val* **T=***val*
RB=*val* **D=***val* **NT=[***val val ...***]**
COMPONENT=toroidal_inductor_physical_n

n1 is the positive node, *n2* through *nN-1* are the taps, and *nN* is the negative node of the inductor. The current is assumed to flow from *n1* through the inductor to *nN*.

The parameter **COMPONENT=toroidal_inductor_physical_n** identifies the element as a physical toroidal inductor with N taps.

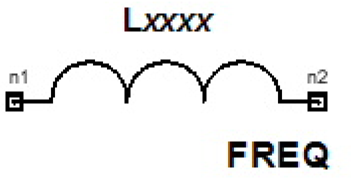
Table 45: Physical Toroidal Inductor with N taps Instance Parameters

Instance Parameter	Description	Unit	Default
N	Number of taps	None	None
MU	Relative permeability of core	None	None
DO	Outer diameter of core	Meter	None
DI	Inner diameter of core	Meter	None
T	Thickness of core	Meter	None
RB	Conductor resistivity	μ-Ohm/cm	0.001
D	Diameter of wire	Meter	None
NT	Number of turns for each coil section, space-separated list	None	None

Toroidal Inductor Instance Netlist Example

```
A1 Port1 Port3 Port4 Port2 MU=1.2 DO=5*2.54e-5 DI=3*2.54e-5
+ T=1*2.54e-5 RB=0.002 D=0.5*2.54e-5 N=2 NT=[3 4 5]
+ COMPONENT=toroidal_inductor_physical_n
```

Inductor, Frequency-Dependent (Netlist Only)



> **Note:** The frequency-dependent inductor is available for use in netlists, but is not supported in the Components window of the **Schematic Editor**.
>
> The frequency-dependent inductor is supported only for frequency-domain analyses such as AC and LNA. To run a time-domain analysis such as TRAN on a circuit including a frequency-dependent inductor, set the **TRAN_EVAL_FREQ** parameter to a constant frequency value.

Frequency-Dependent Inductor Instance Netlist Syntax

Instead of the standard inductor syntax with a specified inductance value, define the inductance by an expression involving the frequency, using the syntax given in this topic. The general form for a frequency-dependent inductor instance is:

```
Lxxxx n1 n2 [L=]'freq-dependent-expr'

[TC1=val]   [TC2=val] [M=val]   [SCALE=val]

[DTEMP=val] [TNOM=val] [TRAN_EVAL_FREQ=val]
```

n1 is the positive node and *n2* is the negative node of the inductor. The current is assumed to flow from *n1* through the inductor to *n2*.

The frequency-dependent expression should be enclosed in single quotation marks. The token **HERTZ** in the expression indicates the frequency as supplied by the analysis. The circuit frequency is available to the model each time the model equations are evaluated. The label **L=** is optional. The first unlabeled value after a *modelname* is taken to be the inductance.

The frequency-dependent inductance expression is evaluated by the Nexxim expression parser, and follows the rules for operands defined in *Names, Number, Constructs, and Expressions* in the Circuit Design Technical Notes. In particular, the Nexxim parser cannot accept complex numbers as operands or arguments to built-in functions.

When the parameter **TRAN_EVAL_FREQ** is provided, Nexxim can run a transient (time-domain) analysis, substituting the value of **TRAN_EVAL_FREQ** for the variable **HERTZ** to produce a constant frequency for the transient analysis.

Table 46: Frequency-Dependent Inductor Instance Parameters

Instance	Description	Unit	Default

Parameter			
DTEMP	Inductor and circuit temperature difference	°C	0.0
DTEMP	Difference between capacitor and circuit temperatures	Celsius	0.0
L	Inductance	Henry	Calculated on the frequency-dependent expression
M	Multiplier to simulate multiple inductors in parallel	None	1.0
SCALE	Scale factor for inductance	None	1.0
TC1	Linear temperature coefficient	$°K^{-1}$	0.0
TC2	Quadratic temperature coefficient	$°K^{-2}$	0.0
TNOM	Nominal temperature	°C	25.0
TRAN_ EVAL_FREQ	Frequency to use for transient analysis	Hertz	0.0

Frequency-Dependent Inductor Netlist Examples

Frequency-domain analysis

```
L1 1 2 L='1/sqrt(HERTZ)' dtemp=30 TC1R=0.1 TC2R=0.05
.LNA LIN 100 1e6 10e6
```

Time-domain analysis

```
L2 11 22 L='1/sqrt(HERTZ)' TRAN_EVAL_FREQ=1e8
.TRAN 0.1ns 10ns
```

Notes

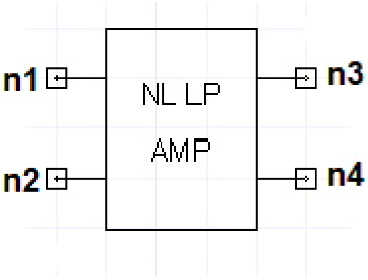
1. The frequency-dependent inductor is supported only for frequency-domain analyses such as AC and LNA. Running a time-domain analysis such as TRAN on a circuit including a frequency-dependent inductor is an error.
2. The frequency-dependent expression should be enclosed in single quotation marks. The token **HERTZ** can be used in the expression to indicate the frequency as supplied by the analysis. The circuit frequency is available to the model each time the model equations are evaluated. The label **L=** is optional. The first unlabeled value is taken to be the inductance.
3. When the parameter **TRAN_EVAL_FREQ** is provided, Nexxim can run a transient (time-domain) analysis, substituting the value of **TRAN_EVAL_FREQ** for the variable **HERTZ** to produce a constant inductance value for the transient analysis.

19 - LoadPull Behavioral Elements

This topic describes the following data-driven, loadpull behavioral elements:

"Nonlinear LoadPull Amplifier" below

Nonlinear LoadPull Amplifier



Nonlinear Loadpull Amplifier Instance Netlist Syntax

The nonlinear loadpull amplifier model uses data-driven load pull values. The user supplies the load pull data via files in the LPD or LPC format from Focus Microwaves, Inc. The user-supplied LPD data gives the output power for a range of output impedances at constant input power and at a given frequency. The LPC data allows sweeps of source power.

The amplifier is behavioral in that no reflections from the inputs are calculated. Source matching is assumed (*Zin* = *Zs**, where * denotes the complex conjugate). The component may be used with one-tone and two-tone harmonic balance analyses, including load-pull analysis to verify impedance matching.

The syntax for a nonlinear loadpull amplifier instance is:

```
ANLLPAMPxxxx n1 n2 n3 n4 loadpull_file=file_reference
source_frequency1=val source_frequency2=val load_resistance=val
load_reactance=val model_switch=val COMPONENT=loadpull_behavioral_
model
```

n1 and *n2* are the input nodes, *n3* and *n4* are the output nodes of the amplifier.

See LPD and LPC File Formats in this topic for specifications on the load pull data required by Nexxim.

See *File References* in the Nexxim Netlist File Format topic for details on file references. See *File References* in the Nexxim Netlist File Format topic for details on file references.

The entry **COMPONENT=loadpull_behavioral_model** identifies the device.

Table 1: Nonlinear Loadpull Amplifier Instance Parameters

Parameter	Description	Unit	Default
loadpull_ file	Pathname\filename of file containing the loadpull data (LPD or LPC format)	None	None
source_ frequency1	Frequency of source connected to the input of the NLAMP. A value greater than 0 Hz is required to enable one-tone or two-tone analysis.	Hertz	None
source_ frequency2	Frequency of second input source when two-tone analysis is appropriate. A value greater than 0 Hz is required to enable two-tone analysis. A value of 0 Hz means the second tone is absent.	Hertz	0
load_ resistance	Resistance of the load. A value of 0 means the resistance is unknown, and Nexxim attempts to predict the value.	Ohm	0
load_ reactance	Reactance of the load. A value of 0 means the reactance is unknown, and Nexxim attempts to predict the value.	Ohm	0
model_ switch	Selects implementation: 0=newer frequency domain implementation 1=earlier (Release 6.0) time domain implementation	None	0

Nonlinear Loadpull Amplifier Netlist Example

```
ANLLPAMP123 sig1 sig2 line1 line2
+ loadpull_file="c:\nexxim_loadpull\test_loadpull\demo.lpd"
+ source_frequency1=1GHz COMPONENT=loadpull_behavioral_model
```

Notes

1. Specifying the **load_resistance** and **load_impedance** can help when the simulation has problems converging.
2. To run a demonstration of analyses with the nonlinear loadpull amplifier component, see *Nonlinear Loadpull Amplifier Demo* in Nexxim Design Examples.

LPD and LPC File Formats

A file in the LPD or LPC format for loadpull data from Focus Microwaves, Inc. (**.lpd** or **.lpc** extension) consists of three parts: the File Header, the Title Line, and the lines of data.

LPD or LPC File Header

The load pull data file must begin with a header containing required information. The file header may contain additional lines of information, but Nexxim uses only the lines in the following list.

```
! Load Pull Measurement Data

!--------------------------------------

! File =filename
! Date =date Time: time
!--------------------------------------

! Comment =

! Frequency =loadpull_frequency
! Char.Impedances = Source: val Load: val
! Source Impedance =rval +jival
!--------------------------------------
```

The entries in bold must appear just as shown. The italic fields are the values to be supplied.

Title Line

The title line specifies the type of measurement data in each column in the file. Nexxim uses only the types of measurement data specified in this topic.

Point R jX Pin[dBm] Pout[dBm] Gain[dB] IMD2Lo[dBc] IMD2Up[dBc] IMD3Lo[dBc] IMD3Up[dBc]

The LPC format supports a sweep of input power. The Title line is the same,

Point R jX Pin[dBm] Pout[dBm] Gain[dB] IMD2Lo[dBc] IMD2Up[dBc] IMD3Lo[dBc] IMD3Up[dBc]

The following table describes these data elements. Load impedance may be specified using either Real/Imaginary or Gamma/Phase values.

Table 2: LPD and LPC Format Data Elements

Title Line Entry	Description
Point	Point index of the load pull (starting with 1)
R	Real part of load impedance
jX	Imaginary part of load impedance
Gamma	Magnitude of reflection coefficient

Title Line Entry	**Description**
Phase	Phase of reflection coefficient
Pin[dBm]	Input power in dBm. For LPD files, the input power is essentially constant. For LPC files, the input power is swept.
Pout[dBm]	Output power in dBm.
Gain	Gain in dB. The file must specify either Pout or Gain. If both are specified, the Gain value is used.
IMD2[dBc] or **IMD2[dBm]**	Second-order intermodulation product, specified in dBc or dBm. If IMD2 is omitted, even-order terms are ignored.
IMD2Lo[dBc], **IMD2Up [dBc]** or **IMD2Lo[dBm]**, **IMD2Up[dBm]**	Alternative to IMD2 Lower and upper 2nd-order intermodulation products, specified in dBc or dBm. Nexxim uses the average of the two values.
IMD3[dBc] or **IMD3[dBm]**	Second-order intermodulation product, specified in dBc or dBm.
IMD3Lo[dBc], **IMD3Up [dBc]** or **IMD3Lo[dBm]**, **IMD3Up[dBm]**	Alternative to IMD3. Lower and upper 2nd-order intermodulation products, specified in dBc or dBm. Nexxim uses the average of the two values.

Example LPD File

Here is an abbreviated example of an LPD load pull data file .

```
! Load Pull Measurement Data
!-------------------------------
! File = C:\data\example.lpd
! Date = Mon Mar 13 17:48:54 2000
!-------------------------------------------------------
! Comment = Example for documentation
! Frequency = 1.9600 GHz
! Char.Impedances = Source: 50 Ohm, Load: 50 Ohm
! Source Impedance = 4.15 +j -2.56 Ohm
!-------------------------------------------------------
Point R jX Pin[dBm] Pout[dBm] Gain[dB] IMD2Lo[dBc] IMD2Up[dBc] IMD3Lo[dBc] IMD3Up[dBc]
!-------------------------------------------------------
001 3.7402 -0.0239 28.84 37.83 8.89 -39.24 -41.13 -57.98 -59.54
```

```
002 3.7006 -0.6991 28.98 37.87 8.88 -38.17 -40.42 -56.51 -57.28

003 3.2289 -0.4435 28.99 37.95 8.96 -38.37 -40.51 -55.95 -57.76

. . .
```

Example LPC File

Here is an abbreviated example of an LPC data file representing a multitone application.

```
! Load Pull Measurement Data

!-----------------------------------------------------

! File = C:\data\sweep.lpc

! Date = Monday, May 10, 2010 Time: 10:01:33

!-----------------------------------------------------

! Comment =

! Frequency = 1.000 GHz

! Char.Impedances = Source: 50 Ohm Load: 50 Ohm

! Source Impedance = 34.66 +j -158.27 Ohm

!-----------------------------------------------------

Point Gamma Phase[deg] Pin[dBm] Pout[dBm] Gain[dB] V2[V] I2[mA] PAEff[%] Pout@F0[dBm] Pout@F1[dBm] Pout@F2[dBm] IMD3Lo[dBc] IMD3Up[dBc]

!-----------------------------------------------------

# 001 0.300 -60.0

5.22 21.35 16.14 4.982 207.037 12.92 20.14 -9.64 -18.96 38.960 38.890

6.25 22.26 16.01 4.982 200.414 16.44 24.63 -7.51 -15.85 36.980 37.020

7.25 23.14 15.89 4.982 193.667 20.82 21.69 -5.41 -12.72 34.910 34.690

8.25 23.80 15.55 4.982 186.526 25.11 22.57 -3.11 -9.51 25.030 26.710

9.24 24.61 15.37 4.982 178.470 31.59 12.54 -0.52 -5.74 25.160 26.760

10.24 25.40 15.17 4.982 167.481 40.32 16.30 2.48 -1.01 22.680 24.470

11.30 26.28 14.99 4.982 152.044 54.32 20.53 5.92 4.47 21.750 16.810

12.34 27.12 14.78 4.982 151.259 66.16 26.45 8.59 9.77 13.890 14.140

13.32 27.67 14.36 4.982 156.795 72.17 25.53 10.44 12.16 12.130 12.880
```

```
14.31 28.05 13.75 4.982 163.230 75.23 25.99 11.73 13.29 11.260 12.460
# 002 0.300 -30.0
...
```

20 - Maxwell Spice Legacy Elements

This topic describes the following elements that are supported in Nexxim for backward compatibility with Maxwell Spice™.

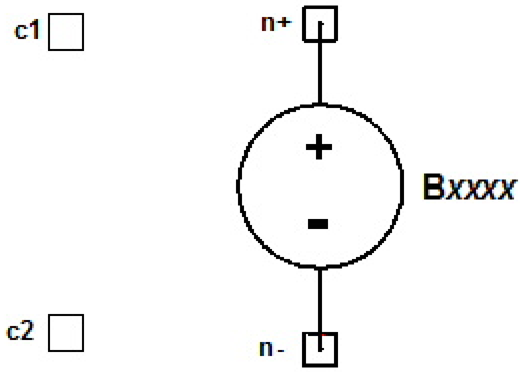
"Voltage-Controlled Voltage Source, Nonlinear Dependent" below

"N-Element, Frequency-Dependent S-Parameters" on the next page

"Voltage-Controlled Current Source, Piecewise Linear" on page 20-3

"S-Element Voltage-Controlled Switch" on page 20-8

Voltage-Controlled Voltage Source, Nonlinear Dependent



Nonlinear VCVS Netlist Format

The B-element is a nonlinear dependent voltage-controlled voltage source generated for Nexxim by Maxwell Spicelink. The format for a B-element is:

`Bxxxx n+ n- V=”expression_of_V(c1)_and_V(c2)”`

n+ is the positive node and *n-* is the negative node of the voltage source. The *expression* is a function of the two control voltages. The expression can contain functions such as ABS, COS, and SIN; see the Nexxim Netlist Format module for a list of supported operators and functions in expressions.

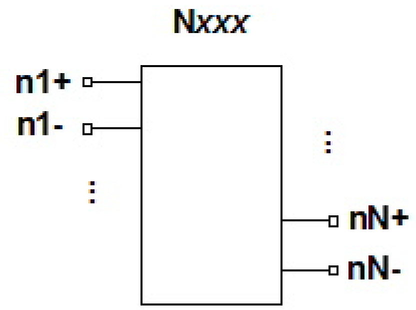
> **Note:**
>
> It is recommended that the expression be enclosed in single or double quotation marks. The expression *must* be enclosed in single or double quotes if it contains any leading, trailing, or embedded white space. If the circuit analysis does not seem to yield the correct results, check to ensure that all generated expressions are enclosed in quotes.

Nonlinear VCVS Netlist Examples

```
Benp 13 0 V="V(5)*V(10)"
```

```
Benm 14 0 V="COS(V(5)) * SIN(V(10))"
```

N-Element, Frequency-Dependent S-Parameters



N-Element Instance Netlist Format

The N element is characterized by a set of frequency-dependent scattering (S) parameters, compatible with the N-element from Maxwell Spicelink™. The N-element has the netlist format:

`N``xxx n1+ n1-... nN+ nN- file_reference`

Each of the N ports is a pair of terminals, positive and negative: *n1+ n1-* through *nN+ nN-*.

N-Element Instance Netlist Example

```
Nmain 20 0 21 0 22 0 23 0 freq_data.txt
```

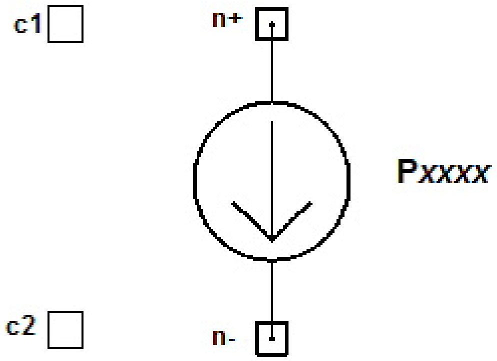
Notes

1. The *file_reference* refers to an external file (usually with a **.fws** extension) containing the S-parameter data. See *File References* in the Nexxim Netlist File Format topic for details.
2. The format of the S-parameter data file is:

```
#
# S-parameter data for model modelname

#

Nports =number of pos/neg pairs

Freq_min =minimum frequency (Hz)

Freq_max =maximum frequency (Hz)

Npoints =number of frequency points in file

Zref =reference impedance

#

freq_min smag11 sphase 11 smag12 sphase12 ...

freq2 smag11 sphase 11 smag12 sphase12 ...
...
freqi smag11 sphase 11 smag12 sphase12 ...
...

freq_max smag11 sphase 11 smag12 sphase12 ...

end of file
```

3. The **Npoints** parameter specifies the number of frequency points (including zero frequency) that follow. The **Zref** parameter specifies the constant, frequency-independent reference impedance that was used for all the ports, typically 50 Ohms.
4. The frequencies *freq1*, *freq2, ...* should be on a regular grid from *Freq_min* to *Freq_max* with steps of size (*Freq_max* - *Freq_min*)/(*Npoints* - 1). *Freq_min* is always zero when the data comes from Maxwell Spicelink.
5. The magnitude is absolute magnitude (not dB) and the phase is in degrees. The S-parameter matrix is specified as a full matrix.

Voltage-Controlled Current Source, Piecewise Linear



The P element is a piecewise linear dependent voltage-controlled current source generated for Nexxim by Maxwell Spicelink. The netlist format for the P element is:

`Pxxxx n+ n- ISRC V(c1) [V(c2)] modelname`

n+ is the positive node and *n-* is the negative node of the current source. **ISRC** is required for the **P** element type. *c1* and *c2* are the nodes whose voltages control the P current source. *modelname* is the name of a .MODEL statement of type **PWL** elsewhere in the netlist.

Piecewise Linear VCCS Netlist Example

```
Pgclamp 6 3 ISRC V(7) pwrclamp

Ppullup 6 2 ISRC (V13) V(8) pulldown
```

Note:

1. The PWL model allows a single dependent dataset, which can be controlled by one or two independent datasets. The model for a P-element PWL dependent source with one independent variable and one dependent variable has the following netlist syntax:

```
.MODELmodelname PWL TABLE=(


+ data_block

+ ) [extrapolation1] [extrapolation2] ...
```

The syntax for a one-independent variable , one-dependent variable block (*data_ block*) is:

```
+ count,

+ i_1,... , + i_count,

+ 1

+ d_2,... d_count
```

2. The syntax for a PWL model with two independent variables and one dependent variable has the following netlist syntax:

```
.MODELmodelname PWL TABLE=(


+ count1

+ i_11, ... i_1count1,

+ 0,

+ data_block_1

...

+ data_block_count1

+ ) [extrapolation1] [extrapolation2] ...
```

The *modelname* is the name used by the P-elements that refer to this model. The keyword **PWL** is required.

3. The **TABLE** data describes families of curves, that allow the simulator to interpolate over one controlling variable at a time. The basic syntax block (*data_ block*) consists of one independent variable and one dependent variable. The independent variable data is introduced by the number of data points for that variable (*count*), followed by the data points (i_{11}, ... $i_{1count1}$). The independent variable dataset is followed by the set of dependent variable data, introduced by a 1 (representing the number of dependent variables), the dependent data points (d_2**,** ... d_{count}). See **Example 1**.
4. If there are two independent variables, the outer variable is specified first, starting with the number of data points for that variable (*count1*), the data points (i_{11}, ... $i_{1count1}$). The second or inner independent variable points and all the dependent data is introduced by a zero (**0**), then by *count1* independent-dependent blocks of data, one block for each point in (i_{11}, ... $i_{1count1}$). See **Example 2**.
5. The table data can be followed by the extrapolation specifications, one for each set of independent data. Each *extrapolation* specifies the type of extrapolation to use: **linear**, **constant**, or **periodic**. **Linear** is the default

PWL Dependent Source Model Examples

Example 1

The first example models a source with one independent variable **i1** and one dependent variable **d1** with the ten data points listed in the following table:

Table 11: Example 1 PWL Model Data

i1	d1
-3.3	3.0e-7
-3.2	2.9e-7
-3.1	2.9e-7
-3.0	2.8e-7
-2.9	2.8e-7
-2.8	2.7e-7
-2.7	2.7e-7
-2.6	2.6e-7
-2.5	2.6e-7

i1	d1
-2.4	2.5e-7

The .MODEL statement for example 1 is:

```
.MODEL pwrclamp PWL TABLE=(   + 10 $ Start of independent variable
data
+ -3.3, -3.2, -3.1, -3.0, -2.9,
+ -2.8, -2.7, -2.6, -2.5, -2.4,
+ 1 $ Start of dependent variable data
+ 3.0e-007, 2.9e-007, 2.9e-007, 2.8e-007, 2.8e-007,
+ 2.7e-007, 2.7e-007, 2.6e-007, 2.6e-007, 2.5e-007
+ ) LINEAR
```

Example 2

The second example models a source with two independent variables i1 and i2, and one dependent variable d1 with the 13 data points listed in the following table:i

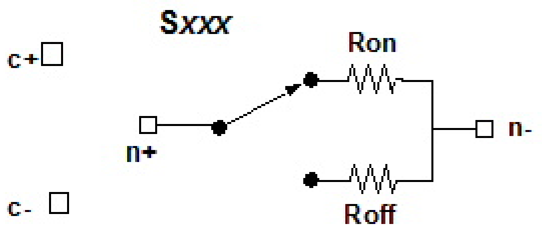
Table 12: Example 2 PWL Model Data

i1	i2	d1
0	0	0
0	1	0
0	2	0
1	-0.5	-0.04979
1	-0.4	-0.04152
1	-0.3	-0.03233
1	-0.2	-0.02176
1	-0.1	-0.01096
1	-0.0	4.85e-9
1	0.1	0.01082
1	0.2	0.02121
1	0.3	0.03117
1	0.4	0.04072

The .MODEL statement for example 2 is:

```
.MODEL pulldown PWL TABLE=(
+ 2, 0.0 1.0, $ First independent variable
+ 0, $ Start of nested data
+ 3, 0.0, 1.0, 2.0 $ First inner block
+ 1, $ Start of dependent variable data for first block
+ 0.0, 0.0, 0.0
+ 10, $ Second inner block
+ -0.5, -0.4, -0.3, -0.2, -0.1,
+ 0.0, 0.1, 0.2, 0.3, 0.4,
+ 1 $ Start of dependent variable data for second block
+ -0.04979, -0.04152, -0.03233, -0.02176, -0.01096,
+ 4.85e-9, 0.01082, 0.02121, 0.03117, 0.04072
+ ) CONSTANT LINEAR
```

S-Element Voltage-Controlled Switch



S-Element Voltage-Controlled Switch Instance Netlist Format

The S-element voltage-controlled switch is generated for Nexxim by Maxwell Spicelink™. This element has the netlist format:

S*xxx n+ n- c+ c- modelname*

n+ and *n-* are the positive and negative signal voltage nodes. *c+* and *c-* are the positive and negative control voltage nodes. *modelname* is the name of a .MODEL statement of type **SW** elsewhere in the netlist. See the SW Switch Model description for the operation of the switch.

S-Element Voltage-Controlled Switch Instance Netlist Example

```
s1 1 2 3 4 switch1
```

SW Switch Model

The SW model statement has the following netlist syntax:

```
.MODELmodelname SW [model_parameters]
```

The *modelname* is the name used by S-elements to reference this model definition. The keyword **SW** is required for voltage-controlled switch models.

Table 13: SW Model Parameters

Parameter	Description	Units	Default
ROFF	OFF resistance	Ohm	1.0e12
RON	ON resistance	Ohm	1.0
VT	Threshold voltage	Volt	0.0

SW Switch Model Netlist Example

```
.MODEL switch1 SW ROFF=1.7 RON=5e+6 VT=5.0
```

SW Switch Model Notes

1. The switch model describes an almost-ideal switch. Properly selected on and off resistances can effectively be zero and infinity by comparison with other circuit elements.
2. The switch is set to ON when [V(c+) - V(c-)] > VT. In the ON state, the resistance from *n+* to *n-* is **Ron**. The switch is set to OFF when [V(c+) - V(c-)] ≤ VT. In the OFF state, the resistance from *n+* to *n-* is **Roff**.

21 - Microstrip Elements

This topic describes the following Microstrip substrate distributed elements:

General Components

Bends

Capacitors

Coupled Bends

Coupled Lines

Couplers

Cross Junctions

Gaps

Inductors

Open-Ended Lines

Radial Stubs

Shorted Stubs

Tapered Lines

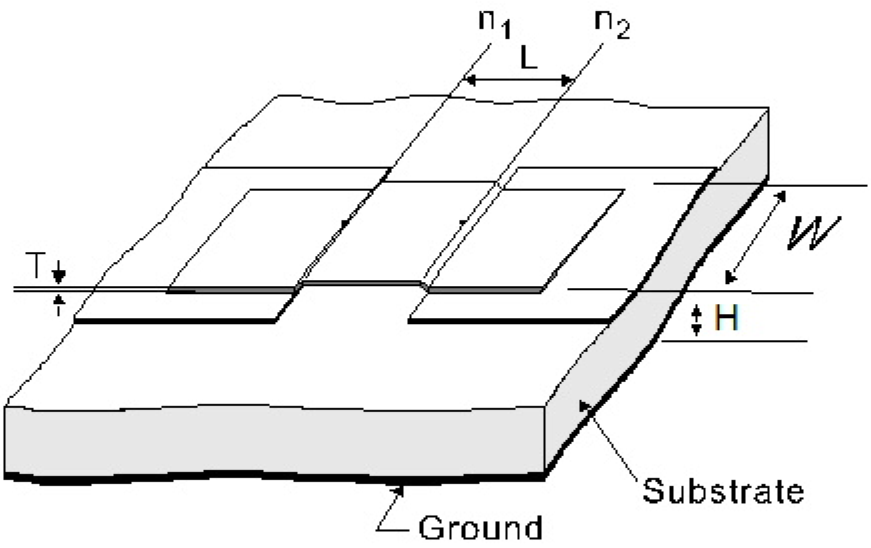
Thin-Film Resistors

Transmission Lines

Y Junctions

This topic also describes the microstrip substrate type.

Air Bridge, Rectangular Cross Section



Netlist Form

An instance of a microstrip air bridge with rectangular cross-section has the following Nexxim netlist syntax:

```
Axxx n1 n2 [W=val] [T=val] [L=val] [R=val] COMPONENT=msjump

+ SUBSTRATE=substrate_name
```

n1 and *n2* are the nodes connected to the bridge. The entry **COMPONENT=msjump** identifies the element.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 4: Air Bridge Instance Parameters

Parameter	Description	Units	Default
W	Width of jumper wire	Meter	0.5e-3
T	Thickness of jumper wire	Meter	0.1e-3
L	Length of jumper wire	Meter	1.0e-3
R	Resistivity of the wire	µohm/cm	0.0

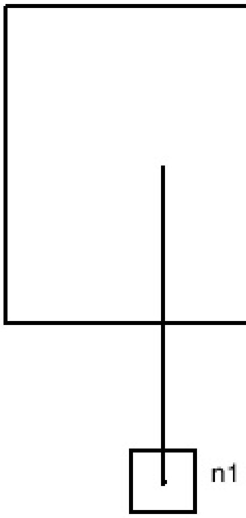
Netlist Example

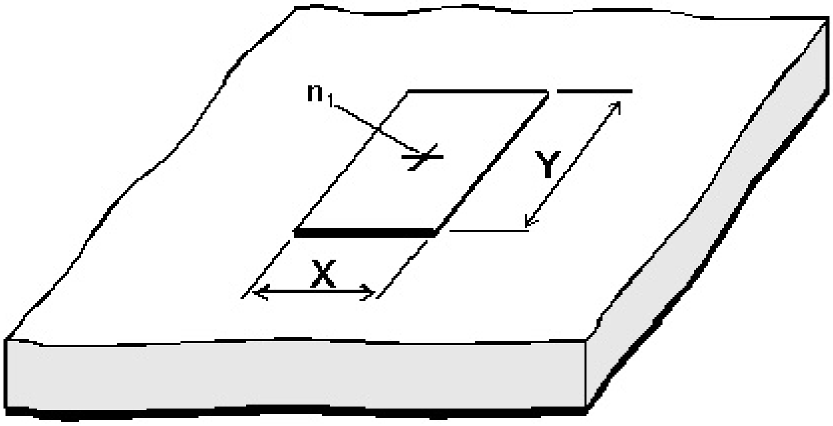
```
Ajumper1 1 2 W=0.3e-3 T=0.05e-3 L=0.8e-3 COMPONENT=msjump
+ SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Bond Pad





Netlist Format

A bond pad instance has the following netlist format:

A*xxx n1* [**X=***val*] [**Y=***val*] **D=***val*

COMPONENT=msbondpad SUBSTRATE=*substrate_name*

n1 is the name of the node attached to the pad. The entry **COMPONENT=msbondpad** identifies the element as a bond pad.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 5: Bond Pad Instance Parameters

Parameter	Description	Unit	Default
X	Length of the bonding pad	Meter	2.0e-3
Y	Width of the bonding pad	Meter	1.0e-3

Netlist Example

```
Apad1 Port1 X=1e-3 Y=2e-3 COMPONENT=msbondpad SUBSTRATE=FR4
```

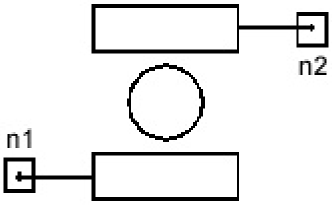
where FR4, the selected layout technology or substrate type, has a definition such as:

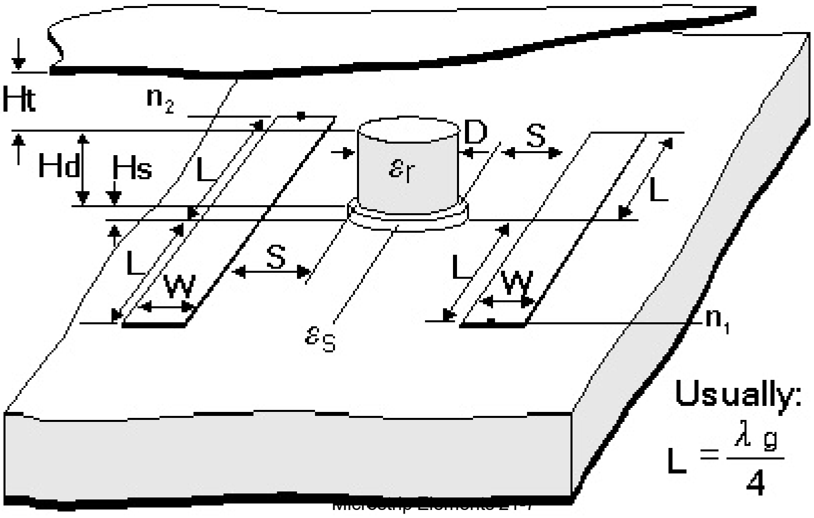
```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**Microstrip**] The model includes dispersion effects.

Dielectric Resonator, Band Pass





Netlist Format

A dielectric resonator, bandpass instance has the following netlist format:

```
Axxx n1 n2 W=val D=val HD=val SDR=val ER=val L=val S=val HT=val

[HS=val ES=val] COMPONENT=dielectric_resonator_bandpass
SUBSTRATE=substrate_name
```

n1 is the name of the node attached to the pad. The entry **COMPONENT=dielectric_resonator_bandpass** identifies the element.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 6: DRBP Instance Parameters

Parameter	Description	Unit	Default
W	Width of the MS	Meter	1e-3
D	Diameter of the DR	Meter	5e-3
HD	Height of the DR	Meter	4e-3
SDR	Conductivity of DR	mho-meter	1e-16
ER	Dielectric constant of DR	None	35.0
L	Length of reference plane to center of DR	Meter	50e-3
S	Distance between DR and MS	Meter	0.3e-3
HT	Distance between cover and the top of the DR	Meter	0.8e-3
HS	Height of the standup layer	Meter	0
ES	Dielectric constant of the standup layer	None	1

Netlist Example

```
Adrbp1 Port1 Port 2 W=0.5e-3 D=3.4e-3 HD=2e-3
COMPONENT=dielectric_resonator_bandpass SUBSTRATE=FR4
```

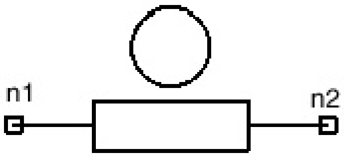
where FR4, the selected layout technology or substrate type, has a definition such as:

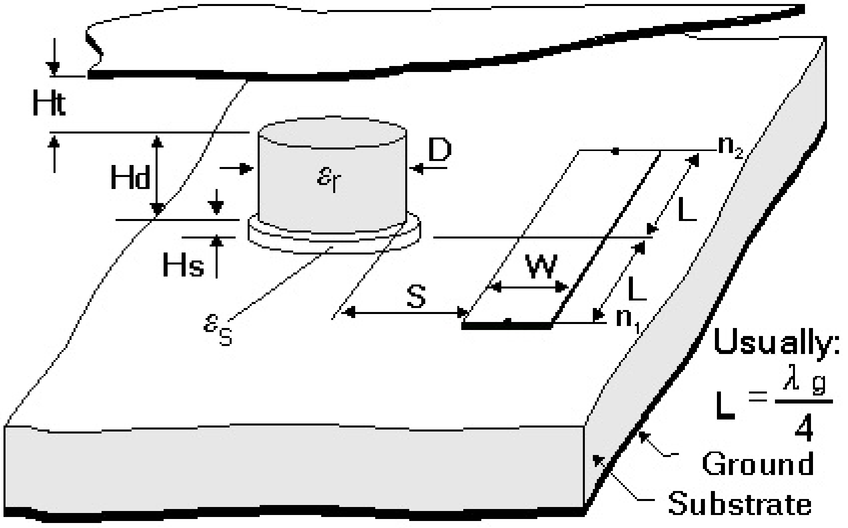
```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. The resonator dimensions should satisfy 0.1 < D/HD < 10.

Dielectric Resonator, Band Stop





Netlist Format

A dielectric resonator, bandstop instance has the following netlist format:

A*xxx n1 n2* **W=***val* **D=***val* **HD=***val* **SDR=***val* **ER=***val* **L=***val* **S=***val* **HT=***val*

[**HS=***val* **ES=***val*] **COMPONENT=dielectric_resonator_bandstop SUBSTRATE=***substrate_name*

n1 is the name of the node attached to the pad. The entry **COMPONENT=dielectric_resonator_bandstop** identifies the element.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 7: DRBS Instance Parameters

Parameter	**Description**	**Unit**	**Default**
W	Width of the MS	Meter	1e-3
D	Diameter of the DR	Meter	5e-3
HD	Height of the DR	Meter	4e-3
SDR	Conductivity of DR	mho-meter	1e-16
ER	Dielectric constant of DR	None	35.0
L	Length of reference plane to center of DR	Meter	50e-3
S	Distance between DR and MS	Meter	0.3e-3
HT	Distance between cover and the top of the DR	Meter	0.8e-3
HS	Height of the standup layer	Meter	0
ES	Dielectric constant of the standup layer	None	1

Netlist Example

```
Adrbs1 Port1 Port 2 W=0.5e-3 D=3.4e-3 HD=2e-3
COMPONENT=dielectric_resonator_bandstop SUBSTRATE=FR4
```

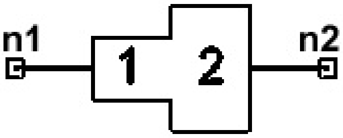
where FR4, the selected layout technology or substrate type, has a definition such as:

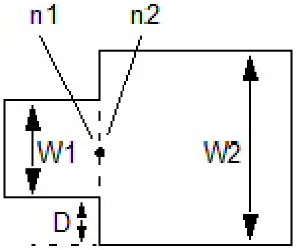
```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. The resonator dimensions should satisfy 0.1 < D/HD < 10.

Step





Netlist Format

A step instance has the following netlist format:

```
Axxx n1 n2 W1=val W2=val D=val [NSUM=val]

COMPONENT=step SUBSTRATE=substrate_name
```

n1 and *n2* are the names of the nodes attached to the step. The entry **COMPONENT=step** identifies the element as a step.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 8: Step Instance Parameters

Parameter	Description	Unit	Default
W1	Width of line connected to node n1	Meter	1e-3
W2	Width of line connected to node n2	Meter	1e-3
D	Offset between lines	Meter	Calculated

Netlist Example

```
A23 Port1 Port2 W1=1e-3 W2=2e-3 D=0.5e-3 COMPONENT=STEP
SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

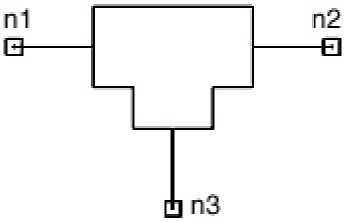
Notes

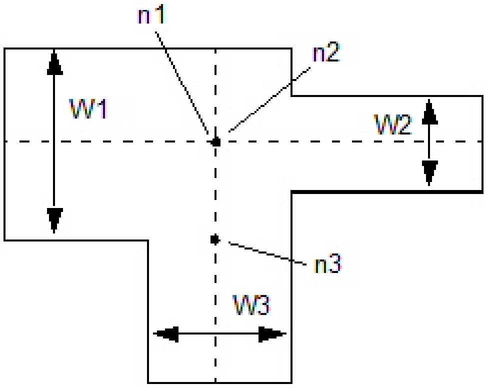
1. [**Microstrip**] The model is valid for frequencies much less than the cutoff frequency of the second higher order mode of the planar waveguide model of the wide microstrip.
2. [**All**] If offset D parameter not specified, it is calculated as (|W1-W2|)/2.
3. [**Microstrip**] Radiation loss is calculated if HU is not specified in the .SUB statement.

References

1. R. Hoffmann, *Handbook of Microwave Integrated Circuits*, Artech House, 1987.

Tee, Reference Planes at Center





Netlist Format

A tee instance has the following netlist format:

```
Axxx n1 n2 n3 W1=val W2=val W3=val [NSUM=val]

COMPONENT=tee SUBSTRATE=substrate_name
```

n1, *n2*, and *n3* are the names of the nodes attached to the tee. The entry **COMPONENT=tee** identifies the element as a tee.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 9: Tee Instance Parameters

Parameter	Description	Unit	Default
W1	Width of line connected to node n1	Meter	1e-3
W2	Width of line connected to node n2	Meter	1e-3

W3	Width of line connected to node n3	Meter	1e-3
NSUM	Number of modes considered in the field expansion	None	3

Netlist Example

```
A23 Port1 Port2 Port3 W1=1e-3 W2=2e-3 W3=3e-3
+ COMPONENT=TEE SUBSTRATE=FR4
```

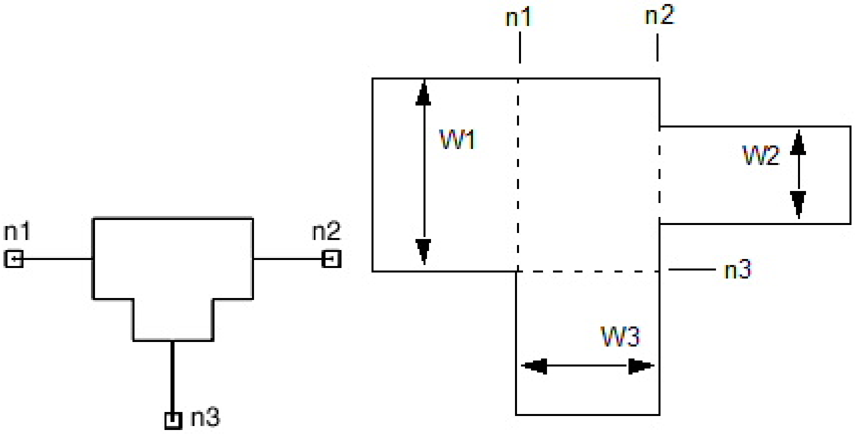
where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] The collinear lines are connected to nodes n1 and n2 and have widths W1 and W2; the perpendicular line is connected to node n3 and has width W3.
2. [**All substrates**] The n1, n2 reference plane is centered on the width of the line connected to node n3 (width W3).
3. [**All substrates**] If W1 > W2: Node n3 is collinear with W1.
4. [**All substrates**] If W2 > W1: Node n3 is collinear with W2.
5. [**Microstrip**] Radiation loss is calculated if HU is not specified in the .SUB statement.
6. [**Microstrip**] To get accurate results, the following condition should be satisfied: $H/\lambda_g << 1$, where λ_g is the guide wavelength in the substrate dielectric.

Tee, Reference Planes at Edge



Netlist Format

A tee instance has the following netlist format:

`A``xxx n1 n2 n3 `**`W1=`**`val `**`W2=`**`val `**`W3=`**`val [`**`NSUM=`**`val]`

`COMPONENT=tee_edge_referenced SUBSTRATE=``substrate_name`

n1, *n2*, and *n3* are the names of the nodes attached to the tee. The entry **COMPONENT=tee_edge_referenced** identifies the element.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 10: Tee Instance Parameters

Parameter	Description	Unit	Default
W1	Width of line connected to node n1	Meter	1e-3
W2	Width of line connected to node n2	Meter	1e-3
W3	Width of line connected to node n3	Meter	1e-3
NSUM	Number of modes considered in the field expansion	None	3

Netlist Example

```
A23 Port1 Port2 Port3 W1=1e-3 W2=2e-3 W3=3e-3
+ COMPONENT=tee_edge_referenced SUBSTRATE=FR4
```

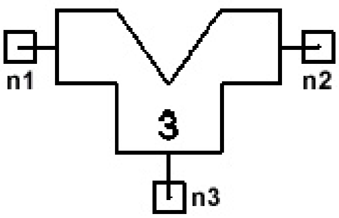
where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] The collinear lines are connected to nodes n1 and n2 and have widths W1 and W2; the perpendicular line is connected to node n3 and has width W3.
2. [**All substrates**] If W1 > W2: Node n3 is collinear with W1.
3. [**All substrates**] If W2 > W1: Node n3 is collinear with W2.
4. [**Microstrip**] Radiation loss is calculated if HU is not specified in the .SUB statement.
5. [**Microstrip**] To get accurate results, the following condition should be satisfied: $H/\lambda_g << 1$, where λ_g is the guide wavelength in the substrate dielectric.

Compensated TEE



NOTE: There is no netlist form for this component. It is available for Planar EM simulation only.

n1, *n2*, and *n3* are the names of the nodes attached to the tee.

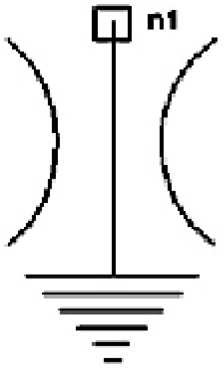
Table 11: Compensated TEE Instance Parameters

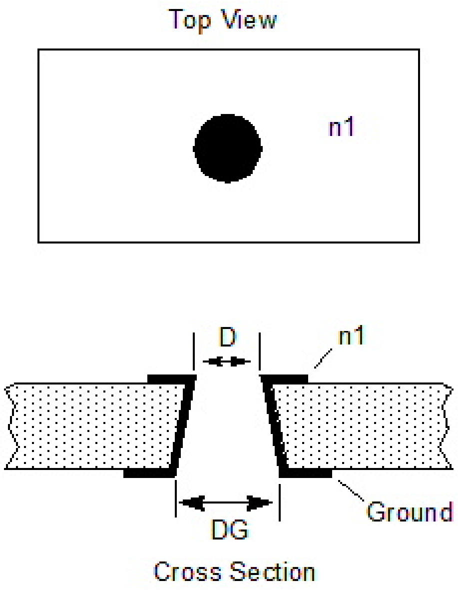
Parameter	Description	Unit	Default
W	Conductor width at ports 1 and 2	Meter	0.001
W3	Conductor width at port 3	None	0.001
D	Notch depth	Meter	0.001
ANG	Notch angle	Degree	45

Notes

1. This model is available for Planar EM simulation only.
2. The notch angle coincides with the center of the line on port 3.
3. The structure is de-embedded to the reference planes that coincide with the edges of W and W3, respectively, unless the notch angle or depth causes the edges of the notch to fall outside the rectangle transcribed by the physical dimensions W and W3. In that case, the reference planes are transferred to the outermost corners of the notch.
4. If a substrate is not defined for the component, the Layout stackup or Footprint stackup may be used.

Via Through Hole





Netlist Format

A via hole instance has the following netlist format:

A*xxx n1* [**D=***val*] [**DG=***val*] **COMPONENT=viahole SUBSTRATE=***substrate_name*

n1 is the name of the node attached to the via through hole. The other node is ground, and is not specified in the syntax. The entry **COMPONENT=viahole** identifies the element as a via through hole.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 12: Via Through Hole Instance Parameters

Parameter	Description	Unit	Default
D	Diameter of upper via hole	Meter	1e-3
DG	Diameter of lower via hole	Meter	D

Netlist Example

```
A19 Port1 D=0.001 COMPONENT=viahole SUBSTRATE=FR4
```

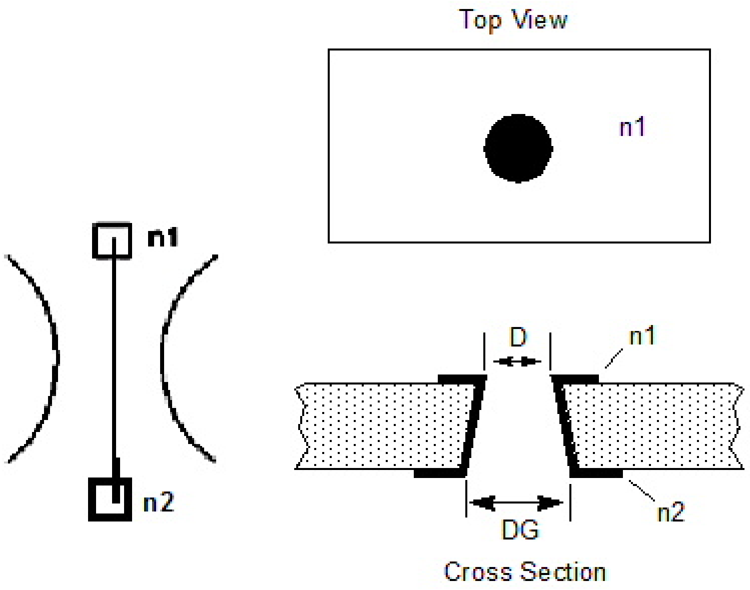
where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] If metallization is not specified in the referenced substrate definition, the via element behaves as an inductance only.
2. [**Microstrip**] To get accurate results, set **H** << ƛ, where:
   ƛ is the wavelength, **H** is the substrate height defined in the referenced substrate type.
3. [**Microstrip**] Radiation loss is included if the cover height is not defined in the substrate definition.

Via Through Hole with Reference



Netlist Format

A via hole instance has the following netlist format:

A*xxx n1 n2* [**D=***val*] [**DG=***val*] **COMPONENT=viahole SUBSTRATE=***substrate_name*

n1 and *n2* are the names of the node attached to the via through hole. The entry **COMPONENT=viahole** identifies the element as a via through hole.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 13: Via Through Hole Instance Parameters

Parameter	Description	Unit	Default
D	Diameter of upper via hole	Meter	1e-3
DG	Diameter of lower via hole	Meter	D

Netlist Example

```
A21 Port1 net_31 D=0.001 COMPONENT=viahole SUBSTRATE=FR4
```

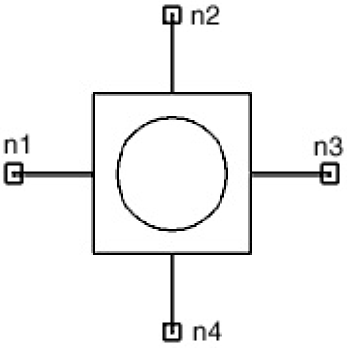
where FR4, the selected layout technology or substrate type, has a definition such as:

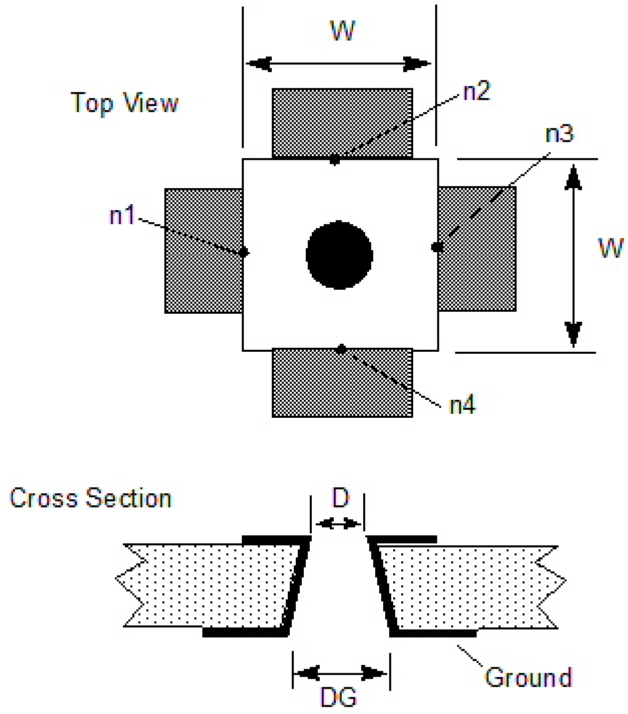
```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] If metalization is not specified in the referenced substrate definition, the via element behaves as an inductance only.
2. [**Microstrip**] To get accurate results, set **H** << ƛ, where:
   ƛ is the wavelength, **H** is the substrate height defined in the referenced substrate type.
3. [**Microstrip**] Radiation loss is included if the cover height is not defined in the substrate type.

Via Pad





Netlist Format

A via pad instance has the following netlist format:

`Axxx n1 [n2 n3 n4] [D=val] [DG=val] [W=val]`

`COMPONENT=viapad SUBSTRATE=substrate_name`

n1 through *n4* are the names of the nodes attached to the via pad. Any nodes not specified are modeled as open stubs. A fifth node is connected to ground, and is not shown in the syntax. The entry **COMPONENT=viapad** identifies the element as a via pad.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 14: Via Through Hole Instance Parameters

Parameter	Description	Unit	Default
D	Diameter of upper via hole	Meter	0.5e-3
DG	Diameter of lower via hole	Meter	D
W	Width and length of square pad	Meter	1e-3

Netlist Example

```
A23 Port1 Port2 Port3 Port4 D=0.0005 W=0.001
+ COMPONENT=viapad SUBSTRATE=FR4
```

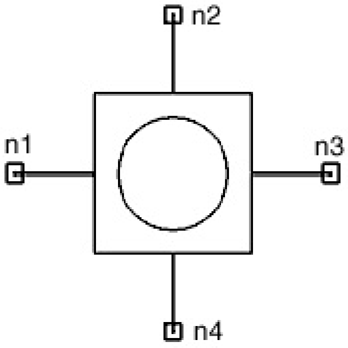
where FR4, the selected layout technology or substrate type, has a definition such as:

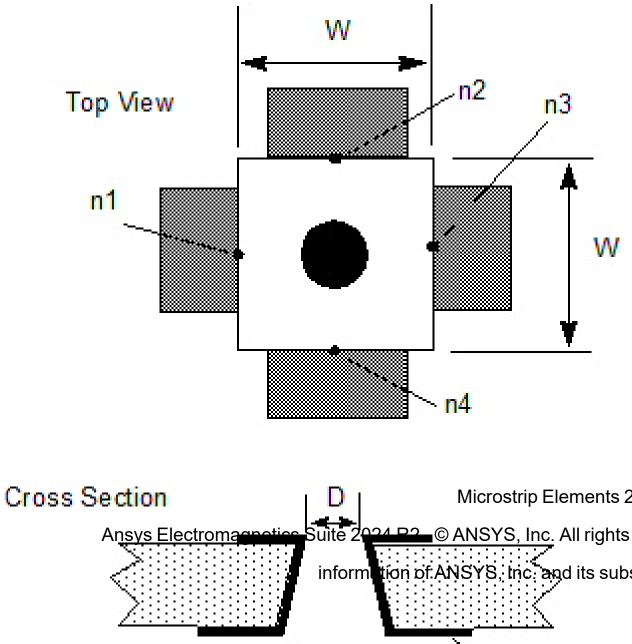
```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] The pad is connected through a via to a ground.
2. [**All substrates**] The pad is square.
3. [**All substrates**] Unconnected nodes are considered to be open.
4. [**All substrates**] Transitions to connected transmission lines are not included in this model.

Via Pad with Reference





Netlist Format

A via pad instance has the following netlist format:

A*xxx n1* [*n2 n3 n4 n5*] [**D=***val*] [**DG=***val*] [**W=** val]

COMPONENT=viapad SUBSTRATE=*substrate_name*

n1 through *n5* are the names of the nodes attached to the via pad. Any nodes not specified are modeled as open stubs. The entry **COMPONENT=viapad** identifies the element as a via pad.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 15: Via Through Hole with Reference Instance Parameters

Parameter	Description	Unit	Default
D	Diameter of upper via hole	Meter	0.5e-3
DG	Diameter of lower via hole	Meter	D
W	Width and length of square pad	Meter	1e-3

Netlist Example

```
A23 Port1 Port2 Port3 Port4 net_49 D=0.0005 W=0.001
+ COMPONENT=viapad SUBSTRATE=FR4
```

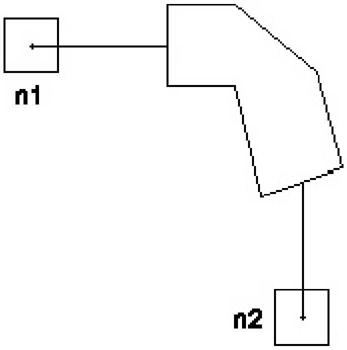
where FR4, the selected layout technology or substrate type, has a definition such as:

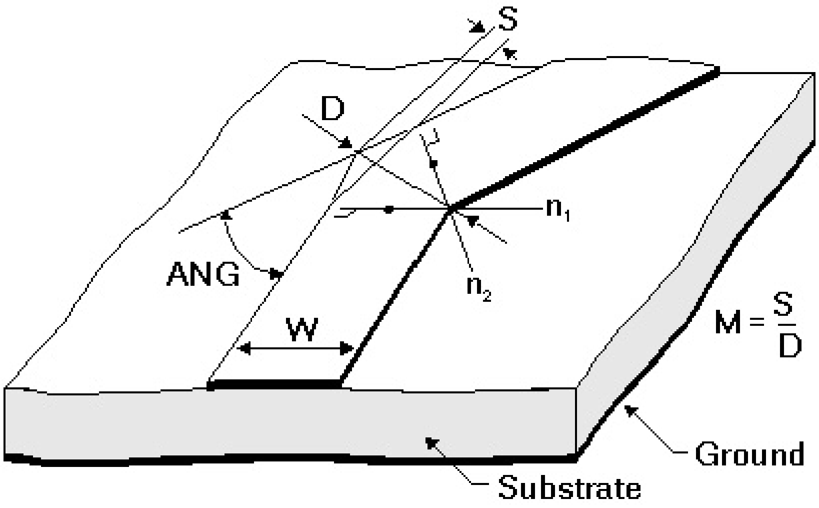
```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] The pad is connected through a via to a ground.
2. [**All substrates**] The pad is square.
3. [**All substrates**] Unconnected nodes are considered to be open.
4. [**All substrates**] Transitions to connected transmission lines are not included in this model.

Bend, Arbitrary Angle





Netlist Form

`Axxxx n1 n2 W=val ANG=val M=val`

`COMPONENT=ms_bend_arbitrary_angle    SUBSTRATE=substrate_name`

n1 and *n2* are the names of the nodes attached to the arbitrary-angled bend.
The entry COMPONENT=ms_bend_arbitrary_angle is required.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 16: Arbitrary-Angle Bend Instance Parameters

Parameter	Description	Unit	Default

W	Width of line	Meter	0.001
ANG	Angle of bend	Degree	45
M	Miter ratio (S/D in figure). Range is from 0 (no miter) to 1	None	0

Netlist Example

```
Abend1 1 2 W=3e-4 ANG=30 M=0.3
+ COMPONENT=ms_bend_arbitrary_angle SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] Reference planes coincide with the inside vertex of the corner.
2. [**Microstrip**] The frequency should be below the cutoff frequency of the first higher mode on the microstrip:

$$f_{cutoff} = \frac{C_0}{\sqrt{2W_{eff}E_{reff}}}$$

Where:

C_0 = speed of light in free space,

W_{eff} = effective width of microstrip,

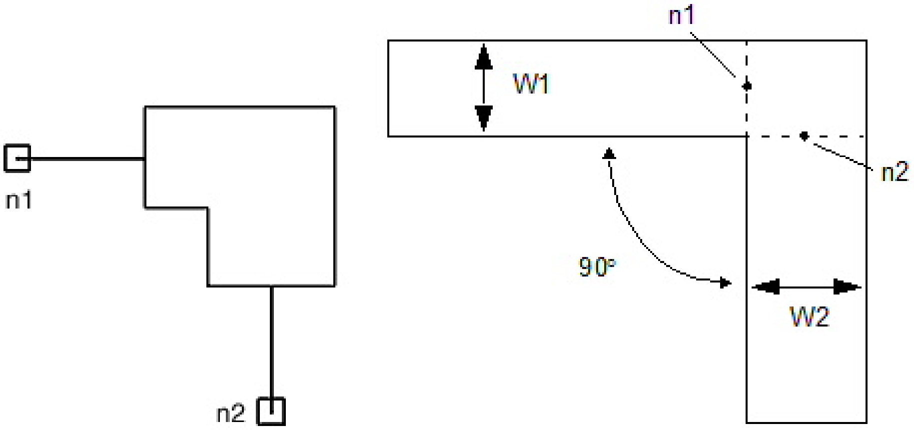
E_{reff} = effective dielectric constant

References

1. Wolff, G. Kompa, and R. Mehran, “Calculation method for microstrip discontinuities and T-junctions,” Electron. Lett., Vol. 8, 1972, pp. 177-179.
2. G. Kompa, and R. Mehran, “Planar waveguide model for calculating microstrip components,” Electron. Lett., Vol. 11, 1975, pp. 459-460.

3. T. Okoshi, Planar Circuits for Microwaves and Lightwaves, Springer-Verlag, Berlin, New York, 1983.

Bend, Unmitered



Netlist Form

A*xxxx n1 n2* **W1=***val* **W2=***val* [**NSUM=***val*]

COMPONENT=unmitered_bend SUBSTRATE=*substrate_name*

n1 and *n2* are the names of the nodes attached to the unmitered bend. The entry **COMPONENT=unmitered_bend** identifies the element as an unmitered bend.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 17: Unmitered Bend Instance Parameters

Parameter	Description	Unit	Default
W1	Width of line 1	Meter	0.001
W2	Width of line 2	Meter	0.001
NSUM	Number of modes considered in the field expansion	None	3

Netlist Example

```
Abend1 1 2 W1=3e-4 W2=5e-3 NSUM=3
+ COMPONENT=unmitered_bend SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

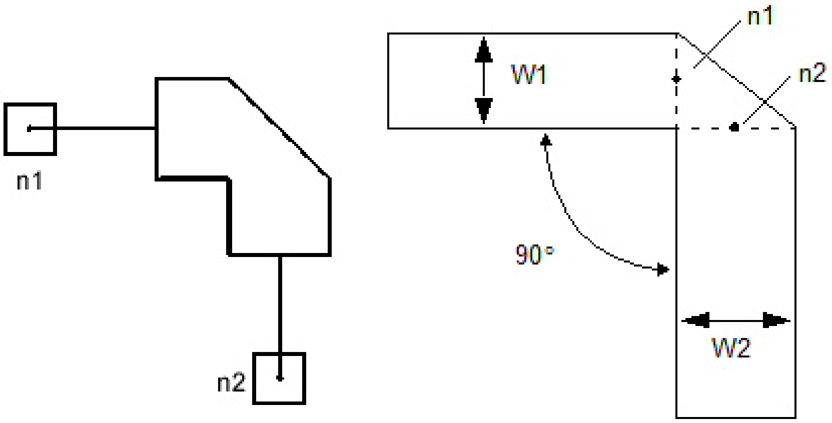
Notes

1. [**All substrates**] This element refers to a right angle bend, where the two intersecting lines can be defined with different widths. The outer corner of the bend is not mitered.
2. [**All substrates**] Reference planes coincide with the inside vertex of the corner.
3. [**Microstrip**] Radiation loss is included if a cover is not specified in the substrate definition.

References

1. Wolff, G. Kompa, and R. Mehran, “Calculation method for microstrip discontinuities and T-junctions,” Electron. Lett., Vol. 8, 1972, pp. 177-179.
2. G. Kompa, and R. Mehran, “Planar waveguide model for calculating microstrip components,” Electron. Lett., Vol. 11, 1975, pp. 459-460.
3. T. Okoshi, Planar Circuits for Microwaves and Lightwaves, Springer-Verlag, Berlin, New York, 1983.

Bend, Mitered



Netlist Form

```
Axxxx n1 n2 W1=val W2=val [NSUM=val]
```

```
COMPONENT=mitered_bend SUBSTRATE=substrate_name
```

n1 and *n2* are the names of the nodes attached to the mitered bend. The entry **COMPONENT=mitered_bend** identifies the element as a mitered bend.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 18: Mitered Bend Instance Parameters

Parameter	Description	Unit	Default
W1	Width of line 1	Meter	0.001
W2	Width of line 2	Meter	0.001
NSUM	Number of modes considered in the field expansion	None	3

Netlist Example

```
A23 Port1 Port2 W1=3e-4 W2=5e-3
+ COMPONENT=mitered_bend SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

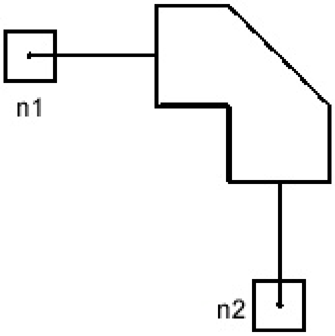
1. [**All substrates**] This element corresponds to the case where the outer corner of the right-angle bend is mitered at an angle, such that the edges of the cut are on the intersection of the reference planes and the outer edges of the bend. In the case W1=W2, the angle of the cut is 45° and the miter ratio is 0.5.
2. [**All substrates**] Reference planes coincide with the inside vertex of the corner.
3. [**Microstrip**] Radiation loss is included if cover is not specified in the substrate definition.

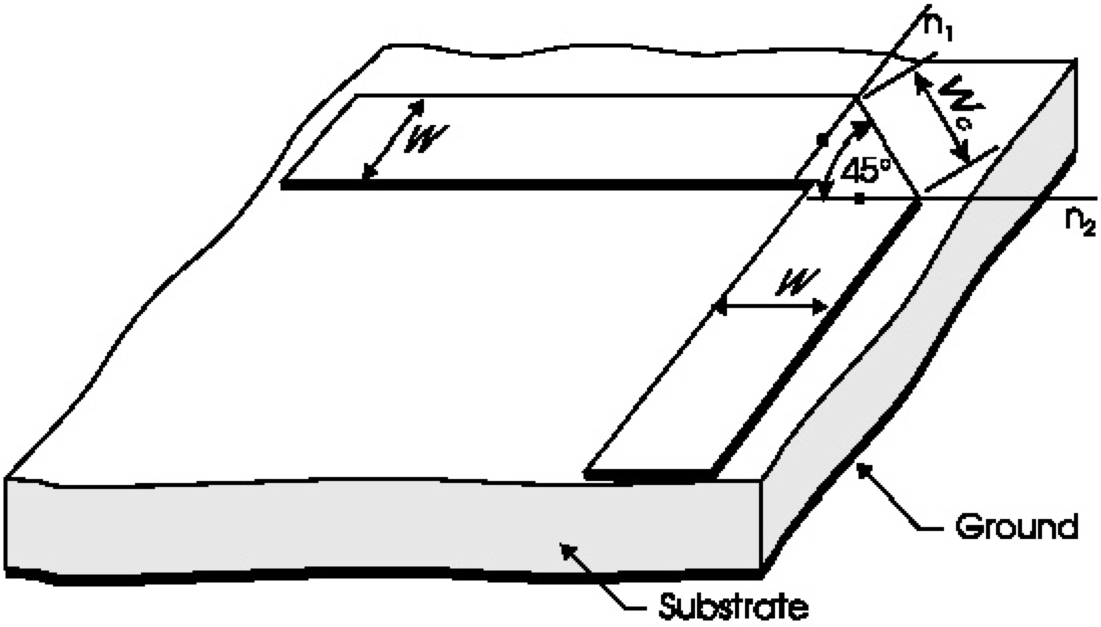
References

1. Wolff, G. Kompa, and R. Mehran, “Calculation method for microstrip discontinuities and T-junctions,” *Electron. Lett.*, Vol. 8, 1972, pp. 177-179.
2. G. Kompa, and R. Mehran, “Planar waveguide model for calculating microstrip components,” *Electron. Lett.*, Vol. 11, 1975, pp. 459-460.

3. T. Okoshi, *Planar Circuits for Microwaves and Lightwaves*, Springer-Verlag, Berlin, New York, 1983.

Bend, Optimally Mitered





Netlist Form

A*xxxx n1 n2* **W=***val* **COMPONENT=optimally_mitered_bend**

SUBSTRATE=*substrate_name*

n1 and *n2* are the names of the nodes attached to the mitered bend. The entry **COMPONENT=optimally mitered_bend** identifies the element as a mitered bend.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 19: Mitered Bend Instance Parameters

Parameter	Description	Unit	Default
W	Width of line	Meter	0.001

Netlist Example

```
A23 Port1 Port2 W1=3e-4
+ COMPONENT=optimally_mitered_bend SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

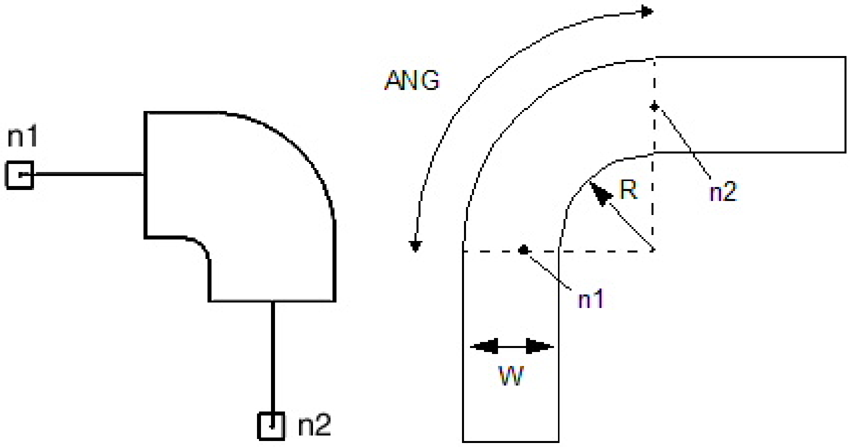
```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] Conditions for accurate results: Frequency ≤18 GHz, $2.2 \le \varepsilon_r \le 25$, $W/H \ge 0.25$
2. [**All substrates**] The miter is 45º and the length W_c is given by

$$\frac{W_c}{W} = 2\sqrt{2} \times \left(0.52 + 0.65 \times e^{\frac{-135W}{W}} \right)$$

Bend, Radial



Netlist Form

A*xxxx n1 n2* **W1=***val* **R=***val* [**ANG=***val*]

COMPONENT=radial_bend SUBSTRATE=*substrate_name*

n1 and *n2* are the names of the nodes attached to the radial bend. The entry COMPONENT=radial_bend identifies the element as a radial bend.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 20: Radial Bend Instance Parameters

Parameter	Description	Unit	Default
W	Width of line	Meter	0.001
R	Inner radius of bend	Meter	1e-20
ANG	Angle of bend	Degree	90

Netlist Example

```
A23 Port1 Port2 W=1e-3 R=1e-6 ANG=75
+ COMPONENT=radial_bend SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

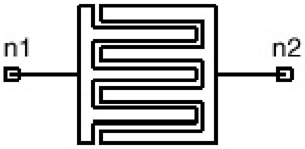
Notes

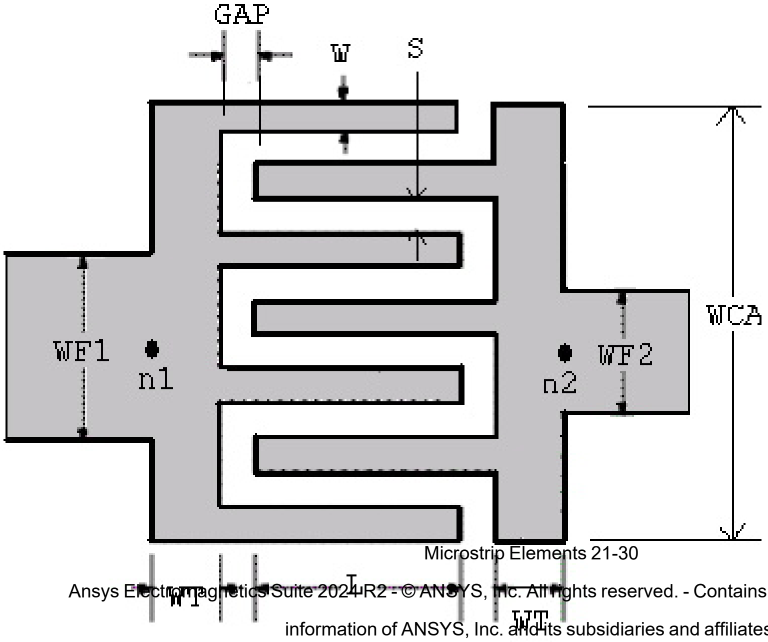
1. [**All substrates**] This element corresponds to the case where the outer corner of the right-angle bend is mitered at an angle, such that the edges of the cut are on the intersection of the reference planes and the outer edges of the bend. In the case W1=W2, the angle of the cut is 45° and the miter ratio is 0.5.
2. [**All substrates**] Reference planes coincide with the inside vertex of the corner.
3. [**Microstrip**] Radiation loss is included if cover is not specified in the substrate definition.

References

1. Wolff, G. Kompa, and R. Mehran, “Calculation method for microstrip discontinuities and T-junctions,” *Electron. Lett.*, Vol. 8, 1972, pp. 177-179.
2. G. Kompa, and R. Mehran, “Planar waveguide model for calculating microstrip components,” *Electron. Lett.*, Vol. 11, 1975, pp. 459-460.
3. T. Okoshi, *Planar Circuits for Microwaves and Lightwaves*, Springer-Verlag, Berlin, New York, 1983.

Interdigital Capacitor, Series





Netlist Form

An instance of an interdigital capacitor, series has the netlist format:

`AMSICAPSE`*`xxxx n1 n2`* **`N=`***`val`* **`W=`***`val`* **`S=`***`val`* **`L=`***`val`* **`WT=`***`val`* **`WF1=`***`val`*
`WF2=`*`val`* **`WCA=`***`val`* **`GAP=`***`val`* **`FT=`***`val`* **`COMPONENT=icap_series`**
`SUBSTRATE=`*`substrate_name`*

n1 and *n2* are the names of the nodes attached to the capacitor. The entry **COMPONENT=icap_series** identifies the element.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 21: Interdigital Capacitor, Series Instance Parameters

Parameter	Description	Unit	Default
N	Number of fingers	None	3
W	Width of fingers	Meter	0.1e-3
S	Spacing between fingers	Meter	0.1e-3
L	Length of overlap between fingers	Meter	1e-3
WT	Width of terminal strip	Meter	0.1e-3
WF1	Width of feedline at node n1	Meter	0.4e-3
WF2	Width of feedline at node n2	Meter	0.4e-3
WCA	Width of capacitor	Meter	Calculated
GAP	Gap between end of finger and terminal strip	Meter	0.1e-3
FT	Transition frequency	Hz	-1

Netlist Example

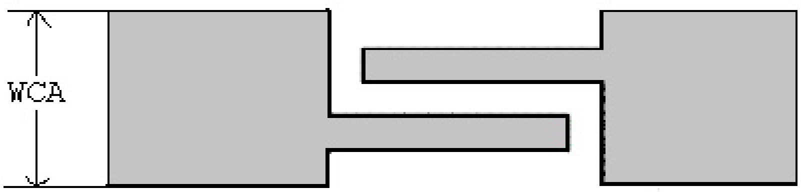
```
AMSICAPSE23 net1 Port2 N=5 W=0.001 S=0.0001 L=1.0e-3
+ COMPONENT=icap_series SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. The feedline widths WF1 and WF2 must be less than or equal to the total width of the capacitor: WF1 ≤ WCA and WF2 ≤ WCA.
2. The finger width W and the spacing between adjacent fingers S are the same for all fingers.
3. The model takes into account the effect of the steps on the feedlines to the terminal strips.
4. The capacitor width WCA has a default value of (N×W + S×(N-1)). WCA can be set to a value larger than the default. An error results if WCA is set to less than the default.



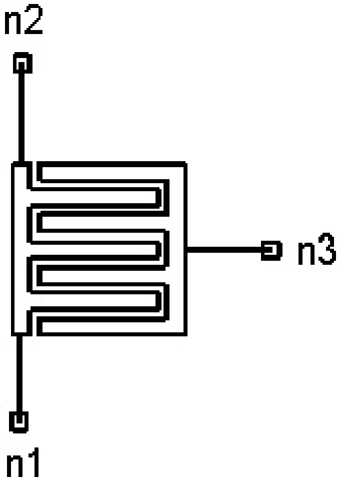
5. The terminal strip width WT can be set to zero. In this case, the user must set WF1=WF2=WCA. The response does not include the effects of the terminal strips and the steps. The user must add these effects using TRL and STEP elements
6. When the number of fingers N is odd, the model assumes that (N+1)/2 fingers are connected to node 1, while (N-1)/2 fingers are connected to node 2 (see dimensional diagram above).
7. The model takes into account the capacitance at the end of each finger and the small strips of length GAP at the beginning of each finger (outside the overlap region).

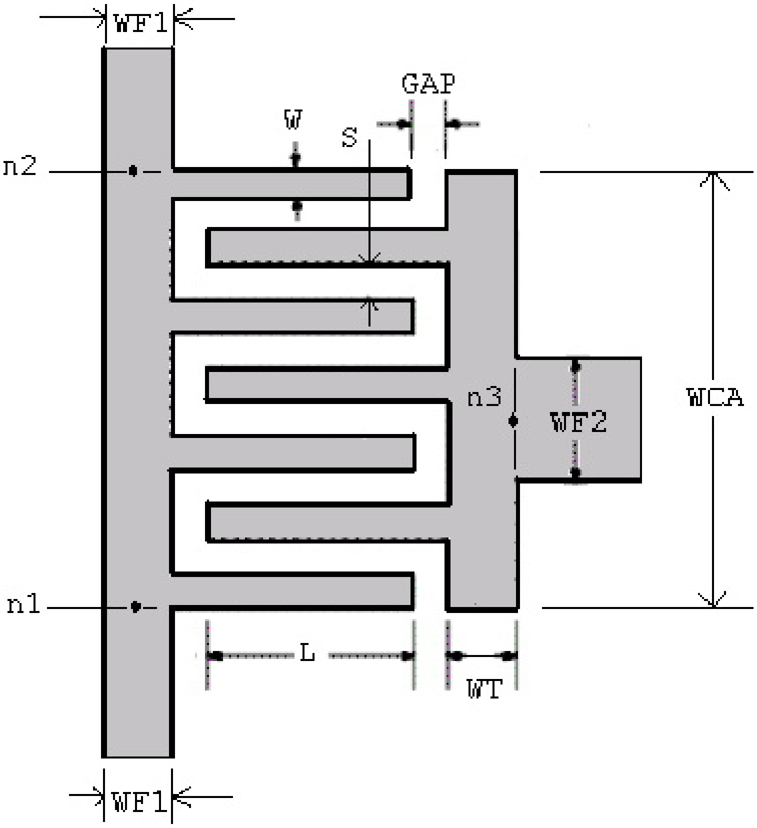
References

[1] J. Hobdell, “Optimization of Interdigital Capacitors,” IEEE Trans, on MTT, Sep 1979, pp. 788-791.

[2] X She, and Y Chow, Interdigital Microstrip Capacitor as a Four-Port Network,”IEEE Proc. Pt. H, June 1986, pp. 191-197.

Interdigital Capacitor, Parallel





Netlist Form

An instance of an interdigital capacitor, parallel has the netlist format:

AMSICAPP*xxxx n1 n2* **N=***val* **W=***val* **S=***val* **L=***val* **WT=***val* **WF1=***val* **WF2=***val* **WCA=***val* **GAP=** *val* **COMPONENT=icap_parallel SUBSTRATE=***substrate_name*

n1 and *n2* are the names of the nodes attached to the capacitor. The entry **COMPONENT=icap_parallel** identifies the element.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 22: Interdigital Capacitor, Parallel Instance Parameters

Parameter	Description	Unit	Default
N	Number of fingers	None	3
W	Width of fingers	Meter	1e-3
S	Spacing between fingers	Meter	1e-3
L	Length of overlap between fingers	Meter	2e-3
WT	Width of terminal strip	Meter	0.75e-3
WF1	Width of feedline at node n1	Meter	1e-3
WF2	Width of feedline at node n2	Meter	1e-3
WCA	Width of capacitor	Meter	Calculated
GAP	Gap between end of finger and terminal strip	Meter	0.5e-3

Netlist Example

```
AMSICAPP23 net1 Port2 N=5 W=0.001 S=0.0001 L=1.0e-3
+ COMPONENT=icap_parallel SUBSTRATE=FR4
```

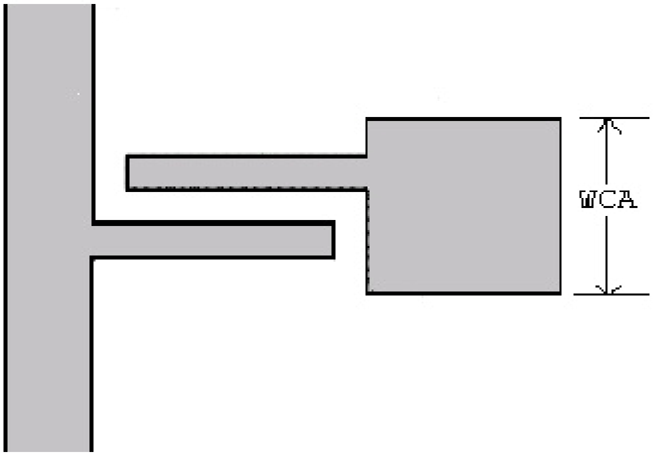
where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. The output line width WF2 must be less than or equal to the total width of the capacitor: WF2 <= WCA.
2. The finger width W and the spacing between adjacent fingers S are the same for all fingers.

3. The model takes into account the effect of the step on the terminal strip to the output at node 3. A T-junction is used to model the connection bewteen the feedline and the ICAP fingers.
4. The capacitor width WCA has a default value of (N*W + S*(N-1)). WCA can be set to a value larger than the default. An error results if WCA is set to less than the default.



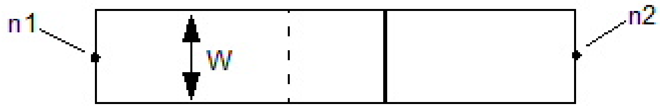
5. The terminal strip width WT can be set to zero. In this case, the user must set WF1=WF2=WCA. The response does not include the effects of the terminal strips and the steps. The user must add these effects using TRL and STEP elements
6. When the number of fingers N is odd, the model assumes that (N+1)/2 fingers are connected to node 1, while (N-1)/2 fingers are connected to node 2 (see dimensional diagram above).
7. The model takes into account the capacitance at the end of each finger and the small strips of length GAP at the beginning of each finger (outside the overlap region).

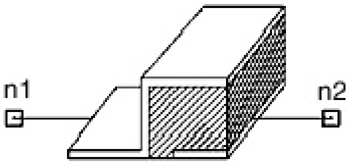
References

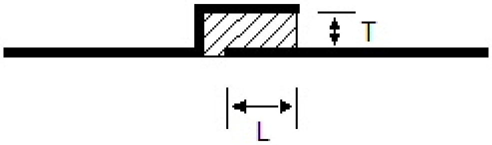
[1] J. Hobdell, “Optimization of Interdigital Capacitors,” IEEE Trans, on MTT, Sep 1979, pp. 788-791.

[2] X She, and Y Chow, Interdigital Microstrip Capacitor as a Four-Port Network,”IEEE Proc. Pt. H, June 1986, pp. 191-197.

Thin Film Capacitor, Physical, T/Q







Netlist Form

```
Axxxx n1 n2 L=val W=val T=val ERF=val Q=val

COMPONENT=mstfc SUBSTRATE=substrate_name
```

n1 and *n2* are the names of the nodes attached to the thin-film capacitor. The entry **COMPONENT=mstfc** identifies the element as a thin-film capacitor, physical T/Q model, microstrip substrate.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 23: Physical Thin-Film Capacitor, T/Q Model Instance Parameters

Parameter	Description	Unit	Default
L	Length of capacitor, assuming rectangular plate	Meter	1e-3
W	Width of capacitor, assuming rectangular plate	Meter	1e-3
T	Dielectric film thickness	Meter	1e-3
ERF	Dielectric constant of film	None	1.0
Q	Quality factor of the thin film	None	1e20

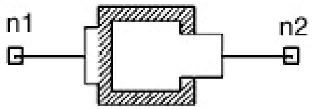
Netlist Example

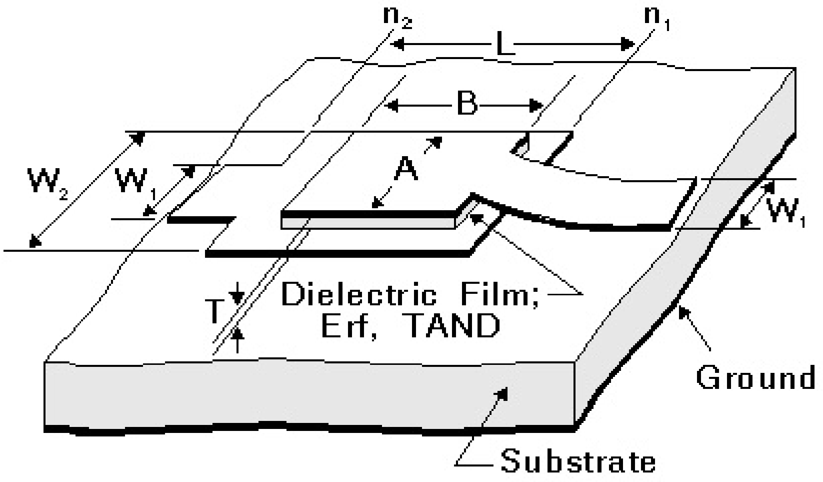
```
A23 Port1 Port2 L=1e-3 W=0.001 T=0.0001 ERF=1.0 Q=1e20
+ COMPONENT=mstfc SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

MIM Rectangular Capacitor, Loss Specified





Netlist Form

A*xxxx n1 n2* **W1=***val* **W2=***val* **L=***val* **A=***val* **B=***val* **T=***val*

ER=*val* **TAND=***val* **COMPONENT=msmimat SUBSTRATE=***substrate_name*

n1 and *n2* are the names of the nodes attached to the capacitor. The entry **COMPONENT=msmimat** identifies the element as a MIM rectangular capacitor, loss specified, microstrip substrate.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 24: MIM Rectangular Capacitor, Loss Specified Instance Parameters

Parameter	Description	Unit	Default
W1	Width of MS feeder line	Meter	1e-3
W2	Width of bottom plate	Meter	1e-3
L	Length of bottom plate	Meter	1e-3
A	Width of upper plate	Meter	1e-3
B	Length of upper plate	Meter	1e-3
T	Dielectric thin film thickness	Meter	1e-4
ER	Dielectric constant of thin film	None	1.0
TAND	Loss tangent of the thin film	None	0.0

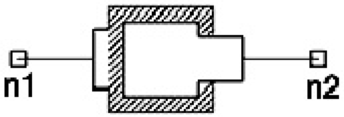
Netlist Example

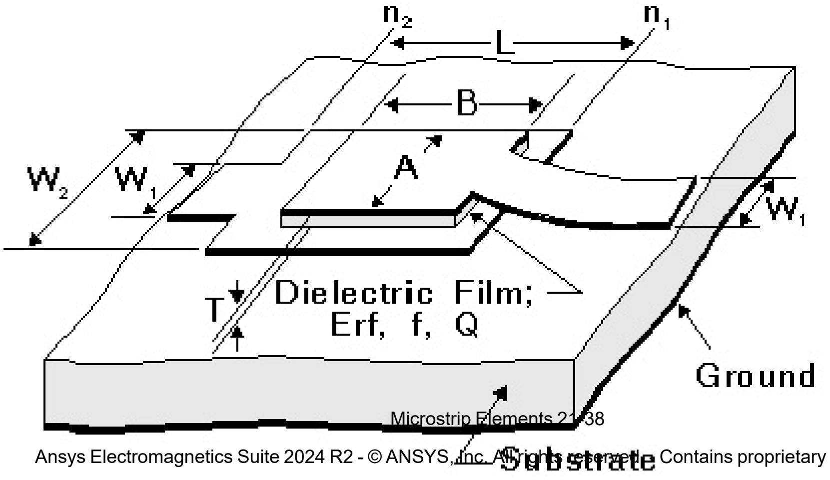
```
A23 Port1 Port2 W1=0.5e-3 W2=0.5e-3 L=1.1e-3 A=0.8e-3 B=0.8e-3
+ T=0.0001 ER=1.4 COMPONENT=msmimat SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

MIM Rectangular Capacitor, Q Specified





Netlist Form

A*xxxx n1 n2* **W1=***val* **W2=***val* **L=***val* **A=***val* **B=***val* **T=***val*

ER=*val* **Q=***val* **COMPONENT=msmimaq SUBSTRATE=***substrate_name*

n1 and *n2* are the names of the nodes attached to the capacitor. The entry **COMPONENT=msmimaq** identifies the element as a MIM rectangular capacitor, Q specified, microstrip substrate.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 25: MIM Rectangular Capacitor, Q Specified Instance Parameters

Parameter	Description	Unit	Default
W1	Width of MS feeder line	Meter	1e-4
W2	Width of bottom plate	Meter	1e-4
L	Length of bottom plate	Meter	1e-4
A	Width of upper plate	Meter	1e-4
B	Length of upper plate	Meter	1e-4
T	Dielectric thin film thickness	Meter	1e-6
ER	Dielectric constant of thin film	None	1.0
Q	Quality factorof the thin film	None	1e20

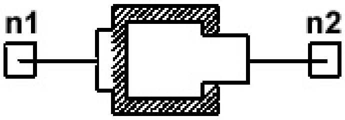
Netlist Example

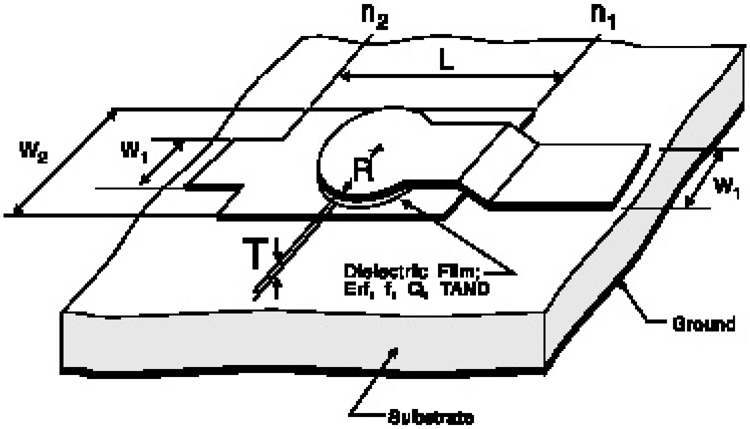
```
A23 Port1 Port2 W1=0.5e-3 W2=0.5e-3 L=1.1e-3 A=0.8e-3 B=0.8e-3
+ T=0.0001 ER=1.4 Q=1e20 COMPONENT=msmimaq SUBSTRATE=FR4
```

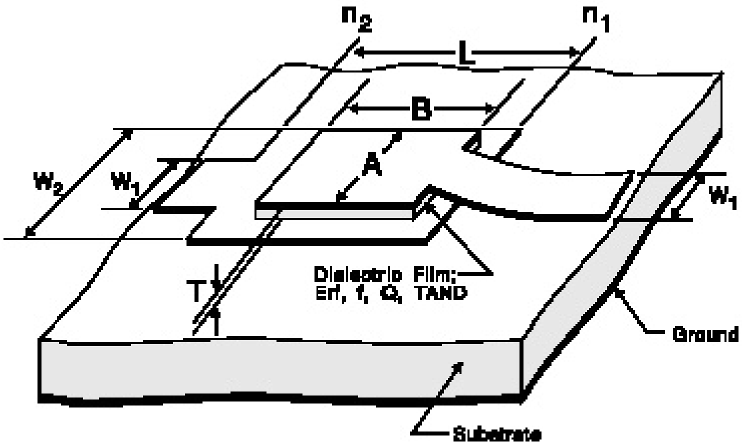
where FR4, the selected layout technology or substrate type, has a definition such as:

.SUB FR4 MS(H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)

MIM Rectangular Capacitor, C and Loss Specified







Netlist Form

A*xxxx n1 n2* **W1=***val* **W2=***val* **L=***val* **C=***val* **TAND=***val* **COMPONENT=msmimct SUBSTRATE=***substrate_name*

n1 and *n2* are the names of the nodes attached to the capacitor. The entry **COMPONENT=msmimct** identifies the element as a MIM rectangular capacitor, capacitance and loss specified, microstrip substrate.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 26: MIM Rectangular Capacitor, C and Loss Specified Instance Parameters

Parameter	Description	Unit	Default
W1	Width of MS feeder line	Meter	1e-3
W2	Width of bottom plate	Meter	1e-3
L	Length of bottom plate	Meter	1e-3
C	Capacitance of MIM	Farad	1e-12
TAND	Loss tangent of the thin film	None	0.0

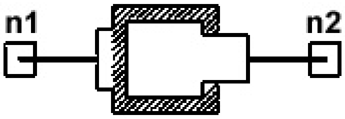
Netlist Example

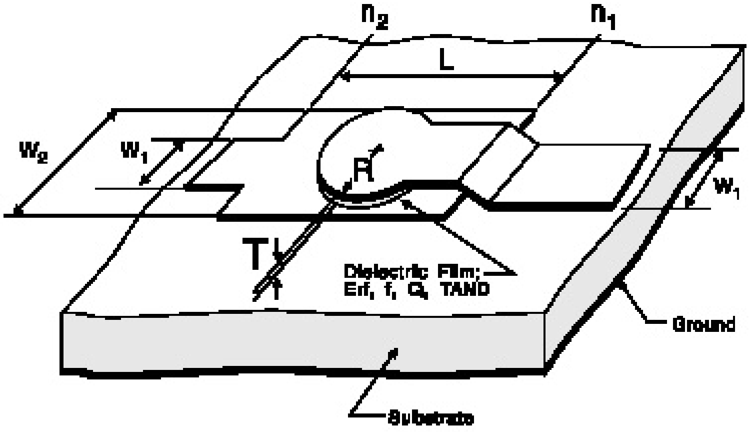
```
A23 Port1 Port2 W1=0.5e-3 W2=0.5e-3 L=1.1e-3 C=1.8e-12 TAND=1.4
COMPONENT=msmimct SUBSTRATE=FR4
```

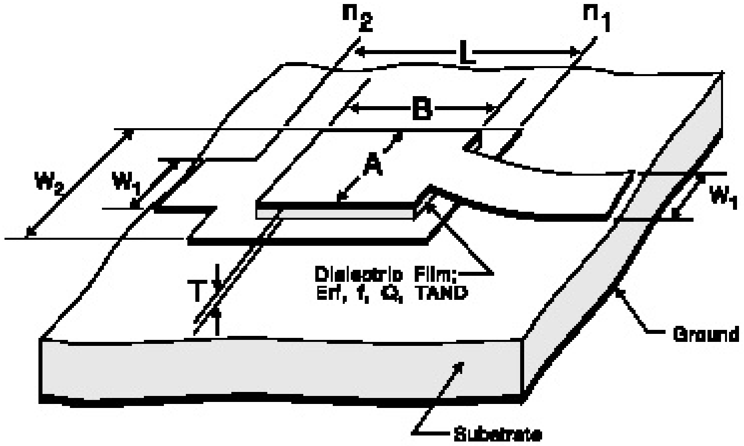
where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

MIM Rectangular Capacitor, C and Q Specified







Netlist Form

A*xxxx n1 n2* **W1=***val* **W2=***val* **L=***val* **C=***val* **ER=***val* **Q=***val*
COMPONENT=msmimcq SUBSTRATE=*substrate_name*

n1 and *n2* are the names of the nodes attached to the capacitor. The entry **COMPONENT=msmimcq** identifies the element as a MIM rectangular capacitor, C and Q specified, microstrip substrate.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 27: MIM Rectangular Capacitor, Loss Specified Instance Parameters

Parameter	Description	Unit	Default
W1	Width of MS feeder line	Meter	1e-3
W	Width of bottom plate	Meter	1e-3
L	Length of bottom plate	Meter	1e-3
C	Capacitance of MIM	Farad	1e-12
Q	Quality factorof the thin film	None	1e20

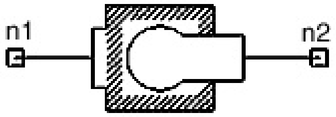
Netlist Example

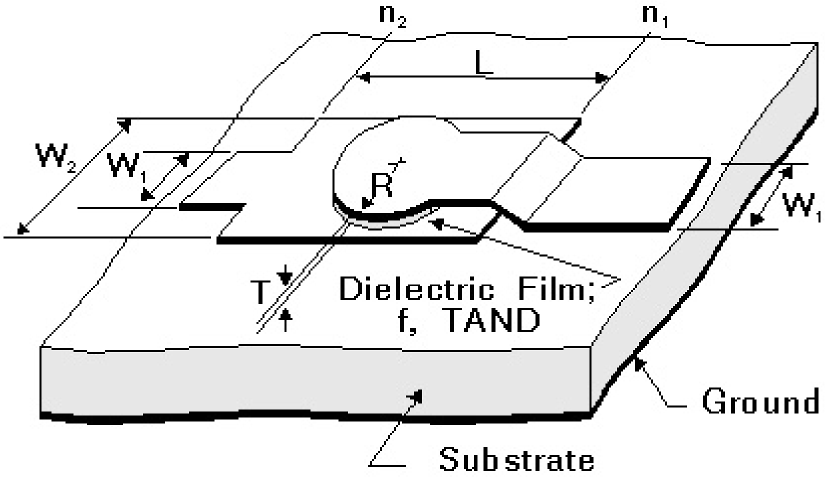
```
A23 Port1 Port2 W1=0.5e-3 W2=0.5e-3 L=1.1e-3 C=0.8e-4 Q=1e20
COMPONENT=msmimcq SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

.SUB FR4 MS(H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)

MIM Circular Capacitor, Loss Specified





Netlist Form

A*xxxx n1 n2* **W1=***val* **W2=***val* **L=***val* **R=***val* **T=***val*

ER=*val* **TAND=***val* **COMPONENT=msmimrt SUBSTRATE=***substrate_name*

n1 and *n2* are the names of the nodes attached to the capacitor. The entry **COMPONENT=msmimrt** identifies the element as a MIM circular capacitor, loss specified, microstrip substrate.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 28: MIM Circular Capacitor, Loss Specified Instance Parameters

Parameter	Description	Unit	Default
W1	Width of MS feeder line	Meter	1e-3
W2	Width of bottom plate	Meter	1e-3
L	Length of bottom plate	Meter	1e-3
R	Radius of upper plate	Meter	1e-3
T	Thickness of dielectric thin film	Meter	1e-4
ER	Dielectric constant of thin film	None	1.0
TAND	Loss tangent of the thin film	None	0.0

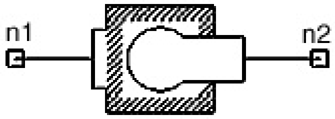
Netlist Example

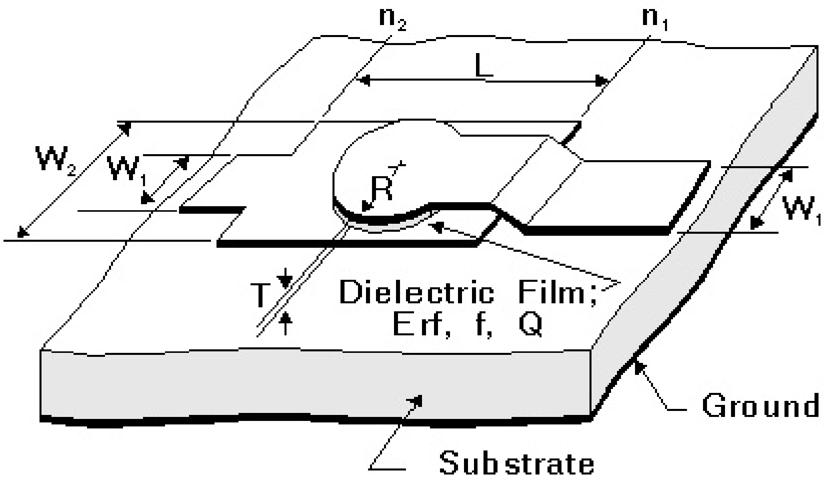
```
A23 Port1 Port2 W1=0.5e-3 W2=0.5e-3 L=1.1e-3 R=0.8e-3
+ T=0.8e-4 ER=1.4 COMPONENT=msmimrt SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

MIM Circular Capacitor, Q Specified





Netlist Form

A*xxxx n1 n2* **W1=***val* **W2=***val* **L=***val* **R=***val* **T=***val*

ER=*val* **Q=***val* **COMPONENT=msmimrq SUBSTRATE=***substrate_name*

n1 and *n2* are the names of the nodes attached to the capacitor. The entry **COMPONENT=msmimrq** identifies the element as a MIM circular capacitor, Q specified, microstrip substrate.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 29: MIM Circular Capacitor, Q Specified Instance Parameters

Parameter	Description	Unit	Default
W1	Width of MS feeder line	Meter	1e-3
W2	Width of bottom plate	Meter	1e-3
L	Length of bottom plate	Meter	1e-3
R	Radius of upper plate	Meter	1e-3
T	Dielectric thin film thickness	Meter	1e-4
ER	Dielectric constant of thin film	None	1.0
Q	Quality factorof the thin film	None	1e20

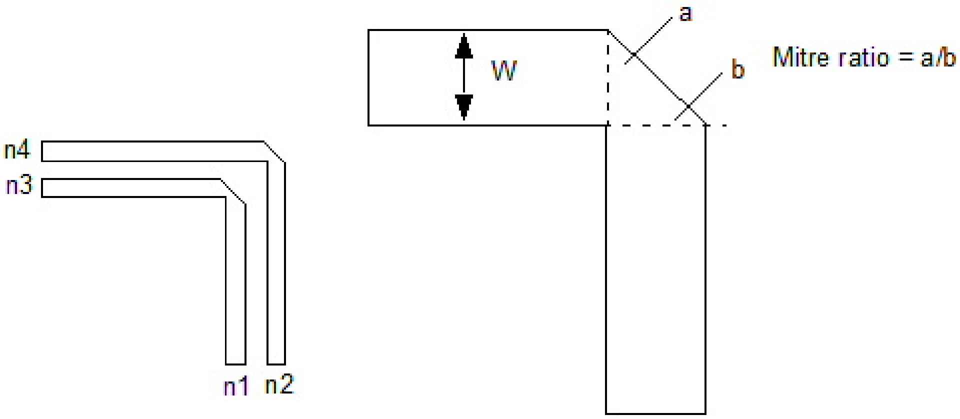
Netlist Example

```
A23 Port1 Port2 W1=0.5e-3 W2=0.5e-3 L=1.1e-3 R=0.8e-3
+ T=0.0001 ER=1.4 Q=1e20 COMPONENT=msmimrq SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Coupled Bend



NOTE: There is no netlist form for this component. It is available for Planar EM simulation only.

n1 and *n2* are the names of the input nodes attached to the coupled bend. *n3* and *n4* are the output nodes.

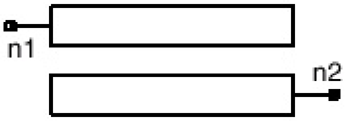
Table 30: Coupled Bend Instance Parameters

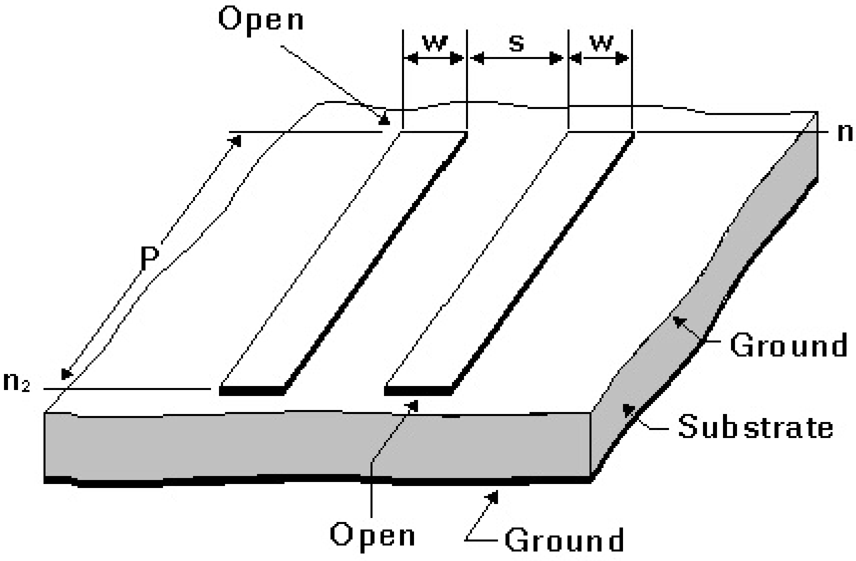
Parameter	Description	Unit	Default
W	Conductor width	Meter	0.001
M	Mitre ratio (**a** /**b** in the reference figure)	None	1
S	Conductor spacing	Meter	0.001
L1	Shift in reference plane 1	Meter	0
L2	Shift in reference plane 2	Meter	0

Notes

1. This model is available for Planar EM simulation only.
2. The default reference plane is typically coincident with the opposing transmission line edge, but is extended if the miter ratio moves the outside edge further out. The reference plane is shifter even further through the use of the L1 and L2 parameters.
3. If a substrate is not defined for the component, the Layout stackup or Footprint stackup may be used.

Coupled Lines, Open Ends Opposite Side, Symmetric





Netlist Form

A symmetric coupled line, open ends opposite side instance has the following netlist syntax:

```
Axxx n1 n2 [W=width] [P=length] [S=spacing]
```

```
COMPONENT=mcplo SUBSTRATE=substrate_name
```

n1 and *n2* are the names of the nodes. The entry **COMPONENT=mcplo** identifies the element as a symmetric coupled line, open end opposite side.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

**Table 31: Symmetric Coupled Line, Open End Opposite Side,
Instance Parameters**

Parameter	Description	Units	Default
P	Physical length	Meter	10e3
S	Spacing between conductors	Meter	1e-3
W	Conductor width	Meter	1e-3

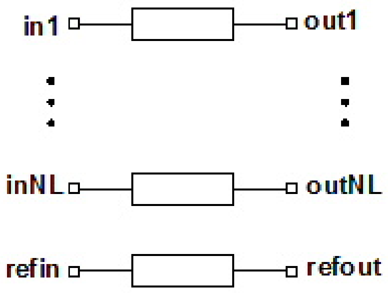
Netlist Example

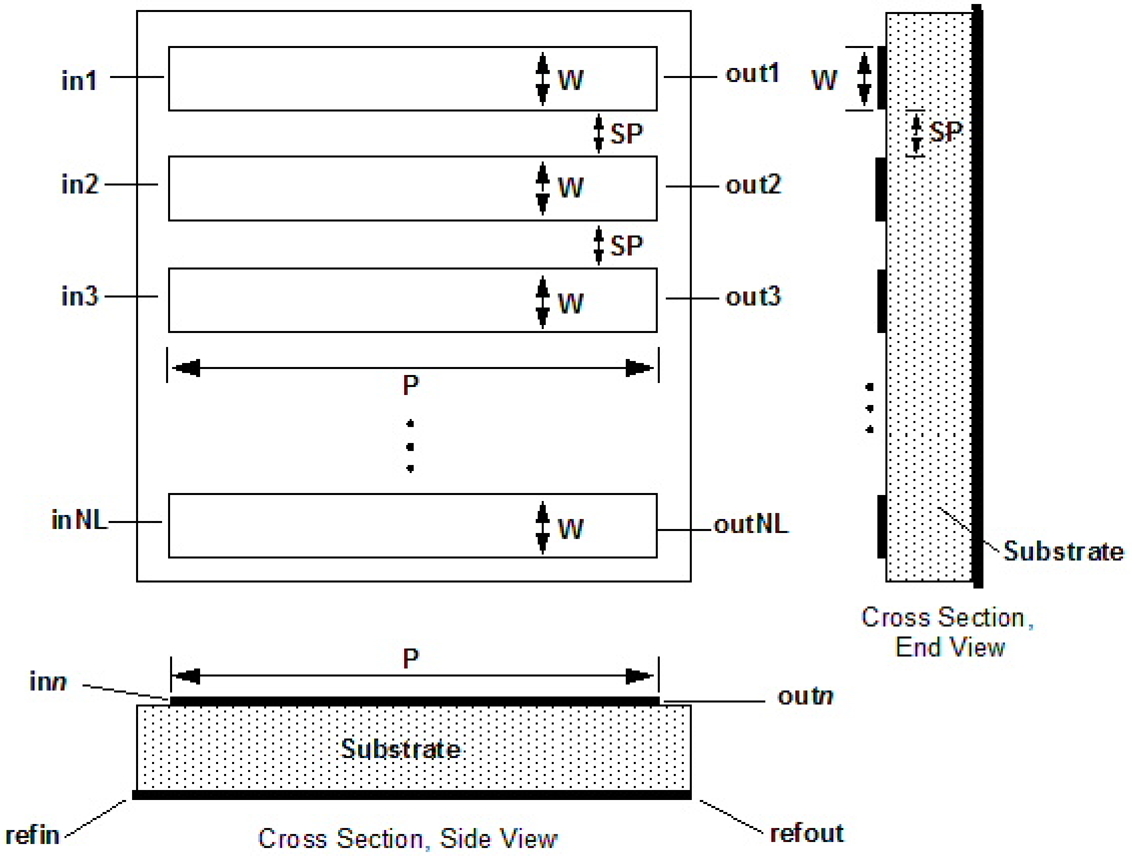
```
A3 Port1 Port2 W=0.33mm P=3.5mm s=0.457mm
+ COMPONENT=mcplo SUBstrate=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Multi-Coupled Lines, Symmetric, Physical Length





Netlist Form

A symmetric multiple coupled line, physical length instance has the following netlist syntax:

```
Axxx in1 [...inNL] refin out1 [...outNL] refout

 NL=NumberofLines [W=width] [P=length] [SP=spacing]

COMPONENT=mcpl SUBSTRATE=substrate_name
```

in1 through *inNL* are the names of the input nodes. *out1* through *outNL* are the corresponding output nodes. *refin* and *refout* are the input and output reference nodes. The entry **COMPONENT=mcpl** identifies the element as a symmetric multiple coupled line, physical length.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 32: Symmetric Multiple Coupled Line, Physical Length, Instance Parameters

Parameter	Description	Units	Default
NL	Number of signal lines	None	1
P	Physical length	Meter	1e-2
SP	Spacing between conductors (NL>1)	Meter	1e-3
W	Conductor width	Meter	1e-3

Netlist Example

```
A3 Port1 Port2 0 net_1911 net_1912 0 W=3.2004e-004 P=1
+ NL=2 sp=4.5720e-004 COMPONENT=mcpl SUBstrate=FR4
```

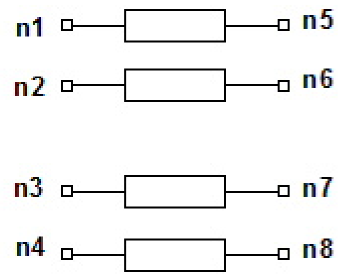
where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 )
```

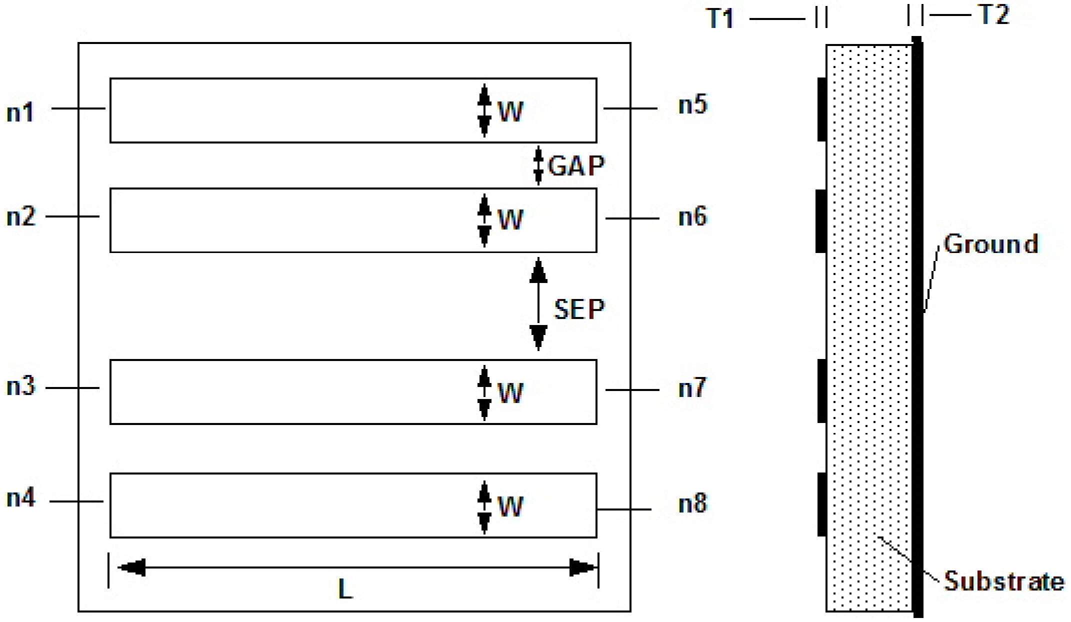
Notes

1. Surface roughness in the substrate definition is not supported in the MCPL implementation.

Multi-Coupled Lines, Differential Pairs, Field Solver



Diagrams show the
N=4 component
(two differential pairs)



Netlist Form

A multicoupled line, two differential pairs, field solver instance has the following netlist syntax:

```
Wxxx n1 n2 n3 n4 0 n5 n6 n7 n8 0   N=4 L=length   FSmodel=modelname
.MATERIAL cond1 METAL CONDUCTIVITY=conductivity

.MATERIAL diel1 DIELECTRIC ER=er LOSSTANGENT=losstangent

.SHAPE rect1 RECTANGLE WIDTH=w HEIGHT=t1 // Conductors
.LAYERSTACK STACK1
+ LAYER=(cond1, t2) // Ground plane
+ LAYER=(diel1, h)
+ LAYER=(AIR, hu)
.MODEL modelname W MODELTYPE=Fieldsolver
+ LAYERSTACK=STACK1
+ CONDUCTOR=(SHAPE=rect1, ORIGIN=(0, 't2 + h')
+ MATERIAL=cond1, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=rect1, ORIGIN=('w+gap', 't2 + h'
+ MATERIAL=cond1, TYPE=REFERENCE)
+ CONDUCTOR=(SHAPE=rect1, ORIGIN=('2w+gap', 't2 + h')
+ MATERIAL=cond1, TYPE=SIGNAL)
```

```
+ CONDUCTOR=(SHAPE=rect1, ORIGIN=('3w+2gap+sep', 't2 + h')
+ MATERIAL=cond1, TYPE=REFERENCE)
```

n1, n2, *n3,* and *n4* are the names of the input nodes. *n5*, *n6*, *n7*, and *n8* are the corresponding output nodes. The entry **N=4** shows that this is a 4-conductor, 2-pair differential line.

The entry **FSmodel=***modelname* identifies the field solver microstrip model.

Table 33: Multicoupled Line, Differential Pairs, Field Solver Instance Parameters

Parameter	Description	Units	Default
mod	Name for field solver model. Required for uniqueness if the design has more than one of the same kind of field solver component	None	Required
L	Physical length	Meter	1e-3
N	Number of lines	None	None
w	Width of conductor	Meter	1e-3
gap	Gap width between differential lines	Meter	1e-3
sep	Separation between pairs of lines	Meter	5e-3
t1	Thickness of conductors	Meter	1e-3
t2	Thickness of grounds	Meter	1e-3
h	Thickness of dielectric layer	Meter	1e-3
hu	Thickness of air layer	Meter	1e-3
er	Dielectric constant		2.2
losstangent	Dielectric loss tangent		0
conductivity	Conductivity of conductor material		57.6e6

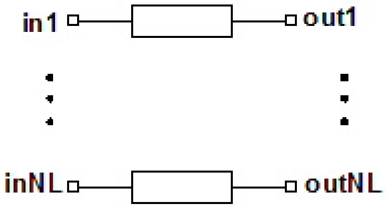
Netlist Example

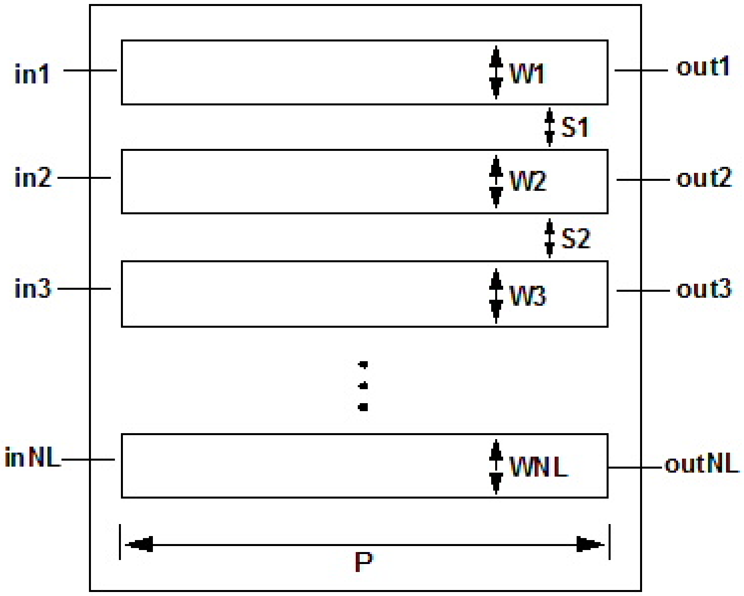
```
W3 Port1 Port2 0 net_1911 net_2 0 N=2 L=0.002 FSmodel=2diffs
```

```
.MATERIAL copper METAL CONDUCTIVITY=5.8e7
.MATERIAL dielectric DIELECTRIC ER=4.4 LOSSTANGENT=0.02
.SHAPE RECT1 RECTANGLE WIDTH=.002 HEIGHT=.001   // Conductors
.LAYERSTACK STACK1
+ LAYER=(PEC, .003) // Bottom ground
+ LAYER=(dielectric, .01)
+ LAYER=(AIR, .03)
.MODEL 2diffs W MODELTYPE=Fieldsolver
```

```
+ LAYERSTACK=STACK1
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=(0, '.003+.01')
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=('.002+.004', '.003+.01')
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=('2*.002+.004', '.003+.01')
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=('3*.002+2*.004', '.001+.01')
+ MATERIAL=conductor, TYPE=SIGNAL)
```

Multi-Coupled Lines, Asymmetric





Netlist Form

An asymmetric multiple coupled line, physical length instance has the following netlist syntax:

A*xxx in1* [...*inNL*] *out1* [...*outNL*]

NL=*NumberofLines* [**P=***length*] [**W=***width*] [**SP=***spacing*]

COMPONENT=ms_mcpl_a SUBSTRATE=*substrate_name*

in1 through *inNL* are the names of the input nodes. *out1* through *outNL* are the corresponding output nodes. The entry **COMPONENT=ms_mcpl_a** identifies the element as an asymmetric multiple coupled line, physical length.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 34: Asymmetric Multiple Coupled Line, Physical Length, Instance Parameters

Parameter	Description	Units	Default
NL	Number of signal lines	None	None
P	Physical length	Meter	1e-3
W1, **W2**, ...	Conductor widths	Meter	1e-3
S1, **S2**, ...	Spacing between conductors (S1 = spacing between 1 and 2, etc.)	Meter	1e-3

Netlist Example (3 Conductors)

```
A3 Port1 Port2 Port 3 Port 4 Port 5 Port 6 NL=3
+ P=15mm W1=0.75mm S1=0.4mm W2=1.3mm S2=0.6mm W3=1.1mm
+ COMPONENT=ms_mcpl_a SUBSTRATE=FR4
```

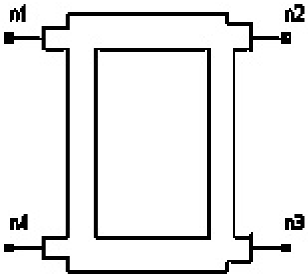
where FR4, the selected layout technology or substrate type, has a definition such as:

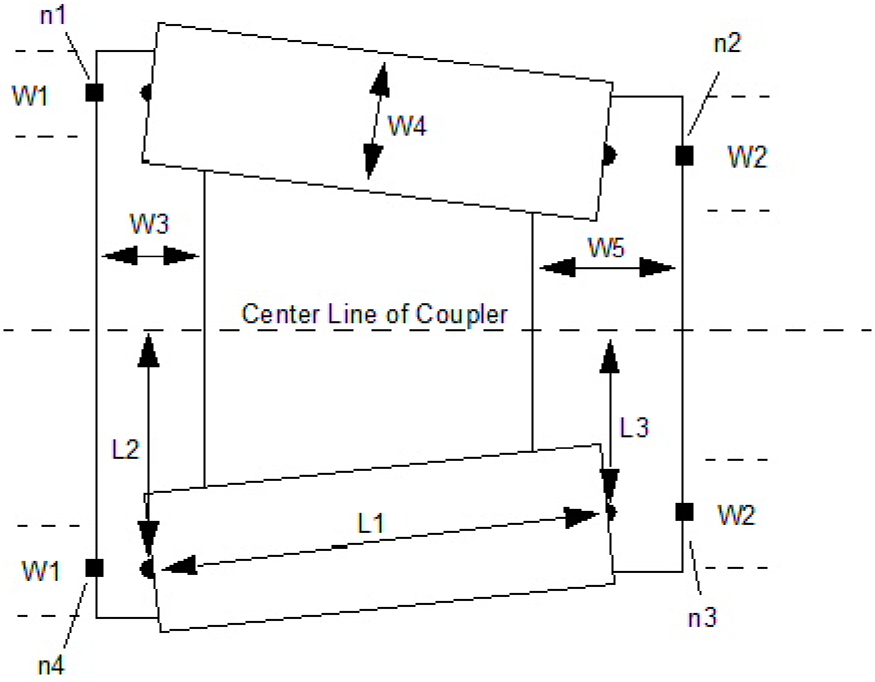
```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005)
```

Notes

1. Surface roughness in the substrate definition is not supported in the MCPL implementation.
2. The asymmetric MCPL elements use the data on the SUBSTRATE definition, but internally the data is converted to W-element FIELD SOLVER format for solution.

Branch Line Coupler





Netlist Format

A branch line coupler length instance has the following netlist format:

AMSCOUPB*xxx n1 n2 n3 n4* **W1=***val* **W2=***val* **W3=***val* **W4=***val* **W5=***val* **L1=***val* **L2=***val* **L3=***val* **COMPONENT=branch_coupler SUBSTRATE=***substrate_name* *n1*, *n2*, *n3*, and *n4* are the names of the nodes attached to the coupler. The entry **COMPONENT=branch_coupler** identifies the element.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 35: Branch Line Coupler Instance Parameters

Parameter	Description	Unit	Default
W1	Width of lines connected to nodes n1 and n4	Meter	0.5e-3
W2	Width of lines connected to nodes n2 and n3	Meter	0.5e-3
W3	Width of line from n1 to n4	Meter	0.5e-3
W4	Width of line from n1 to n2 Width of line from n3 to n4 NOTE: The lines with width W4 extend to the midpoints of the lines with widths W3 and W5.	Meter	0.5e-3
W5	Width of line from n2 to n3	Meter	0.5e-3
L1	Length along center line of W4, on the midpoint of the line with width W3 to the midpoint of the line with width W5.	Meter	2e-3
L2	Half length along center line of W3, on the horizontal center line of the coupler to the intersection of the center lines of the lines with widths W3 and W4.	Meter	2e-3
L3	Half length along center line of W5, on the horizontal center line of the coupler to the intersection of the center lines of the lines with widths W5 and W4.	Meter	0

Netlist Example

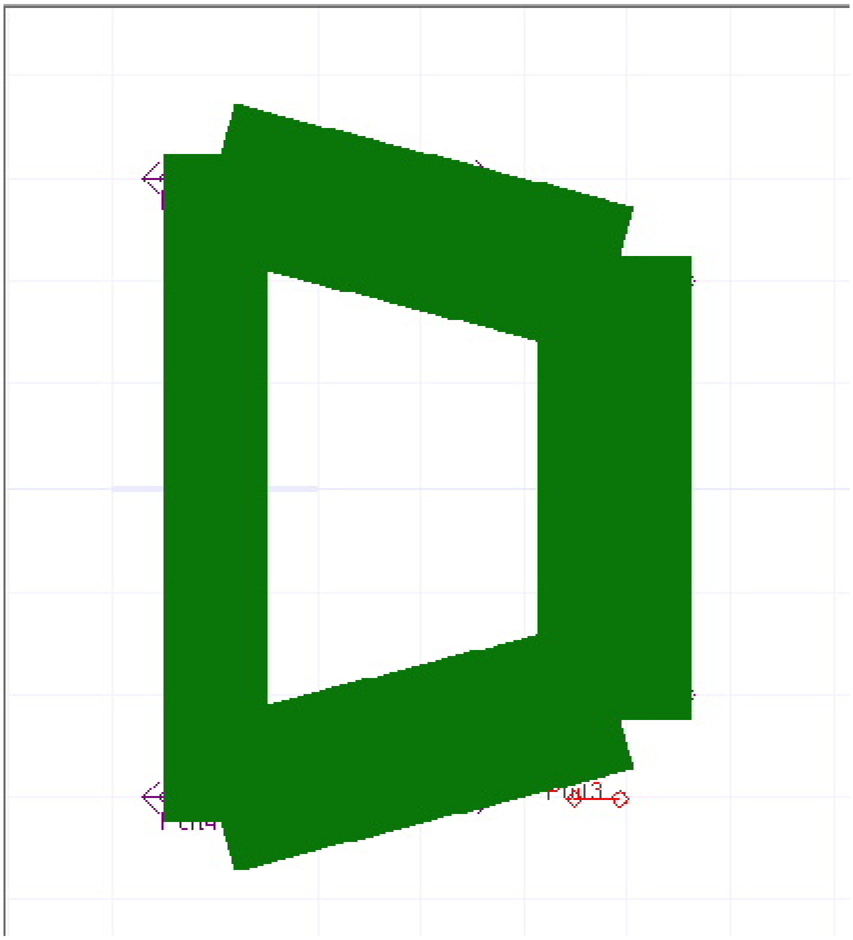
```
AMSCOUPB1 net1 Port2 net3 Port4 W1=1e-3 W2=.2e-3 W3=.7e-3
+ W4=.4e-3 L1=1.8e-3 L2=1.5e-3 L3=1.5e-3
+ COMPONENT=branch_coupler SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

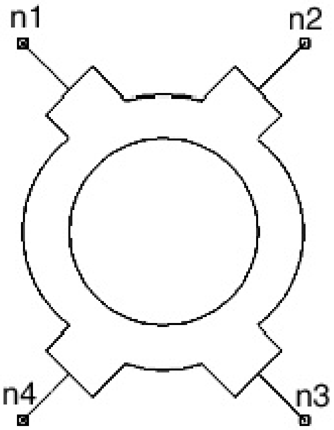
```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

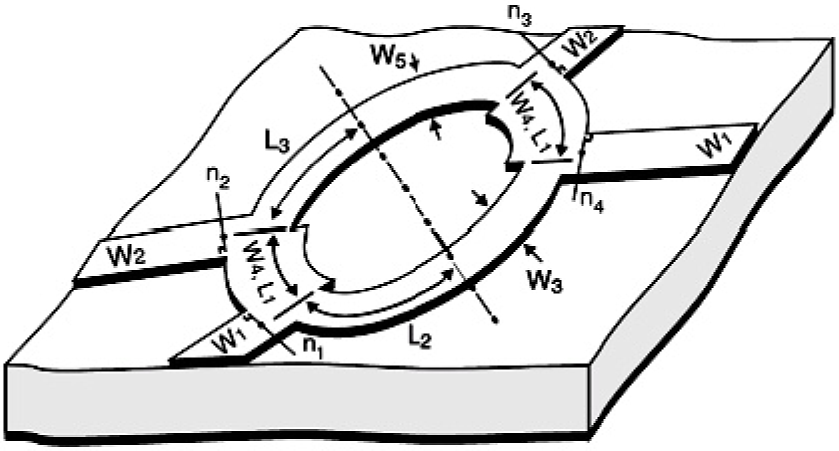
Layout Example

Here is an example of a MSCOUPB footprint with dimensions W1=0.5mm, W2=0.5mm, W3=1mm, W4=1.5mm, W5=1.5mm, L1=4mm, L2=3mm, L3=2mm.



Ring Coupler





Netlist Format

A ring coupler instance has the following netlist format:

```
AMSCOUPRxxx n1 n2 n3 n4 W1=val W2=val W3=val W4=val W5=val
L1=val L2=val L3=val COMPONENT=ring_coupler
SUBSTRATE=substrate_name
```

n1, *n2*, *n3*, and *n4* are the names of the nodes attached to the coupler. The entry **COMPONENT=ring_coupler** identifies the element.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 36: Ring Coupler Instance Parameters

Parameter	Description	Unit	Default
W1	Width of lines connected to nodes n1 and n4	Meter	0.5e-3
W2	Width of lines connected to nodes n2 and n3	Meter	0.5e-3
W3	Width of line from n1 to n4	Meter	0.5e-3
W4	Width of line from n1 to n2 Width of line from n3 to n4	Meter	0.5e-3
W5	Width of line from n2 to n3	Meter	0.5e-3
L1	Length along center line of W4	Meter	2e-3
L2	Half length along center line of W3	Meter	2e-3
L3	Half length along center line of W5	Meter	0

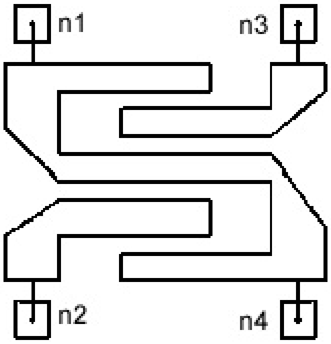
Netlist Example

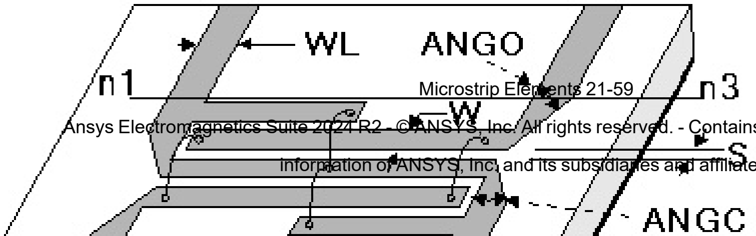
```
AMSCOUPR1 net1 Port2 net3 Port4 W1=1e-3 W2=.2e-3 W3=.7e-3
+ W4=.4e-3 L1=1.8e-3 L2=1.5e-3 L3=1.5e-3
+ COMPONENT=ring_coupler SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Lange Coupler, Physical Length





Netlist Format

A Lange coupler, physical length instance has the following netlist format:

`ALANG`*`xxx n1 n2 n3 n4`* **`N=4 W=`***`val`* **`S=`***`val`* **`P=`***`val`*

`NW=`*`val`* **`DW=`***`val`* **`SW=`***`val`* **`WL=`***`val`* **`ANGC=`***`val`* **`ANGO=`***`val`*

`COMPONENT=mslange_physical SUBSTRATE=`*`substrate_name`*

n1, *n2*, *n3*, and *n4* are the names of the nodes attached to the coupler. The entry **COMPONENT=mslange_physical** identifies the element.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 37: Lange Coupler, Physical Length Instance Parameters

Parameter	Description	Unit	Default
N	Number of lines. Must be 4.	None	4
W	Conductor width	Meter	1e-3
S	Conductor spacing	Meter	1e-3
P	Physical length	Meter	10e-3
NW	Number of bond wires	None	1
DW	Diameter of bond wires	Meter	25.4e-6
SW	Spacing between bond wires	Meter	25.4e-6
WL	Width of connecting lines	Meter	1e-3
ANGC	Miter angle of center arm bends	Degree	45
ANGO	Miter angle of outer arm bends	Degree	45

Netlist Example

```
ALANG1 Port1 Port2 Port3 Port4 N=4 W=1e-3 S=.2e-3 P=10e-3
+ COMPONENT=mslange_physical SUBSTRATE=FR4
```

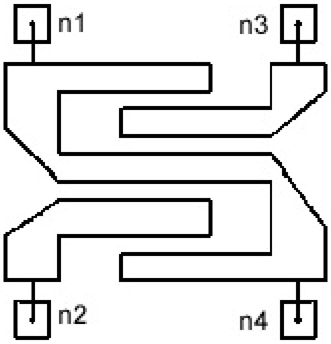
where FR4, the selected layout technology or substrate type, has a definition such as:

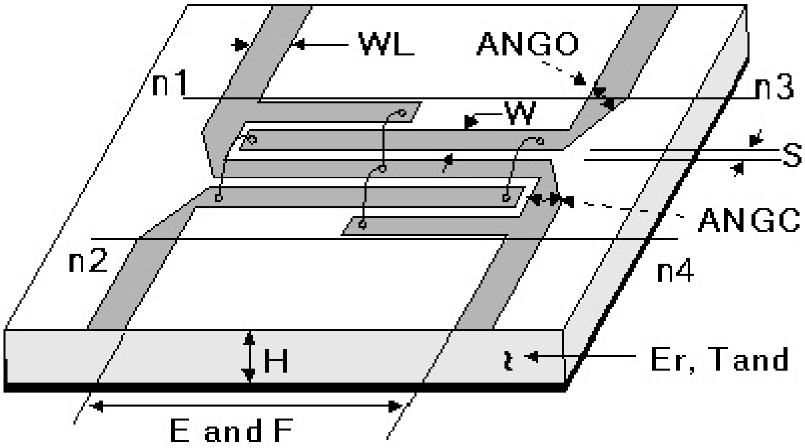
```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. The bond wire is considered to be a semicircular shape with diameter DW.
2. Taking port 1 to be defined between node 1 and ground (node 0), the remaining ports are defined between the following nodes:
   Coupled port: Node n2 and GND
   Isolated port: Node n3 and GND
   Through port: Node n4 and GND

Lange Coupler, Electrical Length





Netlist Format

A Lange coupler, physical length instance has the following netlist format:

ALANGE`xxx n1 n2 n3 n4` **N=4 W=**`val` **S=**`val` **E=**`val` **F=**`val`

NW=`val` **DW=**`val` **SW=**`val` **WL=**`val` **ANGC=**`val` **ANGO=**`val`

COMPONENT=mslange_electrical SUBSTRATE=*substrate_name*

n1, *n2*, *n3*, and *n4* are the names of the nodes attached to the coupler. The entry **COMPONENT=mslange_electrical** identifies the element.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on the MS substrate type.

Table 38: Lange Coupler, Electrical Length Instance Parameters

Parameter	Description	Unit	Default
N	Number of lines. Must be 4.	None	4
W	Conductor width	Meter	1e-3
S	Conductor spacing	Meter	1e-3
E	Electrical length	Degree	10e-3
F	Reference frequency for E	Hertz	1e9
NW	Number of bond wires	None	1
DW	Diameter of bond wires	Meter	25.4e-6
SW	Spacing between bond wires	Meter	25.4e-6
WL	Width of connecting lines	Meter	1e-3
ANGC	Miter angle of center arm bends	Degree	45
ANGO	Miter angle of outer arm bends	Degree	45

Netlist Example

```
ALANG1 Port1 Port2 Port3 Port4 N=4 W=1e-3 S=0.2e-3 F=2.5e9
+ COMPONENT=mslange_electrical SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

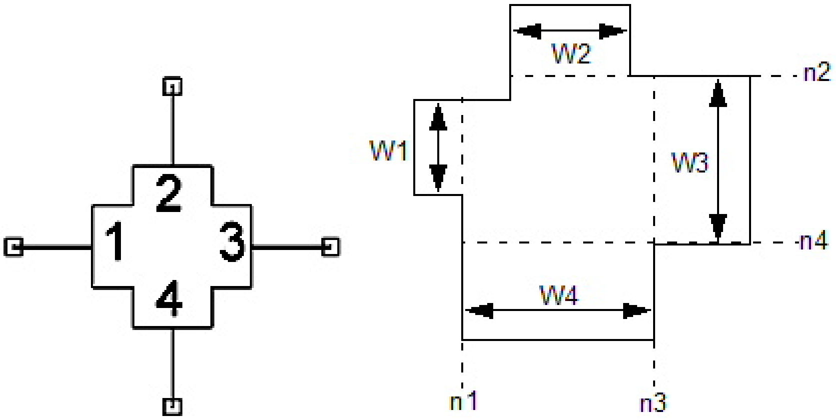
```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. The bond wire is considered to be a semicircular shape with diameter DW.
2. Taking port 1 to be defined between node 1 and ground (node 0), the remaining ports are defined between the following nodes:
   Coupled port: Node n2 and GND

Isolated port: Node n3 and GND
Through port: Node n4 and GND

Cross Junction



Netlist Format

A cross instance has the following netlist format:

`A``xxx n1 n2 n3 n4 `**`W1=`**`val `**`W2=`**`val `**`W3=`**`val `**`W4=`**`val [`**`NSUM=`**`val]`

`COMPONENT=cross SUBSTRATE=``substrate_name`

n1, *n2*, *n3*, and *n4* are the names of the nodes attached to the cross. The entry **COMPONENT=cross** identifies the element as a cross.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 39: Cross Instance Parameters

Parameter	Description	Unit	Default
W1	Width of line connected to node n1	Meter	1e-3
W2	Width of line connected to node n2	Meter	1e-3
W3	Width of line connected to node n3	Meter	1e-3
W4	Width of line connected to node n4	Meter	1e-3
NSUM	Number of modes considered in the field expansion	None	4

Netlist Example

```
Across1 Port1 Port2 Port3 Port4 W1=1e-3 W2=2e-3 W3=3e-3 W4=4e-3
+ COMPONENT=cross SUBSTRATE=FR4
```

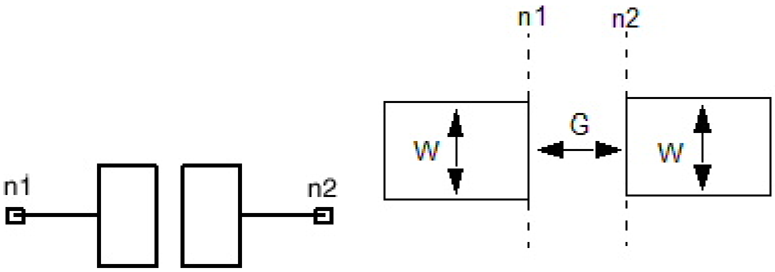
where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] The angle between intersecting lines is 90°.
2. [**All substrates**] Increasing NSUM improves the accuracy but increases the analysis time.
3. [**Microstrip**] To get accurate results with the default value of NSUM (NSUM=4), the following condition should be satisfied: $H/\lambda_g < 1$ for all widths W1, W2, W3, and W4, where λ_g is the guide wavelength of the dominant mode.

Gap, Symmetric



Netlist Format

A symmetric gap instance has the following netlist syntax:

A*xxx n1 n2* **W=***val* **G=***val* **COMPONENT=symmetric_gap SUBSTRATE=***substrate_name*

n1 and *n2* are the names of the nodes attached to the symmetric gap. The entry **COMPONENT=symmetric_gap** identifies the element as a symmetric gap.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 40: Symmetric Gap Instance Parameters

Parameter	Description	Units	Default
W	Line width	Meter	1e-3
G	Gap spacing	Meter	1e-4

Netlist Example

```
A23 Port1 Port2 W=5e-3 G=3e-4
+ COMPONENT=symmetric_gap SUBSTRATE=FR4
```

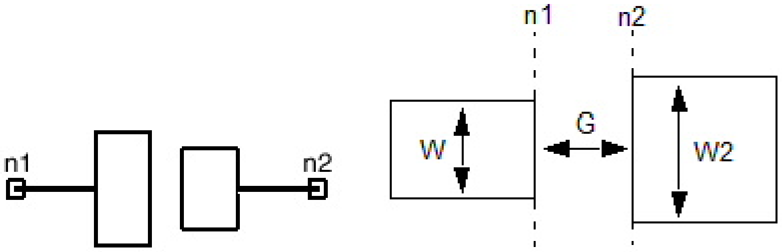
where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**Microstrip**] The following condition should be satisfied:
   $0.01 \leq G/H < 5$

Gap, Asymmetric



Netlist Format

An asymmetric gap instance has the following netlist syntax:

A*xxx n1 n2* **W1=***val* **W2=***val* **G=***val* **COMPONENT=asymmetric_gap SUBSTRATE=***substrate_name*

n1 and *n2* are the names of the nodes attached to the asymmetric gap. The entry **COMPONENT=asymmetric_gap** identifies the element as an asymmetric gap.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 41: Asymmetric Gap Instance Parameters

Parameter	Description	Units	Default
W1	Line width of the conductor at node 1	Meter	1e-3
W2	Line width of the conductor at node 2	Meter	1e-3
G	Gap spacing	Meter	1e-4

Netlist Example

```
A23 Port1 Port2 W1=5e-3 W2=7e-3 G=3e-4
+ COMPONENT=asymmetric_gap SUBSTRATE=FR4
```

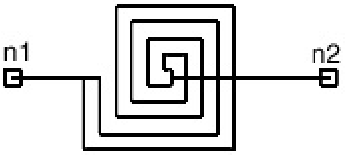
where FR4, the selected layout technology or substrate type, has a definition such as:

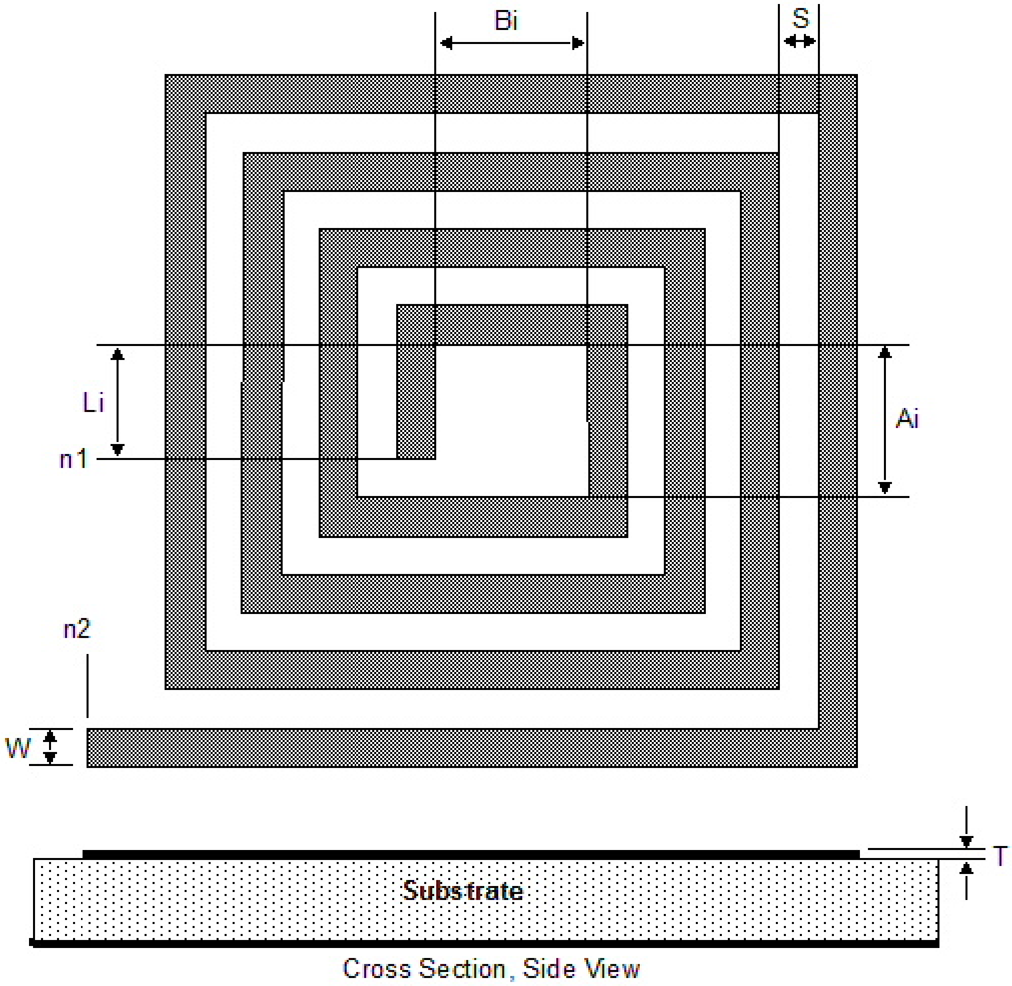
```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**Microstrip**] For ±2.5% accuracy (where H is the dielectric thickness and E_R is the dielectric constant of the substrate):
   $G/H \geq 0.2$
   $6.0 \leq E_R \leq 13.0$
   $1.0 \leq \max(W1,W2)/\min(W1,W2) \leq 3.0$
   $0.1 \leq \min(W1,W2)/H \leq 3.0$
   $0.1 \leq \max(W1,W2)/H \leq 3.1$
   $F[GHz] \times H[mm] \leq 12.0$
2. [**Microstrip**] The following condition should be satisfied:
   $0.01 \leq G/H < 5$
3. [**Microstrip**] The equivalent model for the asymmetric gap structure is the PI-network of three capacitors including substrate and radiation losses.

Rectangular Inductor





Netlist Form

A regular inductor instance has the following netlist syntax:

A*xxx n1 n2* **LI=***val* **AI=***val* **BI=***val* **N=***val* **W=***val* **S=***val* **T=***val*

RB=*val* **COE=***val* **COMPONENT=msreci SUBSTRATE=***substrate_name*

n1 and *n2* are the names of the nodes connected to the inductor. The entry **COMPONENT=msreci** identifies the element as a regular inductor.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 42: Rectangular Inductor Instance Parameters

Parameter	Description	Units	Default
AI	Inner length parallel to LI	Meter	3e-3
BI	Inner length perpendicular to LI	Meter	3e-3
COE	Coefficient of contribution from crossovers	None	1.0
LI	Length of the innermost line	Meter	5e-3
N	Number of turns. Fractional turns are calculated based on the number of full turns	None	3
RB	Bulk resistivity	μOhm-cm	Defaults to substrate metallization
S	Spacing between conductors	Meter	1e-3
T	Conductor thickness	Meter	Defaults to substrate metallization
W	Conductor width	Meter	1e-3

Netlist Example

```
A23 Port1 Port2 LI=5e-3 AI=3e-3 BI=3e-3 N=3 W=0.001
+ S=1e-3 T=0.0 RB=0.0 COE=1
+ COMPONENT=msreci SUBSTRATE=FR4
```

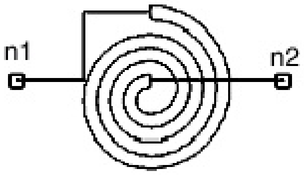
where FR4, the selected layout technology or substrate type, has a definition such as:

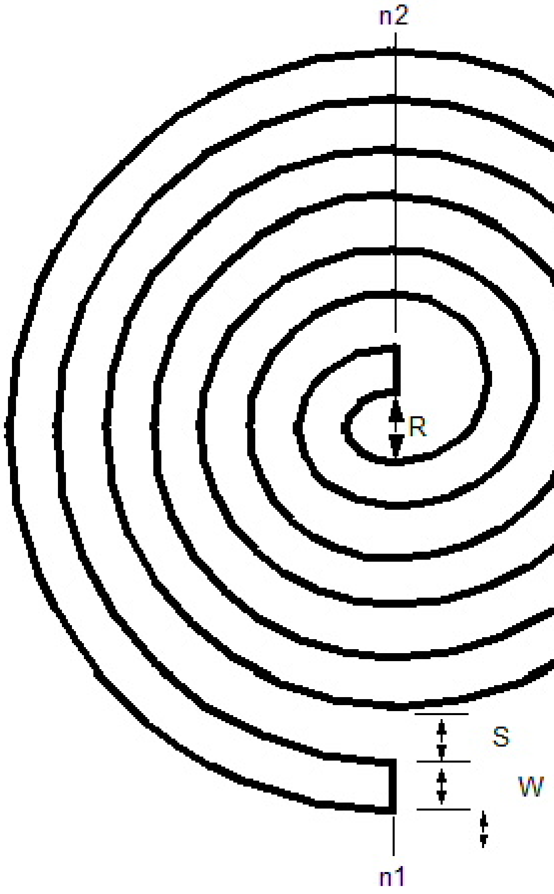
```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] This model is not recommended for use beyond the first resonant point.
2. [**All substrates**] The inductor model is a partial representation of a physical inductor. Air bridges are required to connect the interior end of the inductor to the rest of the circuit. The air bridges must be modeled separately. See MS Air Bridge.

Spiral Inductor





Netlist Form

A spiral inductor instance has the following netlist syntax:

```
Axxx n1 n2 N=val W=val S=val R=val [T=val] [RB=val] [GND=val]
[COE=val]
 COMPONENT=ms_spiral_inductor SUBSTRATE=substrate_name
```

n1 and *n2* are the names of the nodes connected to the inductor. The entry **COMPONENT=ms_spiral_inductor** identifies the element as a spiral inductor.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 43: Spiral Inductor Instance Parameters

Parameter	Description	Units	Default
COE	Coefficient of contribution from crossovers	None	1.0

GND	**1** specifies the existence of a ground plane beneath the inductor **0** specifies no ground plane	None	1
N	Number of turns. Fractional turns are calculated based on the number of full turns	None	3
R	Inside radius of innermost turn	Meter	1e-3
RB	Bulk resistivity	μOhm-cm	Defaults to substrate metallization
S	Spacing between conductors	Meter	1e-3
T	Conductor thickness	Meter	Defaults to substrate metallization
W	Conductor width	Meter	1e-3

Netlist Example

```
A23 Port1 Port2 N=3 W=5e-4 S=5e-4 R=1e-3 T=0.0
+ RB=0.0 COE=1 GND=0
+ COMPONENT=ms_spiral_inductor SUBSTRATE=FR4
```

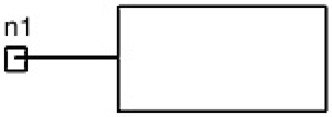
where FR4, the selected layout technology or substrate type, has a definition such as:

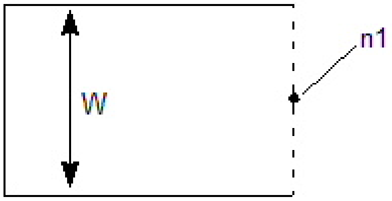
```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] The innermost turn radius, R, must be greater than the line width, W.
2. [**All substrates**] This model is not recommended for use beyond the first resonant point.
3. [**All substrates**] The inductor model is a partial representation of a physical inductor. Air bridges are required to connect the interior end of the inductor to the rest of the circuit. The air bridges must be modeled separately. See MS Air Bridge.

Open End Effect





Netlist Format

An open end effect instance has the following netlist syntax:

A*xxx n1* **W=***val* [**OPEN=POS**|**NEG**] **COMPONENT=open_end SUBSTRATE=***substrate_name*

n1 is the name of the node attached to the open end effect. The entry **COMPONENT=open_end** identifies the element as an open end effect.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 44: Open End Effect Instance Parameters

Parameter	Description	Units	Default
W	Line width	Meter	1e-3
OPEN	POS means a positive open-end effect is applied NEG means a negative open-end effect is applied (used for de-embedding)	None	POS

Netlist Example

```
A12 Port1 W=0.0001 COMPONENT=open_end SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

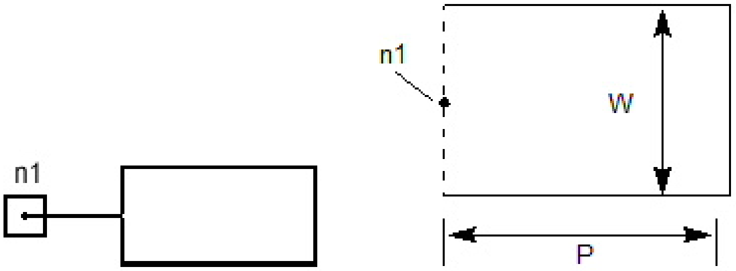
Notes

1. [**All substrates**] The transmission line is extended by a ΔL length, which is a function of the dielectric constant, frequency, and physical dimensions of the line. If the OPEN

parameter is set to NEG, a negative effect is applied. This holds true for the length extension ΔL, and the associated dielectric losses.

2. [**Microstrip**] Radiation loss is included if the cover height, HU, is not defined in the corresponding .SUB statement.
3. [**Microstrip**] For ±2.5% accuracy (where H is the dielectric thickness and E_R is the dielectric constant of the substrate):
   F[GHz] < 708/H[MILS]
   $E_R \leq 50$
   $0.01 \leq W/H \leq 100$

Open Stub, Physical Length



Netlist Form

An instance of an open stub with physical length has the following netlist syntax:

`Axxx n1 W=val P=val COMPONENT=open_stub SUBSTRATE=substrate_name`

n1 is the name of the node attached to the open stub. The entry **COMPONENT=open_stub** identifies the element as an open stub with physical length.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 45: Open Stub with Physical Length, Instance Parameters

Parameter	Description	Units	Default
W	Line width	Meter	1e-3
P	Physical length	Meter	10e-3

Netlist Example

```
A44 Port1 W=0.001 P=10e-3 COMPONENT=open_stub SUBSTRATE=FR4
```

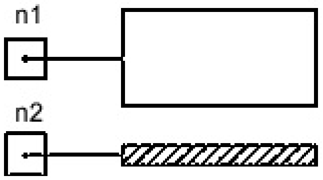
where FR4, the selected layout technology or substrate type, has a definition such as:

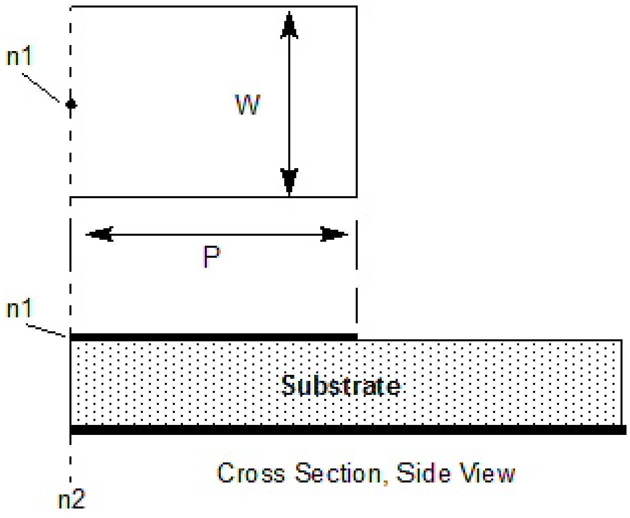
```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] The physical model using physical length includes the open end length correction.
2. [**All substrates**] The open stub model is equivalent to a transmission line model followed by an open model. This is also true in the case of negative length specifications, which are used for deembedding purposes. Note that in the latter case, the open stub model is equivalent to the transmission line model with a negative length terminated by an open.
3. [**Microstrip**] This model includes radiation effects if a cover height is not supplied (i.e., open structure.)
4. [**Microstrip**] The following limits apply: .01 ≤ W/H ≤ 100, where H is the thickness of the dielectric .

Open Stub, Physical Length with Reference





Netlist Form

An instance of an open stub, physical length with reference node has the following netlist syntax:

A*xxx n1 n2* **W=***val* **P=***val* **COMPONENT=open_stub SUBSTRATE=***substrate_name*

n1 is the name of the node attached to the open stub. *n2* is the name of the reference node. The entry **COMPONENT=open_stub** identifies the element as an open stub, physical length (with or without a reference node).

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 46: Open Stub, Physical Length with Reference, Instance Parameters

Parameter	Description	Units	Default
W	Line width	Meter	1e-3
P	Physical length	Meter	10e-3

Netlist Example

```
A44 Port1 Port3  W=0.001 P=10e-3
+ COMPONENT=open_stub SUBSTRATE=FR4
```

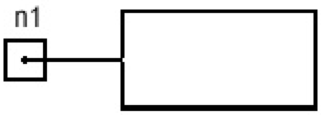
where FR4, the selected layout technology or substrate type, has a definition such as:

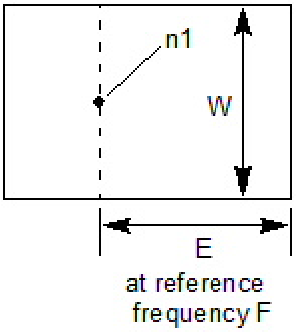
```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] The physical model using physical length includes the open end length correction.
2. [**All substrates**] The open stub model is equivalent to a transmission line model followed by an open model. This is also true in the case of negative length specifications, which are used for deembedding purposes. Note that in the latter case, the open stub model is equivalent to the transmission line model with a negative length terminated by an open.
3. [**Microstrip**] This model includes radiation effects if a cover height is not supplied (i.e., open structure.)
4. [**Microstrip**] The following limits apply: .01 ≤ W/H ≤ 100, where H is the thickness of the dielectric

Open Stub, Electrical Length





Netlist Format

An instance of an open stub with electrical length has the following netlist syntax:

A*xxx n1* **W=***val* **E=***val* **F=***val* **COMPONENT=open_stub_e SUBSTRATE=***substrate_name*

n1 is the name of the node attached to the open stub. A reference node of ground (node 0) is automatically supplied, and is not shown in the netlist. The entry COMPONENT=open_stub_e identifies the element as an open stub with electrical length.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 47: Open Stub with Electrical Length, Instance Parameters

Parameter	Description	Units	Default
W	Line width	Meter	1e-3
E	Electrical length	Degree	45
F	Reference frequency for E	Hz	1e9

Netlist Example

```
A44 Port1 W=1.0e-3 E=45 F=1.0e9
+ COMPONENT=open_stub_e SUBSTRATE=FR4
```

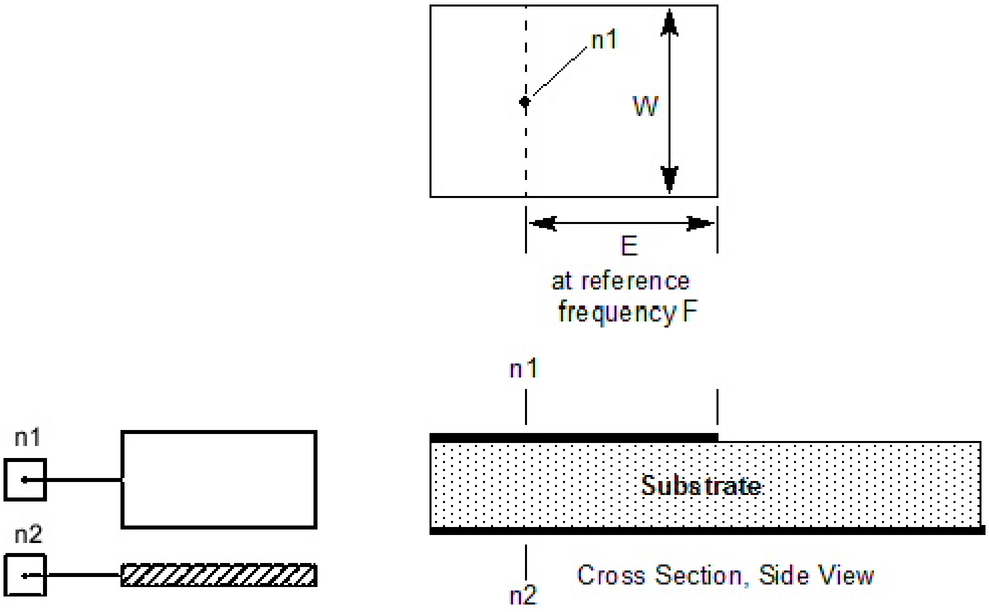
where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] The open stub, electrical length model is equivalent to a transmission line model followed by an open model. This is also true in the case of negative length specifications, which are used for deembedding purposes. Note that in the latter case, the open stub model is equivalent to the transmission line model with a negative length terminated by an open.
2. [**Microstrip**] This model includes radiation effects if a cover height is not supplied (i.e., open structure.)
3. [**Microstrip**] The following limits apply (H is the thickness of the dielectric):
   0.01 ≤**W/H** ≤ 100

Open Stub, Electrical Length with Reference



Netlist Format

An instance of an open stub, electrical length with reference has the following netlist syntax:

```
Axxx n1 n2 W=val E=val F=val COMPONENT=open_stub_e
SUBSTRATE=substrate_name
```

n1 is the name of the node attached to the open stub. *n2* is the name of the reference node. The entry **COMPONENT=open_stub_e** identifies the element as an open stub, electrical length, with or without a reference node.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 48: Open Stub, Electrical Length with Reference, Instance Parameters

Parameter	Description	Units	Default
W	Line width	Meter	1e-3
E	Electrical length	Degree	45
F	Reference frequency for E	Hz	1e9

Netlist Example

```
A44 Port1 Port2 W=1.0e-3 E=45 F=1.0e9
+ COMPONENT=open_stub_e SUBSTRATE=FR4
```

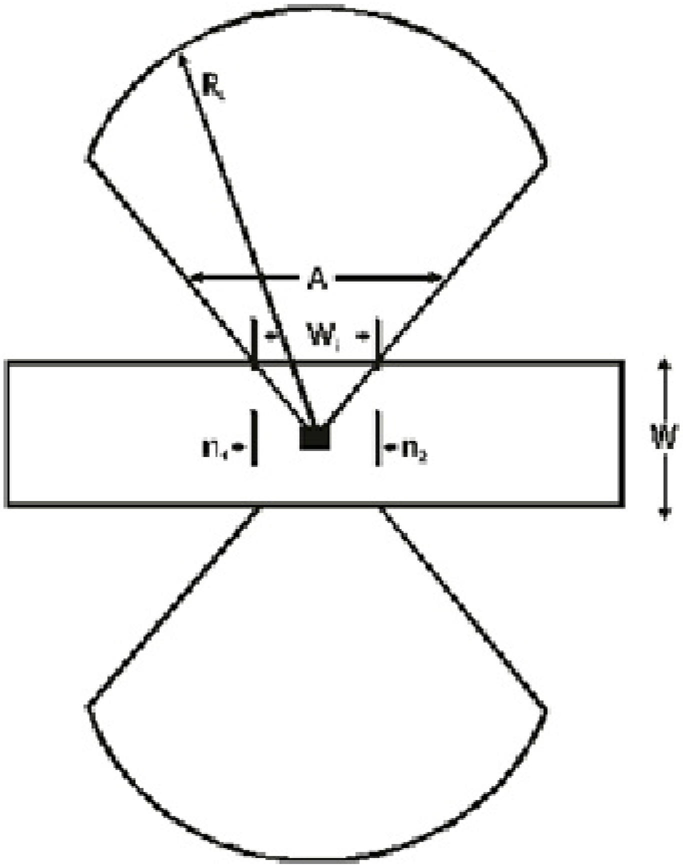
where FR4, the selected layout technology or substrate type, has a definition such as:

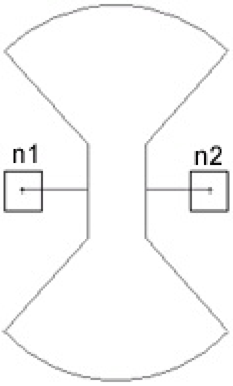
```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] The open stub, electrical length model is equivalent to a transmission line model followed by an open model. This is also true in the case of negative length specifications, which are used for deembedding purposes. Note that in the latter case, the open stub model is equivalent to the transmission line model with a negative length terminated by an open.
2. [**Microstrip**] This model includes radiation effects if a cover height is not supplied (i.e., open structure.)
3. [**Microstrip**] The following limits apply (H is the thickness of the dielectric):
   0.01 ≤**W/H** ≤ 100

Radial Stub, Butterfly, Aperture Width Specified





Netlist Format

An instance of a butterfly radial stub with aperture width specified has the following netlist syntax:

A*xxx n1 n2* **A=***val* **WI=***val* **RL=***val* **W=***val* **COMPONENT=radial_stub_width_butterfly SUBSTRATE=***substrate_name*

n1 and *n2* are the names of the nodes attached to the radial stub. The entry **COMPONENT=radial_stub_width_butterfly** identifies the element as a butterfly radial stub with aperture width specified.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 49: Radial Stub, Butterfly, Width Specified, Instance Parameters

Parameter	Description	Units	Default

A	Aperture angle	Degree	60
RL	Outer radius of stub	Meter	10.0e-3
W	Feedline width	Meter	0.5e-3
WI	Stub aperture width	Meter	0.5e-3

Netlist Example

```
A44 Port1 Port2 A=70 RL=5.1e-3 W=1.0e-3 WI=0.4e-3
+ COMPONENT=radial_stub_width_butterfly SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

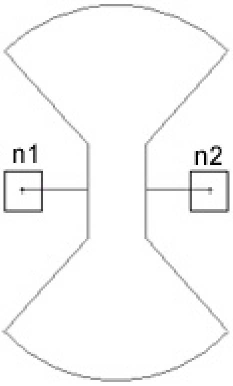
Notes

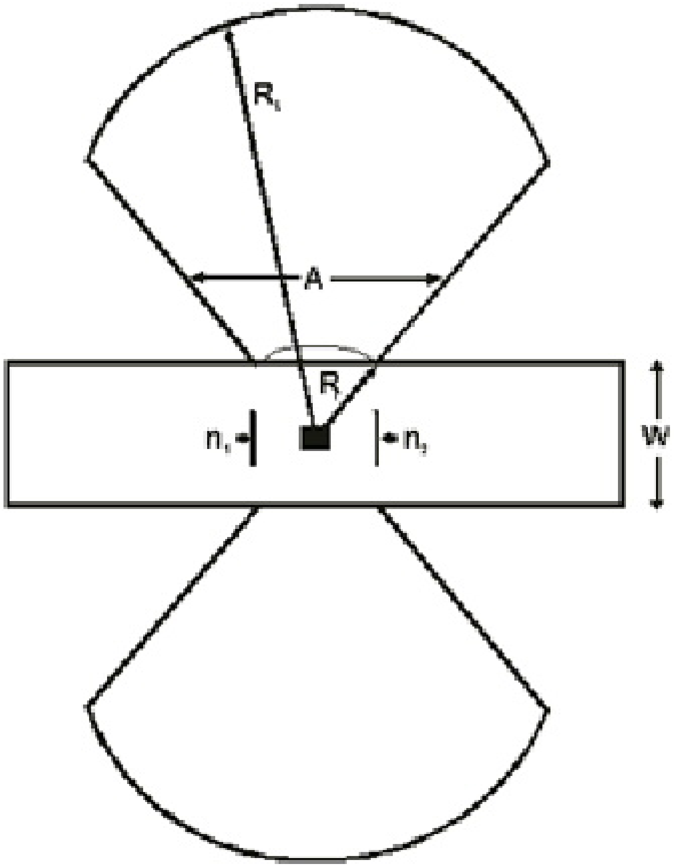
1. [**Microstrip**] The model is valid for $H/\lambda_g << 1$, where H is the substrate thickness defined in the corresponding .SUB statement, and λ_g is the wavelength in the substrate.
2. Inline configurations of the Radial Stub model include coupling to the main line. Implied MSTEEE, MSTEEC, or MSCROSS junctions are included in this model.
3. The stub is open at the outer radius RL.
4. Conductor and dielectric losses are included if the metallization or the surface resistivity are specified with the substrate data.

References

1. B. A. Syrett, “A Broad-Band Element for Microstrip Bias or Tuning Circuits,” IEEE Transactions on Microwave Theory and Techniques, Vol. MTT-28, No. 8, Aug. 1980, pp. 925-927.
2. F. Gianinni, R. Sorrentino, “Planar Circuit Analysis of Microstrip Radial Stubs,” IEEE MTT-32, No. 12, Dec. 1984, pp. 1652-1655.
3. F. Gianinni, “CAD-Oriented Lossy Models for Radial Stubs,” IEEE MTT-36, No. 2, Feb. 1988, pp. 305-313.

Radial Stub, Butterfly, Inner Radius Specified





Netlist Format

An instance of a butterfly radial stub with inner radius specified has the following netlist syntax:

```
Axxx n1 n2 A=val RI=val RL=val W=val
COMPONENT=radial_stub_radius_butterfly SUBSTRATE=substrate_name
```

n1 and *n2* are the names of the nodes attached to the radial stub. The entry **COMPONENT=radial_stub_radius_butterfly** identifies the element as a butterfly radial stub with inner radius specified.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 50: Radial Stub, Butterfly, Radius Specified, Instance Parameters

Parameter	Description	Units	Default

A	Aperture angle	Degree	60
RI	Inner radius of stub	Meter	0.2e-3
RL	Outer radius of stub	Meter	10.0e-3
W	Feedline width	Meter	0.5e-3

Netlist Example

```
A44 Port1 Port2 A=45 RI=0.33e-3 RL=5e-3 W=0.4e-3
+ COMPONENT=radial_stub_radius_butterfly SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

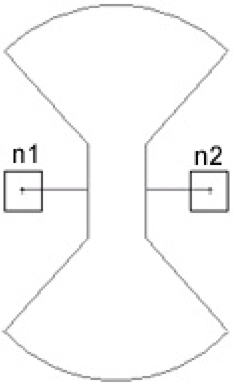
Notes

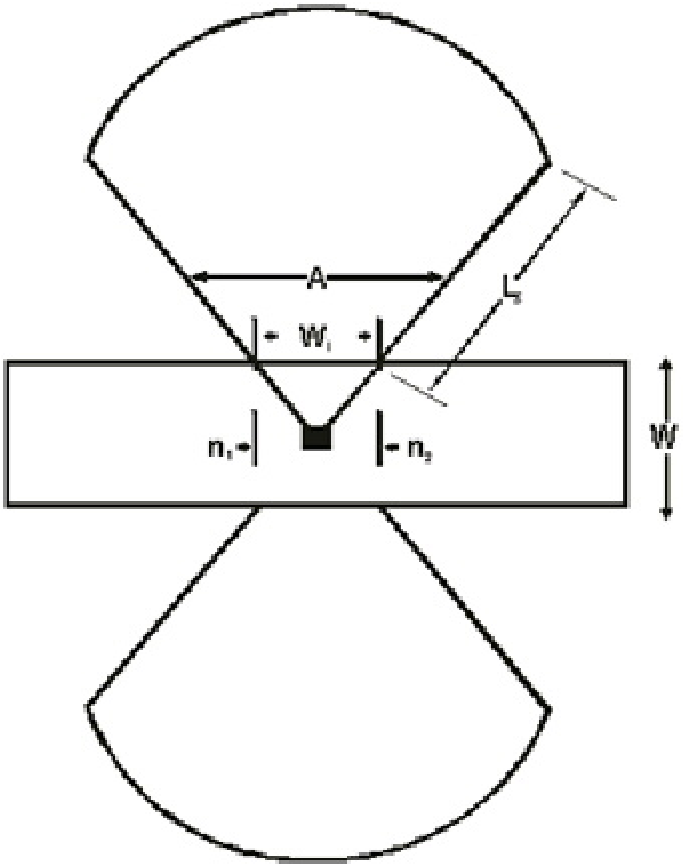
1. [**Microstrip**] The model is valid for $H/\lambda_g << 1$, where H is the substrate thickness defined in the corresponding .SUB statement, and λ_g is the wavelength in the substrate.
2. Inline configurations of the Radial Stub model include coupling to the main line. Implied MSTEEE, MSTEEC, or MSCROSS junctions are included in this model.
3. The stub is open at the outer radius RL.
4. Conductor and dielectric losses are included if the metallization or the surface resistivity are specified with the substrate data.

References

1. B. A. Syrett, “A Broad-Band Element for Microstrip Bias or Tuning Circuits,” IEEE Transactions on Microwave Theory and Techniques, Vol. MTT-28, No. 8, Aug. 1980, pp. 925-927.
2. F. Gianinni, R. Sorrentino, “Planar Circuit Analysis of Microstrip Radial Stubs,” IEEE MTT-32, No. 12, Dec. 1984, pp. 1652-1655.
3. F. Gianinni, “CAD-Oriented Lossy Models for Radial Stubs,” IEEE MTT-36, No. 2, Feb. 1988, pp. 305-313.

Radial Stub, Butterfly, Stub Edge Specified





Netlist Format

An instance of a butterfly radial stub with stub edge specified has the following netlist syntax:

A*xxx n1 n2* **A=***val* **WI=***val* **LS=***val* **W=***val* **COMPONENT=radial_stub_edge_butterfly SUBSTRATE=***substrate_name*

n1 and *n2* are the names of the nodes attached to the radial stub. The entry **COMPONENT=radial_stub_edge_butterfly** identifies the element as a butterfly radial stub with stub edge specified.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 51: Radial Stub, Butterfly, Edge Specified, Instance Parameters

Parameter	Description	Units	Default

A	Aperture angle	Degree	60
WI	Stub aperture width	Meter	0.5e-3
LS	Stub edge length	Meter	10.0e-3
W	Feedline width	Meter	0.5e-3

Netlist Example

```
A44 Port1 Port2 A=65 WI=0.33e-3 LS=8.5e-3 W=0.7e-3
+ COMPONENT=radial_stub_edge_butterfly SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

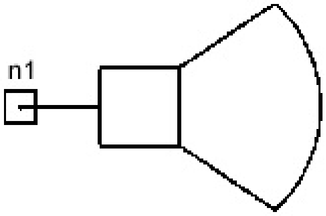
Notes

1. [**Microstrip**] The model is valid for $H/\lambda_g << 1$, where H is the substrate thickness defined in the corresponding .SUB statement, and λ_g is the wavelength in the substrate.
2. Inline configurations of the Radial Stub model include coupling to the main line. Implied MSTEEE, MSTEEC, or MSCROSS junctions are included in this model.
3. The stub is open at the outer radius RL.
4. Conductor and dielectric losses are included if the metallization or the surface resistivity are specified with the substrate data.

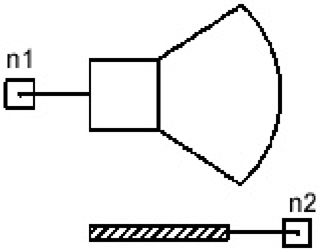
References

1. B. A. Syrett, “A Broad-Band Element for Microstrip Bias or Tuning Circuits,” IEEE Transactions on Microwave Theory and Techniques, Vol. MTT-28, No. 8, Aug. 1980, pp. 925-927.
2. F. Gianinni, R. Sorrentino, “Planar Circuit Analysis of Microstrip Radial Stubs,” IEEE MTT-32, No. 12, Dec. 1984, pp. 1652-1655.
3. F. Gianinni, “CAD-Oriented Lossy Models for Radial Stubs,” IEEE MTT-36, No. 2, Feb. 1988, pp. 305-313.

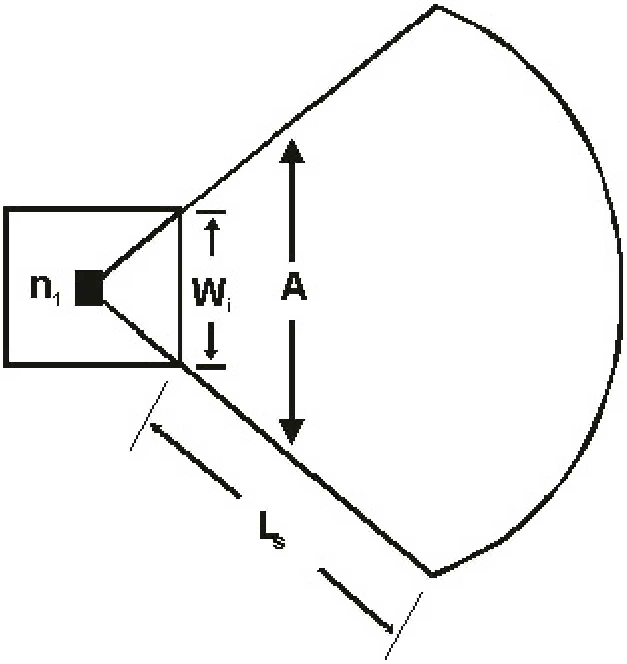
Radial Stub, Series, Aperture Width Specified



Schematic symbol MSRSTW



Schematic symbol MSRSTW_REF



Netlist Format

An instance of a series radial stub with aperture width specified has the following netlist syntax:

```
Axxx n1 [n2]   A=val WI=val RL=val
COMPONENT=radial_stub_width_series SUBSTRATE=substrate_name
```

n1 is the name of the node attached to the radial stub. *n2*, when present, is the reference node. The entry **COMPONENT=radial_stub_width_series** identifies the element as a series radial stub with aperture width specified.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 52: Radial Stub, Series, Width Specified, Instance Parameters

Parameter	Description	Units	Default
A	Aperture angle	Degree	60
WI	Stub aperture width	Meter	0.5e-3
RL	Outer radius of stub	Meter	10.0e-3

Netlist Example

```
A44 Port1 Port2 A=65 WI=0.8e-3 RL=15e-3
+ COMPONENT=radial_stub_width_series SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

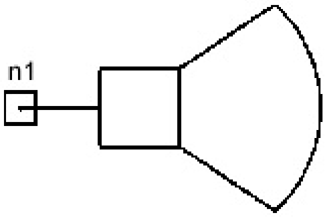
1. [**Microstrip**] Valid for $H/\lambda_g << 1$, where H is the substrate thickness defined in the corresponding .SUB statement, and λ_g is the wavelength in the substrate.
2. The stub is open at the outer radius RL.
3. Conductor and dielectric losses are included if the metallization or the surface resistivity are specified with the substrate data.

References

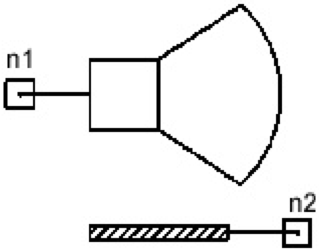
1. B. A. Syrett, “A Broad-Band Element for Microstrip Bias or Tuning Circuits,” IEEE Transactions on Microwave Theory and Techniques, Vol. MTT-28, No. 8, Aug. 1980, pp. 925-927.

2. F. Gianinni, R. Sorrentino, “Planar Circuit Analysis of Microstrip Radial Stubs,” IEEE MTT-32, No. 12, Dec. 1984, pp. 1652-1655.
3. F. Gianinni, “CAD-Oriented Lossy Models for Radial Stubs,” IEEE MTT-36, No. 2, Feb. 1988, pp. 305-313.

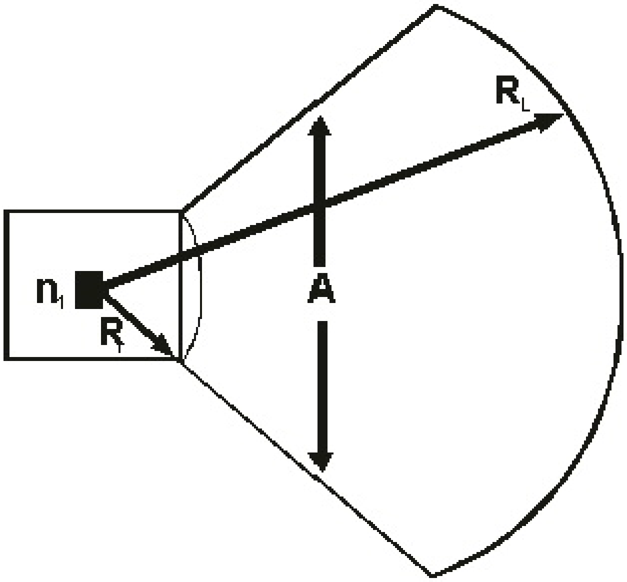
Radial Stub, Series, Inner Radius Specified



Schematic symbol MSRSTR



Schematic symbol MSRSTR_REF



Netlist Format

An instance of a series radial stub with inner radius specified has the following netlist syntax:

```
Axxx n1 [n2]   A=val RI=val RL=val
COMPONENT=radial_stub_radius_series SUBSTRATE=substrate_name
```

n1 is the name of the node attached to the radial stub. *n2*, when present, is the reference node. The entry **COMPONENT=radial_stub_radius_series** identifies the element as a series radial stub with inner radius specified.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 53: Radial Stub, Series, Radius Specified, Instance Parameters

Parameter	**Description**	**Units**	**Default**
A	Aperture angle	Degree	60
RI	Inner radius of stub	Meter	0.2e-3
RL	Outer radius of stub	Meter	10.0e-3

Netlist Example

```
A44 Port1 Port2 A=65 RI=0.1e-3 RL=5.5e-3
+ COMPONENT=radial_stub_radius_series SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

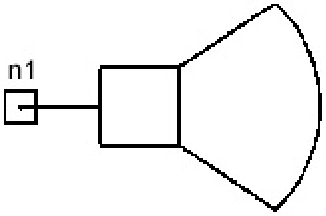
Notes

1. [**Microstrip**] Valid for $H/\lambda_g << 1$, where H is the substrate thickness defined in the corresponding .SUB statement, and λ_g is the wavelength in the substrate.
2. The stub is open at the outer radius RL.
3. Conductor and dielectric losses are included if the metallization or the surface resistivity are specified with the substrate data.

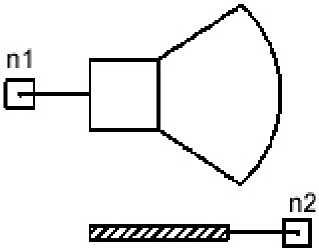
References

1. B. A. Syrett, “A Broad-Band Element for Microstrip Bias or Tuning Circuits,” IEEE Transactions on Microwave Theory and Techniques, Vol. MTT-28, No. 8, Aug. 1980, pp. 925-927.
2. F. Gianinni, R. Sorrentino, “Planar Circuit Analysis of Microstrip Radial Stubs,” IEEE MTT-32, No. 12, Dec. 1984, pp. 1652-1655.
3. F. Gianinni, “CAD-Oriented Lossy Models for Radial Stubs,” IEEE MTT-36, No. 2, Feb. 1988, pp. 305-313.

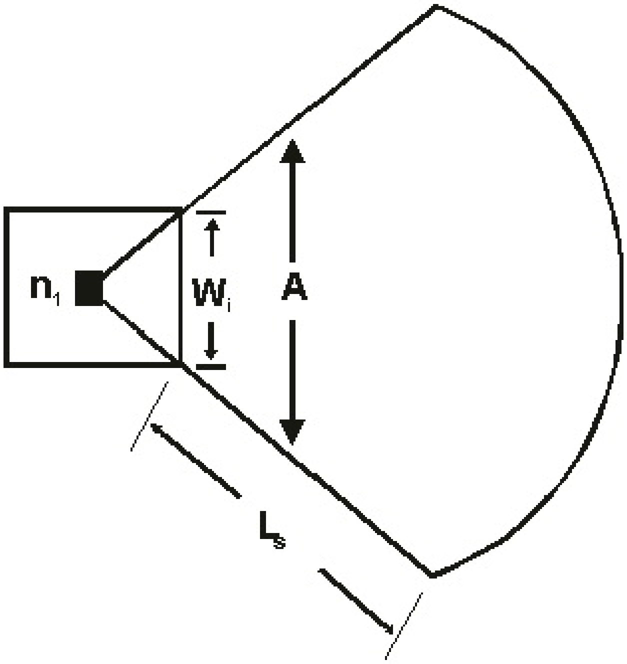
Radial Stub, Series, Stub Edge Specified



Schematic symbol MSRSTL



Schematic symbol MSRSTL_REF



Netlist Format

An instance of a series radial stub with stub edge specified has the following netlist syntax:

A*xxx n1* [*n2*]   **A=***val* **WI=***val* **LS=***val*
COMPONENT=radial_stub_edge_series SUBSTRATE=*substrate_name*

n1 is the name of the node attached to the radial stub. *n2*, when present, is the reference node. The entry **COMPONENT=radial_stub_edge_series** identifies the element as a series radial stub with stub edge specified.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 54: Radial Stub, Series, Edge Specified, Instance Parameters

Parameter	Description	Units	Default
A	Aperture angle	Degree	60
WI	Stub aperture width	Meter	0.5e-3
LS	Stub edge length	Meter	10.0e-3

Netlist Example

```
A44 Port1 Port2 A=50 WI=0.8e-3 LS=11e-3
+ COMPONENT=radial_stub_edge_series SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

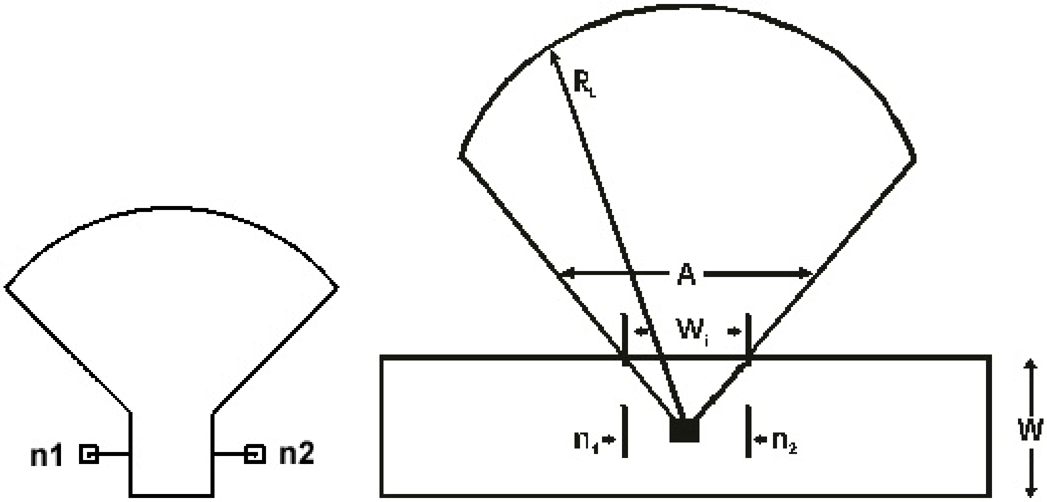
Notes

1. [**Microstrip**] Valid for $H/\lambda_g << 1$, where H is the substrate thickness defined in the corresponding .SUB statement, and λ_g is the wavelength in the substrate.
2. The stub is open at the outer radius RL.
3. Conductor and dielectric losses are included if the metallization or the surface resistivity are specified with the substrate data.

References

1. B. A. Syrett, “A Broad-Band Element for Microstrip Bias or Tuning Circuits,” IEEE Transactions on Microwave Theory and Techniques, Vol. MTT-28, No. 8, Aug. 1980, pp. 925-927.
2. F. Gianinni, R. Sorrentino, “Planar Circuit Analysis of Microstrip Radial Stubs,” IEEE MTT-32, No. 12, Dec. 1984, pp. 1652-1655.
3. F. Gianinni, “CAD-Oriented Lossy Models for Radial Stubs,” IEEE MTT-36, No. 2, Feb. 1988, pp. 305-313.

Radial Stub, Shunt, Aperture Width Specified



Netlist Format

An instance of a shunt radial stub with aperture width specified has the following netlist syntax:

A*xxx n1 n2* **A=***val* **WI=***val* **RL=***val* **W=***val*
COMPONENT=radial_stub_width_shunt SUBSTRATE=*substrate_name*

n1 and *n2* are the names of the nodes attached to the radial stub. The entry **COMPONENT=radial_stub_width_shunt** identifies the element as a shunt radial stub with aperture width specified.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 55: Radial Stub, Shunt, Width Specified, Instance Parameters

Parameter	Description	Units	Default
A	Aperture angle	Degree	60
WI	Stub aperture width	Meter	0.5e-3
RL	Stub outer radius	Meter	10.0e-3
W	Feedline width	Meter	0.5e-3

Netlist Example

```
A44 Port1 Port2 A=60 WI=1.1e-3 RL=12e-3 W=0.6e-3
+ COMPONENT=radial_stub_width_shunt SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

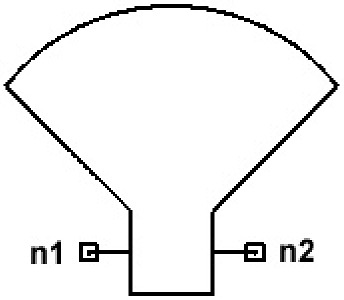
Notes

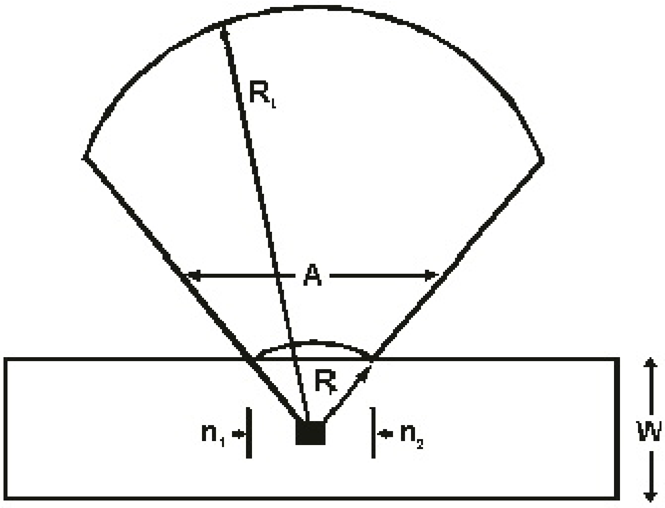
1. [**Microstrip**] Valid for $H/\lambda_g << 1$, where H is the substrate thickness defined in the corresponding .SUB statement, and λ_g is the wavelength in the substrate.
2. Inline configurations of the Radial Stub model include coupling to the main line. Implied MSTEEE, MSTEEC, or MSCROSS junctions are included in this model.
3. The stub is open at the outer radius RL.
4. Conductor and dielectric losses are included if the metallization or the surface resistivity are specified with the substrate data.

References

1. B. A. Syrett, “A Broad-Band Element for Microstrip Bias or Tuning Circuits,” IEEE Transactions on Microwave Theory and Techniques, Vol. MTT-28, No. 8, Aug. 1980, pp. 925-927.
2. F. Gianinni, R. Sorrentino, “Planar Circuit Analysis of Microstrip Radial Stubs,” IEEE MTT-32, No. 12, Dec. 1984, pp. 1652-1655.
3. F. Gianinni, “CAD-Oriented Lossy Models for Radial Stubs,” IEEE MTT-36, No. 2, Feb. 1988, pp. 305-313.

Radial Stub, Shunt, Inner Radius Specified





Netlist Format

An instance of a shunt radial stub with inner radius specified has the following netlist syntax:

```
Axxx n1 n2 A=val RI=val RL=val W=val
COMPONENT=radial_stub_radius_shunt SUBSTRATE=substrate_name
```

n1 and *n2* are the names of the nodes attached to the radial stub. The entry **COMPONENT=radial_stub_radius_shunt** identifies the element as a shunt radial stub with inner radius specified.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 56: Radial Stub, Shunt, Radius Specified, Instance Parameters

Parameter	Description	Units	Default
A	Aperture angle	Degree	60
RI	Inner radius	Meter	0.2e-3
RL	Outer radius	Meter	10.0e-3
W	Feedline width	Meter	0.5e-3

Netlist Example

```
A44 Port1 Port2 A=65 RI=0.1e-3 RL=9e-3 W=0.8e-3
+ COMPONENT=radial_stub_radius_shunt SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

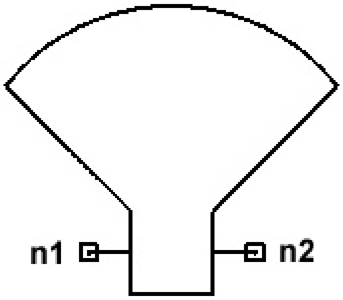
Notes

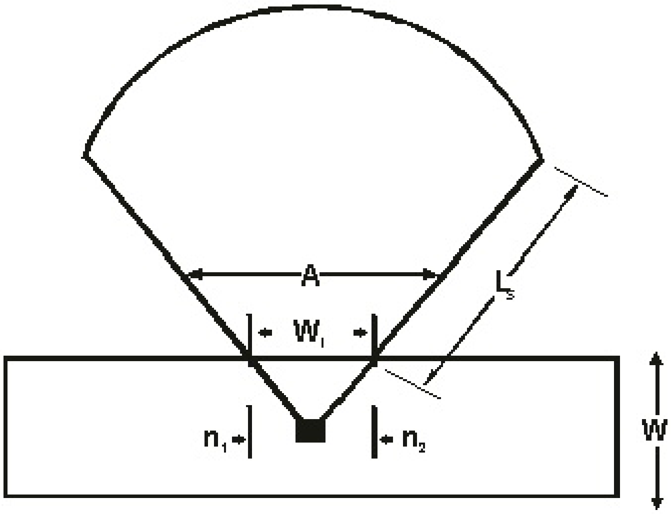
1. [**Microstrip**] Valid for $H/\lambda_g << 1$, where H is the substrate thickness defined in the corresponding .SUB statement, and λ_g is the wavelength in the substrate.
2. Inline configurations of the Radial Stub model include coupling to the main line. Implied MSTEEE, MSTEEC, or MSCROSS junctions are included in this model.
3. The stub is open at the outer radius RL.
4. Conductor and dielectric losses are included if the metallization or the surface resistivity are specified with the substrate data.

References

1. B. A. Syrett, “A Broad-Band Element for Microstrip Bias or Tuning Circuits,” IEEE Transactions on Microwave Theory and Techniques, Vol. MTT-28, No. 8, Aug. 1980, pp. 925-927.
2. F. Gianinni, R. Sorrentino, “Planar Circuit Analysis of Microstrip Radial Stubs,” IEEE MTT-32, No. 12, Dec. 1984, pp. 1652-1655.
3. F. Gianinni, “CAD-Oriented Lossy Models for Radial Stubs,” IEEE MTT-36, No. 2, Feb. 1988, pp. 305-313.

Radial Stub, Shunt, Stub Edge Specified





Netlist Format

An instance of a shunt radial stub with stub edge specified has the following netlist syntax:

```
Axxx n1 n2 A=val WI=val LS=val W=val
COMPONENT=radial_stub_edge_shunt SUBSTRATE=substrate_name
```

n1 and *n2* are the names of the nodes attached to the radial stub. The entry **COMPONENT=radial_stub_edge_shunt** identifies the element as a shunt radial stub with stub edge specified.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 57: Radial Stub, Shunt, Edge Specified, Instance Parameters

Parameter	Description	Units	Default
A	Aperture angle	Degree	60
WI	Stub aperture width	Meter	0.5e-3
LS	Stub edge length	Meter	10.0e-3
W	Feedline width	Meter	0.5e-3

Netlist Example

```
A44 Port1 Port2 A=90 RI=0.6e-3 RL=10e-3 W=0.5e-3
+ COMPONENT=radial_stub_edge_shunt SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

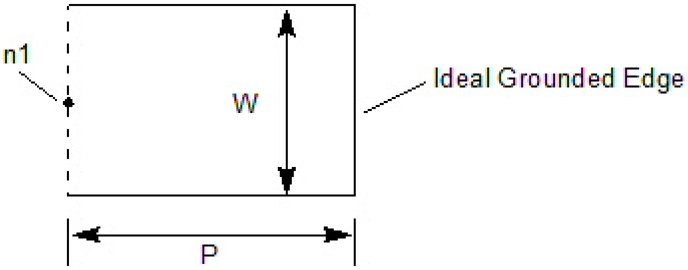
Notes

1. [**Microstrip**] Valid for $H/\lambda_g << 1$, where H is the substrate thickness defined in the corresponding .SUB statement, and λ_g is the wavelength in the substrate.
2. Inline configurations of the Radial Stub model include coupling to the main line. Implied MSTEEE, MSTEEC, or MSCROSS junctions are included in this model.
3. The stub is open at the outer radius RL.
4. Conductor and dielectric losses are included if the metallization or the surface resistivity are specified with the substrate data.

References

1. B. A. Syrett, “A Broad-Band Element for Microstrip Bias or Tuning Circuits,” IEEE Transactions on Microwave Theory and Techniques, Vol. MTT-28, No. 8, Aug. 1980, pp. 925-927.
2. F. Gianinni, R. Sorrentino, “Planar Circuit Analysis of Microstrip Radial Stubs,” IEEE MTT-32, No. 12, Dec. 1984, pp. 1652-1655.
3. F. Gianinni, “CAD-Oriented Lossy Models for Radial Stubs,” IEEE MTT-36, No. 2, Feb. 1988, pp. 305-313.

Shorted Stub, Physical Length



Netlist Form

An instance of a shorted stub with physical length has the following netlist syntax:

```
Axxx n1 W=val P=val COMPONENT=shorted_stub_physical
SUBSTRATE=substrate_name
```

n1 is the name of the node attached to the shorted stub. The entry **COMPONENT=shorted_stub_physical** identifies the element as a shorted stub, physical length.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 58: Shorted Stub, Physical Length, Instance Parameters

Parameter	Description	Units	Default
W	Line width	Meter	1e-3
P	Physical length	Meter	10e-3

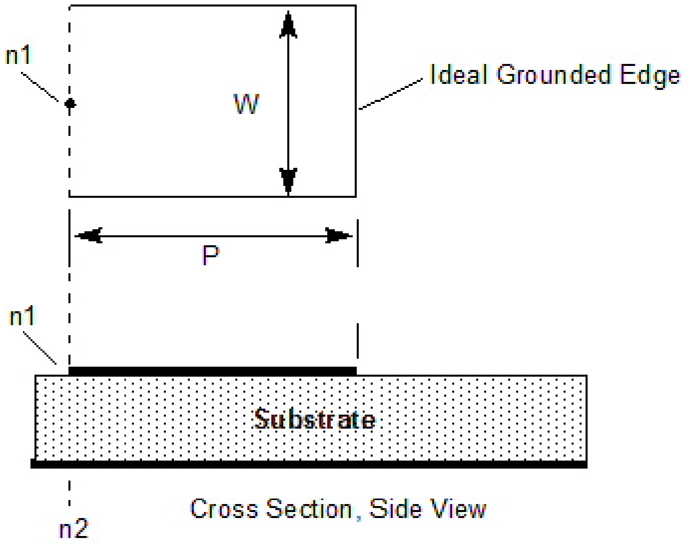
Netlist Example

```
A44 Port1 W=0.001 P=10e-3
+ COMPONENT=shorted_stub_physical SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Shorted Stub, Physical Length with Reference



Netlist Form

An instance of a shorted stub, physical length with reference node has the following netlist syntax:

```
Axxx n1 n2 W=val P=val COMPONENT=shorted_stub_physical
SUBSTRATE=substrate_name
```

n1 is the name of the node attached to the shorted stub. *n2* is the reference node. The entry **COMPONENT=shorted_stub_physical** identifies the element as a shorted stub, physical length with or without a reference node.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 59: Shorted Stub, Physical Length with Reference, Instance Parameters

Parameter	Description	Units	Default
W	Line width	Meter	1e-3
P	Physical length	Meter	10e-3

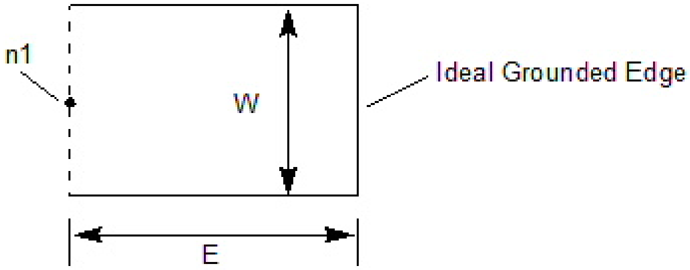
Netlist Example

```
A44 Port1 Port3 W=0.001 P=10e-3
+ COMPONENT=shorted_stub_physical SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Shorted Stub, Electrical Length



Netlist Format

An instance of a shorted stub with electrical length has the following netlist syntax:

A*xxx n1* **W=***val* **E=***val* **F=***val* **COMPONENT=shorted_stub_electrical SUBSTRATE=***substrate_name*

n1 is the name of the node attached to the shorted stub. A reference node of ground (node 0) is automatically supplied, and is not shown in the netlist. The entry **COMPONENT=shorted_stub_electrical** identifies the element as a shorted stub with electrical length.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 60: Shorted Stub with Electrical Length, Instance Parameters

Parameter	Description	Units	Default
W	Line width	Meter	1e-3

E	Electrical length	Degree	45
F	Reference frequency for E	Hz	1e9

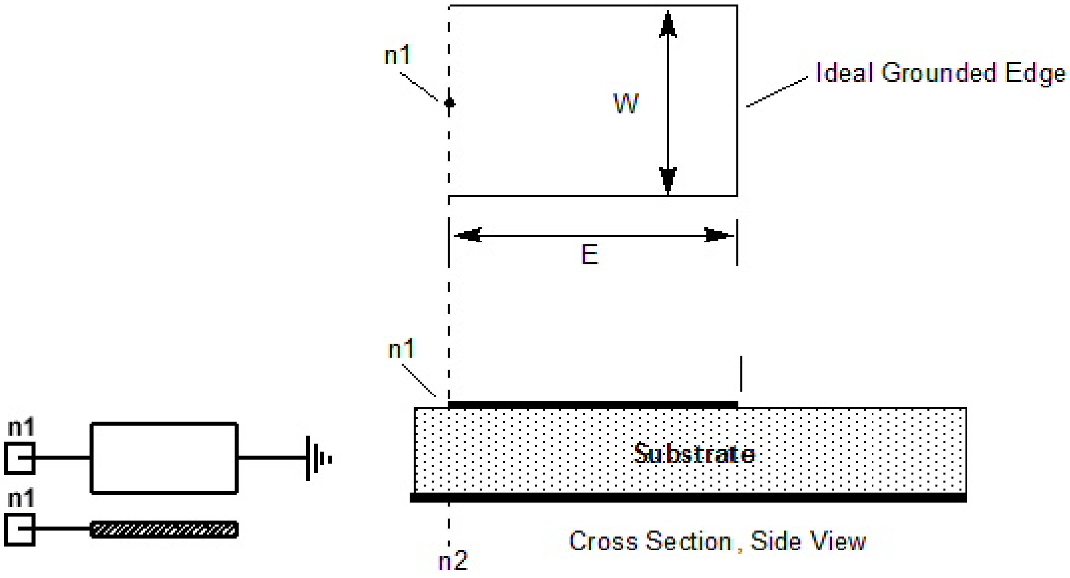
Netlist Example

```
A44 Port1 W=1.0e-3 E=45 F=1.0e9
+ COMPONENT=shorted_stub_electrical SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Shorted Stub, Electrical Length with Reference



Netlist Format

An instance of a shorted stub, electrical length with reference has the following netlist syntax:

`A`*`xxx n1 n2`* **`W=`***`val`* **`E=`***`val`* **`F=`***`val`* **`COMPONENT=shorted_stub_electrical`**
`SUBSTRATE=`*`substrate_name`*

n1 is the name of the node attached to the shorted stub. *n2* is the reference node. The entry **COMPONENT=shorted_stub_electrical** identifies the element as a shorted stub, electrical length with or without a reference node.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 61: Shorted Stub, Electrical Length with Reference, Instance Parameters

Parameter	Description	Units	Default
W	Line width	Meter	1e-3
E	Electrical length	Degree	45
F	Reference frequency for E	Hz	1e9

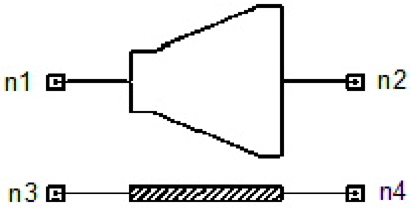
Netlist Example

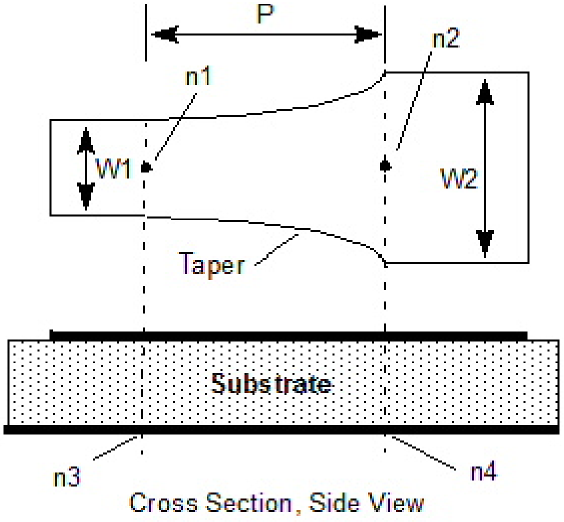
```
A44 Port1 Port 2 W=1.0e-3 E=45 F=1.0e9
+ COMPONENT=shorted_stub_electrical SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TANDD=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Tapered Line, W Specified, with Reference





Netlist Format

An instance of a tapered line, W specified, with reference has the following netlist syntax:

A*xxx n1 n2 n3 n4* **W1=***val* **W2=***val* **P=***val*

TAPER=LinImp|ExpImp|LinWidth|ExpWidth

COMPONENT=taper_width_specified SUBSTRATE=*substrate_name*

n1 and *n2* are the names of the nodes attached to the tapered line, *n3* and *n4* are the reference nodes. The entry **COMPONENT=taper_width_specified** identifies the element as a tapered line, W specified, with reference node.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 62: Tapered Line, W Specified, with Reference, Instance Parameters

Parameter	Description	Units	Default
P	Physical length	Meter	1e-2
W1	Width of line at node 1	Meter	1e-3
W2	Width of line at node 2	Meter	1e-3
TAPER	Taper type: LinWidth—Linear Width ExpWidth—Exponential Width LinImp—Linear Impedance ExpImp—Exponential Impedance	None	LinWidth

Netlist Example

```
A2 Port1 Port2 W1=0.001 W2=0.003 P=0.01 TAPER=ExpWidth

+ COMPONENT=TAPER_WIDTH_SPECIFIED   SUBSTRATE=FR4
```

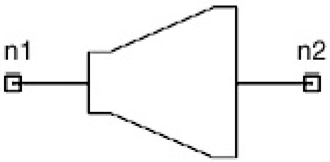
where FR4, the selected layout technology or substrate type, has a definition such as:

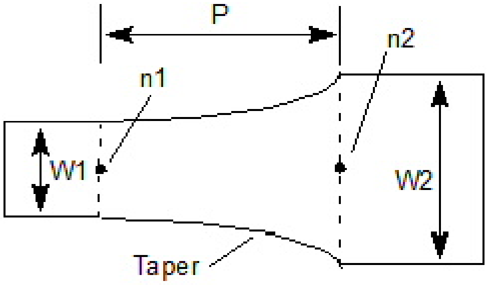
```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] Node numbers can be reversed such that *n1* and associated width **W1** are at the wide end of the taper.
2. [**All substrates**] The Tapered Line with Reference syntax is supported in netlists only. See the next three topics for the tapered line elements available in schematics.
3. [**Microstrip**] The substrate definition should satisfy the following conditions: $0.01 \le W/H \le 100$, $\max(W1,W2) \le 0.5\lambda_g$, where λ_g is the guide wavelength.

Tapered Line, W Specified, Impedance Taper





Netlist Format

An instance of a tapered line, W specified, impedance taper has the following netlist syntax:

```
Axxx n1 n2 n3 n4 W1=val W2=val P=val TAPER=LinImp|ExpImp

 COMPONENT=taper_width_specified SUBSTRATE=substrate_name
```

n1 and *n2* are the names of the nodes attached to the tapered line, *n3* and *n4* are the reference nodes. The entry **COMPONENT=taper_width_specified** identifies the element as a tapered line, W specified.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 63: Tapered Line, W Specified, Impedance Taper, Instance Parameters

Parameter	Description	Units	Default
P	Physical length	Meter	1e-2
W1	Width of line at node 1	Meter	1e-3

W2	Width of line at node 2	Meter	1e-3
TAPER	Taper type: LinImp—Linear Impedance ExpImp—Exponential Impedance	None	ExpImp

Netlist Example

```
A2 Port1 Port2 W1=0.001 W2=0.003 P=0.01 TAPER=ExpImp

+ COMPONENT=taper_width_specified   SUBSTRATE=FR4
```

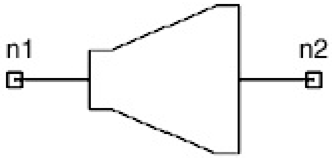
where FR4, the selected layout technology or substrate type, has a definition such as:

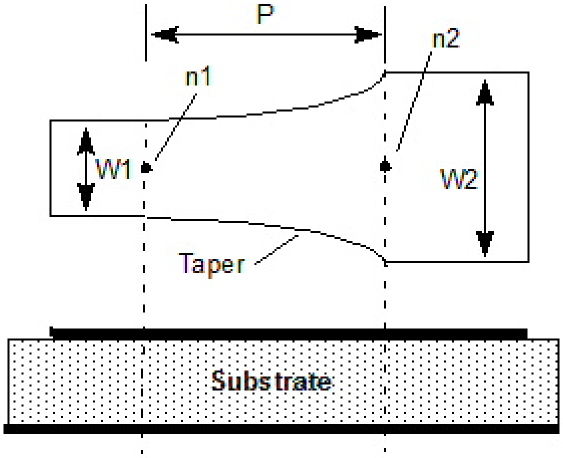
```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] Node numbers can be reversed, so *n1* and associated width **W1** are at the wide end of the taper.
2. [**All substrates**] The Nexxim impedance tapered line element does not have a physical footprint in Ansys Electronics Desktop.
3. [**Microstrip**] The substrate definition should satisfy the following conditions: $0.01 \le W/H \le 100$, $\max(W1,W2) \le 0.5\lambda_g$, where λ_g is the guide wavelength.

Tapered Line, W Specified, Exponential Width Taper





Netlist Format

An instance of a tapered line, W specified, exponential width taper has the following netlist syntax:

A*xxx n1 n2 n3 n4* **W1=***val* **W2=***val* **P=***val* **TAPER=ExpWidth COMPONENT=taper_width_specified SUBSTRATE=***substrate_name*

n1 and *n2* are the names of the nodes attached to the tapered line, *n3* and *n4* are the reference nodes. The entry **COMPONENT=taper_width_specified** identifies the element as a tapered line, W specified.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 64: Tapered Line, W Specified, Exponential Width Taper, Instance Parameters

Parameter	Description	Units	Default
P	Physical length	Meter	1e-2
W1	Width of line at node 1	Meter	1e-3
W2	Width of line at node 2	Meter	1e-3
TAPER	Taper type: Must be ExpWidth—Exponential Width	None	ExpWidth

Netlist Example

```
A2 Port1 Port2 W1=0.001 W2=0.003 P=0.01 TAPER=ExpWidth
+ COMPONENT=taper_width_specified SUBSTRATE=SUBSTRATE=FR4
```

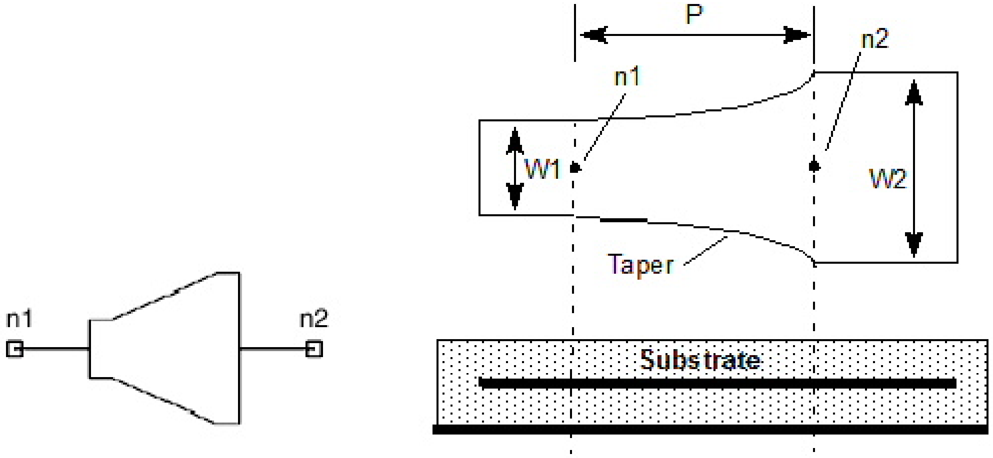
where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] Node numbers can be reversed, so *n1* and associated width **W1** are at the wide end of the taper.
2. [**All substrates**] The Nexxim exponential width tapered line element has a physical footprint in Ansys Electronics Desktop.
3. [**Microstrip**] The substrate definition should satisfy the following conditions: $0.01 \le W/H \le 100$, $\max(W1,W2) \le 0.5\lambda_g$, where λ_g is the guide wavelength.

Tapered Line, W Specified, Linear Width Taper



Netlist Format

An instance of a tapered line, W specified, linear width taper has the following netlist syntax:

A*xxx n1 n2 n3 n4* **W1=***val* **W2=***val* **P=***val* **TAPER=LinWidth COMPONENT=taper_width_specified SUBSTRATE=***substrate_name*

n1 and *n2* are the names of the nodes attached to the tapered line, *n3* and *n4* are the reference nodes. The entry **COMPONENT=taper_width_specified** identifies the element as a tapered line, W specified.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 65: Tapered Line, W Specified, Linear Width Taper, Instance Parameters

Parameter	Description	Units	Default
P	Physical length	Meter	1e-2
W1	Width of line at node 1	Meter	1e-3
W2	Width of line at node 2	Meter	1e-3
TAPER	Taper type: Must be LinWidth—Linear Width	None	LinWidth

Netlist Example

```
A2 Port1 Port2 W1=0.001 W2=0.003 P=0.01 TAPER=LinWidth
+ COMPONENT=taper_width_specified   SUBSTRATE=SUBSTRATE=FR4
```

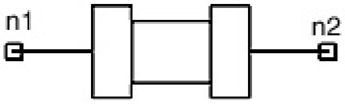
where FR4, the selected layout technology or substrate type, has a definition such as:

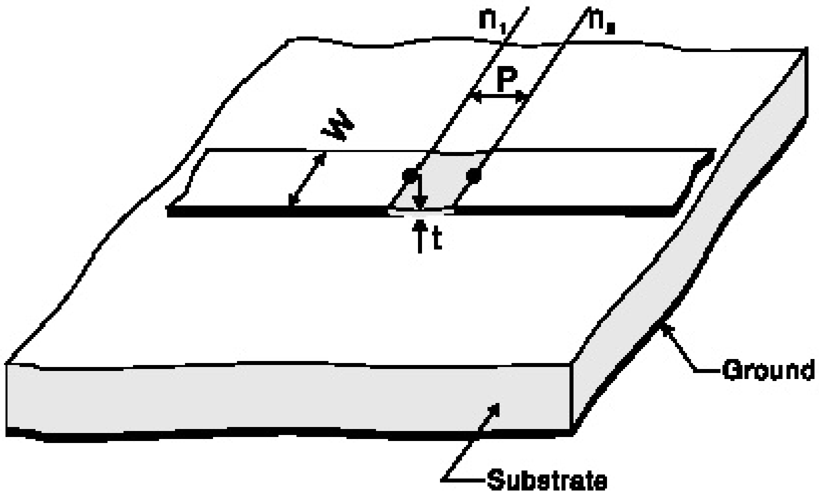
```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] Node numbers can be reversed, so *n1* and associated width **W1** are at the wide end of the taper.
2. [**All substrates**] The Nexxim linear width tapered line element has a physical footprint in Ansys Electronics Desktop.
3. [**Microstrip**] The substrate definition should satisfy the following conditions: $0.01 \le W/H \le 100$, $\max(W1,W2) \le 0.5\lambda_g$, where λ_g is the guide wavelength.

Thin-Film Resistor, Bulk Resistivity





Netlist Format

An instance of a thin-film resistor with bulk resistivity specified has the following netlist syntax:

ATFRB*xxx n1 n2* **W=***val* **P=***val* **RB=***val* **T=***val*
COMPONENT=ms_thinfilm_rb SUBSTRATE=*substrate_name*

n1 and *n2* are the names of the nodes attached to the resistor. The entry **COMPONENT=ms_thinfilm_rb** identifies the element.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 66: Thin-Film Resistor, Bulk Resistivity, Instance Parameters

Parameter	Description	Units	Default
P	Line length	Meter	10e-3
W	Line width	Meter	1e-3
RB	Bulk resistivity	µOhm-cm	2.44
T	Thickness of thin-film resistor	Meter	0.1e-3

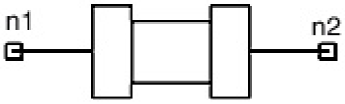
Netlist Example

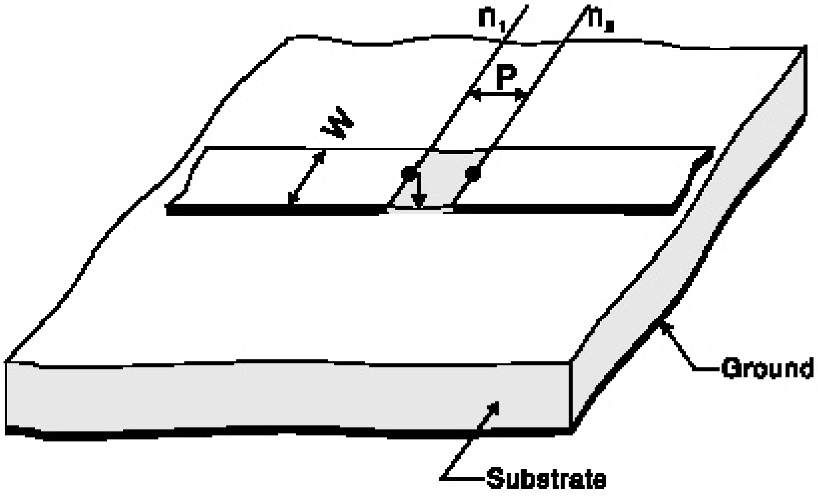
```
ATFRB2 Port1 Port2 W=0.001 P=0.01
+ COMPONENT=ms_thinfilm_rb   SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Thin-Film Resistor, Surface Resistivity





Netlist Format

An instance of a thin-film resistor with surface resistivity specified has the following netlist syntax:

ATFRS*xxx n1 n2* **W=***val* **P=***val* **RS=***val* **COMPONENT=ms_thinfilm_rs SUBSTRATE=***substrate_name*

n1 and *n2* are the names of the nodes attached to the resistor. The entry **COMPONENT=ms_thinfilm_rs** identifies the element.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 67: Thin-Film Resistor, Surface Resistivity, Instance Parameters

Parameter	Description	Units	Default
P	Line length	Meter	10e-3
W	Line width	Meter	1e-3
RS	Sheet resistivity	µOhm-cm	100

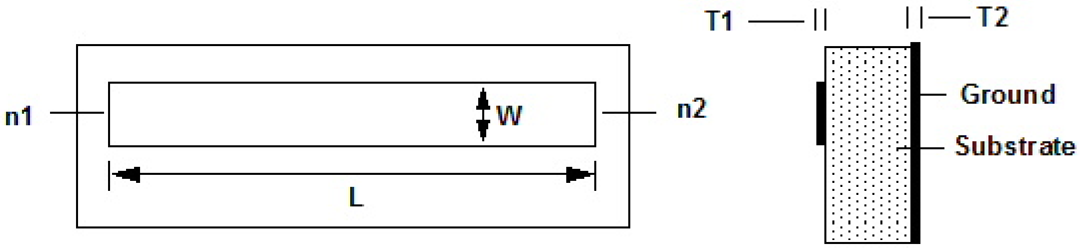
Netlist Example

```
ATFRS2 Port1 Port2 W=0.001 P=0.01
+ COMPONENT=ms_thinfilm_rs   SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Transmission Line, Field Solver



Netlist Format

A field solver microstrip transmission line has the following netlist syntax:

W*xxx n1* **0***n2* **0 N=1 W=***val* **L=***val* **FSmodel=***modelname*

```
.MATERIAL conductor METAL CONDUCTIVITY=val
.MATERIAL dielectric DIELECTRIC ER=val LTAND=val
.SHAPE RECT1 RECTANGLE WIDTH=w HEIGHT=t1 // Conductors
.LAYERSTACK layerstack
+ LAYER=(conductor, t2) // Ground plane
+ LAYER=(dielectric, h)
+ LAYER=(AIR, hu)
```

```
.MODEL modelname W MODELTYPE=Fieldsolver
+ LAYERSTACK=layerstack
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=(0, 't2 + h')
```

n1, and *n2* are the names of the input and output nodes. The entry **N=1** shows that this is a single transmission line. The names for the *modelname*, *conductor*, *dielectric*, and *layerstack* are supplied by the user.

The entry **FSmodel=***modelname* identifies the field solver microstrip W-model.

Table 68: Transmission Line, Field Solver Instance Parameters

Parameter	Description	Units	Default
W	Width of conductor	Meter	0.001
L	Physical length	Meter	0.01
N	Number of lines for W-element (must be 1 for transmission line)	None	1
H	Thickness of dielectric layer	Meter	1e-3
HU	Thickness of air layer	Meter	B/2
T1	Thickness of conductors	Meter	0.001
T2	Thickness of ground planes	Meter	0.001
CONDUCTIVITY	Conductivity of conductor material		57.6e6
ER	Dielectric constant		2.2
TAND	Dielectric loss tangent		0

> **Note:** The default values for the transmission line are the ones assigned when placing a component on the Component library in a schematic. There are NO defaults for netlist designs; all values must be specified.

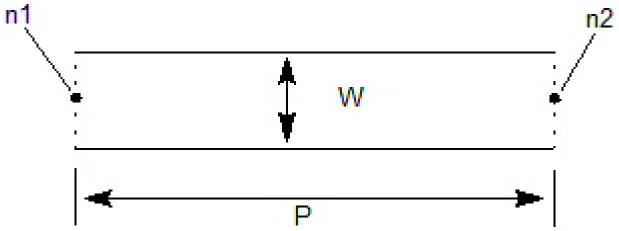
Netlist Example

```
W3 Port1 0 Port2 0 N=1 W-0.0001 L=0.002 FSmodel=MS1
```

```
.MATERIAL cond1 METAL CONDUCTIVITY=5.8e7
.MATERIAL diel1 DIELECTRIC ER=4.4 LOSSTANGENT=0.02
.SHAPE RECT1 RECTANGLE WIDTH=.005 // Conductor width W
+ HEIGHT=.001   // Conductor thichness T1
.LAYERSTACK microstrip
+ LAYER=(cond1, .001) // Bottom ground, T2
+ LAYER=(diel1, .01) // Dielectric, H
+ LAYER=(AIR, .002) // Air layer, HU
.MODEL MS1 W MODELTYPE=Fieldsolver
+ LAYERSTACK=microstrip
```

```
+ CONDUCTOR=(SHAPE=RECT1, + ORIGIN=(0, '.001 + .01'), // T2 + H
+ MATERIAL=cond1, TYPE=SIGNAL)
```

Transmission Line, Physical Length



Netlist Format

An instance of a transmission line with physical length has the following netlist syntax:

A*xxx n1 n2* [**W=***val*] [**P=***val*] **COMPONENT=trl SUBSTRATE=***substrate_name*

n1 and *n2* are the names of the nodes attached to the transmission line. The entry **COMPONENT=TRL** identifies the element as a transmission line with physical length.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 69: Transmission Line with Physical Length, Instance Parameters

Parameter	Description	Units	Default
P	Physical length	Meter	1e-2
W	Conductor width	Meter	1e-3

Netlist Example

```
A2 Port1 Port2 W=0.001 P=0.01
+ COMPONENT=TRL   SUBSTRATE=FR4
```

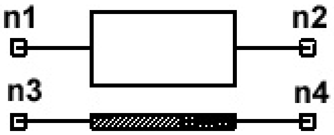
where FR4, the selected layout technology or substrate type, has a definition such as:

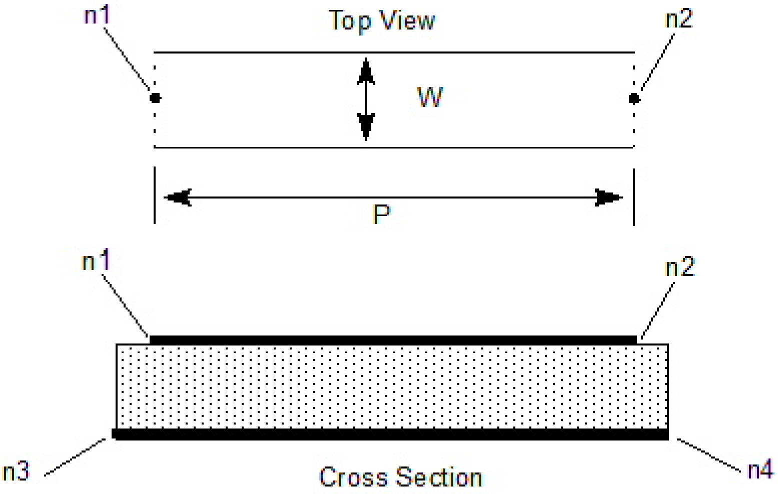
```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**Microstrip**] The substrate definition should satisfy the following conditions: 0.01 ≤ W/H ≤ 10, E_R < 18, T ≤ W, and T ≤ H/2.

Transmission Line, Physical Length with Reference





Netlist Format

An instance of a transmission line with physical length and reference nodes has the following netlist syntax:

A*xxx n1 n2 n3 n4* [**W=***val*] [**P=***val*] **COMPONENT=TRL SUBSTRATE=***substrate_name*

n1, *n2*, *n3*, and *n4* are the names of the nodes attached to the transmission line. The entry **COMPONENT=TRL** identifies the element as a transmission line with physical length.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 70: Transmission Line with Physical Length and Reference Nodes, Instance Parameters

Parameter	Description	Units	Default
P	Physical length	Meter	1e-2
W	Conductor width	Meter	1e-3

Netlist Example

```
A5 Port1 Port2 0 0 W=0.001 P=0.01
+ COMPONENT=TRL SUBSTRATE=FR4
```

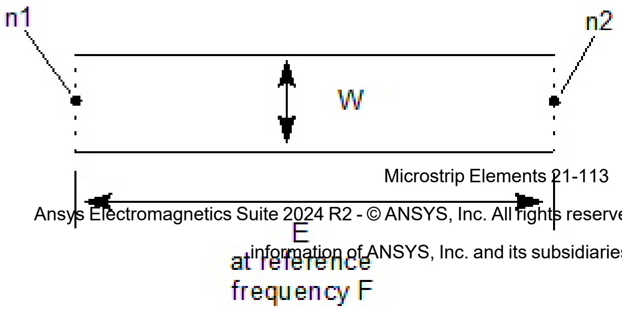
where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**Microstrip**] The substrate definition should satisfy the following conditions: $0.01 \le W/H \le 10$, $E_R < 18$, $T \le W$, and $T \le H/2$.

Transmission Line, Electrical Length



Netlist Format

An instance of a transmission line with electrical length has the following netlist syntax:

A*xxx n1 n2* **W=***val* **E=***val* **F=***val* **COMPONENT=TRL_E SUBSTRATE=***substrate_name*

n1 and *n2* are the names of the nodes attached to the transmission line. The entry **COMPONENT=TRL_E** identifies the element as a transmission line with electrical length.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 71: Transmission Line with Electrical Length, Instance Parameters

Parameter	Description	Units	Default
W	Conductor width	Meter	0.001
E	Electrical length	Degree	45
F	Reference frequency for E	Hz	1e9

Netlist Example

```
A7 Port1 Port2 W=0.001 E=45 F=5000000000
+ COMPONENT=TRL_E SUBSTRATE=FR4
```

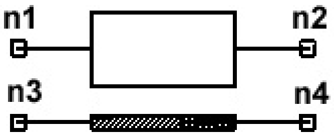
where FR4, the selected layout technology or substrate type, has a definition such as:

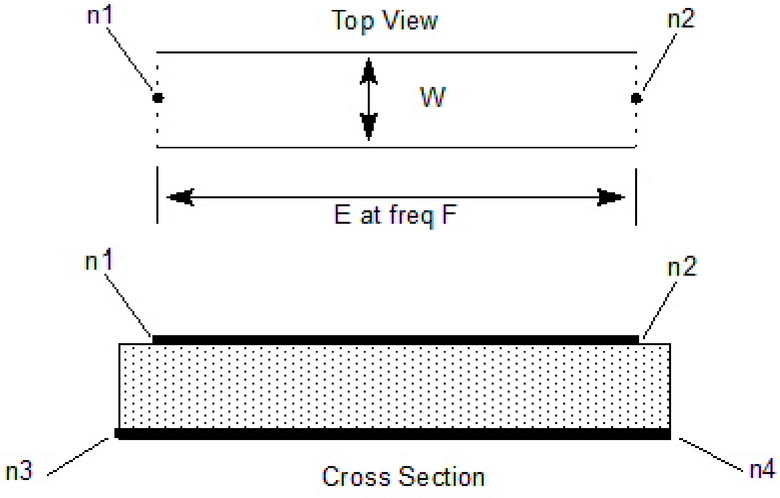
```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**Microstrip**] The following conditions should be satisfied: 0.01 ≤ W/H ≤ 10, E_R < 18, T ≤ W, and T ≤ H/2.

Transmission Line, Electrical Length with Reference





Netlist Format

An instance of a transmission line with physical length and reference nodes has the following netlist syntax:

```
Axxx n1 n2 n3 n4 [W=val] [E=val] [F=val] COMPONENT=TRL_E
SUBSTRATE=substrate_name
```

n1, *n2*, *n3*, and *n4* are the names of the nodes attached to the transmission line. The entry **COMPONENT=TRL_E** identifies the element as a transmission line with electrical length.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 72: Transmission Line with Electrical Length, Instance Parameters

Parameter	Description	Units	Default
W	Conductor width	Meter	0.001
E	Electrical length	Degree	45
F	Reference frequency for E	Hz	1e9

Netlist Example

```
A7 Port1 Port2 Port3 Port4 W=0.001 E=45 F=5000000000
+ COMPONENT=TRL_E SUBSTRATE=FR4
```

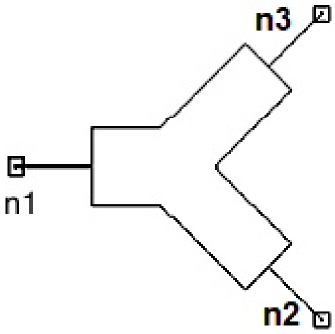
where FR4, the selected layout technology or substrate type, has a definition such as:

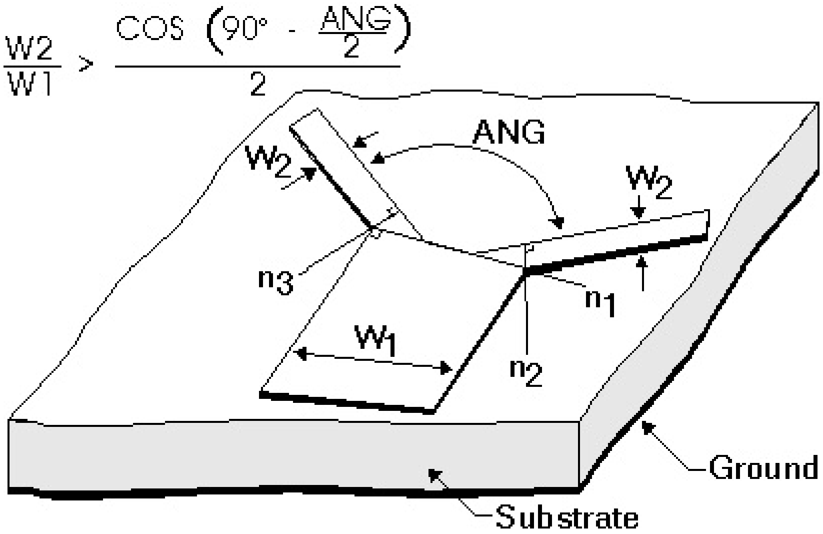
```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

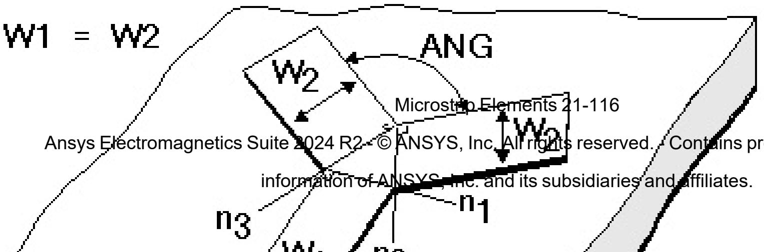
Notes

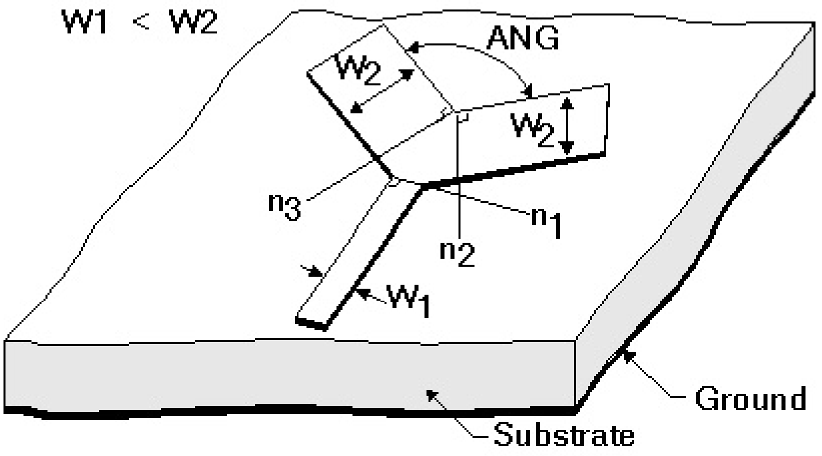
1. [**Microstrip**] The following conditions should be satisfied: 0.01 ≤ W/H ≤ 10, $E_R < 18$, T ≤ W, and T ≤ H/2.

Y Junction









Netlist Format

An instance of a Y-junction has the following netlist syntax:

AYJUN*xxx n1 n2 n3* **W1=***val* **W2=***val* **ANG=***val* **COMPONENT=yjunction SUBSTRATE=***substrate_name*

n1, *n2*, and *n3* are the names of the nodes attached to the junction. The entry **COMPONENT=yjunction** identifies the element.

The entry **SUBSTRATE=***substrate_name* identifies the microstrip substrate model name selected for the design (see"Selecting a Microstrip Substrate" on page 21-119). See the "Microstrip Substrate Model" on page 21-122 for information on this substrate type.

Table 73: Y Junction Instance Parameters

Parameter	Description	Units	Default
W1	Width of conductor at node 1	Meter	0.001
W2	Width of conductor at nodes 2 and 3	Meter	0.001
ANG	Angle of the Y junction	Degree	45

Netlist Example

```
AYJUN10 sig1 sig2 sig3 W1=1mm W2=0.75mm ANG=57
+ COMPONENT=yjunction SUBSTRATE=FR4
```

where FR4, the selected layout technology or substrate type, has a definition such as:

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**Microstrip**] The frequency should be below the cutoff frequency of the first higher-order mode of the microstrip:

$$f_{cutoff} = \frac{C_0}{2 \cdot W_{eff}\sqrt{Er_{eff}}}$$

Where C_0 is the speed of light in free space, W_{eff} is the effective width of the microstrip, and Er_{eff} is the effective dielectric constant.

2. For the angle ANG,

(a) when $W1_{eff} < 2W2_{eff}$,

$$\cos(ANG/2) \le \frac{W2_{eff}}{2 \cdot W1_{eff}}$$

(b) when $W1_{eff} > 2W2_{eff}$,

$$\cos(ANG/2) \le \frac{W2_{eff}}{2 \cdot W1_{eff}}$$

where $W1_{eff}$ and $W2_{eff}$ are the effective widths of microstrip lines W1 and W2.

3. The model parameters are checked for possible violations of these limits. You may perform a similar check using the following approximate formula for calculating effective width W_{eff} on the microstrip line width W and substrate parameters:

$$W_{eff} = W + \frac{T}{\pi} \cdot \left[\ln\left(\frac{2H}{T}\right) + 1 \right]$$

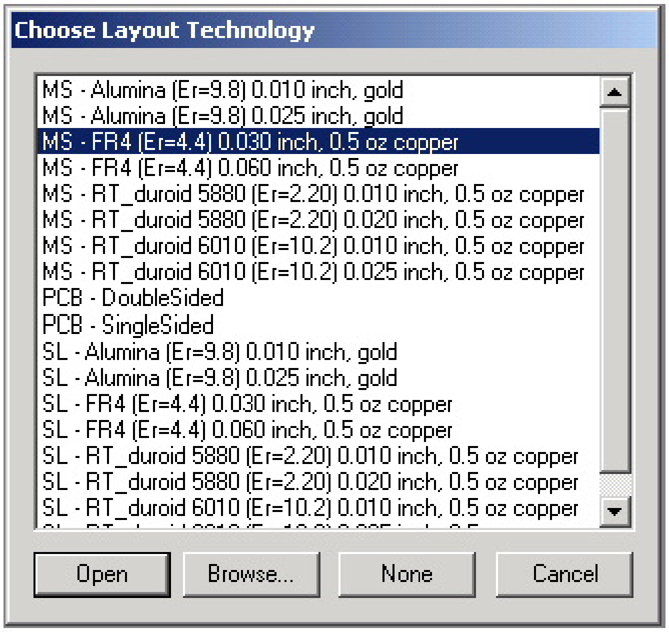
Where T is the metallization thickness and H is the substrate height, both as defined in the .SUB statement.

References

[1] Reza Mahran, “Calculation of Microstrip Bends and Y-junctions with Arbitrary Angles”, IEEE Transactions on Microwave Theory and Techniques, vol. MTT-26, No. 6, JUNE 1978, pp 400-405.

Selecting a Microstrip Substrate

For Nexxim designs that are created with the **Schematic Editor**, you can select a predefined microstrip substrate to apply to all distributed elements instantiated in a design. The selection of a technology is made on the **Choose Layout Technology** window that appears when you select **Insert Nexxim Circuit Design** on the Project menu:



MS - Alumina (Er=9.8) 0.010 inch, gold
MS - Alumina (Er=9.8) 0.025 inch, gold
MS - FR4 (Er=4.4) 0.030 inch, 0.5 oz copper
MS - FR4 (Er=4.4) 0.060 inch, 0.5 oz copper
MS - RT_duroid 5880 (Er=2.20) 0.010 inch, 0.5 oz copper
MS - RT_duroid 5880 (Er=2.20) 0.020 inch, 0.5 oz copper
MS - RT_duroid 6010 (Er=10.2) 0.010 inch, 0.5 oz copper
MS - RT_duroid 6010 (Er=10.2) 0.025 inch, 0.5 oz copper
PCB - DoubleSided
PCB - SingleSided
SL - Alumina (Er=9.8) 0.010 inch, gold
SL - Alumina (Er=9.8) 0.025 inch, gold
SL - FR4 (Er=4.4) 0.030 inch, 0.5 oz copper
SL - FR4 (Er=4.4) 0.060 inch, 0.5 oz copper
SL - RT_duroid 5880 (Er=2.20) 0.010 inch, 0.5 oz copper
SL - RT_duroid 5880 (Er=2.20) 0.020 inch, 0.5 oz copper
SL - RT_duroid 6010 (Er=10.2) 0.010 inch, 0.5 oz copper

Select the appropriate substrate technology and click **Open**. To choose a technology that is not on the list, click **Browse**. Using the explorer window, browse to and select the Technology (**.asty**) file that contains the technology you want to use. Then click **Open**. When a substrate has been selected, Ansys Electronics Desktop creates a **.SUB** entry for this substrate type in the internal netlist representing the schematic design.

Then, when a distributed element is instantiated, it includes a **SUBSTRATE=***substrate_name* entry in its netlist syntax. **Electronics Desktop** automatically inserts the *substrate_name* that was selected from the **Choose Layout Technology** window (**FR4** in the example pictured above) into the internal netlist entry for the instantiated element.

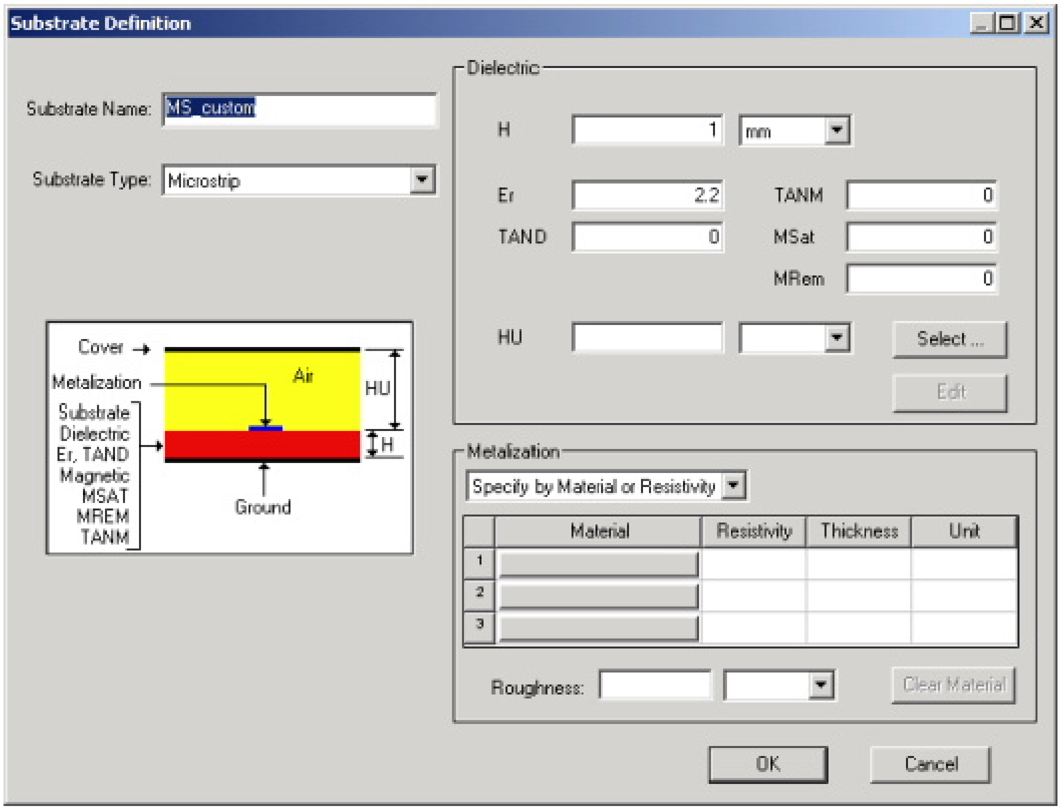
If you wish to use a custom substrate type (or no substrate type) instead of one of the predefined types, click **None**. The design opens, but no substrate type is applied to instances of distributed elements unless you either create a custom substrate type or select a predefined type on a component-by-component basis.

> **Note:** All distributed elements in a given design must use the same substrate type.

Creating a Custom Microstrip Substrate

To create a new, custom substrate definition, open the Nexxim design icon (e.g., “Nexxim1”, then right-click the **Data** field and select **Add Substrate Definition** to open the **Substrate**

Definition window. Specify the name of your new substrate (the following example uses the name “MS_custom”).



Substrate Name: MS_custom

Substrate Type: Microstrip

H: 1 mm

Er: 2.2

TAND: 0

TANM: 0

MSat: 0

MRem: 0

Metalization: Specify by Material or Resistivity

	Material	Resistivity	Thickness	Unit
1				
2				
3				

(see the "Microstrip Substrate Model" on the next page help topic for guidelines on defining Microstrip substrates.

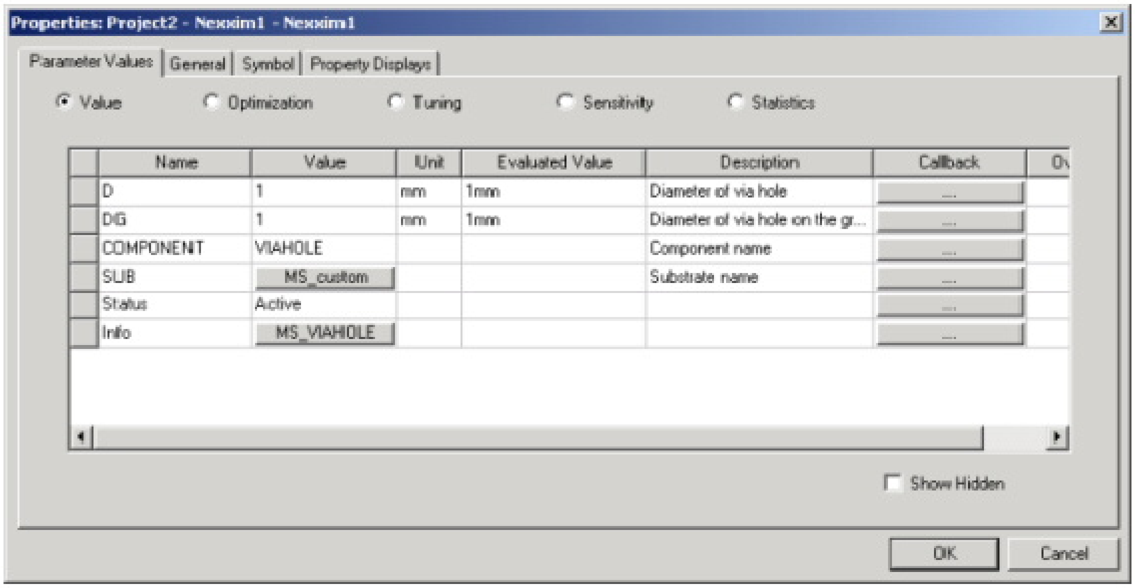
When the substrate definition is complete, click **OK**.

If you selected **None** for the global substrate type in the **Choose Layout Technology** group box, the custom substrate becomes the global substrate type.

> **Note:** All distributed elements in a given design must use the same substrate type.

Selecting a Substrate at the Component Level

To specify a custom substrate type, or to change to a different predefined substrate type, you must make the assignment individually for each component. Double-click the distributed element to open the **Properties** window:



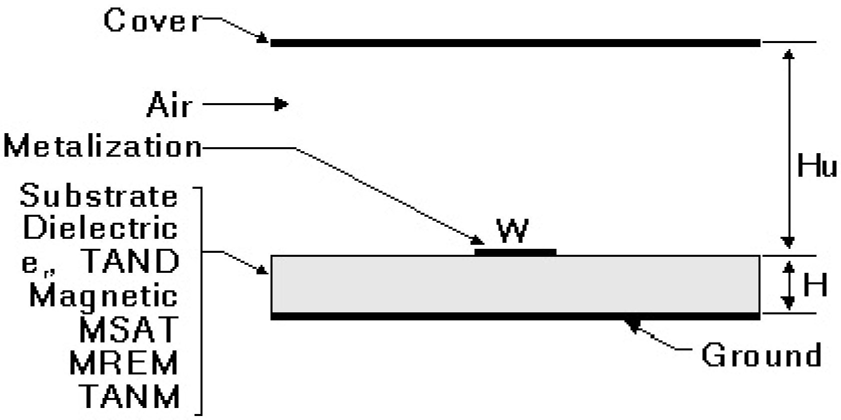
Name	Value	Unit	Evaluated Value	Description	Callback	Ov
D	1	mm	1mm	Diameter of via hole	...	
DG	1	mm	1mm	Diameter of via hole on the gr...	...	
COMPONENT	VIAHOLE			Component name	...	
SUB	MS_custom			Substrate name	...	
Status	Active				...	
Info	MS_VIAHOLE				...	

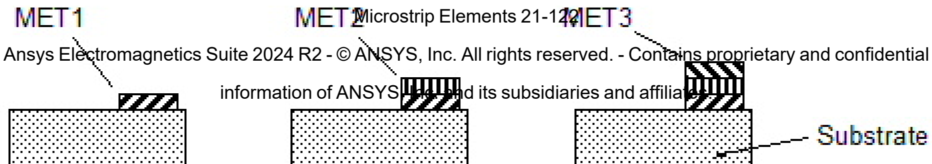
The **SUB** property identifies the substrate that is currently applied to the element. In the example, above, a custom substrate type named “MS_custom” appears as the value of the **SUB** property.

To change to a different substrate type, enter the appropriate substrate name as the value of the **SUB** property, and click **OK**.

> **Note:** All distributed elements in a given design must use the same substrate type.

Microstrip Substrate Model





Defining a Microstrip Model

To add a microstrip substrate model to a new Nexxim design, select one of the MS substrate types on the **Choose Layout Technology** window that appears when you select **Insert Nexxim Circuit Design** on the **Project** drop-down menu. A substrate that is added from this window has a default substrate name and metalization parameters.

To add a new substrate to an existing design, expand the **Project** icon, the **Design** icon. Right-click the **Data** icon and select **Add Substrate Definition** to open the **Substrate Definition** window. Then add the substrate name and parameters as appropriate, and click **OK**. A substrate added in this manner requires you to specify the metalization parameters explicitly.

To edit the definition of a substrate, expand the **Project** icon, the **Design** icon, the **Data** icon. Click on the icon for the substrate you wish to edit to open the **Substrate Definition** window. Add or modify the substrate parameters as appropriate, then click **OK**.

Microstrip Substrate Model Netlist Form

The Microstrip substrate model has the following netlist format:

```
.SUBsubstrate_name MS ( [H=val] [ER=val] [HU=val] [TAND=val]

[MSAT=val] [MREM=val] [TANM=val]

[MET1=val] [T1=val] [MET2=val] [T2=val] [MET3=val] [T3=val]

[RGH=val])
```

The *substrate_name* is the name for the substrate type used in distributed elements that refer to this substrate definition. The entry **MS** is required to identify the Microstrip substrate type. The **MS** identifier must immediately follow the *substrate_name*.

Inside the parentheses, the labeled parameters may be entered in any order.

Table 74: Microstrip Substrate Parameters

Parameter	Description	Unit	Default
ER	Dielectric constant of substrate, 1 ≤ ER ≤ 128	None	4.5
H	Substrate thickness, H > 0	Meter	1e-3
HU	Distance to top cover. Default of 0 means “No top cover.” To choose a covered model, set HU > 0. HU < 40 x H enables covered microstrip modeling. In several models, radiation effects are modeled when the cover height is not specified and may result in a slower simulation. HU > 40 x H disables radiation modeling without	Meter	0.0 (No cover)

	introducing any undesirable effects.		
MET1, **MET2**, **MET3**	Resistivity of metal layer 1, 2, and 3	µOhm-cm	0.0
MREM	4π x the remanent magnetization in gauss, MREM ≤ MSAT	None	0.0
MSAT	4π x the material saturation magnetization in gauss, MSAT ≥ 0 The substrate is considered to be a dielectric substrate unless a non-zero positive MSAT is specified	None	0.0
RGH	RMS surface roughness	Meter	0.0
T1, **T2**, **T3**	Thickness of metal layer 1, 2, and 3	Meter	0.0
TAND	Dielectric loss tangent, [0,0.1]	None	0.0
TANM	Magnetic loss tangent, 0 ≤ TANM ≤ 0.1	None	0.0

Microstrip Substrate Model Netlist Example

```
.SUB FR4 MS( H=7.6200e-004 Er=4.4 TAND=0.02 TANM=0
+ MSat=0 MRem=0 HU=0.00508 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Surface roughness in the substrate definition is not supported in some MCPL implementations.

22 - MOSFET Levels 1 through 27

This topic describes the following MOSFETs:

"MOSFET Instance, Schichman-Hodges Model (Level 1)" below

"Schichman-Hodges MOSFET Model, Level 1 " on page 22-3

"MOSFET Instance, SPICE 2G Grove-Frohman Model (Level 2)" on page 22-10

"IDS Grove-Frohman MOSFET Model, Level 2 " on page 22-12

"MOSFET Instance, SPICE 2G Empirical Model (Level 3)" on page 22-18

"SPICE 2G Empirical MOSFET Model, Level 3" on page 22-20

"MOSFET Instance, Advanced SPICE Level 2 Model (Level 8)" on page 22-27

"Advanced IDS MOSFET Model, Level 8" on page 22-28

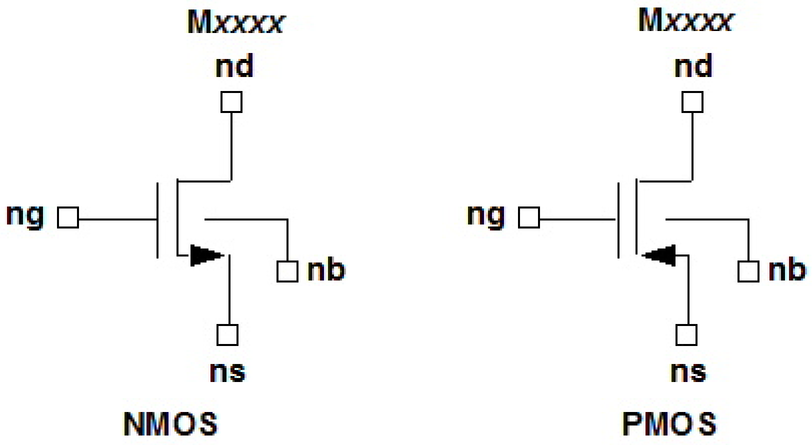
For additional MOSFETs, see

"MOSFET Levels 49 through 54" on page 23-1

"MOSFET Levels 55 through 66" on page 24-1

"MOSFET Levels 69 through 99" on page 25-1

MOSFET Instance, Schichman-Hodges Model (Level 1)



Schichman-Hodges MOSFET Instance Netlist Syntax

The syntax for a Level 1 Schichman-Hodges MOSFET instance is:

```
Mxxxx nd ng ns [nb] modelname [[L=]length] [[W=]width]
[AD=val] [AS=val] [PD=val] [PS=val]
[NRD=val] [NRS=val]
[SCALE=val] [M=val] [TEMP=val] [DTEMP=val]
```

nd is the drain node, *ng* is the gate node, *ns* is the source node, and *nb* is the bulk or substrate node of the MOSFET. *modelname* is the name of a Level 1 MOSFET model defined in a .MODEL statement elsewhere in the netlist.

When the option **WL** is in effect (on the .OPTION statement), the syntax becomes:

```
Mxxxx nd ng ns [nb] modelname [width] [length]
[AD=val] [AS=val] [PD=val] [PS=val]
[NRD=val] [NRS=val]
[SCALE=val] [M=val] [TEMP=val] [DTEMP=val]
```

Table 66: Level 1 MOSFET Instance Parameters

Instance Parameter	Description	Unit	Default
AD	Drain diffusion area	Meter^2	ACM=0 or 1: 0.0 ACM=2 or 3: -1.0
AS	Source diffusion area	Meter^2	ACM=0 or 1: 0.0 ACM=2 or 3: -1.0
ASPEC	ASPEC option	None	0.0
DTEMP	Difference between MOSFET and circuit temperatures	°C	0.0
L	Channel length	Meter	1.0e-4
M	Multiplier: number of parallel transistors to be simulated	None	1.0
NRD	Number of squares for drain resistance	Square	0.0
NRS	Number of squares for source resistance	Square	0.0
PD	Drain perimeter	Meter	0.0

PS	Source perimeter	Meter	0.0
SCALE	Element scale factor (also an option for .OPTIONs statement)	None	1.0
TEMP	Nominal circuit temperature	°C	Calculated
W	Channel width	Meter	1.0e-4

Schichman-Hodges MOSFET Instance Netlist Example

```
M1 10 11 12 mosfet1
```

```
M12 G3 VDD 0 0 mosfet2 M=2 DTEMP=30
```

```
Mtest 34 56 78 90 fetex
```

Schichman-Hodges MOSFET Model, Level 1

The netlist syntax for a Level 1 MOSFET model is:

`.MODEL modelname NMOS [LEVEL=1] [(][parameter=val] ... [)]`

or

`.MODEL modelname PMOS [LEVEL=1] [(][parameter=val] ... [)]`

modelname is the name used by MOSFET instances to refer to this .MODEL statement. The Level 1 Schichman-Hodges MOSFET model is the default if **LEVEL** is omitted on the .MODEL statement.

Table 67: Level 1 MOSFET Basic Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	1 selects the Schichman-Hodges MOSFET model	None	1 (default if LEVEL parameter is omitted)
COX (**CO**)	Oxide capacitance per unit of gate area	Farad/Meter 2	Calculated
GEO	Layout geometry 0 = Drain and source not shared 1 = Drain shared 2 = Source shared 3 = Drain and source shared	None	0
KP (**BETA**,	Intrinsic transconductance parameter.	Amp/Volt^2	Calculated

BET)			
LAMBDA (**LAM**, **LA**)	Channel length modulation	Volt^{-1}	0.0
NI	Intrinsic concentration	cm^{-3}	Calculated
SCALM	Model parameter scale factor (also an option for .OPTIONs statement)	None	1.0
TNOM	Nominal device temperature	°C	25
TOX	Gate oxide thickness	Meter	1.0e-7
UO	Carrier mobility	cm^2/Volt-Second	Calculated
UPDATE	Update selector for parasitics model	None	0.0

Table 68: Level 1 MOSFET Diode DC Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
ACM	Area calculation method selector 0 = SPICE model, parameters depend on element areas 1 = ASPEC model, parameters depend on element width 2 = HSPICE model (combines ACM 0 and 1, extensions for lightly-doped drain technology 3 = HSPICE method, ACM 2 plus shared sources and drains and gate-edge source/drain peripheral capacitances	None	0
ASPEC	IS option switch	None	0.0
JS	Bulk junction saturation current	ACM = 1: Amp/Meter Else: Amp/Meter^2	0.0
JSW	Sidewall bulk junction saturation current	Amp/Meter	0.0
IS	Bulk junction saturation current	Amp	1.0e-14
N	Emission coefficient	None	1.0
NDS	Reverse bias slope coefficient	None	1.0

VNDS	Reverse diode current transition point	Volt	-1.0

Table 69: Level 1 MOSFET Diode Capacitance Model Parameters

Model Parameter	Description	Unit	Default
CBD	Zero-bias bulk-drain junction capacitance	Farad	0.0
CBS	Zero-bias bulk-source junction capacitance	Farad	0.0
CJ (**CDB**, **CSB**, **CJA**)	Zero-bias junction capacitance	ACM = 1: Farad/Meter Else: Farad/Meter ^{2}	Calculated
CJSW (**CJP**)	Zero-bias gate-edge sidewall bulk junction capacitance	Farad/Meter	0.0
CJGATE	Zero-bias gate-edge sidewall bulk junction capacitance (ACM = 3)	Farad/Meter	CJSW
FC	Forward-bias capacitance depletion coefficient	None	0.0
MJ (**EXA**, **EXJ**, **EXS**, **EXD**)	Bulk junction grading coefficient	None	0.5
MJSW (**EXP**)	Bulk sidewall junction grading coefficient	None	0.33
PB (**PHA**, **PHS**, **PHD**)	Bulk junction contact potential	Volt	0.8
PHP	Bulk sidewall junction contact potential	Volt	PB
TT	Transit time	Second	0.0

Table 70: Level 1 MOSFET Drain and Source Resistance Model Parameters

Model Parameter	Description	Unit	Default
LRD	Drain resistance length sensitivity	Ohm/Meter	0.0
LRS	Source resistance length sensitivity	Ohm/Meter	0.0
PRD	Drain resistance area sensitivity	Ohm/Meter^2	0.0
PRS	Source resistance area sensitivity	Ohm/Meter^2	0.0

RD	Drain ohmic resistance	Ohm	0.0
RDC	Additional drain resistance due to contact resistance	Ohm	0.0
RS	Source ohmic resistance	Ohm	0.0
RSC	Additional source resistance due to contact resistance	Ohm	0.0
RSH (**RL**)	Drain and source diffusion sheet resistance	Ohm/Square	0.0
WRD	Drain resistance width sensitivity	Ohm/Meter	0.0
WRS	Source resistance width sensitivity	Ohm/Meter	0.0

Table 71: Level 1 MOSFET Geometry Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
DEL	Channel length reduction	Meter	0.0
HDIF	Length of heavily-doped diffusion region, from contact to lightly-doped region (ACM = 2 or 3)	Meter	0.0
LD (**DLAT**, **LATD**)	Lateral diffusion into channel from source and drain	Meter	If neither LD nor XJ are specified: LD = 0.0 If XJ specified but LD not specified: LD = 0.75 × XJ
LDIF	Length of lightly-doped diffusion adjacent to gate (ACM = 1 or 2)	Meter	0.0
LDAC	Lateral diffusion for AC analysis	Meter	None
LMLT	Length shrink factor	None	1.0
LREF	Channel length reference	Meter	0.0
WD	Lateral diffusion into channel from bulk along width	Meter	0.0
WDAC	Lateral diffusion for AC analysis	Meter	None
WMLT	Diffusion layer and width reduction factor	None	1.0
WREF	Channel width reference	Meter	0.0
XJ	Metallurgical junction depth	Meter	0.0
XL (**DL**,	Correction for mask and etch effects	Meter	0.0

LDEL)			
XW (**DW**, **WDEL**)	Correction for mask and etch effects	Meter	0.0

Table 72: Level 1 MOSFET Threshold Voltage Model Parameters

Model Parameter	Description	Unit	Default
DELVTO	Threshold voltage shift at zero bias	Volt	0.0
GAMMA	Body effect factor	Volt$^{1/2}$	Calculated
NFS (**DFS**, **NF**, **DNF**)	Fast surface state density	cm^{-2} × Volt^{-1}	0.0
NGATE	Polysilicon gate doping	1/cm^3	No default. If NGATE ≤ 0.0, it is set to 1.0e+18
NSS	Surface state density	cm^{-2}	0.0
NSUB (**DNB**, **NB**)	Substrate doping	1/cm^3	1.0e+15
PHI	Surface inversion potential	Volt	Calculated
TPG (**TPS**)	Type of gate material 0 = Aluminum gate 1 = Polysilicon gate same as source-drain diffusion -1 = Polysilicon gate opposite to source-drain diffusion	None	1
VTO (**VT0**)	Zero-bias threshold voltage	Volt	Calculated

Table 73: Level 1 MOSFET Gate Overlap Capacitance Model Parameters

Model Parameter	Description	Unit	Default
CGBO (**CGB**)	Gate-bulk overlap capacitance per meter channel length. If CGBO not specified but WD and TOX are specified, CGBO is calculated from TOX and WD.	Farad/Meter	0.0

CGDO (**CGD**, **C2**)	Gate-drain overlap capacitance per meter channel length	Farad/Meter	Calculated
CGSO (**CGS**, **C1**)	Gate-source overlap capacitance per meter channel length	Farad/Meter	Calculated
METO	Fringing field factor for gate-to-source and gate-to-drain overlap capacitance calculation	Meter	0.0

Table 74: Level 1 MOSFET Noise Model Parameters

Model Parameter	Description	Unit	Default
AF	Flicker noise exponent	None	1.0
GDSNOI	Channel thermal noise coefficient (for NLEV = 3)	None	1.0
KF	Flicker noise coefficient	None	0.0
NLEV	Noise equation selector	None	2

Table 75: Level 1 MOSFET Temperature Effect Model Parameters

Model Parameter	Description	Unit	Default
BEX	Low field mobility (UO) temperature exponent	None	-1.5
CTA	Junction capacitance (CJ) temperature coefficient	°K^{-1}	0.0
CTP	Junction sidewall capacitance (CJSW) temperature coefficient	°K^{-1}	0.0
EG	Energy gap for pn junction diodes	electron-Volt	Calculated
F1EX	Bulk junction bottom grading coefficient (Not used in current implementation)	None	0.0
GAP1	1st bandgap correction factor	electron-Volt/°K	7.02e-4
GAP2	2nd bandgap correction factor	°K	1108
LAMEX	LAMBDA temperature coefficient	°K^{-1}	0.0
PTA	Junction potential (PB) temperature coefficient (TLEVC = 1 or 2)	Volt/°K	0.0
PTC	Fermi potential (PHI) temperature coefficient (TLEVC = 1 or 2)	Volt/°K	0.0

PTP	Junction potential (PHP) temperature coefficient (TLEVC = 1 or 2)	Volt/°K	0.0
TCV	Threshold voltage (VTH) temperature coefficient	Volt/°K	0.0
TLEV	Temperature equation selector 0 = SPICE-style 1 = ASPEC style	None	0.0
TLEVC	Temperature equation selector for junction capacitances and potentials 0 = SPICE-style 1 = ASPEC style	None	0.0
TRD	Temperature coefficient for drain resistor (RD)	°K^{-1}	0.0
TRS	Temperature coefficient for source resistor (RS)	°K^{-1}	0.0
XTI	Saturation current temperature exponent	None	0.0

Table 76: Meyer Capacitance Model Parameters for CAPOP = 0, 1, or 2

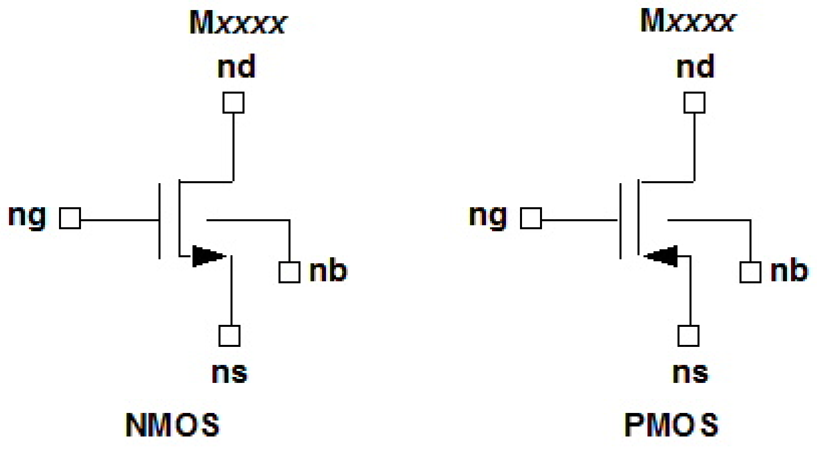
Model Parameter	Description	Unit	Default
CGBEX	cgb exponent (CAPOP = 1 only)	None	0.5
CF1	Modified Meyer control for transition of cgs from depletion to weak inversion for CGSO (CAPOP = 2 only)	Volt	0.0
CF2	Modified Meyer control for transition of cgs from weak to strong inversion region (CAPOP = 2 only)	Volt	0.1
CF3	Modified Meyer control for transition of cgs and cgd from saturation to linear region as a function of vds (CAPOP = 2 only)	None	1.0
CF4	Modified Meyer control for contour of cgb and cgs smoothing factors	None	50.0
CF5	Modified Meyer control for capacitance multiplier for cgs in saturation region	None	0.667
CF6	Modified Meyer control for contour of cgd smoothing factor	None	500.0
XQC	Selector for gate capacitance drain versus source charge sharing coefficient 0 = 0/100 0.4 = 40/60 0.5 = 50/50	None	0.5

	≥1 = 0/100 Any other value < 1 = 40/60		

Schichman-Hodges MOSFET Model Netlist Example

```
.MODEL N NMOS

+ LEVEL=1

+ KP=2.33082E-05

+ LAMBDA=0.013333 VT0=0.69486 GAMMA=0.60309 PHI=1

+ TOX=1.9800000E-08  XJ=0.2U

+ LD=0.1U           NSUB=4.9999999E+16

+ NSS=0.0000000E+00

+ CJ=4.091E-4        MJ=0.307           PB=1.0

+ CJSW=3.078E-10     MJSW=1.0E-2

+ CGSO=3.93E-10      CGDO=3.93E-10
```

MOSFET Instance, SPICE 2G Grove-Frohman Model (Level 2)



SPICE 2G Grove-Frohman MOSFET Instance Netlist Syntax

The syntax for a Level 2 Grove-Frohman MOSFET instance is:

```
Mxxxx nd ng ns [nb] modelname [[L=]length] [[W=]width]
[AD=val] [AS=val] [PD=val] [PS=val]
[NRD=val] [NRS=val] [SCALE=val] [VDSAT=val]
[ASPEC=val] [DTEMP=val]
[M=val] [TEMP=val]
```

nd is the drain node, *ng* is the gate node, *ns* is the source node, and *nb* is the bulk or substrate node of the MOSFET. *modelname* is the name of a Level 2 MOSFET model defined in a .MODEL statement elsewhere in the netlist.

When the option **WL** is in effect (on the .OPTION statement), the syntax becomes:

```
Mxxxx nd ng ns [nb] modelname [width] [length]
[AD=val] [AS=val] [PD=val] [PS=val]
[NRD=val] [NRS=val] [SCALE=val] [VDSAT=val]
[ASPEC=val] [DTEMP=val]
[M=val] [TEMP=val]
```

Table 77: Level 2 MOSFET Instance Parameters

Instance Parameter	Description	Unit	Default
AD	Drain diffusion area	Meter^2	0.0
AS	Source diffusion area	Meter^2	0.0
ASPEC	ASPEC option	None	0.0
DTEMP	Difference between MOSFET and circuit temperatures	°C	0.0
L	MOSFET channel length	Meter	1.0e-4
M	Multiplier: simulates parallel transistors	None	1.0
NRD	Number of squares of drain diffusion for resistance calculations	Square	0.0
NRS	Number of squares of source diffusion for resistance calculations	Square	0.0
PD	Drain diffusion periphery	Meter	0.0
PS	Source diffusion periphery	Meter	0.0
SCALE	Scale factor for instance parameters	None	1.0
TEMP	Device temperature	°C	Calculated
VDSAT	Saturation voltage	Volt	0.0
W	MOSFET channel width	Meter	1.0e-4

SPICE 2G Grove-Frohman MOSFET Instance Netlist Example

```
M23 22 33 44 mosmodel2
```

IDS Grove-Frohman MOSFET Model, Level 2

The netlist syntax for a Level 2 MOSFET model is:

`.MODELmodelname NMOS LEVEL=2 [(][parameter=val] ... [)]`

or

`.MODELmodelname PMOS LEVEL=2 [(][parameter=val] ... [)]`

modelname is the name used by MOSFET instances to refer to this .MODEL statement. The **LEVEL=2** entry selects the IDS Grove-Frohman MOSFET model.

Table 78: Level 2 MOSFET Basic Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	2 is required to select the IDS Grove-Frohman model	None	1 (default if LEVEL parameter is omitted)
ACM	Area calculation method selector 0 = SPICE model, parameters depend on element areas 1 = ASPEC model, parameters depend on element width 2 = HSPICE model (combines ACM 0 and 1, extensions for lightly-doped drain technology 3 = HSPICE method, ACM 2 plus shared sources and drains and gate-edge source/drain peripheral capacitances	None	0
ALPHA	Impact ionization current coefficient	None	0.0
CAPOP	Capacitance model selector	None	2
CBD	Zero-bias bulk-drain junction capacitance	Farad	0.0
CBS	Zero-bias bulk-source junction capacitance	Farad	0.0
CJ (**CDB**,	Zero-bias bulk junction bottom capacitance	Farad/Meter^2	Calculated

CSB, **CJA**)			
CJGATE	Zero-bias gate-edge sidewall bulk junction capacitance (ACM = 3)	Farad/Meter	CJSW
CJSW (**CJP**)	Zero-bias bulk junction sidewall capacitance	Farad/Meter	0.0
COX (**CO**)	Oxide capacitance of gate per unit area	Farad/Meter^2	Calculated
DEL	Channel length reduction	Meter	0.0
DELVTO	Threshold voltage shift at zero bias	Volt	0.0
ECRIT (**ESAT**)	Critical electric field for carrier velocity saturation. Zero represents an infinite value. Grove: electrons 6e+4, holes 2.4e+4	Volt-cm^{-1}	0.0
FC	Forward-bias depletion coefficient for capacitance	None	0.0
F1EX	Bulk junction bottom grading coefficient (Not used)	None	0.0
GEO	Layout geometry 0 = Drain and source not shared 1 = Drain shared 2 = Source shared 3 = Drain and source shared	None	0
HDIF	Length of heavily-doped diffusion region, from contact to lightly-doped region (ACM = 2 or 3)	Meter	0.0
IIRAT	Portion of impact ionization current that goes to source	None	0.0
IS	Bulk junction saturation current	Amp	1.0e-14
JS	Bulk junction saturation current density	Amp/Meter^2	0.0
JSW	Sidewall bulk junction saturation current	Amp/Meter	0.0
KP (**BET**, **BETA**)	Intrinsic transconductance parameter	Amp/Volt^2	Calculated
LALPHA	Alpha length sensitivity	µMeter/Volt	0.0
LAMBDA (**LAM**, **LA**)	Channel length modulation	Volt^{-1}	0.0
LD (**DLAT**, **LATD**)	Lateral diffusion into channel from source and drain diffusions	Meter	XJ not present: 0.0

			XJ present: 0.75×XJ
LDIF	Length of lightly-doped diffusion adjacent to gate (ACM = 1 or 2)	Meter	0.0
LDAC	Lateral diffusion	Meter	None
LMLT	Length shrink factor	None	1.0
LREF	Channel length reference	Meter	0.0
LVCR	VCR length sensitivity	μMeter/Volt	0.0
MJ (**EXA**, **EXJ**, **EXS**, **EXD**)	Bulk junction capacitance grading coefficient	None	0.5
MJSW (**EXP**)	Bulk junction sidewall capacitance grading coefficient	None	0.33
N	Emission coefficient	None	1.0
NDS	Reverse bias slope coefficient	None	1.0
NEFF	Total channel charge coefficient	None	1.0
NGATE	Polysilicon gate doping	$1/cm^3$	Calculated
NSS	Surface state density	cm^{-2}	0.0
PB (**PHA**, **PHS**, **PHD**)	Bulk junction potential	Volt	0.8
PHP	Bulk sidewall junction contact potential	Volt	PB
TOX	Gate oxide thickness	Meter	1e-7
SCALM	Model parameter scale factor (also an option for .OPTIONs statement)	None	1.0
TNOM	Nominal device temperature	°C	25
TPG (**TPS**)	Type of gate material 0 = Aluminum gate 1 = Polysilicon gate same as source-drain diffusion -1 = Polysilicon gate opposite to source-drain diffusion	None	1
TT	Transit time	Second	0.0
VCR	Critical voltage	Volt	0.0
UPDATE	Update selector for parasitics model	None	0.0
VMAX	Maximum carrier drift velocity	Meter/Second	0.0

(**VMX**)			
VNDS	Reverse diode current transition point	Volt	-1.0
WALPHA	Alpha width sensitivity	µMeter/Volt	0.0
WD	Lateral diffusion into channel from bulk along width	Meter	0.0
WMLT	Width shrink factor	None	1.0
WREF	Channel width reference	Meter	0.0
WVCR	VCR width sensitivity	µMeter/Volt	0.0
XJ	Metallurgical junction depth	Meter	0.0
XL (**DL**, **LDEL**)	Length bias factor for mask and etch effects	Meter	0.0
XLREF	Channel length reference bias factor for mask and etch effects	Meter	0.0
XW (**DW**, **WDEL**)	Width bias factor for mask and etch effects	Meter	0.0
XWREF	Channel width reference bias factor for mask and etch effects	Meter	0.0

Table 79: Level 2 MOSFET Drain and Source Resistance Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
LRD	Drain resistance length sensitivity	Ohm/Meter	0.0
LRS	Source resistance length sensitivity	Ohm/Meter	0.0
PRD	Drain resistance area sensitivity	Ohm/Meter^2	0.0
PRS	Source resistance area sensitivity	Ohm/Meter^2	0.0
RD	Drain ohmic resistance	Ohm	0.0
RDC	Drain contact resistance	Ohm	0.0
RS	Source ohmic resistance	Ohm	0.0
RSC	Additional source resistance due to contact resistance	Ohm	0.0
RSH (**RL**)	Sheet resistance	Ohm/square	0.0
WRD	Drain resistance width sensitivity	Ohm/Meter	0.0
WRS	Source resistance width sensitivity	Ohm/Meter	0.0

Table 80: Level 2 MOSFET Threshold Voltage Model Parameters

Model Parameter	Description	Unit	Default
DELTA	Narrow width factor for adjusting threshold	None	0.0
GAMMA	Body effect factor	Volt$^{1/2}$	Calculated
NFS (**DFS**, **NF, DNF**)	Fast surface state density	1/cm^2-Volt	0.0
NSUB (**DNB**, **NB**)	Bulk surface doping	cm^{-3}	1.0e15
PHI	Surface inversion potential	Volt	Calculated
VTO (**VT0**)	Threshold voltage at zero bias	Volt	Calculated

Table 81: Level 2 MOSFET Noise Model Parameters

Model Parameter	Description	Unit	Default
AF	Flicker noise exponent	None	1.0
GDSNOI	Channel thermal noise coefficient	None	1.0
KF	Flicker noise coefficient	None	0.0
NLEV	Noise equation selector	None	2.0

Table 82: Level 2 MOSFET Gate Overlap Capacitance Model Parameters

Model Parameter	Description	Unit	Default
CGBO (**CGB**)	Gate-bulk overlap capacitance per meter channel length	Farad/Meter	0.0
CGDO (**CGD**, **C2**)	Gate-drain overlap capacitance per meter channel width	Farad/Meter	Calculated
CGSO (**CGS**, **C1**)	Gate-source overlap capacitance per meter channel width	Farad/Meter	Calculated
METO	Fringing field factor for gate-to-source and gate-to-drain overlap capacitance calculation	Meter	0.0

Table 83: Level 2 MOSFET Mobility Model Parameters

Model Parameter	Description	Unit	Default

MOB	Mobility equation selector 0 = Level 2 model and equations, using vde instead of vds 3 = Temperature-dependent 6 = UEXP-dependent (Level 8) 7 = NSUB-dependent	None	0
THETA	Mobility modulation for MOB=7	Volt^{-1}	0.0
UCRIT	Critical field for mobility degradation. The limit at which the surface mobility UO begins to decrease.	Volt/cm	1.0e+4
UEXP (**F2**)	Critical field exponent for surface mobility degradation empirical formula	None	0.0
UO (**UB**, **UBO**)	Low-field bulk mobility	$\mathrm{Centimeter}^{2}/\mathrm{Volt}$-Second	If KP is entered, UO is calculated from KP Else, NMOS = 600e-4 PMOS = 250e-4
UTRA	Transverse field coefficient Nonzero values for UTRA can result in negative resistance regions at the onset of saturation.	None	0.0

Table 84: Level 2 MOSFET Temperature Effect Model Parameters

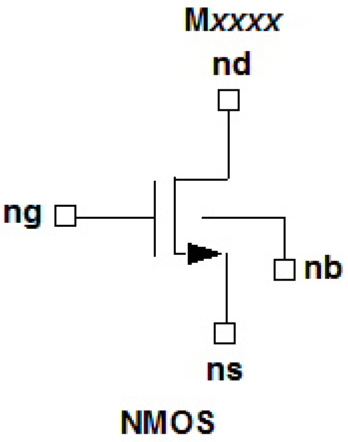
Model Parameter	**Description**	**Unit**	**Default**
BEX	Low field mobility (UO) temperature exponent	None	-1.5
CTA	Junction capacitance (CJ) temperature coefficient	$°K^{-1}$	0.0
CTP	Junction sidewall capacitance (CJSW) temperature coefficient	$°K^{-1}$	0.0
EG	Energy gap for pn junction diodes	electron-Volt	Calculated
GAP1	1st bandgap correction factor	electron-Volt/°K	7.02e-4

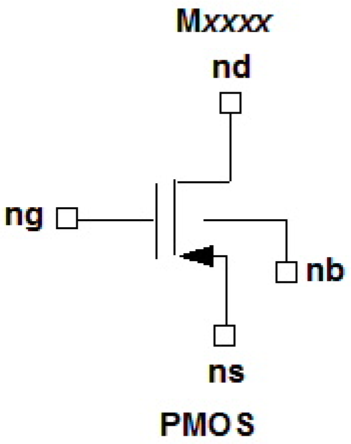
GAP2	2nd bandgap correction factor	°K	1108
LAMEX	LAMBDA temperature coefficient	°K^{-1}	0.0
PTA	Junction potential (PB) temperature coefficient (TLEVC = 1 or 2)	Volt/°K	0.0
PTC	Fermi potential (PHI) temperature coefficient (TLEVC = 1 or 2)	Volt/°K	0.0
PTP	Junction potential (PHP) temperature coefficient (TLEVC = 1 or 2)	Volt/°K	0.0
TCV	Threshold voltage (VTH) temperature coefficient	Volt/°K	0.0
TLEV	Temperature equation selector 0 = SPICE-style 1 = ASPEC style	None	0
TLEVC	Temperature equation selector for junction capacitances and potentials 0 = SPICE-style 1 = ASPEC style	None	0
TRD	Temperature coefficient for drain resistor (RD)	°K^{-1}	0.0
TRS	Temperature coefficient for source resistor (RS)	°K^{-1}	0.0
XTI	Saturation current temperature exponent	None	0.0

SPICE 2G Grove-Frohman MOSFET Model Netlist Example

```
.MODEL nmos2 NMOS LEVEL=2

+ VTO=0.78 TOX=400E-10 NSUB=8.0E15 XJ=-0.15E-6

+ LD=0.20E-6 UO=650 UCRIT=0.62E5 UEXP=0.125 VMAX=5.1E4 NEFF=4.0

+ DELTA=1.4 RSH=37 CGSO=2.95E-10 CGDO=2.95E-10 CJ=195E-6

+ CJSW=5E-10 MJ=0.76 MJSW=0.30 PB=0.80
```

MOSFET Instance, SPICE 2G Empirical Model (Level 3)





SPICE 2G Empirical MOSFET Instance Netlist Syntax

The syntax for a Level 3 IDS Empirical MOSFET instance is:

```
Mxxxx nd ng ns [nb] modelname [[L=]length] [[W=]width]
[AD=val] [AS=val] [PD=val] [PS=val]
[NRD=val] [NRS=val] [DTEMP=val]
[M=val] [TEMP=val] [SCALE=val] [ASPEC=val]
```

nd is the drain node, *ng* is the gate node, *ns* is the source node, and *nb* is the bulk or substrate node of the MOSFET. *modelname* is the name of a Level 3 MOSFET model defined in a .MODEL statement elsewhere in the netlist.

When the option **WL** is in effect (on the .OPTION statement), the syntax becomes:

```
Mxxxx nd ng ns [nb] modelname [width] [length]
[AD=val] [AS=val] [PD=val] [PS=val]
[NRD=val] [NRS=val] [DTEMP=val]
[M=val] [TEMP=val] [SCALE=val] [ASPEC=val]
```

Table 85: Level 3 MOSFET Instance Parameters

Instance Parameter	Description	Unit	Default
AD	Drain diffusion area	Meter^2	0.0
AS	Source diffusion area	Meter^2	0.0
ASPEC	ASPEC option	None	0.0
DTEMP	Difference between MOSFET and circuit	°C	0.0

	temperatures		
L	Channel length	Meter	1.0e-4
M	Multiplier to simulate multiple transistors in parallel	None	1.0
NRD	Number of squares of drain diffusion	Square	0.0
NRS	Number of squares of source diffusion	Square	0.0
PD	Drain diffusion periphery	Meter	0.0
PS	Source diffusion periphery	Meter	0.0
SCALE	Scale factor for instance parameters	None	1.0
TEMP	Device temperature	°C	Calculated
W	Channel width	Meter	1.0e-4

SPICE 2G Empirical MOSFET Instance Netlist Example

```
M1 10 11 12 mosfet1
```

```
M12 G3 VDD 0 0 mosfet2 M=2 L=1.5e-4 W=2e-4
```

SPICE 2G Empirical MOSFET Model, Level 3

The netlist syntax for a Level 3 MOSFET model is:

`.MODELmodelname NMOS LEVEL=3 [(][parameter=val] ... [)]`

or

`.MODELmodelname PMOS LEVEL=3 [(][parameter=val] ... [)]`

modelname is the name used by MOSFET instances to refer to this .MODEL statement. The **LEVEL=3** entry selects the IDS empirical MOSFET model.

Table 86: Level 3 MOSFET Basic Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	3 is required to select the Empirical MOSFET model	None	1 (default if LEVEL parameter is omitted)
ACM	Area calculation method selector 0 = SPICE model, parameters depend on element areas	None	0

	1 = ASPEC model, parameters depend on element width 2 = HSPICE model (combines ACM 0 and 1, extensions for lightly-doped drain technology 3 = HSPICE method, ACM 2 plus shared sources and drains and gate-edge source/drain peripheral capacitances		
ALPHA	Impact ionization current coefficient	None	0.0
CAPOP	Capacitance model selector	None	2
COX (**CO**)	Oxide capacitance per unit of gate area	Farad/Meter^2	Calculated
IIRAT	Portion of impact ionization current that goes to source	None	0.0
LALPHA	Alpha length sensitivity	μMeter/Volt	0.0
LVCR	VCR length sensitivity	μMeter/Volt	0.0
KAPPA	Saturation field factor	Volt^{-1}	0.2
KP (**BETA, BET**)	Intrinsic transconductance parameter	Amp/Volt^2	Calculated
N	Emission coefficient	None	1.0
NDS	Reverse bias slope coefficient	None	1.0
SCALM	Model parameter scale factor (also an option for .OPTIONs statement)	None	1.0
TNOM	Nominal device temperature	°C	25
TPG (**TPS**)	Type of gate material 0 = Aluminum gate 1 = Polysilicon gate same as source-drain diffusion -1 = Polysilicon gate opposite to source-drain diffusion	None	1
TT	Transit time	Second	0.0
UPDATE	Update selector for parasitics model	None	0.0
VCR	Critical voltage	Volt	0.0
VNDS	Reverse diode current transition point	Volt	-1.0
WALPHA	Alpha width sensitivity	μMeter/Volt	0.0
WVCR	VCR width sensitivity	μMeter/Volt	0.0

Table 87: Level 3 MOSFET DC Model Parameters

Model Parameter	Description	Unit	Default
IS	Bulk junction saturation current	Amp	1.0e-14
JS	Bulk junction saturation current density	Amp/Meter^2	0.0
JSW	Sidewall bulk junction saturation current	Amp/Meter	0.5

Table 88: Level 3 MOSFET Capacitance Model Parameters

Model Parameter	Description	Unit	Default
CBD	Zero-bias bulk-drain junction capacitance	Farad	0.0
CBS	Zero-bias bulk-source junction capacitance	Farad	0.0
CJ (**CJB**, **CSB**, **CJA**)	Zero-bias bulk junction bottom capacitance	Farad/Meter^2	Calculated
CJGATE	Zero-bias gate-edge sidewall bulk junction capacitance (ACM = 3)	Farad/Meter	CJSW
CJSW (**CJP**)	Zero-bias bulk junction sidewall capacitance	Farad/Meter	0.0
FC	Forward-bias depletion coefficient for capacitance	None	0.0
MJ (**EXA**, **EXJ**, **EXS**, **EXD**)	Bulk junction capacitance grading coefficient	None	0.5
MJSW	Bulk junction sidewall capacitance grading coefficient	None	0.33
NSUB	Substrate doping	cm^{-3}	1.0e15
PB (**PHA**, **PHS**, **PHD**)	Bulk junction contact potential	Volt	0.8
PHP	Bulk sidewall junction contact potential	Volt	PB

Table 89: Level 3 MOSFET Drain and Source Resistance Model Parameters

Model Parameter	Description	Unit	Default
LRD	Drain resistance length sensitivity	Ohm/Meter	0.0
LRS	Source resistance length sensitivity	Ohm/Meter	0.0
PRD	Drain resistance area sensitivity	Ohm/Meter^2	0.0

PRS	Source resistance area sensitivity	Ohm/Meter^2	0.0
RD	Drain ohmic resistance	Ohm	0.0
RDC	Additional drain resistance due to contact resistance	Ohm	0.0
RS	Source ohmic resistance	Ohm	0.0
RSC	Additional source resistance due to contact resistance	Ohm	0.0
RSH (**RL**)	Drain and source diffusion sheet resistance	Ohm/Square	0.0
WRD	Drain resistance width sensitivity	Ohm/Meter	0.0
WRS	Source resistance width sensitivity	Ohm/Meter	0.0

Table 90: Level 3 MOSFET MOS Geometry Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
DEL	Channel length reduction	Meter	0.0
GEO	Layout geometry 0 = Drain and source not shared 1 = Drain shared 2 = Source shared 3 = Drain and source shared	None	0
HDIF	Length of heavily-doped diffusion region, from contact to lightly-doped region (ACM = 2 or 3)	Meter	0.0
LD (**DLAT**, **LATD**)	Lateral diffusion into channel from source and drain	Meter	If neither LD nor XJ specified: LD = 0.0 If XJ specified but LD not specified: LD = 0.75 × XJ
LDIF	Length of lightly-doped diffusion adjacent to gate (ACM = 1 or 2)	Meter	0.0
LDAC	Lateral diffusion for AC analysis	Meter	None
LMLT	Length shrink factor	None	1.0
LREF	Channel length reference	Meter	0.0

TOX	Oxide thickness	Meter	1.0e-7
WD	Lateral diffusion into channel from bulk along width	Meter	0.0
WDAC	Lateral diffusion for AC analysis	Meter	None
WMLT	Diffusion layer and width reduction factor	None	1.0
WREF	Channel width reference	Meter	0.0
XJ	Metallurgical junction depth	Meter	0.0
XL (**DL**, **LDEL**)	Length bias factor for mask and etch effects	Meter	0.0
XLREF	Channel length reference bias factor for mask and etch effects	Meter	0.0
XW (**DW**, **WDEL**)	Width bias factor for mask and etch effects	Meter	0.0
XWREF	Channel width reference bias factor for mask and etch effects	Meter	0.0

Table 91: Level 3 MOSFET Gate Overlap Capacitance Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
CGBO (**CGB**)	Gate-bulk overlap capacitance per meter channel length	Farad/Meter	0.0
CGDO (**CGD**, **C2**)	Gate-drain overlap capacitance per meter channel width	Farad/Meter	Calculated
CGSO (**CGS**, **C1**)	Gate-source overlap capacitance per meter channel width	Farad/Meter	Calculated
METO	Fringing field factor for gate-to-source and gate-to-drain overlap capacitance calculation	Meter	0.0

Table 92: Level 3 MOSFET Threshold Voltage Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
DELTA	Narrow width effect on threshold voltage	None	0.0
DELVTO	Threshold voltage shift at zero bias	Volt	0.0
ETA	Vds dependence of threshold	None	0.0

	voltage		
GAMMA	Bulk threshold parameter	Volt$^{1/2}$	Calculated
N0	Gate subthreshold factor	None	0.0
ND	Drain subthreshold factor	Volt^{-1}	0.0
NFS	Fast surface state density	cm^{-2}	0.0
NGATE	Polysilicon gate doping	1/cm^{3}	No default. If NGATE ≤ 0.0, it is set to 1.0e+18
NSS	Surface state density	cm^{-2}	0.0
PHI	Surface potential at strong inversion	Volt	Calculated
VTO (**VT0**)	Zero-bias threshold voltage	Volt	Calculated
WIC	Subthreshold model selector	Integer	0

Table 93: Level 3 MOSFET Mobility Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
THETA	Mobility modulation	None	0.0
UO	Surface mobility	cm^{2}/Volt-Second	If KP is entered, UO is calculated from KP Else, NMOS = 600e-4 PMOS = 250e-4
VMAX (**VMX**)	Maximum carrier drift velocity	Meter/Second	0.0 (infinite)

Table 94: Level 3 MOSFET Noise Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
AF	Flicker noise exponent	None	1.0
GDSNOI	Channel thermal noise coefficient (for NLEV = 3)	None	1.0
KF	Flicker noise coefficient	None	0.0
NLEV	Noise equation selector	None	2

Table 95: Level 3 MOSFET Temperature Effect Model Parameters

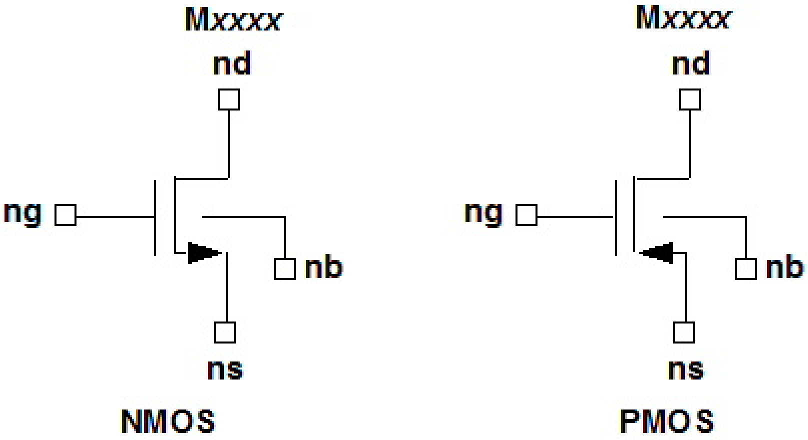
Model Parameter	Description	Unit	Default
BEX	Low field mobility (UO) temperature exponent	None	-1.5
CTA	Junction capacitance (CJ) temperature coefficient	°K^{-1}	0.0
CTP	Junction sidewall capacitance (CJSW) temperature coefficient	°K^{-1}	0.0
EG	Energy gap for pn junction diodes	electron-Volt	Calculated
GAP1	1st bandgap correction factor	electron-Volt/°K	7.02e-4
GAP2	2nd bandgap correction factor	°K	1108
PTA	Junction potential (PB) temperature coefficient (TLEVC = 1 or 2)	Volt/°K	0.0
PTC	Fermi potential (PHI) temperature coefficient (TLEVC = 1 or 2)	Volt/°K	0.0
PTP	Junction potential (PHP) temperature coefficient (TLEVC = 1 or 2)	Volt/°K	0.0
TCV	Threshold voltage (VTH) temperature coefficient	Volt/°K	0.0
TLEV	Temperature equation selector 0 = SPICE-style 1 = ASPEC style	None	0
TLEVC	Temperature equation selector for junction capacitances and potentials 0 = SPICE-style 1 = ASPEC style	None	0
TRD	Temperature coefficient for drain resistor (RD)	°K^{-1}	0.0
TRS	Temperature coefficient for source resistor (RS)	°K^{-1}	0.0
XTI	Saturation current temperature exponent	None	0.0

SPICE 2G Empirical MOSFET Model Netlist Example

```
.MODEL nmos3 NMOS LEVEL=3

+ CGBO=4.0E-10 CGDO=3.0E-10 CGSO=3.0E-10 CJ=5.6E-4 CJSW=5.0E-11

+ DELTA=0.7 ETA=3.7E-2 GAMMA=0.6 KAPPA=2.9E-2 KP=2.0E-4
```

```
+ LD=5.0E-8 MJ=0.56 MJSW=0.52 NFS=6.0E+11 NSUB=1.4E+17
+ PB=1.0 PHI=0.7 RSH=2.0 THETA=0.27 TOX=1.0E-8 TPG=1.0
+ UO=550 XJ=0.2E-6 VMAX=2.0E+5 VTO=0.65
```

MOSFET Instance, Advanced SPICE Level 2 Model (Level 8)



Advanced SPICE Level 2 (HSPICE Level 8) Instance Netlist Syntax

The syntax for a Advanced SPICE Level 2 (HSPICE Level 8) MOSFET instance is:

M*xxxx nd ng ns* [*nb*] *modelname* [[**L=**]*length*] [[**W=**]*width*]
[**AD=***val*] [**AS=***val*] [**PD=***val*] [**PS=***val*]
[**NRD=***val*] [**NRS=***val*] [**VDSAT=***val*] [**DTEMP=***val*]
[**M=***val*] [**TEMP=***val*] [**ASPEC=***val*] [**SCALE=***val*]

nd is the drain node, *ng* is the gate node, *ns* is the source node, and *nb* is the bulk or substrate node of the MOSFET. *modelname* is the name of a Level 8 MOSFET model defined in a .MODEL statement elsewhere in the netlist.

When the option **WL** is in effect (on the .OPTION statement), the syntax becomes:

M*xxxx nd ng ns* [*nb*] *modelname* [*width*] [*length*]
[**AD=***val*] [**AS=***val*] [**PD=***val*] [**PS=***val*]
[**NRD=***val*] [**NRS=***val*] [**VDSAT=***val*] [**DTEMP=***val*]
[**M=***val*] [**TEMP=***val*] [**ASPEC=***val*] [**SCALE=***val*]

Table 96: Level 8 MOSFET Instance Parameters

Instance Parameter	Description	Unit	Default
AD	Drain diffusion area	Meter ^{2}	0.0
AS	Source diffusion area	Meter ^{2}	0.0
ASPEC	ASPEC option	None	0.0
DTEMP	Difference between MOSFET and circuit temperatures	°C	0.0
L	MOSFET channel length	Meter	1.0e-4
M	Multiplier: simulates parallel transistors	None	0.0
NRD	Number of squares of drain diffusion for resistance calculations	None	0.0
NRS	Number of squares of source diffusion for resistance calculations	None	1.0
PD	Drain diffusion periphery	Meter	0.0
PS	Source diffusion periphery	Meter	0.0
SCALE	Scale factor for instance parameters	None	1.0
TEMP	Device temperature	°C	Calculated
VDSAT	Saturation voltage	Volt	0.0
W	MOSFET channel width	Meter	1.0e-4

Level 8 MOSFET Instance Netlist Examples

```
M1 10 11 12 mosfet1

M12 G3 VDD 0 0 mosfet2 M=2 DTEMP=30

Mtest 34 56 78 90 fetex
```

Advanced IDS MOSFET Model, Level 8

The syntax for a Level 8 MOSFET model is:

`.MODELmodelname NMOS LEVEL=8 [(][parameter=val] ... [)]`

or

`.MODELmodelname PMOS LEVEL=8 [(][parameter=val] ... [)]`

modelname is the name used by MOSFET instances to refer to this .MODEL statement. The **LEVEL=8** entry selects the advanced IDS Grove-Frohman MOSFET model.

Table 97: Level 8 MOSFET Basic Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	8 is required to select the advanced IDS MOSFET model	Integer	1 (default if LEVEL parameter is omitted)
ACM	Area calculation method selector 0 = SPICE model, parameters depend on element areas 1 = ASPEC model, parameters depend on element width 2 = HSPICE model (combines ACM 0 and 1, extensions for lightly-doped drain technology 3 = HSPICE method, ACM 2 plus shared sources and drains and gate-edge source/drain peripheral capacitances	None	0
ALPHA	Impact ionization current coefficient	None	0.0
CAPOP	Capacitance model selector	Integer	2
COX (**CO**)	Oxide capacitance per unit of gate area	Farad/Meter^2	Calculated
ECRIT (**ESAT**)	Critical electric field for carrier velocity saturation. Zero represents an infinite value. Grove: electrons 6e+4, holes 2.4e+4	Volt-cm^{-1}	0.0
IIRAT	Portion of impact ionization current that goes to source	None	0.0
KP (**BET**, **BETA**)	Intrinsic transconductance parameter.	Amp/Volt^2	Calculated
LALPHA	Alpha length sensitivity	μMeter/Volt	0.0
LRD	Drain resistance length sensitivity	Ohm/Meter	0.0
LRS	Source resistance length sensitivity	Ohm/Meter	0.0
LVCR	VCR length sensitivity	μMeter/Volt	0.0

PRD	Drain resistance area sensitivity	Ohm/Meter^2	0.0
PRS	Source resistance area sensitivity	Ohm/Meter^2	0.0
RD	Drain ohmic resistance	Ohm	0.0
RDC	Additional drain resistance due to contact resistance	Ohm	0.0
RS	Source ohmic resistance	Ohm	0.0
RSC	Additional source resistance due to contact resistance	Ohm	0.0
RSH (**RL**)	Drain and source diffusion sheet resistance	Ohm/Square	0.0
SCALM	Model parameter scale factor (also an option for .OPTIONs statement)	None	1.0
SNVB	Slope of doping concentration versus vsb	1e6/Volt-cm^3	0.0
TNOM	Nominal device temperature	°C	25
UPDATE	Update selector for parasitics model	None	0.0
VCR	Critical voltage	Volt	0.0
VMAX (**VMX**, **VSAT**)	Maximum carrier drift velocity. Zero represents an infinite value.	Meter/second	0.0
WALPHA	Alpha width sensitivity	μMeter/Volt	0.0
WRD	Drain resistance width sensitivity	Ohm/Meter	0.0
WRS	Source resistance width sensitivity	Ohm/Meter	0.0
WVCR	VCR width sensitivity	μMeter/Volt	0.0

Table 98: Level 8 MOSFET Threshold Voltage Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
DELTA	Narrow width factor for adjusting threshold	None	0.0
DELVTO	Threshold voltage shift at zero bias	Volt	0.0
ETA	Drain-induced barrier-lowering (DIBL) effect coefficient for threshold voltage	None	0.0
GAMMA	Body effect factor	Volt$^{1/2}$	Calculated
NFS (**DFS**, **NF**, **DNF**)	Fast surface state density	cm^{-2} × Volt^{-1}	0.0

NGATE	Polysilicon gate doping	1/cm^3	No default. If NGATE ≤ 0.0, it is set to 1.0e+18
NSS	Surface state density	cm^{-2}	0.0
TPG (**TPS**)	Type of gate material 0 = Aluminum gate 1 = Polysilicon gate same as source-drain diffusion -1 = Polysilicon gate opposite to source-drain diffusion	None	1
VTO (**VT**)	Zero-bias threshold voltage	Volt	Calculated

Table 99: Level 8 MOSFET Mobility Model Parameters

Model Parameter	Description	Unit	Default
MOB	Mobility equation selector 0 = Level 2 model and equations, using vde instead of vds 3 = Temperature-dependent 6 = UEXP-dependent (Level 8) 7 = NSUB-dependent	Integer	6
THETA	Mobility modulation for MOB=7	Volt^{-1}	0.0
UCRIT	Critical field for mobility degradation (MOB = 6)	UEXP > 0: Volt/cm UEXP ≤ 0: Volt^{-1}	1.0e+4
UEXP (**F2**)	Critical field exponent for surface mobility degradation empirical formula	None	0.0
UO (**UB**, **UBO**)	Low-field bulk mobility	Centimeter^2/Volt-Second	If KP is entered, UO is calculated from KP Else, NMOS = 600e-4 PMOS = 250e-4

UTRA	Transverse field coefficient Nonzero values for UTRA can result in negative resistance regions at the onset of saturation.	None	0.0

Table 100: Level 8 MOSFET Channel Length Modulation Model Parameters

Model Parameter	Description	Unit	Default
CLM	Channel length modulation 6 = SPICE equations 7 = Intersil equations 8 = Modified Intersil equations	Integer	7
A1	CLM = 8: Channel length modulation exponent	None	0.2
LAMBDA (**LAM**, **LA**)	Channel length modulation coefficient	None	0.0
LAM1	Channel length modulation length correction	Meter^{-1}	0.0

Table 101: Level 8 MOSFET Gate Overlap Capacitance Model Parameters

Model Parameter	Description	Unit	Default
CGBO (**CGB**)	Gate-bulk overlap capacitance per meter channel length	Farad/Meter	0.0
CGDO (**CGD**, **C2**)	Gate-drain overlap capacitance per meter channel width	Farad/Meter	Calculated
CGSO (**CGS**, **C1**)	Gate-source overlap capacitance per meter channel width	Farad/Meter	Calculated
METO	Fringing field factor for gate-to-source and gate-to-drain overlap capacitance calculation	Meter	0.0

Table 102: Level 8 MOSFET MOS Geometry Model Parameters

Model Parameter	Description	Unit	Default
DEL	Channel length reduction	Meter	0.0
GEO	Layout geometry	None	0

	0 = Drain and source not shared 1 = Drain shared 2 = Source shared 3 = Drain and source shared		
HDIF	Length of heavily-doped diffusion region, from contact to lightly-doped region (ACM = 2 or 3)	Meter	0.0
LD (**DLAT**, **LATD**)	Lateral diffusion into channel from source and drain	Meter	If neither LD nor XJ is specified: LD = 0.0 If XJ specified but LD not specified: LD = 0.75 × XJ
LDIF	Length of lightly-doped diffusion adjacent to gate (ACM = 1 or 2)	Meter	0.0
LDAC	Lateral diffusion for AC analysis	Meter	None
LMLT	Length shrink factor	None	1.0
LREF	Channel length reference	Meter	0.0
TOX	Oxide thickness	Meter	1.0e-7
WD	Lateral diffusion into channel from bulk along width	Meter	0.0
WMLT	Diffusion layer and width reduction factor	None	1.0
WREF	Channel width reference	Meter	0.0
XJ	Metallurgical junction depth	Meter	0.0
XL (**DL**, **LDEL**)	Length bias factor for mask and etch effects	Meter	0.0
XLREF	Channel length reference bias factor for mask and etch effects	Meter	0.0
XW (**DW**, **WDEL**)	Width bias factor for mask and etch effects	Meter	0.0
XWREF	Channel width reference bias factor for mask and etch effects	Meter	0.0

Table 103: Level 8 MOSFET Noise Model Parameters

Model Parameter	Description	Unit	Default
AF	Flicker noise exponent	None	1.0
GDSNOI	Channel thermal noise coefficient (for NLEV = 3)	None	1.0

KF	Flicker noise coefficient	None	0.0
NLEV	Noise equation selector	None	2

Table 104: Level 8 MOSFET DC Model Parameters

Model Parameter	Description	Unit	Default
IS	Bulk junction saturation current	Amp	1.0e-14
JS	Bulk junction saturation current density	Amp/Meter^2	0.0
JSW	Sidewall bulk junction saturation current	Amp/Meter	0.0
N	Emission coefficient	None	1.0
NDS	Reverse bias slope coefficient	None	1.0
VNDS	Reverse diode current transition point	Volt	-1.0

Table 105: Level 8 MOSFET Capacitance Model Parameters

Model Parameter	Description	Unit	Default
CBD	Zero-bias bulk-drain junction capacitance	Farad	0.0
CBS	Zero-bias bulk-source junction capacitance	Farad	0.0
CJ (**CJB**, **CSB**, **CJA**)	Zero-bias bulk junction bottom capacitance	Farad/Meter^2	Calculated
CJGATE	Zero-bias gate-edge sidewall bulk junction capacitance (ACM = 3)	Farad/Meter	CJSW
CJSW (**CJP**)	Zero-bias bulk junction sidewall capacitance	Farad/Meter	0.0
FC	Forward-bias depletion coefficient for capacitance	None	0.0
MJ (**EXA**, **EXJ**, **EXS**, **EXD**)	Bulk junction capacitance grading coefficient	None	0.5
MJSW	Bulk junction sidewall capacitance grading coefficient	None	0.33
NSUB (**DNB**, **NB**)	Substrate doping	1/cm^3	1.0e+15
PB (**PHA**, **PHS**, **PHD**)	Bulk junction contact potential	Volt	0.8
PHI	Surface inversion potential	Volt	Calculated
PHP	Bulk sidewall junction contact potential	Volt	PB

TT	Transit time	Second	0.0

Table 106: Level 8 MOSFET Temperature Effect Model Parameters

Model Parameter	Description	Unit	Default
BEX	Low field mobility (UO) temperature exponent	None	-1.5
CTA	Junction capacitance (CJ) temperature coefficient	°K^{-1}	0.0
CTP	Junction sidewall capacitance (CJSW) temperature coefficient	°K^{-1}	0.0
EG	Energy gap for pn junction diodes	electron-Volt	Calculated
GAP1	1st bandgap correction factor	electron-Volt/°K	7.02e-4
GAP2	2nd bandgap correction factor	°K	1108
LAMEX	LAMBDA temperature coefficient	°K^{-1}	0.0
PTA	Junction potential (PB) temperature coefficient (TLEVC = 1 or 2)	Volt/°K	0.0
PTC	Fermi potential (PHI) temperature coefficient (TLEVC = 1 or 2)	Volt/°K	0.0
PTP	Junction potential (PHP) temperature coefficient (TLEVC = 1 or 2)	Volt/°K	0.0
TCV	Threshold voltage (VTH) temperature coefficient	Volt/°K	0.0
TLEV	Temperature equation selector 0 = SPICE-style 1 = ASPEC style	None	0
TLEVC	Temperature equation selector for junction capacitances and potentials 0 = SPICE-style 1 = ASPEC style	None	0
TRD	Temperature coefficient for drain resistor (RD)	°K^{-1}	0.0
TRS	Temperature coefficient for source resistor (RS)	°K^{-1}	0.0
XTI	Saturation current temperature exponent	None	0.0

Advanced Level 2 Model Netlist Example

```
.model MODnmos8511 nmos level=8 tnom=27 a0=0.7047165 a1=0 a2=1
+ af=0.97
+ ags=0.6217114 alpha0=3.407059e-07 alpha1=1.1897968
+ at=-123332 b0=0.0004671489
+ b1=0.0005506269 beta0=14.9176967 capmod=2 cdsc=-0.0006524708
+ cdscb=2.445784e-05 cf=0 cgbo=0 cgdl=0 cgdo=0 cgsl=0 cgso=0
+ cit=-0.001911036
+ cj=0.002035 cjswg=4.584e-11 cjsw=4.23e-10 ckappa=0.6
+ clc=1e-07 cle=0.6
+ delta=0.00702037 dlc=2.62154504166667e-09 drout=0.009089753
+ dsub=2.4414572
+ dvt0=0.5983559 dvt0w=0 dvt1=0.0444708 dvt1w=5300000
+ dvt2=0.1445384
+ dvt2w=-0.032 dwb=-3.726423e-08 dwc=-1.6119005773e-06
+ dwg=-1.480819e-08 ef=1
+ elm=5 eta0=20 etab=-48.3355303 hdif=3.3e-07 js=1.33e-07
+ k1=0.5356169
+ k2=-0.0268863 k3=-22.7398585 k3b=-10.1702254 keta=-0.0131408
+ kf=2.7e-27
+ kt1=-0.3241618 kt1l=-2.027033e-09 kt2=-0.0717199
+ la0=-0.4454584
+ lags=0.5587801 ldif=0 lint=2.62154504166417e-09
+ lk1=-0.0442092 lk2=0.0160318
+ lln=1 lmin=2.4e-07 lpdiblc2=0.00344163 lpscbe1=6.048571e-06
+ luc=-0.0507473
+ lvoff=-0.016263 lwn=1 mj=0.5118 mjsw=0.4916 mobmod=3 n=1
+ nch=2.68413e+17
```

```
+ nfactor=2.786641 nlx=7.630352e-07 noimod=1 nqsmod=0

+ pa0=-5.7084744

+ pags=16.5085896 pb=0.9966 pbsw=0.9966 pclm=1.4696409

+ pdiblc1=0.001387071

+ pdiblc2=0.004761822 pdiblcb=-0.0236973 pdwg=-4.6926e-07

+ pk1=0.11649996

+ pk2=-0.142513512 prt=-32.4592531 prwb=-0.3947007

+ prwg=0.1120965

+ pscbe1=10000000000 pscbe2=1e-09 pu0=-0.0046465272

+ pua=2.31453768e-09

+ pua1=-3.89208e-10 pub=4.8e-19 pub1=1.061016e-17 puc=0

+ pvag=0.3332895

+ pvth0=-0.156971064 rd=0 rdsw=362.8942358 rs=0 rsh=0

+ tox=5.5e-09 u0=0.0283165

+ ua=-1.228226e-09 ua1=1.18763e-09 ub=2.205781e-18

+ ub1=-1.52409e-18

+ uc=0.1636595 uc1=0.3106885 ute=-1.5522555 voff=-0.1171691

+ vsat=98816.62

+ vth0=4.762307 w0=2.5e-06 wint=-1.61190057730003e-06

+ wkt2=0 wln=1 wmin=5.8e-07

+ wr=1 wu0=-0.23228496 wua1=-1.59852e-08 wub1=1.9266792e-17

+ wuc=0.7466712

+ wuc1=0 wwn=1 xj=1.5e-07 xpart=0.4
```

23 - MOSFET Levels 49 through 54

This topic describes the following MOSFETs:

"MOSFET Instance, BSIM3v3 Models (Level 49 or 53)" below

"BSIM3v3 MOSFET Model, LEVEL=49 and 53 " on page 23-6

"MOSFET Instance, Philips MOS903 Geometrical Model (Level 50)" on page 23-53

"Philips MOS9 Geometrical MOSFET Model (Level 50)" on page 23-54

"MOSFET Instance, BSIM4 Model (Level 54)" on page 23-62

"BSIM4 MOSFET Model, Level 54" on page 23-66

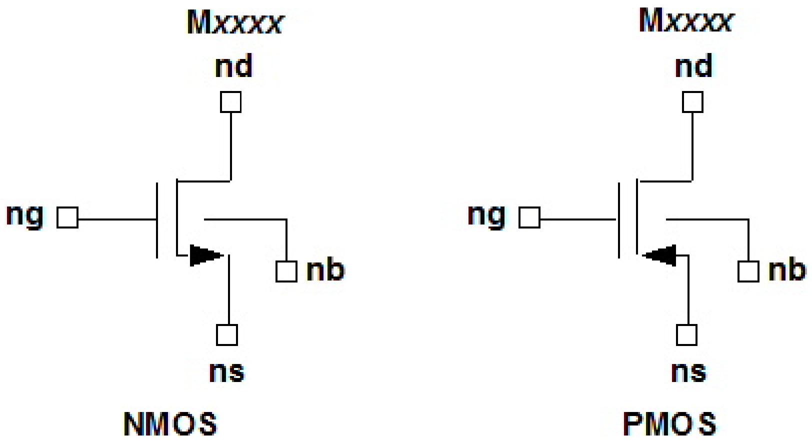
For additional MOSFETs, see

"MOSFET Levels 1 through 27" on page 22-1

"MOSFET Levels 55 through 66" on page 24-1

"MOSFET Levels 69 through 99" on page 25-1

MOSFET Instance, BSIM3v3 Models (Level 49 or 53)



The syntax for an Enhanced BSIM3v3 (HSPICE™ Level 49) or Berkeley standard BSIM3v3 (HSPICE™ Level 53) MOSFET instance is:

```
Mxxxx nd ng ns [nb] modelname [[L=]length] [[W=]width]
[AD=val] [AS=val] [PD=val] [PS=val] [NRD=val] [NRS=val]
[MULU0=val] [MULUA=val] [MULUB=val]
[M=val] [DELVTO=val] [DTEMP=val] [SCALE=val]
```

nd is the drain node, *ng* is the gate node, *ns* is the source node, and *nb* is the bulk or substrate node of the MOSFET. *modelname* is the name of a Level 49 or 53 MOSFET model defined in a .MODEL statement elsewhere in the netlist.

When the option **WL** is in effect (on the .OPTION statement), the syntax becomes:

```
Mxxxx nd ng ns [nb] modelname [width] [length]
[AD=val] [AS=val] [PD=val] [PS=val] [NRD=val] [NRS=val]
[MULU0=val] [MULUA=val] [MULUB=val]
[M=val] [DELVTO=val] [DTEMP=val] [SCALE=val]
```

Table 42: Level 49/53 MOSFET Instance Parameters

Instance Parameter	Description	Unit	Default
AD	Drain area	Meter^2	0.0
AS	Source area	Meter^2	0.0
DELVTO	Shift in zero-bias threshold voltage vth0. Value must be a real scalar	Volt	0.0
DTEMP	Temperature difference between circuit and device	°C	0.0
L	Physical gate length	Meter	10.0e-6
M	Multiplier to simulate transistors in parallel	None	1.0
MULU0	Low-field mobility multiplier	None	1.0
MULUA	First-order mobility multiplier	None	1.0
MULUB	Second-order mobility multiplier	None	1.0
NRD	Relative resistivity of drain	Square	0.0
NRS	Relative resistivity of source	Square	0.0
PD	Drain perimeter	Meter	0.0
PS	Source perimeter	Meter	0.0
SA	Distance between OD edge to poly from one side	Meter	0.0
SB	Distance between OD edge to poly on the other side	Meter	0.0

SCALE	Scale factor for instance parameters	None	1.0 (or global SCALE option)
W	Physical gate width	Meter	100.0e-6

BSIM3v3 MOSFET Instance Netlist Example

```
M1 10 11 12 mosfet1
```

```
M12 G3 VDD 0 0 mosfet2 M=2
```

```
Mtest 34 56 78 90 fetex
```

BSIM3v3 Output Quantities

The BSIM3v3 instance can output the quantities listed in the following table. The output quantities are the values of model parameters and the values of variables that are calculated internally to the model.

In the **Schematic Editor**, you request Nexxim to create these outputs with the Output Quantities selection on the Solution Setup windows.

In a netlist, you request Nexxim to create these outputs with the following statement:

`.PRINT O(`*`instance_name`***`)`**

Where *instance_name* identifies the device instance in the netlist, shown as **M***xxxx* in the netlist syntax.

Table 43: BSIM3v3 Output Quantities

Output Code	**Parameter or Variable**	**Description**	**Unit**
LV1	L	Effective length	Meter
LV2	W	Effective width	Meter
LV3	AD	Effective drain area	Meter^2
LV4	AS	Effective source area	Meter^2
LV9	VTH	Threshold voltage	Volt
LV10	VDSAT	Saturation voltage	Volt
LV11	PD	Drain diode perimeter	Meter
LV12	PS	Source diode perimeter	Meter
LV13	RDS	Drain resistance	Square

Output Code	Parameter or Variable	Description	Unit
LV14	RSS	Source resistance	Square
LV15	XQC	Charge-sharing coefficient	None
LV16	GDEFF	Effective drain conductance for RGEOMOD!=0	Mho
LV17	GSEFF	Effective source conductance for RGEOMOD!=0	Mho
LV18	CDSAT	Drain-bulk saturation current at -1V	Amp
LV19	CSSAT	Drain-source saturation current at -1V	Amp
LV20	VDBEFF	Effective drain-bulk voltage	Volt
LV21	BETAEFF	BETA effective	Volt
LV22	GAMMAEFF	GAMMA effective	$\text{Volt}^{0.5}$
LV24	UBEFF	UB effective	$(\text{Meter/Volt})^{0.5}$
LV26	VFBEFF	VFB effective	Volt
LX1	VBS	Bulk-source voltage	Volt
LX2	VGS	Gate-source voltage	Volt
LX3	VDS	Drain-source voltage	Volt
LX4	CDO	DC drain current	Amp
LX5	CBSO	DC source-bulk diode current	Amp
LX6	CBDO	DC drain-bulk diode current	Amp
LX7	GMO	DC gate transconductance	Mho
LX8	GDSO	DC drain-source transconductance	Mho
LX9	GMBSO	DC substrate transconductance	Mho
LX10	GBDO	Conductance of the drain diode	Mho
LX11	GBSO	Conductance of the source diode	Mho
LX12	QB	Total bulk charge	Coulomb
LX13	CQB	Total bulk charge current	Amp
LX14	QG	Total gate charge	Coulomb
LX15	CQG	Total gate charge current	Amp
LX16	QD	Total drain charge	Coulomb
LX17	CQD	Total drain charge current	Amp

Output Code	Parameter or Variable	Description	Unit
LX18	CGGBO	Intrinsic gate capacitance (CGS + CGD + CGB)	Farad
LX19	CGDBO	Intrinsic gate-to-drain capacitance (-dqg_dvd)	Farad
LX20	CGSBO	Intrinsic gate-to-source capacitance (-dqg_dvs)	Farad
LX21	CBGBO	Intrinsic bulk-to-gate capacitance (-dqb_dvg)	Farad
LX22	CBDBO	Intrinsic bulk-to-drain capacitance (-dqb_dvd)	Farad
LX23	CBSBO	Intrinsic bulk-to-source capacitance (-dqb_dvs)	Farad
LX24	QBD	Drain-bulk charge	Coulomb
LX26	QBS	Source-bulk charge	Coulomb
LX28	CAP_BS	Bias-dependent bulk-source capacitance	Farad
LX29	CAP_BD	Bias-dependent bulk-drain capacitance	Farad
LX32	CDGBO	Intrinsic gate-to-drain capacitance (-dqd_dvg)	Farad
LX33	CDDBO	Intrinsic drain capacitance (-dqd_dvd)	Farad
LX34	CDSBO	Intrinsic drain-to-source capacitance (-dqd_dvs)	Farad
LX55	QSRCO	Total charge (QG + QB + QD)	Coulomb
LX97	QGI	Intrinsic gate charge	Coulomb
LX98	QSI	Intrinsic source charge	Coulomb
LX99	QDI	Intrinsic drain charge	Coulomb
LX100	QBI	Intrinsic bulk charge	Coulomb
LX101	CDDBI	Intrinsic drain capacitance	Farad
LX102	CBDBI	Intrinsic bulk-to-drain capacitance	Farad
LX103	CBSBI	Intrinsic bulk-to-source capacitance	Farad

BSIM3v3 MOSFET Model, LEVEL=49 and 53

The syntax for a LEVEL 49 or 53 Berkeley Short-channel IGFET MOSFET (BSIM3v3) model is:

```
.MODELmodelname NMOS LEVEL=val [parameter=val] ...
```

or

```
.MODELmodelname PMOS LEVEL=val [parameter=val] ...
```

modelname is the name used by MOSFET instances to refer to this .MODEL statement. **LEVEL=49** selects the HSPICE™-enhanced BSIM3 model. **LEVEL=53** selects the Berkeley standard BSIM3v3.

Table 44: Level 49 or 53 MOSFET Flag/Selector Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	49 selects the HSPICE-enhanced BSIM3v3 MOSFET model 53 selects the original Berkeley BSIM3v3 MOSFET model	None	1 (default if LEVEL parameter is omitted)
VERSION	BSIM3 version selector	None	3.24
ACM	Area calculation method	None	Level 49: 0 Level 53: 10
CALCACM	ACM calculation flag	None	0
CAPMOD	Capacitance model selector (0, 1, 2, 3) For CAPMOD=0, level 49 and level 53 use different charge models	None	3
GDSNOI	Channel thermal Noise coefficient	None	1.0
MOBMOD	Mobility model selector	None	1
NLEV	Noise level selector	None	99
NOIMOD	Berkeley noise combination model selector 1=SPICE2 flicker, SPICE2 channel 2=BSIM flicker, BSIM channel 3=BSIM flicker, SPICE2 channel 4=SPICE2 flicker, BSIM channel	None	1

NQSMOD	Flag for NQS model	None	0
TLEV	Temperature model level selector	None	0
TLEVC	Temperature model level selector	None	0
UPDATE	Parasitics calculation flag	None	0
VFBFLAG	Flag for dependence of V_{FB} on V_{TM0}	None	0

Table 45: Level 49 or 53 MOSFET Basic Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
A0	Bulk charge effect coefficient for channel length	None	1.0
A1	1st nonsaturation effect parameter	$Volt^{-1}$	0.0
A2	2nd nonsaturation effect parameter	None	1.0
ACDE	Exponential coefficient for charge thickness in the accumulation and depletion regions (CAPMOD = 3)	Meter/Volt	1.0
AGS	Gate bias coefficient of ABULK	$Volt^{-1}$	0.0
ALPHA0	1st parameter of impact ionization current	Meter/Volt	0.0
ALPHA1	Substrate current parameter	$Volt^{-1}$	0.0
B0	Bulk charge coefficient for channel width	Meter	0.0
B1	Bulk charge effect width offset	Meter	0.0
BETA0	2nd parameter of impact ionization current	$Volt^{-1}$	30
CDSC	Drain-source to channel coupling capacitance	$Farad/Meter^2$	2.4e-4
CDSCB	Body-bias sensitivity coefficient of C_{DSC}	$Farad/Volt-Meter^2$	0.0
CDSCD	Drain bias sensitivity of C_{DSC}	$Farad/Volt-Meter^2$	0.0
CIT	Interface trap capacitance	$Farad/Meter^2$	0.0
COX	Oxide capacitance	Farad	Calculated
DELTA	Parameter for DC V_{DSeff}	Volt	0.01
DL (**XL**)	Channel length shortening	Meter	0.0
DROUT	Channel length dependence of DIBL effect on R_{OUT}	None	0.56
DSUB	DIBL coefficient in subthreshold region	None	DROUT

DVT0	1st short channel coefficient for V_{TH}	None	2.2
DVT0W	1st narrow width coefficient for V_{TH} at small L	None	0.0
DVT1	2nd short channel coefficient for VTH	None	0.53
DVT1W	2nd narrow width coefficient for V_{TH} at small L	Meter^{-1}	5.3e+6
DVT2	Body-bias coefficient of short channel effect on V_{TH}	Volt^{-1}	-0.032
DVT2W	3rd narrow width coefficient for V_{TH} at small L	Volt^{-1}	-0.032
DW (**XW**, **WDEL**)	Channel width narrowing	Meter	0.0
EG	Energy gap for PN junction diode	electron-Volt	TLEV=0 or 1: 1.11 TLEV=2: 1.16
ETA0	Subthreshold region DIBL coefficient	None	0.08
ETAB	Body-bias coefficient for the subthreshold DIBL effect	Volt^{-1}	-0.07
GAP1	1st bandgap correction factor	eV/°K	7.02e-4
GAP2	2nd bandgap correction factor	°K	1108
GEO	Shared geometry parameter	None	0.0
HDIF	Length of heavily-doped diffusion	Meter	0.0
IJTH	Diode limiting current [Not binnable]	Amp	0.1
K1	1st-order body bias factor	Amp/Meter	0.53
K2	2nd-order body bias factor	None	-0.0186
K3	Narrow width coefficient	None	80.0
K3B	Body effect coefficient of K3	Volt^{-1}	0.0
KETA	Body-bias coefficient of bulk charge effect	Volt^{-1}	-0.047
LD (**DLAT**, **LATD**)	Lateral diffusion	Meter	Calculated
LDIF	Length of lightly-doped region adjacent to gate	Meter	0.0
MOIN	Gate bias-dependent surface potential coefficient	None	15.0
NCH (**NPEAK**)	Peak doping concentration near interface If NCH not specified and GAMMA is specified, NCH is calculated from GAMMA	cm^{-3}	1.7e+17 (or calculated)

NFACTOR	Subthreshold region swing factor	None	1.0
NGATE	Poly gate doping concentration	cm^{-3}	0.0
NI	Intrinsic concentration	cm^{-3}	Calculated
NLX	Lateral nonuniform doping along channel	Meter	1.74e-7
NOFF	C-V parameter in VGSTeff, CV for weak-to-strong inversion transition	None	1.0
NSUB	Substrate doping concentration	cm^{-3}	6.0e+16
PCLM	Channel length modulation parameter.	None	1.3
PDIBLC1 (**PDIBL1**)	Parameter for DIBL effect on R_{OUT}	None	0.39
PDIBLC2 (**PDIBL2**)	Parameter for DIBL effect on R_{OUT}	None	0.0086
PDIBLCB (**PDIBLB**)	Body bias coefficient of DIBL effect on R_{OUT}	$Volt^{-1}$	0.0
PRWB	Body effect coefficient of RDSW	$1/Volt^{1/2}$	0.0
PRWG	Gate bias effect coefficient of RDSW	Volt-1	0.0
PSCBE1	1st substrate current-induced body effect parameter	Volt/Meter	4.24e+8
PSCBE2	2nd substrate current-induced body effect parameter	Meter/Volt	1.0e-5
PVAG	Gate dependence of Early voltage	None	0.0
RD	Drain resistance	Ohm	0.0
RDC	Additional drain contact resistance	Ohm	0.0
RDSW	Parasitic source-drain resistance per unit width	Ohm/μMeter WR	0.0
RS	Source resistance	Ohm	0.0
RSC	Additional source contact resistance	Ohm	0.0
RSH	Source/drain sheet resistance per square. [Not binnable]	Ohm/square	0.0
SCALM	Scale factor for model parameters	None	1.0 (or global SCALM option)
TNOM (**TREF**)	Temperature at which parameters are extracted	°C	25

TOX	Gate oxide thickness	Meter	1.50e-8
TOXM	Reference gate oxide thickness	Meter	TOX
U0	Low field mobility at T = TREF = TNOM	cm^2/Volt-sec	NMOS: 670 PMOS: 250
UA	1st-order mobility degradation coefficient	Meter/Volt	2.25e-9
UB	2nd-order mobility degradation coefficient	Meter^2/Volt^2	5.87e-19
UC	Body bias sensitivity coefficient of mobility	MOBMOD=1, 2: Meter/Volt^2 MOBMOD=3: Volt^{-1}	MOBMOD=1, 2: -4.65e-11 MOBMOD=3: -0.0465
VBM	Maximum substrate bias, for VTH calculation	Volt	-3.0
VFB	DC flatband voltage	Volt	-1.0
VOFF	Offset voltage in subthreshold region at large W and L	Volt	-0.08
VOFFCV	C-V parameter in VGSTeff, CV for weak-to-strong inversion transition	None	0.0
VSAT	Saturation velocity of carrier at T = TREF = TNOM	Meter/sec	8.0e+4
VTH0 (**VTHO**)	Threshold voltage of long-channel device at VBS=0 and large L	Volt	Calculated
WMLT	Width diffusion shrink reduction factor	None	1.0
W0	Narrow width effect coefficient	Meter	2.5e-6
WR	Width offset from Weff for RDS calculation	None	1.0
XJ	Junction depth	Meter	1.5e-7

Table 46: Level 49 or 53 MOSFET AC and Capacitance Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
CF	Fringing field capacitance	Farad/Meter	Calculated
CGBO	Gate-to-bulk overlap capacitance per unit gate length [Not binnable]	Farad/Meter	Calculated
CGDL (**CGD1**)	Lightly-doped region drain-gate overlap capacitance per unit gate width	Farad/Meter	0.0

CGDO	Non-LDD region drain-gate overlap capacitance per unit gate width [Not binnable]	Farad/Meter	Calculated
CGSL (**CGS1**)	Lightly-doped region source-gate overlap capacitance per unit gate width	Farad/Meter	0.0
CGSO	Non-LDD region source-gate overlap capacitance per unit gate width [Not binnable]	Farad/Meter	Calculated
CKAPPA	Coefficient for lightly-doped region overlap capacitance	Volt	0.6
CLC	Constant term for short-channel model	Meter	1.0e-7
CLE	Exponential term for short-channel model	None	0.6
DLC	Length offset fitting parameter from CV [Not binnable]	Meter	LINT
DWB	Coefficient of Weff substrate body bias dependence [Not binnable]	Meter/Volt$^{1/2}$	0.0
DWC	Width offset fitting parameter from CV	Meter	WINT
DWG	Coefficient of Weff gate dependence	Meter/Volt	0.0
LINT	Length offset fitting parameter from I-V without bias [Not binnable]	Meter	0.0
LL	Coefficient of length dependence for width offset [Not binnable]	Meter^{LLN}	0.0
LLC	Coefficient of length dependence for C-V channel length offset	Meter^{LLN}	LL
LLN	Exponent of length dependence of width offset [Not binnable]	None	1.0
LW	Coefficient of width dependence for length offset [Not binnable]	Meter^{LWN}	0.0
LWC	Coefficient of width dependence for C-V channel length offset	Meter^{LWN}	LW
LWL	Coefficient of length and width cross term for length offset [Not binnable]	Meter$^{LWN+LLN}$	0.0
LWLC	Coefficient of length and width cross terms for C-V channel length offset	Meter$^{LLN+LWN}$	LWL
LWN	Exponent of width dependence for width offset [Not binnable]	None	1.0

VFBCV	Flat-band voltage [CAPMOD=0]	Volt	-1.0
WINT	Width offset fitting parameter from I-V without bias [Not binnable]	Meter	0.0
WL	Coefficient of length dependence for width offset	Meter^{WLN}	0.0
WLC	Coefficient of length dependence for C-V channel width offset	Meter^{WLN}	WL
WLN	Exponent of length dependence of width offset [Not binnable]	None	1.0
WW	Coefficient of width dependence for width offset [Not binnable]	Meter^{WWN}	0.0
WWC	Coefficient of width dependence for C-V channel width offset	Meter^{WWN}	WW
WWL	Coefficient of length and width cross term for width offset [Not binnable]	Meter$^{WWN+WLN}$	0.0
WWLC	Coefficient of length and width cross terms for C-V channel width offset	Meter$^{WLN+WWN}$	WWL
WWN	Exponent of width dependence for width offset [Not binnable]	None	1.0
XPART	Selector for gate capacitance drain versus source charge sharing coefficient 0, 0.4 = 40/60 0.5 = 50/50 ≥ 1 = 0/100 Any other value < 1 = 40/60 [Not binnable]	None	Level 49: 1 (0/100) Level 53: 0 (40/60)

Table 47: Level 49 or 53 MOSFET Temperature Model Parameters

Model Parameter	Description	Unit	Default
AT	Temperature coefficient for saturation velocity	Meter/sec	3.3e+4
KT1	Temperature coefficient for VTH	Volt	-0.11
KT1L	Temperature	Meter-Volt	0.0

	coefficient channel length dependence of VTH		
KT2	Body bias coefficient of VTH temperature effect	None	0.022
PRT	Temperature coefficient for RDSW	Ohm/μMeter	0.0
TCJ (**CTA**)	Temperature coefficient of CJ [Not binnable]	°K^{-1}	0.0
TCJSW (**CTP**)	Temperature coefficient of CJSW [Not binnable]	°K^{-1}	0.0
TCJSWG	Temperature coefficient of CJSWG [Not binnable]	°K^{-1}	0.0
TNOM	Temperature at which parameters are extracted	°C	25 (or global TNOM option)
TPB (**PTA**)	Temperature coefficient of PB [Not binnable]	Volt/°K	0.0
TPBSW (**PTP**)	Temperature coefficient of PBSW [Not binnable]	Volt/°K	0.0
TPBSWG	Temperature coefficient of PBSWG [Not binnable]	Volt/°K	0.0
TRD	Temperature coefficient for drain resistance	Ohm/°K	0.0
TRS	Temperature coefficient for source resistance	Ohm/°K	0.0
UA1	Temperature coefficient of UA	Meter/Volt	4.31e-9

UB1	Temperature coefficient of UB	Meter2/Volt^2	-7.61e-18
UC1	Temperature coefficient of UC	MOBMOD=1, 2: Meter/Volt^2 MOBMOD=3: Volt^{-1}	MOBMOD=1, 2: -5.6e-11 MOBMOD=3: -0.056
UTE	Mobility temperature exponent	None	-1.5
XTI	Junction current temperature coefficient	None	ACM=0, 1, 2, 3: 0.0 ACM=10, 11, 12, 13: 3.0

Table 48: Level 49 or 53 MOSFET Binning Adjustment Model Parameters

Model Parameter	Description	Unit	Default
BINUNIT	Binning unit selector 1 = microns 0 = Meters	None	1
BINFLAG	<=0.9 Do not use adjustment parameters LREF, WREF >0.9 Use LREF, WREF	None	0.0
LREF	Reference channel length	Meter	0.0
WREF	Reference channel width	Meter	0.0
LMAX	Upper bound of channel length range	Meter	1.0
LMIN	Lower bound of channel length range	Meter	0.0
WMAX	Upper bound of channel width range	Meter	1.0
WMIN	Lower bound of channel width range	Meter	0.0

Notes on BSIM3v3 Binning Adjustment

Binning is a way to extend a single device architecture by providing systematic variations on the device parameters. The philosophy is that when you vary the channel geometry, other parameters also change, in ways that can be completely characterized by the device manufacturer. The manufacturer or foundry provides a “design kit” that contains a set of

.MODEL statements specifying the parameter settings for the different geometries. The design kit with the .MODEL statements can be included in the Nexxim design as a subcircuit.

1. A binning model is identified by giving the model name in the .MODEL statement the form *modelname***.***n*, where the entry *n* after the decimal point can be an integer or any other unique identifier. The MOSFET instance definition refers to the *modelname* without any extension. The netlist can contain any number of different binning models with the same base *modelname*. For example, three binning models could be named NMOSBSIM3.1 NMOSBSIM3.2, and NMOSBSIM3.3. The instance statement reference is NMOSBSIM3.

Each of the available binning models corresponds to a range of channel lengths and widths specified with the **LMIN**, **LMAX**, **WMIN**, and **WMAX** model parameters. The ranges must not overlap.

Each binning model typically specifies values for the model parameters that are related to the channel geometry variations.

2. The MOSFET instance statement must contain values for instance parameters **L** and **W**. The **L** and **W** parameters can be specified with variables so a sweep of binning models can be performed.
3. The simulator finds the binning model to which the following conditions BOTH apply:

- The **LMIN** and **LMAX** model parameter range includes the value of instance parameter **L** (scaled by the instance parameter **SCALE**).
- The **WMIN** and **WMAX** model parameter range includes the value of instance parameter **W** (scaled by the instance parameter **SCALE**).

If none of the available binning models matches the **L** and **W** instance parameters, simulation does not proceed.

4. Within a BSIM3v3 model, (binned or not) the binned model parameters are adjusted by the effective channel length and width. The formulas for the adjustment use the following symbols:

N = value of the model parameter (e.g., **A0**).

LN = value of the length dependence parameter (e.g., **LA0**).

WN = value of the width dependence parameter (e.g., **WA0**).

PN = value of the cross dependence parameter (e.g., **PA0**).

Leff = effective channel length (calculated from **L** using scale factors and other adjustments).

Weff = effective channel width (calculated from **W** using scale factors and other adjustments).

LREFeff = effective reference channel length (calculated from model parameter **LREF** using scale factors and other adjustments).

WREFeff = effective reference channel width (calculated from **WREF** using scale factors and other adjustments).

When model parameter **BINFLAG** is greater than 0.9 AND the model parameters **LREF** and **WREF** are both greater than 0:

```
Value = N + LN*(1/Leff-1/LREFeff)
+ WN*(1/Weff-1/WREFeff)
+ PN*(1/(Leff-1/LREFeff)*(1/(Weff-1/WREFeff)))
```

Otherwise:

```
Value = N + LN*(1/Leff) + WN*(1/Weff) + PN*(1/(Leff*Weff))
```

5. When model parameter **BINUNIT** equals 1, the effective parameters (Leff, Weff, LREFeff, and WREFeff) are scaled to units of microns. By default (**BINUNIT** not equal to 1), units are meters.

Table 49: Level 49 or 53 MOSFET Process Model Parameters

Model Parameter	Description	Unit	Default
GAMMA1	Body effect coefficient near the surface	Volt½	Calculated
GAMMA2	Body effect coefficient in the bulk	Volt½	Calculated
VBX	Bulk-source bias voltage at which the depletion region thickness equals XT	Volt	Calculated
XT	Doping depth	Meter	1.55e-7

Table 50: Level 49 or 53 MOSFET Noise Model Parameters

Model Parameter	Description	Unit	Default
AF	Flicker noise exponent	None	1.0
EF	Flicker noise frequency exponent	None	1.0
EM	Flicker noise parameter	Volt-Meter	4.1e+7
KF	Flicker noise coefficient	None	0.0
NOIA	Noise parameter A for flicker noise calculation (NOIMOD = 2 or 3) [Not binnable]	None	NMOS: 1.0e+20 PMOS: 9.9e+18

NOIB	Noise parameter B for flicker noise calculation (NOIMOD = 2 or 3) [Not binnable]	None	NMOS: 5.0e+4 PMOS: 2.4e+3
NOIC	Noise parameter C for flicker noise calculation (NOIMOD = 2 or 3) [Not binnable]	None	NMOS: -1.4e-12 PMOS: 1.4e-12

Table 51: Level 49 or 53 MOSFET Junction Model Parameters

Model Parameter	Description	Unit	Default
CBD	Zero-bias bulk-drain junction capacitance	Farad	0.0
CBS	Zero-bias bulk-source junction capacitance	Farad	0.0
CJ	Zero-bias bottom junction capacitance [Not binnable]	Farad/Meter 2	5.79e-4
CJSW	Zero-bias sidewall bulk junction capacitance [Not binnable]	Farad/Meter	0.0
CJSWG (**CJGATE**)	Zero-bias sidewall bulk junction capacitance grading coefficient [Not binnable]	Farad/Meter	CJSW
JS	Bulk junction saturation current density [Not binnable]	Amp/Meter^2	0.0
JSW	Sidewall bulk junction saturation current density [Not binnable]	Amp/Meter	0.0
MJ	Bulk junction grading coefficient [Not binnable]	None	0.5
MJSW	Sidewall bulk junction grading coefficient [Not binnable]	None	0.33
MJSWG	Gate-edge sidewall bulk junction grading coefficient [Not binnable]	Volt	MJSW

N (**NJ**)	Emission coefficient [Not binnable]	None	1
NDS	Reverse bias slope coefficient	None	1.0
PB	Bulk junction contact potential [Not binnable]	Volt	1.0
PBSW (**PHP**)	Sidewall bulk junction contact potential [Not binnable]	Volt	1.0
PBSWG	Gate-edge sidewall bulk junction contact potential [Not binnable]	Volt	PBSW
TT	Transition time	Second	0.0
VNDS	Reverse diode current transition point	Volt	-1.0

Table 52: Level 49 or 53 MOSFET Nonquasistatic (NQS) Model Parameter

Model Parameter	**Description**	**Unit**	**Default**
ELM	Elmore constant	None	5.0

Table 53: Level 49 or 53 MOSFET Stress Effect Model Parameter

Model Parameter	**Description**	**Unit**	**Default**
STIMOD	Stress effect model selector	None	0.0
SAREF (**SA0**)	Reference distance between OD edge to poly of the one side	Meter	1.0e-6
SBREF (**SB0**)	Reference distance between OD edge to poly of the other side	Meter	1.0e-6
WLOD	Width parameter for stress effect	Meter	0.0
KU0	Mobility degradation enhancement coefficient for stress effect	Meter	0.0
KVSAT	Saturation velocity enhancement coefficient for stress effect	Meter	0.0
KVTH0	Threshold shift parameter for stress effect	Volt-Meter	0.0

TKU0	Temperature coefficient of KU0	None	0.0
LLODKU0	Length parameter for U0 stress effect	None	0.0
WLODKU0	Width parameter for U0 stress effect	None	0.0
LLODVTH	Length parameter for Vth stress effect	None	0.0
WLODVTH	Width parameter for Vth stress effect	None	0.0
LKU0	Length dependence of KU0	Meter^{LLODKU0}	0.0
WKU0	Width dependence of KU0	Meter^{WLODKU0}	0.0
PKU0	Cross-term dependence of KU0	Meter$^{LLODKU0+WLODKU0}$	0.0
LKVTH0	Length dependence of KVTH0	Meter^{LLODVTH}	0.0
WKUVTH0	Width dependence of KVTH0	Meter^{WLODVTH}	0.0
PKVTH0	Cross-term dependence of KVTH0	Meter$^{LLODVTH+WLODVTH}$	0.0
STK2	K2 shift factor related to Vth0 change	Meter	0.0
LODK2	K2 shift modification actorfor stress effect	None	1.0
STETA0	ETA0 shift factor related to Vth0 change	Meter	0.0
LODETA0	ETA0 shift modification actorfor stress effect	None	1.0

The unit for the length dependence parameters is the unit of the basic parameter divided by Meter.

Table 54: Level 49 or 53 Length Dependence Parameters

Model Parameter	**Description**	**Default**
La0	Length dependence of a0	0.0
La1	Length dependence of a1	0.0
La2	Length dependence of a2	0.0
Lacde	Length dependence of acde	0.0
Lags	Length dependence of ags	0.0
Lalpha0	Length dependence of alpha0	0.0
Lalpha1	Length dependence of alpha1	0.0
Lat	Length dependence of at	0.0
Lb0	Length dependence of b0	0.0
Lb1	Length dependence of b1	0.0

Lbeta0	Length dependence of beta0	0.0
Lcdsc	Length dependence of cdsc	0.0
Lcdscb	Length dependence of cdscb	0.0
Lcdscd	Length dependence of cdscd	0.0
Lcf	Length dependence of cf	0.0
Lcgdl	Length dependence of cgdl	0.0
Lcgsl	Length dependence of cgsl	0.0
Lcit	Length dependence of cit	0.0
Lckappa	Length dependence of ckappa	0.0
Lclc	Length dependence of clc	0.0
Lcle	Length dependence of cle	0.0
Ldelta	Length dependence of delta	0.0
Ldrout	Length dependence of drout	0.0
Ldsub	Length dependence of dsub	0.0
Ldvt0	Length dependence of dvt0	0.0
Ldvt0w	Length dependence of dvt0w	0.0
Ldvt1	Length dependence of dvt1	0.0
Ldvt1w	Length dependence of dvt1w	0.0
Ldvt2	Length dependence of dvt2	0.0
Ldvt2w	Length dependence of dvt2w	0.0
Ldwb	Length dependence of dwb	0.0
Ldwg	Length dependence of dwg	0.0
Lelm	Length dependence of elm	0.0
Leta0	Length dependence of eta0	0.0
Letab	Length dependence of etab	0.0
Lgamma1	Length dependence of gamma1	0.0
Lgamma2	Length dependence of gamma2	0.0
Lk1	Length dependence of k1	0.0
Lk2	Length dependence of k2	0.0
Lk3	Length dependence of k3	0.0
Lk3b	Length dependence of k3b	0.0
Lketa	Length dependence of keta	0.0

Lkt1	Length dependence of kt1	0.0
Lkt1l	Length dependence of kt1l	0.0
Lkt2	Length dependence of kt2	0.0
Lmoin	Length dependence of moin	0.0
Lnch (**Lnpeak**)	Length dependence of nch	0.0
Lnfactor	Length dependence of nfactor	0.0
Lngate	Length dependence of ngate	0.0
Lnlx	Length dependence of nlx	0.0
Lnoff	Length dependence of noff	0.0
Lnsub	Length dependence of nsub	0.0
Lpclm	Length dependence of pclm	0.0
Lpdibl1	Length dependence of Pdibl1	0.0
Lpdibl2	Length dependence of Pdibl2	0.0
Lpdiblb	Length dependence of Pdiblb	0.0
Lprt	Length dependence of prt	0.0
Lprwb	Length dependence of prwb	0.0
Lprwg	Length dependence of prwg	0.0
Lpscbe1	Length dependence of pscbe1	0.0
Lpscbe2	Length dependence of pscbe2	0.0
Lpvag	Length dependence of pvag	0.0
Lrdsw	Length dependence of rdsw	0.0
Lu0	Length dependence of u0	0.0
Lua	Length dependence of ua	0.0
Lua1	Length dependence of ua1	0.0
Lub	Length dependence of ub	0.0
Lub1	Length dependence of ub1	0.0
Luc	Length dependence of uc	0.0
Luc1	Length dependence of uc1	0.0
Lute	Length dependence of ute	0.0
Lvbm	Length dependence of vbm	0.0
Lvbx	Length dependence of vbx	0.0

Lvfb	Length dependence of vfb	0.0
Lvfbcv	Length dependence of vfbcv	0.0
Lvoff	Length dependence of voff	0.0
Lvoffcv	Length dependence of voffcv	0.0
Lvsat	Length dependence of vsat	0.0
Lvth0	Length dependence of vth0	0.0
Lw0	Length dependence of w0	0.0
Lwr	Length dependence of wr	0.0
Lxj	Length dependence of xj	0.0
Lxt	Length dependence of xt	0.0

The unit for the width dependence parameters is the unit of the basic parameter divided by Meter.

Table 55: Level 49 or 53 Width Dependence Model Parameters

Model Parameter	**Description**	**Default**
Wa0	Width dependence of a0	0.0
Wa1	Width dependence of a1	0.0
Wa2	Width dependence of a2	0.0
Wacde	Width dependence of acde	0.0
Wags	Width dependence of ags	0.0
Walpha0	Width dependence of alpha0	0.0
Walpha1	Width dependence of alpha1	0.0
Wat	Width dependence of at	0.0
Wb0	Width dependence of b0	0.0
Wb1	Width dependence of b1	0.0
Wbeta0	Width dependence of beta0	0.0
Wcdsc	Width dependence of cdsc	0.0
Wcdscb	Width dependence of cdscb	0.0
Wcdscd	Width dependence of cdscd	0.0
Wcf	Width dependence of cf	0.0

Wcgdl	Width dependence of cgdl	0.0
Wcgsl	Width dependence of cgsl	0.0
Wcit	Width dependence of cit	0.0
Wckappa	Width dependence of ckappa	0.0
Wclc	Width dependence of clc	0.0
Wcle	Width dependence of cle	0.0
Wdelta	Width dependence of delta	0.0
Wdrout	Width dependence of drout	0.0
Wdsub	Width dependence of dsub	0.0
Wdvt0	Width dependence of dvt0	0.0
Wdvt0w	Width dependence of dvt0w	0.0
Wdvt1	Width dependence of dvt1	0.0
Wdvt1w	Width dependence of dvt1w	0.0
Wdvt2	Width dependence of dvt2	0.0
Wdvt2w	Width dependence of dvt2w	0.0
Wdwb	Width dependence of dwb	0.0
Wdwg	Width dependence of dwg	0.0
Welm	Width dependence of elm	0.0
Weta0	Width dependence of eta0	0.0
Wetab	Width dependence of etab	0.0
Wgamma1	Width dependence of gamma1	0.0
Wgamma2	Width dependence of gamma2	0.0
Wk1	Width dependence of k1	0.0
Wk2	Width dependence of k2	0.0
Wk3	Width dependence of k3	0.0
Wk3b	Width dependence of k3b	0.0
Wketa	Width dependence of keta	0.0
Wkt1	Width dependence of kt1	0.0
Wkt1l	Width dependence of kt1l	0.0
Wkt2	Width dependence of kt2	0.0
Wmoin	Width dependence of moin	0.0
Wnch (**Wnpeak**)	Width dependence of nch	0.0

Wnfactor	Width dependence of nfactor	0.0
Wngate	Width dependence of ngate	0.0
Wnlx	Width dependence of nlx	0.0
Wnoff	Width dependence of noff	0.0
Wnsub	Width dependence of nsub	0.0
Wpclm	Width dependence of pclm	0.0
Wpdibl1	Width dependence of Pdibl1	0.0
Wpdibl2	Width dependence of Pdibl2	0.0
Wpdiblb	Width dependence of Pdiblb	0.0
Wprt	Width dependence of prt	0.0
Wprwb	Width dependence of prwb	0.0
Wprwg	Width dependence of prwg	0.0
Wpscbe1	Width dependence of pscbe1	0.0
Wpscbe2	Width dependence of pscbe2	0.0
Wpvag	Width dependence of pvag	0.0
Wrdsw	Width dependence of rdsw	0.0
Wu0	Width dependence of u0	0.0
Wua	Width dependence of ua	0.0
Wua1	Width dependence of ua1	0.0
Wub	Width dependence of ub	0.0
Wub1	Width dependence of ub1	0.0
Wuc	Width dependence of uc	0.0
Wuc1	Width dependence of uc1	0.0
Wute	Width dependence of ute	0.0
Wvbm	Width dependence of vbm	0.0
Wvbx	Width dependence of vbx	0.0
Wvfb	Width dependence of vfb	0.0
Wvfbcv	Width dependence of vfbcv	0.0
Wvoff	Width dependence of voff	0.0
Wvoffcv	Width dependence of voffcv	0.0
Wvsat	Width dependence of vsat	0.0
Wvth0	Width dependence of vth0	0.0

Ww0	Width dependence of w0	0.0
Wwr	Width dependence of wr	0.0
Wxj	Width dependence of xj	0.0
Wxt	Width dependence of xt	0.0

The unit for cross dependence parameters is the unit of the basic parameter divided by Meter^2.

Table 56: Level 49 or 53 MOSFET Cross Dependence Model Parameters

Model Parameter	Description	Default
Pa0	Cross dependence of a0	0.0
Pa1	Cross dependence of a1	0.0
Pa2	Cross dependence of a2	0.0
Pacde	Cross dependence of acde	0.0
Pags	Cross dependence of ags	0.0
Palpha0	Cross dependence of alpha0	0.0
Palpha1	Cross dependence of alpha1	0.0
Pat	Cross dependence of at	0.0
Pb0	Cross dependence of b0	0.0
Pb1	Cross dependence of b1	0.0
Pbeta0	Cross dependence of beta0	0.0
Pcdsc	Cross dependence of cdsc	0.0
Pcdscb	Cross dependence of cdscb	0.0
Pcdscd	Cross dependence of cdscd	0.0
Pcf	Cross dependence of cf	0.0
Pcgdl	Cross dependence of cgdl	0.0
Pcgsl	Cross dependence of cgsl	0.0
Pcit	Cross dependence of cit	0.0
Pckappa	Cross dependence of ckappa	0.0
Pclc	Cross dependence of clc	0.0
Pcle	Cross dependence of cle	0.0
Pdelta	Cross dependence of delta	0.0

Pdrout	Cross dependence of drout	0.0
Pdsub	Cross dependence of dsub	0.0
Pdvt0	Cross dependence of dvt0	0.0
Pdvt0w	Cross dependence of dvt0w	0.0
Pdvt1	Cross dependence of dvt1	0.0
Pdvt1w	Cross dependence of dvt1w	0.0
Pdvt2	Cross dependence of dvt2	0.0
Pdvt2w	Cross dependence of dvt2w	0.0
Pdwb	Cross dependence of dwb	0.0
Pdwg	Cross dependence of dwg	0.0
Pelm	Cross dependence of elm	0.0
Peta0	Cross dependence of eta0	0.0
Petab	Cross dependence of etab	0.0
Pgamma1	Cross dependence of gamma1	0.0
Pgamma2	Cross dependence of gamma2	0.0
Pk1	Cross dependence of k1	0.0
Pk2	Cross dependence of k2	0.0
Pk3	Cross dependence of k3	0.0
Pk3b	Cross dependence of k3b	0.0
Pketa	Cross dependence of keta	0.0
Pkt1	Cross dependence of kt1	0.0
Pkt1l	Cross dependence of kt1l	0.0
Pkt2	Cross dependence of kt2	0.0
Pmoin	Cross dependence of moin	0.0
Pnch	Cross dependence of nch	0.0
Pnfactor	Cross dependence of nfactor	0.0
Pngate	Cross dependence of ngate	0.0
Pnlx	Cross dependence of nlx	0.0
Pnoff	Cross dependence of noff	0.0
Pnsub	Cross dependence of nsub	0.0
Ppclm	Cross dependence of pclm	0.0
Ppdiblc1 (**Ppdibl1**)	Cross dependence of Pdiblc1	0.0

Ppdiblc2 (**Ppdibl2**)	Cross dependence of Pdiblc2	0.0
Ppdiblcb (**Ppdiblb**)	Cross dependence of Pdiblcb	0.0
Pprt	Cross dependence of prt	0.0
Pprwb	Cross dependence of prwb	0.0
Pprwg	Cross dependence of prwg	0.0
Ppscbe1	Cross dependence of pscbe1	0.0
Ppscbe2	Cross dependence of pscbe2	0.0
Ppvag	Cross dependence of pvag	0.0
Prdsw	Cross dependence of rdsw	0.0
Pu0	Cross dependence of u0	0.0
Pua	Cross dependence of ua	0.0
Pua1	Cross dependence of ua1	0.0
Pub	Cross dependence of ub	0.0
Pub1	Cross dependence of ub1	0.0
Puc	Cross dependence of uc	0.0
Puc1	Cross dependence of uc1	0.0
Pute	Cross dependence of ute	0.0
Pvbm	Cross dependence of vbm	0.0
Pvbx	Cross dependence of vbx	0.0
Pvfb	Cross dependence of vfb	0.0
Pvfbcv	Cross dependence of vfbcv	0.0
Pvoff	Cross dependence of voff	0.0
Pvoffcv	Cross dependence of voffcv	0.0
Pvsat	Cross dependence of vsat	0.0
Pvth0	Cross dependence of vth0	0.0
Pw0	Cross dependence of w0	0.0
Pwr	Cross dependence of wr	0.0
Pxj	Cross dependence of xj	0.0
Pxt	Cross dependence of xt	0.0

BSIM3v3 MOSFET Model Netlist Examples

```
.model nenh nmos
```

```
+Level=49 VERSION=3.22

+Tnom=27.0 capmod=3 paramchk=0 mobmod=1

+Nch=1e+16  Tox=5E-08 Xj=3.85E-08

+Lint=9.36e-8 Wint=0

+Vth0= .779    K1=1.04  K2= -3.83e-2  K3=50

+Dvt0= 2.812  Dvt1= 0.462  Dvt2=-9.17e-2

+Nlx= 3.52291E-08  W0= 1.163e-6

+K3b= 2.233

+Vsat= 86301.58  Ua= 6.47e-9  Ub= 4.23e-18  Uc=-4.706281E-11

+U0=400 wr=1

+A0= .3496967 Ags=.1    B0=0.546    B1= 1

+ Dwg = -6.0E-09 Dwb = -3.56E-09 Prwb = -.213

+Keta=-3.605872E-02  A1= 2.778747E-02  A2= .9

+Voff=-6.735529E-02  NFactor= 1.139926  Cit= 1.622527E-04

+cj=0.00042 mj=0.5 pb=1.0

+cjsw=9e-12 mjsw=0.33 pbsw=1.0

+cjswg=9e-12 mjswg=0.33 pbswg=1.0

+cgsl=5.0e-10 ckappa=0.6

+cgdl=3.6e-10

+cf=0.0 cgso=5.2e-10 cgdo=5.2e-10

+cgbo=4.0e-10

+Cdsc=2.4e-4

+Cdscb= 0  Dvt0w =  0 Dvt1w =  0 Dvt2w =  0

+Cdscd =  0 Prwg =  0

+dlc=9.36e-8 dwc=0.0

+Eta0= 1.0281729E-02  Etab=-5.042203E-03

+Dsub= .31871233
```

```
+Pclm= 1.114846  Pdiblc1= 2.45357E-03  Pdiblc2= 6.406289E-03

+Drout= .31871233  Pscbe1= 5000000  Pscbe2= 5E-09

+Pdiblcb = -.234

+Pvag= 0 delta=0.01

+Wl =  0 Ww =0 Wwl =  0

+Wln =  0 Wwn =  .2613948 Ll =0.0

+Lw =  0 Lwl =  0 Lln =  .316394

+Lwn =  0

+kt1=-.3  kt2=-.051

+At= 22400

+Ute=-1.48

+Ua1= 3.31E-10  Ub1= 2.61E-19 Uc1= -3.42e-10

+Kt1l=0 Prt=764.3

+xpart=0.2

+JS =1e-2 JSW=0

+VFBCV=-1 VFB=-1
```

BSIM3v3.3 Model Equations

1. I-V Model Equations

1.1 Threshold Voltage

$$
\begin{aligned}
V_{th} = {} & V_{th0ox} + K_{1ox} \cdot \sqrt{\Phi_s - V_{bseff}} - K_{2ox} V_{bseff} + K_{1ox}\left(\sqrt{1 + \frac{Nlx}{L_{eff}}} - ?\right)\sqrt{\Phi_s} \\
& + (K_3 + K_{3b} V_{bseff}) \frac{T}{W_{eff} + W_0} \Phi_s \\
& - D_{VT0w}\left(\exp\left(-D_{VT1w} \frac{W_{eff} L_{eff}}{2 l_{tw}}\right) + 2\exp\left(-D_{VT1w} \frac{W_{eff} L_{eff}}{l_{tw}}\right)\right)(V_{bi} - \Phi_s) \\
& - D_{VT0}\left(\exp\left(-D_{VT1} \frac{L_{eff}}{2 l_t}\right) + 2\exp\left(-D_{VT1} \frac{L_{eff}}{l_t}\right)\right)(V_{bi} - \Phi_s) \\
& - \left(\exp\left(-D_{sub} \frac{L_{eff}}{2 l_{to}}\right) + 2\exp\left(-D_{sub} \frac{L_{eff}}{l_{to}}\right)\right)(E_{tao} + E_{tab} V_{bseff}) V_{ds}
\end{aligned}
$$

$$V_{th0ox} = V_{th0} - (K_1 \cdot \sqrt{\Phi_s})$$

$$K_{1ox} = K_1 \cdot \frac{T_{ox}}{T_{oxm}}$$

$$K_{2ox} = K_2 \cdot \frac{T_{ox}}{T_{oxm}}$$

$$l_t = \sqrt{\varepsilon_{si} X_{dep} / C_{ox}} \times (1 + D_{VT2} V_{bseff})$$

$$l_{tw} = \sqrt{\varepsilon_{si} X_{dep} / C_{ox}} \times (1 + D_{VT2w} V_{bseff})$$

$$l_{to} = \sqrt{\varepsilon_{si} X_{dep0} / C_{ox}} \quad X_{dep} = \sqrt{\frac{2\varepsilon_{si}(\Phi s - V_{bseff})}{qN_{ch}}}$$

$$X_{dep0} = \sqrt{\frac{2\varepsilon_{si}\Phi s}{qN_{ch}}}$$

$$V_{bseff} = V_{bc} + 0.5[V_{bs} - V_{bc} - \delta_1 + \sqrt{(V_{bs} - V_{bc} - \delta_1)^2 - 4\delta_1 V_{bc}}]$$

δ_1=0.001

$$V_{bc} = 0.9\left(\Phi_s - \frac{K_1^2}{4K_2^2}\right)$$

$$V_{bi} = V_t \ln\left(\frac{N_{ch}N_{DS}}{n_i^2}\right)$$

1.2 Effective (V_{gs}-V_{th})

$$V_{gseff} = \frac{2nv_t \ln\left[1 + \exp\left(\frac{V_{gs} - V_{th}}{2nv_t}\right)\right]}{1 + 2nC_{OX}\sqrt{\frac{2\Phi_s}{q\varepsilon_{si}N_{ch}}} \times \exp\left(-\frac{V_{gs} - V_{th} - 2V_{off}}{2nv_t}\right)}$$

$$n = 1 + N_{factor}\frac{C_d}{C_{ox}} + \frac{(C_{dsc} + C_{dscd}V_{ds} + C_{dscb}V_{bseff})\left(\exp\left(-D_{VT1}\frac{L_{eff}}{2l_t}\right) + 2\exp\left(-D_{VT1}\frac{L_{eff}}{l_t}\right)\right)}{C_{ox}} + \frac{C_{it}}{C_{ox}}$$

$$C_d = \frac{\varepsilon_{si}}{X_{dep}}$$

1.3 Mobility

For MOBMOD = 1:

$$\mu_{eff} = \frac{\mu_0}{1 + (U_a + U_c V_{bseff})\left(\frac{V_{gseff} + 2V_{th}}{T_{OX}}\right) + U_b\left(\frac{V_{gsteff} + 2V_{th}}{T_{OX}}\right)^2}$$

For MOBMOD = 2:

$$\mu_{eff} = \frac{\mu_0}{1 + (U_a + U_c V_{bseff})\left(\frac{V_{gseff}}{T_{OX}}\right) + U_b\left(\frac{V_{gsteff}}{T_{OX}}\right)^2}$$

For MOBMOD = 3:

$$\mu_{eff} = \frac{\mu_0}{1 + \left[U_a\left(\frac{V_{gseff} + 2V_{th}}{T_{OX}}\right) + U_b\left(\frac{V_{gsteff} + 2V_{th}}{T_{OX}}\right)^2\right](1 + UcV_{bseff})}$$

1.4 Drain Saturation Voltage

For $R_{ds} > 0$ or ƛ ≠ 1:

$$V_{dsat} = \frac{-b - \sqrt{b^2 - 4ac}}{2a}$$

$$a = A_{bulk}^2 W_{eff} \nu_{sat} C_{ox} R_{DS} + \left(\frac{1}{\lambda} - 1\right) A_{bulk}$$

$$b = -\left((V_{gsteff} + 2V_t)\left(\frac{2}{\lambda} - 1\right) + A_{bulk} E_{sat} L_{eff} + 3A_{bulk}(Vgsteff + 2\nu_t) W_{eff} \nu_{sat} C_{ox} R_{DS}\right)$$

$$c = (V_{gsteff} + 2V_t) E_{sat} L_{eff} + 2(Vgsteff + 2\nu_t)^2 W_{eff} \nu_{sat} C_{ox} R_{DS}$$

ƛ = $A_1 V_{\text{gsteff}} + A_2$

For $R_{ds} = 0$ and ƛ = 1:

$$V_{dsat} = \frac{E_{sat} L_{eff} (V_{gsteff} + 2\nu_t)}{A_{bulk} E_{sat} Leff + (V_{gsteff} + 2\nu_t)}$$

$$A_{bulk} = \left(1 + \frac{K_{1ox}}{2\sqrt{\Phi_s - V_{bseff}}}\left(\frac{A_0 L_{eff}}{L_{eff} + 2\sqrt{X_J X_{dep}}}\left(1 - A_{gs} V_{gsteff}\left(\frac{L_{eff}}{L_{eff} + 2\sqrt{X_J X_{dep}}}\right)^2\right) + \frac{B_0}{W_{eff} + B_1}\right)\right) \cdot \frac{1}{1 + KetaV_{bseff}}$$

$$E_{sat} = \frac{2V_{sat}}{\mu_{eff}}$$

1.5 Effective V $_{ds}$

$$V_{dseff} = V_{dsat} - 0.5(V_{dsat} - V_{ds} - \delta + \sqrt{(V_{dsat} - V_{ds} - \delta)^2 + 4\delta V_{dsat}})$$

1.6 Drain Current Expression

$$I_{ds} = \frac{I_{dso(Vdseff)}}{1 + \frac{R_{ds} I_{dso(Vdseff)}}{V_{dseff}}}\left(1 + \frac{V_{ds} - V_{dseff}}{V_A}\right)\left(1 + \frac{V_{ds} - V_{dseff}}{V_{ASCBE}}\right)$$

$$I_{dso} = \frac{W_{eff}\mu_{eff} C_{ox} V_{gsteff}\left(1 - A_{bulk}\frac{V_{dseff}}{2V_{gsteff} + 2\nu_t}\right) V_{dseff}}{L_{eff}[1 + V_{dseff}/(E_{sat} L_{eff})]}$$

$$V_A = V_{Asat} + \left(1 + \frac{P_{vag} Vgsteff}{E_{sat} L_{eff}}\right)\left(\frac{1}{V_{ACLM}} + \frac{1}{V_{ADIBLC}}\right)^{-1}$$

$$V_{ACLM} = \frac{A_{bulk} E_{sat} L_{eff} + V_{gsteff}}{P_{CLM} A_{bulk} E_{sat} litl}(V_{ds} - V_{dseff})$$

$$V_{ADIBLC} = \frac{V_{gsteff} + 2\nu_t}{\theta_{rout}(1 + P_{DIBLCB} V_{bseff})}\left(1 - \frac{A_{bulk} V_{dsat}}{A_{bulk} V_{dsat} + V_{gsteff} + 2\nu_t}\right)$$

$$\theta_{rout} = P_{DIBLC1}\left[\exp\left(-D_{ROUT}\frac{L_{eff}}{2 l_{t0}}\right) + 2\exp\left(-D_{ROUT}\frac{L_{eff}}{l_{t0}}\right)\right] + P_{DIBLC2}$$

$$\frac{1}{V_{ASCBE}} = \frac{P_{scbe2}}{L_{eff}}\exp\left(\frac{-P_{scbe1} litl}{V_{ds} - V_{dseff}}\right)$$

$$V_{Asat} = \frac{E_{sat} L_{eff} + V_{dsat} + 2R_{DS}\nu_{sat} C_{ox} W_{eff} V_{gsteff}\left[1 - \frac{A_{bulk} V_{dsat}}{2(V_{gsteff} + 2\nu_t)}\right]}{2/\lambda - 1 + R_{DS}\nu_{sat} C_{ox} W_{eff} A_{bulk}}$$

$$litl = \sqrt{\frac{\varepsilon_{si} T_{ox} X_j}{\varepsilon_{ox}}}$$

1.7 Substrate Current

$$I_{sub} = \frac{\alpha_0 + \alpha_1 \cdot L_{eff}}{L_{eff}}(V_{ds} - V_{dseff}) \exp\left(-\frac{\beta_0}{V_{ds} - V_{dseff}}\right) \frac{I_{ds0}}{1 + \frac{R_{ds} I_{ds0}}{V_{dseff}}}\left(1 + \frac{V_{ds} - V_{dseff}}{V_A}\right)$$

1.8 Polysilicon Depletion Effect

$$V_{poly} = 0.5 X_{poly} E_{poly} = \frac{q N_{gate} X_{poly}^2}{2\varepsilon_{si}}$$

$$\varepsilon_{ox} E_{ox} = \varepsilon_{si} E_{poly} = \sqrt{2q\varepsilon_{si} N_{gate} Vpoly}$$

$$V_{gs} - V_{FB} - \Phi_s = V_{poly} + V_{ox}\, a(V_{gs} - V_{FB} - \Phi_s - V_{poly})^2 - V_{poly} = 0$$

$$a = \frac{\varepsilon_{ox}^2}{2q\varepsilon_{si} N_{gate} T_{ox}^2}$$

$$V_{gseff} = V_{FB} + \Phi_s + \frac{q\varepsilon_{si} N_{gate} T_{ox}^2}{\varepsilon_{ox}^2}\left(\sqrt{1 + \frac{2\varepsilon_{ox}^2 (V_{gs} - V_{FB} - \Phi_s)}{q\varepsilon_{si} N_{gate} T_{ox}^2}} - 1\right)$$

1.9 Effective Channel Length and Width

$L_{eff} = L_{drawn} - 2dL$

$W_{eff} = W_{drawn} - 2dW$

$W'_{eff} = W_{drawn} - 2dW'$

$$dW = dW' + dW_g V_{gsteff} + dW'(\sqrt{\Phi_s - V_{bseff}} - \sqrt{\Phi_s})$$

$$dW' = W_{int} + \frac{W_l}{L^{Wln}} + \frac{W_w}{W^{Wwn}} + \frac{W_{wl}}{L^{Wln} W^{Wwn}}$$

$$dL = L_{int} + \frac{L_l}{L^{Lln}} + \frac{L_w}{W^{Lwn}} + \frac{L_{wl}}{L^{Lln} W^{Wwn}}$$

1.10 Source/Drain Resistance

$$R_{ds} = \frac{R_{dsw}(1 + P_{rwg} V_{gsteff} + P(\sqrt{\Phi_s - V_{bseff}} - \sqrt{\Phi_s}))}{(10^6 W'_{eff})^{W_r}}$$

1.11 Temperature Effects

$$V_{th(T)} = V_{th(Tnorm)} + (K_{T1} + K_{t1l}/L_{eff})(T/T_{norm} - 1)$$

$$\mu_{o(T)} = \mu_{o(Tnorm)} \left(\frac{T}{T_{norm}}\right)^{\mu_e}$$

$$\nu_{sat(T)} = \nu_{sat(Tnorm)} - A_T(T/T_{norm} - 1)$$

$$R_{dsw(T)} = R_{dsw}(T_{norm}) + P_{rt}(T/T_{norm} - 1)$$

$$U_{a(T)} = U_{a(Tnorm)} + U_{a1}(T/T_{norm} - 1)$$

$$U_{b(T)} = U_{b(Tnorm)} + U_{b1}(T/T_{norm} - 1)$$

$$U_{c(T)} = U_{c(Tnorm)} + U_{c1}(T/T_{norm} - 1)$$

2. Capacitance Model Equations

2.1 Dimension Dependence

$$L_{active} = L_{drawn} - 2\delta L_{eff}$$

$$W_{active} = W_{drawn} - 2\delta W_{eff}$$

$$\delta L_{eff} = DLC + \frac{Llc}{L^{Lln}} + \frac{Lwc}{W^{Lwn}} + \frac{Lwlc}{L^{Lln}W^{Lwn}}$$

$$\delta W_{eff} = DWC + \frac{Wlc}{L^{Wln}} + \frac{Wwc}{W^{Wwn}} + \frac{Wwlc}{L^{Wln}W^{Wwn}}$$

2.2 Overlap Capacitance

2.2.1 Source Overlap Capacitance

2.2.1.1 For CAPMOD = 0:

$$\frac{Q_{overlap,s}}{W_{active}} = CGS0 \times V_{gs}$$

2.2.1.2 For CAPMOD = 1

2.2.1.2.1 For $V_{gs} < 0$:

$$\frac{Q_{overlap,s}}{W_{active}} = CGS0 \times V_{gs} + \frac{CKAPPA \cdot CGS1}{2}\left(-1 + \sqrt{1 - \frac{4V_{gs}}{CKAPPA}}\right)$$

2.2.1.2.2 For Vgs ≥ 0:

$$\frac{Q_{overlap,s}}{W_{active}} = (CGS0 + CKAPPA + CGS1) \cdot V_{gs}$$

2.2.1.3 For CAPMOD = 2

$$\frac{Q_{overlap,s}}{W_{active}} = CGS0 \cdot V_{gs} + CGS1\left(V_{gs} - V_{gs,overlap} - \frac{CKAPPA}{2}\left(-1 + \sqrt{1 - \frac{4V_{gs,overlap}}{CKAPPA}}\right)\right)$$

$$V_{gs,overlap} = 0.5\left(V_{gs} + \delta_1 - \sqrt{(V_{gs} + \delta_1)^2 + 4\delta_1}\right),\ \delta_1 = 0.02$$

2.2.2 Drain Overlap Capacitance

2.2.2.1 For CAPMOD = 0:

$$\frac{Q_{overlap,d}}{W_{active}} = CGD0 \times V_{gd}$$

2.2.2.2 For CAPMOD = 1

2.2.2.2.1 If $V_{gd} < 0$:

$$\frac{Q_{overlap,d}}{W_{active}} = CGD0 \times V_{gd} + \frac{CKAPPA \cdot CGD1}{2}\left(-1 + \sqrt{1 - \frac{4V_{gd}}{CKAPPA}}\right)$$

2.2.2.2.2 If $V_{gd} \geq 0$:

$$\frac{Q_{overlap,d}}{W_{active}} = (CGD0 + CKAPPA + CGD1) \cdot V_{gd}$$

2.2.2.3 For CAPMOD = 2:

$$\frac{Q_{overlap,d}}{W_{active}} = CGD0 \cdot V_{gd} + CGD1\left(V_{gd} - V_{gd,overlap} - \frac{CKAPPA}{2}\left(-1 + \sqrt{1 - \frac{4V_{gd,overlap}}{CKAPPA}}\right)\right)$$

$$V_{gd,overlap} = 0.5\left(V_{gd} + \delta_1 - \sqrt{(V_{gd} + \delta_1)^2 + 4\delta_1}\right),\ \delta_1 = 0.02$$

2.2.3 Gate Overlap Charge

$$Q_{overlap,g} = -(Q_{overlap,s} + Q_{overlap,d})$$

2.3 Intrinsic Charges:

2.3.1 For CAPMOD = 0

2.3.1.1 Accumulation Region ($V_{gs} < V_{fbcv} + V_{bs}$)

$$Q_g = W_{active}L_{active}C_{ox}(V_{gs} - V_{bs} - V_{fbcv})$$

$Q_{sub} = -Q_g$

$Q_{inv} = 0$

2.3.1.2 Subthreshold Region ($V_{gs} < V_{th}$)

$$Q_{sub0} = -W_{active}L_{active}C_{ox}\cdot\frac{K_{1ox}^2}{2}\left(-1+\sqrt{1+\frac{4(V_{gs}-V_{fbcv}-V_{bs})}{K_{1ox}^2}}\right)$$

$Q_g = -Q_b$

$Q_{inv} = 0$

2.3.1.3 Strong Inversion Region ($V_{gs} > V_{th}$)

$$V_{dsat,cv} = \frac{V_{gs}-V_{th}}{A'_{bulk}}\quad A'_{bulk} = A_{bulk0}\left(1+\left(\frac{CLC}{L_{eff}}\right)^{CLE}\right)$$

$$A_{bulk0} = \left(1+\frac{K_{1ox}}{2\sqrt{\Phi_s-V_{bseff}}}\left(\frac{A_0L_{eff}}{L_{eff}+2\sqrt{X_JX_{dep}}}+\frac{B_0}{W_{eff}+B_1}\right)\right)\cdot\frac{1}{1+KetaV_{bseff}}$$

$$V_{th} = V_{fbcv}+\Phi_s+K_{1ox}\sqrt{\Phi_s-V_{bseff}}$$

2.3.1.3.1 50/50 Charge Partition

2.3.1.3.1.1 If $V_{ds} < V_{dsat}$

$$Q_g = C_{ox}W_{active}L_{active}\left(V_{gs}-V_{fbcv}-\Phi_s-\frac{V_{ds}}{2}+\frac{A'_{bulk}V^2_{ds}}{12\left(V_{gs}-V_{th}-\frac{A'_{bulk}V_{ds}}{2}\right)}\right)$$

$$Q_{inv} = -C_{ox}W_{active}L_{active}\left(V_{gs} - V_{th} - \Phi_s - \frac{A'_{bulk}V_{ds}}{2} + \frac{A'^2_{bulk}V^2_{ds}}{12\left(V_{gs} - V_{th} - \frac{A'_{bulk}V_{ds}}{2}\right)}\right)$$

$$Q_b = C_{ox}W_{active}L_{active}\left(V_{fb} - V_{th} + \Phi_s - \frac{(1 + A'_{bulk})V_{ds}}{2} + \frac{(1 + A'_{bulk})A'_{bulk}V^2_{ds}}{12\left(V_{gs} - V_{th} - \frac{A'_{bulk}V_{ds}}{2}\right)}\right)$$

$$Q_s = Q_d = 0.5Q_{inv} = \frac{-C_{ox}W_{active}L_{active}}{2}\left(V_{gs} - V_{th} - \Phi_s - \frac{A'_{bulk}V_{ds}}{2} + \frac{A'^2_{bulk}V^2_{ds}}{12\left(V_{gs} - V_{th} - \frac{A'_{bulk}V_{ds}}{2}\right)}\right)$$

2.3.1.3.1.2 Else ($V_{ds} \geq V_{dsat}$)

$$Q_g = W_{active}L_{active}C_{ox}\left(V_{gs} - V_{fb} - \Phi_s - \frac{V_{dsat}}{3}\right)$$

$$Q_s = Q_d = \frac{W_{active}L_{active}C_{ox}(V_{gs} - V_{th})}{3}$$

$$Q_b = -W_{active}L_{active}C_{ox}\left(V_{fb} + \Phi_s - V_{th} + \frac{(1 - A'_{bulk})V_{dsat}}{3}\right)$$

2.3.1.3.2 Strong Inversion Region ($V_{gs} > V_{th}$): 40/60 Charge Partition

2.3.1.3.2.1 If $V_{ds} < V_{dsat}$

$$Q_g = C_{ox} W_{active} L_{active} \left(V_{gs} - V_{fb} - \Phi_s - \frac{V_{ds}}{2} + \frac{A'_{bulk} V^2_{ds}}{12\left(V_{gs} - V_{th} - \frac{A'_{bulk} V_{ds}}{2} \right)} \right)$$

$$Q_{inv} = -C_{ox} W_{active} L_{active} \left(V_{gs} - V_{th} - \frac{A'_{bulk} V_{ds}}{2} + \frac{A'^2_{bulk} V^2_{ds}}{12\left(V_{gs} - V_{th} - \frac{A'_{bulk} V_{ds}}{2} \right)} \right)$$

$$Q_b = C_{ox} W_{active} L_{active} \left(V_{fb} - V_{th} + \Phi_s + \frac{(1 + A'_{bulk}) V_{ds}}{2} - \frac{(1 - A'_{bulk}) A'_{bulk} V^2_{ds}}{12\left(V_{gs} - V_{th} - \frac{A'_{bulk} V_{ds}}{2} \right)} \right)$$

$$Q_d = -WLC \left[\frac{V_{gs} - V_{th}}{2} - \frac{A'_{bulk} V_{ds}}{2} + \frac{AV\left[\frac{(V_{gs} - V_{th})^2}{6} - \frac{A'_{bulk} V_{ds} (V_{gs} - V_{th})}{8} + \frac{(A'_{bulk} V_{ds})^2}{40} \right]}{\left(V_{gs} - V_{th} - \frac{A'_{bulk} V_{ds}}{2} \right)^2} \right]$$

$Q_s = -(Q_g + Q_b + Q_d)$

2.3.1.3.2.2 Else ($V_{ds} \geq V_{dsat}$)

$$Q_g = W_{active} L_{active} C_{ox} \left(V_{gs} - V_{fb} - \Phi_s - \frac{V_{dsat}}{3} \right)$$

$$Q_d = \frac{4W_{active}L_{active}C_{ox}(V_{gs} - V_{th})}{15}$$

$Q_s = -(Q_g + Q_b + Q_d)$

$$Q_b = -W_{active}L_{active}C_{ox}\left(V_{fb} + \Phi_s - V_{th} + \frac{(1 - A'_{bulk})V_{dsat}}{3}\right)$$

2.3.1.3.3 Strong Inversion Region ($V_{gs} > V_{th}$): 0/100 Charge Partition

2.3.1.3.3.1 If $V_{ds} < V_{dsat}$

$$Q_g = C_{ox}W_{active}L_{active}\left(V_{gs} - V_{fb} - \Phi_s - \frac{V_{ds}}{2} + \frac{A'_{bulk}V^2_{ds}}{12\left(V_{gs} - V_{th} - \frac{A'_{bulk}V_{ds}}{2}\right)}\right)$$

$$Q_{inv} = -C_{ox}W_{active}L_{active}\left(V_{gs} - V_{th} - \frac{A'_{bulk}V_{ds}}{2} + \frac{A'^2_{bulk}V^2_{ds}}{12\left(V_{gs} - V_{th} - \frac{A'_{bulk}V_{ds}}{2}\right)}\right)$$

$$Q_b = C_{ox}W_{active}L_{active}\left(V_{fb} - V_{th} + \Phi_s + \frac{(1 + A'_{bulk})V_{ds}}{2} - \frac{(1 - A'_{bulk})A'_{bulk}V^2_{ds}}{12\left(V_{gs} - V_{th} - \frac{A'_{bulk}V_{ds}}{2}\right)}\right)$$

$$Q_d = -C_{ox}W_{active}L_{active}\left(\frac{V_{gs}-V_{th}}{2}-\Phi_s-\frac{A'_{bulk}V_{ds}}{4}+\frac{A'^2_{bulk}V^2_{ds}}{24\left(V_{gs}-V_{th}-\frac{A'_{bulk}V_{ds}}{2}\right)}\right)$$

$Q_s = -(Q_g + Q_b + Q_d)$

2.3.1.3.3.2 Else ($V_{ds} \geq V_{dsat}$)

$$Q_g = W_{active}L_{active}C_{ox}\left(V_{gs}-V_{fb}-\Phi_s-\frac{V_{dsat}}{3}\right)$$

$$Q_b = -W_{active}L_{active}C_{ox}\left(V_{fb}+\Phi_s-V_{th}+\frac{(1-A'_{bulk})V_{dsat}}{3}\right)$$

$Q_s = -(Q_g + Q_b)$

$Q_d = 0$

2.3.2 CAPMOD = 1

2.3.2.1 Flatband Voltage

$$V_{fb} = V_{th}-\Phi_s-K_{1ox}\sqrt{\Phi_s-V_{bseff}}$$

Note:

The bias dependencies given for the threshold voltage V_{th} in the I-V Model Equations section are not considered in calculating the flatband voltage V_{fb} for CAPMOD=1.

2.3.2.2 If ($V_{gs} < V_{fb} + V_{bs} + V_{gsteffcv}$)

$Q_{g1} = W_{active}L_{active}C_{ox}(V_{gs} - V_{fb} - V_{bs} - V_{gsteffcv})$

2.3.2.3 If ($V_{gs} \geq V_{fb} + V_{bs} + V_{gsteffcv}$)

$$Q_{g1} = W_{active}L_{active}C_{ox}\cdot\frac{K^2_{1ox}}{2}\left(-1+\sqrt{1+\frac{4(V_{gs}-V_{fb}-V_{gsteff,CV}-V_{bseff})}{K^2_{1ox}}}\right)$$

$Q_{b1} = -Q_{g1}$

$$V_{dsat,cv} = \frac{V_{gsteffcv}}{A'_{bulk}}$$

$$A'_{bulk} = A_{bulk0}\left(1+\left(\frac{CLC}{L_{eff}}\right)^{CLE}\right)$$

$$A_{bulk0} = \left(1+\frac{K_{1ox}}{2\sqrt{\Phi_s-V_{bseff}}}\left(\frac{A_0L_{eff}}{L_{eff}+2\sqrt{X_JX_{dep}}}+\frac{B_0}{W_{eff}+B_1}\right)\right)\cdot\frac{1}{1+KetaV_{bseff}}$$

$$V_{gsteff,cv} = noff\cdot n\mathrm{v}_t\ln\left(1+\exp\left(\frac{V_{gs}-V_{th}-voffcv}{noff\cdot n\mathrm{v}_t}\right)\right)$$

2.3.2.4 If ($V_{ds} \le V_{dsat}$)

$$Q_g = Q_{g1}+C_{ox}W_{active}L_{active}\left(V_{gsteff,cv}-\frac{V_{ds}}{2}+\frac{A'_{bulk}V^2_{ds}}{12\left(V_{gsteff,cv}-V_{th}-\frac{A'_{bulk}V_{ds}}{2}\right)}\right)$$

$$Q_b = Q_{b1} + C_{ox} W_{active} L_{active} \left(- \left(\frac{(1 - A'_{bulk}) V_{ds}}{2} - \frac{(1 - A'_{bulk}) A'_{bulk} V^2_{ds}}{12 \left(V_{gsteff,cv} - V_{th} - \frac{A'_{bulk} V_{ds}}{2} \right)} \right) \right)$$

2.3.2.4.1 50/50 Channel-charge Partition

$$Q_s = Q_d = -\frac{W_{active} L_{active} C_{ox}}{2} \left(V_{gsteff,cv} - \frac{A'_{bulk} V_{ds}}{2} + \frac{(A'_{bulk} V_{ds})^2}{12 \left(V_{gsteff,cv} - \frac{A'_{bulk} V_{ds}}{2} \right)} \right)$$

2.3.2.4.2 40/60 Channel-charge Partition

$$Q_s = -\frac{W_{active} L_{active} C_{ox}}{2 \left(V_{gsteff,cv} - \frac{A'_{bulk} V_{ds}}{2} \right)^2} \left(V^3{}_{gsteff,cv} - \frac{4V^2{}_{gsteff,cv} (A'_{bulk} V_{ds})}{3} + \frac{2V_{gsteff,cv} (A'_{bulk} V_{ds})^2}{3} - \frac{2(A'_{bulk} V_{ds})^3}{15} \right)$$

$Q_d = -(Q_g + Q_b + Q_s)$

2.3.2.4.3 0/100 Channel-charge Partition

$$Q_s = -W_{active} L_{active} C_{ox} \left(\frac{V_{gsteffcv}}{2} + \frac{A'_{bulk} V_{ds}}{4} - \frac{(A'_{bulk} V_{ds})^2}{24 \left(V_{gsteffcv} - \frac{A'_{bulk} V_{ds}}{2} \right)} \right)$$

$Q_d = -(Q_g + Q_b + Q_s)$

2.3.2.5 If ($V_{ds} > V_{dsat}$)

$$Q_g = Q_{g1} + W_{active} L_{active} C_{ox} \left(V_{gsteffcv} - \frac{V_{dsat}}{3} \right)$$

$$Q_b = Q_{b1} + (-W_{active})L_{active}C_{ox}\left(\frac{V_{gsteffcv} - V_{dsat}}{3}\right)$$

2.3.2.5.1 50/50 Channel-charge Partition

$$Q_s = Q_d = -\frac{W_{active}L_{active}C_{ox}}{3}V_{gsteffcv}$$

2.3.2.5.1 40/60 Channel-charge Partition

$$Q_s = -\frac{2W_{active}L_{active}C_{ox}}{5}V_{gsteffcv}$$

$Q_d = -(Q_g + Q_b + Q_s)$

2.3.2.5.1 0/100 Channel-charge Partition

$$Q_s = -\frac{2W_{active}L_{active}C_{ox}}{3}V_{gsteffcv}$$

$Q_d = -(Q_g + Q_b + Q_s)$

2.3.3 CAPMOD = 2

$$V_{fb} = V_{th} - \Phi_s - K_{1ox}\sqrt{\Phi_s - V_{bseff}}$$

> **Note:**
>
> The bias dependencies given for the threshold voltage V_{th} in the I-V Model Equations section are not considered in calculating the flatband voltage V_{fb} for CAPMOD=2.

$Q_g = -(Q_{inv} + Q_{acc} + Q_{sub0} + \delta Q_{sub})$

$Q_b = Q_{acc} + Q_{sub0} + \delta Q_{sub}$

$Q_{inv} = Q_s + Q_d$

$$V_{FBeff} = V_{fb} - 0.5(V_3 + \sqrt{V_3^2 + 4\delta_3 V_{fb}})$$

$V_3 = V_{fb} - V_{gb} - \delta_3$, $\delta_3 = 0.02$

$Q_{acc} = -W_{active} L_{active} C_{ox} (V_{FBeff} - V_{fb})$

$$Q_{sub0} = -W_{active} L_{active} C_{ox} \cdot \frac{K_{1ox}^2}{2}\left(-1 + \sqrt{1 + \frac{4(V_{gs} - V_{FBeff} - V_{gsteff,cv} - ?_{bseff})}{K_{1ox}^2}}\right)$$

$$V_{dsat,cv} = \frac{V_{gsteffcv}}{A'_{bulk}} A'_{bulk} = A_{bulk0}\left(1 + \left(\frac{CLC}{L_{active}}\right)^{CLE}\right)$$

$$A_{bulk0} = \left(1 + \frac{K_{1ox}}{2\sqrt{\Phi_s - V_{bseff}}}\left(\frac{A_0 L_{eff}}{L_{eff} + 2\sqrt{X_J X_{dep}}} + \frac{B_0}{W_{eff} + B_1}\right)\right) \cdot \frac{1}{1 + KetaV_{bseff}}$$

$$V_{gsteff,cv} = noff \cdot nv_t \ln\left(1 + \exp\left(\frac{V_{gs} - V_{th} - voffcv}{noff \cdot nv_t}\right)\right)$$

$$V_{FBeff} = V_{dsat,cv} - 0.5(V_4 + \sqrt{V_4^2 + 4\delta_4 V_{dsat,cv}})$$

$V_4 = V_{dsat,cv} - V_{ds} - \delta_4$, $\delta_4 = 0.02$

$$Q_{inv} = -W_{active}L_{active}C_{ox}\left(V_{gsteffcv} - \frac{A'_{bulk}V_{cveff}}{2} + \frac{(A'_{bulk}V_{cveff})^2}{12\left(V_{gsteffcv} - \frac{A'_{bulk}V_{cveff}}{2}\right)}\right)$$

$$\delta Q_{sub} = C_{ox}W_{active}L_{active}\left(\frac{1 - A'_{bulk}V_{cveff}}{2} - \frac{(1 - A'_{bulk})A'_{bulk}V^2{}_{cveff}}{12\left(V_{gsteff,cv} - V_{th} - \frac{A'_{bulk}V_{cveff}}{2}\right)}\right)$$

2.3.3.1 50/50 Charge Partition

$$Q_s = Q_d = 0.5Q_{inv} = -\frac{W_{active}L_{active}C_{ox}}{2}\left(V_{gsteffcv} - \frac{A'_{bulk}V_{cveff}}{2} + \frac{(A'_{bulk}V_{cveff})^2}{12\left(V_{gsteffcv} - \frac{A'_{bulk}V_{cveff}}{2}\right)}\right)$$

2.3.3.2 40/60 Channel Partition

$$Q_s = \frac{W_{active}L_{active}C_{ox}}{2\left(V_{gsteffcv} - \frac{A'_{bulk}V_{cveff}}{2}\right)}\left(V^3_{gseffcv} - \frac{4V^2_{gsteffcv}(A'_{bulk}V_{cveff})}{3} + \frac{2V_{gsteffcv}(A'_{bulk}V_{cveff})^2}{3} - \frac{2(A'_{bulk}V_{cveff})^3}{15}\right)$$

$$Q_d = \frac{W_{active}L_{active}C_{ox}}{2\left(V_{gsteffcv} - \frac{A'_{bulk}V_{cveff}}{2}\right)}\left(V^3_{gseffcv} - \frac{5V^2_{gsteffcv}(A'_{bulk}V_{cveff})}{3} + V_{gsteffcv}(A'_{bulk}V_{cveff})^2 - \frac{(A'_{bulk}V_{cveff})^3}{5}\right)$$

2.3.3.3 0/100 Channel Partition

$$Q_s = -W_{active}L_{active}C_{ox}\left(\frac{V_{gsteffcv}}{2} - \frac{A'_{bulk}V_{cveff}}{4} + \frac{(A'_{bulk}V_{cveff})^2}{24\left(V_{gsteffcv} - \frac{A'_{bulk}V_{cveff}}{2}\right)}\right)$$

$$Q_d = -W_{active}L_{active}C_{ox}\left(\frac{V_{gsteffcv}}{2} - \frac{3A'_{bulk}V_{cveff}}{2} + \frac{(A'_{bulk}V_{cveff})^2}{8\left(V_{gsteffcv} - \frac{A'_{bulk}V_{cveff}}{2}\right)}\right)$$

2.3.4 CAPMOD = 3 (Charge-Thickness Model)

$$V_{fb} = V_{th} - \Phi_s - K_{1ox}\sqrt{\Phi_s - V_{bseff}}$$

> **Note:**
>
> The bias dependencies given for the threshold voltage V_{th} in the I-V Model Equations section are not considered in calculating the flatband voltage V_{fb} for CAPMOD=3.

$$Q_{acc} = WLC_{oxeff} \cdot V_{gbacc}$$

$\delta_3 = 0.02$

$$V_{gbacc} = \frac{V_0 + \sqrt{V_0^2 + 4\delta_3 V_{fb}}}{2}$$

$V_0 = V_{fb} + V_{fbeff} - V_{gs} - \delta_3$

$$V_{FBeff} = V_{fb} - \frac{V_3 + \sqrt{V_3^2 + 4\delta_3 V_{fb}}}{2}$$

$V_3 = V_{fb} + V_{bseff} - V_{gs} - \delta_3$

$$C_{oxeff} = \frac{C_{ox} C_{cen}}{C_{ox} + C_{cen}} \; C_{cen} = \frac{\varepsilon_{si}}{X_{DC}}$$

$$\Phi_\delta = \Phi_s - 2\Phi_B = \nu \ln\left(\frac{V_{gsteffCV} \cdot (V_{gsteffCV} + 2K_{1ox}\sqrt{2\Phi_B})}{moin \cdot K_{1ox}^2 \nu_t}\right)$$

$$Q_{sub0} = \frac{WLC_{oxeff} K_{1ox}^2}{2} \cdot \left[-1 + \sqrt{1 + \frac{4(V_{gs} - V_{FBeff} - V_{bseffs} - V_{gsteffcv})}{K_{1ox}^2}}\right]$$

$$V_{cveff} = V_{dsat} - \frac{V_1 + \sqrt{V_1^2 + 4\delta_3 V_{dsat}}}{2}$$

$V_1 = V_{dsat} - V_{ds} - \delta_3$

$$V_{dsat} = \frac{V_{gsteff,cv} - \varphi_\delta}{A'_{bulk}}$$

$$Q_{inv} = -WLC_{oxeff}\left(V_{gsteffcv} - \varphi_\delta - \frac{A'_{bulk}V_{cveff}}{2} + \frac{(A'_{bulk}V_{cveff})^2}{12\left(V_{gsteffcv} - \varphi_\delta - \frac{A'_{bulk}V_{cveff}}{2}\right)}\right)$$

$$\delta Q_{sub} = WLC_{oxeff}\left(\frac{1-A'_{bulk}V_{cveff}}{2} - \frac{(1-A'_{bulk})(A'_{bulk}V_{cveff})^2}{12\left(V_{gsteffcv} - \varphi_\delta - \frac{A'_{bulk}V_{cveff}}{2}\right)}\right)$$

2.3.4.1 50/50 Charge Partition

$$Q_S = Q_D = \frac{Q_{inv}}{2} = -\frac{WLC_{oxeff}}{2}\left(V_{gsteffcv} - \varphi_\delta - \frac{A'_{bulk}V_{cveff}}{2} + \frac{(A'_{bulk}V_{cveff})^2}{12\left(V_{gsteffcv} - \varphi_\delta - \frac{A'_{bulk}V_{cveff}}{2}\right)}\right)$$

2.3.4.2 40/60 Charge Partition

$$Q_S = \frac{WLC_{oxeff}}{2\left(V_{gsteffcv} - \varphi_\delta - \frac{A'_{bulk}V_{cveff}}{2}\right)^2}$$
$$\left[(V_{gsteffcv} - \varphi_\delta)^3 - \frac{4(V_{gsteffcv} - \varphi_\delta)^2(A'_{bulk}V_{cveff})}{3} + \frac{2(V_{gsteffcv} - \varphi_\delta)(A'_{bulk}V_{cveff})^2}{3} - \frac{2(A'_{bulk}V_{cveff})^3}{15}\right]$$

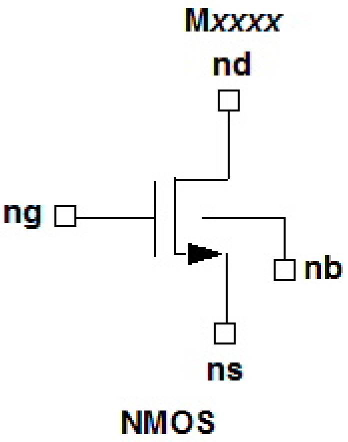
$$Q_S = \frac{WLC_{oxeff}}{2\left(V_{gsteffcv} - \varphi_\delta - \frac{A'_{bulk}V_{cveff}}{2}\right)^2}$$
$$\left[(V_{gsteffcv} - \varphi_\delta)^3 - \frac{5(V_{gsteffcv} - \varphi_\delta)^2(A'_{bulk}V_{cveff})}{3} + (V_{gsteffcv} - \varphi_\delta)(A'_{bulk}V_{cveff})^2 - \frac{(A'_{bulk}V_{cveff})^3}{5}\right]$$

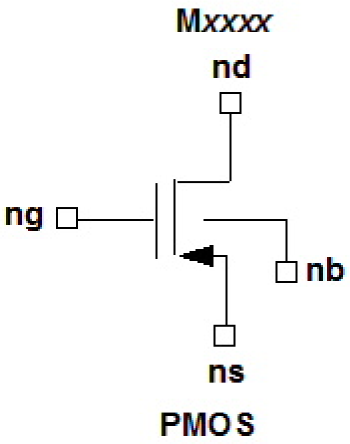
2.3.4.3 0/100 Charge Partition

$$Q_S = -\frac{WLC_{oxeff}}{2}\left(V_{gsteffcv} - \varphi_\delta - \frac{A'_{bulk}V_{cveff}}{2} + \frac{(A'_{bulk}V_{cveff})^2}{12\left(V_{gsteffcv} - \varphi_\delta - \frac{A'_{bulk}V_{cveff}}{2}\right)}\right)$$

$$Q_S = -\frac{WLC_{oxeff}}{2}\left(V_{gsteffcv} - \varphi_\delta - \frac{3A'_{bulk}V_{cveff}}{2} + \frac{(A'_{bulk}V_{cveff})^2}{4\left(V_{gsteffcv} - \varphi_\delta - \frac{A'_{bulk}V_{cveff}}{2}\right)}\right)$$

MOSFET Instance, Philips MOS903 Geometrical Model (Level 50)





Philips MOS903 Geometrical MOSFET Instance Netlist Syntax

The syntax for a Level 50 Philips MOS903 MOSFET instance is:

```
Mxxxx nd ng ns [nb] modelname [L=length] [W=width]
[DTEMP=val] [DTA=val] [MULT=val]
```

nd is the drain node, *ng* is the gate node, *ns* is the source node, and *nb* is the bulk or substrate node of the MOSFET. *modelname* is the name of a Level 50 MOSFET model defined in a .MODEL statement elsewhere in the netlist.

When the option WL is in effect (on the .OPTION statement), the syntax becomes:

```
Mxxxx nd ng ns [nb] modelname [width] [length]
[DTEMP=val] [DTA=val] [MULT=val]
```

Table 57: Level 50 MOSFET Instance Parameters

Instance Parameter	Description	Unit	Default
DTA	Temperature offset of the device with respect to T_A	°C	0.0
DTEMP	Difference between circuit and MOSFET temperature	°C	0.0
L	Drawn channel length in the layout of the actual transistor	Meter	1.5e-6
MULT	Number of devices in parallel	None	1.0
W	Drawn channel width in the layout of the actual transistor	Meter	20.0e-6

Philips MOS903 MOSFET Instance Netlist Example

```
M17 5 3 0 0 MNXM17 L=2.5E-007 W=1E-006
```

Philips MOS9 Geometrical MOSFET Model (Level 50)

Philips MOS903 MOSFET Model Netlist Syntax

The syntax for a Level 50 Philips MOS9 Geometrical MOSFET model is:

```
.MODELmodelname NMOS LEVEL=50 [parameter=val] ...
```

or

```
.MODELmodelname PMOS LEVEL=50 [parameter=val] ...
```

modelname is the name used by MOSFET instances to refer to this .MODEL statement. The **LEVEL=50** entry selects the Philips MOS903 MOSFET model.

Table 58: Level 50 MOSFET Model Parameters

Model	Description	Unit	Default

Parameter			
LEVEL	50 is required to select the Philips MOS9 MOSFET model	None	1 (default if LEVEL parameter is omitted)
VERSION	903 selects the Philips MOSFET 903 Model	None	903
A1R	Weak-avalanche current factor for the reference transistor at the reference temperature	None	NMOS: 6.0 PMOS: 10.0
A2R	Weak-avalanche current exponent for the reference transistor	Volt	NMOS: 38.0 PMOS: 59.0
A3R	Factor of drain-source voltage above which above which weak-avalanche occurs, for the reference transistor	None	NMOS: 0.65 PMOS: 0.52
ALPR	Channel length modulation factor for the reference transistor	None	NMOS: 0.003 PMOS: 0.044
BETSQ	Gain factor of infinite square transistor at the reference temperature	Amp/Volt^2	NMOS: 83.0e-6 PMOS: 26.1e-6
COL	Gate overlap capacitance per unit channel width	Farad/Meter	0.320e-9
ETAALP	Exponent of length dependence of α	None	NMOS: 0.15 PMOS: 0.17
ETABET	Exponent of the temperature dependence of the gain factor	None	1.6
ETADSR	Exponent of the VDS dependence of γ_1 for the reference transistor	None	0.6
ETAGAMR	Exponent of back-bias dependence of $\gamma_0$for the reference transistor	None	NMOS: 2.0 PMOS: 1.0
ETAMR	Exponent of back-bias dependence of M for the reference transistor	None	NMOS: 2.0 PMOS: 1.0
ETAZET	Exponent of length dependence of ζ_1	None	NMOS: 0.17 PMOS: 0.03

FBET1	Relative mobility decrease due to first profile	None	0.0
FBET2	Relative mobility decrease due to second profile	None	0.0
FTHE1	Coefficient describing the width dependence of Θ_1 for W < W_{DOG}	None	0.0
GAM1R	Drain-induced threshold shift for high gate drive	None	NMOS: 0.145 PMOS: 0.077
GAMOOR	Drain-induced threshold shift coefficient for large gate drive for the reference transistor	Volt**(1-η_{DS})	NMOS: 0.018 PMOS: 0.007
GTHE1	Selector for Θ_1 scaling rule 0 = old, 1=new	None	0.0
KOR	Low-back-bias body factor for the reference transistor	Volt½	NMOS: 0.65 PMOS: 0.470
KR	High-back-bias body factor for the reference transistor	Volt½	NMOS: 0.11 PMOS: 0.470
LAP	Effective channel length reduction per side due to the lateral diffusion of the source/drain dopant ions	Meter	NMOS: 0.100e-6 PMOS: 0.025e-6
LER	Effective channel length of the reference transistor	Meter	NMOS: 1.1e-6 PMOS: 1.25e-6
LP1	Characteristic length of first profile	Meter	1.0e-6
LP2	Characteristic length of second profile	Meter	1.0e-8
LVAR	Difference between the actual and the programmed polysilicon gate length	Meter	NMOS: -0.22e-6 PMOS: -0.460e-6
MOR	Subthreshold slope factor for the reference transistor at the reference temperature	None	NMOS: 0.5 PMOS: 0.375
NFAR	1st flicker noise coefficient of the reference transistor (NFMOD=1)	1/Volt-Meter^4	NMOS: 7.15e+22 PMOS: 1.53e+22

NFBR	2nd flicker noise coefficient of the reference transistor (NFMOD=1)	1/Volt-Meter^2	NMOS: 2.16e+7 PMOS: 4.06e+6
NFCR	3rd flicker noise coefficient of the reference transistor (NFMOD=1)	1/Volt	NMOS: 0.0 PMOS: 2.92e-10
NFMOD	Flicker noise switch 0 selects old flicker noise model 1 selects new flicker noise model	None	0.0
NFR	Flicker noise coefficient of the reference transistor (NFMOD=0)	Volt^2	NMOS: 0.7e-10 PMOS: 0.214e-10
NTR	Thermal noise coefficient for the reference transistor	Joule	NMOS: 0.244e-19 PMOS: 0.211e-19
PHIBR	Strong inversion surface potential for the reference transistor at the reference temperature	Volt	0.65
SL2GAMOO	2nd coefficient of the length dependence of γ_{00}	None	0.0
SL2K	2nd coefficient of the length dependence of K	Volt½-Meter^2	0.0
SL2KO	2nd coefficient of the length dependence of K0	Volt½-Meter^2	0.0
SL2VTO	2nd length coefficient of the dependence of V_{TO}	Volt-Meter^2	0.0
SL3VTO	3rd coefficient of the length dependence of V_{TO}	Volt	0.0
SLA1	Length coefficient of the dependence of a_1	Meter	NMOS: 1.3e-6 PMOS: -15.0e-6
SLA2	Length coefficient of the dependence of a_2	Volt-Meter	NMOS: 1.0e-6 PMOS: -8.0e-6
SLA3	Length coefficient of the dependence of a_3	Meter	NMOS: -

			0.550e-6 PMOS: -0.450e-6
SLALP	Coefficient of length dependence of α	Meter**(η_α)	NMOS: -5.65e-3 PMOS: 9.0e-3
SLGAM1	Coefficient of the length dependence of γ_1	None	NMOS: 0.160e-6 PMOS: 0.105e-6
SLGAMOO	Coefficient of the length dependence of γ_{00}	Meter^2	NMOS: 20.0e-15 PMOS: 11.0e-15
SLK	Coefficient of the length dependence of K	Volt$^{1/2}$-Meter	NMOS: -0.280e-6 PMOS: -0.200e-6
SLKO	Coefficient of the length dependence of K_0	Volt$^{1/2}$-Meter	NMOS: -0.130e-6 PMOS: -0.200e-6
SLMO	Coefficient of the length dependence of M_0	Meter$^{1/2}$	NMOS: 0.280e-3 PMOS: 0.047e-3
SLTHE1R	Coefficient of the length dependence of Θ_1 at the reference temperature	Meter/Volt	NMOS: 0.140e-6 PMOS: 0.070e-6
SLTHE2R	Coefficient of the length dependence of Θ_2 at the reference temperature	Meter/Volt$^{1/2}$	NMOS: -0.033e-6 PMOS: -0.075e-6
SLTHE3R	Coefficient of the length dependence of Θ_3 at the reference temperature	Meter/Volt	NMOS: 0.185e-6

			PMOS: 0.027e-6
SLVSBT	Coefficient of the length dependence of V_{SBT}	Volt-Meter	NMOS: -4.43e-6 PMOS: 0.0
SLVSBX	Coefficient of the length dependence of V_{SBX}	Volt-Meter	0.0
SLVTO	Coefficient of the length dependence of V_{TO}	Volt-Meter	NMOS: -0.135e-6 PMOS: 0.035e-6
SLZET1	Coefficient of the length dependence of ζ_1	Meter**(η_ζ)	NMOS: -0.39 PMOS: -2.8
STA1	Coefficient of the temperature dependence of a_1	°K^{-1}	0.0
STLTHE1	Coefficient of the temperature dependence of the length dependence of Θ_1	Meter/Volt-°K	0.0
STLTHE2	Coefficient of the temperature dependence of the length dependence of Θ_2	Meter/Volt$^{1/2}$-°K	0.0
STLTHE3	Coefficient of the temperature dependence of the length dependence of Θ_3	Meter/Volt-°K	NMOS: -0.62e-9 PMOS: 0.0
STMO	Coefficient of the temperature dependence coefficient of M_0	°K^{-1}	0.0
STTHE1R	Coefficient of the temperature dependence of Θ_1 for the reference transistor	1/Volt-°K	0.0
STTHE2R	Coefficient of the temperature dependence of Θ_2 for the reference transistor	1/Volt$^{1/2}$-°K	0.0
STTHE3R	Coefficient of the temperature dependence of Θ_3 for the reference transistor	1/Volt-°K	NMOS: -0.66e-3 PMOS: 0.0
STVTO	Coefficient of the temperature dependence of V_{TO}	Volt/°K	NMOS: -1.2e-3 PMOS: -1.7e-3
SWA1	Coefficient of the width dependence of a_1	Meter	NMOS: 3.0e-6 PMOS: 30.0e-6

SWA2	Coefficient of the width dependence of a_2	Volt-Meter	NMOS: 2.0e-6 PMOS: 15.0e-6
SWA3	Coefficient of the width dependence of a_3	Meter	NMOS: 0.0 PMOS: -0.140e-6
SWALP	Coefficient of the width dependence of α	Meter	NMOS: 1.67e-9 PMOS: 0.180e-9
SWGAM1	Coefficient of the width dependence of γ_1	Volt**(1-η_{DS})-Meter	NMOS: -0.010e-6 PMOS: -0.011e-6
SWK	Coefficient of the width dependence of K	Volt$^{1/2}$-Meter	NMOS: 0.275e-6 PMOS: 0.115e-6
SWKO	Coefficient of the width dependence of KO	Volt$^{1/2}$-Meter	NMOS: 0.002e-6 PMOS: 0.115e-6
SWTHE1	Coefficient of the width dependence of Θ_1	Meter/Volt	NMOS: -0.058e-6 PMOS: -0.080e-6
SWTHE2	Coefficient of the width dependence of Θ_2	Meter/Volt$^{1/2}$	NMOS: 0.030e-6 PMOS: 0.020e-6
SWTHE3	Coefficient of the width dependence of Θ_3	Meter/Volt	NMOS: 0.020e-6 PMOS: 0.011e-6
SWVSBX	Coefficient of the width dependence of V_{SBX}	Volt-Meter	NMOS: -

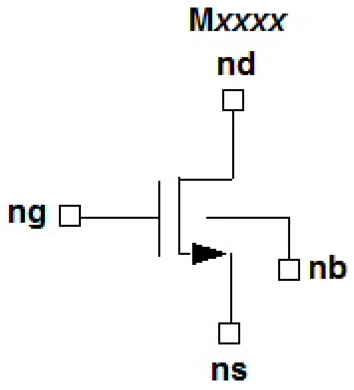
			0.675e-6 PMOS: 0.0
SWVTO	Coefficient of the width dependence of V_{TO}	Volt-Meter	NMOS: 0.130e-6 PMOS: 0.050e-6
TH3MOD	Switch that activates Θ_3 clipping	None	1
THE1R	Coefficient of the mobility reduction due to the gate-induced field for the reference transistor at the reference temperature	Volt^{-1}	0.190
THE2R	Coefficient of the mobility reduction due to the back-bias for the reference transistor at the reference temperature	Volt$^{1/2}$	NMOS: 0.012 PMOS: 0.165
THE3R	Coefficient of the mobility reduction due to the lateral field for the reference transistor at the reference temperature	Volt^{-1}	NMOS: 0.145 PMOS: 0.027
TOX	Gate oxide layer thickness	Meter	25.0e-9
TR	Temperature at which the parameters for the reference transistor have been determined	°C	21.0
VPR	Characteristic voltage of the channel length modulation for the reference transistor	Volt	NMOS: 0.34 PMOS: 0.235
VSBTR	Limiting voltage of the V_{SB} dependence of M and γ_0	Volt	NMOS: 2.1 PMOS: 100.0
VSBXR	Transition voltage for dual-k-factor model for the reference transistor	Volt	NMOS: 0.66 PMOS: 1.0e-12
VTOR	Threshold voltage at zero back-bias for the reference transistor at the reference temperature	Volt	NMOS: 0.73 PMOS: 1.1
WDOG	Characteristic drawn gate width below which dogboning appears	Meter	0.0
WER	Effective channel width of the reference transistor	Meter	NMOS: 20.0e-6 PMOS: 20.0e-6

WOT	Effective reduction of the channel width per side due to the lateral diffusion of the channel-stop dopant ion	Meter	0.0
WVAR	Difference between the actual and the programmed field-oxide opening	Meter	NMOS: -0.025e-6 PMOS: -0.130e-6
ZET1R	Weak-inversion correction factor for the reference transistor	None	NMOS: 0.42 PMOS: 1.3

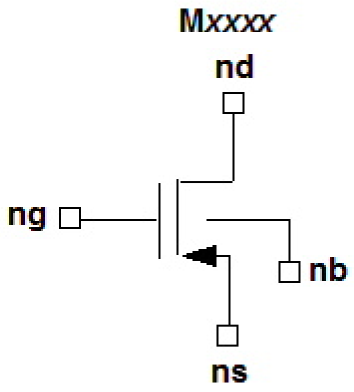
Philips MOS903 MOSFET Geometrical Model Netlist Example

```
.model  _MNXMI7 nmos level=50  LER=1.92e-007 WER=1.00028e-005

+ LVAR=-1.5e-008 LAP=2.15e-008 WVAR=5e-008 WOT=2.36e-008 TR=27

+ VTOR=0.557867 STVTO=0 SLVTO=0 SL2VTO=0 SWVTO=0

+ KOR=0.400564 SLKO=0 SWKO=0 KR=0.140908 SLK=0 SWK=0

+ PHIBR=0.65 VSBXR=0.69554 SLVSBX=0 SWVSBX=0

+ BETSQ=0.000238156 ETABET=0 THE1R=0.678252 STTHE1R=0

+ WDOG=5e-007 SLTHE1R=0 STLTHE1=0 SWTHE1=0 THE2R=0.0135513

+ STTHE2R=0 SLTHE2R=0 STLTHE2=0 SWTHE2=0 THE3R=0.539003

+ STTHE3R=0 SLTHE3R=0 STLTHE3=0 SWTHE3=0 GAM1R=0.100434

+ SLGAM1=0 SWGAM1=0 ETADSR=0.6 ALPR=0.0108148 ETAALP=0

+ SLALP=0 SWALP=0 VPR=0.164 GAMOOR=0.03667 SLGAMOO=0

+ ETAGAMR=1 MOR=0.3763 STMO=0 SLMO=0 ETAMR=1 ZET1R=1.25

+ ETAZET=0.5 SLZET1=0 VSBTR=56.66 SLVSBT=0 A1R=39.7305 STA1=0

+ SLA1=0 SWA1=0 A2R=20.6076 SLA2=0 SWA2=0 A3R=0.635236 SLA3=0

+ SWA3=0 TOX=6e-009 COL=4.23e-010 NTR=2.2148e-020

+ NFR=3.215e-011 NFMOD=0 NFAR=2.8e+024 NFBR=2.36e+008 NFCR=0
```

MOSFET Instance, BSIM4 Model (Level 54)



NMOS



PMOS

This level implements the University of California, Berkeley, BSIM4.3.0 MOSFET model.

BSIM4 MOSFET Instance Netlist Syntax

The syntax for a LEVEL=54 BSIM4 MOSFET instance is:

```
Mxxxx nd ng ns [nb] modelname [L=length] [W=width]
[ACNQSMOD=val] [AD=val] [AS=val] [GEO=val] [GEOMOD=val]
[M=val] [MIN=val] [NF=val] [NRD=val] [NRS=val]
[PD=val] [PS=val]
[RBODYMOD=val] [RGATEMOD=val] [RGEOMOD=val] [TRNQSMOD=val]
[RBDB=val] [RBPB=val] [RBPD=val] [RBPS=val] [RBSB=val]
[SA=val] [SB=val] [SD=val] [MULU0=val] [DELVTO=val]
[TNOM=val] [DTEMP=val] [SCALE=val]
[OFF=val] [ICVDS=val] [ICVGS=val] [ICVBS=val]
[RDC=val] [RSC=val] [SCA=val] [SCB=val] [SCC=val] [SC=val]
[XGW=val] [NGCON=val]
```

nd is the drain node, *ng* is the gate node, *ns* is the source node, and *nb* is the bulk or substrate node of the MOSFET. *modelname* is the name of a BSIM4 MOSFET model defined in a .MODEL statement elsewhere in the netlist.

When the option WL is in effect (on the .OPTION statement), the syntax becomes:

```
Mxxxx nd ng ns [nb] modelname [width] [length]
[ACNQSMOD=val] [AD=val] [AS=val] [GEO=val] [GEOMOD=val]
[M=val] [MIN=val] [NF=val] [NRD=val] [NRS=val]
[PD=val] [PS=val]
[RBODYMOD=val] [RGATEMOD=val] [RGEOMOD=val] [TRNQSMOD=val]
[RBDB=val] [RBPB=val] [RBPD=val] [RBPS=val] [RBSB=val]
```

```
[SA=val] [SB=val] [SD=val] [MULU0=val] [DELVTO=val]
[TNOM=val] [DTEMP=val] [SCALE=val]
```

Table 59: Level 54 MOSFET Instance Parameters

Instance Parameter	Description	Unit	Default
ACNQSMOD	AC small-signal NQS model selector	None	0
AD	Drain diffusion area	Meter^2	0
AS	Source diffusion area	Meter^2	0
DELVTO	Shift in VTH0	Volt	0.0
DTEMP	Difference between device and circuit temperature NOTE: DTEMP is supported only in netlists for Release 3.5.	°C	0.0
GEOMOD	Geometry-dependent parasitics model selector, specifying how the end source/drain diffusions are connected 0 = Isolated 1 = shared drain 2 = shared source 3 = shared source and drain	None	0 (isolated)
ICVBS	Initial Vbs voltage	Volt	0
ICVDS	Initial Vds voltage	Volt	0
ICVGS	Initial Vgs voltage	Volt	0
L	Physical gate length	Meter	5.0e-6
M	Multiplier: simulates parallel transistors	None	1.0
MIN	Flag to minimize the number of drain or source diffusions for even-fingered device	None	0
MULU0	Mobility multiplier	None	1.0
NF	Number of device fingers	None	1
NGCON	Number of gate contacts	None	1
NRD	Number of drain diffusion squares	Square	1
NRS	Number of source diffusion squares	Square	1
OFF	Flag to indicate that device is initially off	None	0

PD	Drain diffusion periphery	Meter	0
PS	Source diffusion periphery	Meter	0
RBDB	Resistance connected between dbNode and bNode	Ohm	50.0
RBODYMOD	Substrate resistance network model selector 0 = Network off	None	0
RBPB	Resistance connected between bNodePrime and bNode	Ohm	50.0
RBPD	Resistance connected between bNodePrime and dbNode	Ohm	50.0
RBPS	Resistance connected between bNodePrime and sbNode	Ohm	50.0
RBSB	Resistance connected between sbNode and bNode	Ohm	50.0
RDC	Drain contact resistance	Ohm	0
RGATEMOD	Gate resistance model selector 0 = No gate resistance	None	0
RGEOMOD	Source/drain diffusion resistance and contact model selector	None	0 (no source/drain diffusion resistance
RSC	Source contact resistance	Ohm	0
SA	Distance from OD edge to poly on one side	Meter	0.0
SB	Distance from OD edge to poly on other side	Meter	0.0
SC	Distance to a single edge	Meter	0
SC	Distance to a single edge	Meter	0.0
SCA	Integral of the first distribution function for scattered well dopant	None	Calculated
SCA	Integral of the first distribution function for scattered well dopant		
SCALE	Element scaling parameter	None	1.0
SCB	Integral of the second distribution function for scattered well dopant	None	Calculated
SCB	Integral of the second distribution function for scattered well dopant		

SCC	Integral of the third distribution function for scattered well dopant	None	Calculated
SCC	Integral of the third distribution function for scattered well dopant		
SD	Distance between neighboring fingers	Meter	0.0
TNOM	Temperature at which parameters are extracted	°C	25
TRNQSMOD	Transient NQS model selector	None	0 (Off)
W	Physical gate width	Meter	5.0e-6
XGW	Distance on the gate contact to the channel edge	Meter	0.0

BSIM4 MOSFET Instance Netlist Example

```
M1 10 11 12 mosfet54
```

```
M12 G3 VDD 0 0 mosfet54 M=2 DTEMP=30
```

BSIM4 MOSFET Model, Level 54

The syntax for a Berkeley BSIM4.3.0 MOSFET model is:

`.MODELmodelname NMOS LEVEL=54 VERSION=val [parameter=val] ...`

or

`.MODELmodelname PMOS LEVEL=54 VERSION=val [parameter=val] ...`

modelname is the name used by MOSFET instances to refer to this .MODEL statement. The **LEVEL=54** entry selects the BSIM4 model.

Table 60: Level 54 MOSFET Model Selector Parameters

Model Parameter	Description	Unit	Default
LEVEL	54 is required to select the Berkeley BSIM4 MOSFET model	None	1 (default if LEVEL parameter is omitted)
VERSION	BSIM4 version selector	None	4.4.0
ACNQSMOD	AC small-signal nonquasistatic model selector (1 = ON)	None	0 (off)
CAPMOD	Capacitance model selector (0, 1, 2, 3)	None	2
CVCHARGEMOD	Capacitance charge model selector	None	0
DIOMOD	Source/drain junction diode I-V model	None	1

	selector		
FNOIMOD	Flicker noise model selector	None	1
GEOMOD	Geometry-dependent parasitics model selector	None	0 (isolated)
IGBMOD	Gate-to-substrate tunneling current model selector	None	0 (off)
IGCMOD	Gate-to-channel tunneling current model selector	None	0 (off)
MOBMOD	Mobility model selector	None	0
MTRLMOD	Selector for non-silicon substrate or metal gate	None	0
PARAMCHK	Switch for parameter checking	None	1 (check)
PERMOD	Switch for including gate-edge perimeter in PS and PD (when present)	None	1 (include)
RBODYMOD	Substrate resistance network model selector	None	0 (network off)
RDSMOD	Bias-dependent source/drain resistance model selector	None	0
RGATEMOD	Gate resistance model selector	None	0
STIMOD	STI model selector	None	0
TEMPMOD	Temperature mode selector	None	0
TNOIMOD	Thermal noise model selector	None	0
TRNQSMOD	Transient nonquasistatic model selector (1 = ON)	None	0 (OFF)
WPEMOD	Flag for WPE model 1 to activate	None	0

Table 61: Level 54 MOSFET Model Process Parameters

Model Parameter	**Description**	**Unit**	**Default**
ADOS	Charge centroid parameter		1.0
BDOS	Charge centroid parameter		1.0
BG0SUB	Bandgap of substrate at 0K	cm^{-3}	1.16
DTOX	TOXE - TOXP	Meter	0.0
EASUB	Electron affinity of substrate		4.05

EOT	Equivalent gate oxide thickness	Meter	15.0e-10
EPSRGATE	Dielectric constant of gate relative to vacuum		11.7
EPSROX	Gate dielectric constant relative to vacuum	None	3.9 (SiO_2)
EPSRSUB	Dielectric constant of substrate relative to vacuum		11.7
GAMMA1	Body-effect coefficient near the surface	$Volt^{1/2}$	Calculated
GAMMA2	Body-effect coefficient in the bulk	$Volt^{1/2}$	Calculated
JTWEFF	TAT current width dependence		0
LEFFEOT	Effective length for extraction of EOT		1.0
NDEP	Channel doping concentration at depletion edge for zero body bias	cm^{-3}	1.7e+17
NGATE	Polysilicon gate doping concentration	cm^{-3}	0.0
NI0SUB	Intrinsic carrier concentration of substrate at 300.15K	cm^{-3}	1.45e10
NSD	Source/drain doping concentration	cm^{-3}	1.0e+20
NSUB	Substrate doping concentration	cm^{-3}	6.0e+16
PHIG	Work function of gate		Calculated
RSH	Source/drain sheet resistance	Ohm/square	0.0
RSHG	Gate electrode sheet resistance	Ohm/square	0.1
TBGASUB	First parameter of band-gap change due to temperature		7.02e-4
TBGBSUB	Second parameter of band-gap change due to temperature		1108.0
TEMPEOT	Temperature for extraction of EOT	°K	300.15
TOXE	Electrical gate equivalent oxide thickness	Meter	TOXREF
TOXM	Gate thickness at which parameters are extracted	Meter	TOXE
TOXP	Physical gate equivalent oxide thickness	Meter	TOXE
UCS	Colombic scattering exponent		Calculated
UCSTE	Temperature coefficient of Colombic mobility		-4.775e-3
VBX	V_{bs} at which the depletion region width equals XT	Volt	Calculated
VDDEOT	Voltage for extraction of EOT	Volt	Calculated
WEFFEOT	Effective width for extraction of EOT		10.0
XJ	Source/drain junction depth	Meter	1.5e-7
XT	Doping depth	Meter	1.55e-7

Table 62: Level 54 MOSFET Basic Model Parameters

Model Parameter	Description	Unit	Default
A0	Coefficient of channel length dependence of bulk charge effect	None	1.0
A1	1st nonsaturation effect parameter	Volt^{-1}	0.0
A2	2nd nonsaturation effect parameter	None	1.0
AGS	Coefficient of V_{GS} dependence of bulk charge effect	Volt^{-1}	0.0
B0	Bulk charge effect coefficient for channel width	Meter	0.0
B1	Bulk charge effect width offset	Meter	0.0
CDSC	Drain-source and channel coupling capacitance	Farad/Meter^2	2.4e-4
CDSCB	Body-bias sensitivity coefficient of C_{DSC}	Farad/Volt-Meter^2	0.0
CDSCD	Drain bias sensitivity of C_{DSC}	Farad/Volt-Meter^2	0.0
CIT	Interface trap capacitance	Farad/Meter^2	0.0
DELTA	Parameter for V_{DSeff}	Volt	0.01
DROUT	Channel length dependence of the DIBL effect on R_{OUT}	None	0.56
DSUB	DIBL coefficient exponent in subthreshold region	None	DROUT
DVT0	1st coefficient of short-channel effect on V_{th}	None	2.2
DVT0W	1st coefficient of narrow width effect on V_{th} for small channel length	None	0.0
DVT1	2nd coefficient of short-channel effect on V_{th}	None	0.53
DVT1W	2nd coefficient of narrow width effect on V_{th} for small channel length	Meter^{-1}	5.3e+6
DVT2	Body-bias coefficient of short-channel effect on V_{th}	Volt^{-1}	-0.032
DVT2W	Body-bias coefficient of narrow width effect on V_{th} for small channel length	Volt^{-1}	-0.032
DVTP0	1st coefficient of drain-induced V_{th} shift for	Meter	0.0

	long channel pocket devices		
DVTP1	2nd coefficient of drain-induced V_{th} shift for long channel pocket devices	$Volt^{-1}$	0.0
DWB	Coefficient of body bias dependence of Weff	$Meter/Volt^{1/2}$	0.0
DWG	Coefficient of gate bias dependence of Weff	Meter/Volt	0.0
ETA0	Subthreshold region DIBL coefficient	None	0.08
ETAB	Body-bias coefficient for the subthreshold DIBL effect	$Volt^{-1}$	-0.07
EU	Exponent for mobility degradation of MOBMOD=2	None	NMOS: 1.67 PMOS: 1.0
FPROUT	Effect of pocket implant on Rout degradation	$Volt/Meter^{1/2}$	0.0
K1	1st-order body bias coefficient	$Volt^{1/2}$	Calculated
K2	2nd-order body bias coefficient	None	Calculated
K3	Narrow width coefficient	None	80.0
K3B	Body effect coefficient of K3	$Volt^{-1}$	0.0
KETA	Body-bias coefficient of bulk charge effect	$Volt^{-1}$	-0.047
LAMBDA	Velocity overshoot coefficient	None	0.0
LC	Velocity back-scattering coefficient	Meter	5.0e-9
LINT	Channel length offset parameter at V_{BS} = 0.	Meter	0.0
LINTNOI	Length reduction parameter offset	Meter	0.0
LMLT	Length scaling parameter	None	1.0
LP	Mobility channel length exponential coefficient		1e-8
LPE0	Lateral non-uniform doping parameter	Meter	1.74e-7
LPEB	Lateral non-uniform doping effect on K1	Meter	0.0
MINV	V_{GSTeff} fitting parameter for moderate inversion condition	None	0.0
MINVCV	Fitting parameter for moderate inversion in $V_{GSTeffcv}$	None	0
NFACTOR	Subthreshold swing factor	None	1.0
PCLM	Channel length modulation parameter	None	1.3
PDIBL1 (PDIBLC1)	Parameter for DIBL effect on R_{OUT}	None	0.39
PDIBL2	Parameter for DIBL effect on R_{OUT}	None	0.0086

(PDIBLC2)			
PDIBLB (PDIBLCB)	Body bias coefficient of DIBL effect on R_{OUT}	Volt^{-1}	0.0
PDITS	Impact of drain-induced VTH shift on R_{OUT}	Volt^{-1}	0.0
PDITSL	Channel length dependence of drain-induced V_{TH} shift for R_{OUT}	Meter^{-1}	0.0
PDITSD	V_{DS} dependence of drain-induced V_{TH} shift for R_{OUT}	Volt^{-1}	0.0
PHIN	Non-uniform vertical doping effect on surface potential	Volt	0.0
PSCBE1	1st substrate current-induced body effect parameter	Volt/Meter	4.24e+8
PSCBE2	2nd substrate current-induced body effect parameter	Meter/Volt	1.0e-5
PVAG	Gate-bias dependence of Early voltage	None	0.0
SCALM	Model scaling parameter	None	1.0
SCREF	Reference distance to calculate SCA, SCB, and SCD	Meter	1e-6
U0	Low field mobility	Meter^{2}/Volt-sec	NMOS: 670 PMOS: 250
UA	Coefficient of 1st-order mobility degradation due to vertical field	Meter/Volt	MOBMOD=0,1: 1.0e-9 MOBMOD=2: 1.0e-15
UB	Coefficient of 2nd-order mobility degradation due to vertical field	Meter^{2}/Volt^{2}	1.0e-19
UC	Coefficient of mobility degradation due to body-bias effect	MOBMOD=1: Volt^{-1} Else: Meter/Volt^{2}	MOBMOD=0, 2: -0.0465e-9 MOBMOD=1: -0.0465
UD	Mobility scattering coefficient		0.0
UP	Mobility channel length coefficient		0.0
VBM	Maximum applied body bias in V_{TH0} calculation	Volt	-3.0

VFB	Flat-band voltage	Volt	Calculated
VFBSDOFF	Flatband voltage offset parameter	Volt	0.0
VOFF	Offset voltage in subthreshold region for large W and L	Volt	-0.08
VOFFL	Channel-length dependence of VOFF	Volt-Meter	0.0
VSAT	Saturation velocity of carrier	Meter/sec	8.0e+4
VTH0 (**VTHO**)	Long-channel threshold voltage at V_{BS}=0	Volt	NMOS: 0.7 PMOS: -0.7
VTL	Thermal velocity	Meter/second	2.05e5
WEB	Coefficient for SCB		0.0
WEC	Coefficient for SCC		0.0
W0	Narrow width effect parameter	Meter	2.5e-6
WINT	Channel width offset parameter	Meter	0.0
WMLT	Width scaling parameter	None	1.0
XN	Velocity back-scattering coefficient	None	3.0

Table 63: Level 54 MOSFET Impact Ionization Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
ALPHA0	1st parameter of impact ionization current	Amp-Meter/Volt	0.0
ALPHA1	Isub parameter for length scaling	Amp/Volt	0.0
BETA0	2nd parameter of impact ionization current	Volt	30.0

Table 64: Level 54 MOSFET Asymmetric and Bias-Dependent Rds Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
PRWB	Body bias dependence of lightly-doped drain (LDD) resistance	$1/\text{Volt}^{½}$	0.0
PRWG	Gate bias dependence of LDD resistance	Volt^{-1}	1.0
RDSW	Zero-bias LDD resistance per unit width for RDSMOD=0	Ohm-μMeter^{WR}	200.0
RDSWMIN	LDD resistance per unit width at high Vgs and zero Vbs for RDSMOD=0	Ohm-μMeter^{WR}	0.0

RDW	Zero-bias LDD resistance per unit width for RDSMOD=1	Ohm-μMeter^{WR}	100.0
RDWMIN	LDD resistance per unit width at high Vgs and zero Vbs for RDSMOD=1	Ohm-μMeter^{WR}	0.0
RSW	Zero-bias lightly-doped source (LDS) resistance (R_s(V)) per unit width for RDSMOD=1	Ohm-μMeter^{WR}	100.0
RSWMIN	LDS resistance per unit width at high Vgs and zero Vbs for RDSMOD=1	Ohm-μMeter^{WR}	0.0
WR	Channel-width dependence parameter of LDD resistance	None	1.0

Table 65: Level 54 MOSFET GIDL and GISL Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
AGIDL	Pre-exponential coefficient for GIDL	Mho	0.0
BGIDL	Exponential coefficient for GIDL	Volt/Meter	2.3e+9
CGIDL	Parameter for body-bias effect on GIDL	Volt^3	0.5
EGIDL	Fitting parameter for band bending for GIDL	Volt	0.8
AGISL	Pre-exponential coefficient for GISL	Mho	0.0
BGISL	Exponential coefficient for GISL	Volt/Meter	2.3e+9
CGISL	Parameter for body-bias effect on GISL	Volt^3	0.5
EGISL	Fitting parameter for band bending for GISL	Volt	0.8

Table 66: Level 54 MOSFET Gate Dielectric Tunneling Current Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
AIGBACC	Parameter for Igb in accumulation	(F-s^2/g)$^{1/2}$/Meter	0.43
AIGBINV	Parameter for Igb in inversion	(F-s^2/g)$^{1/2}$/Meter	0.35
AIGC	Parameter for Igcs and Igcd	(F-s^2/g)$^{1/2}$/Meter	NMOS: 0.054 PMOS:

			0.31
AIGD	Parameter for Igd		Calculated
AIGS	Parameter for Igs		Calculated
AIGSD	Parameter for Igs and Igd	$(F\text{-}s^2/g)^{1/2}$/Meter	NMOS: 0.43 PMOS: 0.31
BIGBACC	Parameter for Igb in accumulation region	$(F\text{-}s^2/g)^{1/2}$/Meter-Volt	0.054
BIGBINV	Parameter for Igb in inversion	$(F\text{-}s^2/g)^{1/2}$/Meter-Volt	0.03
BIGC	Parameter for Igcs and Igcd	$(F\text{-}s^2/g)^{1/2}$/Meter-Volt	NMOS: 0.054 PMOS: 0.024
BIGD	Parameter for Igd		Calculated
BIGS	Parameter for Igs		Calculated
BIGSD	Parameter for Igs and Igd	$(F\text{-}s^2/g)^{1/2}$/Meter-Volt	NMOS: 0.054 PMOS: 0.024
CIGBACC	Parameter for Igb in accumulation	Volt^{-1}	0.075
CIGBINV	Parameter for Igb in inversion	Volt^{-1}	0.006
CIGC	Parameter for Igcs and Igcd	Volt^{-1}	NMOS: 0.075 PMOS: 0.03
CIGD	Parameter for Igd		Calculated
CIGS	Parameter for Igs		Calculated
CIGSD	Parameter for Igs and Igd	Volt^{-1}	NMOS: 0.075 PMOS: 0.03

DLCIG	Source/drain overlap length for Igs and Igd	Meter	LINT
DLCIGD	Delta L for Igd model	Meter	LINT
EIGBINV	Parameter for Igb in inversion	Volt	1.1
NIGBACC	Parameter for Igb in accumulation	None	1.0
NIGBINV	Parameter for Igb in inversion	None	3.0
NIGC	Parameter for Igcs, Igcd, Igs, and Igd	None	1.0
NTOX	Exponent for the gate oxide ratio	None	1.0
PIGCD	Vds dependence of Igcs and Igcd	None	1.0
POXEDGE	Factor for gate oxide thickness in source/drain overlap regions	None	1.0
TOXREF	Nominal gate oxide thickness for gate dielectric tunneling current model only	Meter	3.0e-9

Table 67: Level 54 MOSFET Charge and Capacitance Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
ACDE	Exponential coefficient for charge thickness in CAPMOD=2 for accumulation and depletion regions	Meter/Volt	1.0
CF	Fringing field capacitance	Farad/Meter	Calculated
CGBO	Gate-bulk overlap capacitance per unit channel length	Farad/Meter	Calculated
CGDO	Non-LDD region drain-gate overlap capacitance per unit channel width	Farad/Meter	Calculated
CGDL	Overlap capacitance between gate and lightly-doped drain region	Farad/Meter	0.0
CGSL	Overlap capacitance between gate and lightly-doped source region	Farad/Meter	0.0
CGSO	Non-LDD region source-gate overlap capacitance per unit channel width	Farad/Meter	Calculated
CKAPPAD	Coefficient of bias-dependent overlap capacitance for the drain side	Volt	CKAPPAS
CKAPPAS	Coefficient of bias-dependent overlap capacitance for the source side	Volt	0.6
CLC	Constant term for short-channel model	Meter	0.1e-6

CLE	Exponential term for short-channel model	None	0.6
DLC	Channel length offset parameter for C-V model	Meter	LINT
DWC	Channel width offset parameter for C-V model	Meter	WINT
MINVCV	Fitting parameter for moderate inversion in Vgsteff		0.0
MOIN	Coefficient for the gate bias-dependent surface potential	None	15.0
NOFF	C-V parameter in $V_{GSTeff,CV}$ for weak-to-strong inversion	None	1.0
VFBCV	Flat-band voltage parameter [CAPMOD=0]	Volt	-1.0
VOFFCV	C-V parameter in $V_{GSTeff,CV}$ for weak-to-strong inversion	Volt	0.0
VOFFCVL	Length dependence parameter for VTHG offset in C-V		0.0
XPART	Charge partition parameter 0 = 40/60 0.5 = 50/50 ≥ 1 = 0/100 Any other value < 1 = 40/60	None	0 (40/60)

Table 68: Level 54 MOSFET High-Speed/RF Model Parameters

Model Parameter	Description	Unit	Default
GBMIN	Conductance in parallel with each of the five substrate resistances to aid convergence	Mho	1.0e-12
RBDB	Resistance connected between dbNode and bNode	Ohm	50.0
RBDBX0	Scaling prefactor for RBDBX		Calculated
RBDBY0	Scaling prefactor for RBDBY		Calculated
RBPB	Resistance connected between bNodePrime and bNode	Ohm	50.0
RBPBX0	Scaling prefactor for RBPBX		100.0
RBPBXL	Length scaling factor for RBPBX		0.0
RBPBXW	Width scaling factor for RBPBX		0.0
RBPBXNF	Number of fingers scaling factor for RBPBX		0.0
RBPBY0	Scaling prefactor for RBPBY		100.0

RBPBYL	Length scaling factor for RBPBY		0.0
RBPBYW	Width scaling factor for RBPBY		0.0
RBPBYNF	Number of fingers scaling factor for RBPBY		0.0
RBPD	Resistance connected between bNodePrime and dbNode	Ohm	50.0
RBPD0	Scaling prefactor for RBPD		Calculated
RBPDL	Length scaling factor for RBPD		0.0
RBPDW	Width scaling factor for RBPD		0.0
RBPDNF	Number of fingers scaling factor for RBPD		0.0
RBPS	Resistance connected between bNodePrime and sbNode	Ohm	50.0
RBPS0	Scaling prefactor for RBPS		Calculated
RBPSL	Length scaling factor for RBPS		0.0
RBPSW	Width scaling factor for RBPS		0.0
RBPSNF	Number of fingers scaling factor for RBPS		0.0
RBSB	Resistance connected between sbNode and bNode	Ohm	50.0
RBSBX0	Scaling prefactor for RBSBX		Calculated
RBSBY0	Scaling prefactor for RBSBY		Calculated
RBSDBXL	Length scaling factor for RBSBX and RBDBX		0.0
RBSDBXW	Width scaling factor for RBSBX and RBDBX		0.0
RBSDBXNF	Number of fingers scaling factor for RBSBX and RBDBX		0.0
RBSDBYL	Length scaling factor for RBSBY and RBDBY		0.0
RBSDBYW	Width scaling factor for RBSBY and RBDBY		0.0
RBSDBYNF	Number of fingers scaling factor for RBSBY and RBDBY		0.0
XRCRG1	Parameter for distributed channel-resistance effect for both intrinsic-input resistance and charge-deficit NQS models	None	12.0
XRCRG2	Parameter to account for the excess channel diffusion resistance for both intrinsic-input resistance and charge-deficit NQS models	None	1.0

Table 69: Level 54 MOSFET Noise Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
AF	Flicker noise exponent	None	1.0

EF	Flicker noise frequency exponent	None	1.0
EM	Saturation field	Volt/Meter	4.1e+7
KF	Flicker noise coefficient	$A^{2-EF}s^{1-EF}F$	0.0
NLEV	HSPICE noise level	None	99
NOIA	Flicker noise parameter A	s^{1-EF}/eV-m^3	NMOS: 1e20 PMOS: 9.9e18
NOIB	Flicker noise parameter B	s^{1-EF}/eV-m	NMOS: 5e4 PMOS: 2.4e3
NOIC	Flicker noise parameter C	s^{1-EF}/eV	8.75e+9
NTNOI	Noise factor for short-channel devices for TNOIMOD=0 only	None	1.0
RNOIA	Thermal noise coefficient	None	0.577
RNOIB	Thermal noise coefficient	None	0.5164
TNOIA	Coefficient of channel-length dependence of total channel thermal noise	None	1.5
TNOIB	Channel-length dependence parameter for channel thermal noise partitioning	None	3.5

Table 70: Level 54 MOSFET Layout-Dependent Parasitics Model Parameters

Model Parameter	Description	Unit	Default
DMCG	Distance from source/drain contact center to the gate edge	Meter	0.0
DMCGT	DMCG of test structures	Meter	0.0
DMCI	Distance from source/drain contact center to the isolation edge in the channel-length direction	Meter	DMCG
DMDG	Same as DMCG but for merged device only	Meter	0.0
DWJ	Offset of the source/drain junction width	Meter	DWC
NGCON	Number of gate contacts	None	1

XGL	Offset of the gate length due to variations in patterning	Meter	0.0
XGW	Distance on the gate contact to the channel edge	Meter	0.0
XL	Channel length offset due to mask/etch effect	Meter	0.0
XW	Channel width offset due to mask/etch effect	Meter	0.0

Table 71: Level 54 MOSFET Asymmetric Source/Drain Junction Diode Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
BVD	Breakdown voltage (drain side)	Volt	BVS
BVS	Breakdown voltage (source side)	Volt	10.0
CJD	Bottom junction capacitance per unit area at zero bias (drain side)	Farad/Meter 2	CJS
CJS	Bottom junction capacitance per unit area at zero bias (source side)	Farad/Meter 2	5.0e-4
CJSWD	Isolation-edge sidewall bulk junction capacitance per unit area (drain side)	Farad/Meter	CJSWS
CJSWGD	Gate-edge sidewall junction capacitance per unit area (drain side)	Farad/Meter	CJSWS
CJSWGS	Gate-edge sidewall junction capacitance per unit length (source side)	Farad/Meter	CJSWS
CJSWS	Isolation-edge sidewall junction capacitance per unit length (source side)	Farad/Meter	5.0e-10
GMIN	Minimum conductance for diodes	Mho	0.0
IJTHDFWD	Limiting current in forward bias region (drain side)	Amp	IJTHSFWD
IJTHDREV	Limiting current in reverse bias region (drain side)	Amp	IJTHSREV
IJTHSFWD	Limiting current in forward bias region (source side)	Amp	0.1
IJTHSREV	Limiting current in reverse bias region (source side)	Amp	0.1
JSD	Bottom junction reverse saturation current density (drain side)	Amp/Meter^2	1e-4
JSS	Bottom junction reverse saturation current density (source side)	Amp/Meter^2	1.0e-4
JSWD	Isolation-edge sidewall reverse saturation current density (drain side)	Amp/Meter	0.0
JSWGD	Gate-edge sidewall reverse saturation current	Amp/Meter	0.0

	density (drain side)		
JSWGS	Gate-edge sidewall reverse saturation current density (source side)	Amp/Meter	0.0
JSWS	Isolation-edge sidewall reverse saturation current density (source side)	Amp/Meter	0.0
JTSS	Bottom trap-assisted saturation current density	Amp/Meter	0.0
JTSD	Bottom trap-assisted saturation current density	Amp/Meter	Calculated
JTSSWS	STI sidewall trap-assisted saturation current density	Amp/Meter	0.0
JTSSWD	STI sidewall trap-assisted saturation current density	Amp/Meter	Calculated
JTSSWGD	Gate-edge sidewall trap-assisted saturation current density	Amp/Meter	Calculated
JTSSWGS	Gate-edge sidewall trap-assisted saturation current density	Amp/Meter	0.0
MJD	Bottom junction capacitance grading coefficient (drain side)	None	0.5
MJS	Bottom junction capacitance grading coefficient (source side)	None	0.5
MJSWD	Isolation-edge sidewall junction capacitance grading coefficient (drain side)	None	0.33
MJSWGD	Gate-edge sidewall bulk junction capacitance grading coefficient (drain side)	None	MJSWS
MJSWGS	Gate-edge sidewall bulk junction capacitance grading coefficient (source side)	None	MJSWS
MJSWS	Isolation-edge sidewall junction capacitance grading coefficient (source side)	None	0.33
NJTS	Non-ideality factor for JTSS, JTSD		20.0
NJTSSW	Non-ideality factor for JTSSWS, JTSSWD		20.0
NJTSSWG	Non-ideality factor for JTSSWGS, JTSSWGD		20.0
NJTSD	Non-ideality factor for JTSD		Calculated
NJTSSWD	Non-ideality factor for JTSSWD		Calculated
NJTSSWGD	Non-ideality factor for JTSSWGD		Calculated
PBD	Bottom junction built-in potential (drain side)	Volt	1.0
PBS	Bottom junction built-in potential (source side)	Volt	1.0
PBSWD	Isolation-edge sidewall junction built-in potential	Volt	1.0

	(drain side)		
PBSWGD	Gate-edge sidewall bulk junction built-in potential (drain side)	Volt	PBSWS
PBSWGS	Gate-edge sidewall bulk junction built-in potential (source side)	Volt	PBSWS
PBSWS	Isolation-edge sidewall junction built-in potential (source side)	Volt	1.0
TNJTS	Temperature coefficient for NJTS		0.0
TNJTSSW	Temperature coefficient for NJTSSW		0.0
TNJTSSWG	Temperature coefficient for NJTSSWG		0.0
XJBVD	Fitting parameter for diode breakdown (drain side)	None	XJBVS
XJBVS	Fitting parameter for diode breakdown (source side)	None	1.0
XTSS	Power dependence of JTSS on temperature		0.02
XTSD	Power dependence of JTSD on temperature		0.02
XTSSWS	Power dependence of JTSSWS on temperature		0.02
XTSSWD	Power dependence of JTSSWD on temperature		0.02
XTSSWGS	Power dependence of JTSSWGS on temperature		0.02
XTSSWGD	Power dependence of JTSSWGD on temperature		0.02
VTSS	Bottom trap-assisted voltage dependent parameter		10.0
VTSD	Bottom trap-assisted voltage dependent parameter		Calculated
VTSSWS	STI sidewall trap-assisted voltage dependent parameter		10.0
VTSSWD	STI sidewall trap-assisted voltage dependent parameter		Calculated
VTSSWGS	Gate-edge sidewall trap-assisted voltage dependent parameter		10.0
VTSSWGD	Gate-edge sidewall trap-assisted voltage dependent parameter		Calculated

Table 72: Level 54 MOSFET Temperature Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
AT	Temperature coefficient	Meter/sec	3.3e+4

	for saturation velocity		
KT1	Temperature coefficient for threshold voltage	Volt	-0.11
KT1L	Channel length dependence of the temperature coefficient for threshold voltage	Volt-Meter	0.0
KT2	Body bias coefficient of V_{TH} temperature effect	None	0.022
NJD	Emission coefficient for drain junction	None	NJS
NJS	Emission coefficient for source junction	None	1.0
PRT	Temperature coefficient for R_{DSW}	Ohm-Meter	0.0
TCJ	Temperature coefficient of CJ	$°K^{-1}$	0.0
TCJSW	Temperature coefficient of CJSW	$°K^{-1}$	0.0
TCJSWG	Temperature coefficient of CJSWG	$°K^{-1}$	0.0
TNJTSD	Temperature coefficient for NJTSD		
TNJTSSWD	Temperature coefficient for NJTSSWD		
TNJTSSWGD	Temperature coefficient for NJTSSWGD		
TNOM	Temperature at which parameters are extracted	°C	25
TPB	Temperature coefficient of PB	Volt/°K	0.0
TPBSW	Temperature coefficient of PBSW	Volt/°K	0.0
TPBSWG	Temperature coefficient of PBSWG	Volt/°K	0.0
TVFBSDOFF	Temperature coefficient of Vfbsdoff		0.0

TVOFF	Temperature coefficient of Voff		0.0
UA1	Temperature coefficient for UA	Meter/Volt	1.0e-9
UB1	Temperature coefficient for UB	$Meter^2/Volt^2$	-1.0e-18
UC1	Temperature coefficient for UC	MOBMOD=0, 2: $Meter/Volt^2$ MOBMOD=1: $Volt^{-1}$	MOBMOD=0, 2:--0.056e-9 MOBMOD=1: 0.056
UD1	Temperature coefficient for UD		0.0
UTE	Mobility temperature exponent	None	-1.5
XTID	Drain junction current temperature exponent	None	XTIS
XTIS	Source junction current temperature exponent	None	3.0

Table 73: Level 54 MOSFET dW and dL Model Parameters

Model Parameter	Description	Unit	Default
LL	Coefficient of length dependence for length offset	$Meter^{LLN}$	0.0
LLC	Coefficient of length dependence for C-V channel length offset	$Meter^{LLN}$	LL
LLN	Power of length dependence for length offset	None	1.0
LW	Coefficient of width dependence for length offset	$Meter^{LWN}$	0.0
LWC	Coefficient of width dependence for C-V channel length offset	$Meter^{LWN}$	LW
LWL	Coefficient of length and width cross term dependence for length offset	$Meter^{LWN+LLN}$	0.0
LWLC	Coefficient of length and width cross term dependence for C-V channel length offset	$Meter^{LWN+LLN}$	LWL
LWN	Power of width dependence for length offset	None	1.0
WL	Coefficient of length dependence for width offset	$Meter^{WLN}$	0.0

WLC	Coefficient of length dependence for C-V channel width offset	Meter^{WLN}	WL
WLN	Exponent of length dependence of width offset	None	1.0
WW	Coefficient of width dependence for width offset	Meter^{WWN}	0.0
WWC	Coefficient of width dependence for C-V channel width offset	Meter^{WWN}	WW
WWL	Coefficient of length and width cross term dependence for width offset	$\text{Meter}^{WWN+WLN}$	0.0
WWLC	Coefficient of length and width cross term dependence for C-V channel width offset	$\text{Meter}^{WWN+WLN}$	WWL
WWN	Power of width dependence for width offset	None	1.0

Table 74: Level 49 or 53 MOSFET W and L Binning Adjustment Model Parameters

Model Parameter	Description	Unit	Default
BINUNIT	Binning unit selector 1 = microns 0 = Meters	None	1
LMAX	Maximum channel length	Meter	1.0
LMIN	Minimum channel length	Meter	0.0
WMAX	Maximum channel width	Meter	1.0
WMIN	Minimum channel width	Meter	0.0

Notes on BSIM4 Binning Adjustment

Binning is a way to extend a single device architecture by providing systematic variations on the device parameters. The philosophy is that when you vary the channel geometry, other parameters also change, in ways that can be completely characterized by the device manufacturer. The manufacturer or foundry provides a “design kit” that contains a set of .MODEL statements specifying the parameter settings for the different geometries. The design kit with the .MODEL statements can be included in the Nexxim design as a subcircuit.

1. A binning model is identified by giving the model name in the .MODEL statement the form *modelname***.***n*, where the entry *n* after the decimal point can be an integer or any other unique identifier. The MOSFET instance definition refers to the *modelname* without any extension. The netlist can contain any number of different binning models with the same

base *modelname*. For example, three binning models could be named NMOSBSIM4.1 NMOSBSIM4.2, and NMOSBSIM4.3. The instance statement reference is NMOSBSIM4.

Each of the available binning models corresponds to a range of channel lengths and widths specified with the **LMIN**, **LMAX**, **WMIN**, and **WMAX** model parameters. The ranges must not overlap.

Each binning model typically specifies values for the model parameters that are related to the channel geometry variations.

2. The MOSFET instance statement must contain values for instance parameters **L** and **W**. The **L** and **W** parameters can be specified with variables so a sweep of binning models can be performed.
3. The simulator finds the binning model to which the following conditions BOTH apply:

- The **LMIN** and **LMAX** model parameter range includes the value of instance parameter **L** (scaled by the instance parameter **SCALE**).
- The **WMIN** and **WMAX** model parameter range includes the value of instance parameter **W** (scaled by the instance parameter **SCALE**).

If none of the available binning models matches the **L** and **W** instance parameters, simulation does not proceed.

4. Within a BSIM4 model (binned or not), the binned model parameters are adjusted by the effective channel length and width. The formula for the adjustment uses the following symbols:

N = value of the model parameter (e.g., **A0**).

LN = value of the length dependence parameter (e.g., **LA0**).

WN = value of the width dependence parameter (e.g., **WA0**).

PN = value of the cross dependence parameter (e.g., **PA0**).

Leff = effective channel length (calculated from **L** using scale factors and other adjustments).

Weff = effective channel width (calculated from **W** using scale factors and other adjustments).

Adjustment formula:

```
Value = N + LN*(1/Leff) + WN*(1/Weff) + PN*(1/(Leff*Weff))
```

5. When model parameter **BINUNIT** equals 1, the effective parameters (Leff, Weff, LREFeff, and WREFeff) are scaled to units of microns. By default (**BINUNIT** not equal to 1), units are meters.

Table 75: Level 54 MOSFET Stress Effect Model Parameters

Model Parameter	Description	Unit	Default

K2WE	K2 shift factor for well proximity effect		0.0
KU0	Mobility degradation/enhancement coefficient for stress effect	Meter	0.0
KU0WE	Mobility degradation factor for WPE		0.0
KVSAT	Saturation velocity degradation/enhancement parameter for stress effect (-1.0 ≤ KVSAT ≤ 1.0)	Meter	0.0
KVTH0	Threshold shift parameter for stress effect	Volt-Meter	0.0
KVTH0WE	Threshold shift factor for well proximity effect		0.0
LKU0	Length coefficient of KU0	None	0.0
LKVTH0	Length dependence of KVTH0	None	0.0
LLODKU0	Length parameter for u0 stress effect	None	0.0
LLODVTH	Length parameter for V_{TH} stress effect (must be > 0.0)	None	0.0
LODETA0	ETA_0 shift modification factor for stress effect	None	1.0
LODK2	K2 shift modification factor for stress effect	None	1.0
PKVTH0	Cross-term dependence of KVTH0	None	0.0
SAREF	Reference distance between OD edge to poly of one side (must be > 0.0)	Meter	1.0e-6
SBREF	Reference distance between OD edge to poly of the other side (must be > 0.0)	Meter	1.0e-6
STETA0	ETA_0 shift factor related to V_{TH0} change	Meter	0.0
STK2	K2 shift factor related to V_{TH0} change	Meter	0.0
TKU0	Temperature coefficient of KU0	None	0.0
WKU0	Width coefficient of KU0	None	0.0
WKVTH0	Width dependence of KVTH0	None	0.0
WLOD	Width parameter for stress effect	Meter	0.0
WLODKU0	Width parameter for u0 stress effect	None	0.0
WLODVTH	Width parameter for V_{TH} stress effect (must be ≥ 0.0)	None	0.0

The unit for each length-dependent parameter is the unit of the base parameter divided by Meter.

Table 76: Level 54 Length Dependence Parameters

Model Parameter	**Description**	**Default**

La0	Length dependence of a0	0.0
La1	Length dependence of a1	0.0
La2	Length dependence of a2	0.0
Lacde	Length dependence of acde	0.0
Lagidl	Length dependence of agidl	0.0
Lagisl	Length dependence of agisl	0.0
Lags	Length dependence of ags	0.0
Laigbacc	Length dependence of aigbacc	0.0
Laigbinv	Length dependence of aigbinv	0.0
Laigc	Length dependence of aigc	0.0
Laigs	Length dependence of aigs	0.0
Laigsd	Length dependence of aigsd	0.0
Laigd	Length dependence of aigd	0.0
Lalpha0	Length dependence of alpha0	0.0
Lalpha1	Length dependence of alpha1	0.0
Lat	Length dependence of at	0.0
Lb0	Length dependence of b0	0.0
Lb1	Length dependence of b1	0.0
Lbeta0	Length dependence of beta0	0.0
Lbgidl	Length dependence of bgidl	0.0
Lbgisl	Length dependence of bgisl	0.0
Lbigbacc	Length dependence of bigbacc	0.0
Lbigbinv	Length dependence of bigbinv	0.0
Lbigc	Length dependence of bigc	0.0
Lbigd	Length dependence of bigd	0.0
Lbigs	Length dependence of bigs	0.0
Lbigsd	Length dependence of bigsd	0.0
Lcf	Length dependence of cf	0.0
Lcdsc	Length dependence of cdsc	0.0
Lcdscb	Length dependence of cdscb	0.0
Lcdscd	Length dependence of cdscd	0.0

Lcgdl	Length dependence of cgdl	0.0
Lcgidl	Length dependence of cgidl	0.0
Lcgid	Length dependence of cgid	0.0
Lcgis	Length dependence of cgis	0.0
Lcgisl	Length dependence of cgisl	0.0
Lcgsl	Length dependence of cgsl	0.0
Lcigbacc	Length dependence of cigbacc	0.0
Lcigbinv	Length dependence of cigbinv	0.0
Lcigc	Length dependence of cigc	0.0
Lcigsd	Length dependence of cigsd	0.0
Lcit	Length dependence of cit	0.0
Lckappad	Length dependence of ckappad	0.0
Lckappas	Length dependence of ckappas	0.0
Lclc	Length dependence of clc	0.0
Lcle	Length dependence of cle	0.0
Ldelta	Length dependence of delta	0.0
Ldrout	Length dependence of drout	0.0
Ldsub	Length dependence of dsub	0.0
Ldvt0	Length dependence of dvt0	0.0
Ldvt0w	Length dependence of dvt0w	0.0
Ldvt1	Length dependence of dvt1	0.0
Ldvt1w	Length dependence of dvt1w	0.0
Ldvt2	Length dependence of dvt2	0.0
Ldvt2w	Length dependence of dvt2w	0.0
Ldvtp0	Length dependence of dvtp0	0.0
Ldvtp1	Length dependence of dvtp1	0.0
Ldwb	Length dependence of dwb	0.0
Ldwg	Length dependence of dwg	0.0
Legidl	Length dependence of egidl	0.0
Legisl	Length dependence of egisl	0.0
Leigbinv	Length dependence of eigbinv	0.0
Leta0	Length dependence of eta0	0.0

Letab	Length dependence of etab	0.0
Leu	Length dependence of eu	0.0
Lfprout	Length dependence of fprout	0.0
Lgamma1	Length dependence of gamma1	0.0
Lgamma2	Length dependence of gamma2	0.0
Lk1	Length dependence of k1	0.0
Lk2	Length dependence of k2	0.0
Lk2we	Length dependence of k2we	0.0
Lk3	Length dependence of k3	0.0
Lk3b	Length dependence of k3b	0.0
Lketa	Length dependence of keta	0.0
Lkt1	Length dependence of kt1	0.0
Lkt1l	Length dependence of kt1l	0.0
Lkt2	Length dependence of kt2	0.0
Lminvcv	Length dependence of minvcv	0.0
lkvth0	Length dependence of KVTH0	0.0
Lmoin	Length dependence of moin	0.0
Lku0we	Length dependence of KU0WE	0.0
Lndep	Length dependence of ndep	0.0
Lnfactor	Length dependence of nfactor	0.0
Lngate	Length dependence of ngate	0.0
Lnigbacc	Length dependence of nigbacc	0.0
Lnigbinv	Length dependence of nigbinv	0.0
Lnigc	Length dependence of nigc	0.0
Lnoff	Length dependence of noff	0.0
Lnsd	Length dependence of nsd	0.0
Lnsub	Length dependence of nsub	0.0
Lntox	Length dependence of ntox	0.0
Llp	Length dependence of lp	0.0
Lpclm	Length dependence of pclm	0.0
Lpdibl1	Length dependence of Pdibl1	0.0

Lpdibl2	Length dependence of Pdibl2	0.0
Lpdiblb	Length dependence of Pdiblb	0.0
Lpdits	Length dependence of pdits	0.0
Lpditsd	Length dependence of pditsd	0.0
Lphin	Length dependence of phin	0.0
Lpigcd	Length dependence of pigcd	0.0
Lpoxedge	Length dependence of poxedge	0.0
Lprt	Length dependence of prt	0.0
Lprwb	Length dependence of prwb	0.0
Lprwg	Length dependence of prwg	0.0
Lpscbe1	Length dependence of pscbe1	0.0
Lpscbe2	Length dependence of pscbe2	0.0
Lpvag	Length dependence of pvag	0.0
Lrdsw	Length dependence of rdsw	0.0
Lrdw	Length dependence of rdw	0.0
Lrsw	Length dependence of rsw	0.0
Ltvoff	Length dependence of tvoff	0.0
Ltvfbsdoff	Length dependence of tvfbsdoff	0.0
Lu0	Length dependence of u0	0.0
Lua	Length dependence of ua	0.0
Lua1	Length dependence of ua1	0.0
Lub	Length dependence of ub	0.0
Lub1	Length dependence of ub1	0.0
Luc	Length dependence of uc	0.0
Luc1	Length dependence of uc1	0.0
Lucs	Length dependence of ucs	0.0
Lucste	Length dependence of ucste	0.0
Lud	Length dependence of ud	0.0
Lud1	Length dependence of ud1	0.0
Lup	Length dependence of up	0.0
Lvbm	Length dependence of vbm	0.0
Lvbx	Length dependence of vbx	0.0

Lvfb	Length dependence of vfb	0.0
Lvfbcv	Length dependence of vfbcv	0.0
Lvfbsdoff	Length dependence of Vfbsdoff	0.0
Lvoff	Length dependence of voff	0.0
Lvoffcv	Length dependence of voffcv	0.0
Lvsat	Length dependence of vsat	0.0
Lvth0, (**Lvtho**)	Length dependence of vth0/vtho	0.0
Lvtl	Length dependence of ctl	0.0
Lw0	Length dependence of w0	0.0
Lwr	Length dependence of wr	0.0
Lxj	Length dependence of xj	0.0
Lxn	Length dependence of xn	0.0
Lxrcrg1	Length dependence of xrcrg1	0.0
Lxrcrg2	Length dependence of xrcrg2	0.0
Lxt	Length dependence of xt	0.0

The unit for each width-dependent parameter is the unit of the base parameter divided by Meter.

Table 77: Level 54 Width Dependence Model Parameters

Model Parameter	**Description**	**Default**
Wa0	Width dependence of a0	0.0
Wa1	Width dependence of a1	0.0
Wa2	Width dependence of a2	0.0
Wacde	Width dependence of acde	0.0
Wagidl	Width dependence of agidl	0.0
Wagisl	Width dependence of agisl	0.0
Wags	Width dependence of ags	0.0
Waigbacc	Width dependence of aigbacc	0.0
Waigbinv	Width dependence of aigbinv	0.0
Waigc	Width dependence of aigc	0.0
Waigd	Width dependence of aigd	0.0
Waigs	Width dependence of aigs	0.0

Waigsd	Width dependence of aigsd	0.0
Wb0	Width dependence of b0	0.0
Wb1	Width dependence of b1	0.0
Wbeta0	Width dependence of beta0	0.0
Wbgidl	Width dependence of bgidl	0.0
Wbgisl	Width dependence of bgisl	0.0
Wbigbacc	Width dependence of bigbacc	0.0
Wbigbinv	Width dependence of bigbinv	0.0
Wbigc	Width dependence of bigc	0.0
Wbigd	Width dependence of bigd	0.0
Wbigs	Width dependence of bigs	0.0
Wbigsd	Width dependence of bigsd	0.0
Wcdsc	Width dependence of cdsc	0.0
Wcdscb	Width dependence of cdscb	0.0
Wcdscd	Width dependence of cdscd	0.0
Wcf	Width dependence of cf	0.0
Wcgdl/Wcgd1	Width dependence of cgdl	0.0
Wcgidl	Width dependence of cgidl	0.0
Wcgisl	Width dependence of cgisl	0.0
Wcgsl/Wcgs1	Width dependence of cgsl	0.0
Wcigbacc	Width dependence of cigbacc	0.0
Wcigbinv	Width dependence of cigbinv	0.0
Wcigc	Width dependence of cigc	0.0
Wcigd	Width dependence of cigd	0.0
Wcigs	Width dependence of cigs	0.0
Wcigsd	Width dependence of cigsd	0.0
Wcit	Width dependence of cit	0.0
Wckappad	Width dependence of ckappad	0.0
Wckappas	Width dependence of ckappas	0.0
Wclc	Width dependence of clc	0.0
Wcle	Width dependence of cle	0.0
Wdelta	Width dependence of delta	0.0

Wdrout	Width dependence of drout	0.0
Wdsub	Width dependence of dsub	0.0
Wdvt0	Width dependence of dvt0	0.0
Wdvt0w	Width dependence of dvt0w	0.0
Wdvt1	Width dependence of dvt1	0.0
Wdvt1w	Width dependence of dvt1w	0.0
Wdvt2	Width dependence of dvt2	0.0
Wdvt2w	Width dependence of dvt2w	0.0
Wdvtp0	Width dependence of dvtp0	0.0
Wdvtp1	Width dependence of dvtp1	0.0
Wdwb	Width dependence of dwb	0.0
Wdwg	Width dependence of dwg	0.0
Wegidl	Width dependence of egidl	0.0
Wegisl	Width dependence of egisl	0.0
Weigbinv	Width dependence of eigbinv	0.0
Weta0	Width dependence of eta0	0.0
Wetab	Width dependence of etab	0.0
Weu	Width dependence of eu	0.0
Wfprout	Width dependence of fprout	0.0
Wgamma1	Width dependence of gamma1	0.0
Wgamma2	Width dependence of gamma2	0.0
Wk1	Width dependence of k1	0.0
Wk2	Width dependence of k2	0.0
Wk2we	Width dependence of k2we	0.0
Wk3	Width dependence of k3	0.0
Wk3b	Width dependence of k3b	0.0
Wketa	Width dependence of keta	0.0
Wkt1	Width dependence of kt1	0.0
Wkt1l	Width dependence of kt1l	0.0
Wkt2	Width dependence of kt2	0.0
Wku0we	Width dependence of KU0WE	0.0

Wkvth0	Width dependence of kvth0	0.0
Wkvth0we	Width dependence of kvth0we	0.0
Wminvcv	Width dependence of minvcv	0.0
Wmoin	Width dependence of moin	0.0
Wndep	Width dependence of ndep	0.0
Wnfactor	Width dependence of nfactor	0.0
Wngate	Width dependence of ngate	0.0
Wnigbacc	Width dependence of nigbacc	0.0
Wnigbinv	Width dependence of nigbinv	0.0
Wnigc	Width dependence of nigc	0.0
Wnoff	Width dependence of noff	0.0
Wnsd	Width dependence of nsd	0.0
Wnsub	Width dependence of nsub	0.0
Wntox	Width dependence of ntox	0.0
Wlp	Width dependence of lp	0.0
Wpclm	Width dependence of pclm	0.0
Wpdibl1	Width dependence of Pdibl1	0.0
Wpdibl2	Width dependence of Pdibl2	0.0
Wpdiblb	Width dependence of Pdiblb	0.0
Wpdits	Width dependence of pdits	0.0
Wpditsd	Width dependence of pditsd	0.0
Wphin	Width dependence of phin	0.0
Wpigcd	Width dependence of pigcd	0.0
Wpoxedge	Width dependence of poxedge	0.0
Wprt	Width dependence of prt	0.0
Wprwb	Width dependence of prwb	0.0
Wprwg	Width dependence of prwg	0.0
Wpscbe1	Width dependence of pscbe1	0.0
Wpscbe2	Width dependence of pscbe2	0.0
Wrdsw	Width dependence of rdsw	0.0
Wrdw	Width dependence of rdw	0.0
Wrsw	Width dependence of rsw	0.0

Wtvoff	Width dependence of tvoff	0.0
Wtvfbsdoff	Width dependence of tvfbsdoff	0.0
Wu0	Width dependence of u0	0.0
Wua	Width dependence of ua	0.0
Wua1	Width dependence of ua1	0.0
Wub	Width dependence of ub	0.0
Wub1	Width dependence of ub1	0.0
Wuc	Width dependence of uc	0.0
Wuc1	Width dependence of uc1	0.0
Wucs	Width dependence of ucs	0.0
Wucste	Width dependence of ucste	0.0
Wud	Width dependence of ud	0.0
Wud1	Width dependence of ud1	0.0
Wup	Width dependence of up	0.0
Wute	Width dependence of ute	0.0
Wvbm	Width dependence of vbm	0.0
Wvbx	Width dependence of vbx	0.0
Wvfb	Width dependence of vfb	0.0
Wvfbcv	Width dependence of vfbcv	0.0
Wvfbsdoff	Width dependence of Vfbsdoff	0.0
Wvoff	Width dependence of voff	0.0
Wvoffcv	Width dependence of voffcv	0.0
Wvsat	Width dependence of vsat	0.0
Wvth0	Width dependence of vth0	0.0
Wvtl	Width dependence of VTL	
Ww0	Width dependence of w0	0.0
Wwr	Width dependence of wr	0.0
Wxj	Width dependence of xj	0.0
Wxn	Width dependence of xn	0.0
Wxrcrg1	Width dependence of xrcrg1	0.0
Wxrcrg2	Width dependence of xrcrg2	0.0
Wxt	Width dependence of xt	0.0

The unit for each cross-dependent parameter is the unit of the base parameter divided by Meter^2.

Table 78: Level 54 MOSFET Cross Dependence Model Parameters

Model Parameter	Description	Default
Pa0	Cross dependence of a0	0.0
Pa1	Cross dependence of a1	0.0
Pa2	Cross dependence of a2	0.0
Pacde	Cross dependence of acde	0.0
Pagidl	Cross dependence of agidl	0.0
Pagisl	Cross dependence of agisl	0.0
Pags	Cross dependence of ags	0.0
Paigbacc	Cross dependence of aigbacc	0.0
Paigbinv	Cross dependence of aigbinv	0.0
Paigc	Cross dependence of aigc	0.0
Paigd	Cross dependence of aigd	0.0
Paigs	Cross dependence of aigs	0.0
Paigsd	Cross dependence of aigsd	0.0
Palpha0	Cross dependence of alpha0	0.0
Palpha1	Cross dependence of alpha1	0.0
Pat	Cross dependence of at	0.0
Pb0	Cross dependence of b0	0.0
Pb1	Cross dependence of b1	0.0
Pbeta0	Cross dependence of beta0	0.0
Pbgidl	Cross dependence of bgidl	0.0
Pbgisl	Cross dependence of bgisl	0.0
Pbigbacc	Cross dependence of bigbacc	0.0
Pbigbinv	Cross dependence of bigbinv	0.0
Pbigc	Cross dependence of bigc	0.0
Pbigd	Cross dependence of bigd	0.0
Pbigs	Cross dependence of bigs	0.0

Pbigsd	Cross dependence of bigsd	0.0
Pcdsc	Cross dependence of cdsc	0.0
Pcdscb	Cross dependence of cdscb	0.0
Pcdscd	Cross dependence of cdscd	0.0
Pcf	Cross dependence of cf	0.0
Pcgdl/Pcgd1	Cross dependence of cgdl	0.0
Pcgidl	Cross dependence of cgidl	0.0
Pcgisl	Cross dependence of cgisl	0.0
Pcgsl/Pcgs1	Cross dependence of cgsl	0.0
Pcigbacc	Cross dependence of cigbacc	0.0
Pcigbinv	Cross dependence of cigbinv	0.0
Pcigc	Cross dependence of cigc	0.0
Pcigd	Cross dependence of cigd	0.0
Pcigs	Cross dependence of cigs	0.0
Pcigsd	Cross dependence of cigsd	0.0
Pcit	Cross dependence of cit	0.0
Pckappad	Cross dependence of ckappad	0.0
Pckappas	Cross dependence of ckappas	0.0
Pclc	Cross dependence of clc	0.0
Pcle	Cross dependence of cle	0.0
Pdelta	Cross dependence of delta	0.0
Pdibl1	Cross dependence of dibl1	0.0
Pdibl2	Cross dependence of dibl2	0.0
Pdiblb	Cross dependence of diblb	0.0
Pdrout	Cross dependence of drout	0.0
Pdsub	Cross dependence of dsub	0.0
Pdvt0	Cross dependence of dvt0	0.0
Pdvt0w	Cross dependence of dvt0w	0.0
Pdvt1	Cross dependence of dvt1	0.0
Pdvt1w	Cross dependence of dvt1w	0.0
Pdvt2	Cross dependence of dvt2	0.0

Pdvt2w	Cross dependence of dvt2w	0.0
Pdvtp0	Cross dependence of dvtp0	0.0
pdvtp1	Cross dependence of dvtp1	0.0
Pdwb	Cross dependence of dwb	0.0
Pdwg	Cross dependence of dwg	0.0
Pegidl	Cross dependence of egidl	0.0
Pegisl	Cross dependence of egisl	0.0
Peigbinv	Cross dependence of eigbinv	0.0
Peta0	Cross dependence of eta0	0.0
Petab	Cross dependence of etab	0.0
Peu	Cross dependence of eu	0.0
Pfprout	Cross dependence of fprout	0.0
Pgamma1	Cross dependence of gamma1	0.0
Pgamma2	Cross dependence of gamma2	0.0
Pk1	Cross dependence of k1	0.0
Pk2	Cross dependence of k2	0.0
Pk2we	Cross dependence of k2we	0.0
Pk3	Cross dependence of k3	0.0
Pk3b	Cross dependence of k3b	0.0
Pketa	Cross dependence of keta	0.0
Pkt1	Cross dependence of kt1	0.0
Pkt1l	Cross dependence of kt1l	0.0
Pkt2	Cross dependence of kt2	0.0
Pku0	Cross dependence of ku0	0.0
Pku0we	Cross dependence of ku0we	0.0
Pkvth0	Cross dependence of kvth0	0.0
Pkvth0we	Cross dependence of kvth0we	0.0
Plambda	Cross dependence of lambda	0.0
Plp	Cross dependence of lp	0.0
Plpe0	Cross dependence of lpe0	0.0
Plpeb	Cross dependence of lpeb	0.0
Pminv	Cross dependence of minv	0.0

Pminvcv	Cross dependence of minvcv	0.0
Pmoin	Cross dependence of moin	0.0
Pndep	Cross dependence of ndep	0.0
Pnfactor	Cross dependence of nfactor	0.0
Pngate	Cross dependence of ngate	0.0
Pnigbacc	Cross dependence of nigbacc	0.0
Pnigbinv	Cross dependence of nigbinv	0.0
Pnigc	Cross dependence of nigc	0.0
Pnoff	Cross dependence of noff	0.0
Pnsd	Cross dependence of nsd	0.0
Pnsub	Cross dependence of nsub	0.0
Pntox	Cross dependence of ntox	0.0
Ppclm	Cross dependence of pclm	0.0
Ppdiblc1 (**Ppdibl1**)	Cross dependence of pdiblc1/	0.0
Ppdiblc2 (**Ppdibl2**)	Cross dependence of pdiblc2	0.0
Ppdiblcb (**Ppdiblb**)	Cross dependence of pdiblcb	0.0
Ppdits	Cross dependence of pdits	0.0
Ppditsd	Cross dependence of pditsd	0.0
Pphin	Cross dependence of phin	0.0
Ppigcd	Cross dependence of pigcd	0.0
Ppoxedge	Cross dependence of poxedge	0.0
Pprt	Cross dependence of prt	0.0
Pprwb	Cross dependence of prwb	0.0
Pprwg	Cross dependence of prwg	0.0
Ppscbe1	Cross dependence of pscbe1	0.0
Ppscbe2	Cross dependence of pscbe2	0.0
Ppvag	Cross dependence of pvag	0.0
Prdsw	Cross dependence of rdsw	0.0
Prdw	Cross dependence of rdw	0.0
Prsw	Cross dependence of rsw	0.0
Prwb	Cross dependence of rwb	0.0

Ptvoff	Cross dependence of tvoff	0.0
Ptvfbsdoff	Cross dependence of tvfbsdoff	0.0
Pu0	Cross dependence of u0	0.0
Pua	Cross dependence of ua	0.0
Pua1	Cross dependence of ua1	0.0
Pub	Cross dependence of ub	0.0
Pub1	Cross dependence of ub1	0.0
Puc	Cross dependence of uc	0.0
Puc1	Cross dependence of uc1	0.0
Pucs	Cross dependence of ucs	0.0
Pucste	Cross dependence of ucste	0.0
Pud	Cross dependence of ud	0.0
Pud1	Cross dependence of ud1	0.0
Pup	Cross dependence of up	0.0
Pute	Cross dependence of ute	0.0
Pvbm	Cross dependence of vbm	0.0
Pvbx	Cross dependence of vbx	0.0
Pvfb	Cross dependence of vfb	0.0
Pvfbcv	Cross dependence of vfbcv	0.0
Pvfbsdoff	Cross dependence of Vfbsdoff	0.0
Pvoff	Cross dependence of voff	0.0
Pvoffcv	Cross dependence of voffcv	0.0
Pvsat	Cross dependence of vsat	0.0
Pvth0, (**Pvtho**)	Cross dependence of vth0/vtho	0.0
Pvtl	Cross dependence of vtl	0.0
Pw0	Cross dependence of w0	0.0
Pwr	Cross dependence of wr	0.0
Pxj	Cross dependence of xj	0.0
Pxn	Cross dependence of xn	0.0
Pxrcrg1	Cross dependence of xrcrg1	0.0
Pxrcrg1	Cross dependence of xrcrg2	0.0
Pxt	Cross dependence of xt	0.0

BSIM4 MOSFET Model Netlist Example

```
.MODEL  N1  NMOS  LEVEL=54
+VERSION=4.3.0 BINUNIT=1 PARAMCHK=1 MOBMOD=0
+CAPMOD=2   IGCMOD=1   IGBMOD=1   GEOMOD=1
+DIOMOD=1   RDSMOD=0   RBODYMOD=0   RGATEMOD=1
+PERMOD=1   ACNQSMOD=0   TRNQSMOD=0   TEMPMOD=0
+TNOM=27     TOXE=1.8E-009  TOXP=10E-010   TOXM=1.8E-009
+DTOX=8E-10  EPSROX=3.9    WINT=5E-009  LINT=1E-009
+LL=0   WL=0    LLN=1  WLN=1
+LW=0   WW=0   LW=1   WWN=1
+LWL=0   WWL=0   XPART=0   TOXREF=1.4E-009
+SAREF=5E-6   SBREF=5E-6   WLOD=2E-6   KU0=-4E-6
+KVSAT=0.2    KVTH0=-2E-8  TKU0=0.0    LLODKU0=1.1
+WLODKU0=1.1    LLODVTH=1.0 WLODVTH=1.0 LKU0=1E-6
+WKU0=1E-6 PKU0=0.0 LKVTH0=1.1E-6    WKVTH0=1.1E-6
+PKVTH0=0.0 STK2=0.0    LODK2=1.0    STETA0=0.0
+LODETA0=1.0
+LAMBDA=4E-10
+VSAT=1.1E+005
+VTL=2.0E5 XN=6.0 LC=5E-9
+RNOIA=0.577 RNOIB=0.37
+VTH0= 0.25
+K1=0.35   K2=0.05   K3=0
+K3B=0   W0=2.5E-006  DVT0=1.8    DVT1=0.52
+DVT2=-0.032    DVT0W=0   DVT1W=0   DVT2W=0
+DSUB=2   MINV=0.05   VOFFL=0   DVTP0=1E-007
+DVTP1=0.05   LPE0=5.75E-008 LPEB=2.3E-010  XJ=2E-008
```

```
+NGATE=5E+020    NDEP=2.8E+018  NSD=1E+020    PHIN=0
+CDSC=0.0002    CDSCB=0   CDSCD=0   CIT=0
+VOFF=-0.15  NFACTOR=1.2    ETA0=0.05   ETAB=0
+UC=-3E-011
+VFB=-0.55  U0=0.032  UA=5.0E-011  UB=3.5E-018
+A0=2   AGS=1E-020
+A1=0   A2=1   B0=-1E-020   B1=0
+KETA=0.04   DWG=0   DWB=0   PCLM=0.08
+PDIBLC1=0.028  PDIBLC2=0.022  PDIBLCB=-0.005 DROUT=0.45
+PVAG=1E-020  DELTA=0.01 PSCBE1=8.14E+008 PSCBE2=5E-008
+FPROUT=0.2    PDITS=0.2    PDITSD=0.23   PDITSL=2.3E+006
+RSH=0   RDSW=50     RSW=150    RDW=150
+RDSWMIN=0   RDWMIN=0   RSWMIN=0   PRWG=0
+PRWB=6.8E-011  WR=1   ALPHA0=0.074  ALPHA1=0.005
+BETA0=30     AGIDL=0.0002    BGIDL=2.1E+009  CGIDL=0.0002
+EGIDL=0.8
+AIGBACC=0.012  BIGBACC=0.0028    CIGBACC=0.002
+NIGBACC=1   AIGBINV=0.014  BIGBINV=0.004  CIGBINV=0.004
+EIGBINV=1.1    NIGBINV=3   AIGC=0.012  BIGC=0.0028
+CIGC=0.002  AIGSD=0.012  BIGSD=0.0028    CIGSD=0.002
+NIGC=1   POXEDGE=1   PIGCD= 1   NTOX=1
+XRCRG1=12     XRCRG2=5
+CGSO=6.238E-010 CGDO=6.238E-010 CGBO=2.56E-011 CGDL=2.495E-10
+CGSL=2.495E-10 CKAPPAS=0.03   CKAPPAD=0.03   ACDE=1
+MOIN=15     NOFF=0.9    VOFFCV=0.02
+KT1=-0.37  KT1L=0.0     KT2=-0.042    UTE=-1.5
+UA1=1E-009    UB1=-3.5E-019  UC1=0   PRT=0
```

```
+AT=53000

+FNOIMOD=1   TNOIMOD=0

+JSS=0.0001    JSWS=1E-011    JSWGS=1E-010    NJS=1

+IJTHSFWD= 0.01   IJTHSREV= 0.001  BVS  = 10     XJBVS   = 1

+JSD=0.0001    JSWD=1E-011    JSWGD=1E-010    NJD=1

+IJTHDFWD=0.01   IJTHDREV=0.001  BVD=10     XJBVD=1

+PBS=1   CJS=0.0005    MJS=0.5    PBSWS=1

+CJSWS=5E-010    MJSWS=0.33   PBSWGS=1   CJSWGS=3E-010

+MJSWGS=0.33   PBD=1   CJD=0.0005    MJD=0.5

+PBSWD=1   CJSWD=5E-010    MJSWD=0.33   PBSWGD=1

+CJSWGD=5E-010    MJSWGD=0.33   TPB=0.005  TCJ=0.001

+TPBSW=0.005  TCJSW=0.001  TPBSWG=0.005  TCJSWG=0.001

+XTIS=3   XTID=3

+DMCG=0E-006    DMCI=0E-006    DMDG=0E-006    DMCGT=0E-007

+DWJ=0.0E-008  XGW=0E-007    XGL=0E-008

+RSHG=0.4    GBMIN=1E-010    RBPB=5   RBPD=15

+RBPS=15     RBDB=15     RBSB=15     NGCON=1
```

24 - MOSFET Levels 55 through 66

This topic describes the following MOSFETs:

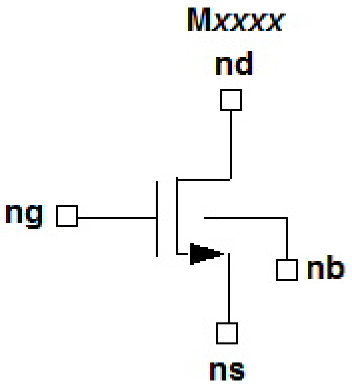
For additional MOSFETs, see

"MOSFET Levels 1 through 27" on page 22-1

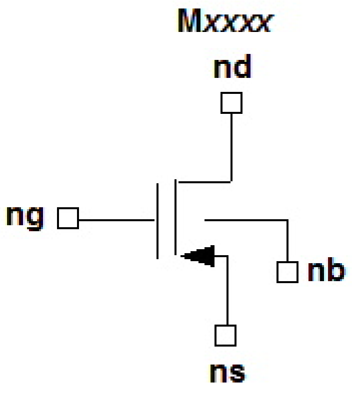
"MOSFET Levels 49 through 54" on page 23-1

"MOSFET Levels 69 through 99" on page 25-1

MOSFET Instance, EPFL-EKV Model (Level 55)



NMOS



PMOS

EPFL-EKV MOSFET Instance Netlist Syntax

The syntax for a Level 55 EPFL-EKV v2.6, R 11 MOSFET instance is:

```
Mxxxx nd ng ns [nb] modelname [[L=]length] [[W=]width]
[AD=val] [AS=val] [PD=val] [PS=val]
[NRD=val] [NRS=val] [VDSAT=val]
[M=val] [SCALE=val] [TEMP=val]
```

nd is the drain node, *ng* is the gate node, *ns* is the source node, and *nb* is the bulk or substrate node of the MOSFET. *modelname* is the name of a Level 55 MOSFET model defined in a .MODEL statement elsewhere in the netlist.

When the option **WL** is in effect (on the .OPTION statement), the syntax becomes:

```
Mxxxx nd ng ns [nb] modelname [width] [length]
[AD=val] [AS=val] [PD=val] [PS=val]
[NRD=val] [NRS=val] [VDSAT=val]
[M=val] [SCALE=val] [TEMP=val
```

Table 38: Level 55 MOSFET Instance Parameters

Instance Parameter	Description	Unit	Default
AD	Drain diffusion area	Meter^2	0.0
AS	Source diffusion area	Meter^2	0.0
L	MOSFET channel length	Meter	2.0e-6

M	Multiplier: simulates parallel transistors	None	1.0
NRD	Number of squares of drain diffusion for resistance calculations	None	1.0
NRS	Number of squares of source diffusion for resistance calculations	None	1.0
PD	Drain diffusion periphery	Meter	0.0
PS	Source diffusion periphery	Meter	0.0
SCALE	Scale factor for instance parameters	None	1.0
TEMP	Device temperature	°C	Circuit temperature
VDSAT	Saturation drift velocity	Meter/sec	0.0
W	MOSFET channel width	Meter	10.0e-6

EPFL-EKV MOSFET Instance Netlist Example

```
M245 11 12 13 14 epsmodel55 L=1.845e-6 W=9.216e-6
```

EPFL-EKV MOSFET Model, Level 55

The syntax for a Level 55 MOSFET model is:

`.MODELmodelname NMOS LEVEL=55 [(][parameter=val] ... [)]`

or

`.MODELmodelname PMOS LEVEL=55 [(][parameter=val] ... [)]`

modelname is the name used by MOSFET instances to refer to this .MODEL statement. The **LEVEL=55** entry selects the EPFL-EKV MOSFET model.

Table 39: Level 55 MOSFET Intrinsic Basic, Optional, and Process-Related Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	55 is required to select the EPFL-EKV MOSFET model	None	1 (default if LEVEL parameter is omitted)
COX	Gate oxide capacitance per unit area	Farad/Meter 2	7.0e-4
DL (**XL**)	Channel shortening	Meter	0.0

DW (**XW**, **WDEL**)	Channel narrowing	Meter	0.0
EKVINT	Interpolation function selector	None	0.0
E0 (**EO**)	Vertical critical field	Volt/Meter	1.0e+12
GAMMA	Body effect parameter	Volt$^{1/2}$	1.0
GEO	Layout geometry 0 = Drain and source not shared 1 = Drain shared 2 = Source shared 3 = Drain and source shared	None	0
KP	Transconductance parameter	Amp/Volt^2	5.0e-5
PHI	Bulk Fermi potential	Volt	0.7
SCALM	Scale factor for model parameters	None	1.0
THETA	Mobility reduction coefficient (Used only when E0 not specified)	Volt^{-1}	0.0
TNOM	Nominal device temperature	°C	25
TT	Transit time	Second	0.0
UCRIT	Longitudinal critical field	Volt/Meter	100.0e+6
UPDATE	Update parameter	None	0.0
VTO (**VT0**)	Threshold voltage at V_{BS} = 0.	Volt	NMOS: 0.5 PMOS: -0.5
XJ	Junction depth	Meter	1.0e-7

Table 40: Level 55 MOSFET Channel Length Modulation and Charge Sharing Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
LAMBDA	Depletion length coefficient	None	0.5
LETA	Short-channel effect coefficient	None	0.1
WETA	Narrow-channel effect coefficient	None	0.25

Table 41: Level 55 MOSFET Reverse Short-Channel Effect Model Parameters

Model	**Description**	**Unit**	**Default**

Parameter			
LK	Reverse short-channel effect peak characteristic length	Meter	2.9e-7
Q0	Reverse short-channel effect peak charge density	Amp-sec/Meter^2	0.0

Table 42: Level 55 MOSFET Impact Ionization Effect Model Parameters

Model Parameter	Description	Unit	Default
IBA	1st impact ionization coefficient	Meter^{-1}	0.0
IBB	2nd impact ionization coefficient	Volt-Meter^{-1}	3.0e+8
IBN	Saturation voltage factor for impact ionization	None	1.0

Table 43: Level 55 MOSFET Temperature Model Parameters

Model Parameter	Description	Unit	Default
BEX	Surface channel mobility temperature exponent	None	-1.5
IBBT	Temperature coefficient for IBB	°K^{-1}	9.0e-4
TCV	Threshold voltage temperature coefficient	Volt/°K	1.0e-3
TR1	1st-order temperature coefficient	°K^{-1}	0.0
TR2	2nd-order temperature coefficient	°K^{-2}	0.0
UCEX	Longitudinal critical field temperature exponent	None	0.8

Table 44: Level 55 MOSFET Flicker Noise Model Parameters

Model Parameter	Description	Unit	Default
AF	Flicker noise exponent	None	1.0
KF	Flicker noise coefficient	None	0.0

Table 45: Level 55 MOSFET Setup Model Parameters

Model Parameter	Description	Unit	Default
NQS	Non-Quasi-Static (NQS) operation selector	None	0.0

SATLIM	Ratio defining the saturation limit	None	e^4 [exp(4)]

Table 46: Level 55 MOSFET Junction Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
ACM	Area calculation method selector	None	0
CBS (**CAPBS**)	Bulk-drain overlap capacitance	Farad	0.0
CBD (**CAPBD**)	Bulk-source overlap capacitance	Farad	0.0
CJ	Zero bias bulk junction bottom capacitance per sq meter of junction area	Farad/Meter 2	0.0
CJGATE	Zero-bias bulk junction sidewall capacitance	Farad/Meter	CJSW
CJSW	Zero-bias bulk junction sidewall capacitance per meter of junction perimeter	Farad/Meter	0.0
FC	Forward-bias capacitance depletion coefficient	None	0.5
HDIF	Length of heavily-doped diffusion region from contact to lightly-doped region	Meter	0.0
LD (**DLAT**, **LATD**)	Lateral diffusion into channel from source and drain diffusion	Meter	Calculated
LDIF	Length of lightly-doped diffusion near gate	Meter	0.0
IS	Bulk junction saturation current	Amp	1.0e-14
JS	Bulk junction saturation current density	Amp/Meter^2	0.0
JSW	Bulk junction sidewall saturation current	Amp/Meter	0.0
MJ	Bulk junction bottom grading coefficient	None	0.5
MJSW	Bulk junction sidewall grading coefficient	None	0.33
N	Emission coefficient	None	1.0
PB	Bulk junction contact potential	Volt	0.8
PBSW	Bulk junction sidewall contact potential	Volt	0.8
WMLT	Diffusion layer width reduction factor	None	1.0
XTI	Junction current temperature coefficient	None	3.0

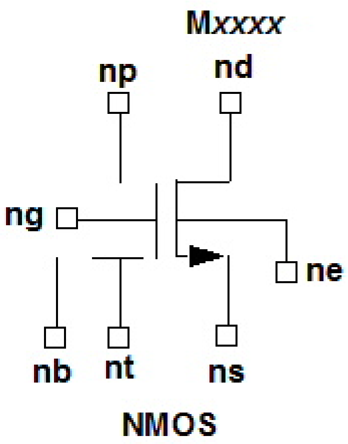
Table 47: Level 55 MOSFET Resistance and Capacitance Model Parameters

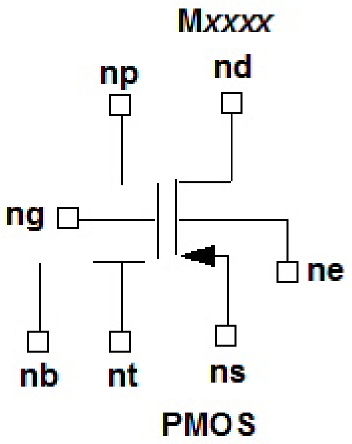
Model Parameter	Description	Unit	Default
CGBO	Gate-bulk overlap capacitance per meter channel length	Farad/Meter	0.0
CGDO	Gate-drain overlap capacitance per meter channel width	Farad/Meter	0.0
CGSO	Gate-source overlap capacitance per meter channel width	Farad/Meter	0.0
RD	Drain resistance	Ohm	0.0
RDC	Drain contact resistance for per-finger device	Ohm	0.0
RS	Source resistance	Ohm	0.0
RSC	Source contact resistance for per-finger device	Ohm	0.0
RSH	Source/drain sheet resistance per square.	Ohm/square	0.0

EPFL-EKV MOSFET Model Netlist Example

```
.MODEL epflekvmosfet LEVEL=55

+ COX=3.45E-3 XJ=0.15E-6 VTO=0.7 GAMMA=0.7 PHI=0.5

+ KP=150E-6 E0=200E+6 UCRIT=2.3E+6 LAMBDA=0.8

+ LETA=0.3 WETA=0.2 Q0=230E-6 LK=0.4E-6

+ IBA=2.0E+8 IBB=2.0E+8 IBN=0.6
```

MOSFET Instance, BSIM3-SOI Model (Level 57)





BSIM3-SOI MOSFET Instance Netlist Syntax

The syntax for a LEVEL=57 BSIM3-SOI v2.0.1 MOSFET instance is:

```
Mxxxx nd ng ns ne [np] [nb] modelname [L=length] [W=width]
[AD=val] [AS=val] [PD=val] [PS=val]
[NRD=val] [NRS=val] [NRB=val] [RTH0=val] [CTH0=val]
[NBC=val] [NSEG=val] [PDBCP=val] [PSBCP=val]
[AGBCP=val] [AEBCP=val] [TNODEOUT=val]
[FRBODY=val] [BJTOFF=val] [M=val]
```

nd is the drain node, *ng* is the front gate node, *ns* is the source node, *ne* is the back gate or substrate node, *np* is the external body contact node, and *nb* is the internal body node of the MOSFET. *modelname* is the name of a BSIM3-SOI MOSFET model defined in a .MODEL statement elsewhere in the netlist.

When the option **WL** is in effect (on the .OPTION statement), the syntax becomes:

```
Mxxxx nd ng ns [nb] modelname [width] [length]
[AD=val] [AS=val] [PD=val] [PS=val]
[NRD=val] [NRS=val] [NRB=val] [RTH0=val] [CTH0=val]
[NBC=val] [NSEG=val] [PDBCP=val] [PSBCP=val]
[AGBCP=val] [AEBCP=val] [TNODEOUT=val]
[FRBODY=val] [BJTOFF=val] [M=val]
```

Table 48: Level 57 MOSFET Instance Parameters

Instance Parameter	Description	Unit	Default
AD	Drain diffusion area	Meter^2	0.0

AEBCP	Parasitic body-to-substrate overlap area for body contact	Meter^2	0.0
AGBCP	Parasitic gate-to-body overlap area for body contact	Meter^2	0.0
AS	Source diffusion area	Meter^2	0.0
BJTOFF	1 = Turn off BJT	None	0
CTH0	Thermal capacitance per unit width	Farad/Meter	1.0e-5
FRBODY	Coefficient of distributed body resistance effects	None	1.0
L	SOI MOSFET channel length	Meter	5.0e-6
M	Multiplier: simulates parallel transistors	None	1.0
NBC	Number of body contact isolation edges	None	0.0
NRB	Number of squares for body series resistance	None	0.0
NRD	Number of squares of drain diffusion for resistance calculations	None	0.0
NRS	Number of squares of source diffusion for resistance calculations	None	0.0
NSEG	Number of segments for channel width partitioning	None	1.0
PD	Drain diffusion perimeter including channel edge	Meter	0.0
PDBCP	Parasitic perimeter length for the body contact at drain side	Meter	0.0
PS	Source diffusion perimeter including channel edge	Meter	0.0
PSBCP	Parasitic perimeter length for the body contact at source side	Meter	0.0
RTH0	Thermal resistance per unit width	Ohm/Meter	0.0
TNODEOUT	Temperature node flag. If TNODEOUT is not specified, specifying four nodes floats the body node, while specifying five nodes sets the fifth node as the external body contact node, and a body resistance is placed between the internal and external terminals (distributed body resistance simulation). If TNODEOUT is specified, the last node is interpreted as the temperature node. In this case, specifying five nodes floats the device, while specifying six nodes implies a body-contacted case. If seven nodes are specified, the simulation assumes the body-contacted case with an accessible internal body node (thermal coupling simulation).	None	Not present

W	SOI MOSFET channel width	Meter	5.0e-6

Netlist Example

```
M65 90 91 92 mos33 L=1.2e-6
```

BSIM3-SOI MOSFET Model, Level 57

The syntax for a BSIM3-SOI Level 57 MOSFET model is:

`.MODELmodelname NMOS LEVEL=57 [(][parameter=val] ... [)]`

or

`.MODELmodelname PMOS LEVEL=57 [(][parameter=val] ... [)]`

modelname is the name used by MOSFET instances to refer to this .MODEL statement. The **LEVEL=57** entry selects a BSIM3-SOI MOSFET model.

Table 49: Level 57 MOSFET Control Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	57 is required to select the BSIM3-SOI MOSFET model	None	1 (default if LEVEL parameter is omitted)
CAPMOD	Flag for short-channel capacitance model	None	2
FNOIMOD	Flicker noise model selector	None	1.0
IGMOD	Gate current model selector	None	0.0
IGCMOD	Gate-channel current model selector	None	0.0
MOBMOD	Mobility model selector	None	1
NOIMOD	Noise model selector	None	1
RGATEMOD	Gate resistance model selector	None	0.0
SCALEM	Model parameter scale factor	None	1.0
SHMOD	Self-heating model selector 0 = No self-heating 1 = Self-heating	None	0
SOIMOD	SOI model selector	None	0.0

TNOIMOD	Thermal noise model selector	None	0.0
VERSION	Model version selector	None	3.22

Table 50: Level 57 MOSFET Process Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
DTOXCV	Difference between electrical and physical gate oxide thicknesses (CAPMOD = 3)	Meter	0.0
NCH	Channel doping concentration	cm^{-3}	1.7e+17
NGATE	Polysilicon gate doping concentration	cm^{-3}	0.0
NSUB	Substrate doping concentration	cm^{-3}	6.0e+16
TBOX	Buried oxide thickness	Meter	3.0e-7
TOX	Gate oxide thickness	Meter	1.0e-8
TOXM	Gate oxide thickness used in extraction	Meter	TOX
TSI	Silicon film thickness	Meter	1.0e-7
XGL	Offset of gate length due to variations in patterning	Meter	0.0
XGW	Distance from gate contact to channel edge	Meter	0.0
XJ	Source/drain junction depth	Meter	Calculated
XT	Doping depth	Meter	1.55e-7
XW	Correction for masking and etching effects	Meter	0.0

Table 51: Level 57 MOSFET DC Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
A0	Bulk charge effect coefficient for channel length	None	1.0
A1	1st non-saturation effect parameter	$Volt^{-1}$	0.0
A2	2nd non-saturation effect parameter	None	1.0
AELY	Channel length dependency of Early voltage for bipolar current	Volt/Meter	0.0
AGIDL	GIDL constant	Ohm^{-1}	0.0
AGS	Gate bias coefficient of A_{bulk}	$Volt^{-1}$	0.0

AHLI	High-level injection parameter for bipolar current	None	0.0
AIGC	Parameter for Igc	None	Calculated
AIGSD	Parameter for Igs,d	None	Calculated
ALPHA0	1st parameter of impact ionization current	Meter/Volt	0.0
ALPHAGB1	1st Vox-dependent parameter for gate current in inversion	Volt^{-1}	0.35
ALPHAGB2	1st Vox-dependent parameter for gate current in accumulation	Volt^{-1}	0.43
B0	Bulk charge effect coefficient for channel width	Meter	0.0
B1	Bulk charge effect width offset	Meter	0.0
BETA0	1st Vds dependence parameter of impact ionization current	Volt^{-1}	0.0
BETA1	2nd Vds dependence parameter of impact ionization current	None	0.0
BETA2	3rd Vds dependence parameter of impact ionization current	Volt	0.1
BETAGB1	2nd Vox-dependent parameter for gate current in inversion	Volt^{-2}	0.03
BETAGB2	2nd Vox-dependent parameter for gate current in accumulation	Volt^{-2}	0.05
BGIDL	GIDL exponential coefficient	Volt/Meter	0.0
BIGC	Parameter for Igc	None	Calculated
BIGSD	Parameter for Igs,d	None	Calculated
CDSC	Drain/source to channel coupling capacitance	Farad/Meter^2	2.4e-4
CDSCB	Body-bias sensitivity of CDSC	Farad/Meter^2	0.0
CDSCD	Drain-bias sensitivity of CDSC	Farad/Meter^2	0.0
CIGC	Parameter for Igc	None	Calculated
CIGSD	Parameter for Igs,d	None	Calculated
CIT	Interface trap capacitance	Farad/Meter^2	0.0
DELTA	Effective Vds parameter	None	0.01
DELTAVOX	Vox smoothing parameter	None	0.005
DK2B	Third backgate body effect parameter for short channel effect	None	0.0

DLCIG	Delta L for Ig model	Meter	LINT
DROUT	Length dependence coefficient of the DIBL correection parameter Rout	None	0.56
DSUB	DIBL coefficient exponent	None	DROUT
DVBD0	1st short-channel effect parameter in FD module	None	0.0
DVBD1	2nd short-channel effect parameter in FD module	None	0.0
DVT0	1st coefficient of short-channel effect on Vth	None	2.2
DVT0W	1st coefficient of narrow-width effect on Vth for small channel length	None	0.0
DVT1	2nd coefficient of short-channel effect on Vth	None	0.53
DVT1W	2nd coefficient of narrow-width effect on Vth for small channel length	None	5.3e+6
DVT2	Body-bias coefficient of short-channel effect on Vth	Volt^{-1}	-0.032
DVT2W	Body-bias coefficient of narrow-width effect on Vth for small channel length	Volt^{-1}	-0.032
DWB	Coefficient of Weff gate dependence	$\text{Meter/Volt}^{1/2}$	0.0
DWBC	Width offset for body contact isolation edge	Meter	0.0
DWG	Coefficient of Weff gate dependence	Meter/Volt	0.0
EBG	Effective band gap in gate current calculation	Volt	1.2
ESATII	Saturation channel electric field for impact ionization current	Volt/Meter	1.0e+7
ETA0	DIBL coefficient in the subthreshold region	None	0.08
ETAB	Body-bias coefficient for the subthreshold DIBL effect	Volt^{-1}	-0.07
FBJTII	Fraction of bipolar current affecting impact ionization	None	0.0
GAMMA1	Vth body coefficient	None	Calculated
GAMMA2	Vth body coefficient	None	Calculated
ISBJT	BJT injection saturation current	Amp/Meter^2	1.0e-6
ISDIF	Body to source/draininjection saturation current	Amp/Meter^2	0.0
ISREC	Recombination in depletion saturation current	Amp/Meter^2	1.0e-5
ISTUN	Reverse tunneling saturation current	Amp/Meter^2	0.0
K1	1st-order body effect coefficient	$\text{Volt}^{1/2}$	0.53

K1B	1st backgate body effect parameter	None	1.0
K1W1	1st-order effect width dependent parameter	Meter	0.0
K1W2	2nd-order effect width dependent parameter	Meter	0.0
K2	2nd-order body effect coefficient	None	-0.0186
K2B	2nd backgate body effect parameter for short-channel effect	None	0.0
K3	3rd-order body effect coefficient	None	0.0
K3B	Body effect coefficient of K3	Volt^{-1}	0.0
KB1	Back gate body charge coefficient	None	1.0
KETA	Body-bias coefficient of bulk change effect	Volt^{-1}	-0.6
KETAS	Surface potential adjuxtment for bulk charge effect	Volt	0.0
LBJT0	Reference channel length for bipolar current	Meter	0.2e-6
LII	Length dependence parameter for impact ionization current	None	0.0
LINT	Length offset fitting parameter from I-V without bias	Meter	0.0
LL	Length reduction parameter	None	0.0
LLC	Length reduction parameter	None	0.0
LLN	Length reduction parameter	None	1.0
LN	Electron/hole diffusion length	Meter	2.0e-6
LW	Length reduction parameter	None	0.0
LWC	Length reduction parameter	None	0.0
LWL	Length reduction parameter	None	0.0
LWLC	Length reduction parameter	None	0.0
LWN	Length reduction parameter	None	1.0
MOINFD	Gate bias dependence coefficient of surface potential in FD module	None	1.0e3
NBJT	Power coefficient of channel length dependency for bipolar current	None	1.0
NDIODE	Diode non-ideality factor	None	1.0
NFACTOR	Subthreshold swing factor	None	1.0
NGCON	Number of gate contacts	None	1.0
NGIDL	GIDL Vds enhancement coefficient	Volt	1.2

NIGC	Parameter for Igc slope	None	1.0
NLX	Lateral non-uniform doping parameter	Meter	1.74e-7
NOFFFD	Smoothing parameter	None	1.0
NRECF0	Recombination non-ideality factor at forward bias	None	2.0
NRECR0	Recombination non-ideality factor at reverse bias	None	10.0
NTOX	Power term of gate current	None	1.0
NTUN	Reverse tunneling non-ideality factor	None	10.0
PCLM	Channel length modulation parameter	None	1.3
PDIBLC1	1st output resistance DIBL effect correction parameter	None	0.39
PDIBLC2	2nd output resistance DIBL effect correction parameter	None	0.0086
PDIBLCB	Body effect on drain-induced barrier lowering	None	0.0
PIGCD	Parameter for Igc partition	None	1.0
POXEDGE	Factor for gate edge Tox	None	1.0
PRWB	Body effect coefficient of RDSW	Volt^{-1}	0.0
PRWG	Gate bias effect coefficient of RDSW	Volt$^{-1/2}$	0.0
PVAG	Vate dependence of Early voltage	None	0.0
RBODY	Intrinsic body contact sheet resistance	Ohm/Meter^{2}	0.0
RBSH	Extrinsic body contact sheet resistance	Ohm/Meter^{2}	0.0
RDSW	Parasitic resistance per unit width	Ohm/μMeter WR	100
RHALO	Body halo sheet resistance	Ohm/Meter	1.0e15
RSH	Source/drain sheet resistance	Ohm/square	0.0
RSHG	Gate sheet resistance	Ohm/square	0.0
SII0	1st Vgs dependence parameter for impact ionization current	Volt^{-1}	0.50
SII1	2nd Vgs dependence parameter for impact ionization current	Volt^{-1}	0.1
SII2	3rd Vgs dependence parameter for impact ionization current	Volt^{-1}	0.0
SIID	Vds dependence parameter of drain saturation voltage for impact ionization current	Volt^{-1}	0.0
TII	Temperature dependence parameter for impact	None	0.0

	ionization current		
TOXQM	Oxide thickness for Igb calculation	Meter	TOX
TOXREF	Target oxide thickness	Meter	2.5e-9
U0	Mobility at TEMP = TNOM	Meter/Volt-sec	NMOS: 0.067 PMOS: 0.025
UA	1st-order mobility degradation coefficient	Meter/Volt	2.25e-9
UB	2nd-order mobility degradation coefficient	Meter/Volt^2	5.87e-19
UC	Body effect of mobility degradation coefficient	Volt^{-1}	Calculated
VABJT	Early voltage for bipolar current	Volt	10
VBM	Maximum body voltage	Volt	3.0
VBSA	Offset voltage	Volt	0.0
VBS0FD	Lower bound of built-in potential lowering for ideal FD operation	Volt	0.0
VBS0PD	Upper bound of built-in potential lowering for ideal FD operation	Volt	0.5
VBX	Vth transition body voltage	Volt	Calculated
VDSATII0	Nominal drain saturation voltage at threshold for impact ionization current	Volt	0.9
VECB	Electron tunneling on the conduction band	Volt	0.026
VEVB	Electron tunneling on the valence band	Volt	0.075
VGB1	3rd Vox-dependent parameter for gate current in inversion	Volt	300
VGB2	3rd Vox-dependent parameter for gate current in accumulation	Volt	17.0
VOFF	Offset voltage in the subthreshold region for large W and L	Volt	-0.08
VOFFFD	Smoothing parameter	None	0.0
VOXH	Limit of Vox in gate current calculation	Volt	5.0
VREC0	Voltage dependent parameter for recombination current	Volt	0.0
VSAT	Saturation velocity at TEMP = TNOM	Meter/sec	8.0e+4
VTH0 (**VTHO**)	Threshold voltage at Vbs = 0 for long wide device	Volt	Calculated

VTUN0	Voltage dependent parameter for tunneling current	Volt	0.0
W0	Narrow width parameter	Meter	2.5e-6
WINT	Width offset fitting parameter from I-V without bias	Meter	0.0
WL	Width reduction parameter	None	0.0
WLC	Width reduction parameter	None	0.0
WLN	Width reduction parameter	None	1.0
WR	Width offset from Weff for RDS calculation	None	1.0
WTH0	Minimum width for thermal resistance calculation	Meter	0.0
WW	Width reduction parameter	None	0.0
WWC	Width reduction parameter	None	0.0
WWL	Width reduction parameter	None	0.0
WWLC	Width reduction parameter	None	0.0
WWN	Width reduction parameter	None	1.0
XRCRG1	Parameter for distributed channel resistance effect for intrinsic input resistance	None	0.0
XRCRG2	Parameter to account for excess channel diffusion resistance for intrinsic input resistance	None	0.0

Table 52: Level 57 MOSFET AC and Capacitance Model Parameters

Model Parameter	Description	Unit	Default
ACDE	Exponential coefficient for charge thickness in CAPMOD=3 for accumulation and depletion regions	Meter/Volt	1.0
ASD	Source/drain bottom diffusion smoothing parameter	Volt	0.3
CF	Gate to source/drain fringing field capacitance	Farad/Meter	Calculated
CGDL	Lightly-doped drain-gate region overlap capacitance	Farad/Meter	0.0
CGDO	Non-LDD region drain-gate overlap capacitance per unit gate width	Farad/Meter	Calculated
CGEO	Gate-substrate overlap capacitance per unit gate width	Farad/Meter	0.0
CGSL	Lightly-doped source-gate region overlap capacitance	Farad/Meter	0.0
CGSO	Non-LDD region source-gate overlap capacitance per	Farad/Meter	Calculated

	unit gate width		
CJSWG	Zero-bias sidewall bulk junction capacitance	Farad/Meter 2	1.0e-10
CKAPPA	Coefficient for lightly-doped region overlap capacitance	Volt	0.6
CLC	Constant term for the short-channel model	Meter	1.0e-8
CLE	Exponential term for the short-channel model	None	0.0
CSDESW	Source/drain sidewall fringing capacitance per unit length	Farad/Meter	0.0
CSDMIN	Source/drain bottom diffusion minimum capacitance	Farad	Calculated
DELVT	Threshold voltage adjust for C-V	Volt	0.0
DLBG	Length offset fitting parameter for back gate charge	Meter	0.0
DLC	Length offset fitting parameter for gate charge	Meter	LINT
DLCB	Length offset fitting parameter for body charge	Meter	0.0
DWC	Width offset fitting parameter from C-V	Meter	WINT
FBODY	Scaling factor for body charge	None	1.0
LDIF0	Channel length dependency coefficient of diffusion capacitance	None	1.0
MJSWG	Source/drain (gate side) sidewall junction capacitance grading coefficient	Volt	0.5
MOIN	Coefficient for the gate bias-dependent surface potential	Volt½	15.0
NDIF	Power coefficient of channel length dependency for diffusion capacitance	None	-1.0
NOFF	Switch to turn C-V on/off	None	1.0
PBSWG	Source/drain (gate side) sidewall junction capacitance built-in potnetial	Volt	0.7
TT	Diffusion capacitance transit time coefficient	Second	1.0e-12
VSDFB	Source/drain bottom diffusion capacitance flatband voltage	Volt	Calculated
VSDTH	Source/drain bottom diffusion capacitance threshold voltage	Volt	Calculated
XPART	Selector for gate capacitance drain versus source charge sharing coefficient 0, 0.4 = 40/60 0.5 = 50/50	None	0 (40/60)

	≥ 1 = 0/100 Any other value < 1 = 40/60		

Table 53: Level 57 MOSFET Temperature Model Parameters

Model Parameter	Description	Unit	Default
AT	Temperature coefficient of VSAT	Meter/sec	3.3e+4
CTH0	Normalized thermal capacitance	Meter-°C/Ohm-sec	1.0e-5
KT1	Temperature coefficient for the threshold voltage	Volt	-0.11
KT2	Body-bias coefficient of the threshold voltage temperature effect	None	0.022
KT1L	Channel length dependence of the temperature coefficient for the threshold voltage	Volt-Meter	0.0
NTRECF	Temperature coefficient for NRECF	None	0.0
NTRECR	Temperature coefficient for NRECR	None	0.0
PRT	Temperature coefficient for RDSW	Ohm-μMeter	0.0
RTH0	Normalized thermal resistance	Meter-°C/Ohm	0.0
TCJSWG	Temperature coefficient for CJSWG	°K^{-1}	0.0
TNOM	Temperature at which parameters are extracted	°C	Circuit temperature
TPBSWG	Temperature coefficient for PBSWG	Volt/°K	0.0
UA1	Temperature coefficient for UA	Meter/Volt	4.31e-9
UB1	Temperature coefficient for UB	Meter ^{2}/Volt^{2}	-7.61e-18
UC1	Temperature coefficient for UC	Vol^{t-1}	Calculated
UTE	Mobility temperature exponent	None	-1.5
XBJT	Power dependence of JBJT on temperature	None	2.0
XDIF	Power dependence of JDIF on temperature	None	2.0
XREC	Power dependence of JREC on temperature	None	1.0
XTUN	Power dependence of JTUN on temperature	None	0.0

Table 54: Level 57 MOSFET Noise Model Parameters

Model Parameter	Description	Unit	Default
AF	Flicker noise exponent	None	1.0
EF	Flicker noise frequency exponent	None	1.0
EM	Flicker noise parameter	None	4.1e7
KF	Flicker noise coefficient	None	0.0
NOIA	Flicker noise parameter	None	NMOS: 1.0e20 PMOS: 9.9e18
NOIB	Flicker noise parameter	None	NMOS: 1.0e4 PMOS: 2.4e3
NOIC	Flicker noise parameter	None	NMOS: -1.4e-12 PMOS: 1.4e-12
NOIF	Floating body excess noise ideality factor	None	1.0
NTNOI	Noise factor for short-channel devices (TNOIMOD = 0 or 2)	None	1.0
RNOIA	Thermal noise parameter	None	0.577
RNOIB	Thermal noise parameter	None	0.37
TNOIA	Coefficient of channel length dependence of total channel thermal noise	None	1.5
TNOIB	Channel length dependence parameter for channel thermal noise partitioning	None	3.5

Table 55: Level 57 MOSFET Binning Model Parameters

Model Parameter	Description	Unit	Default
BINUNIT	Binning unit selector	None	1.0
LMIN	Minimum channel length	Meter	0.0
LMAX	Maximum channel length	Meter	1.0

WMIN	Minimum channel width	Meter	0.0
WMAX	Maximum channel width	Meter	1.0

Notes on BSIM3SOI Binning Adjustment

Binning is a way to extend a single device architecture by providing systematic variations on the device parameters. The philosophy is that when you vary the channel geometry, other parameters also change, in ways that can be completely characterized by the device manufacturer. The manufacturer or foundry provides a “design kit” that contains a set of .MODEL statements specifying the parameter settings for the different geometries. The design kit with the .MODEL statements can be included in the Nexxim design as a subcircuit.

1. A binning model is identified by giving the model name in the .MODEL statement the form *modelname***.***n*, where the entry *n* after the decimal point can be an integer or any other unique identifier. The MOSFET instance definition refers to the *modelname* without any extension. The netlist can contain any number of different binning models with the same base *modelname*. For example, three binning models could be named NMOSBSIM3.1 NMOSBSIM3.2, and NMOSBSIM3.3. The instance statement reference is NMOSBSIM3.

   Each of the available binning models corresponds to a range of channel lengths and widths specified with the **LMIN**, **LMAX**, **WMIN**, and **WMAX** model parameters. The ranges must not overlap.

   Each binning model typically specifies values for the model parameters that are related to the channel geometry variations.

2. The MOSFET instance statement must contain values for instance parameters **L** and **W**. The **L** and **W** parameters can be specified with variables so a sweep of binning models can be performed.
3. The simulator finds the binning model to which the following conditions BOTH apply:
   - The **LMIN** and **LMAX** model parameter range includes the value of instance parameter **L** (scaled by the instance parameter **SCALE**).
   - The **WMIN** and **WMAX** model parameter range includes the value of instance parameter **W** (scaled by the instance parameter **SCALE**).

   If none of the available binning models matches the **L** and **W** instance parameters, simulation does not proceed.

4. Within a BSIM3 model, (binned or not) the binned model parameters are adjusted by the effective channel length and width. The formulas for the adjustment use the following symbols:

   N = value of the model parameter (e.g., **A0**).

   LN = value of the length dependence parameter (e.g., **LA0**).

WN = value of the width dependence parameter (e.g., **WA0**).

PN = value of the cross dependence parameter (e.g., **PA0**).

Leff = effective channel length (calculated from **L** using scale factors and other adjustments).

Weff = effective channel width (calculated from **W** using scale factors and other adjustments).

LREFeff = effective reference channel length (calculated from model parameter **LREF** using scale factors and other adjustments).

WREFeff = effective reference channel width (calculated from **WREF** using scale factors and other adjustments).

When model parameter **BINFLAG** is greater than 0.9 AND the model parameters **LREF** and **WREF** are both greater than 0:

```
Value = N + LN*(1/Leff-1/LREFeff)
+ WN*(1/Weff-1/WREFeff)
+ PN*(1/(Leff-1/LREFeff)*(1/(Weff-1/WREFeff)))
```

Otherwise:

```
Value = N + LN*(1/Leff) + WN*(1/Weff) + PN*(1/(Leff*Weff))
```

5. When model parameter **BINUNIT** equals 1, the effective parameters (Leff, Weff, LREFeff, and WREFeff) are scaled to units of microns. By default (**BINUNIT** not equal to 1), units are meters.

Table 56: Level 57 MOSFET Dependence Parameters

Model Parameter	Description	Unit	Default
Lnch	Length dependence of Nch	None	0.0
Wnch	Width dependence of Nch	None	0.0
Pnch	Cross-term dependence of Nch	None	0.0
lnsub	Length dependence of Nsub	None	0.0
Wnsub	Width dependence of Nsub	None	0.0
Pnsub	Cross-term dependence of Nsub	None	0.0
Lngate	Length dependence of Ngate	None	0.0
Wngate	Width dependence of Ngate	None	0.0
Pngate	Cross-term dependence of Ngate	None	0.0
Lvth0 (lvtho)	Length dependence of Vth0	None	0.0
Wvth0 (lvtho)	Width dependence of Vth0	None	0.0

Pvth0 (lvtho)	Cross-term dependence of Vth0	None	0.0
Lk1	Length dependence of K1	None	0.0
Wk1	Width dependence of K1	None	0.0
Pk1	Cross-term dependence of K1	None	0.0
Lk2	Length dependence of K2	None	0.0
Wk2	Width dependence of K2	None	0.0
Pk2	Cross-term dependence of K2	None	0.0
Lk3	Length dependence of K3	None	0.0
Wk3	Width dependence of K3	None	0.0
Pk3	Cross-term dependence of K3	None	0.0
Lkb1	Length dependence of KB1	None	0.0
Wkb1	Width dependence of KB1	None	0.0
Pkb1	Cross-term dependence of KB1	None	0.0
Lk3b	Length dependence of K3B	None	0.0
Wk3b	Width dependence of K3B	None	0.0
Pk3b	Cross-term dependence of K3B	None	0.0
Lk1w1	Length dependence of K1W1	None	0.0
Wk1w1	Width dependence of K1W1	None	0.0
Pk1w1	Cross-term dependence of K1W1	None	0.0
Lk1w2	Length dependence of K1W2	None	0.0
Wk1w2	Width dependence of K1W2	None	0.0
Pk1w2	Cross-term dependence of K1W2	None	0.0
Lw0	Length dependence of W0	None	0.0
Ww0	Width dependence of W0	None	0.0
Pw0	Cross-term dependence of W0	None	0.0
Lnlx	Length dependence of Nlx	None	0.0
Wnlx	Width dependence of Nlx	None	0.0
Pnlx	Cross-term dependence of Nlx	None	0.0
Ldvt0	Length dependence of DVT0	None	0.0
Wdvt0	Width dependence of DVT0	None	0.0
Pdvt0	Cross-term dependence of DVT0	None	0.0

Ldvt1	Length dependence of DVT1	None	0.0
Wdvt1	Width dependence of DVT1	None	0.0
Pdvt1	Cross-term dependence of DVT1	None	0.0
Ldvt2	Length dependence of DVT2	None	0.0
Wdvt2	Width dependence of DVT2	None	0.0
Pdvt2	Cross-term dependence of DVT2	None	0.0
Ldvt0w	Length dependence of DVT0W	None	0.0
Wdvt0w	Width dependence of DVT0W	None	0.0
Pdvt0w	Cross-term dependence of DVT0W	None	0.0
Ldvt1w	Length dependence of DVT1W	None	0.0
Wdvt1w	Width dependence of DVT1W	None	0.0
Pdvt1w	Cross-term dependence of DVT1W	None	0.0
Ldvt2w	Length dependence of DVT2W	None	0.0
Wdvt2w	Width dependence of DVT2W	None	0.0
Pdvt2w	Cross-term dependence of DVT2W	None	0.0
Lu0	Length dependence of U0	None	0.0
Wu0	Width dependence of U0	None	0.0
Pu0	Cross-term dependence of U0	None	0.0
Lua	Length dependence of UA	None	0.0
Wua	Width dependence of UA	None	0.0
Pua	Cross-term dependence of UA	None	0.0
Lub	Length dependence of UB	None	0.0
Wub	Width dependence of UB	None	0.0
Pub	Cross-term dependence of UB	None	0.0
Luc	Length dependence of UC	None	0.0
Wuc	Width dependence of UC	None	0.0
Puc	Cross-term dependence of UC	None	0.0
Lvsat	Length dependence of Vsat	None	0.0
Wvsat	Width dependence of Vsat	None	0.0
Pvsat	Cross-term dependence of Vsat	None	0.0
La0	Length dependence of A0	None	0.0
Wa0	Width dependence of A0	None	0.0

Pa0	Cross-term dependence of A0	None	0.0
La1	Length dependence of A1	None	0.0
Wa1	Width dependence of A1	None	0.0
Pa1	Cross-term dependence of A1	None	0.0
La2	Length dependence of A2	None	0.0
Wa2	Width dependence of A2	None	0.0
Pa2	Cross-term dependence of A2	None	0.0
Lb0	Length dependence of B0	None	0.0
Wb0	Width dependence of B0	None	0.0
Pb0	Cross-term dependence of B0	None	0.0
Lb1	Length dependence of B1	None	0.0
Wb1	Width dependence of B1	None	0.0
Pb1	Cross-term dependence of B1	None	0.0
Lags	Length dependence of Ags	None	0.0
Wags	Width dependence of Ags	None	0.0
Pags	Cross-term dependence of Ags	None	0.0
Lketa	Length dependence of KETA	None	0.0
Wketa	Width dependence of KETA	None	0.0
Pketa	Cross-term dependence of KETA	None	0.0
Lketas	Length dependence of KETAS	None	0.0
Wketas	Width dependence of KETAS	None	0.0
Pketas	Cross-term dependence of KETAS	None	0.0
Lrdsw	Length dependence of RDSW	None	0.0
Wrdsw	Width dependence of RDSW	None	0.0
Prdsw	Cross-term dependence of RDSW	None	0.0
Lprwb	Length dependence of PRWB	None	0.0
Wprwb	Width dependence of PRWB	None	0.0
Pprwb	Cross-term dependence of PRWB	None	0.0
Lprwg	Length dependence of PRWG	None	0.0
Wprwg	Width dependence of PRWG	None	0.0
Pprwg	Cross-term dependence of PRWG	None	0.0

Lwr	Length dependence of WR	None	0.0
Wwr	Width dependence of WR	None	0.0
Pwr	Cross-term dependence of WR	None	0.0
Lnfactor	Length dependence of NFACTOR	None	0.0
Wnfactor	Width dependence of NFACTOR	None	0.0
Pnfactor	Cross-term dependence of NFACTOR	None	0.0
Ldwb	Length dependence of DWB	None	0.0
Wdwb	Width dependence of DWB	None	0.0
Pdwb	Cross-term dependence of DWB	None	0.0
Ldwg	Length dependence of DWG	None	0.0
Wdwg	Width dependence of DWG	None	0.0
Pdwg	Cross-term dependence of DWG	None	0.0
Lvoff	Length dependence of Voff	None	0.0
Wvoff	Width dependence of Voff	None	0.0
Pvoff	Cross-term dependence of Voff	None	0.0
Leta0	Length dependence of ETA0	None	0.0
Weta0	Width dependence of ETA0	None	0.0
Peta0	Cross-term dependence of ETA0	None	0.0
Letab	Length dependence of ETAB	None	0.0
Wetab	Width dependence of ETAB	None	0.0
Petab	Cross-term dependence of ETAB	None	0.0
Ldsub	Length dependence of DSUB	None	0.0
Wdsub	Width dependence of DSUB	None	0.0
Pdsub	Cross-term dependence of DSUB	None	0.0
Lcit	Length dependence of CIT	None	0.0
Wcit	Width dependence of CIT	None	0.0
Pcit	Cross-term dependence of CIT	None	0.0
Lcdsc	Length dependence of CDSC	None	0.0
Wcdsc	Width dependence of CDSC	None	0.0
Pcdsc	Cross-term dependence of CDSC	None	0.0
Lcdscb	Length dependence of CDSCB	None	0.0
Wcdscb	Width dependence of CDSCB	None	0.0

Pcdscb	Cross-term dependence of CDSCB	None	0.0
Lcdscd	Length dependence of CDSCD	None	0.0
Wcdscd	Width dependence of CDSCD	None	0.0
Pcdscd	Cross-term dependence of CDSCD	None	0.0
Lpclm	Length dependence of PCLM	None	0.0
Wpclm	Width dependence of PCLM	None	0.0
Ppclm	Cross-term dependence of PCLM	None	0.0
Lpdiblc1	Length dependence of PDIBLC1	None	0.0
Wpdiblc1	Width dependence of PDIBLC1	None	0.0
Ppdiblc1	Cross-term dependence of PDIBLC1	None	0.0
Lpdiblc2	Length dependence of PDIBLC2	None	0.0
Wpdiblc2	Width dependence of PDIBLC2	None	0.0
Ppdiblc2	Cross-term dependence of PDIBLC2	None	0.0
Lpdiblcb	Length dependence of PDIBLCB	None	0.0
Wpdiblcb	Width dependence of PDIBLCB	None	0.0
Ppdiblcb	Cross-term dependence of PDIBLCB	None	0.0
Ldrout	Length dependence of DROUT	None	0.0
Wdrout	Width dependence of DROUT	None	0.0
Pdrout	Cross-term dependence of DROUT	None	0.0
Lpvag	Length dependence of PVAG	None	0.0
Wpvag	Width dependence of PVAG	None	0.0
Ppvag	Cross-term dependence of PVAG	None	0.0
Ldelta	Length dependence of DELTA	None	0.0
Wdelta	Width dependence of DELTA	None	0.0
Pdelta	Cross-term dependence of DELTA	None	0.0
Lalpha0	Length dependence of ALPHA0	None	0.0
Walpha0	Width dependence of ALPHA0	None	0.0
Palpha0	Cross-term dependence of ALPHA0	None	0.0
Lfbjtii	Length dependence of FBJTII	None	0.0
Wfbjtii	Width dependence of FBJTII	None	0.0
Pfbjtii	Cross-term dependence of FBJTII	None	0.0

Lbeta0	Length dependence of BETA0	None	0.0
Wbeta0	Width dependence of BETA0	None	0.0
Pbeta0	Cross-term dependence of BETA0	None	0.0
Lbeta1	Length dependence of BETA1	None	0.0
Wbeta1	Width dependence of BETA1	None	0.0
Pbeta1	Cross-term dependence of BETA1	None	0.0
Lbeta2	Length dependence of BETA2	None	0.0
Wbeta2	Width dependence of BETA2	None	0.0
Pbeta2	Cross-term dependence of BETA2	None	0.0
Lvdsatii0	Length dependence of VDSATII0	None	0.0
Wvdsatii0	Width dependence of VDSATII0	None	0.0
Pvdsatii0	Cross-term dependence of VDSATII0	None	0.0
Llii	Length dependence of LII	None	0.0
Wlii	Width dependence of LII	None	0.0
Plii	Cross-term dependence of LII	None	0.0
Lesatii	Length dependence of ESATII	None	0.0
Wesatii	Width dependence of ESATII	None	0.0
Pesatii	Cross-term dependence of ESATII	None	0.0
Lsii0	Length dependence of SII0	None	0.0
Wsii0	Width dependence of SII0	None	0.0
Psii0	Cross-term dependence of SII0	None	0.0
Lsii1	Length dependence of SII1	None	0.0
Wsii1	Width dependence of SII1	None	0.0
Psii1	Cross-term dependence of SII1	None	0.0
Lsii2	Length dependence of SII2	None	0.0
Wsii2	Width dependence of SII2	None	0.0
Psii2	Cross-term dependence of SII2	None	0.0
Lsiid	Length dependence of SIID	None	0.0
Wsiid	Width dependence of SIID	None	0.0
Psiid	Cross-term dependence of SIID	None	0.0
Lagidl	Length dependence of AGIDL	None	0.0
Wagidl	Width dependence of AGIDL	None	0.0

Pagidl	Cross-term dependence of AGIDL	None	0.0
Lbgidl	Length dependence of BGIDL	None	0.0
Wbgidl	Width dependence of BGIDL	None	0.0
Pbgidl	Cross-term dependence of BGIDL	None	0.0
Lngidl	Length dependence of NGIDL	None	0.0
Wngidl	Width dependence of NGIDL	None	0.0
Pngidl	Cross-term dependence of NGIDL	None	0.0
Lntun	Length dependence of Ntun	None	0.0
Wntun	Width dependence of Ntun	None	0.0
Pntun	Cross-term dependence of Ntun	None	0.0
Lndiode	Length dependence of Ndiode	None	0.0
Wndiode	Width dependence of Ndiode	None	0.0
Pndiode	Cross-term dependence of Ndiode	None	0.0
Lnrecf0	Length dependence of Nrecf0	None	0.0
Wnrecf0	Width dependence of Nrecf0	None	0.0
Pnrecf0	Cross-term dependence of Nrecf0	None	0.0
Lnrecr0	Length dependence of Nrecr0	None	0.0
Wnrecr0	Width dependence of Nrecr0	None	0.0
Pnrecr0	Cross-term dependence of Nrecr0	None	0.0
Lisbjt	Length dependence of Isbjt	None	0.0
Wisbjt	Width dependence of Isbjt	None	0.0
Pisbjt	Cross-term dependence of Isbjt	None	0.0
Lisdif	Length dependence of Isdif	None	0.0
Wisdif	Width dependence of Isdif	None	0.0
Pisdif	Cross-term dependence of Isdif	None	0.0
Lisrec	Length dependence of Isrec	None	0.0
Wisrec	Width dependence of Isrec	None	0.0
Pisrec	Cross-term dependence of Isrec	None	0.0
Listun	Length dependence of Istun	None	0.0
Wistun	Width dependence of Istun	None	0.0
Pistun	Cross-term dependence of Istun	None	0.0

Lvrec0	Length dependence of Vrec0	None	0.0
Wvrec0	Width dependence of Vrec0	None	0.0
Pvrec0	Cross-term dependence of Vrec0	None	0.0
Lvtun0	Length dependence of Vtun0	None	0.0
Wvtun0	Width dependence of Vtun0	None	0.0
Pvtun0	Cross-term dependence of Vtun0	None	0.0
Lnbjt	Length dependence of Nbjt	None	0.0
Wnbjt	Width dependence of Nbjt	None	0.0
Pnbjt	Cross-term dependence of Nbjt	None	0.0
Llbjt0	Length dependence of LBJT0	None	0.0
Wlbjt0	Width dependence of LBJT0	None	0.0
Plbjt0	Cross-term dependence of LBJT0	None	0.0
Lvabjt	Length dependence of Vabjt	None	0.0
Wvabjt	Width dependence of Vabjt	None	0.0
Pvabjt	Cross-term dependence of Vabjt	None	0.0
Laely	Length dependence of AELY	None	0.0
Waely	Width dependence of AELY	None	0.0
Paely	Cross-term dependence of AELY	None	0.0
Lahly	Length dependence of AHLY	None	0.0
Wahly	Width dependence of AHLY	None	0.0
Pahly	Cross-term dependence of AHLY	None	0.0
Lxj	Length dependence of XJ	None	0.0
Wxj	Width dependence of XJ	None	0.0
Pxj	Cross-term dependence of XJ	None	0.0
Lalphagb1	Length dependence of ALPHAGB1	None	0.0
Walphagb1	Width dependence of ALPHAGB1	None	0.0
Palphagb1	Cross-term dependence of ALPHAGB1	None	0.0
Lalphagb2	Length dependence of ALPHAGB2	None	0.0
Walphagb2	Width dependence of ALPHAGB2	None	0.0
Palphagb2	Cross-term dependence of ALPHAGB2	None	0.0
Lbetagb1	Length dependence of BETAGB1	None	0.0
Wbetagb1	Width dependence of BETAGB1	None	0.0

Pbetagb1	Cross-term dependence of BETAGB1	None	0.0
Lbetagb2	Length dependence of BETAGB2	None	0.0
Wbetagb2	Width dependence of BETAGB2	None	0.0
Pbetagb2	Cross-term dependence of BETAGB2	None	0.0
Lntrecf	Length dependence of Ntrecf	None	0.0
Wntrecf	Width dependence of Ntrecf	None	0.0
Pntrecf	Cross-term dependence of Ntrecf	None	0.0
Lntrecr	Length dependence of Ntrecr	None	0.0
Wntrecr	Width dependence of Ntrecr	None	0.0
Pntrecr	Cross-term dependence of Ntrecr	None	0.0
Lxbjt	Length dependence of XBJT	None	0.0
Wxbjt	Width dependence of XBJT	None	0.0
Pxbjt	Cross-term dependence of XBJT	None	0.0
Lxdif	Length dependence of XDIF	None	0.0
Wxdif	Width dependence of XDIF	None	0.0
Pxdif	Cross-term dependence of XDIF	None	0.0
Lxrec	Length dependence of XTUN	None	0.0
Wxrec	Width dependence of XTUN	None	0.0
Pxrec	Cross-term dependence of XTUN	None	0.0
Lcgdl	Length dependence of CGDL	None	0.0
Wcgdl	Width dependence of CGDL	None	0.0
Pcgdl	Cross-term dependence of CGDL	None	0.0
Lcgsl	Length dependence of CGSL	None	0.0
Wcgsl	Width dependence of CGSL	None	0.0
Pcgsl	Cross-term dependence of CGSL	None	0.0
Lckappa	Length dependence of CKAPPA	None	0.0
Wckappa	Width dependence of CKAPPA	None	0.0
Pckappa	Cross-term dependence of CKAPPA	None	0.0
Lute	Length dependence of UTE	None	0.0
Wute	Width dependence of UTE	None	0.0
Pute	Cross-term dependence of UTE	None	0.0

Lkt1	Length dependence of KT1	None	0.0
Wkt1	Width dependence of KT1	None	0.0
Pkt1	Cross-term dependence of KT1	None	0.0
Lkt2	Length dependence of KT2	None	0.0
Wkt2	Width dependence of KT2	None	0.0
Pkt2	Cross-term dependence of KT2	None	0.0
Lkt1l	Length dependence of KT1L	None	0.0
Wkt1l	Width dependence of KT1L	None	0.0
Pkt1l	Cross-term dependence of KT1L	None	0.0
Lua1	Length dependence of UA1	None	0.0
Wua1	Width dependence of UA1	None	0.0
Pua1	Cross-term dependence of UA1	None	0.0
Lub1	Length dependence of UB1	None	0.0
Wub1	Width dependence of UB1	None	0.0
Pub1	Cross-term dependence of UB1	None	0.0
Luc1	Length dependence of UC1	None	0.0
Wuc1	Width dependence of UC1	None	0.0
Puc1	Cross-term dependence of UC1	None	0.0
Lat	Length dependence of AT	None	0.0
Wat	Width dependence of AT	None	0.0
Pat	Cross-term dependence of AT	None	0.0
Lprt	Length dependence of PRT	None	0.0
Wprt	Width dependence of PRT	None	0.0
Pprt	Cross-term dependence of PRT	None	0.0
Lnigc	Length dependence of NIGC	None	0.0
Wnigc	Width dependence of NIGC	None	0.0
Pnigc	Cross-term dependence of NIGC	None	0.0
Laigc	Length dependence of AIGC	None	0.0
Waigc	Width dependence of AIGC	None	0.0
Paigc	Cross-term dependence of AIGC	None	0.0
Lbigc	Length dependence of B IGC	None	0.0
Wbigc	Width dependence of BIGC	None	0.0

Pbigc	Cross-term dependence of BIGC	None	0.0
Lcigc	Length dependence of CIGC	None	0.0
Wcigc	Width dependence of CIGC	None	0.0
Pcigc	Cross-term dependence of CIGC	None	0.0
Laigsd	Length dependence of AIGSD	None	0.0
Waigsd	Width dependence of AIGSD	None	0.0
Paigsd	Cross-term dependence of AIGSD	None	0.0
Lbigsd	Length dependence of BIGSD	None	0.0
Wbigsd	Width dependence of BIGSD	None	0.0
Pbigsd	Cross-term dependence of BIGSD	None	0.0
Lcigsd	Length dependence of CIGSD	None	0.0
Wcigsd	Width dependence of CIGSD	None	0.0
Pcigsd	Cross-term dependence of CIGSD	None	0.0
Lpigcd	Length dependence of PIGCD	None	0.0
Wpigcd	Width dependence of PIGCD	None	0.0
Ppigcd	Cross-term dependence of PIGCD	None	0.0
Lpoxedge	Length dependence of POXEDGE	None	0.0
Wpoxedge	Width dependence of POXEDGE	None	0.0
Ppoxedge	Cross-term dependence of POXEDGE	None	0.0
Lxrcrg1	Length dependence of XRCRG1	None	0.0
Wxrcrg1	Width dependence of XRCRG1	None	0.0
Pxrcrg1	Cross-term dependence of XRCRG1	None	0.0
Lxrcrg2	Length dependence of XRCRG2	None	0.0
Wxrcrg2	Width dependence of XRCRG2	None	0.0
Pxrcrg2	Cross-term dependence of XRCRG2	None	0.0
Lvsdfb	Length dependence of VSDFB	None	0.0
Wvsdfb	Width dependence of VSDFB	None	0.0
Pvsdfb	Cross-term dependence of VSDFB	None	0.0
Lvsdth	Length dependence of VSDTH	None	0.0
Wvsdth	Width dependence of VSDTH	None	0.0
Pvsdth	Cross-term dependence of VSDTH	None	0.0

Ldelvt	Length dependence of DELVT	None	0.0
Wdelvt	Width dependence of DELVT	None	0.0
Pdelvt	Cross-term dependence of DELVT	None	0.0
Lacde	Length dependence of ACDE	None	0.0
Wacde	Width dependence of ACDE	None	0.0
Pacde	Cross-term dependence of ACDE	None	0.0
Lmoin	Length dependence of MOIN	None	0.0
Wmoin	Width dependence of MOIN	None	0.0
Pmoin	Cross-term dependence of MOIN	None	0.0
Lnoff	Length dependence of Noff	None	0.0
Wnoff	Width dependence of Noff	None	0.0
Pnoff	Cross-term dependence of Noff	None	0.0

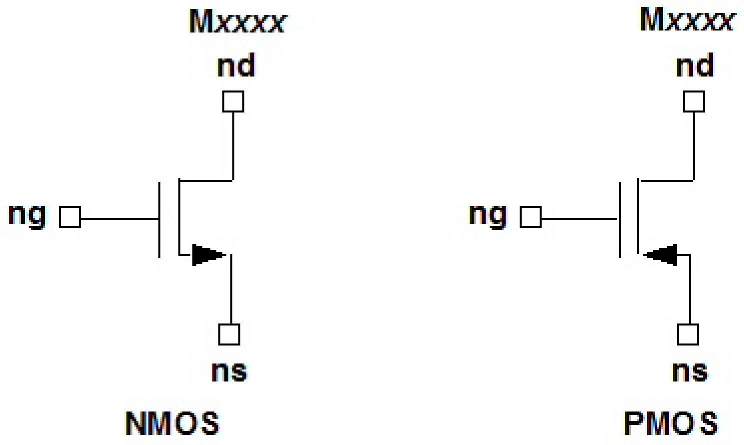
BSIM3-SOI MOSFET Model Netlist Example

```
.MODEL mossoi1 NMOS LEVEL=57

+Tnom=27.0 capmod=3 mobmod=1

+Nch=1e+16  Tox=5E-08 Xj=3.85E-08

+Lint=9.36e-8 Wint=0

+Vth0= .779    K1=1.04  K2= -3.83e-2  K3=50

+Dvt0= 2.812  Dvt1= 0.462  Dvt2=-9.17e-2

+Nlx= 3.52291E-08  W0= 1.163e-6

+K3b= 2.233

+Vsat= 86301.58  Ua= 6.47e-9  Ub= 4.23e-18  Uc=-4.706281E-11

+U0=400 wr=1

+A0= .3496967 Ags=.1    B0=0.546    B1= 1

+ Dwg = -6.0E-09 Dwb = -3.56E-09 Prwb = -.213

+Keta=-3.605872E-02  A1= 2.778747E-02  A2= .9

+Voff=-6.735529E-02  NFactor= 1.139926  Cit= 1.622527E-04

+cj=0.00042 mj=0.5 pb=1.0
```

```
+cjsw=9e-12 mjsw=0.33 pbsw=1.0

+cjswg=9e-12 mjswg=0.33 pbswg=1.0

+cgsl=5.0e-10 ckappa=0.6

+cgdl=3.6e-10

+cf=0.0 cgso=5.2e-10 cgdo=5.2e-10

+cgbo=4.0e-10

+Cdsc=2.4e-4

+Cdscb= 0  Dvt0w =  0 Dvt1w =  0 Dvt2w =  0

+Cdscd =  0 Prwg =  0

+dlc=9.36e-8 dwc=0.0

+Eta0= 1.0281729E-02  Etab=-5.042203E-03

+Dsub= .31871233

+Pclm= 1.114846  Pdiblc1= 2.45357E-03  Pdiblc2= 6.406289E-03

+Drout= .31871233  Pscbe1= 5000000  Pscbe2= 5E-09

+Pdiblcb = -.234

+Pvag= 0 delta=0.01

+Wl =  0 Ww =0 Wwl =  0

+Wln =  0 Wwn =  .2613948 Ll =0.0

+Lw =  0 Lwl =  0 Lln =  .316394

+Lwn =  0

+kt1=-.3  kt2=-.051

+At= 22400

+Ute=-1.48

+Ua1= 3.31E-10  Ub1= 2.61E-19 Uc1= -3.42e-10

+Kt1l=0 Prt=764.3

+xpart=0.2

+JS =1e-2 JSW=0
```

```
+VFBCV=-1 VFB=-1
```

MOSFET Instance, RPI Poly-Si TFT Model (Level 62)



Poly-Si TFT MOSFET Instance Netlist Syntax

RPI Poly-Si TFT MOSFET instances use the following netlist syntax:

M*xxxx nd ng ns modelname* [**L=***length*] [**W=***width*]
[**NRD=***val*] [**NRS=***val*] [**M=***val*]

nd is the drain node, *ng* is the gate node, and *ns* is the source node of the MOSFET. *modelname* is the name of a Level 62 MOSFET model defined in a .MODEL statement elsewhere in the netlist.

Table 57: Level 62 MOSFET Instance Parameters

Instance Parameter	Description	Unit	Default
L	Physical gate length	Meter	1e-4
M	Multiplier: simulates parallel transistors	None	1.0
NRD	Relative resistivity of the drain	Ohm/square	1.0 (If HDIF>0.0, NRD defaults to 0.0)
NRS	Relative resistivity of the source	Ohm/square	1.0

			(If HDIF>0.0, NRS defaults to 0.0)
W	Physical gate width	Meter	1e-4

Netlist Example

```
M213 55 56 57 mos62
```

RPI Poly-Si TFT MOSFET Model, LEVEL=62

Netlist Syntax

The syntax for a LEVEL 62 MOSFET model is:

`.MODELmodelname NMOS LEVEL=62 [parameter=val] ...`

or

`.MODELmodelname PMOS LEVEL=62 [parameter=val] ...`

modelname is the name used by MOSFET instances to refer to this .MODEL statement. The **LEVEL=62** entry selects the RPI AIM-SPICE MOS16 Polysilicon thin-film transistor (Poly-Si TFT) MOSFET model.

Table 58: LEVEL=62 MOSFET Model Parameters

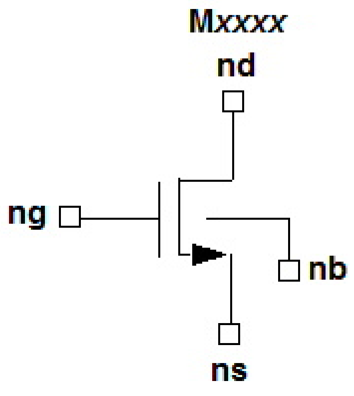
Model Parameter	Description	Unit	Default
LEVEL=62	Selects RPI AIM-SPICE MOS16 Poly-Si TFT MOSFET model	None	1
VERSION	Version number	None	1.0
ACM	Area calculation method	None	0
AF	Flicker noise exponent	None	1.0
ASAT	Proportionality constant of VSAT	None	1.0
AT	DIBL parameter 1	Meter/Volt	3.0e-8
BLK	Leakage barrier lower constant	None	0.001
BT	DIBL parameter 2	Volt-Meter	1.9e-6
CAPMOD	Capacitance model selector	None	0
CGDO	Gate-drain overlap capacitance per meter channel width	Farad/Meter	Not used if not provided
CGSO	Gate-source overlap capacitance per meter	Farad/Meter	Not used if not

	channel width		provided
CLK (**I0**)	Leakage scaling constant	Amp/Meter	6.0
CT	ALPHASAT length coefficient		0.0
DASAT	Temperature coefficient of ASAT	°C^{-1}	0.0
DD	Vds field constant	Meter	1400e-10
DELTA	Transition width parameter	None	4.0
DG	Transition width parameter	Meter	2000e-10
DMU1	Temperature coefficient of MU1	cm^2/Volt-sec-°C	0.0
DVT	Difference between VON and VTO	Volt	0.0
DVTO (**DVT0**)	Temperature coefficient of DVT		0.0
EB	Barrier height of diode	electron-Volt	0.68
EPS	Substrate dielectric constant		11.0
ETA	Subthreshold ideality factor	None	7.0
ETAC0	Capacitance subthreshold ideality factor at zero drain bias	None	ETA
ETAC00	Capacitance subthreshold coefficient of drain bias	$Volt^{-1}$	0.0
HDIF	Length of heavily-doped idffusion region	Meter	0.0
I00	Reverse diode saturation current	Amp/Meter	150
INTDSNOD	Intrinsic source and drain flag	None	0.0
ISUBMOD	Channel length modulation flag	None	0.0
KSS	Fractions of channel resistance (small signal parameter)	None	0.0
L0	Length at which ALPHASAT saturates	Meter	0.0
LAMBDA	Channel length modulation parameter		0.048
LASAT	Coefficient for length dependence of ASAT	Meter	0.0
LD	Lateral diffucion into channel	Meter	Not used if not present
LDIF	Length of heavily doped diffusion region	Meter	0.0
LKINK	Kink effect constant	Meter	19.0e-6
LMLT	Shrink factor	None	1.0
LMS	MS length coefficient		0.0

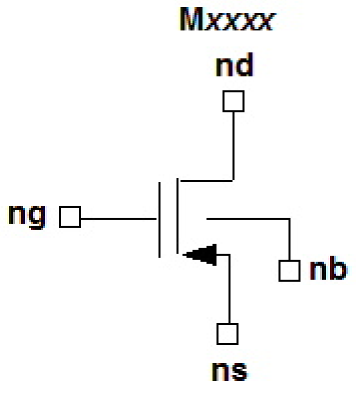
LS	Channel length modulation		35.0e-9
LU0	MU0 length coefficient		0.0
LU1	Low field mobility length coefficient		0.0
MC	Capacitance knee shape parameter	None	3.0
ME (**MS**)	Long channel transition		2.5
META	ETA floating body		1.0
METO	Fringing field constant	None	0.0
MINME	Minimum of ME		2.0
MINR	Minimum resistance	Ohm	0.1
MK (**MKINK**)	Kink effect exponent	None	1.3
MMU (**M**)	Low field mobility exponent	None	1.7
MSS	Vdse transition		1.5
MU0	High field mobility	cm^2/Volt-sec	100
MU1	Low field mobility parameter	cm^2/Volt-sec	0.0022
MUS	Subthreshold mobility	cm^2/Volt-sec	1.0
RD	Drain resistance	Ohm	0.0
RDC	Drain contact ohmic resistance	Ohm	0.0
RDX	Resistance in series with Cgd	Ohm	0.0
RS	Source resistance	Ohm	0.0
RSC	Source contact ohmic resistance	Ohm	0.0
RSH	Sheet resistance	Ohm	0.0
RSX	Resistance in series with Cgs	Ohm	0.0
SCALEM	Length and width scale factor	None	1.0
SCALERPI	Scaling selector		0.0
SIGMA	Minimum leakage		1.0e-14
THETA	Mobility modulation		0.0
TNOM	Temperature at which parameters are extracted	°C	27
TOX	Thin-oxide thickness	Meter	1.0e-7
TRISE	Temperature rise from ambient		0.0
VFB	Flatband voltage	Volt	NMOS: -3.0 PMOS: 3.0

VKINK	Kink effect voltage	Volt	9.1
VMAX	Carrier saturation velocity		4.0e4
VON	On-state voltage	Volt	0.0
VP	CLM voltage	Volt	0.2
VSI (**VSIGMA**)	Above threshold DIBL (Vgs dependence parameter)	Volt	2.0
VST (**VSIGMAT**)	Above threshold DIBL (Vgs dependence parameter)	Volt	2.0
VTO (**VT0**)	Zero-bias threshold voltage	Volt	Not used if not present
WD	Width of lateral diffusion	Meter	0.0
WMLT	Width shrink factor		1.0
XJ	Junction depth	Meter	1.5e-7
XL	Correction for mask etch effect		0.0
XW	Correction for mask etch effect		0.0
ZEROC	Flag for capacitance calculation in CAPMOD=1 0 = calculate capacitance 1 = set capacitance to 0	None	0

MOSFET Instance, Philips MOS11 Version 1100 Model (Level 63)



NMOS



PMOS

Philips MOS11 MOSFET Instance Netlist Syntax

Philips MOS11 Level 1100, 11010 (1101 physical), and 11011 (1101 binned) MOSFETs are grouped as HSPICE™ Level 63. Philips MOS11 instances all use the following netlist syntax:

```
Mxxxx nd ng ns [nb] modelname [[L=]length] [[W=]width]
[AD=val] [AS=val] [PD=val] [PS=val]
[DTA=val] [MULT=val] [DTEMP=val]
```

nd is the drain node, *ng* is the gate node, *ns* is the source node, and *nb* is the bulk or substrate node of the MOSFET. *modelname* is the name of a Level 63 MOSFET model defined in a .MODEL statement elsewhere in the netlist.

When the option **WL** is in effect (on the .OPTION statement), the syntax becomes:

```
Mxxxx nd ng ns [nb] modelname [width] [length]
[AD=val] [AS=val] [PD=val] [PS=val]
[DTA=val] [MULT=val] [DTEMP=val
```

Table 59: Level 63 MOSFET Instance Parameters

Instance Parameter	Description	Unit	Default
AD	Drain diffusion area	Meter^2	0.0
AS	Source diffusion area	Meter^2	0.0
DTA	Temperature offset of the device with respect to T_A	°C	0.0
DTEMP	Difference between element and circuit temperatures	°C	0.0
L	Physical gate length	Meter	2.0e-6
MULT	Multiplier: simulates parallel transistors	None	1.0
PD	Drain perimeter	Meter	0.0
PS	Source perimeter	Meter	0.0
W	Physical gate width	Meter	1.0e-5

Netlist Example

```
M213 55 56 57 mos11_3 dtemp=3
```

Philips MOS1100 MOSFET Model, Level 63, Version 1100

The syntax for a Level 63 Philips MOS1100 MOSFET model is:

```
.MODELmodelname NMOS LEVEL=63 [VERSION=1100] [parameter=val]
...
```

or

```
.MODELmodelname PMOS LEVEL=63 [VERSION=1100] [parameter=val]
...
```

modelname is the name used by MOSFET instances to refer to this .MODEL statement. The **LEVEL=63** entry selects the Philips MOS11 MOSFET model. The **VERSION** parameter selects among the 1100, 1101 physical scaling, and 1101 binned scaling versions of the MOS11 model. **VERSION=1100** selects the MOS1100 model. See "Philips MOS1101 Version 11010 Physical MOSFET Model, (Level 63)" on page 24-49 and "Philips MOS1101 Binned MOSFET Model, Level 63, Version 11011" on page 24-56 for information on those MOSFET models.

Table 60: Level 63 Version 1100 MOSFET Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	63 is required to select the Philips MOS11 MOSFET model	Integer	1 (default if LEVEL parameter is omitted)
VERSION	Philips version selector 1100 selects the Philips MOS Model 11, Philips Level 1100	Integer	1100
A1R	Weak-avalanche current factor for the reference transistor at the reference temperature	None	6.0
A2R	Weak-avalanche current exponent for the reference transistor	Volt	38.0
A3R	Factor of drain-source voltage above which weak-avalanche occurs, for the reference transistor	None	1.0
ALPEXP	Exponent of length dependence of α_R	None	1.0
ALPR	Channel length modulation factor for the reference transistor	None	0.01
BACC	Probability factor for intrinsic gate tunneling current in accumulation	Volt	48.0
BETSQ	Gain factor for an infinite square transistor at the reference temperature	Amp/Volt^2	NMOS: 3.709e-4 PMOS: 1.15e-

			4
BINV	Probability factor for intrinsic gate tunneling current in inversion	Volt	48.0
COL	Gate overlap capacitance per unit channel length	Farad/Meter	3.2e-10
ETABET (**ETABETR**)	Exponent of temperature dependence of gain factor	None	NMOS: 1.3 PMOS: 0.5
ETAMOBR	Effective field parameter for dependence on depletion/inversion charge for the reference transistor	None	NMOS: 1.4 PMOS: 3.0
ETAPH	Exponent of temperature dependence of Θ_{SR} for the reference temperature	None	1.75
ETAR	Exponent of temperature dependence of Θ_R	None	NMOS: 0.95 PMOS: 0.4
ETASAT	Exponent of temperature dependence of Θ_{SAT}	None	NMOS: 1.04 PMOS: 0.86
FBET1	Relative mobility decrease due to 1st lateral profile	None	0.0
FBET2	Relative mobility decrease due to 2nd lateral profile	None	0.0
GATENOISE	Flag for inclusion or exclusion of induced gate thermal noise	None	0.0
IGACCR	Gain factor for intrinsic gate tunneling current in accumulation for the reference transistor	$Amp/Volt^2$	0.0
IGINVR	Gain factor for intrinsic gate tunneling current in inversion for the reference transistor	$Amp/Volt^2$	0.0
IGOVR	Gain factor for source/drain overlap current for the reference transistor	$Amp/Volt^2$	0.0
KOR	Body effect factor for the reference transistor	$Volt^{1/2}$	0.5
KOV	Body effect factor for the source/drain overlap extensions	$Volt^{1/2}$	2.5
KPINV	Inverse of body effect factor of the polysilicon gate	$Volt^{1/2}$	0.0
LAP	Effective channel length reduction per side due to the lateral diffusion of the source/drain dopant ions	Meter	4.0e-8

LER	Effective channel length of the reference transistor	Meter	1.0e-6
LMIN (**LLMIN**)	Minimum effective channel length in technology, used for calculation of smoothing factor m.	Meter	1.5e-7
LP1	Characteristic length of the 1st lateral profile	Meter	8.0e-7
LP2	Characteristic length of the 2nd lateral profile	Meter	8.0e-7
LVAR	Difference between the actual length and the programmed polysilicon gate length	Meter	0.0
MOEXP	Exponent of length dependence of M_O	None	1.34
MOR	Parameter for short-channel subthreshold slope for the reference transistor	None	0.0
NFAR	1st flicker noise coefficient for the reference transistor	1/Volt-Meter^4	1.573e22
NFBR	2nd flicker noise coefficient for the reference transistor	1/Volt-Meter^2	4.752e8
NFCR	3rd flicker noise coefficient for the reference transistor	1/Volt	0.0
NT (**NTR**)	Thermal noise coefficient at the actual temperature	Joule	1.656e-20
NUEXP	Exponent of the temperature dependence of the parameter v	None	NMOS: 5.25 PMOS: 3.23
NUR	Exponent of the field dependence of the mobility model minus 1 (i.e., v -1) at the reference temperature	None	1.0
PHIBR	Surface potential at the onset of strong inversion at the reference temperature	Volt	0.95
SDIBLEXP	Exponent of the length dependence of σ_{DIBL}	None	1.35
SDIBLO	Drain-induced barrier lowering parameter for the reference transistor	Volt^{½}	NMOS: 2.0e-3 PMOS: 1.0e-3
SL2KO	2nd coefficient of the length dependence of K_0	Volt^{½}-Meter^2	0.0
SL2PHIB	2nd coefficient of the length dependence of ψ_B	Volt-Meter^2	0.0
SLA1	Coefficient of length dependence of a_1	Meter	0.0
SLA2	Coefficient of length dependence of a_2	Volt-Meter	0.0
SLA3	Coefficient of length dependence of a_3	Meter	0.0

SLALP	Coefficient of length dependence of α_R	None	1.0
SLKO	Coefficient of length dependence of KO	$\text{Volt}^{1/2}$-Meter	0.0
SLPHIB	Coefficient of the length dependence of ψ_B	Volt-Meter	0.0
SLSSF	Coefficient of length dependence of σ_{SF}	Meter	1.0e-6
SLTHESAT	Coefficient of length dependence of Θ_{SAT}	None	1.0
SSFR	Static feedback parameter for the reference transistor	$\text{Volt}^{1/2}$	6.25e-3
STA1	Temperature dependence coefficient of A1	$^\circ K^{-1}$	0.0
STETAMOB	Temperature dependence coefficient of η_{MOB}	$^\circ K^{-1}$	0.0
STVFB	Coefficient of temperature dependence of V_{FB}	Volt/°K	5.0e-4
SWA1	Coefficient of width dependence of a_1	Meter	0.0
SWA2	Coefficient of width dependence of a_2	Volt-Meter	0.0
SWA3	Coefficient of width dependence of a_3	Meter	0.0
SWALP	Coefficient of width dependence of α_R	Meter	0.0
SWETAMOB	Width dependence coefficient of η_{MOB}	Meter	0.0
SWKO	Coefficient of width dependence of K_O	$\text{Volt}^{1/2}$-Meter	0.0
SWPHIB	Width dependence coefficient of ψ_B	Volt-Meter	0.0
SWSSF	Width dependence coefficient of σSF	Meter	0.0
SWTHEPH	Width dependence coefficient of Θ_{SR}	Meter	0.0
SWTHER	Width dependence coefficient of Θ_R	Meter	0.0
SWTHESAT	Width dependence coefficient of Θ_{SAT}	Meter	0.0
SWTHESR	Width dependence coefficient of Θ_{SR}	Meter	0.0
SWTHETH	Width dependence coefficient of ΘTH	Meter	0.0
THEPHR	Coefficient of the mobility reduction due to phonon scattering for the reference transistor at the reference temperature	Volt^{-1}	NMOS: 1.29e-2 PMOS: 1.0e-3
THER1	Numerator of the gate voltage dependent part of series resistance for the reference transistor	Volt	0.0
THER2	Denominator of the gate voltage dependent part of series resistance for the reference transistor	Volt	1.0
THERR	Coefficient of the series resistance for the reference transistor at the reference temperature	Volt^{-1}	NMOS: 0.155 PMOS: 0.08

THESATEXP	Exponent of the length dependence of Θ_{SAT}	None	1.0
THESATR	Velocity saturation parameter due to optical/acoustic phonon scattering for the reference transistor at the reference temperature	$Volt^{-1}$	NMOS: 0.5 PMOS: 0.2
THESRR	Coefficient of the mobility reduction due to surface roughness scattering for the reference transistor at the reference temperature	$Volt^{-1}$	NMOS: 0.4 PMOS: 0.73
THETHEXP	Exponent of the length dependence of Θ_{TH}	None	1.0
THETHR	Coefficient of self-heating for the reference transistor at the reference temperature	$Volt^{-3}$	1.0e-3
TOX	Gate oxide layer thickness	Meter	3.2e-9
TR	Temperature at which the parameters for the reference transistor is determined	°C	21.0
VFBOV	Flatband voltage for the source/drain overlap extensions	Volt	0.0
VFBR (**VFB**)	Flatband voltage for the reference transistor at the reference temperature	Volt	-1.05
VP	Characteristic voltage for channel length modulation	Volt	0.05
WER	Effective channel width of the reference transistor	Meter	1.0e-5
WOT	Effective reduction of the channel width per side due to the lateral diffusion of the channel stop dopant ions	Meter	0.0
WVAR	Difference between the actual width and the programmed field oxide opening	Meter	0.0

Table 61: Level 63 MOSFET JUNCAP Model Parameters

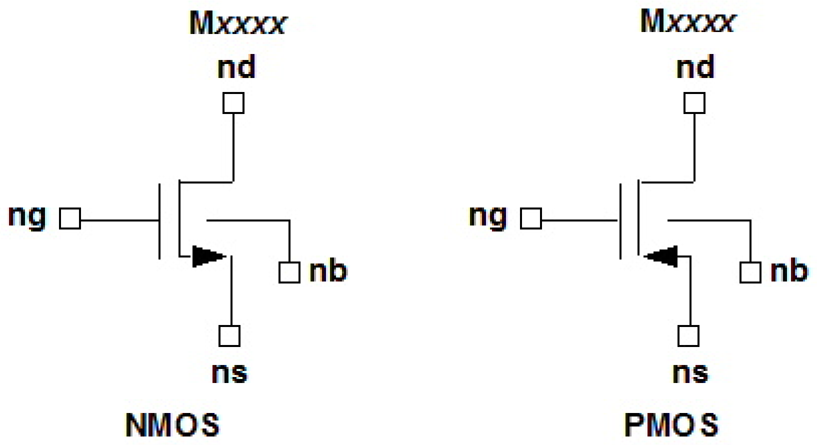
Model Parameter	**Description**	**Unit**	**Default**
CJBR	Bottom junction capacitance at $V=V_R$	$Farad/Meter^2$	1.00e-12
CJGR	Gate edge-junction capacitance at $V=V_R$	Farad/Meter	1.00e-12
CJSR	Sidewall junction capacitance at $V=V_R$	Farad/Meter	1.00e-

			12
JSDBR	Bottom saturation-current density due to diffusion from back contact	Amp/Meter^2	1.00e-3
JSDGR	Gate-edge saturation-current density due to diffusion from back contact	Amp/Meter	1.00e-3
JSDSR	Sidewall saturation-current density due to diffusion from back contact	Amp/Meter	1.00e-3
JSGBR	Bottom saturation-current density due to electron-hole generation at $V=V_R$	Amp/Meter^2	1.00e-3
JSGGR	Gate-edge saturation-current density due to electron-hole generation at $V=V_R$	Amp/Meter	1.00e-3
JSGSR	Sidewall saturation-current density due to electron-hole generation at $V=V_R$	Amp/Meter	1.00e-3
NB	Emission coefficient of the bottom forward current	None	1.0
NG	Emission coefficient of the gate-edge forward current	None	1.0
NS	Emission coefficient of the sidewall forward current	None	1.0
PB	Bottom junction grading coefficient	None	0.40
PG	Gate edge junction grading coefficient	None	0.40
PS	Sidewall junction grading coefficient	None	0.40
VDBR	Diffusion voltage of the bottom junction at $T=T_R$	Volt	1.00
VB	Reverse breakdown voltage	Volt	0.9
VDGR	Diffusion voltage of the gate edge junction at $T=T_R$	Volt	1.00
VDSR	Diffusion voltage of the sidewall junction at $T=T_R$	Volt	1.00
VR	Voltage at which parameters have been determined	Volt	0.0

Philips MOS11 MOSFET Model Netlist Example

```
.MODEL mos11_3 PMOS
```

MOSFET Instance, Philips MOS1101 Version 11010 Physical Model (Level 63)



Philips MOS11010 Physical MOSFET Instance Netlist Syntax

Philips MOS11 Level 1100, 11010 (1101 physical), and 11011 (1101 binned) MOSFET models are grouped as HSPICE™ Level 63. All Philips MOS11 instances use the following netlist syntax:

```
Mxxxx nd ng ns [nb] modelname [[L=]length] [[W=]width]
[AD=val] [AS=val] [PD=val] [PS=val]
[DTA=val] [MULT=val] [DTEMP=val]
```

nd is the drain node, *ng* is the gate node, *ns* is the source node, and *nb* is the bulk or substrate node of the MOSFET. *modelname* is the name of a Level 63 MOSFET model defined in a .MODEL statement elsewhere in the netlist.

When the option **WL** is in effect (on the .OPTION statement), the syntax becomes:

```
Mxxxx nd ng ns [nb] modelname [width] [length]
[AD=val] [AS=val] [PD=val] [PS=val]
[DTA=val] [MULT=val] [DTEMP=val]
```

All Philips MOS11 MOSFETs use the same set of instance parameters. See "MOSFET Instance, Philips MOS11 Version 1100 Model (Level 63)" on page 24-40 for details on the instance parameters for all Level 63 MOSFETs.

Philips MOS1101 Version 11010 Physical MOSFET Model, (Level 63)

The Philips MOS Model 11 Version 11010 uses the physical geometry scaling rules. The syntax for a Philips MOS1100 MOSFET model (HSPICE™ Level 63, Version 11010) is:

```
.MODELmodelname NMOS LEVEL=63 VERSION=11010 [parameter=val] ...
```

or

```
.MODELmodelname PMOS LEVEL=63 VERSION=11010 [parameter=val] ...
```

modelname is the name used by MOSFET instances to refer to this .MODEL statement. The **LEVEL=63** entry selects the Philips MOS11 MOSFET model. The **VERSION** parameter selects among the 1100, 11010 physical geometry scaling, and 11011 binned geometry scaling versions of the MOS11 model. **VERSION=11010** selects the Philips Level 11010 (MOS1101) physical scaling model.

See "Philips MOS1100 MOSFET Model, Level 63, Version 1100" on page 24-41 for information on that MOSFET model.

See "Philips MOS1101 Binned MOSFET Model, Level 63, Version 11011" on page 24-56 for information on that MOSFET model.

Table 62: Level 63, Version 11010 MOSFET Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	Level=63 selects the Philips MOS11 MOSFET model	Integer	1 (default if LEVEL parameter is omitted)
VERSION	Philips version selector 11010 is required to select the Philips MOS Model 11, Level 1101 (physical geometry scaling rules)	Integer	1100
A1R	Weak-avalanche current factor for the reference transistor at the reference temperature	None	6.0
A2R	Weak-avalanche current exponent for the reference transistor	Volt	38.0
A3R	Factor of drain-source voltage above which weak-avalanche occurs, for the reference transistor	None	1.0
AGIDLR	Gain factor for gate-induced drain leakage current for the actual transistor	Amp/Volt 3	0.0

ALPEXP	Exponent of length dependence of α_R	None	1.0
ALPR	Channel length modulation factor for the reference transistor	None	0.01
BACC	Probability factor for intrinsic gate tunneling current in accumulation	Volt	48
BETSQ	Gain factor for an infinite square transistor at the reference temperature	Amp/Volt^2	NMOS: 3.709e-4 PMOS: 1.15e-4
BGIDL	Probability factor for gate-induced drain leakage current at the reference temperature	Volt	41.0
BINV	Probability factor for intrinsic gate tunnelingreference current in inversion	Volt	NMOS: 48 PMOS: 87.5
CGIDL	Factor for the lateral field dependence of the gate-induced drain leakage current	None	0.0
COL	Gate overlap capacitance	Farad	3.2e-16
ETABETR (**ETABET**)	Exponent of temperature dependence of gain factor	None	NMOS: 1.3 PMOS: 0.5
ETAMOBR	Effective field parameter for dependence on depletion/inversion charge for the reference transistor	None	NMOS: 1.4 PMOS: 3.0
ETAPH	Exponent of temperature dependence of ΘSR for the reference temperature	None	NMOS: 1.35 PMOS: 3.75
ETAR	Exponent of temperature dependence of ΘR	None	NMOS: 0.95 PMOS: 0.4
ETASR	Exponent of temperature dependence of ΘSR	None	NMOS: 0.65 PMOS: 0.5
ETASAT	Exponent of temperature dependence of ΘSAT	None	NMOS: 1.04 PMOS: 0.86
FBET1	Relative mobility decrease due to 1st lateral profile	None	0.0
FBET2	Relative mobility decrease due to 2nd lateral profile	None	0.0
GATENOISE	Flag for inclusion or exclusion of induced gate thermal noise	None	0.0

IGACCR	Gain factor for intrinsic gate tunneling current in accumulation for the reference transistor	Amp/Volt^2	0.0
IGINVR	Gain factor for intrinsic gate tunneling current in inversion for the reference transistor	Amp/Volt^2	0.0
IGOVR	Gain factor for source/drain overlap current for the reference transistor	Amp/Volt^2	0.0
KOR	Body effect factor for the reference transistor	Volt$^{1/2}$	0.5
KOV	Body effect factor for the source/drain overlap extensions	Volt$^{1/2}$	2.5
KPINV	Inverse of body effect factor of the polysilicon gate	Volt$^{1/2}$	0.0
LAP	Effective channel length reduction per side due to the lateral diffusion of the source/drain dopant ions	Meter	4.0e-8
LMIN (**LLMIN**)	Minimum effective channel length in technology, used for calculation of smoothing factor m.	Meter	1.5e-7
LP1	Characteristic length of the 1st lateral profile	Meter	8.0e-7
LP2	Characteristic length of the 2nd lateral profile	Meter	8.0e-7
LVAR	Difference between the actual length and the programmed polysilicon gate length	Meter	0.0
MOEXP	Exponent of length dependence of M_O	None	1.34
MOO	Parameter for short-channel threshold slope	None	0.0
MOR	Parameter for short-channel subthreshold slope for the reference transistor	None	0.0
NFAR	1st flicker noise coefficient for the reference transistor	1/Volt-Meter^4	NMOS: 1.573e23 PMOS: 3.825e24
NFBR	2nd flicker noise coefficient for the reference transistor	1/Volt-Meter^2	NMOS: 4.752e9 PMOS: 1.015e9
NFCR	3rd flicker noise coefficient for the reference transistor	1/Volt	NMOS: 0.0 PMOS: 7.3e-8
NT	Thermal noise coefficient at the actual temperature	Joule	1.656e-20
NUEXP	Exponent of the temperature dependence of the parameter v	None	NMOS: 5.25

			PMOS: 3.23
NU	Exponent of the field dependence of the mobility model minus 1 (i.e., ν - 1) at the reference temperature	None	2.0
PHIBR	Surface potential at the onset of strong inversion at the reference temperature	Volt	0.95
SDIBLEXP	Exponent of the length dependence of σ_{DIBL}	None	1.35
SDIBLO	Drain-induced barrier lowering parameter for the reference transistor	$Volt^{1/2}$	1.0e-4
SL2KO	2nd coefficient of the length dependence of K_0	None	0.0
SL2PHIB	2nd coefficient of the length dependence of ψ_B	None	0.0
SLA1	Coefficient of length dependence of a_1	None	0.0
SLA2	Coefficient of length dependence of a_2	None	0.0
SLA3	Coefficient of length dependence of a_3	None	0.0
SLALP	Coefficient of length dependence of α_R	None	1.0
SLETABET	Coefficient of length dependence of η_{BR}	None	0.0
SLKO	Coefficient of length dependence of K_O	None	0.0
SLPHIB	Coefficient of the length dependence of ψ_B	None	0.0
SLSSF	Coefficient of length dependence of σ_{SF}	Meter	1.0
SLTHESAT	Coefficient of length dependence of Θ_{SAT}	None	1.0
SSFR	Static feedback parameter for the reference transistor	$Volt^{1/2}$	6.25e-3
STA1	Temperature dependence coefficient of a_1	$°K^{-1}$	0.0
STBGIDL	Coefficient of the temperature dependence of B_{GIDL}	Volt/°K	-3.638e-4
STETAMOB	Temperature dependence coefficient of η_{MOB}	$°K^{-1}$	0.0
STPHIB	Coefficient of temperature dependence of ψ_B	Volt/°K	-8.5e-4
STVFB	Coefficient of temperature dependence of V_{FB}	Volt/°K	5.0e-4
SWA1	Coefficient of width dependence of a_1	None	0.0
SWA2	Coefficient of width dependence of a_2	None	0.0
SWA3	Coefficient of width dependence of a_3	None	0.0
SWALP	Coefficient of width dependence of α_R	None	0.0
SWETAMOB	Width dependence coefficient of η_{MOB}	None	0.0
SWKO	Coefficient of width dependence of K_O	None	0.0

SWPHIB	Width dependence coefficient of ψ_B	None	0.0
SWSSF	Width dependence coefficient of σ_{SF}	None	0.0
SWTHEPH	Width dependence coefficient of Θ_{SR}	None	0.0
SWTHER	Width dependence coefficient of Θ_R	None	0.0
SWTHESAT	Width dependence coefficient of Θ_{SAT}	None	0.0
SWTHESR	Width dependence coefficient of Θ_{SR}	None	0.0
SWTHETH	Width dependence coefficient of Θ_{TH}	None	0.0
THEPHR	Coefficient of the mobility reduction due to phonon scattering for the reference transistor at the reference temperature	Volt^{-1}	NMOS: 1.29e-2 PMOS: 1e-3
THER1	Numerator of the gate voltage dependent part of series resistance for the reference transistor	Volt	0.0
THER2	Denominator of the gate voltage dependent part of series resistance for the reference transistor	Volt	1.0
THERR	Coefficient of the series resistance for the reference transistor at the reference temperature	Volt^{-1}	NMOS: 0.155 PMOS: 0.08
THESATEXP	Exponent of the length dependence of Θ_{SAT}	None	1.0
THESATR	Velocity saturation parameter due to optical/acoustic phonon scattering for the reference transistor at the reference temperature	Volt^{-1}	NMOS: 0.5 PMOS: 0.2
THESRR	Coefficient of the mobility reduction due to surface roughness scattering for the reference transistor at the reference temperature	Volt^{-1}	NMOS: 0.4 PMOS: 0.73
THETHEXP	Exponent of the length dependence of Θ_{TH}	None	1.0
THETHR	Coefficient of self-heating for the reference transistor at the reference temperature	Volt^{-3}	NMOS: 1.0e-3 PMOS: 0.5e-3
TOX	Gate oxide layer thickness	Meter	3.2e-9
TR	Temperature at which the parameters for the reference transistor are determined	°C	21.0
VFBOV	Flatband voltage for the source/drain overlap extensions	Volt	0.0
VFB (**VFBR**)	Flatband voltage for the reference transistor at the reference temperature	Volt	-1.05
VP	Characteristic voltage for channel length	Volt	0.05

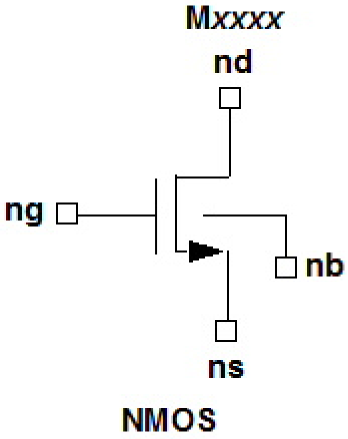
	modulation		
WOT	Effective reduction of the channel width per side due to the lateral diffusion of the channel stop dopant ions	Meter	0.0
WVAR	Difference between the actual width and the programmed field oxide opening	Meter	0.0

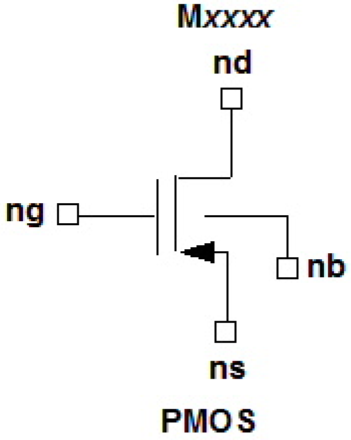
Table 63: Level 63 MOSFET JUNCAP Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
CJBR	Bottom junction capacitance at $V=V_R$	Farad/Meter^2	1.00e-12
CJGR	Gate edge-junction capacitance at $V=V_R$	Farad/Meter	1.00e-12
CJSR	Sidewall junction capacitance at $V=V_R$	Farad/Meter	1.00e-12
JSDBR	Bottom saturation-current density due to diffusion from back contact	Amp/Meter^2	1.00e-3
JSDGR	Gate-edge saturation-current density due to diffusion from back contact	Amp/Meter	1.00e-3
JSDSR	Sidewall saturation-current density due to diffusion from back contact	Amp/Meter	1.00e-3
JSGBR	Bottom saturation-current density due to electron-hole generation at $V=V_R$	Amp/Meter^2	1.00e-3
JSGGR	Gate-edge saturation-current density due to electron-hole generation at $V=V_R$	Amp/Meter	1.00e-3
JSGSR	Sidewall saturation-current density due to electron-hole generation at $V=V_R$	Amp/Meter	1.00e-3
NB	Emission coefficient of the bottom forward current	None	1.0
NG	Emission coefficient of the gate-edge forward current	None	1.0
NS	Emission coefficient of the sidewall forward current	None	1.0
PB	Bottom junction grading coefficient	None	0.40
PG	Gate edge junction grading coefficient	None	0.40

PS	Sidewall junction grading coefficient	None	0.40
VDBR	Diffusion voltage of the bottom junction at $T=T_R$	Volt	1.00
VB	Reverse breakdown voltage	Volt	0.9
VDGR	Diffusion voltage of the gate edge junction at $T=T_R$	Volt	1.00
VDSR	Diffusion voltage of the sidewall junction at $T=T_R$	Volt	1.00
VR	Voltage at which parameters have been determined	Volt	0.0

MOSFET Instance, Philips MOS1101 Version 11011 Binned Model (Level 63)





Philips MOS11011 Binned MOSFET Instance Netlist Syntax

Philips MOS11 Level 1100, 11010 (1101 physical), and 11011 (1101 binned) MOSFET models are grouped as HSPICE™ Level 63. All Philips MOS11 instances use the following netlist syntax:

```
Mxxxx nd ng ns [nb] modelname [[L=]length] [[W=]width]
[AD=val] [AS=val] [PD=val] [PS=val] [DTA=val]
[MULT=val] [DTEMP=val]
```

nd is the drain node, *ng* is the gate node, *ns* is the source node, and *nb* is the bulk or substrate node of the MOSFET. *modelname* is the name of a Level 63 MOSFET model defined in a .MODEL statement elsewhere in the netlist.

When the option **WL** is in effect (on the .OPTION statement), the syntax becomes:

```
Mxxxx nd ng ns [nb] modelname [width] [length]
[AD=val] [AS=val] [PD=val] [PS=val]
[DTA=val] [MULT=val] [DTEMP=val]
```

All Philips MOS11 MOSFETs use the same set of instance parameters. See "MOSFET Instance, Philips MOS11 Version 1100 Model (Level 63)" on page 24-40 for details on the instance parameters for all Level 63 MOSFETs.

Philips MOS1101 Binned MOSFET Model, Level 63, Version 11011

The Philips MOS Model 11, Version 11010 uses the binning geometry scaling rules. The syntax for a Philips MOS11011 Binned Scaling MOSFET model (HSPICE™ Level 63, Version 11011) is:

```
.MODELmodelname NMOS LEVEL=63 VERSION=11011 [parameter=val] ...
```

or

```
.MODELmodelname PMOS LEVEL=63 VERSION=11011 [parameter=val] ...
```

modelname is the name used by MOSFET instances to refer to this .MODEL statement. The **LEVEL=63** entry selects the Philips MOS11 MOSFET model. The **VERSION** parameter selects among the 1100, 11010 physical geometry scaling, and 11011 binned geometry scaling versions of the MOS11 model. **VERSION=11011** selects the MOS11011 Binned model. See "Philips MOS1101 Version 11010 Physical MOSFET Model, (Level 63)" on page 24-49 and "Philips MOS1100 MOSFET Model, Level 63, Version 1100" on page 24-41 for information on those MOSFET models.

Table 64: Level 63 VERSION=11011 MOSFET Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	63 is required to select the Philips MOS11 MOSFET model	Integer	1 (default if LEVEL parameter is omitted)
VERSION	Philips version selector 11011 is required to select the	Integer	1100

	Philips MOS Model 11, Level 1101 (binning geometry scaling rules)		
GATENOISE	Flag for inclusion or exclusion of induced gate thermal noise	None	0
KOV	Body effect factor for the source/drain overlap extensions	Volt$^{1/2}$	2.5
KPINV	Inverse of body effect factor of the polysilicon gate	Volt$^{1/2}$	0.0
LAP	Effective channel length reduction per side due to the lateral diffusion of the source/drain dopant ions	Meter	4.0e-8
LVAR	Difference between the actual length and the programmed polysilicon gate length	Meter	0.0
NT	Thermal noise coefficient at the reference temperature	Joule	1.656e-20
NU	Exponent of the field dependence of the mobility model at the reference temperature	None	2.0
PLA1	Coefficient for the length dependent part of a_1	None	0.0
PLA2	Coefficient for the length dependent part of a_2	Volt	0.0
PLA3	Coefficient for the length dependent part of a_3	None	0.0
PLAGIDL	Coefficient for the length dependent part of a_{GIDL}	Amp/Volt^3	0.0
PLALP	Coefficient for the length dependent part of α	None	0.0
PLBACC	Coefficient for the length dependent part of B_{ACC}	Volt	0.0
PLBGIDL	Coefficient for the length dependent part of B_{GIDL}	Volt	0.0
PLBET	Coefficient for the length dependent part of β	Amp-Volt^{-2}	0.0
PLBINV	Coefficient for the length dependent part of B_{INV}	Volt	0.0
PLCGDO	Coefficient for the length dependent	Farad	0.0

	part of C_{GDO}		
PLCGIDL	Coefficient for the length dependent part of C_{GIDL}	None	0.0
PLCGSO	Coefficient for the length dependent part of C_{GSO}	Farad	0.0
PLCOX	Coefficient for the length dependent part of C_{OX}	Farad	0.0
PLETAMOB	Coefficient for the length dependent part of η_{MOB}	None	0.0
PLIGACC	Coefficient for the length dependent part of I_{GACC}	Amp/Volt^2	0.0
PLIGINV	Coefficient for the length dependent part of I_{GINV}	Amp/Volt^2	0.0
PLIGOV	Coefficient for the length dependent part of I_{GOV}	Amp/Volt^2	0.0
PLKO	Coefficient for the length dependent part of K_O	Volt^{½}	0.0
PLMEXP	Coefficient for the length dependent part of 1/m	None	0.0
PLMO	Coefficient for the length dependent part of M_0	None	0.0
PLNFA	Coefficient for the length dependent part of NF_A	1/Volt-Meter^4	0.0
PLNFB	Coefficient for the length dependent part of NF_B	1/Volt-Meter^2	0.0
PLNFC	Coefficient for the length dependent part of NF_C	1/Volt	0.0
PLPHIB	Coefficient for the length dependent part of ψ_B	Volt	0.0
PLSDIBL	Coefficient for the length dependent part of σ_{DIBL}	Volt$^{-½}$	0.0
PLSSF	Coefficient for the length dependent part of σ_{SF}	Volt$^{-½}$	0.0
PLTA1	Coefficient for the length dependent part of ST_{A1}	°K^{-1}	0.0
PLTBGIDL	Coefficient for the length dependent part of STB_{GIDL}	Volt/°K	0.0

PLTETABET	Coefficient for the length dependent part of η_{BET}	None	0.0
PLTETAMOB	Coefficient for the length dependent part of η_{MOB}	°K^{-1}	0.0
PLTETAPH	Coefficient for the length dependent part of η_{PH}	None	0.0
PLTETAR	Coefficient for the length dependent part of η_{R}	None	0.0
PLTETASAT	Coefficient for the length dependent part of η_{SAT}	None	0.0
PLTETASR	Coefficient for the length dependent part of η_{SR}	None	0.0
PLTHEPH	Coefficient for the length dependent part of Θ_{PH}	$Volt^{-1}$	0.0
PLTHER	Coefficient for the length dependent part of Θ_{R}	$Volt^{-1}$	0.0
PLTHESAT	Coefficient for the length dependent part of Θ_{SAT}	$Volt^{-1}$	0.0
PLTHESR	Coefficient for the length dependent part of Θ_{SR}	$Volt^{-1}$	0.0
PLTHETH	Coefficient for the length dependent part of Θ_{TH}	$Volt^{-3}$	0.0
PLTNUEXP	Coefficient for the length dependent part of v_{EXP}	None	0.0
PLTPHIB	Coefficient for the length dependent part of $ST_{\psi B}$	Volt/°K	0.0
PLTVFB	Coefficient for the length dependent part of ST_{VFB}	Volt/°K	0.0
PLWA1	Coefficient for the length times width dependent part of a_1	None	0.0
PLWA2	Coefficient for the length times width dependent part of a_2	Volt	0.0
PLWA3	Coefficient for the length times width dependent part of a_3	None	0.0
PLWAGIDL	Coefficient for the length times width dependent part of A_{GIDL}	$Amp/Volt^3$	0.0
PLWBINV	Coefficient for the length times	Volt	0.0

	width dependent part of B_{INV}		
PLWALP	Coefficient for the length times width dependent part of α	None	0.0
PLWBACC	Coefficient for the length times width dependent part of B_{ACC}	Volt	0.0
PLWBGIDL	Coefficient for the length times width dependent part of B_{GIDL}	Volt	0.0
PLWBET	Coefficient for the length times width dependent part of β	Amp-Volt^{-2}	0.0
PLWCGDO	Coefficient for the length times width dependent part of C_{GDO}	Farad	0.0
PLWCGIDL	Coefficient for the length times width dependent part of C_{GIDL}	None	0.0
PLWCGSO	Coefficient for the length times width dependent part of C_{GSO}	Farad	0.0
PLWCOX	Coefficient for the length times width dependent part of C_{OX}	Farad	0.0
PLWETAMOB	Coefficient for the length times width dependent part of η_{MOB}	None	0.0
PLWIGACC	Coefficient for the length times width dependent part of I_{GACC}	Amp/Volt^{2}	0.0
PLWIGINV	Coefficient for the length times width dependent part of I_{GINV}	Amp/Volt^{2}	0.0
PLWIGOV	Coefficient for the length times width dependent part of I_{GOV}	Amp/Volt^{2}	0.0
PLWKO	Coefficient for the length times width dependent part of K_O	Volt^{½}	0.0
PLWMEXP	Coefficient for the length times width dependent part of 1/m	None	0.0
PLWMO	Coefficient for the length times width dependent part of M_0	None	0.0
PLWNFA	Coefficient for the length times width dependent part of NF_A	1/Volt-Meter^{4}	0.0
PLWNFB	Coefficient for the length times width dependent part of NF_B	1/Volt-Meter^{2}	0.0
PLWNFC	Coefficient for the length times width dependent part of NF_C	1/Volt	0.0

PLWPHIB	Coefficient for the length times width dependent part of ψ_B	Volt	0.0
PLWSDIBL	Coefficient for the length times width dependent part of σ_{DIBL}	Volt$^{-½}$	0.0
PLWSSF	Coefficient for the length times width dependent part of σ_{SF}	Volt$^{-½}$	0.0
PLWTA1	Coefficient for the length times width dependent part of ST_{A1}	°K^{-1}	0.0
PLWTBGIDL	Coefficient for the length times width dependent part of ST_{BGIDL}	Volt/°K	0.0
PLWTETABET	Coefficient for the length times width dependent part of η_{BET}	None	0.0
PLWTETAMOB	Coefficient for the length times width dependent part of η_{MOB}	°K^{-1}	0.0
PLWTETAPH	Coefficient for the length times width dependent part of η_{PH}	None	0.0
PLWTETAR	Coefficient for the length times width dependent part of η_R	None	0.0
PLWTETASAT	Coefficient for the length times width dependent part of η_{SAT}	None	0.0
PLWTETASR	Coefficient for the length times width dependent part of η_{SR}	None	0.0
PLWTHEPH	Coefficient for the length times width dependent part of Θ_{PH}	Volt^{-1}	0.0
PLWTHER	Coefficient for the length times width dependent part of Θ_R	Volt^{-1}	0.0
PLWTHESAT	Coefficient for the length times width dependent part of Θ_{SAT}	Volt^{-1}	0.0
PLWTHESR	Coefficient for the length times width dependent part of Θ_{SR}	Volt^{-1}	0.0
PLWTHETH	Coefficient for the length times width dependent part of Θ_{TH}	Volt^{-3}	0.0
PLWTNUEXP	Coefficient for the length times width dependent part of v_{EXP}	None	0.0
PLWTPHIB	Coefficient for the length times width dependent part of $ST_{\psi B}$	Volt/°K	0.0
PLWTVFB	Coefficient for the length times	Volt/°K	0.0

	width dependent part of ST_{VFB}		
POA1	Coefficient for the geometry independent part of a_1	None	NMOS: 6.022 PMOS: 6.858
POA2	Coefficient for the geometry independent part of a_2	Volt	NMOS: 38.02e+1 PMOS: 57.32e+1
POA3	Coefficient for the geometry independent part of a_3	None	NMOS: 0.6407 PMOS: 0.4254
POAGIDL	Coefficient for the geometry independent part of A_{GIDL}	Amp/Volt^3	0.0
POALP	Coefficient for the geometry independent part of α	None	0.025
POBACC	Coefficient for the geometry independent part of B_{ACC}	Volt	NMOS: 48 PMOS: 87.5
POBGIDL	Coefficient for the geometry independent part of B_{GIDL}	Volt	41.0
POBET	Coefficient for the geometry independent part of β	Amp-Volt^{-2}	NMOS: 1.922e-3 PMOS: 3.814e-4
POBINV	Coefficient for the geometry independent part of B_{INV}	Volt	48
POCGDO	Coefficient for the geometry independent part of C_{GDO}	Farad	NMOS: 6.392e-15 PMOS: 6.358e-15
POCGIDL	Coefficient for the geometry independent part of C_{GIDL}	None	0.0
POCGSO	Coefficient for the geometry independent part of C_{GSO}	Farad	NMOS: 6.392e-15 PMOS: 6.358e-15
POCOX	Coefficient for the geometry independent part of C_{OX}	Farad	NMOS: 2.98e-14 PMOS: 2.717e-14
POETAMOB	Coefficient for the geometry independent part of η_{MOB}	None	NMOS: 1.40 PMOS: 3.0

POIGACC	Coefficient for the geometry independent part of I_{GACC}	Amp/Volt^2	0.0
POIGINV	Coefficient for the geometry independent part of I_{GINV}	Amp/Volt^2	0.0
POIGOV	Coefficient for the geometry independent part of I_{GOV}	Amp/Volt^2	0.0
POKO	Coefficient for the geometry independent part of K_O	Volt^{½}	0.5
POMEXP	Coefficient for the geometry independent part of 1/m	None	0.2
POMO	Coefficient for the geometry independent part of M_0	None	0.0
PONFA	Coefficient for the geometry independent part of NF_A	1/Volt-Meter^4	NMOS: 8.323e22 PMOS: 1.90e22
PONFB	Coefficient for the geometry independent part of NF_B	1/Volt-Meter^2	NMOS:2.514e+7 PMOS: 5.043e+6
PONFC	Coefficient for the geometry independent part of NF_C	1/Volt	NMOS: 0.0 PMOS: 3.627e-10
POPHIB	Coefficient for the geometry independent part of ψ_B	Volt	0.950
POSDIBL	Coefficient for the geometry independent part of σ_{DIBL}	Volt$^{-½}$	NMOS: 8.53e-4 PMOS: 3.55e-5
POSSF	Coefficient for the geometry independent part of σ_{SF}	Volt$^{-½}$	NMOS: 1.2e-2 PMOS: 1.0e-2
POTA1	Coefficient for the geometry independent part of ST_{A1}	°K^{-1}	0.0
POTBGIDL	Coefficient for the geometry-independent part of ST_{BGIDL}	Volt/°K	-3.638e-4
POTETABET	Coefficient for the geometry independent part of η_{BET}	None	NMOS: 1.30 PMOS: 0.5
POTETAMOB	Coefficient for the geometry independent part of η_{MOB}	°K^{-1}	0.0
POTETAPH	Coefficient for the geometry	None	NMOS: 1.35

	independent part of η_{PH}		PMOS: 3.75
POTETAR	Coefficient for the geometry independent part of η_R	None	NMOS: 0.95 PMOS: 0.4
POTETASAT	Coefficient for the geometry independent part of η_{SAT}	None	NMOS: 1.04 PMOS: 0.86
POTETASR	Coefficient for the geometry independent part of η_{SR}	None	NMOS: 0.65 PMOS: 0.5
POTHEPH	Coefficient for the geometry independent part of Θ_{PH}	$Volt^{-1}$	NMOS: 1.290e-2 PMOS: 1.0e-3
POTHER	Coefficient for the geometry independent part of Θ_R	$Volt^{-1}$	NMOS: 8.12e-2 PMOS: 7.9e-2
POTHESAT	Coefficient for the geometry independent part of ΘSAT	$Volt^{-1}$	NMOS: 2.513e-1 PMOS: 1.728e-1
POTHESR	Coefficient for the geometry independent part of ΘSR	$Volt^{-1}$	NMOS: 3.562e-1 PMOS: 7.30e-1
POTHETH	Coefficient for the geometry independent part of Θ_{TH}	$Volt^{-3}$	NMOS: 1.0e-5 PMOS: 0.0
POTNUEXP	Coefficient for the geometry independent part of v_{EXP}	None	NMOS: 5.25 PMOS: 3.23
POTPHIB	Coefficient for the geometry independent part of $ST_{\psi B}$	Volt/°K	-8.5e-4
POTVFB	Coefficient for the geometry independent part of ST_{VFB}	Volt/°K	5.0e-4
PWA1	Coefficient for the width dependent part of a_1	None	0.0
PWA2	Coefficient for the width dependent part of a_2	Volt	0.0
PWA3	Coefficient for the width dependent part of a_3	None	0.0
PWAGIDL	Coefficient for the width dependent part of A_{GIDL}	$Amp/Volt^3$	0.0
PWALP	Coefficient for the width dependent part of α	None	0.0

PWBACC	Coefficient for the width dependent part of B_{ACC}	Volt	0.0
PWBET	Coefficient for the width dependent part of β	Amp-Volt^{-2}	0.0
PWBGIDL	Coefficient for the width dependent part of B_{GIDL}	Volt	0.0
PWBINV	Coefficient for the width dependent part of B_{INV}	Volt	0.0
PWCGDO	Coefficient for the width dependent part of C_{GDO}	Farad	0.0
PWCGIDL	Coefficient for the width dependent part of C_{GIDL}	None	0.0
PWCGSO	Coefficient for the width dependent part of C_{GSO}	Farad	0.0
PWCOX	Coefficient for the width dependent part of C_{OX}	Farad	0.0
PWETAMOB	Coefficient for the width dependent part of η_{MOB}	None	0.0
PWIGACC	Coefficient for the width dependent part of I_{GACC}	Amp/Volt^{2}	0.0
PWIGINV	Coefficient for the width dependent part of I_{GINV}	Amp/Volt^{2}	0.0
PWIGOV	Coefficient for the width dependent part of I_{GOV}	Amp/Volt^{2}	0.0
PWKO	Coefficient for the width dependent part of K_{O}	Volt$^{1/2}$	0.0
PWMEXP	Coefficient for the width dependent part of 1/m	None	0.0
PWMO	Coefficient for the width dependent part of M_{0}	None	0.0
PWNFA	Coefficient for the width dependent part of NF_{A}	1/Volt-Meter^{4}	0.0
PWNFB	Coefficient for the width dependent part of NF_{B}	1/Volt-Meter^{2}	0.0
PWNFC	Coefficient for the width dependent part of NF_{C}	1/Volt	0.0
PWPHIB	Coefficient for the width dependent	Volt	0.0

	part of ψ_B		
PWSDIBL	Coefficient for the width dependent part of σ_{DIBL}	$Volt^{-½}$	0.0
PWSSF	Coefficient for the width dependent part of σ_{SF}	$Volt^{-½}$	0.0
PWTA1	Coefficient for the width dependent part of ST_{A1}	$°K^{-1}$	0.0
PWTBGIDL	Coefficient for the width dependent part of ST_{BGIDL}	Volt/°K	0.0
PWTETABET	Coefficient for the width dependent part of η_{BET}	None	0.0
PWTETAMOB	Coefficient for the width dependent part of η_{MOB}	$°K^{-1}$	0.0
PWTETAPH	Coefficient for the width dependent part of η_{PH}	None	0.0
PWTETAR	Coefficient for the width dependent part of η_R	None	0.0
PWTETASAT	Coefficient for the width dependent part of η_{SAT}	None	0.0
PWTETASR	Coefficient for the width dependent part of η_{SR}	None	0.0
PWTHEPH	Coefficient for the width dependent part of Θ_{PH}	$Volt^{-1}$	0.0
PWTHER	Coefficient for the width dependent part of Θ_R	$Volt^{-1}$	0.0
PWTHESAT	Coefficient for the width dependent part of Θ_{SAT}	$Volt^{-1}$	0.0
PWTHESR	Coefficient for the width dependent part of Θ_{SR}	$Volt^{-1}$	0.0
PWTHETH	Coefficient for the width dependent part of Θ_{TH}	$Volt^{-3}$	0.0
PWTNUEXP	Coefficient for the width dependent part of v_{EXP}	None	0.0
PWTPHIB	Coefficient for the width dependent part of $ST_{\psi B}$	Volt/°K	0.0
PWTVFB	Coefficient for the width dependent part of ST_{VFB}	Volt/°K	0.0

THER1	Numerator of the gate voltage dependent part of series resistance for the reference transistor	Volt	0.0
THER2	Denominator of the gate voltage dependent part of series resistance for the reference transistor	Volt	1.0
TOX	Gate oxide layer thickness	Meter	3.2e-9
TR	Temperature at which the parameters for the reference transistor are determined	°C	21.0
VFB	Flatband voltage for the reference transistor at the reference temperature	Volt	-1.05
VFBOV	Flatband voltage for the source/drain overlap extensions	Volt	0.0
VP	Characteristic voltage for channel length modulation	Volt	5.0e-2
WOT	Effective reduction of the channel width per side due to the lateral diffusion of the channel stop dopant ions	Meter	0.0
WVAR	Difference between the actual width and the programmed field oxide opening	Meter	0.0

Table 65: Level 63 MOSFET JUNCAP Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
CJBR	Bottom junction capacitance at $V=V_R$	Farad/Meter^2	1.00e-12
CJGR	Gate edge-junction capacitance at $V=V_R$	Farad/Meter	1.00e-12
CJSR	Sidewall junction capacitance at $V=V_R$	Farad/Meter	1.00e-12
JSDBR	Bottom saturation-current density due to diffusion from back contact	Amp/Meter^2	1.00e-3
JSDGR	Gate-edge saturation-current density due to diffusion	Amp/Meter	1.00e-3

	from back contact		
JSDSR	Sidewall saturation-current density due to diffusion from back contact	Amp/Meter	1.00e-3
JSGBR	Bottom saturation-current density due to electron-hole generation at $V=V_R$	Amp/Meter^2	1.00e-3
JSGGR	Gate-edge saturation-current density due to electron-hole generation at $V=V_R$	Amp/Meter	1.00e-3
JSGSR	Sidewall saturation-current density due to electron-hole generation at $V=V_R$	Amp/Meter	1.00e-3
NB	Emission coefficient of the bottom forward current	None	1.0
NG	Emission coefficient of the gate-edge forward current	None	1.0
NS	Emission coefficient of the sidewall forward current	None	1.0
PB	Bottom junction grading coefficient	None	0.40
PG	Gate edge junction grading coefficient	None	0.40
PS	Sidewall junction grading coefficient	None	0.40
VDBR	Diffusion voltage of the bottom junction at $T=T_R$	Volt	1.00
VB	Reverse breakdown voltage	Volt	0.9
VDGR	Diffusion voltage of the gate edge junction at $T=T_R$	Volt	1.00
VDSR	Diffusion voltage of the sidewall junction at $T=T_R$	Volt	1.00
VR	Voltage at which parameters have been determined	Volt	0.0

Notes on MOS 11011 Binning Geometry Scaling

Binning is a way to extend a single device architecture by providing systematic variations on the device parameters. The philosophy is that when you vary the channel geometry, other parameters also change, in ways that can be completely characterized by the device manufacturer. The manufacturer or foundry provides a “design kit” that contains a set of .MODEL statements specifying the parameter settings for the different geometries. The design kit with the .MODEL statements can be included in the Nexxim design as a subcircuit.

1. A binning model is identified by giving the model name in the .MODEL statement the form *modelname***.***n*, where the entry *n* after the decimal point can be an integer or any unique identifier. The MOSFET instance definition refers to the *modelname* without any extension. The netlist can contain any number of different binning models with the same base *modelname*. For example, three binning models could be named NMOS11011.1 NMOS11011.2, and NMOS11011.3. The instance statement reference is NMOS11011.

Each of the available binning models corresponds to a range of channel lengths and widths specified with the **LMIN**, **LMAX**, **WMIN**, and **WMAX** model parameters. The ranges must not overlap.

Each binning model typically specifies values for the model parameters that are related to the channel geometry variations.

2. The MOSFET instance statement must contain values for instance parameters **L** and **W**. The **L** and **W** parameters can be specified with variables so a sweep of binning models can be performed.
3. The simulator finds the binning model to which the following conditions BOTH apply:

- The **LMIN** and **LMAX** model parameter range includes the value of instance parameter **L** (scaled by the instance parameter **SCALE**).
- The **WMIN** and **WMAX** model parameter range includes the value of instance parameter **W** (scaled by the instance parameter **SCALE**).

If none of the available binning models matches the **L** and **W** instance parameters, simulation does not proceed.

4. Within a MOS 11011 model, model parameters are adjusted by the effective channel length and width. There are three types of binning geometry adjustments. The formulas for the adjustment use the following symbols:

POx = value of the geometry-independent model parameter (e.g., **PONFA**).

PLx = value of the length dependence parameter (e.g., **PLNFA**).

PWx = value of the width dependence parameter (e.g., **PWNFA**).

PWLx = value of the cross dependence parameter (e.g., **PWLNFA**).

Le = **L** + **LVAR** - 2.0 * **LAP** = effective channel length.

We= **W** + **LVAR** - 2.0 * **WOT** = effective channel width.

Len = 1.0e-6 = normalized effective channel length.

Wen = 1.0e-6 = normalized effective channel width.

Type I adjustment:

```
Value = POx+PLx*(Len/Le)+PWx*(Wen/We)+PWLx*(Len/Le)*(Wen/We)
```

Type II adjustment:

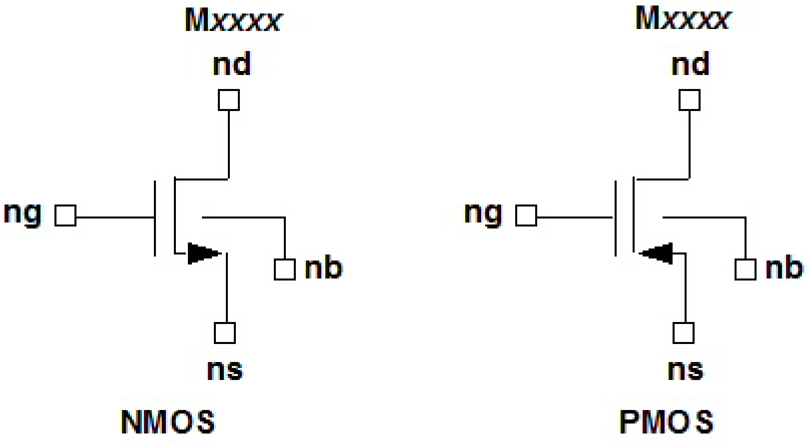
```
Value = POx+PLx*(Le/Len)+PWx*(We/Wen)+PWLx*(Le/Len)*(We/Wen)
```

Type III adjustment:

```
Value = POx+PLx*(Len/Le)+PWx*(Wen/We)+PWLx*(We/Le)
```

5. The parameters that receive Type I adjustments are A1R, A2R, A3R, ALPR, BACC, BGIDL, BINV, CGIDL, ETABETR, ETAMOBR, ETAPH, ETAR, ETASAT, ETASR, KOR, MOO, MOR, NFAR, NFBR, NFCR, PHIBR, SDIBLO, SSFR, STA1, STBGIDL, STETAMOB, STPHIB, STVFB, THEPHR, THERR, THESAT, THESRR, THETHR.
6. The parameters that receive Type II adjustments are COX, IGACCR, IGINVR, IGOVR.
7. The parameters that receive Type III adjustments are AGIDL, BETA, CGDO, CGSO.

MOSFET Instance, HiSIM1.0 Model (Level 64)



HiSIM1.0 MOSFET Instance Netlist Syntax

The syntax for a Level 64 HiSIM1.0 MOSFET instance is:

M*xxxx nd ng ns* [*nb*] *modelname* [[**L=**]*length*] [[**W=**]*width*]
[**AD=***val*] [**AS=***val*] [**PD=***val*] [**PS=***val*]
[**NRD=***val*] [**NRS=***val*]
[**SOURCECONDUCT=***val*] [**DRAINCONDUCT=***val*]
[**TEMP=***val*] [**DTEMP=***val*]

nd is the drain node, *ng* is the gate node, *ns* is the source node, and *nb* is the bulk or substrate node of the MOSFET. *modelname* is the name of a Level 64 MOSFET model defined in a .MODEL statement elsewhere in the netlist.

When the option **WL** is in effect (on the .OPTION statement), the syntax becomes:

M*xxxx nd ng ns* [*nb*] *modelname* [*width*] [*length*]
[**AD=***val*] [**AS=***val*] [**PD=***val*] [**PS=***val*]
[**NRD=***val*] [**NRS=***val*]
[**SOURCECONDUCT=***val*] [**DRAINCONDUCT=***val*]

```
[TEMP=val] [DTEMP=val]
```

Table 66: Level 64 MOSFET Instance Parameters

Instance Parameter	Description	Unit	Default
L	Channel length	Meter	1.5e-4
W	Channel width	Meter	5.55e-4
AD	Drain area	Meter^2	0.0
AS	Source area	Meter^2	0.0
PD	Drain perimeter	Meter	0.0
PS	Source perimeter	Meter	0.0
NRD	Number of squares for drain	Square	0.0
NRS	Number of squares for source	Square	0.0
DRAINCONDUCT	Drain contact conductance	Siemens	0.0
SOURCECONDUCT	Source contact conductance	Siemens	0.0
TEMP	Device temperature	°K	300.15
DTEMP	Difference between device and circuit temperatures	°C	0.0

HiSIM1.0 MOSFET Model, Level 64

The syntax for a LEVEL 64 MOSFET model is:

```
.MODELmodelname NMOS LEVEL=64 [(][parameter=val] ... [)]
```

or

```
.MODELmodelname PMOS LEVEL=64 [(][parameter=val] ... [)]
```

modelname is the name used by MOSFET instances to refer to this .MODEL statement. The **LEVEL=64** entry selects the Hiroshima University STARC IGFET Version 1.0 (HiSIM1.0) MOSFET model.

Table 67: Level 64 MOSFET Model Selector Parameters

Model Parameter	Description	Unit	Default
LEVEL	64 is required to select the HiSIM1.0	None	1 (default if LEVEL

	MOSFET model		parameter is omitted)
INFO	Info	None	0
COADOV	Switch to add overlap capacitances to intrinsic ones	None	1 (yes)
COCGBO	Switch to calculate gate-bulk overlap capacitance by CGBO	None	0 (no)
COCGDO	Switch to calculate gate-drain overlap capacitance by CGDO	None	0 (no)
COCGSO	Switch to calculate gate-source overlap capacitance by CGSO	None	0 (no)
COGIDL	Switch to calculate gate induced drain leakage (GIDL) current	None	0 (no)
COIIGS	Switch to calculate gate tunneling current	None	0 (no)
COIPRV		None	1.0
COISUB	Switch to calculate substrate current	None	0 (no)
CONOIS	Switch to calculate 1/f noise	None	0 (no)
COOVLP	Selector for overlap capacitance model <1 = constant value 0 = approximate the linear reduction of the field >0 = consider the lateral impurity profile	None	0
COPPRV		None	1.0
CORSRD	RS/RD contact resistor inclusion flag	None	0 (no)
COXX08		None	0.0
COXX09		None	0.0
NOISE	Channel thermal and flicker noise combination selector 1 = SPICE2 thermal, SPICE2 flicker 2 = HiSIM1 (BSIM3) thermal, HiSIM flicker 3 = SPICE2 thermal, HiSIM1 flicker 4 = HiSIM1 noise, SPICE2 flicker 5 = No thermal, HiSIM1 flicker	None	5

Table 68: Level 64 MOSFET Technological Model Parameters

Model Parameter	Description	Unit	Default
LP	Pocket penetration length	Meter	0.0
NSUBC	Substrate impurity concentration	cm^{-3}	5.94e+17
NSUBP	Maximum pocket concentration	cm^{-3}	5.94e+17
RD	Drain-contact resistance	Ohm-Meter	0.0
RS	Source-contact resistance	Ohm-Meter	0.0
TOX	Oxide thickness	Meter	3.6e-9
TPOLY	Height of the gate polysilicon	Meter	0.0
VFBC	Flatband voltage	Volt	-0.722729
XJ	Junction depth	Meter	0.0
XLD	Gate overlap length	Meter	0.0
XPOLYD	Difference between gate-poly and design lengths	Meter	0.0
XWD	Gate overlap width	Meter	0.0

Table 69: Level 64 MOSFET Temperature Dependence Parameters

Model Parameter	Description	Unit	Default
BGTMP1	Bandgap narrowing	eV/°K	9.03e-5
BGTMP2	Bandgap narrowing	$eV/°K^2$	3.05e-7

Table 70: Level 64 MOSFET Quantum Effect Model Parameters

Model Parameter	Description	Unit	Default
QME1	Coefficient for quantum mechanical effect	Volt-Meter	0.0
QME2	Coefficient for quantum mechanical effect	Volt	0.0
QME3	Coefficient for quantum mechanical effect	Meter	0.0

Table 71: Level 64 Poly Depletion MOSFET Model Parameters

Model Parameter	Description	Unit	Default
PGD1	Strength of poly depletion	Volt	0.0

PGD2	Threshold voltage of poly depletion	Volt	0.0
PGD3	Vds dependence of poly depletion	None	0.0

Table 72: Level 64 Short Channel MOSFET Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
PARL1	Strength of lateral electric field gradient	None	1.0
PARL2	Depletion width of channel/contact junction	Meter	2.2e-8
SC1	Short-channel coefficient 1	None	13.5
SC2	Short-channel coefficient 2	Volt^{-1}	1.8
SC3	Short-channel coefficient 3	Meter/Volt	0.0
SCP1	Short-channel coefficient 1 for pocket	None	0.0
SCP2	Short-channel coefficient 2 for pocket	Volt^{-1}	0.0
SCP3	Short-channel coefficient 3 for pocket	Meter/Volt	0.0

Table 73: Level 64 Narrow Channel MOSFET Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
MUEPH2	Mobility reduction	None	0.0
W0	Minimum gate width	log(cm)	0.0
WFC	Threshold voltage reduction	Farad-Meter/cm^2	0.0

Table 74: Level 64 MOSFET Mobility Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
BB	High-field mobility degradation	None	NMOS: 2.0 PMOS: 1.0
MUECB0	Coulomb scattering	$\text{cm}^2\text{/Volt-sec}$	300.0
MUECB1	Coulomb scattering	$\text{cm}^2\text{/}[(\text{Volt-sec}) \times (\text{Volt-cm})^{\text{MUEPH1}}]$	30.0

MUEPH0	Phonon scattering	None	0.295
MUEPH1	Phonon scattering	None	1.0e+7
MUESR0	Surface-roughness scattering	cm^2/ [(Volt-sec) x (Volt-cm)^{MUESR1}]	1.0
MUESR1	Surface-roughness scattering	None	7.0e+8
MUETMP	Temperature dependence of phonon scattering	None	0.0
NDEP	Coefficient of effective electric field	None	1.0
NINV	Coefficient of effective electric field	None	0.5
NINVD	Modification of NINV	Volt^{-1}	0.0
RPOCK1	Coefficient of resistance caused by the potential barrier	Volt^2 x μMeter$^{(1-RPOCP1)}$x Amp$^{(1-RPOCP2)}$	0.0
RPOCK2	Coefficient of resistance caused by the potential barrier	Volt	0.0
VMAX	Maximum saturation velocity	cm/sec	1.0e+7
VOVER	Velocity overshoot effect	cm^{VOVERP}	0.0
VOVERP	Lgate dependence of velocity overshoot	None	0.0

Table 75: Level 64 Channel Length Modulation MOSFET Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
CLM1	Hardness coefficient of channel/contact junction	None	0.3
CLM2	Coefficient for Q_B contribution	None	0.0
CLM3	Coefficient for Q_I contribution	None	0.0

Table 76: Level 64 MOSFET Substrate Current Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
SUB1	Substrate current coefficient 1	Volt^{-1}	0.0
SUB2	Substrate current coefficient 2	Volt	-70.0
SUB3	Substrate current coefficient 3	None	1.0

Table 77: Level 64 Gate Current MOSFET Model Parameters

Model Parameter	Description	Unit	Default
GLEAK1	Gate current coefficient 1	Amp/(Volt$^{3/2}$x °C)	0.0
GLEAK2	Gate current coefficient 2	V^{-2}x Meter^{-1}x Farad$^{-3/2}$	0.0
GLEAK3	Gate current coefficient 3	None	0.0

Table 78: Level 64 GIDL Current MOSFET Model Parameters

Model Parameter	Description	Unit	Default
GIDL1	GIDL current coefficient 1	Meter x Amp/(Volt$^{3/2}$x °C)	0.0
GIDL2	GIDL current coefficient 2	V^{-2}x Meter^{-1}x Farad$^{-3/2}$	0.0
GIDL3	GIDL current coefficient 3	None	0.0

Table 79: Level 64 MOSFET 1/f Noise Model Parameters

Model Parameter	Description	Unit	Default
AF	Flicker noise exponent	None	1.0
CIT	Capacitance caused by the interface trapped carriers	Farad/cm^2	0.0
EF	Flicker noise frequency exponent	None	0.0
KF	Flicker noise coefficient	None	0.0
NFALP	Contribution of the mobility fluctuation	Volt-sec	2.0e-15
NFTRP	Ratio of trap density to attenuation coefficient	Volt^{-1}x cm^{-2}	1.0e+11

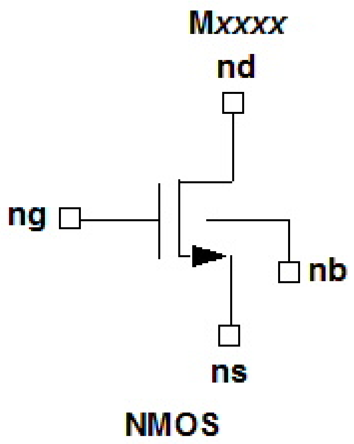
Table 80: Level 64 Symmetry Conservation at Vds=0, Short Channel MOSFET Model Parameters

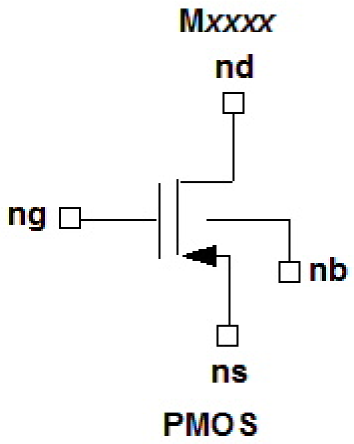
Model Parameter	Description	Unit	Default
PZADD0	Symmetry conservation coefficient	Volt	1.0e-3
VZADD0	Symmetry conservation coefficient	Volt	1.0e-2

Table 81: Level 64 MOSFET Additional Capacitance Model Parameters

Model Parameter	Description	Unit	Default
CGBO	Gate-bulk overlap capacitance	Farad/Meter	0.0
CGDO	Gate-drain overlap capacitance	Farad/Meter	0.0
CGSO	Gate-source overlap capacitance	Farad/Meter	0.0
CJ	Bottom junction capacitance per unit area at zero bias	Farad/Meter^2	8.397247e-4
CJSW	Source-drain sidewall junction capacitance per unit length at zero bias	Farad/Meter	5.0e-10
CJSWG	Source-drain sidewall junction capacitance per unit length at zero bias	Farad/Meter	5.0e-10
JS0	Saturation current density	Amp/Meter^2	1.0e-4
JS0SW	Sidewall saturation current density	Amp/Meter	0.0
MJ	Bottom junction capacitance grading coefficient	None	0.5
MJSW	Bulk junction sidewall grading coefficient	None	0.33
MJSWG	Source/drain sidewall junction capacitance grading coefficient	None	0.33
NJ	Emission coefficient	None	1.0
NJSW	Sidewall emission coefficient	None	1.0
PB	Bulk junction built-in potential	Volt	1.0
PBSW	Source-drain sidewall junction built-in potential	Volt	1.0
PBSWG	Source-drain gate sidewall junction built-in potential	Volt	1.0
XTI	Junction current temperature exponent	None	3.0

MOSFET Instance, HiSIM2.0 Model (Level 66)





HiSIM2.0 MOSFET Instance Netlist Syntax

The syntax for a Level 66 HiSIM2.0 MOSFET instance is:

```
Mxxxx nd ng ns [nb] modelname [[L=]length] [[W=]width]
[AD=val] [AS=val] [PD=val] [PS=val]
[NRD=val] [NRS=val][XGW=val] [XGL=val]
[NF=val] [NGCON=val] [LOD=val] [TEMP=val] [DTEMP=val]
[M=val] [SA=val] [SB=val] [SD=val] [DNSUBC=val]
[RBPB=val] [RBPD=val] [RBPS=val] [RBDB=val] [RBSB=val]
[CORBNET=val] [CORG=val] [ICVBS=val] [ICVDS=val] [ICVGS=val]
```

nd is the drain node, *ng* is the gate node, *ns* is the source node, and *nb* is the bulk or substrate node of the MOSFET. *modelname* is the name of a Level 66 MOSFET model defined in a .MODEL statement elsewhere in the netlist.

When the option **WL** is in effect (on the .OPTION statement), the syntax becomes:

```
Mxxxx nd ng ns [nb] modelname [width] [length]
[AD=val] [AS=val] [PD=val] [PS=val]
[NRD=val] [NRS=val][XGW=val] [XGL=val]
[NF=val] [NGCON=val] [LOD=val] [TEMP=val] [DTEMP=val]
[M=val] [SA=val] [SB=val] [SD=val] [DNSUBC=val]
[RBPB=val] [RBPD=val] [RBPS=val] [RBDB=val] [RBSB=val]
[CORBNET=val] [CORG=val] [ICVBS=val] [ICVDS=val] [ICVGS=val]
```

Table 82: Level 66 MOSFET Instance Parameters

Instance Parameter	Description	Unit	Default

AD	Drain area	Meter^2	0.0
AS	Source area	Meter^2	0.0
CORBNET	Activate body resistance (1) or do not activate (0)	None	0
CORG	Activate sheet resistance (1) or do not activate (0)	None	0
DNSUBC (**NSUBCDFM**)	Substrate impurity concentration	1/cm^3	None
DTEMP	Difference between device and circuit temperatures	°C	0.0
ICVBS			0.0
ICVDS			0.0
ICVGS			0.0
L	Channel length	Meter	5.0e-6
LOD	Length of diffusion between gate and STI	Meter	10.0e-6
M	Multiplier for multiple parallel transistors	None	1.0
NF	Number of gate fingers	None	1.0
NGCON	Number of gate contacts	None	1.0
NRD	Number of squares for drain	Square	1.0
NRS	Number of squares for source	Square	1.0
PD	Drain perimeter	Meter	0.0
PS	Source perimeter	Meter	0.0
RBDB	Substrate resistance network	Ohm	50.0
RBPB	Substrate resistance network	Ohm	50.0
RBPD	Substrate resistance network	Ohm	50.0
RBPS	Substrate resistance network	Ohm	50.0
RBSB	Substrate resistance network	Ohm	50.0
SA	Length of diffusion between gate and STI	Meter	0.0
SB	Length of diffusion between gate and STI	Meter	0.0
SD			0.0
TEMP	Device temperature	°K	Calculated
W	Channel width	Meter	5.0e-6

XGL	Offset of gate length	Meter	0.0
XGW	Distance from gate contact to channel edge	Meter	0.0

HiSIM2.0 MOSFET Model, Level 66

The syntax for a LEVEL 66 MOSFET model is:

`.MODELmodelname NMOS LEVEL=66 [(][parameter=val] ... [)]`

or

`.MODELmodelname PMOS LEVEL=66 [(][parameter=val] ... [)]`

modelname is the name used by MOSFET instances to refer to this .MODEL statement. The **LEVEL=66** entry selects the Hiroshima University STARC IGFET Version 2.0 (HiSIM2.0) MOSFET model.

Table 83: Level 66 MOSFET Model Selector Parameters

Model Parameter	Description	Unit	Default
LEVEL	66 is required to select the HiSIM2.0 MOSFET model	None	1 (default if LEVEL parameter is omitted)
VERSION	Version number	None	231
INFO	Info	None	0
COADOV	Switch to add overlap capacitances to intrinsic ones	None	1 (yes)
CODFM	Switch to enable design for manufacturing	None	0 (off)
COGIDL	Switch to calculate gate induced drain leakage (GIDL) current	None	0 (no)
COFLICK	Switch to calculate flicker noise	None	0 (no)
COIGN	Switch to calcualte induced gate noise	None	0 (no)
COIIGS	Switch to calculate gate tunneling current	None	0 (no)
COIPRV	Use ids_prv as initial guess of Ids	None	1.0
COISTI	Switch to calculate STI	None	0 (no)
COISUB	Switch to calculate substrate current	None	0 (no)
CONQS	Calculate in NQS or QS mode	None	0

COOVLP	Selector for overlap capacitance model <1 = constant value 0 = approximate the linear reduction of the field >0 = consider the lateral impurity profile	None	0
COPPRV	Use psX_prv as initial guess of prX (X=0|1)	None	1.0
CORBNET	Activate body resistance (1) or do not activate (0)	None	0
CORG	Activate sheet resistance (1) or do not activate (0)	None	0
CORSRD	RS/RD contact resistor inclusion flag	None	0 (no)
COTHRM1	Switch to calculate thermal noise	None	0 (no)
NOISE	Channel thermal and flicker noise combination selector 1 = SPICE2 thermal, SPICE2 flicker 2 = HiSIM1 (BSIM3) thermal, HiSIM flicker 3 = SPICE2 thermal, HiSIM1 flicker 4 = HiSIM1 noise, SPICE2 flicker 5 = No thermal, HiSIM1 flicker	None	1

Table 84: Level 66 MOSFET Basic Device Parameters

Model Parameter	**Description**	**Unit**	**Default**
TOX	Physical oxide thickness	Meter	3.0e-9
XLD	Gate-overlap length	Meter	0.0
XWD	Gate-overlap width	Meter	0.0
TPOLY	Height of the gate poly-Si for fringing capacitance	Meter	200e-9
LL	Coefficient of gate length modification	None	0.0
LLD	Coefficient of gate length modification	None	0.0
LLN	Coefficient of gate length modification	None	0.0
WL	Coefficient of gate width modification	None	0.0

WLD	Coefficient of gate width modification	None	0.0
WLN	Coefficient of gate width modification	None	0.0
NSUBC	Substrate impurity concentration	cm^{-3}	5.0e17
MPHDFM (**DMPHNSUBC**)	NSUBCDFM dependence of phonon scattering for DFM		-0.3
NSUBP	Maximum pocket concentration	cm^{-3}	1.0e18
LP	Pocket penetration length	Meter	15.0e-9
NPEXT	Maximum concentration of pocket tail	cm^{-3}	5.0e17
LPEXT	Extension length of pocket tail	Meter	1.0e-50
VBFC	Flat-band voltage	Volt	-1.0
VBI	Built-in potential	Volt	Version 231: 1.0 Else: 1.1
KAPPA	Dielectric constant for gate dielectric	None	3.9
EG0	Bandgap	eV	1.1785
BGTMP1	Temperature dependence of bandgap	eV/°K	90.25e-6
BGTMP2	Temperature dependence of bandgap	eV/ °K^2	0.1e-6
TNOM	Circuit nominal temperature	°C	27
XL	Difference between real and drawn gate length	Meter	0.0
XW	Difference between real and drawn gate width	Meter	0.0

Table 85: Level 66 MOSFET Velocity Parameters

Model Parameter	**Description**	**Unit**	**Default**
VMAX	Saturation velocity	cm/Second	10e6
VOVER	Velocity overshoot effect	cm^{VOVERP}	0.3
VOVERP	Leff dependence of velocity overshoot	None	0.3
VTMP	Temperature dependence of the saturation velocity	cm/Second	0.0

Table 86: Level 66 MOSFET Quantum Effect Model Parameters

Model Parameter	**Description**	**Unit**	**Default**

QME1	Vgs dependence of quantum mechanical effect	Meter/Volt^2	0.0
QME2	Vgs dependence of quantum mechanical effect	Volt	1.0
QME3	Minimum Tox modification	Meter	0.0

Table 87: Level 66 Poly Depletion MOSFET Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
PGD1	Strength of poly depletion effect	Volt	Version 231: 1.0e-4 Other: 0.0
PGD2	Threshold voltage of poly depletion effect	Volt	1.0
PGD3	Vds dependence of poly depletion effect	None	0.8
PGD4	Lgate dependence of poly depletion effect	None	0.0

Table 88: Level 66 Short Channel MOSFET Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
PARL2	Depletion width of channel/contact junction	Meter	10e-9
SC1	Magnitude of short-channel effect	None	1.0
SC2	Vds dependence of short-channel effect	Meter/Volt	1.0
SC3	Vbs dependence of short-channel effect	Meter/Volt	0.0
SCP1	Magnitude of short-channel effect due to pocket	None	1.0
SCP2	Vds dependence of short-channel effect due to pocket	Meter/Volt	0.1
SCP3	Vbs dependence of short-channel effect due to pocket	Meter/Volt	0.0
SCP21	Short-channel-effect modification for small Vds	Volt	0.0
SCP22	Short-channel-effect modification for small Vds	Volt^4	0.0
BS1	Body-coefficient modification by impurity profile	Volt^2	0.0
BS2	Body-coefficient modification by impurity profile	Volt	0.9

Table 89: Level 66 MOSFET Mobility Model Parameters

Model	**Description**	**Unit**	**Default**

Parameter			
BB	High-field mobility degradation	None	NMOS: 2.0 PMOS: 1.0
DMPHNSUBC			0.0
MUECB0	Coulomb scattering	cm^2/Volt-sec	1000.0
MUECB1	Coulomb scattering	cm^2/Volt-sec	100.0
MUEPH0	Phonon scattering	None	0.3
MUEPH1	Phonon scattering	$[cm^2/(Volt\text{-}sec)] \times (Volt/cm)^{MUEPH0}]$	NMOS: 25.0e3 PMOS: 9.0e3
MUEPHL	Length dependence of phonon mobility reduction	None	0.0
MUEPLP	Length dependence of phonon mobility reduction	None	1.0
MUESR0	Surface-roughness scattering	None	2.0
MUESR1	Surface-roughness scattering	$[cm^2/(Volt\text{-}sec)] \times [(Volt/cm)^{MUESR0}]$	1.0e15
MUESRL	Length dependence of surface roughness mobility reduction	None	0.0
MUESLP	Length dependence of surface roughness mobility reduction	None	1.0
MUETMP	Temperature dependence of phonon scattering	None	1.5
NDEP	Depletion charge contribution on effective electric field	None	1.0
NDEPL	Modification of depletion charge contribution for short-channel case	None	0.0
NDEPLP	Modification of depletion charge contribution for short-channel case	None	1.0
NINV	Inversion charge contribution on effective electric field	None	0.5

Table 90: Level 66 MOSFET Narrow Channel Effect Parameters

Model Parameter	Description	Unit	Default
WFC	Threshold voltage change due to capacitance change	Farad/ (cm^2-Meter)	0.0
WVTH0	Threshold voltage shift	None	0.0
NSUBP0	Modification of pocket concentration for narrow width	cm^{-3}	0.0
NSUBWP	Modification of pocket concentration for narrow width	None	1.0
MUEPHW	Phonon-related mobility reduction	None	0.0
MUEPWP	Phonon-related mobility reduction	None	1.0
MUESRW	Change of surface-roughness-related mobility	None	0.0
MUESWP	Change of surface-roughness-related mobility	None	1.0
VTHSTI	Threshold voltage shift due to STI	None	0.0
VDSTI	Vds dependence of STI subthreshold	None	0.0
SCSTI1	The same effect as SC1 but at STI edge	None	0.0
SCSTI2	The same effect as SC2 but at STI edge	None	0.0
SCSTI3	The same effect as SC3 but at STI edge	None	0.0
NSTI	Substrate-impurity concentration at the STI edge	cm^{-3}	Version 231: 1.0e17 Other: 5.0e17
WSTI	Width of the high-field region at the STI edge	Meter	0.0
WSTIL	Channel length dependence of WSTI	None	0.0
WSTILP	Channel length dependence of WSTI	None	1.0
WSTIW	Channel-width dependence of WSTI	None	0.0
WSTIWP	Channel-width dependence of WSTI	None	1.0
WL1	Threshold voltage shift of STI leakage due to narrow channel effect	None	0.0
WL1P	Threshold voltage shift of STI leakage due to narrow channel effect	None	1.0
NSUBPSTI1	Pocket concentration change due to diffusion-region length between gate and STI	Meter	0.0

NSUBPSTI2	Pocket concentration change due to diffusion-region length between gate and STI	Meter	0.0
NSUBPSTI3	Pocket concentration change due to diffusion-region length between gate and STI	Meter	1.0
MUESTI1	Mobility change due to diffusion-region length between gate and STI	None	0.0
MUESTI2	Mobility change due to diffusion-region length between gate and STI	None	0.0
MUESTI3	Mobility change due to diffusion-region length between gate and STI	None	1.0
SAREF	Length of diffusion between gate and STI	Meter	1e-6
SBREF	Length of diffusion between gate and STI	Meter	1e-6

Table 91: Level 66 MOSFET Small Size Effect Parameters

Model Parameter	**Description**	**Unit**	**Default**
WL2	Threshold voltage shift due to small size effect	None	0.0
WL2P	Threshold voltage shift due to small size effect	None	1.0
MUEPHS	Mobility modification due to small size effect	None	0.0
MUEPSP	Mobility modification due to small size effect	None	1.0
VOVERS	Modification of maximum velocity due to small size effect	None	0.0
VOVERSP	Modification of maximum velocity due to small size effect	None	0.0

Table 92: Level 66 MOSFET Channel Length Modulation Parameters

Model Parameter	**Description**	**Unit**	**Default**
CLM1	Hardness coefficient of channel/contact junction	None	0.7
CLM2	Coefficient for Q_B contribution	None	2.0
CLM3	Coefficient for Q_I contribution	None	1.0
CLM4	Smoothing effect for Gds	None	500e-6
CLM5	Effect of pocket implantation	None	1.0
CLM6	Effect of pocket implantation	None	0.0

Table 93: Level 66 MOSFET Substrate Current Parameters

Model Parameter	Description	Unit	Default
SUB1	Substrate current coefficient of magnitude	Volt^{-1}	10.0
SUB1L	Lgate dependence of SUB1	Meter	2.5e-3
SUB1LP	Lgate dependence of SUB1	None	1.0
SUB2	Substrate current coefficient of exponential term	Volt	25.0
SUB2L	Lgate dependence of SUB2	Meter	2.0e-6
SVDS	Substrate current dependence on Vds	None	0.8
SLG	Substrate current dependence on Lgate	Meter	3.0e-8
SLGL	Substrate current dependence on Lgate	Meter^{SLGLP}	0.0
SLGLP	Substrate current dependence on Lgate	None	1.0
SVBS	Substrate current dependence on Vbs	None	0.5
SVBSL	Lgate dependence of SVBS	Meter^{SLBSLP}	0.0
SVBSLP	Lgate dependence of SVBS	None	1.0
SVGS	Substrate current dependence on Vgs	None	0.8
SVGSL	Lgate dependence of SVGS	Meter^{SVGSLP}	0.0
SVGSLP	Lgate dependence of SVGS	None	1.0
SVGSW	Wgate dependence of SVGS	Meter^{SVGSWP}	0.0
SVGSWP	Wgate dependence of SVGS	None	1.0

Table 94: Level 64 MOSFET II-Induced Bulk Potential Change Parameters

Model Parameter	Description	Unit	Default
IBPC1	Impact-ionization induced bulk potential change	Volt/Ampere	0.0
IBPC2	Impact-ionization induced bulk potential change	Volt^{-1}	0.0

Table 95: Level 66 Gate Leakage Current MOSFET Model Parameters

Model Parameter	Description	Unit	Default
GLEAK1	Gate to channel current coefficient	Amp/(Volt$^{3/2}$x °C)	50.0
GLEAK2	Gate to channel current coefficient	1/(V$^{0.5}$x	10e6

		Meter)	
GLEAK3	Gate to channel current coefficient	None	60.0e-3
GLEAK4	Gate to channel current coefficient	1/Meter	4.0
GLEAK5	Gate to channel current coefficient (short channel correction)	Volt/Meter	7.5e3
GLEAK6	Gate to channel current coefficient (Vds dependence correction)	Volt	250e-3
GLEAK7	Gate to channel current coefficient (gate length and width dependence correction	Meter^2	1e-6
EGIG (**IGTEMP1**)	Temperature dependence of gate leakage	Volt	0.0
IGTEMP2	Temperature dependence of gate leakage	Volt-°K	0.0
IGTEMP3	Temperature dependence of gate leakage	Volt-°K^2	0.0
GLKSD1	Gate to source/drain current coefficient	Ampere-Meter/Volt^2	1e-15
GLKSD2	Gate to source/drain current coefficient	1/(Volt-Meter)	5.0e6
GLKSD3	Gate to source/drain current coefficient	1/Meter	-5.0e6
GLKB1	Gate to bulk current coefficient	Ampere/Volt^2	5.0e-16
GLKB2	Gate to bulk current coefficient	Meter/Volt	1.0
GLKB3	Flat-band shift for gate to bulk current	Volt	0.0
GLPART1	Partitioning ration of gate leakage current	None	0.5
FN1	Coefficient of Fowler-Nordheim current contribution	Meter^2/Volt$^{1.5}$	50
FN2	Coefficient of Fowler-Nordheim current contribution	1/(Meter-Volt$^{0.5}$)	170e-6
FN3	Coefficient of Fowler-Nordheim current contribution	Volt	0.0
FVBS	Vbs dependence of Fowler-Nordheim current	None	12e-3

Table 96: Level 66 MOSFET GIDL Current Parameters

Model Parameter	**Description**	**Unit**	**Default**
GIDL1	Magnitude of GIDL	(Meter- Amp)/(Volt$^{3/2}$ - °C)	2.0
GIDL2	Field dependence of GIDL	V^{-2}x Meter^{-1}x Farad$^{-3/2}$	3.0e7

GIDL3	Vds dependence of GIDL	None	0.9
GIDL4	Threshold of Vds dependence	Volt	Version 231: 0.9 Other: 0.0
GIDL5	Correction of high-field contribution	None	0.2

Table 97: Level 66 MOSFET Symmetry Conservation at Vds=0, Short Channel Model Parameters

Model Parameter	Description	Unit	Default
VZADD0	Symmetry conservation coefficient	Volt	10e-3
PZADD0	Symmetry conservation coefficient	Volt	5e-3
DDLTMAX	Smoothing coefficient for Vds	None	10.0
DDLTSLP	Lgate dependence of smoothing coefficient	None	0.0
DDLTICT	Lgate dependence of smoothing coefficient	None	10.0

Table 98: Level 66 MOSFET Source/Bulk and Drain/Bulk Diode Parameters

Model Parameter	Description	Unit	Default
JS0	Saturation current density	Amp/Meter^2	0.5e-6
JS0SW	Sidewall saturation current density	Amp/Meter	0.0
NJ	Emission coefficient	None	1.0
NJSW	Sidewall emission coefficient	None	1.0
XTI	Temperature coefficient for forward cuirrent densities	None	2.0
XTI2	Temperature coefficient for forward cuirrent densities	None	0.0
DIVX	Reverse temperature coefficient	1/Volt	0.0
CTEMP	Temperature coefficient of reverse currents	None	0.0
CISB	Reverse-biased saturation current	Ampere	0.0
CISBK	Reverse-biased saturation current at low temperature	Ampere	0.0
CVB	Bias dependence coefficient of CISB	None	0.0
CVBK	Bias dependence coefficient of CISB at low temperature	None	0.0

CJ	Bottom junction capacitance per unit area at zero bias	Farad/Meter^2	5.0e-4
CJSW	Source-drain sidewall junction capacitance per unit length at zero bias	Farad/Meter	5.0e-10
CJSWG	Source-drain sidewall junction capacitance per unit length at zero bias	Farad/Meter	5.0e-10
MJ	Bottom junction capacitance grading coefficient	None	0.5
MJSW	Bulk junction sidewall grading coefficient	None	0.33
MJSWG	Source/drain sidewall junction capacitance grading coefficient	None	0.33
PB	Bulk junction built-in potential	Volt	1.0
PBSW	Source-drain sidewall junction built-in potential	Volt	1.0
PBSWG	Source-drain gate sidewall junction built-in potential	Volt	1.0
VDIFFJ	Diode threshold voltage between source/drain and substrate	Volt	0.6e-3

Table 99: Level 66 MOSFET 1/f Noise Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
CIT	Capacitance caused by the interface trapped carriers	Farad/cm^2	0.0
NFALP	Contribution of the mobility fluctuation	Volt-sec	1.0e-19
NFTRP	Ratio of trap density to attenuation coefficient	Volt^{-1}x cm^{-2}	10.0e9

Table 100: Level 66 MOSFET Subthreshold Swing Parameters

Model Parameter	**Description**	**Unit**	**Default**
PTHROU	Correction for subthreshold swing	None	0.0

Table 101: Level 66 MOSFET Non-Quasi-Static Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
DLY1	Coefficient for delay due to diffusion of carriers	Second	100e-12

DLY2	Coefficient for delay due to conduction of carriers	None	0.7
DLY3	Coefficient for RC delay of bulk carriers	Ohm	0.8e-6

Table 102: Level 66 MOSFET Capacitance Parameters

Model Parameter	Description	Unit	Default
CGBO	Gate-bulk overlap capacitance	Farad/Meter	0.0
CGDO	Gate-drain overlap capacitance	Farad/Meter	0.0
CGSO	Gate-source overlap capacitance	Farad/Meter	0.0
XQY	Distance from drain junction to maximum electric field point	Meter	0.0
XQY1	Vbs dependence of Qy	Farad-μm^{XQY2-1}	0.0
XQY2	Lgate dependence of Qy	None	2.0
NOVER	Impurity concentration in the overlap region	cm^{-3}	0.0
LOVER	Overlap length	Meter	50e-9
OVSLP	Coefficient for overlap capacitance	None	2.1e-7
OVMAG	Coefficient for overlap capacitance	Volt	0.6
VFBOVER	Flatband voltage in overlap region	Volt	-0.5

Table 103: Level 66 MOSFET Parasitic Resistance Parameters

Model Parameter	Description	Unit	Default
RS	Source-contact resistance in LDD region	(Volt-Meter)/Ampere	0.0
RD	Drain-contact resistance in LDD region	(Volt-Meter)/Ampere	0.0
RSH	Source/drain sheet resistance	(Volt-square)/Ampere	0.0
RSHG	Gate sheet resistance	(Volt-square)/Ampere	0.0
GBMIN	Substrate resistance network	None	1.0e-12
RBPB	Substrate resistance network	Ohm	50.0
RBPD	Substrate resistance network	Ohm	50.0
RBPS	Substrate resistance network	Ohm	50.0
RBDB	Substrate resistance network	Ohm	50.0

RBSB	Substrate resistance network	Ohm	50.0

Table 104: Level 66 MOSFET Binning Parameters

Model Parameter	Description	Unit	Default
LMIN	Minimum gate length	Meter	0.0
LMAX	Maximum gate length	Meter	1.0
WMIN	Minimum gate width	Meter	0.0
WMAX	Maximum gate width	Meter	1.0
LBINN			1.0
WBINN			1.0

Table 105: Level 66 MOSFET Length Dependence Parameters

Model Parameter	Description	Unit	Default
LVMAX	Length dependence of Vmax	None	0.0
LBGTMP1	Length dependence of Bgtmp1	None	0.0
LBGTMP2	Length dependence of Bgtmp2	None	0.0
LEG0	Length dependence of Eg0	None	0.0
LLOVER	Length dependence of Lover	None	0.0
LVFBOVER	Length dependence of Vfbover	None	0.0
LNOVER	Length dependence of Nover	None	0.0
LWL2	Length dependence of WL2	None	0.0
LVFBC	Length dependence of Vfbc	None	0.0
LNSUBC	Length dependence of Nsubc	None	0.0
LNSUBP	Length dependence of Nsubp	None	0.0
LSCP1	Length dependence of Scp1	None	0.0
LSCP2	Length dependence of Scp2	None	0.0
LSCP3	Length dependence of Scp3	None	0.0
LSC1	Length dependence of Sc1	None	0.0
LSC2	Length dependence of Sc2	None	0.0
LSC3	Length dependence of Sc3	None	0.0

LPGD1	Length dependence of Pgd1	None	0.0
LPGD3	Length dependence of Pgd3	None	0.0
LNDEP	Length dependence of Ndep	None	0.0
LNINV	Length dependence of Ninv	None	0.0
LMUECB0	Length dependence of MUecb0	None	0.0
LMUECB1	Length dependence of MUecb1	None	0.0
LMUEPH1	Length dependence of MUeph1	None	0.0
LVTMP	Length dependence of Vtmp	None	0.0
LWVTH0	Length dependence of Wvth0	None	0.0
LMUESR1	Length dependence of MUesr1	None	0.0
LMUETMP	Length dependence of MUetmp	None	0.0
LSUB1	Length dependence of sub1	None	0.0
LSUB2	Length dependence of sub2	None	0.0
LSVDS	Length dependence of SVDS	None	0.0
LSVBS	Length dependence of SVBS	None	0.0
LSVGS	Length dependence of SVGS	None	0.0
LFN1	Length dependence of FN1	None	0.0
LFN2	Length dependence of FN2	None	0.0
LFN3	Length dependence of FN3	None	0.0
LVFBS	Length dependence of Vfbs	None	0.0
LNSTI	Length dependence of NSTI	None	0.0
LWSTI	Length dependence of Wsti	None	0.0
LSCSTI1	Length dependence of SCSTI1	None	0.0
LSCSTI1	Length dependence of SCSTI2	None	0.0
LVTHSTI	Length dependence of Vthsti	None	0.0
LMUESTI1	Length dependence of MUesti1	None	0.0
LMUESTI2	Length dependence of MUesti2	None	0.0
LMUESTI3	Length dependence of MUesti3	None	0.0
LNSUBPSTI1	Length dependence of Nsubpsti1	None	0.0
LNSUBPSTI2	Length dependence of Nsubpsti2	None	0.0
LNSUBPSTI3	Length dependence of Nsubpsti3	None	0.0

LCGSO	Length dependence of Cgso	None	0.0
LCGDO	Length dependence of Cgdo	None	0.0
LJS0	Length dependence of Js0	None	0.0
LJS0SW	Length dependence of Js0sw	None	0.0
LNJ	Length dependence of Nj	None	0.0
LCISBK	Length dependence of Cisbk	None	0.0
LCLM1	Length dependence of Clm1	None	0.0
LCLM2	Length dependence of Clm2	None	0.0
LCLM3	Length dependence of Clm3	None	0.0
LWFC	Length dependence of Wfc	None	0.0
LGIDL1	Length dependence of GIDL1	None	0.0
LGIDL2	Length dependence of GIDL2	None	0.0
LGLEAK1	Length dependence of Gleak1	None	0.0
LGLEAK2	Length dependence of Gleak2	None	0.0
LGLEAK3	Length dependence of Gleak3	None	0.0
LGLEAK6	Length dependence of Gleak6	None	0.0
LGLKSD1	Length dependence of Glksd1	None	0.0
LGLKSD2	Length dependence of Glksd2	None	0.0
LGLKB1	Length dependence of Glkb1	None	0.0
LGLKB2	Length dependence of Glkb2	None	0.0
LNFTRP	Length dependence of Nftrp	None	0.0
LNFALP	Length dependence of Nfalp	None	0.0
LPTHROU	Length dependence of Pthrou	None	0.0
LVDIFFJ	Length dependence of Vdiffj	None	0.0
LIBPC1	Length dependence of Ibpc1	None	0.0
LIBPC2	Length dependence of Ibpc2	None	0.0

Table 106: Level 66 MOSFET Width Dependence Parameters

Model Parameter	**Description**	**Unit**	**Default**
WVMAX	Width dependence of Vmax	None	0.0
WBGTMP1	Width dependence of Bgtmp1	None	0.0

WBGTMP2	Width dependence of Bgtmp2	None	0.0
WEG0	Width dependence of Eg0	None	0.0
WLOVER	Width dependence of Lover	None	0.0
WVFBOVER	Width dependence of Vfbover	None	0.0
WNOVER	Width dependence of Nover	None	0.0
WWL2	Width dependence of WL2	None	0.0
WVFBC	Width dependence of Vfbc	None	0.0
WNSUBC	Width dependence of Nsubc	None	0.0
WNSUBP	Width dependence of Nsubp	None	0.0
WSCP1	Width dependence of Scp1	None	0.0
WSCP2	Width dependence of Scp2	None	0.0
WSCP3	Width dependence of Scp3	None	0.0
WSC1	Width dependence of Sc1	None	0.0
WSC2	Width dependence of Sc2	None	0.0
WSC3	Width dependence of Sc3	None	0.0
WPGD1	Width dependence of Pgd1	None	0.0
WPGD3	Width dependence of Pgd3	None	0.0
WNDEP	Width dependence of Ndep	None	0.0
WNINV	Width dependence of Ninv	None	0.0
WMUECB0	Width dependence of MUecb0	None	0.0
WMUECB1	Width dependence of MUecb1	None	0.0
WMUEPH1	Width dependence of MUeph1	None	0.0
WVTMP	Width dependence of Vtmp	None	0.0
WWVTH0	Width dependence of Wvth0	None	0.0
WMUESR1	Width dependence of MUesr1	None	0.0
WMUETMP	Width dependence of MUetmp	None	0.0
WSUB1	Width dependence of sub1	None	0.0
WSUB2	Width dependence of sub2	None	0.0
WSVDS	Width dependence of SVDS	None	0.0
WSVBS	Width dependence of SVBS	None	0.0
WSVGS	Width dependence of SVGS	None	0.0

WFN1	Width dependence of FN1	None	0.0
WFN2	Width dependence of FN2	None	0.0
WFN3	Width dependence of FN3	None	0.0
WVFBS	Width dependence of Vfbs	None	0.0
WNSTI	Width dependence of NSTI	None	0.0
WWSTI	Width dependence of Wsti	None	0.0
WSCSTI1	Width dependence of SCSTI1	None	0.0
WSCSTI1	Width dependence of SCSTI2	None	0.0
WVTHSTI	Width dependence of Vthsti	None	0.0
WMUESTI1	Width dependence of MUesti1	None	0.0
WMUESTI2	Width dependence of MUesti2	None	0.0
WMUESTI3	Width dependence of MUesti3	None	0.0
WNSUBPSTI1	Width dependence of Nsubpsti1	None	0.0
WNSUBPSTI2	Width dependence of Nsubpsti2	None	0.0
WNSUBPSTI3	Width dependence of Nsubpsti3	None	0.0
WCGSO	Width dependence of Cgso	None	0.0
WCGDO	Width dependence of Cgdo	None	0.0
WJS0	Width dependence of Js0	None	0.0
WJS0SW	Width dependence of Js0sw	None	0.0
WNJ	Width dependence of Nj	None	0.0
WCISBK	Width dependence of Cisbk	None	0.0
WCLM1	Width dependence of Clm1	None	0.0
WCLM2	Width dependence of Clm2	None	0.0
WCLM3	Width dependence of Clm3	None	0.0
WWFC	Width dependence of Wfc	None	0.0
WGIDL1	Width dependence of GIDL1	None	0.0
WGIDL2	Width dependence of GIDL2	None	0.0
WGLEAK1	Width dependence of Gleak1	None	0.0
WGLEAK2	Width dependence of Gleak2	None	0.0
WGLEAK3	Width dependence of Gleak3	None	0.0
WGLEAK6	Width dependence of Gleak6	None	0.0
WGLKSD1	Width dependence of Glksd1	None	0.0

WGLKSD2	Width dependence of Glksd2	None	0.0
WGLKB1	Width dependence of Glkb1	None	0.0
WGLKB2	Width dependence of Glkb2	None	0.0
WNFTRP	Width dependence of Nftrp	None	0.0
WNFALP	Width dependence of Nfalp	None	0.0
WPTHROU	Width dependence of Pthrou	None	0.0
WVDIFFJ	Width dependence of Vdiffj	None	0.0
WIBPC1	Width dependence of Ibpc1	None	0.0
WIBPC2	Width dependence of Ibpc2	None	0.0

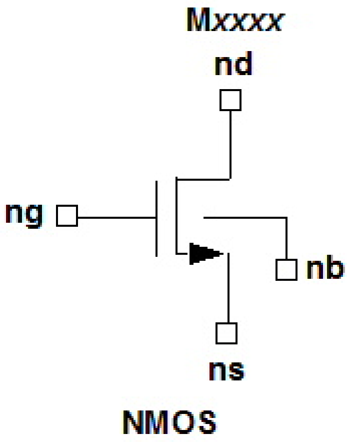
Table 107: Level 66 MOSFET Cross Dependence Parameters

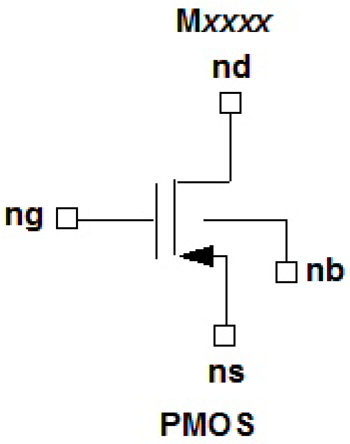
Model Parameter	**Description**	**Unit**	**Default**
PVMAX	Cross dependence of Vmax	None	0.0
PBGTMP1	Cross dependence of Bgtmp1	None	0.0
PBGTMP2	Cross dependence of Bgtmp2	None	0.0
PEG0	Cross dependence of Eg0	None	0.0
PLOVER	Cross dependence of Lover	None	0.0
PVFBOVER	Cross dependence of Vfbover	None	0.0
PNOVER	Cross dependence of Nover	None	0.0
PWL2	Cross dependence of WL2	None	0.0
PVFBC	Cross dependence of Vfbc	None	0.0
PNSUBC	Cross dependence of Nsubc	None	0.0
PNSUBP	Cross dependence of Nsubp	None	0.0
PSCP1	Cross dependence of Scp1	None	0.0
PSCP2	Cross dependence of Scp2	None	0.0
PSCP3	Cross dependence of Scp3	None	0.0
PSC1	Cross dependence of Sc1	None	0.0
PSC2	Cross dependence of Sc2	None	0.0
PSC3	Cross dependence of Sc3	None	0.0
PPGD1	Cross dependence of Pgd1	None	0.0
PPGD3	Cross dependence of Pgd3	None	0.0

PNDEP	Cross dependence of Ndep	None	0.0
PNINV	Cross dependence of Ninv	None	0.0
PMUECB0	Cross dependence of MUecb0	None	0.0
PMUECB1	Cross dependence of MUecb1	None	0.0
PMUEPH1	Cross dependence of MUeph1	None	0.0
PVTMP	Cross dependence of Vtmp	None	0.0
PWVTH0	Cross dependence of Wvth0	None	0.0
PMUESR1	Cross dependence of MUesr1	None	0.0
PMUETMP	Cross dependence of MUetmp	None	0.0
PSUB1	Cross dependence of sub1	None	0.0
PSUB2	Cross dependence of sub2	None	0.0
PSVDS	Cross dependence of SVDS	None	0.0
PSVBS	Cross dependence of SVBS	None	0.0
PSVGS	Cross dependence of SVGS	None	0.0
PFN1	Cross dependence of FN1	None	0.0
PFN2	Cross dependence of FN2	None	0.0
PFN3	Cross dependence of FN3	None	0.0
PVFBS	Cross dependence of Vfbs	None	0.0
PNSTI	Cross dependence of NSTI	None	0.0
PWSTI	Cross dependence of Wsti	None	0.0
PSCSTI1	Cross dependence of SCSTI1	None	0.0
PSCSTI1	Cross dependence of SCSTI2	None	0.0
PVTHSTI	Cross dependence of Vthsti	None	0.0
PMUESTI1	Cross dependence of MUesti1	None	0.0
PMUESTI2	Cross dependence of MUesti2	None	0.0
PMUESTI3	Cross dependence of MUesti3	None	0.0
PNSUBPSTI1	Cross dependence of Nsubpsti1	None	0.0
PNSUBPSTI2	Cross dependence of Nsubpsti2	None	0.0
PNSUBPSTI3	Cross dependence of Nsubpsti3	None	0.0
PCGSO	Cross dependence of Cgso	None	0.0
PCGDO	Cross dependence of Cgdo	None	0.0
PJS0	Cross dependence of Js0	None	0.0

PJS0SW	Cross dependence of Js0sw	None	0.0
PNJ	Cross dependence of Nj	None	0.0
PCISBK	Cross dependence of Cisbk	None	0.0
PCLM1	Cross dependence of Clm1	None	0.0
PCLM2	Cross dependence of Clm2	None	0.0
PCLM3	Cross dependence of Clm3	None	0.0
PWFC	Cross dependence of Wfc	None	0.0
PGIDL1	Cross dependence of GIDL1	None	0.0
PGIDL2	Cross dependence of GIDL2	None	0.0
PGLEAK1	Cross dependence of Gleak1	None	0.0
PGLEAK2	Cross dependence of Gleak2	None	0.0
PGLEAK3	Cross dependence of Gleak3	None	0.0
PGLEAK6	Cross dependence of Gleak6	None	0.0
PGLKSD1	Cross dependence of Glksd1	None	0.0
PGLKSD2	Cross dependence of Glksd2	None	0.0
PGLKB1	Cross dependence of Glkb1	None	0.0
PGLKB2	Cross dependence of Glkb2	None	0.0
PNFTRP	Cross dependence of Nftrp	None	0.0
PNFALP	Cross dependence of Nfalp	None	0.0
PPTHROU	Cross dependence of Pthrou	None	0.0
PVDIFFJ	Cross dependence of Vdiffj	None	0.0
PIBPC1	Cross dependence of Ibpc1	None	0.0
PIBPC2	Cross dependence of Ibpc2	None	0.0

MOSFET Instance, HiSIM2.40 LDMOS (Level 66, COLDMOS=1)





HiSIM2.40 LDMOS FET Instance Netlist Syntax

The syntax for a Level 66 HiSIM2.40 LDMOS FET instance is:

```
Mxxxx nd ng ns [nb] modelname [[L=]length] [[W=]width]
[AD=val] [AS=val] [PD=val] [PS=val]
[NRD=val] [NRS=val][XGW=val] [XGL=val]
[NF=val] [NGCON=val] [LOD=val] [TEMP=val] [DTEMP=val]
[M=val] [SA=val] [SB=val] [SD=val] [DNSUBC=val]
[RBPB=val] [RBPD=val] [RBPS=val] [RBDB=val] [RBSB=val]
[CORBNET=val] [CORG=val] [ICVBS=val] [ICVDS=val] [ICVGS=val]
```

nd is the drain node, *ng* is the gate node, *ns* is the source node, and *nb* is the bulk or substrate node of the MOSFET. *modelname* is the name of a Level 66 LDMOS FET model defined in a .MODEL statement elsewhere in the netlist.

When the option **WL** is in effect (on the .OPTION statement), the syntax becomes:

```
Mxxxx nd ng ns [nb] modelname [width] [length]
[AD=val] [AS=val] [PD=val] [PS=val]
[NRD=val] [NRS=val][XGW=val] [XGL=val]
[NF=val] [NGCON=val] [LOD=val] [TEMP=val] [DTEMP=val]
[M=val] [SA=val] [SB=val] [SD=val] [DNSUBC=val]
[RBPB=val] [RBPD=val] [RBPS=val] [RBDB=val] [RBSB=val]
[CORBNET=val] [CORG=val] [ICVBS=val] [ICVDS=val] [ICVGS=val]
```

Table 108: HiSIM 2.40 LDMOS Instance Parameters

Instance Parameter	Description	Unit	Default

AD	Drain area	Meter^2	0.0
AS	Source area	Meter^2	0.0
CORBNET	Activate body resistance (1) or do not activate (0)	None	0
CORG	Activate sheet resistance (1) or do not activate (0)	None	0
NSUBCDFM	Substrate impurity concentration	1/cm^3	None
DTEMP	Difference between device and circuit temperatures	°C	0.0
ICVBS			0.0
ICVDS			0.0
ICVGS			0.0
L	Channel length	Meter	5.0e-6
LOD	Length of diffusion between gate and STI	Meter	10.0e-6
M	Multiplier for multiple parallel transistors	None	1.0
NF	Number of gate fingers	None	1.0
NGCON	Number of gate contacts	None	1.0
NRD	Number of squares for drain	Square	1.0
NRS	Number of squares for source	Square	1.0
PD	Drain perimeter	Meter	0.0
PS	Source perimeter	Meter	0.0
RBDB	Substrate resistance network	Ohm	50.0
RBPB	Substrate resistance network	Ohm	50.0
RBPD	Substrate resistance network	Ohm	50.0
RBPS	Substrate resistance network	Ohm	50.0
RBSB	Substrate resistance network	Ohm	50.0
SA	Length of diffusion between gate and STI	Meter	0.0
SB	Length of diffusion between gate and STI	Meter	0.0
SD			0.0
TEMP	Device temperature	°K	Calculated
W	Channel width	Meter	5.0e-6
XGL	Offset of gate length	Meter	0.0
XGW	Distance from gate contact to channel edge	Meter	0.0

HiSIM2.0 MOSFET Model, Level 66 (COLDMOS=1)

The syntax for a HiSIM2.40 LDMOS FETs model is:

```
.MODELmodelname NMOS LEVEL=66 COLDMOS=1 [parameter=val] ...
```

or

```
.MODELmodelname PMOS LEVEL=66 COLDMOS=1 [parameter=val] ...
```

modelname is the name used by MOSFET instances to refer to this .MODEL statement. The **LEVEL=66** and **COLDMOS=1** entries select the Hiroshima University 2.40 HiSIM2.40 LDMOS FET model.

Table 109: HiSIM 2.40 LDMOS Model Selector Parameters

Model Parameter	Description	Unit	Default
LEVEL	66 is required to select the HiSIM2.0 MOSFET model	None	1 (default if LEVEL parameter is omitted)
COLDMOS	Required selector for the HiSIM2.40 LDMOS model	None	None
VERSION	Version number	None	231
INFO	Info	None	0
NOISE	Channel thermal/flicker noise combination selector	None	1
COADOV	Switch to add overlap capacitances to intrinsic ones	None	1 (yes)
CODFM	Switch to enable design for manufacturing	None	0 (off)
COGIDL	Switch to calculate gate induced drain leakage (GIDL) current	None	0 (no)
COFLICK	Switch to calculate flicker noise	None	0 (no)
COIGN	Switch to calcualte induced gate noise	None	0 (no)
COIIGS	Switch to calculate gate tunneling current	None	0 (no)
COIPRV	Use ids_prv as initial guess of Ids	None	1.0
COISTI	Switch to calculate STI	None	0 (no)
COISUB	Switch to calculate substrate current	None	0 (no)
CONQS	Calculate in NQS or QS mode	None	0
COOVLP	Selector for overlap capacitance model	None	0

	<1 = constant value 0 = approximate the linear reduction of the field >0 = consider the lateral impurity profile		
COPPRV	Use psX_prv as initial guess of prX (X=0|1)	None	1.0
CORBNET	Activate body resistance (1) or do not activate (0)	None	0
CORG	Activate sheet resistance (1) or do not activate (0)	None	0
CORSRD	RS/RD contact resistor inclusion flag	None	1 (yes)
COTHRM1	Switch to calculate thermal noise	None	0 (no)
NOISE	Channel thermal and flicker noise combination selector 1 = SPICE2 thermal, SPICE2 flicker 2 = HiSIM1 (BSIM3) thermal, HiSIM flicker 3 = SPICE2 thermal, HiSIM1 flicker 4 = HiSIM1 noise, SPICE2 flicker 5 = No thermal, HiSIM1 flicker	None	1

Table 110: HiSIM 2.40 LDMOS Basic Device Parameters

Model Parameter	Description	Unit	Default
TOX	Physical oxide thickness	Meter	30.0e-9
XLD	Gate-overlap length	Meter	30.0e-9
XWD	Gate-overlap width	Meter	0.0
TPOLY	Height of the gate poly-Si for fringing capacitance	Meter	200e-9
LL	Coefficient of gate length modification	None	0.0
LLD	Coefficient of gate length modification	None	0.0
LLN	Coefficient of gate length modification	None	0.0
WL	Coefficient of gate width modification	None	0.0
WLD	Coefficient of gate width modification	None	0.0
WLN	Coefficient of gate width modification	None	0.0
NSUBC	Substrate impurity concentration	cm^{-3}	1.0e17

NSUBP	Maximum pocket concentration	cm^{-3}	1.0e17
LP	Pocket penetration length	Meter	0.0
NPEXT	Maximum concentration of pocket tail	cm^{-3}	5.0e17
LPEXT	Extension length of pocket tail	Meter	1.0e-50
VBFC	Flat-band voltage	Volt	-1.0
VBI	Built-in potential	Volt	1.1
KAPPA	Dielectric constant for gate dielectric	None	3.9
EG0	Bandgap	eV	1.1785
BGTMP1	Temperature dependence of bandgap	eV/°K	90.25e-6
BGTMP2	Temperature dependence of bandgap	eV/°K^2	0.1e-6
TNOM	Circuit nominal temperature	°C	27
XL	Difference between real and drawn gate length	Meter	0.0
XW	Difference between real and drawn gate width	Meter	0.0

Table 111: HiSIM 2.40 LDMOS Velocity Parameters

Model Parameter	**Description**	**Unit**	**Default**
VMAX	Saturation velocity	cm/Second	10e6
VOVER	Velocity overshoot effect	cm^{VOVERP}	0.3
VOVERP	Leff dependence of velocity overshoot	None	0.3
VTMP	Temperature dependence of the saturation velocity	cm/Second	0.0

Table 112: HiSIM 2.40 LDMOS Quantum Effect Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
QME1	Vgs dependence of quantum mechanical effect	$Meter/Volt^2$	0.0
QME2	Vgs dependence of quantum mechanical effect	Volt	1.0
QME3	Minimum Tox modification	Meter	0.0

Table 113: HiSIM 2.40 LDMOS Poly Depletion Model Parameters

Model Parameter	**Description**	**Unit**	**Default**

PGD1	Strength of poly depletion effect	Volt	0.0
PGD2	Threshold voltage of poly depletion effect	Volt	1.0
PGD3	Vds dependence of poly depletion effect	None	0.8
PGD4	Lgate dependence of poly depletion effect	None	0.0

Table 114: HiSIM 2.40 LDMOS Short Channel Model Parameters

Model Parameter	Description	Unit	Default
PARL2	Depletion width of channel/contact junction	Meter	10e-9
SC1	Magnitude of short-channel effect	None	1.0
SC2	Vds dependence of short-channel effect	Meter/Volt	1.0
SC3	Vbs dependence of short-channel effect	Meter/Volt	0.0
SCP1	Magnitude of short-channel effect due to pocket	None	1.0
SCP2	Vds dependence of short-channel effect due to pocket	Meter/Volt	0.1
SCP3	Vbs dependence of short-channel effect due to pocket	Meter/Volt	0.0
SCP21	Short-channel-effect modification for small Vds	Volt	0.0
SCP22	Short-channel-effect modification for small Vds	Volt^4	0.0
BS1	Body-coefficient modification by impurity profile	Volt^2	0.0
BS2	Body-coefficient modification by impurity profile	Volt	0.9

Table 115: HiSIM 2.40 LDMOS Mobility Model Parameters

Model Parameter	Description	Unit	Default
BB	High-field mobility degradation	None	NMOS: 2.0 PMOS: 1.0
DMPHNSUBC			0.0
MUECB0	Coulomb scattering	cm^2/Volt-sec	1000.0
MUECB1	Coulomb scattering	cm^2/Volt-sec	100.0

MUEPH0	Phonon scattering	None	0.3
MUEPH1	Phonon scattering	[cm^2/(Volt-sec)] x (Volt/cm)^{MUEPH0}]	NMOS: 25.0e3 PMOS: 9.0e3
MUEPHL	Length dependence of phonon mobility reduction	None	0.0
MUEPLP	Length dependence of phonon mobility reduction	None	1.0
MUESR0	Surface-roughness scattering	None	2.0
MUESR1	Surface-roughness scattering	[cm^2/(Volt-sec)] x [(Volt/cm)^{MUESR0}]	1.0e16
MUESRL	Length dependence of surface roughness mobility reduction	None	0.0
MUESLP	Length dependence of surface roughness mobility reduction	None	1.0
MUETMP	Temperature dependence of phonon scattering	None	1.7
NDEP	Depletion charge contribution on effective electric field	None	1.0
NDEPL	Modification of depletion charge contribution for short-channel case	None	0.0
NDEPLP	Modification of depletion charge contribution for short-channel case	None	1.0
NINV	Inversion charge contribution on effective electric field	None	0.5

Table 116: HiSIM 2.40 LDMOS Narrow Channel Effect Parameters

Model Parameter	Description	Unit	Default
WFC	Threshold voltage change due to capacitance change	Farad/(cm^2-Meter)	0.0
WVTH0	Threshold voltage shift	None	0.0
NSUBP0	Modification of pocket concentration for narrow width	cm^{-3}	0.0

NSUBWP	Modification of pocket concentration for narrow width	None	1.0
MUEPHW	Phonon-related mobility reduction	None	0.0
MUEPWP	Phonon-related mobility reduction	None	1.0
MUESRW	Change of surface-roughness-related mobility	None	0.0
MUESWP	Change of surface-roughness-related mobility	None	1.0
VTHSTI	Threshold voltage shift due to STI	None	0.0
VDSTI	Vds dependence of STI subthreshold	None	0.0
SCSTI1	The same effect as SC1 but at STI edge	None	0.0
SCSTI2	The same effect as SC2 but at STI edge	None	0.0
NSTI	Substrate-impurity concentration at the STI edge	cm^{-3}	5.0e17
WSTI	Width of the high-field region at the STI edge	Meter	0.0
WSTIL	Channel length dependence of WSTI	None	0.0
WSTILP	Channel length dependence of WSTI	None	1.0
WSTIW	Channel-width dependence of WSTI	None	0.0
WSTIWP	Channel-width dependence of WSTI	None	1.0
WL1	Threshold voltage shift of STI leakage due to narrow channel effect	None	0.0
WL1P	Threshold voltage shift of STI leakage due to narrow channel effect	None	1.0
NSUBPSTI1	Pocket concentration change due to diffusion-region length between gate and STI	Meter	0.0
NSUBPSTI2	Pocket concentration change due to diffusion-region length between gate and STI	Meter	0.0
NSUBPSTI3	Pocket concentration change due to diffusion-region length between gate and STI	Meter	1.0
MUESTI1	Mobility change due to diffusion-region length between gate and STI	None	0.0
MUESTI2	Mobility change due to diffusion-region length between gate and STI	None	0.0
MUESTI3	Mobility change due to diffusion-region length between gate and STI	None	1.0
SAREF	Length of diffusion between gate and STI	Meter	1e-6
SBREF	Length of diffusion between gate and STI	Meter	1e-6

Table 117: HiSIM 2.40 LDMOS Small Size Effect Parameters

Model Parameter	Description	Unit	Default
WL2	Threshold voltage shift due to small size effect	None	0.0
WL2P	Threshold voltage shift due to small size effect	None	1.0
MUEPHS	Mobility modification due to small size effect	None	0.0
MUEPSP	Mobility modification due to small size effect	None	1.0
VOVERS	Modification of maximum velocity due to small size effect	None	0.0
VOVERSP	Modification of maximum velocity due to small size effect	None	0.0

Table 118: HiSIM 2.40 LDMOS Channel Length Modulation Parameters

Model Parameter	Description	Unit	Default
CLM1	Hardness coefficient of channel/contact junction	None	50.0e-3
CLM2	Coefficient for Q_B contribution	None	2.0
CLM3	Coefficient for Q_I contribution	None	1.0
CLM5	Effect of pocket implantation	None	1.0
CLM6	Effect of pocket implantation	None	0.0

Table 119: HiSIM 2.40 LDMOS Substrate Current Parameters

Model Parameter	Description	Unit	Default
SUB1	Substrate current coefficient of magnitude	Volt^{-1}	50.0e-3
SUB1L	Lgate dependence of SUB1	Meter	2.5e-3
SUB1LP	Lgate dependence of SUB1	None	1.0
SUB2	Substrate current coefficient of exponential term	Volt	100.0
SUB2L	Lgate dependence of SUB2	Meter	2.0e-6
SVDS	Substrate current dependence on Vds	None	0.8
SLG	Substrate current dependence on Lgate	Meter	3.0e-8
SLGL	Substrate current dependence on Lgate	$\text{Meter}^{\text{SLGLP}}$	0.0
SLGLP	Substrate current dependence on Lgate	None	1.0
SVBS	Substrate current dependence on Vbs	None	0.5
SVBSL	Lgate dependence of SVBS	$\text{Meter}^{\text{SLBSLP}}$	0.0

SVBSLP	Lgate dependence of SVBS	None	1.0
SVGS	Substrate current dependence on Vgs	None	0.8
SVGSL	Lgate dependence of SVGS	$\text{Meter}^{\text{SVGSLP}}$	0.0
SVGSLP	Lgate dependence of SVGS	None	1.0
SVGSW	Wgate dependence of SVGS	$\text{Meter}^{\text{SVGSWP}}$	0.0
SVGSWP	Wgate dependence of SVGS	None	1.0

Table 120: HiSIM 2.40 LDMOS II-Induced Bulk Potential Change Parameters

Model Parameter	**Description**	**Unit**	**Default**
IBPC1	Impact-ionization induced bulk potential change	Volt/Ampere	0.0
IBPC2	Impact-ionization induced bulk potential change	Volt^{-1}	0.0

Table 121: HiSIM 2.40 LDMOS Gate Leakage Current Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
GLEAK1	Gate to channel current coefficient	$\text{Amp/(Volt}^{3/2}\text{x °C)}$	50.0
GLEAK2	Gate to channel current coefficient	$\text{1/(V}^{0.5}\text{x Meter)}$	10e6
GLEAK3	Gate to channel current coefficient	None	60.0e-3
GLEAK4	Gate to channel current coefficient	1/Meter	4.0
GLEAK5	Gate to channel current coefficient (short channel correction)	Volt/Meter	7.5e3
GLEAK6	Gate to channel current coefficient (Vds dependence correction)	Volt	250e-3
GLEAK7	Gate to channel current coefficient (gate length and width dependence correction	Meter^2	1e-6
IGTEMP2	Temperature dependence of gate leakage	Volt-°K	0.0
IGTEMP3	Temperature dependence of gate leakage	Volt-°K^2	0.0
GLKSD1	Gate to source/drain current coefficient	$\text{Ampere-Meter/Volt}^2$	1e-15
GLKSD2	Gate to source/drain current coefficient	1/(Volt-Meter)	5.0e6

GLKSD3	Gate to source/drain current coefficient	1/Meter	-5.0e6
GLKB1	Gate to bulk current coefficient	Ampere/Volt^2	5.0e-16
GLKB2	Gate to bulk current coefficient	Meter/Volt	1.0
GLKB3	Flat-band shift for gate to bulk current	Volt	0.0
GLPART1	Partitioning ration of gate leakage current	None	0.5
FN1	Coefficient of Fowler-Nordheim current contribution	Meter^2/Volt$^{1.5}$	50
FN2	Coefficient of Fowler-Nordheim current contribution	1/(Meter-Volt$^{0.5}$)	170e-6
FN3	Coefficient of Fowler-Nordheim current contribution	Volt	0.0
FVBS	Vbs dependence of Fowler-Nordheim current	None	12e-3

Table 122: HiSIM 2.40 LDMOS GIDL Current Parameters

Model Parameter	**Description**	**Unit**	**Default**
GIDL1	Magnitude of GIDL	(Meter - Amp)/(Volt$^{3/2}$- °C)	2.0
GIDL2	Field dependence of GIDL	V^{-2}x Meter^{-1}x Farad$^{-3/2}$	3.0e7
GIDL3	Vds dependence of GIDL	None	0.9
GIDL4	Threshold of Vds dependence	Voltq	0.0
GIDL5	Correction of high-field contribution	None	0.2

Table 123: HiSIM 2.40 LDMOS Symmetry Conservation at Vds=0, Short Channel Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
VZADD0	Symmetry conservation coefficient	Volt	10e-3
PZADD0	Symmetry conservation coefficient	Volt	5e-3
DDLTMAX	Smoothing coefficient for Vds	None	10.0
DDLTSLP	Lgate dependence of smoothing coefficient	None	0.0
DDLTICT	Lgate dependence of smoothing coefficient	None	10.0

Table 124: HiSIM 2.40 LDMOS Source/Bulk and Drain/Bulk Diode Parameters

Model Parameter	**Description**	**Unit**	**Default**

JS0	Saturation current density	Amp/Meter^2	0.5e-6
JS0SW	Sidewall saturation current density	Amp/Meter	0.0
NJ	Emission coefficient	None	1.0
NJSW	Sidewall emission coefficient	None	1.0
XTI	Temperature coefficient for forward cuirrent densities	None	2.0
XTI2	Temperature coefficient for forward cuirrent densities	None	0.0
DIVX	Reverse temperature coefficient	1/Volt	0.0
CTEMP	Temperature coefficient of reverse currents	None	0.0
CISB	Reverse-biased saturation current	Ampere	0.0
CISBK	Reverse-biased saturation current at low temperature	Ampere	0.0
CVB	Bias dependence coefficient of CISB	None	0.0
CVBK	Bias dependence coefficient of CISB at low temperature	None	0.0
CJ	Bottom junction capacitance per unit area at zero bias	Farad/Meter^2	5.0e-4
CJSW	Source-drain sidewall junction capacitance per unit length at zero bias	Farad/Meter	5.0e-10
CJSWG	Source-drain sidewall junction capacitance per unit length at zero bias	Farad/Meter	5.0e-10
MJ	Bottom junction capacitance grading coefficient	None	0.5
MJSW	Bulk junction sidewall grading coefficient	None	0.33
MJSWG	Source/drain sidewall junction capacitance grading coefficient	None	0.33
PB	Bulk junction built-in potential	Volt	1.0
PBSW	Source-drain sidewall junction built-in potential	Volt	1.0
PBSWG	Source-drain gate sidewall junction built-in potential	Volt	1.0
VDIFFJ	Diode threshold voltage between source/drain and substrate	Volt	0.6e-3

Table 125: HiSIM 2.40 LDMOS 1/f Noise Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
CIT	Capacitance caused by the interface trapped carriers	Farad/cm^2	0.0

NFALP	Contribution of the mobility fluctuation	Volt-sec	1.0e-19
NFTRP	Ratio of trap density to attenuation coefficient	$Volt^{-1} x\ cm^{-2}$	10.0e9

Table 126: HiSIM 2.40 LDMOS Subthreshold Swing Parameters

Model Parameter	Description	Unit	Default
PTHROU	Correction for subthreshold swing	None	0.0

Table 127: HiSIM 2.40 LDMOS Non-Quasi-Static Model Parameters

Model Parameter	Description	Unit	Default
DLY1	Coefficient for delay due to diffusion of carriers	Second	100e-12
DLY2	Coefficient for delay due to conduction of carriers	None	0.7
DLY3	Coefficient for RC delay of bulk carriers	Ohm	0.8e-6

Table 128: HiSIM 2.40 LDMOS Capacitance Parameters

Model Parameter	Description	Unit	Default
CGBO	Gate-bulk overlap capacitance	Farad/Meter	0.0
CGDO	Gate-drain overlap capacitance	Farad/Meter	0.0
CGSO	Gate-source overlap capacitance	Farad/Meter	0.0
XQY	Distance from drain junction to maximum electric field point	Meter	0.0
XQY1	Vbs dependence of Qy	Farad-μm^{XQY2-1}	0.0
XQY2	Lgate dependence of Qy	None	2.0
NOVER	Impurity concentration in the overlap region	cm^{-3}	0.0
LOVER	Overlap length	Meter	30e-9
OVSLP	Coefficient for overlap capacitance	None	2.0e-8
OVMAG	Coefficient for overlap capacitance	Volt	500.0
VFBOVER	Flatband voltage in overlap region	Volt	-0.5

Table 129: HiSIM 2.40 LDMOS Parasitic Resistance Parameters

Model Parameter	Description	Unit	Default
RS	Source-contact resistance in LDD region	(Volt-Meter)/Ampere	0.0
RD	Drain-contact resistance in LDD region	(Volt-Meter)/Ampere	0.0
RSH	Source/drain sheet resistance	(Volt-square)/Ampere	0.0
RSHG	Gate sheet resistance	(Volt-square)/Ampere	0.0
GBMIN	Substrate resistance network	None	1.0e-12
RBPB	Substrate resistance network	Ohm	50.0
RBPD	Substrate resistance network	Ohm	50.0
RBPS	Substrate resistance network	Ohm	50.0
RBDB	Substrate resistance network	Ohm	50.0
RBSB	Substrate resistance network	Ohm	50.0

Table 130: HiSIM 2.40 LDMOS Binning Parameters

Model Parameter	Description	Unit	Default
LMIN	Minimum gate length	Meter	0.0
LMAX	Maximum gate length	Meter	1.0
WMIN	Minimum gate width	Meter	0.0
WMAX	Maximum gate width	Meter	1.0
LBINN			1.0
WBINN			1.0

Table 131: HiSIM 2.40 LDMOS Specific Parameters

Model Parameter	Description	Unit	Default
COSELFHEAT	Switch to enable self-heating effect	None	0
XLDLD	Gate overlap length at drain side	Meter	1.0e-6
LOVERLD	Overlap length at drain side	Meter	1.0e-6
DLYDFT	Coefficient for carrier transit delay	cm^2/Volt-sec	5.0e-2
DLYOV	Coefficient for RC delay of carriers	Second/Farad	2.0e-4
MPHDFM	NSUBCDFM dependence of phonon		-0.3

	scattering for DFM		
RDVG11	Vgs dependence of RD for CORSRD=1,3	None	0.1
RDVG12	Vgs dependence of RD for CORSRD=1,3	None	100.0
RDVD	Vds dependence of RD for CORSRD=1,3	Ohm/Volt	20.0
QDFTMAG	Adjustment for capacitance peak	None	0.0
DLD	LOVERLD modification by Vgs	Volt	2.0
RTH0	Thermal resistance	°K/Watt	0.1
CTH0	Thermal capacitance	Watt-second/°K	1.0e-7
QDFTVD			1.0
LLOVERLD	Length dependence of LOVERLD	None	0.0
WLOVERLD	Width dependence of LOVERLD	None	0.0
PLOVERLD	Cross dependence of LOVERLD	None	0.0
RD2	Drain contact resistance	Meter/Ampere	0.0
RD3	Drain contact resistance	Meter/Ampere	0.0
RD20	RD23 boundary for CORSD=2,3	None	0.0
RD21	Vds dependence of RD for CORSD=2,3	None	1.0
RD22	Vbs dependence of RD for CORSD=2,3	Ohm-Meter/Volt	0.0
RD23	Modification of RD for CORSD=2,3	Ohm-Meter/Volt^{RD25}	0.5
RD24	Vgs dependence of RD for CORSD=2,3	Ohm-Meter/Volt^{RD25-1}	0.0
RD25	Vgs dependence of RD for CORSD=2,3	Volt	0.0
RD26	Smoothing parameter of RD21 boundary for CORSD=2,3	None	0.001
QOVRAT1	Coefficient for Qover partitioning	None	0.1
QOVRAT2	Coefficient for Qover partitioning	Volt	1.0
RDVDL	Lgate dependence of RD for CORSD=1,3	None	0.0
RDVDLP	Lgate dependence of RD for CORSD=1,3	None	1.0
RDVDS	Small size dependence of RD for CORSD=1,3	None	0.0
RDVDSP	Small size dependence of RD for CORSD=1,3	None	1.0
RD23L	Lgate dependence of RD21 boundary for CORSD=2,3	None	0.0
RD23LP	Lgate dependence of RD21 boundary for CORSD=2,3	None	1.0

RD23S	Small size dependence of RD21 for CORSD=2,3	None	0.0
RD23SP	Small size dependence of RD21 for CORSD=2,3	None	1.0
RDS	Small size dependence of RD21 for CORSD=1,3	None	0.0
RDSP	Small size dependence of RD21 for CORSD=1,3	None	1.0
LDRIFT	Length of drift region	Meter	3.5e-6

Table 132: HiSIM 2.40 LDMOS Length Dependence Parameters

Model Parameter	Description	Unit	Default
LVMAX	Length dependence of Vmax	None	0.0
LBGTMP1	Length dependence of Bgtmp1	None	0.0
LBGTMP2	Length dependence of Bgtmp2	None	0.0
LEG0	Length dependence of Eg0	None	0.0
LLOVER	Length dependence of Lover	None	0.0
LVFBOVER	Length dependence of Vfbover	None	0.0
LNOVER	Length dependence of Nover	None	0.0
LWL2	Length dependence of WL2	None	0.0
LVFBC	Length dependence of Vfbc	None	0.0
LNSUBC	Length dependence of Nsubc	None	0.0
LNSUBP	Length dependence of Nsubp	None	0.0
LSCP1	Length dependence of Scp1	None	0.0
LSCP2	Length dependence of Scp2	None	0.0
LSCP3	Length dependence of Scp3	None	0.0
LSC1	Length dependence of Sc1	None	0.0
LSC2	Length dependence of Sc2	None	0.0
LSC3	Length dependence of Sc3	None	0.0
LPGD1	Length dependence of Pgd1	None	0.0
LPGD3	Length dependence of Pgd3	None	0.0
LNDEP	Length dependence of Ndep	None	0.0

LNINV	Length dependence of Ninv	None	0.0
LMUECB0	Length dependence of MUecb0	None	0.0
LMUECB1	Length dependence of MUecb1	None	0.0
LMUEPH1	Length dependence of MUeph1	None	0.0
LVTMP	Length dependence of Vtmp	None	0.0
LWVTH0	Length dependence of Wvth0	None	0.0
LMUESR1	Length dependence of MUesr1	None	0.0
LMUETMP	Length dependence of MUetmp	None	0.0
LSUB1	Length dependence of sub1	None	0.0
LSUB2	Length dependence of sub2	None	0.0
LSVDS	Length dependence of SVDS	None	0.0
LSVBS	Length dependence of SVBS	None	0.0
LSVGS	Length dependence of SVGS	None	0.0
LFN1	Length dependence of FN1	None	0.0
LFN2	Length dependence of FN2	None	0.0
LFN3	Length dependence of FN3	None	0.0
LVFBS	Length dependence of Vfbs	None	0.0
LNSTI	Length dependence of NSTI	None	0.0
LWSTI	Length dependence of Wsti	None	0.0
LSCSTI1	Length dependence of SCSTI1	None	0.0
LSCSTI1	Length dependence of SCSTI2	None	0.0
LVTHSTI	Length dependence of Vthsti	None	0.0
LMUESTI1	Length dependence of MUesti1	None	0.0
LMUESTI2	Length dependence of MUesti2	None	0.0
LMUESTI3	Length dependence of MUesti3	None	0.0
LNSUBPSTI1	Length dependence of Nsubpsti1	None	0.0
LNSUBPSTI2	Length dependence of Nsubpsti2	None	0.0
LNSUBPSTI3	Length dependence of Nsubpsti3	None	0.0
LCGSO	Length dependence of Cgso	None	0.0
LCGDO	Length dependence of Cgdo	None	0.0
LJS0	Length dependence of Js0	None	0.0
LJS0SW	Length dependence of Js0sw	None	0.0

LNJ	Length dependence of Nj	None	0.0
LCISBK	Length dependence of Cisbk	None	0.0
LCLM1	Length dependence of Clm1	None	0.0
LCLM2	Length dependence of Clm2	None	0.0
LCLM3	Length dependence of Clm3	None	0.0
LWFC	Length dependence of Wfc	None	0.0
LGIDL1	Length dependence of GIDL1	None	0.0
LGIDL2	Length dependence of GIDL2	None	0.0
LGLEAK1	Length dependence of Gleak1	None	0.0
LGLEAK2	Length dependence of Gleak2	None	0.0
LGLEAK3	Length dependence of Gleak3	None	0.0
LGLEAK6	Length dependence of Gleak6	None	0.0
LGLKSD1	Length dependence of Glksd1	None	0.0
LGLKSD2	Length dependence of Glksd2	None	0.0
LGLKB1	Length dependence of Glkb1	None	0.0
LGLKB2	Length dependence of Glkb2	None	0.0
LNFTRP	Length dependence of Nftrp	None	0.0
LNFALP	Length dependence of Nfalp	None	0.0
LPTHROU	Length dependence of Pthrou	None	0.0
LVDIFFJ	Length dependence of Vdiffj	None	0.0
LIBPC1	Length dependence of Ibpc1	None	0.0
LIBPC2	Length dependence of Ibpc2	None	0.0

Table 133: HiSIM 2.40 LDMOS Width Dependence Parameters

Model Parameter	**Description**	**Unit**	**Default**
WVMAX	Width dependence of Vmax	None	0.0
WBGTMP1	Width dependence of Bgtmp1	None	0.0
WBGTMP2	Width dependence of Bgtmp2	None	0.0
WEG0	Width dependence of Eg0	None	0.0
WLOVER	Width dependence of Lover	None	0.0
WVFBOVER	Width dependence of Vfbover	None	0.0

WNOVER	Width dependence of Nover	None	0.0
WWL2	Width dependence of WL2	None	0.0
WVFBC	Width dependence of Vfbc	None	0.0
WNSUBC	Width dependence of Nsubc	None	0.0
WNSUBP	Width dependence of Nsubp	None	0.0
WSCP1	Width dependence of Scp1	None	0.0
WSCP2	Width dependence of Scp2	None	0.0
WSCP3	Width dependence of Scp3	None	0.0
WSC1	Width dependence of Sc1	None	0.0
WSC2	Width dependence of Sc2	None	0.0
WSC3	Width dependence of Sc3	None	0.0
WPGD1	Width dependence of Pgd1	None	0.0
WPGD3	Width dependence of Pgd3	None	0.0
WNDEP	Width dependence of Ndep	None	0.0
WNINV	Width dependence of Ninv	None	0.0
WMUECB0	Width dependence of MUecb0	None	0.0
WMUECB1	Width dependence of MUecb1	None	0.0
WMUEPH1	Width dependence of MUeph1	None	0.0
WVTMP	Width dependence of Vtmp	None	0.0
WWVTH0	Width dependence of Wvth0	None	0.0
WMUESR1	Width dependence of MUesr1	None	0.0
WMUETMP	Width dependence of MUetmp	None	0.0
WSUB1	Width dependence of sub1	None	0.0
WSUB2	Width dependence of sub2	None	0.0
WSVDS	Width dependence of SVDS	None	0.0
WSVBS	Width dependence of SVBS	None	0.0
WSVGS	Width dependence of SVGS	None	0.0
WFN1	Width dependence of FN1	None	0.0
WFN2	Width dependence of FN2	None	0.0
WFN3	Width dependence of FN3	None	0.0
WVFBS	Width dependence of Vfbs	None	0.0
WNSTI	Width dependence of NSTI	None	0.0

WWSTI	Width dependence of Wsti	None	0.0
WSCSTI1	Width dependence of SCSTI1	None	0.0
WSCSTI1	Width dependence of SCSTI2	None	0.0
WVTHSTI	Width dependence of Vthsti	None	0.0
WMUESTI1	Width dependence of MUesti1	None	0.0
WMUESTI2	Width dependence of MUesti2	None	0.0
WMUESTI3	Width dependence of MUesti3	None	0.0
WNSUBPSTI1	Width dependence of Nsubpsti1	None	0.0
WNSUBPSTI2	Width dependence of Nsubpsti2	None	0.0
WNSUBPSTI3	Width dependence of Nsubpsti3	None	0.0
WCGSO	Width dependence of Cgso	None	0.0
WCGDO	Width dependence of Cgdo	None	0.0
WJS0	Width dependence of Js0	None	0.0
WJS0SW	Width dependence of Js0sw	None	0.0
WNJ	Width dependence of Nj	None	0.0
WCISBK	Width dependence of Cisbk	None	0.0
WCLM1	Width dependence of Clm1	None	0.0
WCLM2	Width dependence of Clm2	None	0.0
WCLM3	Width dependence of Clm3	None	0.0
WWFC	Width dependence of Wfc	None	0.0
WGIDL1	Width dependence of GIDL1	None	0.0
WGIDL2	Width dependence of GIDL2	None	0.0
WGLEAK1	Width dependence of Gleak1	None	0.0
WGLEAK2	Width dependence of Gleak2	None	0.0
WGLEAK3	Width dependence of Gleak3	None	0.0
WGLEAK6	Width dependence of Gleak6	None	0.0
WGLKSD1	Width dependence of Glksd1	None	0.0
WGLKSD2	Width dependence of Glksd2	None	0.0
WGLKB1	Width dependence of Glkb1	None	0.0
WGLKB2	Width dependence of Glkb2	None	0.0
WNFTRP	Width dependence of Nftrp	None	0.0

WNFALP	Width dependence of Nfalp	None	0.0
WPTHROU	Width dependence of Pthrou	None	0.0
WVDIFFJ	Width dependence of Vdiffj	None	0.0
WIBPC1	Width dependence of Ibpc1	None	0.0
WIBPC2	Width dependence of Ibpc2	None	0.0

Table 134: HiSIM 2.40 LDMOS Cross Dependence Parameters

Model Parameter	Description	Unit	Default
PVMAX	Cross dependence of Vmax	None	0.0
PBGTMP1	Cross dependence of Bgtmp1	None	0.0
PBGTMP2	Cross dependence of Bgtmp2	None	0.0
PEG0	Cross dependence of Eg0	None	0.0
PLOVER	Cross dependence of Lover	None	0.0
PVFBOVER	Cross dependence of Vfbover	None	0.0
PNOVER	Cross dependence of Nover	None	0.0
PWL2	Cross dependence of WL2	None	0.0
PVFBC	Cross dependence of Vfbc	None	0.0
PNSUBC	Cross dependence of Nsubc	None	0.0
PNSUBP	Cross dependence of Nsubp	None	0.0
PSCP1	Cross dependence of Scp1	None	0.0
PSCP2	Cross dependence of Scp2	None	0.0
PSCP3	Cross dependence of Scp3	None	0.0
PSC1	Cross dependence of Sc1	None	0.0
PSC2	Cross dependence of Sc2	None	0.0
PSC3	Cross dependence of Sc3	None	0.0
PPGD1	Cross dependence of Pgd1	None	0.0
PPGD3	Cross dependence of Pgd3	None	0.0
PNDEP	Cross dependence of Ndep	None	0.0
PNINV	Cross dependence of Ninv	None	0.0
PMUECB0	Cross dependence of MUecb0	None	0.0
PMUECB1	Cross dependence of MUecb1	None	0.0

PMUEPH1	Cross dependence of MUeph1	None	0.0
PVTMP	Cross dependence of Vtmp	None	0.0
PWVTH0	Cross dependence of Wvth0	None	0.0
PMUESR1	Cross dependence of MUesr1	None	0.0
PMUETMP	Cross dependence of MUetmp	None	0.0
PSUB1	Cross dependence of sub1	None	0.0
PSUB2	Cross dependence of sub2	None	0.0
PSVDS	Cross dependence of SVDS	None	0.0
PSVBS	Cross dependence of SVBS	None	0.0
PSVGS	Cross dependence of SVGS	None	0.0
PFN1	Cross dependence of FN1	None	0.0
PFN2	Cross dependence of FN2	None	0.0
PFN3	Cross dependence of FN3	None	0.0
PVFBS	Cross dependence of Vfbs	None	0.0
PNSTI	Cross dependence of NSTI	None	0.0
PWSTI	Cross dependence of Wsti	None	0.0
PSCSTI1	Cross dependence of SCSTI1	None	0.0
PSCSTI1	Cross dependence of SCSTI2	None	0.0
PVTHSTI	Cross dependence of Vthsti	None	0.0
PMUESTI1	Cross dependence of MUesti1	None	0.0
PMUESTI2	Cross dependence of MUesti2	None	0.0
PMUESTI3	Cross dependence of MUesti3	None	0.0
PNSUBPSTI1	Cross dependence of Nsubpsti1	None	0.0
PNSUBPSTI2	Cross dependence of Nsubpsti2	None	0.0
PNSUBPSTI3	Cross dependence of Nsubpsti3	None	0.0
PCGSO	Cross dependence of Cgso	None	0.0
PCGDO	Cross dependence of Cgdo	None	0.0
PJS0	Cross dependence of Js0	None	0.0
PJS0SW	Cross dependence of Js0sw	None	0.0
PNJ	Cross dependence of Nj	None	0.0
PCISBK	Cross dependence of Cisbk	None	0.0

PCLM1	Cross dependence of Clm1	None	0.0
PCLM2	Cross dependence of Clm2	None	0.0
PCLM3	Cross dependence of Clm3	None	0.0
PWFC	Cross dependence of Wfc	None	0.0
PGIDL1	Cross dependence of GIDL1	None	0.0
PGIDL2	Cross dependence of GIDL2	None	0.0
PGLEAK1	Cross dependence of Gleak1	None	0.0
PGLEAK2	Cross dependence of Gleak2	None	0.0
PGLEAK3	Cross dependence of Gleak3	None	0.0
PGLEAK6	Cross dependence of Gleak6	None	0.0
PGLKSD1	Cross dependence of Glksd1	None	0.0
PGLKSD2	Cross dependence of Glksd2	None	0.0
PGLKB1	Cross dependence of Glkb1	None	0.0
PGLKB2	Cross dependence of Glkb2	None	0.0
PNFTRP	Cross dependence of Nftrp	None	0.0
PNFALP	Cross dependence of Nfalp	None	0.0
PPTHROU	Cross dependence of Pthrou	None	0.0
PVDIFFJ	Cross dependence of Vdiffj	None	0.0
PIBPC1	Cross dependence of Ibpc1	None	0.0
PIBPC2	Cross dependence of Ibpc2	None	0.0

25 - MOSFET Levels 69 through 99

This topic describes the following MOSFETs:

"MOSFET Instance, PSP 103.1 Local Model (Level 69)" below

"PSP 103.1 MOSFET Local Model (Level 69, SWGEO=0)" on page 25-3

"MOSFET Instance, PSP 103.1 Geometric Model (Level 69)" on page 25-16

"PSP 103.1 MOSFET Geometric Model (Level 69, SWGEO=1)" on page 25-18

"MOSFET Instance, PSP 103.1 Binning Model (Level 69)" on page 25-38

"PSP 103.1 MOSFET Binning Model (Level 69, SWGEO=2)" on page 25-40

"MOSFET Instance, BSIM-CMG Model (Level 72)" on page 25-64

"BSIM-CMG MOSFET Model, Level 72" on page 25-66

"MOSFET Instance, HiSIM HV (Level 73)" on page 25-89

"HiSIM HV IGFET Model, Level 73" on page 25-91

"MOSFET Instance, UTSOI Local Model (Level 76)" on page 25-118

"UTSOI MOSFET Local Model (Level 76, SWSCALE=0) " on page 25-119

"MOSFET Instance, UTSOI Global Model (Level 76)" on page 25-126

"UTSOI MOSFET Global Model (Level 76, SWSCALE=1)" on page 25-127

"MOSFET Instance, Motorola MET LDMOS Model (Level 99)" on page 25-137

"Motorola MET LDMOS MOSFET Model, Level 99" on page 25-138

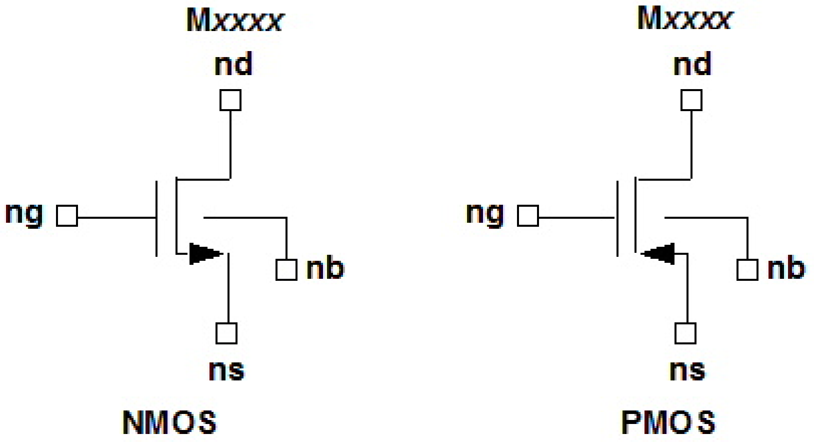
For additional MOSFETs, see

"MOSFET Levels 1 through 27" on page 22-1

"MOSFET Levels 49 through 54" on page 23-1

"MOSFET Levels 55 through 66" on page 24-1

MOSFET Instance, PSP 103.1 Local Model (Level 69)



PSP 103.1 Local Model MOSFET Instance Netlist Syntax

The syntax for a Level 69 PSP 103.1 local model MOSFET instance is:

```
Mxxxx nd ng ns nb modelname
[ABDRAIN=val] [ABSOURCE=val] [LGDRAIN=val] [LGSOURCE=val]
[LSDRAIN=val] [LSSOURCE=val]
[JW=val] [DELVTO=val] [FACTUO=val]
[M=val] [MULT=val]
```

nd is the drain node, *ng* is the gate node, *ns* is the source node, and *nb* is the bulk or substrate node of the MOSFET. *modelname* is the name of a Level 69 PSP 103.1 MOSFET local model (with model parameter **SWGEO=0**) defined in a .MODEL statement elsewhere in the netlist.

Table 1: Level 69 PSP 103.1 Local Model MOSFET Instance Parameters

Instance Parameter	Description	Unit	Default
ABDRAIN (AD)	Drain junction area	Meter^2	1.0e-12
ABSOURCE (AS)	Source junction area	Meter^2	1.0e-12
LGDRAIN	Gate-edge part of drain junction perimeter	Meter	1.0e-6
LGSOURCE	Gate-edge part of source junction perimeter	Meter	1.0e-6
LSDRAIN (PD)	STI-edge part of drain junction perimeter	Meter	1.0e-6
LSSOURCE (PS)	STI-edge part of source junction perimeter	Meter	1.0e-6
JW	Junction width	Meter	1.0e-6
DELVTO	Threshold voltage shift factor	V	0.0
FACTUO	Zero-field mobility pre-factor	None	1

M	Multiplier for multiple parallel transistors Total multiplier = M x MULT	None	1.0
MULT	Multiplier for multiple parallel transistors Total multiplier = M x MULT	None	1.0

PSP 103.1 MOSFET Local Model (Level 69, SWGEO=0)

The syntax for a Level 69 PSP103.1 local model MOSFET model is:

```
.MODELmodelname NMOS LEVEL=69 SWGEO=0

+ [(][parameter=val] ... [)]
```

or

```
.MODELmodelname PMOS LEVEL=69 SWGEO=0

+ [(][parameter=val] ... [)]
```

modelname is the name used by MOSFET instances to refer to this .MODEL statement. The LEVEL=69 entry (plus the model parameter **SWGEO=0**) selects the PSP 103.1 MOSFET local model.

Table 1: Level 69 PSP 103.1 MOSFET Local Model Selector Parameters

Model Parameter	Description	Unit	Default
LEVEL	69 is required to select the PSP 103.1 MOSFET model. The instance parameters **BINMOD=0** and **GEOMOD=0** select the local model over the global and binned models.	None	1 (default if LEVEL parameter is omitted)
SWGEO	Selector for model: 0=local, 1=geometric, 2=binning	None	0 is required to select the local model
SWNUD	Switch for nonuniform doping model. 0=off. 1=calculate surface potential; NUD model does not affect CV, avoids non-reciprocal capacitances. 2=skip extra surface potential calculation, may result in non-reciprocal capacitances	None	0

SWDELVTAC	Switch for V_{TH} charge adjustment model 0=off, 1=on	None	0
TR (**TREF**, **TNOM**)	Reference temperature	°C	21.0
SWIGATE	Flag for gate current (0 = off)	None	0
SWIMPACT	Flag for impact ionization current (0 = off)	None	0
SWGIDL	Flag for GIDL/GISL current (0 = off)	None	0
SWJUNCAP	Selector for JUNCAP model (0 = off, 1, 2, 3)	None	0
SWJUNASYM	Flag for asymmetric junctions (0 = off)	None	0
QMC	Quantum-mechanical correction factor	None	1

Table 2: Level 69 PSP 103.1 MOSFET Local Model Process Parameters

Model Parameter	**Description**	**Unit**	**Default**
VFB	Flat-band voltage at reference temperature	Volt	-1.0
STVFB	Temperature dependence of flat-band voltage	Volt/°K	5.0e-4
TOX	Gate oxide thickness	Meter	2.0e-9
EPSROX	Relative permittivity of gate dielectric	None	3.9
NEFF	Substrate doping	1/Meter^3	5.0e23
GFACNUD	Body factor change due to non-uniform doping (NUD) effect (min 0.01)	None	1.0
VSBNUD	Lower V_{SB} value for NUD effect	Volt	0
DVSBNUD	V_{SB} range for NUD effect (min: 0.1)	Volt	0
FACNEFFAC	Prefactor for effective substrate doping in separate charge calculation when SWDELVTAC=1	None	1
DELVTAC	Offset of ϕ_B in separate charge calculation when SWDELVTAC=1	Volt	0
VNSUB	Effective doping bias-dependence parameter	Volt	0.0
NSLP	Effective doping bias-dependence parameter	Volt	0.05
DNSUB	Effective doping bias-dependence parameter	1/Volt	0.0
DPHIB	Offset of PHIB	Volt	0.0
NP	Gate-polysilicon doping	1/Meter^3	1.0e26
CT	Interface states factor	None	0.0
TOXOV	Overlap oxide thickness	Meter	2.0e-9

TOXOVD	Overlap oxide thickness for drain side	Meter	2.0e-9
NOV	Effective doping of overlap region	1/Meter^3	5.0e25
NOVD	Effective doping of overlap region for drain side	1/Meter^3	5.0e25

Table 3: Level 69 PSP 103.1 MOSFET Local Model DIBL Parameters

Model Parameter	Description	Unit	Default
CF	DIBL parameter	1/Volt	0.0
CFB	Back-bias dependence of CF	1/Volt	0.0

Table 4: Level 69 PSP 103.1 MOSFET Local Model Mobility Parameters

Model Parameter	Description	Unit	Default
BETN	Product of channel aspect ratio and zero-field mobility at TR.	Meter ^{2}/Volt/Second	7.0e-2
STBET	Temperature dependence of BETN		1.0
MUE	Mobility reduction coefficient at reference temperature	Meter/Volt	0.5
STMUE	Temperature dependence of MUE	None	0.0
THEMU	Mobility reduction exponent at reference temperature	None	1.5
STTHEMU	Temperature dependence of mobility reduction exponent THEMU	None	1.5
CS	Coulomb scattering parameter at reference temperature	None	0.0
STCS	Temperature dependence of CS	None	0.0
XCOR	Non-universality parameter	1/Volt	0.0
STXCOR	Temperature dependence of XCOR	None	0.0
FETA	Effective field parameter	None	1.0

Table 5: Level 69 PSP 103.1 MOSFET Local Model Series Resistance Parameters

Model Parameter	Description	Unit	Default
RS	Source/drain series resistance at reference temperature	Ohm	30.0
STRS	Temperature dependence of RS	None	1.0
RSB	Back-bias dependence of RS	1/Volt	0.0
RSG	Gate-bias dependence of RS	1/Volt	0.0

Table 6: Level 69 PSP 103.1 MOSFET Local Model Velocity Saturation Parameters

Model Parameter	Description	Unit	Default
THESAT	Velocity saturation parameter at reference temperature	1/Volt	1.0
STTHESAT	Temperature dependence of THESAT	None	1.0
THESATB	Back-bias dependence of velocity saturation	1/Volt	0.0
THESATG	Gate-bias dependence of velocity saturation	1/Volt	0.0

Table 7: Level 69 PSP 103.1 MOSFET Local Model Saturation Voltage Parameter

Model Parameter	Description	Unit	Default
AX	Linear/saturation transition factor	None	3.0

Table 8: Level 69 PSP 103.1 MOSFET Local Model Channel Length Modulation Parameters

Model Parameter	Description	Unit	Default
ALP	CLM pre-factor		0.01
ALP1	CLM enhancement factor above threshold	Volt	0.0
ALP2	CLM enhancement factor below threshold	1/Volt	0.0
VP	CLM logarithmic dependence factor	Volt	0.05

Table 9: Level 69 PSP 103.1 MOSFET Local Model Impact Ionization Parameters

Model Parameter	Description	Unit	Default
A1	Impact-ionization prefactor	None	1.0

A2	Impact-ionization exponent at reference temperature	Volt	10.0
STA2	Temperature dependence of A2	Volt	0.0
A3	Saturation-voltage dependence of impact ionization	None	1.0
A4	Back-bias dependence of impact ionization	1/Volt$^{0.5}$	0.0

Table 10: Level 69 PSP 103.1 MOSFET Local Model Gate Currrent Parameters

Model Parameter	Description	Unit	Default
GCO	Gate tunneling energy adjustment	None	0.0
IGINV	Gate channel current pre-factor	Ampere	0.0
IGOV	Gate overlap current pre-factor	Ampere	0.0
IGOVD	Gate overlap current pre-factor for drain side	Ampere	0.0
STIG	Temperature dependence of gate current	None	2.0
GC2	Gate current slope factor	None	0.375
GC3	Gate current curvature factor	None	0.063
CHIB	Tunneling barrier height	Volt	3.1

Table 11: Level 69 PSP 103.1 MOSFET Local Model Gate-Induced Drain Leakage Parameters

Model Parameter	Description	Unit	Default
AGIDL	GIDL pre-factor	Ampere/Volt^{3}	0.0
AGIDLD	GIDL pre-factor for drain side	Ampere/Volt^{3}	0.0
BGIDL	GIDL probability factor at reference temperature	Volt	41.0
BGIDLD	GIDL probability factor at TR for drain side	Volt	41.0
STBGIDL	Temperature dependence of BGIDL	Volt/°K	0.0
STBGIDLD	Temperature dependence of BGIDL for drain side	Volt/°K	0.0
CGIDL	Back-bias dependence of GIDL	None	0.0
CGIDLD	Back-bias dependence of GIDL for drain side	None	0.0

Table 12: Level 69 PSP 103.1 MOSFET Local Model Charge Model Parameters

Model	Description	Unit	Default

Parameter			
COX	Oxide capacitance for intrinsic channel	Farad	1e-14
CGOV	Oxide capacitance for gate-drain/source overlap	Farad	1e-15
CGOVD	Oxide capacitance for gate-drain/source overlap for drain side	Farad	1e-15
CGBOV	Oxide capacitance for gate-bulk overlap	Farad	0.0
CFR	Outer fringe capacitance	Farad	0.0
CFRD	Outer fringe capacitance for drain side	Farad	0.0

Table 13: Level 69 PSP 103.1 MOSFET Local Model Noise Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
FNT	Thermal noise coefficient	None	1.0
NFA	First coefficient of flicker noise	1/Volt-Meter^4	8.0e22
NFB	Second coefficient of flicker noise	1/Volt-Meter^2	3.0e7
NFC	Third coefficient of flicker noise	1/Volt	0.0
EF	Flicker noise frequency exponent	None	1.0

Table 14: Level 69 PSP 103.1 MOSFET Local Model Temperature Offset Parameters

Model Parameter	**Description**	**Unit**	**Default**
DTA	Temperature offset from ambient circuit temperature	°K	0.0

Table 15: Level 69 PSP 103.1 MOSFET Local Model Basic JUNCAP2 Parameters

Model Parameter	**Description**	**Unit**	**Default**
TRJ	Reference temperature (for both source-bulk and source-drain junctions)	°C	21.0
SWJUNEXP	Flag for JUNCAP2 Express: 0=full JUNCAP2 model,	None	0

	1=Express model (for both source-bulk and source-drain junctions)		
IMAX	Maximum current up to which forward current behaves exponentially (for both source-bulk and source-drain junctions)	Ampere	1000.0

Table 16: Level 69 PSP 103.1 MOSFET Local Model JUNCAP2 Source-Bulk Capacitance Parameters

Model Parameter	Description	Unit	Default
CJORBOT	Zero-bias capacitance per unit area of bottom component for source-bulk junction	Farad/Meter ^{2}	1.0e-3
CJORSTI	Zero-bias capacitance per unit length of STI-edge component for source-bulk junction	Farad/Meter	1.0e-9
CJORGAT	Zero-bias capacitance per unit length of gate-edge component for source-bulk junction	Farad/Meter	1.0e-9
VBIRBOT	Built-in voltage at the reference temperature of bottom component for source-bulk junction	Volt	1.0
VBIRSTI	Built-in voltage at the reference temperature of STI-edge component for source-bulk junction	Volt	1.0
VBIRGAT	Built-in voltage at the reference temperature of gate-edge component for source-bulk junction	Volt	1.0
PBOT	Grading coefficient of bottom component for source-bulk junction	None	0.5
PSTI	Grading coefficient of STI-edge component for source-bulk junction	None	0.5
PGAT	Grading coefficient of gate-edge component for source-bulk junction	None	0.5

Table 17: Level 69 PSP 103.1 MOSFET Local Model JUNCAP2 Source-Bulk Ideal Current Parameters

Model Parameter	Description	Unit	Default
PHIGBOT	Zero-temperature bandgap voltage of bottom component for source-bulk junction	Volt	1.16
PHIGSTI	Zero-temperature bandgap voltage of STI-edge	Volt	1.16

	component for source-bulk junction		
PHIGGAT	Zero-temperature bandgap voltage of gate-edge component for source-bulk junction	Volt	1.16
IDSATRBOT	Saturation current density at the reference temperature of bottom component for source-bulk junction	Ampere/Meter^2	1.0e-12
IDSATRSTI	Saturation current density at the reference temperature of STI-edge component for source-bulk junction	Ampere/Meter	1.0e-18
IDSATRGAT	Saturation current density at the reference temperature of gate-edge component for source-bulk junction	Ampere/Meter	1.0e-18
CSRHBOT	Shockley-Read-Hall prefactor of bottom component for source-bulk junction	Ampere/Meter^3	1.0e2
CSRHSTI	Shockley-Read-Hall prefactor of STI-edge component for source-bulk junction	Ampere/Meter^2	1.0e-4
CSRHGAT	Shockley-Read-Hall prefactor of gate-edge component for source-bulk junction	Ampere/Meter^2	1.0e-4
XJUNSTI	Junction depth of STI-edge component for source-bulk junction	Meter	1.0e-7
XJUNGAT	Junction depth of gate-edge component for source-bulk junction	Meter	1.0e-7

Table 18: Level 69 PSP 103.1 MOSFET Local Model JUNCAP2 Source-Bulk Trap-Assisted Tunneling Parameters

Model Parameter	**Description**	**Unit**	**Default**
CTATBOT	Trap-assisted tunneling prefactor of bottom component for source-bulk junction	Ampere/Meter^3	1.0e2
CTATSTI	Trap-assisted tunneling prefactor of STI-edge component for source-bulk junction	Ampere/Meter^2	1.0e-4
CTATGAT	Trap-assisted tunneling prefactor of gate-edge component for source-bulk junction	Ampere/Meter^2	1.0e-4
MEFFTATBOT	Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for source-bulk junction	None	0.25
MEFFTATSTI	Effective mass (in units of m_0) for trap-assisted	None	0.25

	tunneling of STI-edge component for source-bulk junction		
MEFFTATGAT	Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for source-bulk junction	None	0.25

Table 19: Level 69 PSP 103.1 MOSFET Local Model JUNCAP2 Source-Bulk Band-to-Band Tunneling Parameters

Model Parameter	**Description**	**Unit**	**Default**
CBBTBOT	Band-to-band tunneling prefactor of bottom component for source-bulk junction	Ampere/Volt^3	1.0e-12
CBBTSTI	Band-to-band tunneling prefactor of STI-edge component for source-bulk junction	Ampere-Meter/Volt^3	1.0e-18
CBBTGAT	Band-to-band tunneling prefactor of gate-edge component for source-bulk junction	Ampere-Meter/Volt^3	1.0e-18
FBBTRBOT	Normalization field at the reference temperature for band-to-band tunneling prefactor of bottom component for source-bulk junction	Volt/Meter	1.0e9
FBBTRSTI	Normalization field at the reference temperature for band-to-band tunneling prefactor of STI-edge component for source-bulk junction	Volt/Meter	1.0e9
FBBTRGAT	Normalization field at the reference temperature for band-to-band tunneling prefactor of gate-edge component for source-bulk junction	Volt/Meter	1.0e9
STFBBTBOT	Temperature scaling parameter for band-to-band tunneling prefactor of bottom component for source-bulk junction	1/°K	-1.0e-3
STFBBTSTI	Temperature scaling parameter for band-to-band tunneling prefactor of STI-edge component for source-bulk junction	1/°K	-1.0e-3
STFBBTGAT	Temperature scaling parameter for band-to-band tunneling prefactor of gate-edge component for source-bulk junction	1/°K	-1.0e-3

Table 20: Level 69 PSP 103.1 MOSFET Local Model JUNCAP2 Source-Bulk Avalanche and Breakdown Parameters

Model Parameter	Description	Unit	Default
VBRBOT	Breakdown voltage of bottom component for source-bulk junction	Volt	10.0
VBRSTI	Breakdown voltage of STI-edge component for source-bulk junction	Volt	10.0
VBRGAT	Breakdown voltage of gate-edge component for source-bulk junction	Volt	10.0
PBRBOT	Breakdown onset tuning parameter of bottom component for source-bulk junction	Volt	4.0
PBRSTI	Breakdown onset tuning parameter of STI-edge component for source-bulk junction	Volt	4.0
PBRGAT	Breakdown onset tuning parameter of gate-edge component for source-bulk junction	Volt	4.0

Table 21: Level 69 PSP 103.1 MOSFET Local Model JUNCAP2 Source-Bulk JUNCAP Express Parameters

Model Parameter	Description	Unit	Default
VJUNREF	Typical maximum source-bulk junction voltage; usually about 2xV_{sup}	Volt	2.5
FJUNQ	Fraction below which source-bulk junction capacitance components are neglected	Volt	0.03

Table 22: Level 69 PSP 103.1 MOSFET Local Model JUNCAP2 Drain-Bulk Capacitance Parameters

Model Parameter	Description	Unit	Default
CJORBOTD	Zero-bias capacitance per unit area of bottom component for drain-bulk junction	Farad/Meter 2	1.0e-3
CJORSTID	Zero-bias capacitance per unit length of STI-edge component for drain-bulk junction	Farad/Meter	1.0e-9
CJORGATD	Zero-bias capacitance per unit length of gate-edge component for drain-bulk junction	Farad/Meter	1.0e-9

VBIRBOTD	Built-in voltage at the reference temperature of bottom component for drain-bulk junction	Volt	1.0
VBIRSTID	Built-in voltage at the reference temperature of STI-edge component for drain-bulk junction	Volt	1.0
VBIRGATD	Built-in voltage at the reference temperature of gate-edge component for drain-bulk junction	Volt	1.0
PBOTD	Grading coefficient of bottom component for drain-bulk junction	None	0.5
PSTID	Grading coefficient of STI-edge component for drain-bulk junction	None	0.5
PGATD	Grading coefficient of gate-edge component for drain-bulk junction	None	0.5

Table 23: Level 69 PSP 103.1 MOSFET Local Model JUNCAP2 Drain-Bulk Ideal Current Parameters

Model Parameter	Description	Unit	Default
PHIGBOTD	Zero-temperature bandgap voltage of bottom component for drain-bulk junction	Volt	1.16
PHIGSTID	Zero-temperature bandgap voltage of STI-edge component for drain-bulk junction	Volt	1.16
PHIGGATD	Zero-temperature bandgap voltage of gate-edge component for drain-bulk junction	Volt	1.16
IDSATRBOTD	Saturation current density at the reference temperature of bottom component for drain-bulk junction	Ampere/Meter^2	1.0e-12
IDSATRSTID	Saturation current density at the reference temperature of STI-edge component for drain-bulk junction	Ampere/Meter	1.0e-18
IDSATRGATD	Saturation current density at the reference temperature of gate-edge component for drain-bulk junction	Ampere/Meter	1.0e-18
CSRHBOTD	Shockley-Read-Hall prefactor of bottom component for drain-bulk junction	Ampere/Meter^3	1.0e2
CSRHSTID	Shockley-Read-Hall prefactor of STI-edge component for drain-bulk junction	Ampere/Meter^2	1.0e-4

CSRHGATD	Shockley-Read-Hall prefactor of gate-edge component for drain-bulk junction	Ampere/Meter^2	1.0e-4
XJUNSTID	Junction depth of STI-edge component for drain-bulk junction	Meter	1.0e-7
XJUNGATD	Junction depth of gate-edge component for drain-bulk junction	Meter	1.0e-7

Table 24: Level 69 PSP 103.1 MOSFET Local Model JUNCAP2 Drain-Bulk Trap-Assisted Tunneling Parameters

Model Parameter	**Description**	**Unit**	**Default**
CTATBOTD	Trap-assisted tunneling prefactor of bottom component for drain-bulk junction	Ampere/Meter^3	1.0e2
CTATSTID	Trap-assisted tunneling prefactor of STI-edge component for drain-bulk junction	Ampere/Meter^2	1.0e-4
CTATGATD	Trap-assisted tunneling prefactor of gate-edge component for drain-bulk junction	Ampere/Meter^2	1.0e-4
MEFFTATBOTD	Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for drain-bulk junction	None	0.25
MEFFTATSTID	Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for drain-bulk junction	None	0.25
MEFFTATGATD	Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for drain-bulk junction	None	0.25

Table 25: Level 69 PSP 103.1 MOSFET Local Model JUNCAP2 Drain-Bulk Band-to-Band Tunneling Parameters

Model Parameter	**Description**	**Unit**	**Default**
CBBTBOTD	Band-to-band tunneling prefactor of bottom component for drain-bulk junction	Ampere/Volt^3	1.0e-12
CBBTSTID	Band-to-band tunneling prefactor of STI-edge component for drain-bulk junction	Ampere-Meter/Volt^3	1.0e-18
CBBTGATD	Band-to-band tunneling prefactor of gate-edge	Ampere-	1.0e-18

	component for drain-bulk junction	Meter/Volt^3	
FBBTRBOTD	Normalization field at the reference temperature for band-to-band tunneling prefactor of bottom component for drain-bulk junction	Volt/Meter	1.0e9
FBBTRSTID	Normalization field at the reference temperature for band-to-band tunneling prefactor of STI-edge component for drain-bulk junction	Volt/Meter	1.0e9
FBBTRGATD	Normalization field at the reference temperature for band-to-band tunneling prefactor of gate-edge component for drain-bulk junction	Volt/Meter	1.0e9
STFBBTBOTD	Temperature scaling parameter for band-to-band tunneling prefactor of bottom component for drain-bulk junction	1/°K	-1.0e-3
STFBBTSTID	Temperature scaling parameter for band-to-band tunneling prefactor of STI-edge component for drain-bulk junction	1/°K	-1.0e-3
STFBBTGATD	Temperature scaling parameter for band-to-band tunneling prefactor of gate-edge component for drain-bulk junction	1/°K	-1.0e-3

Table 26: Level 69 PSP 103.1 MOSFET Local Model JUNCAP2 Drain-Bulk Avalanche and Breakdown Parameters

Model Parameter	Description	Unit	Default
VBRBOTD	Breakdown voltage of bottom component for drain-bulk junction	Volt	10.0
VBRSTID	Breakdown voltage of STI-edge component for drain-bulk junction	Volt	10.0
VBRGATD	Breakdown voltage of gate-edge component for drain-bulk junction	Volt	10.0
PBRBOTD	Breakdown onset tuning parameter of bottom component for drain-bulk junction	Volt	4.0
PBRSTID	Breakdown onset tuning parameter of STI-edge component for drain-bulk junction	Volt	4.0
PBRGATD	Breakdown onset tuning parameter of gate-edge component for drain-bulk junction	Volt	4.0

Table 27: Level 69 PSP 103.1 MOSFET Local Model JUNCAP2 Drain-Bulk JUNCAP Express Parameters

Model Parameter	Description	Unit	Default
VJUNREFD	Typical maximum drain-bulk junction voltage; usually about 2 x V_{sup}	Volt	2.5
FJUNQD	Fraction below which drain-bulk junction capacitance components are neglected	Volt	0.03

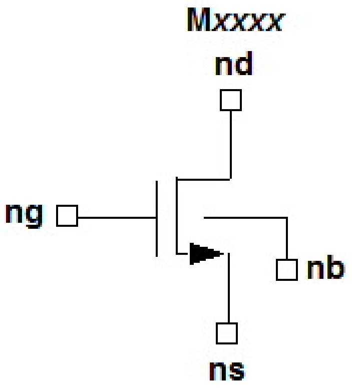
Table 28: Level 69 PSP 103.1 MOSFET Local Model Parasitic Resistance Parameters

Model Parameter	Description	Unit	Default
RG	Gate resistance R_{gate}	Ohm	0.0
RSE	External source resistance	Ohm	0
RDE	External drain resistance	Ohm	0
RBULK	Bulk resistance R_{bulk}	Ohm	0.0
RWELL	Well resistance R_{well}	Ohm	0.0
RJUNS	Source-side bulk resistance R_{juns}	Ohm	0.0
RJUND	Drain-side bulk resistance R_{jund}	Ohm	0.0

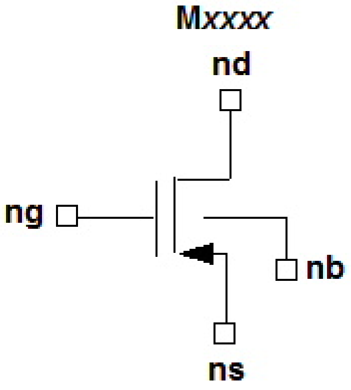
Table 29: Level 69 PSP 103.1 MOSFET Local Model NQS Parameters

Model Parameter	Description	Unit	Default
SWNQS	Switch for NQS effects 0 = off 1,2,3,5, or 9 = number of collocation points	None	0
MUNQS	Relative mobility for NQS modeling	None	1.0

MOSFET Instance, PSP 103.1 Geometric Model (Level 69)



NMOS



PMOS

PSP 103.1 Geometric Model MOSFET Instance Netlist Syntax

The syntax for a Level 69 PSP 103.1 geometric model MOSFET instance is:

```
Mxxxx nd ng ns nb modelname
[L=length] [W=width]
[ABSOURCE=val] [LSSOURCE=val] [LGSOURCE=val]
[ABDRAIN=val] [LSDRAIN=val] [LGDRAIN=val]
[SA=val] [SB=val] [SC=val] [SD=val]
[SCA=val] [SCB=val][SCC=val] [NRS=val] [NRD=val]
[DELVTO=val] [FACTUO=val] [NGCON=val] [XGW=val]
[NF=val] [M=val] [MULT=val]
```

nd is the drain node, *ng* is the gate node, *ns* is the source node, and *nb* is the bulk or substrate node of the MOSFET. *modelname* is the name of a Level 69 PSP 103.1 MOSFET geometric model (with model parameter **SWGEO=1**) defined in a .MODEL statement elsewhere in the netlist.

Table 1: Level 69 PSP 103.1 Geometric Model MOSFET Instance Parameters

Instance Parameter	Description	Unit	Default
L	Drawn channel length	Meter	1.0e-6
W	Drawn channel width (total width)	Meter	1.0e-6
ABDRAIN (AD)	Drain junction area	Meter 2	1.0e-12
ABSOURCE (AS)	Source junction area	Meter 2	1.0e-12

LGDRAIN	Gate-edge part of drain junction perimeter	Meter	1.0e-6
LGSOURCE	Gate-edge part of source junction perimeter	Meter	1.0e-6
LSDRAIN (PD)	STI-edge part of drain junction perimeter	Meter	1.0e-6
LSSOURCE (PS)	STI-edge part of source junction perimeter	Meter	1.0e-6
DELVTO	Threshold voltage shift factor	V	0.0
FACTUO	Zero-field mobility pre-factor	None	1
SA	Distance between OD-edge and poly at source side	Meter	0.0
SB	Distance between OD-edge and poly at drain side	Meter	0.0
SD	Distance betweeen neighboring fingers	Meter	0
SCA	Integral of the first distribution function for scattered well dopant	None	0
SCB	Integral of the second distribution function for scattered well dopant	None	0
SCC	Integral of the third distribution function for scattered well dopant	None	0
SC	Distance between OD-edge and nearest well edge	Meter	0.0
NRS	Number of squares of source diffusion	None	0
NRD	Number of squares of drain diffusion	None	0
NGCON	Number of gate contacts	None	1
XGW	Distance on the gate contact to the channel edge	Meter	1.0e-7
NF	Number of fingers; internally rounded to the nearest integer	None	1
M	Multiplier for multiple parallel transistors Total multiplier = M x MULT	None	1.0
MULT	Multiplier for multiple parallel transistors Total multiplier = M x MULT	None	1.0

PSP 103.1 MOSFET Geometric Model (Level 69, SWGEO=1)

The syntax for a Level 69 PSP103.1 geometric model MOSFET model is:

```
.MODELmodelname NMOS LEVEL=69 SWGEO=1

+ [(][parameter=val] ... [)]
```

or

```
.MODELmodelname PMOS LEVEL=69 SWGEO=1

+ [(][parameter=val] ... [)]
```

modelname is the name used by MOSFET instances to refer to this .MODEL statement. The **LEVEL=69** entry (plus the model parameter **SWGEO=1**) selects the PSP 103.1 MOSFET global model.

Table 1: Level 69 PSP 103.1 MOSFET Geometric Model Selector Parameters

Model Parameter	Description	Unit	Default
LEVEL	69 is required to select the PSP 103.1 MOSFET model. The instance parameters **GEOMOD=1** and **BINMOD=0** select the global model over the local and binned models.	None	1 (default if LEVEL parameter is omitted)
SWGEO	Selector for model: 0=local, 1=geometric, 2=binning	None	1 is required to select the geometric model
SWNUD	Switch for nonuniform doping model. 0=off. 1=calculate surface potential; NUD model does not affect CV, avoids non-reciprocal capacitances. 2=skip extra surface potential calculation, may result in non-reciprocal capacitances	None	0
SWDELVTAC	Switch for V_{TH} charge adjustment model 0=off, 1=on	None	0
TR (**TREF**, **TNOM**)	Reference temperature	°C	21.0
SWIGATE	Flag for gate current (0 = off)	None	0
SWIMPACT	Flag for impact ionization current (0 = off)	None	0
SWGIDL	Flag for GIDL/GISL current (0 = off)	None	0
SWJUNCAP	Flag for JUNCAP model (0 = off, 1, 2, 3)	None	0
SWJUNASYM	Flag for asymmetric junctions (0=off)	None	0
QMC	Quantum-mechanical correction factor	None	1

Table 2: Level 69 PSP 103.1 MOSFET Geometric Model Process Parameters

Model Parameter	Description	Unit	Default
LVARO	Geometry-independent difference between actual and programmed polysilicon gate length	Meter	0.0
LVARL	Length dependence of difference between actual and programmed polysilicon gate length	None	0.0
LVARW	Width dependence of difference between actual and programmed polysilicon gate length	None	0.0
LAP	Effective channel length reduction per side due to lateral diffusion of channel-stop dopant ions	Meter	0.0
WVARO	Geometry-independent difference between actual and programmed field-oxide opening	Meter	0.0
WVARL	Length dependence of difference between actual and programmed field-oxide opening	None	0.0
WVARW	Width dependence of difference between actual and programmed field-oxide opening	None	0.0
WOT	Effective channel width reduction per side due to lateral diffusion of channel-stop dopant ions	Meter	0.0
DLQ	Effective channel length offset for CV	Meter	0.0
DWQ	Effective channel width offset for CV	Meter	0.0
VFBO	Geometry-independent flat-band voltage at reference temperature	Volt	-1.0
VFBL	Length dependence of flat-band voltage	None	0.0
VFBW	Width dependence of flat-band voltage	None	0.0
VFBLW	Area dependence of flat-band voltage	None	0.0
STVFBO	Geometry-independent temperature dependence of flat-band voltage	Volt/°K	5.0e-4
STVFBL	Length dependence of temperature dependence of flat-band voltage	None	0.0
STVFBW	Width dependence of temperature dependence of flat-band voltage	None	0.0
STVFBLW	Area dependence of temperature dependence of flat-band voltage	None	0.0
TOXO	Gate oxide thickness	Meter	2.0e-9
EPSROXO	Relative permittivity of gate dielectric	None	3.9

GFACNUDO	Geometry-independent part of GFACNUD	None	1
GFACNUDL	Length dependence of GFACNUD	None	0
GFACNUDLEXP	Exponent for GFACNUDL	None	1
GFACNUDW	Width dependence of GFACNUD	None	0
GFACNUDLW	Area dependence of GFACNUD	None	0
VSBNUDO	Geometry-independent part of VSBNUD	Volt	0
DVSBNUDO	Geometry-independent part of DVSBNUD	Volt	1
FACNEFFACO	Geometry-independent part of FACNEFFAC	None	1
FACNEFFACL	Length dependence of FACNEFFAC	None	0
FACNEFFACW	Width dependence of FACNEFFAC	None	0
FACNEFFACLW	Area dependence of FACNEFFAC	None	0
DELVTACO	Geometry-independent part of DELVTAC	Volt	0
DELVTACL	Length dependence of DELVTAC	Volt	0
DELVTACLEXP	Exponent of length dependence of DELVTAC	None	1
DELVTACW	Width dependence of DELVTAC	Volt	0
DELVTACLW	Area dependence of DELVTAC	Volt	0
NSUB0	Geometry-independent substrate doping	1/Meter^3	3.0e23
NSUBW	Width dependence of substrate doping due to segregation	None	0.0
WSEG	Characteristic width of segregation of substrate doping	Meter	1.0e-8
NPCK	Pocket doping level	1/Meter^3	1.0e24
NPCKW	Width dependence of pocket doping due to segregation	None	0.0
WSEGP	Characteristic length for segregation of pocket doping	Meter	1.0e-8
LPCK	Characteristic length for lateral doping profile	Meter	1.0e-8
LPCKW	Width dependence of LPCK due to segregation	None	0.0
FOL1	First-order length dependence of short channel body-effect	None	0
FOL2	Second-order length dependence of short channel body-effect	None	0
VNSUBO	Effective doping bias-dependence parameter	Volt	0.0

NSLPO	Effective doping bias-dependence parameter	Volt	0.05
DNSUBO	Effective doping bias-dependence parameter	1/Volt	0.0
DPHIBO	Geometry-independent offset of PHIB	Volt	0.0
DPHIBL	Length dependence DPHIB	Volt	0.0
DPHIBLEXP	Exponent for length dependence of DPHIB	None	1
DPHIBW	Width dependence of DPHIB	None	0
DPHIBLW	Area dependence of DPHIB	None	0
NPO	Geometry-independent gate polysilicon doping	1/Meter^3	1.0e26
NPL	Length dependence of gate polysilicon doping	None	0.0
CTO	Geometry-independent part of interface states factor CT	None	0.0
CTL	Length dependence of interface states factor CT	None	0.0
CTLEXP	Exponent describing length dependence of CT	None	1.0
CTW	Width dependence of CT	None	0.0
CTLW	Area dependence of CT	None	0.0
TOXOVO	Overlap oxide thickness	Meter	2.0e-9
TOXOVDO	Overlap oxide thickness for drain side	Meter	2.0e-9
LOV	Overlap length for overlap capacitance	Meter	0.0
LOVD	Overlap length for gate/drain overlap capacitance‘	Meter	0.0
NOVO	Effective doping of overlap region	1/Meter^3	5.0e25
NOVDO	Effective doping of overlap region for drain side	1/Meter^3	5.0e25

Table 3: Level 69 PSP 103.1 Geometric Model MOSFET DIBL Parameters

Model Parameter	**Description**	**Unit**	**Default**
CFL	Length dependence of DIBL factor CF	1/Volt	0.0
CFLEXP	Exponent describing length dependence of CF	None	0.0
CFW	Width dependence of CF	None	0.0
CFBO	Back-bias dependence of CF	1/Volt	0.0

Table 4: Level 69 PSP 103.1 Geometric Model MOSFET Mobility Parameters

Model Parameter	Description	Unit	Default
UO	Zero-field mobility at reference temperature	Meter ^{2} /Volt/Second	5.0e-2
FBET1	Relative mobility decrease due to first lateral profile	None	0.0
FBET1W	Width dependence of FBET1	None	0.0
LP1	Mobility related characteristic length of first lateral profile	Meter	1.0e-8
LP1W	Width dependence of LP1	None	0.0
FBET2	Relative mobility decrease due to second lateral profile	None	0.0
LP2	Mobility related characteristic length of second lateral profile	Meter	1.0e-8
BETW1	First higher-order width scaling coefficient of BETN	None	0.0
BETW2	Second higher-order width scaling coefficient of BETN	None	0.0
WBET	Characteristic width for width scaling of BETN	Meter	1.0e-9
STBETO	Geometry-independent temperature dependence of BETN	None	1.0
STBETL	Length dependence of temperature dependence of BETN	None	0.0
STBETW	Width dependence of temperature dependence of BETN	None	0.0
STBETLW	Area dependence of temperature dependence of BETN	None	0.0
MUEO	Geometry-independent mobility reduction coefficient MUE at reference temperature	Meter/Volt	0.5
MUEW	Width dependence of MUE	None	0.0
STMUEO	Temperature dependence of MUE	None	0.0
THEMUO	Mobility reduction exponent at reference temperature	None	1.5
STTHEMUO	Temperature dependence of mobility reduction exponent THEMU	None	1.5
CSO	Geometry-independent Coulomb scattering parameter CS at reference temperature	None	0.0
CSL	Length dependence of Coulomb scattering parameter CS	None	0.0

CSLEXP	Exponent for length dependence of CS	None	0
CSW	Width dependence of Coulomb scattering parameter CS	None	0.0
CSLW	Area dependence of Coulomb scattering parameter CS	None	0.0
STCSO	Temperature dependence of CS	None	0.0
XCORO	Geometry-independent non-universality parameter	1/Volt	0.0
XCORL	Length dependence of XCOR	None	0.0
XCORW	Width dependence of XCOR	None	0.0
XCORLW	Area dependence of XCOR	None	0.0
STXCORO	Temperature dependence of XCOR	None	0.0
FETAO	Effective field parameter	None	1.0

Table 5: Level 69 PSP 103.1 Geometric Model MOSFET Series Resistance Parameters

Model Parameter	**Description**	**Unit**	**Default**
RSW1	Source/drain series resistance for a channel width of W_{EN} at reference temperature	Ohm	2500.0
RSW2	Higher-order width scaling of source/drain series resistance		0.0
STRSO	Temperature dependence of source/drain series resistance	None	1.0
RSBO	Back-bias dependence of series resistance	1/Volt	0.0
RSGO	Gate-bias dependence of series resistance	1/Volt	0.0

Table 6: Level 69 PSP 103.1 Geometric Model MOSFET Velocity Saturation Parameters

Model Parameter	**Description**	**Unit**	**Default**
THESATO	Geometry-independent velocity saturation parameter at reference temperature	1/Volt	0.0
THESATL	Length dependence of THESAT	1/Volt	0.5
THESATLEXP	Exponent for length dependence of THESAT	None	1.0
THESATW	Width dependence of THESAT	None	0.0
THESATLW	Area dependence of THESAT	None	0.0

STTHESATO	Geometry-independent temperature dependence of THESAT	None	1.0
STTHESATL	Length dependence of STTHESAT	None	0.0
STTHESATW	Width dependence of STTHESAT	None	0.0
STTHESATLW	Area dependence of STTHESAT	None	0.0
THESATBO	Back-bias dependence ot THESAT	1/Volt	0.0
THESATGO	Gate-bias dependence of THESAT	1/Volt	0.0

Table 7: Level 69 PSP 103.1 Geometric Model MOSFET Saturation Voltage Parameters

Model Parameter	Description	Unit	Default
AXO	Geometry-independent linear/saturation transition parameter	None	18.0
AXL	Length dependence of AX	None	0.4

Table 8: Level 69 PSP 103.1 Geometric Model MOSFET Channel Length Modulation Parameters

Model Parameter	Description	Unit	Default
ALPL	Length dependence of CLM prefactor ALP	None	5.0e-4
ALPLEXP	Exponent for length dependence of ALP	None	1.0
ALPW	Width dependence of ALP	None	0.0
ALP1L1	Length dependence of CLM enhancement factor above threshold ALP1	Volt	0.0
ALP1LEXP	Exponent describing the length dependence of ALP1	None	0.5
ALP1L2	Second-order length dependence of ALP1	None	0.0
ALP1W	Width dependence of ALP1	None	0.0
ALP2L1	Geometry-independent CLM enhancement factor below threshold ALP2	Volt	0.0
ALP2LEXP	Exponent describing the length dependence of ALP2	None	0.5
ALP2L2	Second-order length dependence of ALP2	None	0.0
ALP2W	Width dependence of ALP2	None	0.0
VPO	CLM logarithmic dependence factor	Volt	0.05

Table 9: Level 69 PSP 103.1 Geometric Model MOSFET Impact Ionization Parameters

Model Parameter	Description	Unit	Default
A1O	Geometry-independent part of impact-ionization prefactor A1	None	1.0
A1L	Length dependence of A1	None	0.0
A1W	Width dependence of A1	None	0.0
A2O	Impact-ionization exponent at reference temperature	Volt	10.0
STA2O	Temperature dependence of A2	Volt	0.0
A3O	Geometry-independent saturation voltage dependence of impact ionization	None	1.0
A3L	Length dependence of A3	None	0.0
A3W	Width dependence of A3	None	0.0
A4O	Geometry-independent back-bias dependence of impact ionization	Volt 0.5	0.0
A4L	Length dependence of A4	None	0.0
A4W	Width dependence of A4	None	0.0

Table 10: Level 69 PSP 103.1 Geometric Model MOSFET Gate Current Parameters

Model Parameter	Description	Unit	Default
GCOO	Gate tunneling energy adjustment	None	0.0
IGINVLW	Gate channel current prefactor for a gate channel area of W_{EN} x L_{EN}		0.0
IGOVW	Gate overlap current prefactor for a channel width of W_{EN}		0.0
IGOVDW	Gate overlap current prefactor for a channel width of W_{EN} for drain side		0.0
STIGO	Temperature dependence of gate current	None	2.0
GC2O	Gate current slope factor	None	0.375
GC3O	Gate current curvature factor	None	0.063
CHIBO	Tunneling barrier height	Volt	3.1

Table 11: Level 69 PSP 103.1 Geometric Model MOSFET Gate-Induced Drain Leakage Parameters

Model Parameter	Description	Unit	Default
AGIDLW	Width dependence of GIDL prefactor	Ampere/Volt ^{3}	0.0
AGIDLDW	Width dependence of GIDL prefactor for drain side	Ampere/Volt ^{3}	0.0
BGIDLO	GIDL probability factor at reference temperature	Volt	41.0
BGIDLDO	GIDL probability factor at reference temperature for drain side	Volt	41.0
STBGIDLO	Temperature dependence of BGIDL	Volt/°K	0.0
STBGIDLDO	Temperature dependence of BGIDL for drain side	Volt/°K	0.0
CGIDLO	Back-bias dependence of GIDL	None	0.0
CGIDLDO	Back-bias dependence of GIDL for drain side	None	0.0

Table 12: Level 69 Geometric Model MOSFET Charge Model Parameters

Model Parameter	Description	Unit	Default
CGBOVL	Oxide capacitance for gate-bulk overlap for a channel length of L_{EN}	Farad	0.0
CFRW	Outer fringe capacitance for a channel width of W_{EN}	Farad	0.0
CFRDW	Outer fringe capacitance for a channel width of W_{EN} for drain side	Farad	0.0

Table 13: Level 69 PSP 103.1 Geometric Model MOSFET Noise Model Parameters

Model Parameter	Description	Unit	Default
FNTO	Thermal noise coefficient	None	1.0
NFALW	First coefficient of flicker noise for a channel area of W_{EN} x L_{EN}	1/Volt/Meter ^{4}	8.0e22
NFBLW	Second coefficient of flicker noise for a channel area of W_{EN} x L_{EN}	1/Volt/Meter ^{2}	3.0e7
NFCLW	Third coefficient of flicker noise for a channel area of	1/Volt	0.0

	W_{EN} x L_{EN}		
EFO	Flicker noise frequency exponent	None	1.0
LINTNOI	Length offset for flicker noise	Meter	0.0
ALPNOI	Exponent for LINTNOI	None	2.0

Table 14: Level 69 PSP 103.1 Geometric Model MOSFET Temperature Offset Parameter

Model Parameter	**Description**	**Unit**	**Default**
DTA	Temperature offset from ambient circuit temperature	°K	0.0

Table 15: Level 69 PSP 103.1 Geometric Model MOSFET Stress Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
SAREF	Reference distance between OD edge to poly from one side	Meter	1e-6
SBREF	Reference distance between OD edge to poly on the other side	Meter	1e-6
WLOD	Width parameter	Meter	0.0
KUO	Mobility degradation/enhancement coefficient	Meter	0.0
KVSAT	Saturation velocity degradation/enhancement parameter	Meter	0.0
TKUO	Temperature coefficient of KUO	None	0.0
LKUO	Length dependence of KUO	$Meter^{LLODKUO}$	0.0
WKUO	Width dependence of KUO	$Meter^{WLODKUO}$	0.0
PKUO	Cross-term dependence of KUO	$Meter^{LLODKUO+WLODKUO}$	0.0
LLODKUO	Length parameter for mobility stress effect	None	0.0
WLODKUO	Width parameter for mobility	None	0.0

	stress effect		
KVTHO	Threshold shift parameter	Volt-Meter	0.0
LKVTHO	Length dependence of KVTHO	Meter^{LLODVTH}	0.0
WKVTHO	Width dependence of KVTHO	Meter^{WLODVTH}	0.0
PKVTHO	Cross-term dependence of KVTHO	Meter$^{LLODVTH+WLODVTH}$	0.0
LLODVTH	Length parameter for threshold voltage stress effect	None	0.0
WLODVTH	Width parameter for threshold voltage stress effect	None	0.0
STETAO	ETAO shift factor related to threshold voltage change	Meter	0.0
LODETAO	ETAO shift modification factor	None	1.0

Table 16: Level 69 PSP 103.1 Geometric Model MOSFET Well Proximity Effect Parameters

Model Parameter	**Description**	**Unit**	**Default**
SCREF	Distance between OD-edge and well edge of a reference device	Meter	1.0e-6
WEB	Coefficient for SCB	None	0
WEC	Coefficient for SCC	None	0
KVTHOWEO	Geometry independent threshold shift parameter	None	0
KVTHOWEL	Length dependence of threshold shift parameter	None	0
KVTHOWEW	Width dependence of threshold shift parameter	None	0
KVTHOWELW	Area dependence of threshold shift parameter	None	0
KUOWEO	Geometry independent mobility degradation parameter	None	0
KUOWEL	Length dependence of mobility degradation parameter	None	0
KUOWEW	Width dependence of mobility degradation parameter	None	0
KUOWELW	Area dependence of mobility degradation parameter	None	0

Table 17: Level 69 PSP 103.1 Geometric Model MOSFET Source-Bulk and Drain-Bulk JUNCAP2 Model Parameters

Model Parameter	Description	Unit	Default
TRJ	Reference temperature	°C	21.0
SWJUNEXP	Flag for JUNCAP2 Express: 0=full JUNCAP2 model, 1=Express model (for both source-bulk and source-drain junctions)	None	0
IMAX	Maximum current up to which forward current behaves exponentially	Ampere	1000.0

Table 18: Level 69 PSP 103.1 MOSFET Geometric Model JUNCAP2 Source-Bulk Capacitance Parameters

Model Parameter	Description	Unit	Default
CJORBOT	Zero-bias capacitance per unit area of bottom component for source-bulk junction	Farad/Meter ^{2}	1.0e-3
CJORSTI	Zero-bias capacitance per unit length of STI-edge component for source-bulk junction	Farad/Meter	1.0e-9
CJORGAT	Zero-bias capacitance per unit length of gate-edge component for source-bulk junction	Farad/Meter	1.0e-9
VBIRBOT	Built-in voltage at the reference temperature of bottom component for source-bulk junction	Volt	1.0
VBIRSTI	Built-in voltage at the reference temperature of STI-edge component for source-bulk junction	Volt	1.0
VBIRGAT	Built-in voltage at the reference temperature of gate-edge component for source-bulk junction	Volt	1.0
PBOT	Grading coefficient of bottom component for source-bulk junction	None	0.5
PSTI	Grading coefficient of STI-edge component for source-bulk junction	None	0.5
PGAT	Grading coefficient of gate-edge component for source-bulk junction	None	0.5

Table 19: Level 69 PSP 103.1 MOSFET Geometric Model JUNCAP2 Source-Bulk Ideal Current Parameters

Model Parameter	Description	Unit	Default
PHIGBOT	Zero-temperature bandgap voltage of bottom component for source-bulk junction	Volt	1.16
PHIGSTI	Zero-temperature bandgap voltage of STI-edge component for source-bulk junction	Volt	1.16
PHIGGAT	Zero-temperature bandgap voltage of gate-edge component for source-bulk junction	Volt	1.16
IDSATRBOT	Saturation current density at the reference temperature of bottom component for source-bulk junction	Ampere/Meter ^{2}	1.0e-12
IDSATRSTI	Saturation current density at the reference temperature of STI-edge component for source-bulk junction	Ampere/Meter	1.0e-18
IDSATRGAT	Saturation current density at the reference temperature of gate-edge component for source-bulk junction	Ampere/Meter	1.0e-18
CSRHBOT	Shockley-Read-Hall prefactor of bottom component for source-bulk junction	Ampere/Meter ^{3}	1.0e2
CSRHSTI	Shockley-Read-Hall prefactor of STI-edge component for source-bulk junction	Ampere/Meter ^{2}	1.0e-4
CSRHGAT	Shockley-Read-Hall prefactor of gate-edge component for source-bulk junction	Ampere/Meter ^{2}	1.0e-4
XJUNSTI	Junction depth of STI-edge component for source-bulk junction	Meter	1.0e-7
XJUNGAT	Junction depth of gate-edge component for source-bulk junction	Meter	1.0e-7

Table 20: Level 69 PSP 103.1 MOSFET Geometric Model JUNCAP2 Source-Bulk Trap-Assisted Tunneling Parameters

Model Parameter	Description	Unit	Default
CTATBOT	Trap-assisted tunneling prefactor of bottom component for source-bulk junction	Ampere/Meter ^{3}	1.0e2
CTATSTI	Trap-assisted tunneling prefactor of STI-edge	Ampere/Meter	1.0e-4

	component for source-bulk junction	2	
CTATGAT	Trap-assisted tunneling prefactor of gate-edge component for source-bulk junction	Ampere/Meter 2	1.0e-4
MEFFTATBOT	Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for source-bulk junction	None	0.25
MEFFTATSTI	Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for source-bulk junction	None	0.25
MEFFTATGAT	Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for source-bulk junction	None	0.25

Table 21: Level 69 PSP 103.1 MOSFET Geometric Model JUNCAP2 Source-Bulk Band-to-Band Tunneling Parameters

Model Parameter	**Description**	**Unit**	**Default**
CBBTBOT	Band-to-band tunneling prefactor of bottom component for source-bulk junction	Ampere/Volt 3	1.0e-12
CBBTSTI	Band-to-band tunneling prefactor of STI-edge component for source-bulk junction	Ampere-Meter/Volt^3	1.0e-18
CBBTGAT	Band-to-band tunneling prefactor of gate-edge component for source-bulk junction	Ampere-Meter/Volt^3	1.0e-18
FBBTRBOT	Normalization field at the reference temperature for band-to-band tunneling prefactor of bottom component for source-bulk junction	Volt/Meter	1.0e9
FBBTRSTI	Normalization field at the reference temperature for band-to-band tunneling prefactor of STI-edge component for source-bulk junction	Volt/Meter	1.0e9
FBBTRGAT	Normalization field at the reference temperature for band-to-band tunneling prefactor of gate-edge component for source-bulk junction	Volt/Meter	1.0e9
STFBBTBOT	Temperature scaling parameter for band-to-band tunneling prefactor of bottom component for source-bulk junction	1/°K	-1.0e-3
STFBBTSTI	Temperature scaling parameter for band-to-band tunneling prefactor of STI-edge component for source-bulk junction	1/°K	-1.0e-3

STFBBTGAT	Temperature scaling parameter for band-to-band tunneling prefactor of gate-edge component for source-bulk junction	1/°K	-1.0e-3

Table 22: Level 69 PSP 103.1 MOSFET Geometric Model JUNCAP2 Source-Bulk Avalanche and Breakdown Parameters

Model Parameter	Description	Unit	Default
VBRBOT	Breakdown voltage of bottom component for source-bulk junction	Volt	10.0
VBRSTI	Breakdown voltage of STI-edge component for source-bulk junction	Volt	10.0
VBRGAT	Breakdown voltage of gate-edge component for source-bulk junction	Volt	10.0
PBRBOT	Breakdown onset tuning parameter of bottom component for source-bulk junction	Volt	4.0
PBRSTI	Breakdown onset tuning parameter of STI-edge component for source-bulk junction	Volt	4.0
PBRGAT	Breakdown onset tuning parameter of gate-edge component for source-bulk junction	Volt	4.0

Table 23: Level 69 PSP 103.1 MOSFET Geometric Model JUNCAP2 Source-Bulk JUNCAP Express Parameters

Model Parameter	Description	Unit	Default
VJUNREF	Typical maximum source-bulk junction voltage; usually about 2 x V_{sup}	Volt	2.5
FJUNQ	Fraction below which source-bulk junction capacitance components are neglected	Volt	0.03

Table 24: Level 69 PSP 103.1 MOSFET Geometric Model JUNCAP2 Drain-Bulk Capacitance Parameters

Model Parameter	Description	Unit	Default

CJORBOTD	Zero-bias capacitance per unit area of bottom component for drain-bulk junction	Farad/Meter^{2}	1.0e-3
CJORSTID	Zero-bias capacitance per unit length of STI-edge component for drain-bulk junction	Farad/Meter	1.0e-9
CJORGATD	Zero-bias capacitance per unit length of gate-edge component for drain-bulk junction	Farad/Meter	1.0e-9
VBIRBOTD	Built-in voltage at the reference temperature of bottom component for drain-bulk junction	Volt	1.0
VBIRSTID	Built-in voltage at the reference temperature of STI-edge component for drain-bulk junction	Volt	1.0
VBIRGATD	Built-in voltage at the reference temperature of gate-edge component for drain-bulk junction	Volt	1.0
PBOTD	Grading coefficient of bottom component for drain-bulk junction	None	0.5
PSTID	Grading coefficient of STI-edge component for drain-bulk junction	None	0.5
PGATD	Grading coefficient of gate-edge component for drain-bulk junction	None	0.5

Table 25: Level 69 PSP 103.1 MOSFET Geometric Model JUNCAP2 Drain-Bulk Ideal Current Parameters

Model Parameter	**Description**	**Unit**	**Default**
PHIGBOTD	Zero-temperature bandgap voltage of bottom component for drain-bulk junction	Volt	1.16
PHIGSTID	Zero-temperature bandgap voltage of STI-edge component for drain-bulk junction	Volt	1.16
PHIGGATD	Zero-temperature bandgap voltage of gate-edge component for drain-bulk junction	Volt	1.16
IDSATRBOTD	Saturation current density at the reference temperature of bottom component for drain-bulk junction	Ampere/Meter^{2}	1.0e-12
IDSATRSTID	Saturation current density at the reference temperature of STI-edge component for drain-bulk junction	Ampere/Meter	1.0e-18
IDSATRGATD	Saturation current density at the reference	Ampere/Meter	1.0e-18

	temperature of gate-edge component for drain-bulk junction		
CSRHBOTD	Shockley-Read-Hall prefactor of bottom component for drain-bulk junction	Ampere/Meter^3	1.0e2
CSRHSTID	Shockley-Read-Hall prefactor of STI-edge component for drain-bulk junction	Ampere/Meter^2	1.0e-4
CSRHGATD	Shockley-Read-Hall prefactor of gate-edge component for drain-bulk junction	Ampere/Meter^2	1.0e-4
XJUNSTID	Junction depth of STI-edge component for drain-bulk junction	Meter	1.0e-7
XJUNGATD	Junction depth of gate-edge component for drain-bulk junction	Meter	1.0e-7

Table 26: Level 69 PSP 103.1 MOSFET Geometric Model JUNCAP2 Drain-Bulk Trap-Assisted Tunneling Parameters

Model Parameter	**Description**	**Unit**	**Default**
CTATBOTD	Trap-assisted tunneling prefactor of bottom component for drain-bulk junction	Ampere/Meter^3	1.0e2
CTATSTID	Trap-assisted tunneling prefactor of STI-edge component for drain-bulk junction	Ampere/Meter^2	1.0e-4
CTATGATD	Trap-assisted tunneling prefactor of gate-edge component for drain-bulk junction	Ampere/Meter^2	1.0e-4
MEFFTATBOTD	Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for drain-bulk junction	None	0.25
MEFFTATSTID	Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for drain-bulk junction	None	0.25
MEFFTATGATD	Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for drain-bulk junction	None	0.25

Table 27: Level 69 PSP 103.1 MOSFET Geometric Model JUNCAP2 Drain-Bulk Band-to-Band Tunneling Parameters

Model	**Description**	**Unit**	**Default**

Parameter			
CBBTBOTD	Band-to-band tunneling prefactor of bottom component for drain-bulk junction	Ampere/Volt^3	1.0e-12
CBBTSTID	Band-to-band tunneling prefactor of STI-edge component for drain-bulk junction	Ampere-Meter/Volt^3	1.0e-18
CBBTGATD	Band-to-band tunneling prefactor of gate-edge component for drain-bulk junction	Ampere-Meter/Volt^3	1.0e-18
FBBTRBOTD	Normalization field at the reference temperature for band-to-band tunneling prefactor of bottom component for drain-bulk junction	Volt/Meter	1.0e9
FBBTRSTID	Normalization field at the reference temperature for band-to-band tunneling prefactor of STI-edge component for drain-bulk junction	Volt/Meter	1.0e9
FBBTRGATD	Normalization field at the reference temperature for band-to-band tunneling prefactor of gate-edge component for drain-bulk junction	Volt/Meter	1.0e9
STFBBTBOTD	Temperature scaling parameter for band-to-band tunneling prefactor of bottom component for drain-bulk junction	1/°K	-1.0e-3
STFBBTSTID	Temperature scaling parameter for band-to-band tunneling prefactor of STI-edge component for drain-bulk junction	1/°K	-1.0e-3
STFBBTGATD	Temperature scaling parameter for band-to-band tunneling prefactor of gate-edge component for drain-bulk junction	1/°K	-1.0e-3

Table 28: Level 69 PSP 103.1 MOSFET Geometric Model JUNCAP2 Drain-Bulk Avalanche and Breakdown Parameters

Model Parameter	Description	Unit	Default
VBRBOTD	Breakdown voltage of bottom component for drain-bulk junction	Volt	10.0
VBRSTID	Breakdown voltage of STI-edge component for drain-bulk junction	Volt	10.0
VBRGATD	Breakdown voltage of gate-edge component for drain-bulk junction	Volt	10.0
PBRBOTD	Breakdown onset tuning parameter of bottom component for	Volt	4.0

	drain-bulk junction		
PBRSTID	Breakdown onset tuning parameter of STI-edge component for drain-bulk junction	Volt	4.0
PBRGATD	Breakdown onset tuning parameter of gate-edge component for drain-bulk junction	Volt	4.0

Table 29: Level 69 PSP 103.1 MOSFET Geometric Model JUNCAP2 Drain-Bulk JUNCAP Express Parameters

Model Parameter	Description	Unit	Default
VJUNREF	Typical maximum drain-bulk junction voltage; usually about 2xV_{sup}	Volt	2.5
FJUNQ	Fraction below which drain-bulk junction capacitance components are neglected	Volt	0.03

Table 30: Level 69 PSP 103.1 MOSFET Geometric Model Parasitic Resistance Parameters

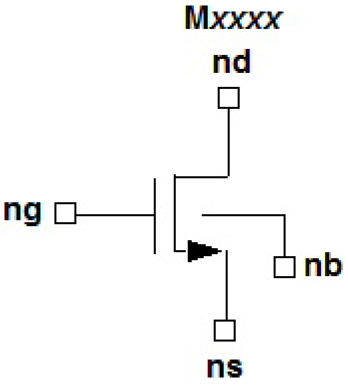
Model Parameter	Description	Unit	Default
RGO	Gate resistance R_{gate}	Ohm	0.0
RINT	Contact resistance between silicide and poly	Ohm/square	0
RVPOLY	Vertical poly resistance	Ohm/square	0
RSHG	Gate electrode diffusion sheet resistance	Ohm/square	0
DLSIL	Silicide extension over the physical gate length	Meter	0
RSH	Sheet resistance of source diffusion	Ohm/square	0
RSHD	Sheet resistance of drain diffusion	Ohm/square	0
RBULKO	Bulk resistance R_{bulk}	Ohm	0.0
RWELLO	Well resistance R_{well}	Ohm	0.0
RJUNSO	Source-side bulk resistance R_{juns}	Ohm	0.0
RJUNDO	Drain-side bulk resistance R_{jund}	Ohm	0.0

Table 31: Level 69 PSP 103.1 Geometric Model MOSFET NQS Parameters

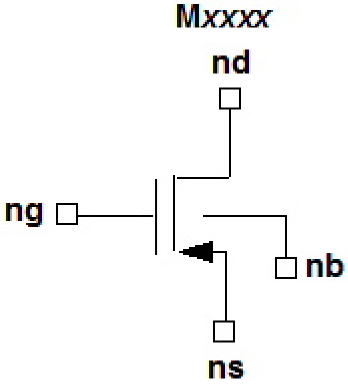
Model Parameter	Description	Unit	Default

SWNQS	Switch for NQS effects 0 = off 1,2,3,5, or 9 = number of collocation points	None	0
MUNQSO	Relative mobility for NQS modeling	None	1.0

MOSFET Instance, PSP 103.1 Binning Model (Level 69)



NMOS



PMOS

PSP 103.1 Binning Model MOSFET Instance Netlist Syntax

The syntax for a Level 69 PSP 103.1 binning model MOSFET instance is:

```
Mxxxx nd ng ns nb modelname
[L=length] [W=width]
[ABSOURCE=val] [LSSOURCE=val] [LGSOURCE=val]
[ABDRAIN=val] [LSDRAIN=val] [LGDRAIN=val]
[SA=val] [SB=val] [SC=val] [SD=val]
[SCA=val] [SCB=val][SCC=val] [NRS=val] [NRD=val]
[DELVTO=val] [FACTUO=val] [NGCON=val] [XGW=val]
[NF=val] [M=val] [MULT=val]
```

nd is the drain node, *ng* is the gate node, *ns* is the source node, and *nb* is the bulk or substrate node of the MOSFET. *modelname* is the name of a Level 69 PSP 103.1 MOSFET model (with model parameter **SWGEO=2**) defined in a .MODEL statement elsewhere in the netlist.

Table 1: Level 69 PSP 103.1 Binning Model MOSFET Instance Parameters

Instance Parameter	Description	Unit	Default
L	Drawn channel length	Meter	1.0e-6
W	Drawn channel width (total width)	Meter	1.0e-6
ABDRAIN (AD)	Drain junction area	Meter^2	1.0e-12
ABSOURCE (AS)	Source junction area	Meter^2	1.0e-12
LGDRAIN	Gate-edge part of drain junction perimeter	Meter	1.0e-6
LGSOURCE	Gate-edge part of source junction perimeter	Meter	1.0e-6
LSDRAIN (PD)	STI-edge part of drain junction perimeter	Meter	1.0e-6
LSSOURCE (PS)	STI-edge part of source junction perimeter	Meter	1.0e-6
DELVTO	Threshold voltage shift factor	Volt	0.0
FACTUO	Zero-field mobility pre-factor	None	1
SA	Distance between OD-edge and poly at source side	Meter	0.0
SB	Distance between OD-edge and poly at drain side	Meter	0.0
SD	Distance betweeen neighboring fingers	Meter	0
SCA	Integral of the first distribution function for scattered well dopant	None	0
SCB	Integral of the second distribution function for scattered well dopant	None	0
SCC	Integral of the third distribution function for scattered well dopant	None	0
SC	Distance between OD-edge and nearest well edge	Meter	0.0
NRS	Number of squares of source diffusion	None	0
NRD	Number of squares of drain diffusion	None	0
NGCON	Number of gate contacts	None	1
XGW	Distance on the gate contact to the channel edge	Meter	1.0e-7
NF	Number of fingers; internally rounded to the nearest integer	None	1
M	Multiplier for multiple parallel transistors	None	1.0

	Total multiplier = M x MULT		
MULT	Multiplier for multiple parallel transistors Total multiplier = M x MULT	None	1.0

PSP 103.1 MOSFET Binning Model (Level 69, SWGEO=2)

The syntax for a Level 69 PSP103.1 binning model MOSFET model is:

```
.MODELmodelname NMOS LEVEL=69 SWGEO=2

+ [(][parameter=val] ... [)]
```

or

```
.MODELmodelname PMOS LEVEL=69 SWGEO=2

+ [(][parameter=val] ... [)]
```

modelname is the name used by MOSFET instances to refer to this .MODEL statement. The **LEVEL=69** entry (plus the model parameter **SWGEO=2**) selects the PSP 103.1 MOSFET binning model.

Table 1: Level 69 PSP 103.1 MOSFET Binning Model Selector Parameters

Model Parameter	Description	Unit	Default
LEVEL	69 is required to select the PSP 103.1 MOSFET model. The instance parameter **BINMOD=1** selects the binning model.	None	1 (default if LEVEL parameter is omitted)
SWGEO	Selector for model: 0=local, 1=geometric, 2=binning	None	2 is required to select the binning model
SWNUD	Switch for nonuniform doping model. 0=off. 1=calculate surface potential; NUD model does not affect CV, avoids non-reciprocal capacitances. 2=skip extra surface potential calculation, may result in non-reciprocal capacitances	None	0
SWDELVTAC	Switch for V_{TH} charge adjustment model 0=off, 1=on	None	0

TR (**TREF**, **TNOM**)	Reference temperature	°C	21.0
SWIGATE	Flag for gate current (0 = off)	None	0
SWIMPACT	Flag for impact ionization current (0 = off)	None	0
SWGIDL	Flag for GIDL/GISL current (0 = off)	None	0
SWJUNCAP	Flag for JUNCAP model (0 = off; 2, 3, 4)	None	0
SWJUNASYM	Flag for asymmetric junctions (0 = off)	None	0
QMC	Quantum-mechanical correction factor	None	1

Table 2: Level 69 PSP 103.1 MOSFET Binning Model Labels

Model Parameter	Description	Unit	Default
LMIN	Dummy parameter to label binning set	Meter	0
LMAX	Dummy parameter to label binning set	Meter	1
WMIN	Dummy parameter to label binning set	Meter	0
WMAX	Dummy parameter to label binning set	Meter	1

Table 3: Level 69 PSP 103.1 MOSFET Binning Model Process Parameters

Model Parameter	Description	Unit	Default
LVARO	Geometry-independent difference between actual and programmed polysilicon gate length	Meter	0.0
LVARL	Length dependence of difference between actual and programmed polysilicon gate length	None	0.0
LAP	Effective channel length reduction per side due to lateral diffusion of channel-stop dopant ions	Meter	0.0
WVARO	Geometry-independent difference between actual and programmed field-oxide opening	Meter	0.0
WVARW	Width dependence of difference between actual and programmed field-oxide opening	None	0.0
WOT	Effective channel width reduction per side due to lateral diffusion of channel-stop dopant ions	Meter	0.0
DLQ	Effective channel length reduction for CV	Meter	0.0
DWQ	Effective channel width reduction for CV	Meter	0.0
POVFB	Coefficient for the geometry-independent part of flat-	Volt	-1.0

	band voltage at reference temperature		
PLVFB	Coefficient for length dependence of flat-band voltage at TR	Volt	0.0
PWVFB	Coefficient for width dependence of flat-band voltage at TR	Volt	0.0
PLWVFB	Coefficient for length times width dependence of flat-band voltage at TR	Volt	0.0
POSTVFB	Coefficient for geometry-independent temperature dependence of flat-band voltage	Volt/°K	5.0e-4
PLSTVFB	Coefficient for length dependence of temperature dependence of flat-band voltage	Volt/°K	0.0
PWSTVFB	Coefficient for width dependence of temperature dependence of flat-band voltage	Volt/°K	0.0
PLWSTVFB	Coefficient for length times width dependence of temperature dependence of flat-band voltage	Volt/°K	0.0
POTOX	Coefficient for geometry-independent part of gate oxide thickness	Meter	2.0e-9
POEPSROX	Coefficient for geometry-independent part of relative permittivity of gate dielectric	None	3.9
PONEFF	Coefficient for geometry-independent substrate doping	1/Meter 3	5.0e23
PLNEFF	Coefficient for length dependence of substrate doping	1/Meter 3	0.0
PWNEFF	Coefficient for width dependence of substrate doping	1/Meter 3	0.0
PLWNEFF	Coefficient for length times width dependence of substrate doping	1/Meter 3	0.0
POGFACNUD	Geometry-independent part of GFACNUD	None	1
PLGFACNUD	Length dependence of GFACNUD	None	0
PWGFACNUD	Width dependence of GFACNUD	None	0
PLWGFACNUD	Area dependence of GFACNUD	None	0
POVSBNUD	Geometry-independent part of VSBNUD	Volt	0
PODVSBNUD	Geometry-independent part of DVSBNUD	Volt	1
POFACNEFFAC	Geometry-independent part of FACNEFFAC	None	1
PLFACNEFFAC	Length dependence of FACNEFFAC	None	0
PWFACNEFFAC	Width dependence of FACNEFFAC	None	0

PLWFACNEFFAC	Area dependence of FACNEFFAC	None	0
PODELVTAC	Geometry-independent part of DELVTAC	Volt	0
PLDELVTAC	Length dependence of DELVTAC	Volt	0
PWDELVTAC	Width dependence of DELVTAC	Volt	0
PLWDELVTAC	Area dependence of DELVTAC	Volt	0
POVNSUB	Coefficient for the geometry-independent part of effective doping bias-dependence parameter	Volt	0.0
PONSLP	Coefficient for the geometry-independent part of effective doping bias-dependence parameter	Volt	0.05
PODNSUB	Coefficient for the geometry-independent part of effective doping bias-dependence parameter	1/Volt	0.0
PODPHIB	Coefficient for geometry-independent offset of PHIB	Volt	0.0
PLDPHIB	Coefficient for length dependence of DPHIB	Volt	0.0
PWDPHIB	Coefficient for width dependence of DPHIB	Volt	0.0
PLWDPHIB	Coefficient for length times width dependence of DPHIB	Volt	0.0
PONP	Coefficient for geometry-independent gate polysilicon doping	1/Meter 3	1.0e26
PLNP	Coefficient for length dependence of gate polysilicon doping	1/Meter 3	0.0
PWNP	Coefficient for width dependence of gate polysilicon doping	1/Meter 3	0.0
PLWNP	Coefficient for length times width dependence of gate polysilicon doping	1/Meter 3	0.0
POCT	Coefficient for geometry-independent part of interface states factor CT	None	0.0
PLCT	Coefficient for length dependence of interface states factor CT	None	0.0
PWCT	Coefficient for width dependence of CT	None	0.0
PLWCT	Coefficient for length times width dependence of CT	None	0.0
POTOXOV	Coefficient for the geometry-independent part of overlap oxide thickness	Meter	2.0e-9
POTOXOVD	Coefficient for the geometry-independent part of overlap oxide thickness for drain side	Meter	2.0e-9
PONOV	Coefficient for the geometry-independent part of	1/Meter 3	5.0e25

	effective doping of overlap region		
PLNOV	Coefficient for length dependence of effective doping of overlap region	1/Meter^3	0.0
PWNOV	Coefficient for width dependence of effective doping of overlap region	1/Meter^3	0.0
PLWNOV	Coefficient for length times width dependence of effective doping of overlap region	1/Meter^3	0.0
PONOVD	Coefficient for the geometry-independent part of effective doping of overlap region for drain side	1/Meter^3	5.0e25
PLNOVD	Coefficient for length dependence of effective doping of overlap region for drain side	1/Meter^3	0.0
PWNOVD	Coefficient for width dependence of effective doping of overlap region for drain side	1/Meter^3	0.0
PLWNOVD	Coefficient for length times width dependence of effective doping of overlap region for drain side	1/Meter^3	0.0

Table 4: Level 69 PSP 103.1 Binned Model MOSFET DIBL Parameters

Model Parameter	**Description**	**Unit**	**Default**
POCF	Coefficient for geometry-independent part of DIBL parameter CF	1/Volt	0.0
PLCF	Coefficient for length dependence of DIBL parameter	1/Volt	0.0
PWCF	Coefficient for width dependence of DIBL parameter	1/Volt	0.0
PLWCF	Coefficient for length times width dependence of DIBL parameter	1/Volt	0.0
POCFB	Coefficient for geometry-independent part of back-bias dependence of CF	1/Volt	0.0

Table 5: Level 69 PSP 102.1 Binned Model MOSFET Mobility Parameters

Model Parameter	**Description**	**Unit**	**Default**
POBETN	Coefficient for the geometry-independent part of product of channel aspect ratio and zero-field mobility at TR	Meter^2 /Volt/Second	0.07
PLBETN	Coefficient for the length dependence of product of	Meter	0.0

	channel aspect ratio and zero-field mobility at TR	^{2}/Volt/Second	
PWBETN	Coefficient for the width dependence of product of channel aspect ratio and zero-field mobility at TR	Meter^{2}/Volt/Second	0.0
PLWBETN	Coefficient for the width dependence of product of channel aspect ratio and zero-field mobility at TR	Meter^{2}/Volt/Second	0.0
POSTBET	Coefficient for the geometry-independent part of temperature dependence of BETN		1.0
PLSTBET	Coefficient for the length dependence of temperature dependence of BETN		0.0
PWSTBET	Coefficient for the width dependence of temperature dependence of BETN		0.0
PLWSTBET	Coefficient for the length times width dependence of temperature dependence of BETN		0.0
POMUE	Coefficient for the geometry-independent part of mobility reduction coefficient MUE at reference temperature	Meter/Volt	0.5
PLMUE	Coefficient for the length dependence of mobility reduction coefficient MUE at reference temperature	Meter/Volt	0.0
PWMUE	Coefficient for the width dependence of mobility reduction coefficient MUE at reference temperature	Meter/Volt	0.0
PLWMUE	Coefficient for the length times width dependence of mobility reduction coefficient MUE at reference temperature	Meter/Volt	0.0
POSTMUE	Coefficient for the geometry-independent part of temperature dependence of MUE	None	0.0
POTHEMU	Coefficient for the geometry-independent part of mobility reduction exponent at reference temperature	None	1.5
POSTTHEMU	Temperature dependence of mobility reduction exponent THEMU	None	1.5
POCS	Coefficient for the geometry-independent part of Coulomb scattering parameter CS at reference temperature	None	0.0
PLCS	Coefficient for the length dependence of Coulomb scattering parameter CS at TR	None	0.0
PWCS	Coefficient for the width dependence of Coulomb scattering parameter CS at TR	None	0.0

PLWCS	Coefficient for the length times width dependence of Coulomb scattering parameter CS at TR	None	0.0
POSTCS	Coefficient for the geometry-independent part of temperature dependence of CS	None	0.0
POXCOR	Coefficient for the geometry-independent part of non-universality parameter	1/Volt	0.0
PLXCOR	Coefficient for the length dependence of XCOR	1/Volt	0.0
PWXCOR	Coefficient for the width dependence of XCOR	1/Volt	0.0
PLWXCOR	Coefficient for the length times width dependence of XCOR	1/Volt	0.0
POSTXCOR	Coefficient for the geometry-independent part of temperature dependence of XCOR	None	0.0
POFETA	Coefficient for the geometry-independent part of effective field parameter	None	1.0

Table 6: Level 69 PSP 103.1 Binned Model MOSFET Series Resistance Parameters

Model Parameter	**Description**	**Unit**	**Default**
PORS	Coefficient for the geometry-independent part of source/drain series resistance at TR	Ohm	30.0
PLRS	Coefficient for the length dependence of RS	Ohm	0.0
PWRS	Coefficient for the width dependence of RS	Ohm	0.0
PLWRS	Coefficient for the length times width dependence of RS	Ohm	0.0
POSTRS	Coefficient for the geometry-independent part of temperature dependence of source/drain series resistance	None	1.0
PORSB	Coefficient for the geometry-independent part of back-bias dependence of series resistance	1/Volt	0.0
PORSG	Coefficient for the geometry-independent part of gate-bias dependence of series resistance	1/Volt	0.0

Table 7: Level 69 PSP 103.1 Binned Model MOSFET Velocity Saturation Parameters

Model Parameter	**Description**	**Unit**	**Default**
POTHESAT	Coefficient for the geometry-independent part of velocity	1/Volt	1.0

	saturation parameter at reference temperature		
PLTHESAT	Coefficient for the length dependence of velocity saturation parameter at reference temperature	1/Volt	0.0
PWTHESAT	Coefficient for the width dependence of velocity saturation parameter at reference temperature	1/Volt	0.0
PLWTHESAT	Coefficient for the length times width dependence of velocity saturation parameter at reference temperature	1/Volt	0.0
POSTTHESAT	Coefficient for the geometry-independent part of temperature dependence of THESAT	None	1.0
PLSTTHESAT	Coefficient for the length dependence of STTHESAT	None	0.0
PWSTTHESAT	Coefficient for the width dependence of STTHESAT	None	0.0
PLWSTTHESAT	Coefficient for the length times width dependence of STTHESAT	None	0.0
POTHESATB	Coefficient for the geometry-independent part of back-bias dependence ot THESAT	1/Volt	0.0
PLTHESATB	Coefficient for the length dependence of Back-bias dependence ot THESAT	1/Volt	0.0
PWTHESATB	Coefficient for the width dependence of back-bias dependence ot THESAT	1/Volt	0.0
PLWTHESATB	Coefficient for the length times width dependence of back-bias dependence ot THESAT	1/Volt	0.0
POTHESATG	Coefficient for the geometry-independent part of gate-bias dependence of THESAT	1/Volt	0.0
PLTHESATG	Coefficient for the length dependence of gate-bias dependence of THESAT	1/Volt	0.0
PWTHESATG	Coefficient for the width dependence of gate-bias dependence of THESAT	1/Volt	0.0
PLWTHESATG	Coefficient for the length times width dependence of gate-bias dependence of THESAT	1/Volt	0.0

Table 8: Level 69 PSP103.1 Binned Model MOSFET Saturation Voltage Parameters

Model Parameter	Description	Unit	Default
POAX	Coefficient for the geometry-independent part of linear/saturation transition parameter AX	None	3.0

PLAX	Coefficient for the length dependence of AX	None	0.0
PWAX	Coefficient for the width dependence of AX	None	0.0
PLWAX	Coefficient for the length times width dependence of AX	None	0.0

Table 9: Level 69 PSP 103.1 Binned Model MOSFET CLM Parameters

Model Parameter	Description	Unit	Default
POALP	Coefficient for the geometry-independent part of CLM prefactor ALP	None	0.01
PLALP	Coefficient for the length dependence of CLM prefactor ALP	None	0.0
PWALP	Coefficient for the width dependence of ALP	None	0.0
PLWALP	Coefficient for the length times width dependence of ALP	None	0.0
POALP1	Coefficient for the geometry-independent part of CLM enhancement factor above threshold ALP1	Volt	0.0
PLALP1	Coefficient for the length dependence of CLM enhancement factor above threshold ALP1	Volt	0.0
PWALP1	Coefficient for the width dependence of CLM enhancement factor above threshold ALP1	Volt	0.0
PLWALP1	Coefficient for the length times width dependence of CLM enhancement factor above threshold ALP1	Volt	0.0
POALP2	Coefficient for the geometry-independent part of CLM enhancement factor below threshold ALP2	1/Volt	0.0
PLALP2	Coefficient for the length dependence of CLM enhancement factor below threshold ALP2	1/Volt	0.0
PWALP2	Coefficient for the width dependence of CLM enhancement factor below threshold ALP2	1/Volt	0.0
PLWALP2	Coefficient for the length times width dependence of CLM enhancement factor below threshold ALP2	1/Volt	0.0
POVP	Coefficient for the geometry-independent part of CLM logarithmic dependence factor	Volt	0.05

Table 10: Level 69 PSP 103.1 Binned Model MOSFET Impact Ionization Parameters

Model Parameter	Description	Unit	Default

POA1	Coefficient for the geometry-independent part of impact-ionization prefactor A1	None	1.0
PLA1	Coefficient for the length dependence of A1	None	0.0
PWA1	Coefficient for the width dependence of A1	None	0.0
PLWA1	Coefficient for the length times width dependence of A1	None	0.0
POA2	Coefficient for the geometry-independent part of impact-ionization exponent at reference temperature	Volt	10.0
POSTA2	Coefficient for the geometry-independent part of temperature dependence of A2	Volt	0.0
POA3	Coefficient for the geometry-independent part of saturation voltage dependence of impact ionization	None	1.0
PLA3	Coefficient for the length dependence of A3	None	0.0
PWA3	Coefficient for the width dependence of A3	None	0.0
PLWA3	Coefficient for the length times width dependence of A3	None	0.0
POA4	Coefficient for the geometry-independent part of back-bias dependence of impact ionization	$1/\text{Volt}^{0.5}$	0.0
PLA4	Coefficient for the length dependence of A4	$1/\text{Volt}^{0.5}$	0.0
PWA4	Coefficient for the width dependence of A4	$1/\text{Volt}^{0.5}$	0.0
PLWA4	Coefficient for the length times width dependence of A4	$1/\text{Volt}^{0.5}$	0.0

Table 11: Level 69 PSP 103.1 Binned Model MOSFET Gate Current Parameters

Model Parameter	**Description**	**Unit**	**Default**
POGCO	Coefficient for the geometry-independent part of gate tunneling energy adjustment	None	0.0
POIGINV	Coefficient for the geometry-independent part of gate channel current prefactor	Ampere	0.0
PLIGINV	Coefficient for the length dependence of channel current prefactor	Ampere	0.0
PWIGINV	Coefficient for the width dependence of channel current prefactor	Ampere	0.0
PLWIGINV	Coefficient for the length times width dependence of	Ampere	0.0

	channel current prefactor		
POIGOV	Coefficient for the geometry-independent part of gate overlap current prefactor	Ampere	0.0
PLIGOV	Coefficient for the length dependence of gate overlap current prefactor	Ampere	0.0
PWIGOV	Coefficient for the width dependence of gate overlap current prefactor	Ampere	0.0
PLWIGOV	Coefficient for the length times width dependence of gate overlap current prefactor	Ampere	0.0
POSTIG	Coefficient for the geometry-independent part of temperature dependence of gate current	None	2.0
POGC2	Coefficient for the geometry-independent part of gate current slope factor	None	0.375
POGC3	Coefficient for the geometry-independent part of gate current curvature factor	None	0.063
POCHIB	Coefficient for the geometry-independent part of tunneling barrier height	Volt	3.1

Table 12: Level 69 PSP 103.1 Binned Model MOSFET GIDL Parameters

Model Parameter	**Description**	**Unit**	**Default**
POAGIDL	Coefficient for the geometry-independent part ofGIDL prefactor	Ampere/Volt ^{3}	0.0
PLAGIDL	Coefficient for the length dependence of GIDL prefactor	Ampere/Volt ^{3}	0.0
PWAGIDL	Coefficient for the width dependence of GIDL prefactor	Ampere/Volt ^{3}	0.0
PLWAGIDL	Coefficient for the length times width dependence of GIDL prefactor	Ampere/Volt ^{3}	0.0
POAGIDLD	Coefficient for the geometry-independent part of GIDL prefactor for the drain side	Ampere/Volt ^{3}	0.0
PLAGIDLD	Coefficient for the length dependence of GIDL prefactor for the drain side	Ampere/Volt ^{3}	0.0
PWAGIDLD	Coefficient for the width dependence of GIDL prefactor for the drain side	Ampere/Volt ^{3}	0.0
PLWAGIDLD	Coefficient for the length times width dependence of	Ampere/Volt	0.0

	GIDL prefactor for the drain side	3	
POBGIDL	Coefficient for the geometry-independent part of GIDL probability factor at reference temperature	Volt	41.0
POBGIDLD	Coefficient for the geometry-independent part of GIDL probability factor at reference temperature for the drain side	Volt	41.0
POSTBGIDL	Coefficient for the geometry-independent part of temperature dependence of BGIDL	Volt/°K	0.0
POSTBGIDLD	Coefficient for the geometry-independent part of temperature dependence of BGIDL for the drain side	Volt/°K	0.0
POCGIDL	Coefficient for the geometry-independent part of back-bias dependence of GIDL	None	0.0
POCGIDLD	Coefficient for the geometry-independent part of back-bias dependence of GIDL for the drain side	None	0.0

Table 13: Level 69 PSP 103.1 Binned Model MOSFET Charge Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
POCOX	Coefficient for the geometry-independent part of oxide capacitance for intrinsic channel	Farad	1e-14
PLCOX	Coefficient for the length dependence of oxide capacitance for intrinsic channel	Farad	0.0
PWCOX	Coefficient for the width dependence of oxide capacitance for intrinsic channel	Farad	0.0
PLWCOX	Coefficient for the length times width dependence of oxide capacitance for intrinsic channel	Farad	0.0
POCGOV	Coefficient for the geometry-independent part of oxide capacitance for gate/drain/source overlap	Farad	1e-15
PLCGOV	Coefficient for the length dependence of oxide capacitance for gate/drain/source overlap	None	0.0
PWCGOV	Coefficient for the width dependence of oxide capacitance for gate/drain/source overlap	None	0.0
PLWCGOV	Coefficient for the length times width dependence of oxide capacitance for gate/drain/source overlap	None	0.0
POCGOVD	Coefficient for the geometry-independent part of oxide capacitance for gate/drain/source overlap for drain side	Farad	1e-15

PLCGOVD	Coefficient for the length dependence of oxide capacitance for gate/drain/source overlap for drain side	None	0.0
PWCGOVD	Coefficient for the width dependence of oxide capacitance for gate/drain/source overlap for drain side	None	0.0
PLWCGOVD	Coefficient for the length times width dependence of oxide capacitance for gate/drain/source overlap for drain side	None	0.0
POCGBOV	Coefficient for the geometry-independent part of oxide capacitance for gate-bulk overlap	Farad	0.0
PLCGBOV	Coefficient for the length dependence of CGBOV	Farad	0.0
PWCGBOV	Coefficient for the width dependence of CGBOV	Farad	0.0
PLWCGBOV	Coefficient for the length times width dependence of CGBOV	Farad	0.0
POCFR	Coefficient for the geometry-independent part of outer fringe capacitance	Farad	0.0
PLCFR	Coefficient for the length dependence of CFR	Farad	0.0
PWCFR	Coefficient for the width dependence of CFR	Farad	0.0
PLWCFR	Coefficient for the length times width dependence of CFR	Farad	0.0
POCFRD	Coefficient for the geometry-independent part of outer fringe capacitance for drain side	Farad	0.0
PLCFRD	Coefficient for the length dependence of CFR for drain side	Farad	0.0
PWCFRD	Coefficient for the width dependence of CFR for drain side	Farad	0.0
PLWCFRD	Coefficient for the length times width dependence of CFR for drain side	Farad	0.0

Table 14: Level 69 PSP 103.1 Binned Model MOSFET Noise Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
POFNT	Coefficient for the geometry-independent part of thermal noise coefficient	None	1.0
PONFA	Coefficient for the geometry-independent part of first coefficient of flicker noise	Volt^{-1}/Meter^{4}	8.0e22
PLNFA	Coefficient for the length dependence of NFA	Volt^{-1}/Meter^{4}	0.0
PWNFA	Coefficient for the width dependence of NFA	Volt^{-1}/Meter^{4}	0.0
PLWNFA	Coefficient for the length times width dependence of NFA	Volt^{-}	0.0

		^{1}/Meter^4	
PONFB	Coefficient for the geometry-independent part of second coefficient of flicker noise	Volt^{-1}/Meter^2	3.0e7
PLNFB	Coefficient for the length dependence of NFB	Volt^{-1}/Meter^2	0.0
PWNFB	Coefficient for the width dependence of NFB	Volt^{-1}/Meter^2	0.0
PLWNFB	Coefficient for the length times width dependence of NFB	Volt^{-1}/Meter^2	0.0
PONFC	Coefficient for the geometry-independent part of third coefficient of flicker noise	1/Volt	0.0
PLNFC	Coefficient for the length dependence of NFC	1/Volt	0.0
PWNFC	Coefficient for the width dependence of NFC	1/Volt	0.0
PLWNFC	Coefficient for the length times width dependence of NFC	1/Volt	0.0
POEF	Coefficient for the geometry-independent part of flicker noise frequency exponent	None	1.0

Table 15: Level 69 PSP 103.1 Binned Model MOSFET Temperature Offset Parameters

Model Parameter	**Description**	**Unit**	**Default**
DTA	Temperature offset from ambient circuit temperature	°K	0.0

Table 16: Level 69 PSP 103.1 Binned Model MOSFET Stress Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
SAREF	Reference distance between OD edge to poly from one side	Meter	1e-6
SBREF	Reference distance between OD edge to poly on the other side	Meter	1e-6
WLOD	Width parameter	Meter	0.0
KUO	Mobility degradation/enhancement coefficient	Meter	0.0
KVSAT	Saturation velocity degradation/enhancement parameter	Meter	0.0
TKUO	Temperature coefficient of KUO	None	0.0

LKUO	Length dependency of KUO	Meter^{LLODKUO}	0.0
WKUO	Width dependency of KUO	Meter^{WLODKUO}	0.0
PKUO	Cross-term dependency of KUO	Meter$^{LLODKUO+WLODKUO}$	0.0
LLODKUO	Length parameter for mobility stress effect	None	0.0
WLODKUO	Width parameter for mobility stress effect	None	0.0
KVTHO	Threshold shift parameter	Volt-Meter	0.0
LKVTHO	Length dependency of KVTHO	Meter^{LLODVTH}	0.0
WKVTHO	Width dependency of KVTHO	Meter^{WLODVTH}	0.0
PKVTHO	Cross-term dependency of KVTHO	Meter$^{LLODVTH+WLODVTH}$	0.0
LLODVTH	Length parameter for threshold voltage stress effect	None	0.0
WLODVTH	Width parameter for threshold voltage stress effect	None	0.0
STETAO	ETAO shift factor related to threshold voltage change	Meter	0.0
LODETAO	ETAO shift modification factor	None	1.0

Table 17: Level 69 PSP 103.1 Binned Model MOSFET Well Proximity Effect Parameters

Model Parameter	**Description**	**Unit**	**Default**
SCREF	Distance between OD-edge and well edge of a reference device	Meter	1.0e-6
WEB	Coefficient for SCB	None	0
WEC	Coefficient for SCC	None	0
POKVTHOWE	Coefficient for the geometry-independent part of threshold shift parameter	None	0
PLKVTHOWE	Coefficient for the length dependence of threshold shift parameter	None	0
PWKVTHOWE	Coefficient for the width dependence of threshold shift parameter	None	0
PLWKVTHOWE	Coefficient for the length times width dependence of threshold shift parameter	None	0

POKUOWE	Coefficient for the geometry-independent part of mobility degradation parameter	None	0
PLKUOWE	Coefficient for the length dependence of mobility degradation parameter	None	0
PWKUOWE	Coefficient for the width dependence of mobility degradation parameter	None	0
PLWKUOWE	Coefficient for the length times width dependence of mobility degradation parameter	None	0

Table 18: Level 69 PSP 103.1 MOSFET Binned Model Basic JUNCAP2 Parameters

Model Parameter	Description	Unit	Default
TRJ	Reference temperature (for both source-bulk and source-drain junctions)	°C	21.0
SWJUNEXP	Flag for JUNCAP2 Express: 0=full JUNCAP2 model, 1=Express model (for both source-bulk and source-drain junctions)	None	0
IMAX	Maximum current up to which forward current behaves exponentially (for both source-bulk and source-drain junctions)	Ampere	1000.0

Table 19: Level 69 PSP 103.1 MOSFET Binned Model JUNCAP2 Source-Bulk Capacitance Parameters

Model Parameter	Description	Unit	Default
CJORBOT	Zero-bias capacitance per unit area of bottom component for source-bulk junction	Farad/Meter 2	1.0e-3
CJORSTI	Zero-bias capacitance per unit length of STI-edge component for source-bulk junction	Farad/Meter	1.0e-9
CJORGAT	Zero-bias capacitance per unit length of gate-edge component for source-bulk junction	Farad/Meter	1.0e-9
VBIRBOT	Built-in voltage at the reference temperature of bottom component for source-bulk junction	Volt	1.0
VBIRSTI	Built-in voltage at the reference temperature of STI-edge component for source-bulk junction	Volt	1.0

VBIRGAT	Built-in voltage at the reference temperature of gate-edge component for source-bulk junction	Volt	1.0
PBOT	Grading coefficient of bottom component for source-bulk junction	None	0.5
PSTI	Grading coefficient of STI-edge component for source-bulk junction	None	0.5
PGAT	Grading coefficient of gate-edge component for source-bulk junction	None	0.5

Table 20: Level 69 PSP 103.1 MOSFET Binned Model JUNCAP2 Source-Bulk Ideal Current Parameters

Model Parameter	**Description**	**Unit**	**Default**
PHIGBOT	Zero-temperature bandgap voltage of bottom component for source-bulk junction	Volt	1.16
PHIGSTI	Zero-temperature bandgap voltage of STI-edge component for source-bulk junction	Volt	1.16
PHIGGAT	Zero-temperature bandgap voltage of gate-edge component for source-bulk junction	Volt	1.16
IDSATRBOT	Saturation current density at the reference temperature of bottom component for source-bulk junction	Ampere/Meter^2	1.0e-12
IDSATRSTI	Saturation current density at the reference temperature of STI-edge component for source-bulk junction	Ampere/Meter	1.0e-18
IDSATRGAT	Saturation current density at the reference temperature of gate-edge component for source-bulk junction	Ampere/Meter	1.0e-18
CSRHBOT	Shockley-Read-Hall prefactor of bottom component for source-bulk junction	Ampere/Meter^3	1.0e2
CSRHSTI	Shockley-Read-Hall prefactor of STI-edge component for source-bulk junction	Ampere/Meter^2	1.0e-4
CSRHGAT	Shockley-Read-Hall prefactor of gate-edge component for source-bulk junction	Ampere/Meter^2	1.0e-4
XJUNSTI	Junction depth of STI-edge component for source-bulk junction	Meter	1.0e-7

XJUNGAT	Junction depth of gate-edge component for source-bulk junction	Meter	1.0e-7

Table 21: Level 69 PSP 103.1 MOSFET Binned Model JUNCAP2 Source-Bulk Trap-Assisted Tunneling Parameters

Model Parameter	Description	Unit	Default
CTATBOT	Trap-assisted tunneling prefactor of bottom component for source-bulk junction	Ampere/Meter ^{3}	1.0e2
CTATSTI	Trap-assisted tunneling prefactor of STI-edge component for source-bulk junction	Ampere/Meter ^{2}	1.0e-4
CTATGAT	Trap-assisted tunneling prefactor of gate-edge component for source-bulk junction	Ampere/Meter ^{2}	1.0e-4
MEFFTATBOT	Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for source-bulk junction	None	0.25
MEFFTATSTI	Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for source-bulk junction	None	0.25
MEFFTATGAT	Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for source-bulk junction	None	0.25

Table 22: Level 69 PSP 103.1 MOSFET Binned Model JUNCAP2 Source-Bulk Band-to-Band Tunneling Parameters

Model Parameter	Description	Unit	Default
CBBTBOT	Band-to-band tunneling prefactor of bottom component for source-bulk junction	Ampere/Volt ^{3}	1.0e-12
CBBTSTI	Band-to-band tunneling prefactor of STI-edge component for source-bulk junction	Ampere-Meter/Volt^3	1.0e-18
CBBTGAT	Band-to-band tunneling prefactor of gate-edge component for source-bulk junction	Ampere-Meter/Volt^3	1.0e-18
FBBTRBOT	Normalization field at the reference temperature for band-to-band tunneling prefactor of bottom component for source-bulk junction	Volt/Meter	1.0e9

FBBTRSTI	Normalization field at the reference temperature for band-to-band tunneling prefactor of STI-edge component for source-bulk junction	Volt/Meter	1.0e9
FBBTRGAT	Normalization field at the reference temperature for band-to-band tunneling prefactor of gate-edge component for source-bulk junction	Volt/Meter	1.0e9
STFBBTBOT	Temperature scaling parameter for band-to-band tunneling prefactor of bottom component for source-bulk junction	1/°K	-1.0e-3
STFBBTSTI	Temperature scaling parameter for band-to-band tunneling prefactor of STI-edge component for source-bulk junction	1/°K	-1.0e-3
STFBBTGAT	Temperature scaling parameter for band-to-band tunneling prefactor of gate-edge component for source-bulk junction	1/°K	-1.0e-3

Table 23: Level 69 PSP 103.1 MOSFET Binned Model JUNCAP2 Source-Bulk Avalanche and Breakdown Parameters

Model Parameter	Description	Unit	Default
VBRBOT	Breakdown voltage of bottom component for source-bulk junction	Volt	10.0
VBRSTI	Breakdown voltage of STI-edge component for source-bulk junction	Volt	10.0
VBRGAT	Breakdown voltage of gate-edge component for source-bulk junction	Volt	10.0
PBRBOT	Breakdown onset tuning parameter of bottom component for source-bulk junction	Volt	4.0
PBRSTI	Breakdown onset tuning parameter of STI-edge component for source-bulk junction	Volt	4.0
PBRGAT	Breakdown onset tuning parameter of gate-edge component for source-bulk junction	Volt	4.0

Table 24: Level 69 PSP 103.1 MOSFET Binned Model JUNCAP2 Source-Bulk JUNCAP Express Parameters

Model	Description	Unit	Default

Parameter			
VJUNREF	Typical maximum source-bulk junction voltage; usually about 2xV_{sup}	Volt	2.5
FJUNQ	Fraction below which source-bulk junction capacitance components are neglected	Volt	0.03

Table 25: Level 69 PSP 103.1 MOSFET Binned Model JUNCAP2 Drain-Bulk Capacitance Parameters

Model Parameter	Description	Unit	Default
CJORBOTD	Zero-bias capacitance per unit area of bottom component for drain-bulk junction	Farad/Meter^2	1.0e-3
CJORSTID	Zero-bias capacitance per unit length of STI-edge component for drain-bulk junction	Farad/Meter	1.0e-9
CJORGATD	Zero-bias capacitance per unit length of gate-edge component for drain-bulk junction	Farad/Meter	1.0e-9
VBIRBOTD	Built-in voltage at the reference temperature of bottom component for drain-bulk junction	Volt	1.0
VBIRSTID	Built-in voltage at the reference temperature of STI-edge component for drain-bulk junction	Volt	1.0
VBIRGATD	Built-in voltage at the reference temperature of gate-edge component for drain-bulk junction	Volt	1.0
PBOTD	Grading coefficient of bottom component for drain-bulk junction	None	0.5
PSTID	Grading coefficient of STI-edge component for drain-bulk junction	None	0.5
PGATD	Grading coefficient of gate-edge component for drain-bulk junction	None	0.5

Table 26: Level 69 PSP 103.1 MOSFET Binned Model JUNCAP2 Drain-Bulk Ideal Current Parameters

Model Parameter	Description	Unit	Default
PHIGBOTD	Zero-temperature bandgap voltage of bottom component for drain-bulk junction	Volt	1.16

PHIGSTID	Zero-temperature bandgap voltage of STI-edge component for drain-bulk junction	Volt	1.16
PHIGGATD	Zero-temperature bandgap voltage of gate-edge component for drain-bulk junction	Volt	1.16
IDSATRBOTD	Saturation current density at the reference temperature of bottom component for drain-bulk junction	Ampere/Meter^2	1.0e-12
IDSATRSTID	Saturation current density at the reference temperature of STI-edge component for drain-bulk junction	Ampere/Meter	1.0e-18
IDSATRGATD	Saturation current density at the reference temperature of gate-edge component for drain-bulk junction	Ampere/Meter	1.0e-18
CSRHBOTD	Shockley-Read-Hall prefactor of bottom component for drain-bulk junction	Ampere/Meter^3	1.0e2
CSRHSTID	Shockley-Read-Hall prefactor of STI-edge component for drain-bulk junction	Ampere/Meter^2	1.0e-4
CSRHGATD	Shockley-Read-Hall prefactor of gate-edge component for drain-bulk junction	Ampere/Meter^2	1.0e-4
XJUNSTID	Junction depth of STI-edge component for drain-bulk junction	Meter	1.0e-7
XJUNGATD	Junction depth of gate-edge component for drain-bulk junction	Meter	1.0e-7

Table 27: Level 69 PSP 103.1 MOSFET Binned Model JUNCAP2 Drain-Bulk Trap-Assisted Tunneling Parameters

Model Parameter	**Description**	**Unit**	**Default**
CTATBOTD	Trap-assisted tunneling prefactor of bottom component for drain-bulk junction	Ampere/Meter^3	1.0e2
CTATSTID	Trap-assisted tunneling prefactor of STI-edge component for drain-bulk junction	Ampere/Meter^2	1.0e-4
CTATGATD	Trap-assisted tunneling prefactor of gate-edge component for drain-bulk junction	Ampere/Meter^2	1.0e-4
MEFFTATBOTD	Effective mass (in units of m_0) for trap-assisted tunneling of bottom component for drain-bulk junction	None	0.25

MEFFTATSTID	Effective mass (in units of m_0) for trap-assisted tunneling of STI-edge component for drain-bulk junction	None	0.25
MEFFTATGATD	Effective mass (in units of m_0) for trap-assisted tunneling of gate-edge component for drain-bulk junction	None	0.25

Table 28: Level 69 PSP 103.1 MOSFET Binned Model JUNCAP2 Drain-Bulk Band-to-Band Tunneling Parameters

Model Parameter	Description	Unit	Default
CBBTBOTD	Band-to-band tunneling prefactor of bottom component for drain-bulk junction	Ampere/Volt ^{3}	1.0e-12
CBBTSTID	Band-to-band tunneling prefactor of STI-edge component for drain-bulk junction	Ampere-Meter/Volt^3	1.0e-18
CBBTGATD	Band-to-band tunneling prefactor of gate-edge component for drain-bulk junction	Ampere-Meter/Volt^3	1.0e-18
FBBTRBOTD	Normalization field at the reference temperature for band-to-band tunneling prefactor of bottom component for drain-bulk junction	Volt/Meter	1.0e9
FBBTRSTID	Normalization field at the reference temperature for band-to-band tunneling prefactor of STI-edge component for drain-bulk junction	Volt/Meter	1.0e9
FBBTRGATD	Normalization field at the reference temperature for band-to-band tunneling prefactor of gate-edge component for drain-bulk junction	Volt/Meter	1.0e9
STFBBTBOTD	Temperature scaling parameter for band-to-band tunneling prefactor of bottom component for drain-bulk junction	1/°K	-1.0e-3
STFBBTSTID	Temperature scaling parameter for band-to-band tunneling prefactor of STI-edge component for drain-bulk junction	1/°K	-1.0e-3
STFBBTGATD	Temperature scaling parameter for band-to-band tunneling prefactor of gate-edge component for drain-bulk junction	1/°K	-1.0e-3

Table 29: Level 69 PSP 103.1 MOSFET Binned Model JUNCAP2 Drain-Bulk Avalanche and Breakdown Parameters

Model Parameter	Description	Unit	Default
VBRBOTD	Breakdown voltage of bottom component for drain-bulk junction	Volt	10.0
VBRSTID	Breakdown voltage of STI-edge component for drain-bulk junction	Volt	10.0
VBRGATD	Breakdown voltage of gate-edge component for drain-bulk junction	Volt	10.0
PBRBOTD	Breakdown onset tuning parameter of bottom component for drain-bulk junction	Volt	4.0
PBRSTID	Breakdown onset tuning parameter of STI-edge component for drain-bulk junction	Volt	4.0
PBRGATD	Breakdown onset tuning parameter of gate-edge component for drain-bulk junction	Volt	4.0

Table 30: Level 69 PSP 103.1 MOSFET Binned Model JUNCAP2 Drain-Bulk JUNCAP Express Parameters

Model Parameter	Description	Unit	Default
VJUNREFD	Typical maximum drain-bulk junction voltage; usually about 2 x V_{sup}	Volt	2.5
FJUNQD	Fraction below which drain-bulk junction capacitance components are neglected	Volt	0.03

Table 31: Level 69 PSP 103.1 MOSFET Binned Model Parasitic Resistance Parameters

Model Parameter	Description	Unit	Default
RGO	Gate resistance R_{gate}	Ohm	0.0
RINT	Contact resistance between silicide and poly	Ohm/square	0
RVPOLY	Vertical poly resistance	Ohm/square	0
RSHG	Gate electrode diffusion sheet resistance	Ohm/square	0
DLSIL	Silicide extension over the physical gate length	Meter	0

RSH	Sheet resistance of source diffusion	Ohm/square	0
RSHD	Sheet resistance of drain diffusion	Ohm/square	0
RBULKO	Bulk resistance R_{bulk}	Ohm	0.0
RWELLO	Well resistance R_{well}	Ohm	0.0
RJUNSO	Source-side bulk resistance R_{juns}	Ohm	0.0
RJUNDO	Drain-side bulk resistance R_{jund}	Ohm	0.0

Table 32: Level 69 PSP 103.1 Binned Model MOSFET NQS Model Parameters

Model Parameter	Description	Unit	Default
SWNQS	Switch for NQS effects 0 = off 1,2,3,5, or 9 = number of collocation points	None	0
MUNQSO	Relative mobility for NQS modeling	None	1.0

PSP 103.1 MOSFET Binning Model Equations

Within a PSP 103.1 model, model parameters are adjusted by the effective channel length and width. There are four types of binning geometry adjustments. The formulas for the adjustment use the following symbols:

POx = value of the geometry-independent model parameter “x” (e.g., **POVFB**).

PLx = value of the length dependence parameter “x” (e.g., **PLVFB**).

PWx = value of the width dependence parameter “x” (e.g., **PWVFB**).

PWLx = value of the cross dependence parameter “x” (e.g., **PLWVFB**).

Le = effective channel length.

We= effective channel width.

Len = normalized effective channel length.

Wen = normalized effective channel width.

Type I adjustment:

```
Value = POx+PLx*(Len/Le)+PWx*(Wen/We)+PLWx*(Len/Le)*(Wen/We)
```

Type II adjustment:

```
Value = POx+PLx*(Le/Len)+PWx*(We/Wen)+PLWx*(Le/Len)*(We/Wen)
```

Type III adjustment:

```
Value = POx+PLx*(Len/Le)+PWx*(We/Wen)+PLWx*(Len/Le)*(We/Wen)
```

Type IV adjustment (no binning):

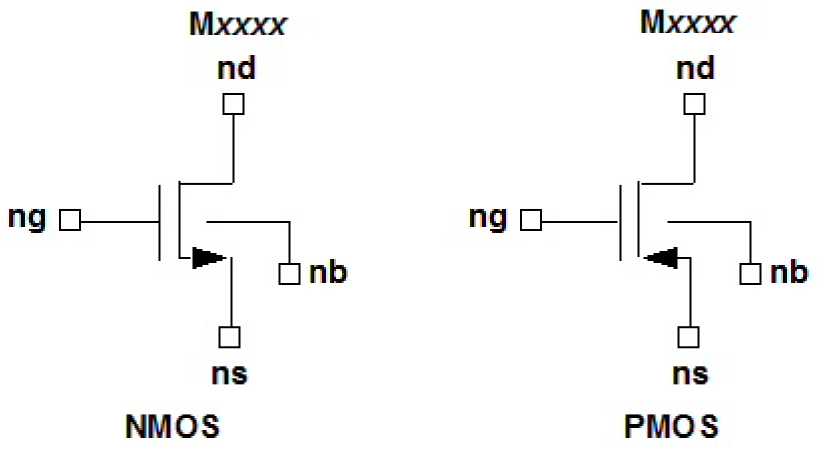
```
Value = POx
```

The parameters that receive Type I adjustments are VFB, STVFB, NEFF, FACNEFFAC, GFACNUD, DPHIB, DELVTAC, NP, CT, NOV, NOVD, CF, STBET, MUE, CS, XCOR, RS, THESAT, STTHESAT, THESATB, THESATG, AX, ALP, ALP1, ALP2, A1, A3, A4, NFA, NFB, NFC.

The parameters that receive Type II adjustments are IGINV, COX, CGBOV.

The parameters that receive Type III adjustments are BETN, IGOV, IGOVD, AGIDL, AGIDLD, CGOV, CGOVD, CFR, CFRD.

MOSFET Instance, BSIM-CMG Model (Level 72)



BSIM-CMG MOSFET Instance Netlist Syntax

The syntax for a LEVEL=72 BSIM-CMG MOSFET instance is:

M*xxxx nd ng ns* [*nb*] *modelname* [*instance_parameters*]

nd is the drain node, *ng* is the gate node, *ns* is the source node, and *nb* is the internal body node of the MOSFET. *modelname* is the name of a BSIM-CMG MOSFET model defined in a .MODEL statement elsewhere in the netlist. All instance parameters except NF, DTEMP, DELVTRAND, U0MULT, and IDS0MULT are also model parameters.

Table 1: Level 72 MOSFET Instance Parameters

Instance Parameter	Description	Unit	Default
L	Designed gate length	Meter	30e-9
D	Diameter of cylinder (GEOMOD=3)	Meter	40e-9
TFIN	Body (fin) thickness	Meter	15e-9
FPITCH	Fin pitch	Meter	80e-9
NF	Number of fingers (must be >1)	None	1
NFIN	Number of fins per finger (must be >0)	None	1
NGCON	Number of gate contacts (1 or 2)	None	1
ASEO	Source to substrate overlap area through oxide (all fingers)	Meter^2	0
ADEO	Drain to substrate overlap area through oxide (all fingers)	Meter^2	0
PSEO	Perimeter of source to substrate overlap area through oxide (all fingers)	Meter	0.0
PDEO	Perimeter of drain to substrate overlap area through oxide (all fingers)	Meter	0.0
ASEJ	Source junction area (all fingers; BULKMOD=1)	Meter^2	0.0
ADEJ	Drain junction area (all fingers; BULKMOD=1)	Meter^2	0.0
PSEJ	Source junction perimeter (all fingers; BULKMOD=1)	Meter	0.0
PDEJ	Drain junction perimeter (all fingers; BULKMOD=1)	Meter	0.0
COVS	Constant gate-to-source overlap capacitance (CGEOMOD=1)	Farad	0.0
COVD	Constant gate-to-drain overlap capacitance (CGEOMOD=1)	Farad	0.0
CGSP	Constant gate-to-source fringe capacitance (CGEOMOD=1)	Farad	0.0
CGDP	Constant gate-to-drain fringe capacitance (CGEOMOD=1)	Farad	0.0
CDSP	Constant drain-to-source fringe capacitance	Farad	0.0
NRS	Number of source diffusion squares (RGEOMOD=0)	None	0

NRD	Number of drain diffusion squares (RGEOMOD=0)	None	0
LRSD	Length of the source/drain	Meter	L
Parameters for Variability Modeling			
XL	L offset for channel length due to mask/etch effect	Meter	0
DTEMP	Device temperature shift handle	°K	0.0
DELVTRAND	Threshold voltage shift handle	Volt	0.0
U0MULT	Multiplier to mobility (divides Dmob, Dmobs)	None	1.0
IDS0MULT	Multiplier to source-drain channel current	None	1.0

Netlist Example

```
M65 netg nets netd netb mosfetmodel72 L=25e-9 NFIN=10
```

BSIM-CMG MOSFET Model, Level 72

The syntax for a BSIM-CMG Level 72 MOSFET model is:

.MODEL*modelname* **NMOS LEVEL=72 VERSION=***val* [*parameter***=***val*] ...

or

.MODEL*modelname* **PMOS LEVEL=72 VERSION=***val* [*parameter***=***val*] ...

modelname is the name used by MOSFET instances to refer to this .MODEL statement. The **LEVEL=72** entry selects a BSIM-CMG MOSFET model.

Table 2: Level 72 MOSFET Control Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	72 is required to select the BSIM-CMG MOSFET model	None	1 (default if LEVEL parameter is omitted)
VERSION	MOSFET model version selector	None	107
DEVTYPE	NMOS=1, PMOS=0	None	1
BULKMOD	Substrate model selector. 0=multi-gate on SOI substrate, 1=multi-gate on bulk substrate	None	0
COREMOD	Simplified surface potential selector. 0=deactivate, 1=run on (lightly doped or undoped)	None	0

GEOMOD	Structure selector. 1=double gate, 2=quadruple gate, 3=cylindrical gate	None	1
CGEO1SW	1=Enables COVS, COVD, CGSP, and CGDP to be in F per fin, per gate finger, per unit channel width	None	0
RDSMOD	Bias-dependent source/drain extension resistance model selector. 0=internal, 1=external	None	0
ASYMMOD	Asymmetric I-V model selector. 0=turn off (forward mode parameters used), 1=activate	None	0
IGCMOD	Igc, Igs, and Igd model selector. 1=activate, 0=deactivate	None	0
IGBMOD	Igb model selector. 1=activate, 0=turn off	None	0
GIDLMOD	GIDL/GISL current switch. 1=turn on, 0=deactivate	None	1
IIMOD	Impact ionization model switch. 0=off, 1=BSIM4-based, 2=BSIM-SOI-based	None	0
NQSMOD	NQS gate resistor and *gi* node switch. 1=activate, 0=deactivate, 2=NQS charge deficit model (BSIM4), q-node activated	None	0
SHMOD	Self-heating and T-node switch 0 = No self-heating 1 = Self-heating	None	0
RGATEMOD	Gate electrode resistor and *ge* node switch. 1=activate, 0=deactivate	None	0
RGEOMOD	Bias-independent parasitic resistance model selector. 1=activate, 0=deactivate	None	0
CGEOMOD	Parasitic capacitance model selector. 1=activate, 0=deactivate	None	0
CAPMOD	Accumulation region capacitance model selector. 0=no accumulation capacitance, 1=accumulation capacitance included	None	0

Table 3: Level 72 MOSFET Process Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
XL	L offset for channel length due to mask/etch effect	Meter	0

LINT	Length reduction parameter (dopant diffusion effect)	Meter	0.0
LL	Length reduction parameter (dopant diffusion effect)	Meter$^{(LLN+1)}$	0.0
LLN	Length reduction parameter (dopant diffusion effect)	None	1.0
DLC	Length reduction parameter for CV (dopant diffusion effect)	Meter	0.0
DLCACC	Length reduction parameter for CV in accumulation region (BULKMOD=1, CAPMOD=1)	Meter	0.0
LLC	Length reduction parameter for CV (dopant diffusion effect)	Meter$^{(LLN+1)}$	0.0
DLBIN	Delta L for binning	Meter	0.0
EOT	SiO2 equivalent gate dielectric thickness (including inversion layer thickness)	Meter	1.0e-9
TOXP	Physical oxide thickness	Meter	1.2e-9
EOTBOX	SiO2 equivalent buried oxide thickness (including substrate depletion)	Meter	140e-9
HFIN	Fin height	Meter	30e-9
FECH	End-channel factor for different orientation/shape. Mobility difference between the side channel and the top channel is handled by this parameter	None	1.0
DELTAW	Reduction in effective width due to shape of fin	Meter	0.0
FECHCV	CV end-channel factor for different orientation/shape.	None	1.0
DELTAWCV	CV reduction in effective width due to shape of fin	Meter	0.0
NBODY	Channel (body) doping concentration	1/Meter^3	1e22
NBODYN1	NFIN dependence of NBODY	None	0
NBODYN2	NFIN dependence of NBODY	None	1e5
NSD	Source/Drain doping concentration	1/Meter^3	2.0e26
NGATE	Polysilicon gate doping concentration. Set NGATE=0 for metal gates.	1/Meter^3	0.0
PHIG	Gate work function	electron-Volt	4.61
PHIGL	Length dependence of gate work function	electron-Volt/Meter	0.0
PHIGN1	NFIN dependence of PHIG	None	0
PHIGN2	NFIN dependence of PHIG	None	1e5

EPSROX	Relative dielectric constant of the gate insulator	None	3.9
EPSRSUB	Relative dielectric constant of the channel material	None	11.9
EASUB	Electron affinity of the substrate material	electron-Volt	4.05
NI0SUB	Intrinsic carrier concentration of channel at 300.15K	1/Meter^3	1.1e16
BG0SUB	Band gap of the channel material at 300.15K	electron-Volt	1.12
NC0SUB	Conduction band density of states at 300.15K	1/Meter^3	2.86e25
IMIN	Parameter for voltage clamping for inversion region calculation in accumulation	Ampere/Meter^2	1e-15

Table 4: Level 72 MOSFET Basic Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
Short Channel Effects			
CIT	Interface trap parameter	Farad/Meter^2	0.0
CDSC	Coupling capacitance between Source/Drain and channel	Farad/Meter^2	7e-3
CDSCN1	NFIN dependence of CDSC	None	0
CDSCN2	NFIN dependence of CDSC	None	1e5
CDSCD	Drain bias sensitivity of CDSC	Farad/Meter^2	7e-3
CDSCDN1	NFIN dependence of CDSCD	None	0
CDSCDN2	NFIN dependence of CDSCD	None	1e5
CDSCDR	Reverse-mode drain bias sensitivity	Farad/Meter^2	CDSCD
CDSCDRN1	NFIN dependence of CDSCDR	None	CDSCN1
CDSCDRN2	NFIN dependence of CDSCDR	None	CDSCN2
DVT0	SCE coefficient	None	0.0
DVT1	SCE exponent coefficient	None	0.60
DVT1SS	Subthreshold swing exponent coefficient	None	DVT1
PHIN	Nonuniform vertical doping effect on surface potential	Volt	0.05
ETA0	DIBL coefficient	None	0.60
ETA0N1	NFIN dependence of ETA0	None	0
ETA0N2	NFIN dependence of ETA0	None	1.0e5

TETA0	Temperature dependence of ETA0	1/°K	0.0
ETA0R	Reverse-mode DIBL coefficient (experimental)	None	ETA0
TETA0R	Temperature dependence of ETA0R	1/°K	TETA0
DSUB	DIBL exponent coefficient	None	1.06
DVTP0	Coefficient for Drain-Induced Threshold (Vth) Shift (DITS)	None	0
DVTP1	DITS exponent coefficient	None	0
K1RSCE	K1 prefactor for reverse short channel effect	Volt$^{0.5}$	0.0
LPE0	Equivalent length of pocket region at zero bias	Meter	5e-9
DVTSHIFT	Additional Vth shift handle	Volt	0
Lateral Non-uniform Doping Effect (IV-CV Vth Shift)			
K0	Lateral NUD voltage	Volt	0.0
K01	Temperature dependence of K0	Volt/°K	0.0
K0SI	Correction factor for strong inversion used in Mnud calculation	None	1.0
K0SI1	Temperature dependence of K0SI	Volt/°K	0.0
K1SI	Correction factor for strong inversion used in mobility calculation	None	K0SI
K1SI1	Temperature dependence of K1SI	1/°K	K0SI1
Body Effect for MG Devices on Bulk Substrate (e.g., FinFETs on BULK)			
PHIBE	Body-effect voltage parameter	Volt	0.7
K1	Body effect coefficient for sub-threshold region	Volt$^{0.5}$	1.0
K11	Temperature dependence of K1	Volt$^{0.5}$/°K	0.0
K1SAT	Body effect coefficient for saturation region (high Vds)	1/Volt$^{0.5}$	0.0
K1SAT1	Temperature dependence of K1SAT	Volt$^{-0.5}$/°K	0.0
Quantum-Mechanical Effect			
QMFACTOR	Prefactor for QM Vth shift correction	None	0.0
QMTCENIV	Prefactor/switch for QM effective width correction for IV	None	0.0

QMTCENCV	Prefactor/switch for QM effective width and oxide thickness correction for CV	None	0.0
QMTCENCVA	Prefactor/switch for QM effective width and oxide thickness correction for accumulation region CV	None	0.0
AQMTCEN	Parameter for geometric dependence of Tcen on R/TFIN/HFIN	None	0.0
BQMTCEN	Parameter for geometric dependence of Tcen on R/TFIN/HFIN	None	12.0e-9
ETAQM	Bulk charge coefficient for QM charge centroid Tcen	None	0.54
QM0	Knee-point for Tcen in inversion (charge normalized to Cox)	Volt	1.0e-3
PQM	Slope of normalized Tcen in inversion	None	0.66
QM0ACC	Knee-point for Tcen in accumulation (charge normalized to Cox)	Volt	1.0e-3
PQMACC	Slope of normalized Tcen in accumulation	None	0.66
Velocity Saturation Model			
VSAT	Saturation velocity for the saturation region	Meter/second	85000
VSATN1	NFIN dependence of VSAT	None	0
VSATN2	NFIN dependence of VSAT	None	1e5
AVSAT			0.0
BVSAT			100.0e-9
VSAT1	Saturation velocity for I_on degradation (forward mode)	Meter/second	VSAT
VSAT1N1	NFIN dependence of VSAT1	None	VSATN1
VSAT1N2	NFIN dependence of VSAT1	None	VSATN2
VSAT1R	Saturation velocity for the linear region in reverse mode	Meter/second	VSAT1
VSAT1RN1	NFIN dependence of VSAT1R	None	VSAT1N1
VSAT1RN2	NFIN dependence of VSAT1R	None	VSAT1N2
AVSAT1			AVSAT
BVSAT1			BVSAT
DELTAVSAT	Velocity saturation parameter in the linear region	None	1.0

PSAT	Exponent for field for velocity saturation	None	2.0
APSAT			0.0
BPSAT			1.0
KSATIV	Parameter for long-channel Vdsat	None	1.0
VSATCV	Saturation velocity for the capacitance model	Meter/second	VSAT
AVSATCV			AVSAT
BVSATCV			BVSAT
DELTAVSATCV	Velocity saturation parameter in the linear region for the capacitance model	None	DELTAVSAT
PSATCV	Exponent for field for velocity saturation for the capacitance model	None	PSAT
APSATCV			APSAT
BPSATCV			BPSAT
MEXP	Smoothing function factor for Vdsat	None	4
AMEXP			0.0
BMEXP			1.0
MEXPR			MEXP
AMEXPR			AMEXP
BMEXPR			BMEXP
PTWG	Correction factor for velocity saturation in forward mode	1/Volt^2	0.0
PTWGR	Correction factor for velocity saturation in reverse mode	1/Volt^2	PTWG
APTWG			0.0
BPTWG			100.0e-9
AT	Saturation velocity temperature coefficient	1/°K	-1.56e-3
TMEXP	Temperature coefficient for Vdseff smoothing	1/°K	0.0
TMEXPR			TMEXP
PTWGT	PTWG temperature coefficient	1/°K	0.004
Mobility Model			
U0	Low field mobility	Meter^2/Volt-sec	3e-2

U0N1	NFIN dependence of U0	None	0
U0N2	NFIN dependence of U0	None	1.0e5
CHARGEWF	Average channel charge weighting (sampling) factor, +1=source-side, 0=middle, -1=drain-side	None	0
ETAMOB	Effective field parameter	None	2.0
UP	Mobility L coefficient	μm^{LPA}	0.0
LPA	Mobility L power coefficient	None	1.0
UA	Phonon/surface roughness scattering parameter	$(cm/MV)^{EU}$	0.3
AUA			0.0
BUA			100.0e-9
UC	Body effect coefficient for mobility (BULKMOD=1)	$(1.0e-6*cm/MV^2)^{EU}$	0.0
EU	Phonon/surface roughness scattering parameter	cm/MV	2.5
AEU			0.0
BEU			100.0e-9
UD	Coulombic scattering parameter	cm/MV	0.0
AUD			0.0
BUD			50.0e-9
UCS	Coulombic scattering parameter	None	1.0
UTE	Mobility temperature coefficient	None	0.0
UTL	Mobility temperature coefficient	None	-1.5e-3
EMOBT	Temperature coefficient of ETAMOB	None	0.0
UA1	Mobility temperature coefficient for UA	None	1.032e-3
UC1	Mobility temperature coefficient for UC	None	0.056e-9
UD1	Mobility temperature coefficient	None	0.0
UCSTE	Mobility temperature coefficient	None	-4.775e-3
Access Resistance Model			
RDSWMIN	Source/drain extension resistance per unit width at high Vgs (RDSMOD=0)	$Ohm\text{-}\mu m^{WR}$	0.0
RDSW	Zero-bias source/drain extension resistance per unit width (RDSMOD=0)	$Ohm\text{-}\mu m^{WR}$	100.0

ARDSW			0.0
BRDSW			100.0e-9
RSWMIN	Source extension resistance per unit width at high Vgs (RDSMOD=1)	Ohm-µm^{WR}	0.0
RSW	Zero-bias source extension resistance per unit width at high Vgs (RDSMOD=1)	Ohm-µm^{WR}	50.0
ARSW			0.0
BRSW			100.0e-9
RDWMIN	Drain extension resistance per unit width at high Vgs (RDSMOD=1)	Ohm-µm^{WR}	0.0
RDW	Zero-bias drain extension resistance per unit width (RDSMOD=1)	Ohm-µm^{WR}	50.0
ARDW			0.0
BRDW			100.0e-9
RSDR	Source side drift resistance parameter in forward mode (RDSMOD=1)	1/V^{PRSDR}	0.0
RSDRR	Source side drift resistance parameter in reverse mode (RDSMOD=1)	1/V^{PRSDR}	RSDR
RDDR	Drain side drift resistance parameter in forward mode (RDSMOD=1)	1/V^{PRSDR}	0.0
RDDRR	Drain side drift resistance parameter in reverse mode (RDSMOD=1)	1/V^{PRSDR}	RDDR
PRSDR	Drain side drift resistance parameter in forward mode (RDSMOD=1)	None	1.0
PRDDR	Drain side drift resistance parameter in reverse mode (RDSMOD=1)	None	PRSDR
PRWGS	Gate-bias dependence of source extension resistance	1/Volt	0.0
PRWGD	Gate-bias dependence of drain extension resistance	1/Volt	PRWGS
WR	W dependence parameter of source/drain extension resistance	None	1.0
PRT	Series resistance temperature coefficient	1/°K	0.001
TRSDR	Source side drift resistance temperature coefficient	1/°K	0.0
TRDDR	Drain side drift resistance temperature	1/°K	TRSDR

	coefficient		
DIBL Model			
PDIBL1	Parameter for DIBL effect on Rout in forward mode	None	0.0
PDIBL1R	Parameter for DIBL effect on Rout in reverse mode	None	PDIBL1
PDIBL2	Parameter for DIBL effect on Rout	None	2e-4
DROUT	L dependence of DIBL effect on Rout	None	1.06
PVAG	Vgs dependence on early voltage	None	1.0
Channel Length Modulation			
PCLM	Channel length modulation (CLM) parameter	None	0.013
APCLM			0.0
BPCLM			100.0e-9
PCLMG	Gate-bias dependence parameter for CLM	None	0.0
PCLMCV	CLM parameter for short channel CV	None	PCLM
Non-saturation Effect			
A1	Non-saturation effect parameter in strong inversion region	Volt^{-2}	0.0
A11	Temperature dependence of A1	Volt^{-2}/ °K	0.0
A2	Non-saturation effect parameter in moderate inversion region	1/Volt	0.0
A21	Temperature dependence of A2	Volt^{-1}/ °K	0.0
Gate Electrode Resistance			
RGEXT	Effective gate electrode external resistance (Experimental)	Ohm	0.0
RGFIN	Effective gate electrode resistance per fin per finger	Ohm	1.0e-3
Geometry-dependent Source/Drain Resistance (RGEOMOD=0)			
RSHS	Source-side sheet resistance	Ohm	0.0
RSHD	Drain-side sheet resistance	Ohm	RSHS
Gate Current			
TOXREF	Nominal gate oxide thickness for gate tunneling current	Meter	1.2e-9

TOXG	Oxide thickness for gate current model	Meter	TOXP
NTOX	Exponent for gate oxide ratio	None	1.0
POXEDGE	Factor for the gate edge Tox	None	1.0
AIGBINV	Parameter for Igb in inversion	$(Fs^2/g)^{0.5}$/Meter	1.11e-2
AIGBINV1	Parameter for Igb in inversion	$(Fs^2/g)^{0.5}$/Meter-K	0.0
BIGBINV	Parameter for Igb in inversion	$(Fs^2/g)^{0.5}$/Meter	9.49e-4
CIGBINV	Parameter for Igb in inversion	1/Volt	6.00e-3
EIGBINV	Parameter for Igb in inversion	Volt	1.1
NIGBINV	Parameter for Igb in inversion	None	3.0
AIGBACC	Parameter for Igb in accumulation	$(Fs^2/g)^{0.5}$/Meter	1.36e-2
AIGBACC1	Parameter for Igb in accumulation	$(Fs^2/g)^{0.5}$/Meter-K	0.0
BIGBACC	Parameter for Igb in accumulation	$(Fs^2/g)^{0.5}$/Meter	1.71e-3
CIGBACC	Parameter for Igb in accumulation	1/Volt	7.5e-2
NIGBACC	Parameter for Igb in accumulation	None	1.0
AIGC	Parameter for Igc in inversion	$(Fs^2/g)^{0.5}$/Meter	1.36e-2
AIGC1	Parameter for Igc in inversion	$(Fs^2/g)^{0.5}$/Meter-K	0
BIGC	Parameter for Igc in inversion	$(Fs^2/g)^{0.5}$/Meter	1.71e-3
CIGC	Parameter for Igc in inversion	1/Volt	0.075
PIGCD	Vds dependence of Igcs and Igcd	None	1.0
DLCIGS	Delta L for Igs model	Meter	0.0
AIGS	Parameter for Igs in inversion	$(Fs^2/g)^{0.5}$/Meter	1.36e-2
AIGS1	Parameter for Igs in inversion	$(Fs^2/g)^{0.5}$/Meter-K	0
BIGS	Parameter for Igs in inversion	$(Fs^2/g)^{0.5}$/Meter	1.71e-3

CIGS	Parameter for Igs in inversion	1/Volt	0.075
DLCIGD	Delta L for Igd model	Meter	DLCIGS
AIGD	Parameter for Igd in inversion	$(Fs^2/g)^{0.5}$/Meter	AIGS
AIGD1	Parameter for Igd in inversion	$(Fs^2/g)^{0.5}$/Meter-K	AIGS1
BIGD	Parameter for Igd in inversion	$(Fs^2/g)^{0.5}$/Meter	BIGS
CIGD	Parameter for Igd in inversion	1/Volt	CIGS
GIDL/GISL Current			
AGISL	Pre-exponential coefficient for GISL	Mho	60.55e-12
BGISL	Exponential coefficient for GISL	Volt/Meter	0.3e9
CGISL	Parameter for body-bias effect of GISL	Volt^3	0.5
EGISL	Band bending parameter for GISL	V	0.2
PGISL	Exponent of electric field for GISL	None	1.0
AGIDL	Pre-exponential coefficient for GIDL	Mho	AGISL
BGIDL	Exponential coefficient for GIDL	Volt/Meter	BGISL
CGIDL	Parameter for body-bias effect of GIDL	Volt^3	CGISL
EGIDL	Band bending parameter for GIDL	V	EGISL
PGIDL	Exponent of electric field for GIDL	None	PGISL
Impact Ionization Current (IIMOD=1)			
ALPHA0	First parameter of Iii	Meter/Volt	0.0
ALPHA01	Temperature dependence of ALPHA0	Meter/Volt/°K	0.0
ALPHA1	L scaling parameter of Iii	1/Volt	0.0
ALPHA11	Temperature dependence of ALPHA1	1/Volt/°K	0.0
BETA0	Vds dependent parameter of Iii	1/Volt	0.0
Impact Ionization Current (IIMOD=2)			
ALPHAII0	First parameter of Iii	Meter/Volt	0.0
ALPHAII01	Temperature dependence of ALPHAII0	Meter/Volt/°K	0.0
ALPHAII1	L scaling parameter of Iii	1/Volt	0.0
ALPHAII11	Temperature dependence of ALPHAII1	1/Volt/°K	0.0
BETAII0	Vds dependence parameter of Iii	1/Volt	0.0

BETAII1	Vds dependence parameter of Iii	1/Volt	0.0
BETAII2	Vds dependence parameter of Iii	1/Volt	0.1
ESATII	Saturation channel E-field for Iii	Volt/Meter	1.0e7
LII	Channel length dependent parameter of Iii	Volt-Meter	0.5e-9
SII0	Vgs dependent parameter of Iii	1/Volt	0.5
SII1	Vgs dependent parameter of Iii	None	0.1
SII2	Vgs dependent parameter of Iii	Volt	0.0
SIID	Vds dependent parameter of Iii	Volt	0.0
Accumulation Capacitance (CAPMOD=1)			
EOTACC	SiO2 equivalent gate dielectric thickness for accumulation region	Meter	EOT
DELVFBACC	Additional Vfb shift required for accumulation region	Volt	0.0
Fringe Capacitance (CGEOMOD=0)			
CFS	Source-side outer fringe capacitance	Farad/Meter	2.5e-11
CFD	Drain-side outer fringe capacitance	Farad/Meter	CFS
Overlap Capacitance (CGEOMOD=0, 2)			
CGSO	Non-LDD region source-gate overlap capacitance per unit channel width	Farad/Meter	0.0
CGDO	Non-LDD region drain-gate overlap capacitance per unit channel width	Farad/Meter	CGSO
CGSL	Overlap capacitance between gate and lightly-doped source region	Farad/Meter	0
CGDL	Overlap capacitance between gate and lightly-doped drain region	Farad/Meter	CGSL
CKAPPAS	Coefficient of bias-dependent overlap capacitance for the source side	Volt	0.6
CKAPPAD	Coefficient of bias-dependent overlap capacitance for the drain side	Volt	CKAPPAS
CGBO	Gate-substrate overlap capacitance per unit channel length per finger per gate contact (NGCON)	Farad/Meter	0
CGBN	Gate-substrate overlap capacitance per unit channel length per fin per finger	Farad/Meter	0
CGBL	Bias-dependent component of gate-to-		0.0

	substrate overlap capacitance per unit channel length per fin per finger		
CKAPPAB		Volt	0.6
Source/Drain to Substrate Sidewall Capacitance			
CSDESW	Source/drain sidewall fringing capacitance per unit length	Farad/Meter	0
Junction Current and Capacitance			
Junction Capacitance			
CJS	Unit area source-side junction capacitance at zero bias	Farad/Meter^2	5.0e-4
CJD	Unit area drain-side junction capacitance at zero bias	Farad/Meter^2	CJS
CJSWS	Unit length sidewall junction capacitance at zero bias (source-side)	Farad/Meter	5.0e-10
CJSWD	Unit area sidewall junction capacitance at zero bias (drain-side)	Farad/Meter	CJSWS
CJSWGS	Unit length gate sidewall junction capacitance at zero bias (source-side)	Farad/Meter	0.0
CJSWGD	Unit area gate sidewall junction capacitance at zero bias (drain-side)	Farad/Meter	CJSWGS
PBS	Bottom junction built-in potential (source-side)	Volt	1.0
PBD	Bottom junction built-in potential (drain-side)	Volt	PBS
PBSWS	Isolation edge sidewall junction built-in potential (source-side)	Volt	1.0
PBSWD	Isolation edge sidewall junction built-in potential (drain-side)	Volt	PBSWS
PBSWGS	Gate edge sidewall junction built-in potential (source-side)	Volt	PBSWS
PBSWGD	Gate edge sidewall junction built-in potential (drain-side)	Volt	PBSWGS
MJS	Source bottom junction capacitance grading coefficient	None	0.5
MJD	Drain bottom junction capacitance grading coefficient	None	MJS
MJSWS	Isolation edge sidewall junction	None	0.5

	capacitance grading coefficient (source-side)		
MJSWD	Isolation edge sidewall junction capacitance grading coefficient (drain-side)	None	MJSWS
MJSWGS	Gate edge sidewall junction capacitance grading coefficient (source-side)	None	MJSWS
MJSWGD	Gate edge sidewall junction capacitance grading coefficient (drain-side)	None	MJSWGS
Second Junction for the Two-step Junction Capacitance			
SJS	Constant for source-side two-step second junction capacitance	None	0.0
SJD	Constant for drain-side two-step second junction capacitance	None	SJS
SJSWS	Constant for sidewall two-step second junction capacitance (source-side)	None	0.0
SJSWD	Constant for sidewall two-step second junction capacitance (drain-side)	None	SJSWS
SJSWGS	Constant for gate sidewall two-step second junction capacitance (source-side)	None	0.0
SJSWGD	Constant for gate sidewall two-step second junction capacitance (drain-side)	None	SJSWS
MJS2	Source bottom two-step second junction capacitance grading coefficient	None	0.125
MJD2	Drain bottom two-step second junction capacitance grading coefficient	None	MJS2
MJSWS2	Isolation edge sidewall two-step second junction capacitance grading coefficient (source side)	None	0.125
MJSWD2	Isolation edge sidewall two-step second junction capacitance grading coefficient	None	MJSWS2
MJSWGS2	Gate edge sidewall two-step second junction capacitance grading coefficient (source side)	None	MJSWS2
MJSWGD2	Gate edge sidewall two-step second junction capacitance grading coefficient	None	MJSWGS2
Junction Current			
JSS	Bottom source junction reverse saturation current density	Ampere/Meter 2	1.0e-4

JSD	Bottom drain junction reverse saturation current density	Ampere/Meter 2	JSS
JSWS	Unit length reverse saturation current for isolation-edge source sidewall junction	Ampere/Meter	0.0
JSWD	Unit length reverse saturation current for isolation-edge drain sidewall junction	Ampere/Meter	JSWS
JSWGS	Unit length reverse saturation current for gate-edge source sidewall junction	Ampere/Meter	0.0
JSWGD	Unit length reverse saturation current for gate-edge drain sidewall junction	Ampere/Meter	JSWGS
NJS	Source junction emission coefficient	None	1.0
NJD	Drain junction emission coefficient	None	NJS
IJTHSFWD	Forward source diode breakdown limiting current	Ampere	0.1
IJTHDFWD	Forward drain diode breakdown limiting current	Ampere	IJTHSFWD
IJTHSREV	Reverse source diode breakdown limiting current	Ampere	0.1
IJTHDREV	Reverse drain diode breakdown limiting current	Ampere	IJTHSREV
BVS	Source diode breakdown voltage	Volt	10.0
BVD	Drain diode breakdown voltage	Volt	BVS
XJBVS	Fitting parameter for source diode breakdown current	None	1.0
XJBVD	Fitting parameter for drain diode breakdown current	None	XJBVS
Tunneling Component of Junction Current			
JTSS	Bottom source junction trap-assisted saturation current density	Ampere/Meter 2	0.0
JTSD	Bottom drain junction trap-assisted saturation current density	Ampere/Meter 2	JTSS
JTSSWS	Unit length trap-assisted saturation current for isolation-edge source sidewall junction	Ampere/Meter	0.0
JTSSWD	Unit length trap-assisted saturation current for isolation-edge drain sidewall junction	Ampere/Meter	JTSSWS
JTSSWGS	Unit length trap-assisted saturation current	Ampere/Meter	0.0

	for gate-edge source sidewall junction		
JTSSWGD	Unit length trap-assisted saturation current for gate-edge drain sidewall junction	Ampere/Meter	JTSSWGS
JTWEFF	Trap-assisted tunneling current width dependence	Meter	0.0
NJTS	Non-ideality factor for JTSS	None	20.0
NJTSD	Non-ideality factor for JTSD	None	NJTS
NJTSSW	Non-ideality factor for JTSSWS	None	20.0
NJTSSWD	Non-ideality factor for JTSSWD	None	NJTSSW
NJTSSWG	Non-ideality factor for JTSSWGS	None	20.0
NJTSSWGD	Non-ideality factor for JTSSWGD	None	NJTSSWG
VTSS	Bottom source junction trap-assisted current voltage dependent parameter	Volt	10
VTSD	Bottom drain junction trap-assisted current voltage dependent parameter	Volt	VTSS
VTSSWS	Unit length trap-assisted current voltage dependent parameter for sidewall source junction	Volt	10
VTSSWD	Unit length trap-assisted current voltage dependent parameter for sidewall drain junction	Volt	VTSSWS
VTSSWGS	Unit length trap-assisted current voltage dependent parameter for gate-edge sidewall source junction	Volt	10
VTSSWGD	Unit length trap-assisted current voltage dependent parameter for gate-edge sidewall drain junction	Volt	VTSSWGS
Recombination-Regeneration Current			
LINTIGEN	Lint offset for thermal generation (R/G) current	Meter	0.0
NTGEN	Parameter for R/G current (Experimental)	None	1.0
AIGEN	Parameter for R/G current (Experimental)	1/Meter^3-Volt	0.0
BIGEN	Parameter for R/G current (Experimental)	1/Meter^3-Volt^3	0.0
NQS Gate Resistance Model and NQS Charge Deficit Model (For NQSMOD=1, set XRCRG1=0 to deactivate NQS gate resistance)			
XRCRG1	Parameter for non-quasi-static gate	None	12.0

	resistance (NQSMOD=1, 2)		
XRCRG2	Parameter for non-quasi-static gate resistance (NQSMOD=1, 2)	None	1.0
NQS Charge Segmentation Model			
NSEG	Number of channel segments for NQSMOD=3	None	4
Flicker Noise			
EF	Flicker noise frequency exponent	None	1.0
LINTNOI	Lint offset for flicker noise calculation	Meter	0.0
EM	Flicker noise parameter	Volt/Meter	4.1e7
NOIA	Flicker noise parameter	$eV^{-1}s^{1-EF}$m-3	6.250e39
NOIB	Flicker noise parameter	$eV^{-1}s^{1-EF}$m-3	3.125e24
NOIC	Flicker noise parameter	$eV^{-1}s^{1-EF}$m-3	8.750e7
Thermal Noise			
NTNOI	Thermal noise parameter	None	1.0

Table 5: Level 72 MOSFET Parameters for Geometry-Dependent Parasitics

Model Parameter	**Description**	**Unit**	**Default**
Geometry-dependent Source/Drain Resistance for Variability Modeling (RGEOMOD=1 and CGEOMOD=2)			
HEPI	Height of the raised source/drain on top of the fin	Meter	10e-9
TSILI	Thickness of the silicide on top of the raised source/drain	Meter	10e-9
RHOC	Contact resistivity at the silicon/silicide interface	Ohm-Meter^2	1.0e-12
RHORSD	Average resistivity of silicon in the raised source/drain region	Ohm-Meter	1.0
CRATIO	Ratio of the corner area filled with silicon to the total corner area	None	0.5
DELTAPRSD	Change in silicon/silicide interface length due to non-rectangular epi	Meter	0.0
SDTERM	Indicates that the source and drain are terminated with silicide	None	0

LSP	Thickness of gate sidewall spacer	Meter	0.2(L+XL)
EPSRSP	Relative dielectric constant of the gate sidewall spacer material	None	3.9
TGATE	Gate height on top of the hard mask	Meter	30e-9
TMASK	Height of the hard mask on top of the fin	Meter	30e-9
ASILIEND	Extra silicide cross-sectional area at the two ends of the FinFET	Meter^2	0.0
ARSDEND	Extra raised source/drain cross-sectional area at the two ends of the FinFET	Meter^2	0.0
PRSDEND	Extra silicon/silicide interface parameter at the two ends of the FinFET	Meter	0.0
NSDE	Active doping concentration at the channel edge	$1/\text{Meter}^3$	2e25
RGEOA	Fitting parameter for RGEOMOD=1	None	1.0
RGEOB	Fitting parameter for RGEOMOD=1	1/Meter	0.0
RGEOC	Fitting parameter for RGEOMOD=1	1/Meter	0.0
RGEOD	Fitting parameter for RGEOMOD=1	1/Meter	0.0
RGEOE	Fitting parameter for RGEOMOD=1	1/Meter	0.0
CGEOA	Fitting parameter for CGEOMOD=2	None	1.0
CGEOB	Fitting parameter for CGEOMOD=2	1/Meter	0.0
CGEOC	Fitting parameter for CGEOMOD=2	1/Meter	0.0
CGEOD	Fitting parameter for CGEOMOD=2	1/Meter	0.0
CGEOE	Fitting parameter for CGEOMOD=2	None	1.0

Table 6: Level 72 MOSFET Temperature Dependence and Self-Heating Parameters

Model Parameter	**Description**	**Unit**	**Default**
TNOM	Temperature at which parameters are extracted	°C	27
TBGASUB	Bandgap temperature coefficient	eV/°K	7.02e-4
TBGBSUB	Bandgap temperature coefficient	°K	1108.0
KT1	Temperature coefficient for the threshold voltage	Volt	0.0
KT1L	Channel length dependence of the temperature coefficient for the threshold voltage	Volt-Meter	0.0

TSS	Subthreshold swing temperature coefficient	1/°K	0.0
IIT	Impact ionization temperature coefficient (IIMOD=1)	None	-0.5
TII	Impact ionization temperature coefficient (IIMOD=2)	None	0.0
TGIDL	GISL/GIDL temperature coefficient	1/°K	-0.003
IGT	Gate current temperature coefficient	None	2.5
TCJ	Temperature coefficient for CJS/CJD	1/°K	0.0
TCJSW	Temperature coefficient for CJSWS/CJSWD	1/°K	0.0
TCJSWG	Temperature coefficient for CJSWGS/CJSWGD	1/°K	0.0
TPB	Temperature coefficient for PBS/PBD	1/°K	0.0
TPBSW	Temperature coefficient for PBSWS/PBSWD	1/°K	0.0
TPBSWG	Temperature coefficient for PBSWGS/PBSWGD	1/°K	0.0
XTIS	Source junction current temperature exponent	None	3.0
XTID	Drain junction current temperature exponent	None	XTIS
XTSS	Power dependence of JTSS on temperature	None	0.02
XTSD	Power dependence of JTSD on temperature	None	XTSS
XTSSWS	Power dependence of JTSSWS on temperature	None	0.02
XTSSWD	Power dependence of JTSSWD on temperature	None	XTSSWS
XTSSWGS	Power dependence of JTSSWGS on temperature	None	0.02
XTSSWGD	Power dependence of JTSSWGD on temperature	None	XTSSWGS
TNJTS	Temperature coefficient for NJTS	None	0.0
TNJTSD	Temperature coefficient for NJTSD	None	TNJTS
TNJTSSW	Temperature coefficient for NJTSSW	None	0.0
TNJTSSWD	Temperature coefficient for NJTSSWD	None	TNJTSWS
TNJTSSWG	Temperature coefficient for NJTSSWG	None	0.0
TNJTSSWGD	Temperature coefficient for NJTSSWGD	None	TNJTSWGS
Self-Heating			
RTH0	Thermal resistance for self-heating calculation	Ohm-Meter-°K/W	0.01
CTH0	Thermal capacitance for self-heating calculation	W-s/Meter/°K	1.0e-5

WTH0	Width-dependent coefficient for self-heating calculation	Meter	0.0

Table 7: Level 57 MOSFET Binning Model Parameters

Model Parameter	Description	Unit	Default
LMIN	Minimum channel length	Meter	None
LMAX	Maximum channel length	Meter	None
NFINMIN	Minimum number of fingers	None	None
NFINMAX	Maximum number of fingers	None	None

Notes on BSIM-CMG Binning Adjustment

Binning is a way to extend a single device architecture by providing systematic variations on the device parameters. The philosophy is that when you vary the channel geometry, other parameters also change, in ways that can be completely characterized by the device manufacturer. The manufacturer or foundry provides a “design kit” that contains a set of .MODEL statements specifying the parameter settings for the different geometries. The design kit with the .MODEL statements can be included in the Nexxim design as a subcircuit.

1. A binning model is identified by giving the model name in the .MODEL statement the form *modelname***.***n*, where the entry *n* after the decimal point can be an integer or any other unique identifier. The MOSFET instance definition refers to the *modelname* without any extension. The netlist can contain any number of different binning models with the same base *modelname*. For example, three binning models could be named NMOSBSIM-CMG.1 NMOSBSIM-CMG.2, and NMOSBSIM-CMG.3. The instance statement reference is NMOSBSIM-CMG.

   Each of the available binning models corresponds to a range of channel lengths (parameter L) and numbers of fingers (NFIN). The range is specified with the **LMIN**, **LMAX**, **NFINMIN**, and **NFINMAX** model parameters. The ranges must not overlap.

   Each binning model specifies values for the model parameters that are related to the channel geometry variations.

2. The MOSFET instance statement must contain values for instance parameters **L** and **NFIN**. The **L** and **NFIN** parameters can be specified with variables so a sweep of binning models can be performed.
3. The simulator finds the binning model to which the following conditions BOTH apply:
   - The **LMIN** and **LMAX** model parameter range includes the value of instance parameter **L**.
   - The **NFINMIN** and **NFINMAX** model parameter range includes the value of instance parameter **NFIN**.

If none of the available binning models matches the **L** and **NFIN** instance parameters, simulation does not proceed.

4. The value of each binned model parameter (such as **VSAT**) is adjusted using the model parameter **DLBIN** and one or more dependency parameters:

A length-dependent term adds **L** to the parameter name (**LVSAT**).

A number-of-fingers-dependent term adds **N** to the parameter name (**NVSAT**).

A term that depends on the product **L** *__NFIN__ adds **P** to the parameter name (**PVSAT**).

5. The formula for the adjustment uses the following symbols:

val= value of the model parameter, for example **VSAT**.

Lval = value of the length dependence parameter (e.g., **LVSAT**).

Nva l= value of the number-of-fins dependence parameter (e.g., **NVSAT**).

Pval = value of the cross dependence parameter (e.g., **PVSAT**).

Leff = effective channel length (calculated from **L** using scale factors and other adjustments).

VAL =adjusted value.

$$VAL = \frac{10^{-6}}{L_{eff} + DLBIN} \cdot Lval + \frac{1.0}{NFIN} \cdot Nval + \frac{10^{-6}}{NFIN(L_{eff} + DLBIN)} \cdot Pval$$

Here is a table of the binnable parameters.

Table 8: Level 72 MOSFET Binnable Parameters

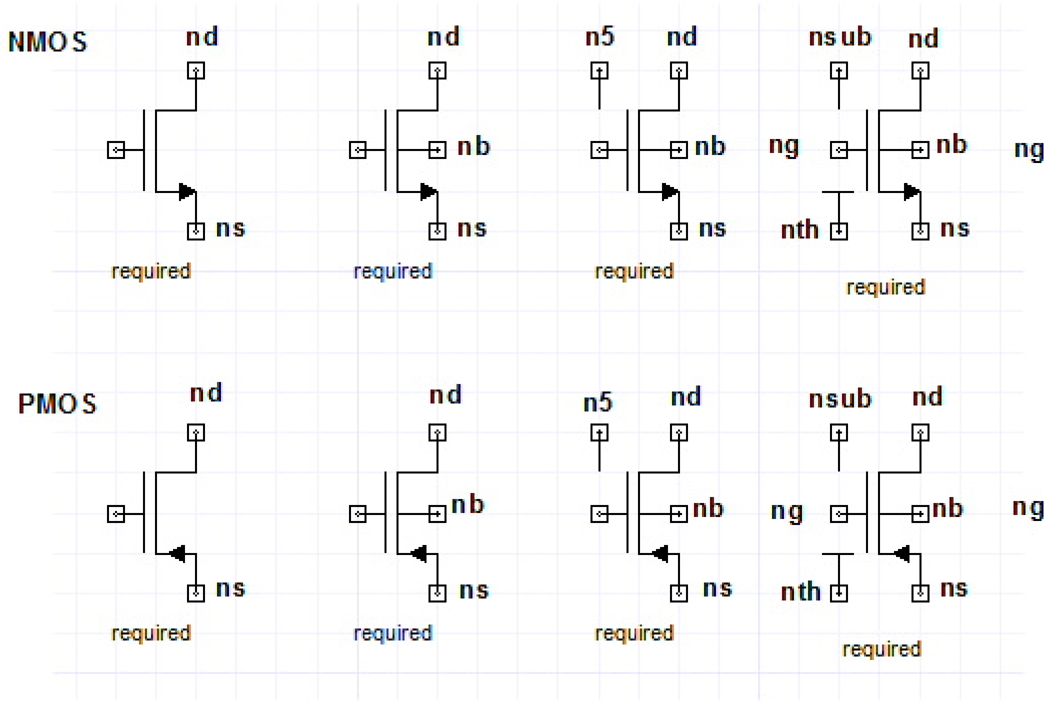
CIT	CDSC	CDSCD	CDSCDR	DVT0	DVT1
DVT1SS	PHIN	ETA0	DSUB	K1RSCE	LPE0
K0	K0SI	K1SI	DVTSHIFT	PHIBE	K1
K1SAT	QMFACTOR	QMTCENIV	QMTCENCV	QMTCENCVA	VSAT
VSAT1	VSAT1R	DELTAVSAT	PSAT	KSATIV	VSATCV
DELTAVSATCV	PSATCV	MEXP	PTWG	PTWGR	A1
A2	U0	ETAMOB	UP	UA	UC

EU	UD	UCS	PCLM	PCLMG	RDSW
RSW	RDW	PRWGS	PRWGD	PDIBL1	PDIBL1R
PDIBL2	DROUT	PVAG	NTOX	AIGBINV	BIGBINV
CIGBINV	EIGBINV	NIGBINV	AIGBACC	BIGBACC	CIGBACC
WR	NIGBACC	AIGC	BIGC	CIGC	
PIGCD	AIGS	BIGS	CIGS	AIGD	BIGD
CIGD	POXEDGE	AGIDL	BGIDL	CGIDL	EGIDL
PGIDL	AGISL	BGISL	CGISL	EGISL	PGISL
ALPHA0	ALPHA1	ALPHAII0	ALPHAII1	BETA0	BETAII0
BETAII1	BETAII2	ESATII	LII	SII0	SII1
SII2	SIID	PCLMCV	CFS	CFD	CGSL
CGDL	CKAPPAS	CKAPPAD	NTGEN	AIGEN	BIGEN
XRCRG1	XRCRG2	KT1	TSS	UTE	UTL
EMOBT	UA1	UC1	UD1	UCSTE	AT
A11	A21	K01	K0SI1	K11	K1SI1
K1SAT1	PTWGT	PRT	IIT	TII	TGIDL
IGT	AIGBINV1	AIGBACC1	AIGC1	AIGS1	AIGD1
NBODY	PHIG	NGATE	ETA0R	DVTB	LPEB
MEXPR	COVS	COVD	CGBL	CKAPPAB	STTHETASAT

BSIM-CMG MOSFET Model Netlist Example

```
.MODEL moscmg1 NMOS LEVEL=72
```

MOSFET Instance, HiSIM HV (Level 73)



HiSIM HV FET Instance Netlist Syntax

The syntax for a Level 73 HiSIM HVFET instance is:

```
Mxxxx nd ng ns [nb] [nsub] [nth] modelname

[instance_parameter=val]
```

nd is the drain node, *ng* is the gate node, *ns* is the source node, *nb* is the bulk node, *nsub* is the substrate node, and *nth* is the thermal node of the MOSFET. For the 5-pin instances, node *n5* is *nth* when **COSUBNODE** =0 and *nsub* when **COSUBNODE** =1.

modelname is the name of a Level 73 FET model defined in a .MODEL statement elsewhere in the netlist.

Table 1: HiSIM HVMOS Instance Parameters

Instance Parameter	Description	Unit	Default
L	Channel length	Meter	2.0e-6
W	Channel width	Meter	5.0e-6

AD	Drain area	Meter^2	0.0
AS	Source area	Meter^2	0.0
PD	Drain perimeter	Meter	0.0
PS	Source perimeter	Meter	0.0
NRD	Number of squares for drain	Square	1.0
NRS	Number of squares for source	Square	1.0
XGL	Offset of gate length	Meter	0.0
XGW	Distance from gate contact to channel edge	Meter	0.0
NF	Number of gate fingers	None	1.0
NGCON	Number of gate contacts	None	1.0
M	Multiplier for multiple parallel transistors	None	1.0
RBDB	Substrate resistance network	Ohm	50.0
RBPB	Substrate resistance network	Ohm	50.0
RBPD	Substrate resistance network	Ohm	50.0
RBPS	Substrate resistance network	Ohm	50.0
RBSB	Substrate resistance network	Ohm	50.0
SA	Length of diffusion between gate and STI	Meter	0.0
SB	Length of diffusion between gate and STI	Meter	0.0
SD	Length of diffusion between gate and gate	Meter	0.0
DTEMP	Difference between device and circuit temperatures	°C	0.0
NSUBCDFM	Substrate impurity concentration	1/cm^3	None
SUBLD1	Parameter for impact-ionization current in the drift region	None	0.0
SUBLD2	Parameter for impact-ionization current in the drift region	None	0.0
LDRIFT1	Parameter for drift region length #1	None	1e-6
LDRIFT2	Parameter for drift region length #2	None	1e-6
LDRIFT1S	Parameter for drift region length #1 on the source side	None	None
LDRIFT2S	Parameter for drift region length #2 on the source side	None	None
LOVERLD	Overlap length on the drain side	Meter	1e-6

LOVER	Overlap length at source side for LOVERS	Meter	None
LOVERS	Overlap length on source side	Meter	None
COSELFHEAT	Calculation of self heating model	None	0
COSUBNODE	Node n5=nth (0) or n5=nsub(1)	None	0
NPEXT	Maximum concentration of pocket tail	cm^{-3}	5e17
FALPH	Parameter for 1/f noise	None	1.0
RD	Drain contact resistance	Ohm	0.0
RS	Source contact resistance	Ohm	0.0
RD22	Vbs dependence of RD for CORSRD=2,3	Ohm-m/$V^{RD22D+1}$	0
RD23	Modification of RD for CORSRD=2,3	Ohm-m/V^{RD21}	5e-3
RD24	Vgs dependence of RD for CORSRD=2,3	Ohm-m/V^{RD21+1}	0.0
RDVG11	Vgs dependence of RD for CORSRD=1,3	None	0.0
RDICT1	LDRIFT1 dependence of resistance for CORSRD=1,3	None	1.0
RDOV13	Alternative LOVER dependence model for CORSRD	None	1.0
RDSLP1	LDRIFT1 dependence of resistance for CORSRD=1,3	None	0.0
RDVB	Vbs dependence of RD for CORSRD=1,3	1/V	0.0
RDVD	Vds dependence of RD for CORSRD=1,3	Ohm/V	7e-2
RTH0	Thermal resistance	Kmc/W	0.1
VOVER	Velocity overshoot effect	$Meter^{VOVERP}$	0.3
CGBO	Gate-to-bulk overlap capacitance	F/Meter	0.0
CVDSOVER	Modification of the Cgg spikes for Vds <>0	None	0.0
POWRAT	Thermal dissipation	None	1.0

HiSIM HV IGFET Model, Level 73

The syntax for a HiSIM FETs model is:

```
.MODELmodelname NMOS LEVEL=73 [model_parameter=val] ...
```

or

`.MODELmodelname PMOS LEVEL=73 [parameter=val] ...`

modelname is the name used by MOSFET instances to refer to this .MODEL statement. The **LEVEL=73** entry selects the HiSIM (Hiroshima University STARC IGFET Model).

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Table 1: HiSIM HV Selector Parameters

Model Parameter	Description	Unit	Default
LEVEL	73 is required to select the HiSIM HV FET model	None	1 (default if LEVEL parameter is omitted)
CORSRD	RS/RD contact resistor inclusion selector	None	3
CORG	Activate sheet resistance (1) or do not activate (0)	None	0
COIPRV	Use ids_prv as initial guess of Ids	None	0
COPPRV	Use psX_prv as initial guess of prX (X=0|1)	None	0
COADOV	Switch to add overlap capacitances to intrinsic ones	None	1 (yes)
COISUB	Switch to calculate substrate current	None	0 (no)
COIIGS	Switch to calculate gate tunneling current	None	0 (no)
COGIDL	Switch to calculate gate induced drain leakage (GIDL) current	None	0 (no)
COFLICK	Switch to calculate flicker noise	None	0 (no)
COISTI	Switch to calculate STI	None	0 (no)
CONQS	Switch to calculate NQS	None	0
COTHRML	Switch to calculate thermal noise	None	0 (no)
COIGN	Switch to calculate induced gate noise	None	0 (no)
CODFM	Switch to enable design for manufacturing	None	0 (off)
COQOVSM	Smoothing method for QOVER	None	1
CORBNET	Activate body resistance (1) or do not activate (0)	None	0
COSYM	Model selector for device symmetry	None	0
COOVLP	Calculate overlap charge on the drain side	None	1
COOVLPS	Calculate overlap charge on the source	None	None

	side		
COTEMP	Temperature dependence model	None	0
CORDRIFT	Drift resistance model	None	1
COLDRIFT	Selector for LDRIFT	None	1
COERRREP	Selector for error report	Nne	1
INFO	Info	None	0

Table 2: HiSIM HV MOS Basic Device Parameters

Model Parameter	**Description**	**Unit**	**Default**
TYPE	1=NMOS, -1=PMOS	None	1
VERSION	Version number	None	2.10
TOX	Physical oxide thickness	Meter	7e-9
XLD	Gate-overlap length	Meter	0.0
XWD	Lateral diffusion along the width direction	Meter	0.0
XWDC	Lateral diffusion along the width direction for capacitance	Meter	XWD
TPOLY	Height of the gate poly-Si for fringing capacitance	Meter	200e-9
LL	Coefficient of gate length modification	None	0.0
LLD	Coefficient of gate length modification	None	0.0
LLN	Coefficient of gate length modification	None	0.0
WL	Coefficient of gate width modification	None	0.0
WLD	Coefficient of gate width modification	None	0.0
WLN	Coefficient of gate width modification	None	0.0
NSUBC	Substrate impurity concentration	cm^{-3}	3.0e17
NSUBP	Maximum pocket concentration	cm^{-3}	1.0e18
LP	Pocket potential length	Meter	15e-9
LPEXT	Extension length of pocket tail	Meter	1.0e-50
VFBC	Constant part of flat-band voltage	Volt	-1.0
VBI	Built-in potential	Volt	1.1
KAPPA	Dielectric constant for gate dielectric	None	3.9
EG0	Bandgap	eV	1.1785
BGTMP1	Temperature dependence of bandgap	eV/°K	90.25e-6

BGTMP2	Temperature dependence of bandgap	eV/°K^2	1e-7
TNOM	Circuit nominal temperature	°C	27
XL	Difference between real and drawn gate length	Meter	0.0
XW	Difference between real and drawn gate width	Meter	0.0

Table 3: HiSIM HV Velocity Parameters

Model Parameter	**Description**	**Unit**	**Default**
VMAX	Saturation velocity	cm/Second	10e7
VMAXT1	Saturation velocity coefficient	None	0
VMAXT2	Saturation velocity coefficient	None	0
VOVERP	Leff dependence of velocity overshoot	None	0.3
VTMP	Temperature dependence of the saturation velocity	cm/Second	0.0

Table 4: HiSIM HV Quantum Effect Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
QME1	Vgs dependence of quantum mechanical effect	Meter/$Volt^2$	0.0
QME2	Vgs dependence of quantum mechanical effect	Volt	2.0
QME3	Minimum Tox modification	Meter	0.0

Table 5: HiSIM HV Poly Depletion Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
PGD1	Strength of poly depletion effect	Volt	0.0
PGD2	Threshold voltage of poly depletion effect	Volt	1.0
PGD4	Lgate dependence of poly depletion effect	None	0.0

Table 6: HiSIM HV Short Channel Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
PARL2	Depletion width of channel/contact junction	Meter	10e-9

SC1	Magnitude of short-channel effect	None	0.0
SC2	Vds dependence of short-channel effect	Meter/Volt	0.0
SC3	Vbs dependence of short-channel effect	Meter/Volt	0.0
SC4	Vbs dependence of short-channel effect	Meter/Volt	0.0
SCP1	Magnitude of short-channel effect due to pocket	None	0.0
SCP2	Vds dependence of short-channel effect due to pocket	Meter/Volt	0.0
SCP3	Vbs dependence of short-channel effect due to pocket	Meter/Volt	0.0
SCP21	Short-channel-effect modification for small Vds	Volt	0.0
SCP22	Short-channel-effect modification for small Vds	Volt^4	0.0
BS1	Body-coefficient modification by impurity profile	Volt^2	0.0
BS2	Body-coefficient modification by impurity profile	Volt	0.9
PTL	Strength of punchthrough effect	None	0.0
PTP	Strength of punchthrough effect	None	3.5
PT2	Vds dependence of punchthrough effect	None	0.0
PTLP	Channel-length dependence of punchthrough effect	None	1.0
PT4	Vbs dependence of punchthrough effect	None	0.0
PT4P	Vbs dependence of punchthrough effect	None	1.0
GDL	Strength of high-field effect	None	0.0
GDLP	Channel-length dependence of high-field effect	None	0.0
GDLD	Channel-length dependence of high-field effect	None	0.0
GDL	Strength of high-field effect	None	0.0

Table 7: HiSIM HV Mobility Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
BB	High-field mobility degradation	None	NMOS: 2.0 PMOS: 1.0
MUECB0	Coulomb scattering	cm^2/Volt-sec	1000.0

MUECB1	Coulomb scattering	cm^2/Volt-sec	100.0
MUEPH0	Phonon scattering	None	0.3
MUEPH1	Phonon scattering	$[cm^2/(Volt\text{-}sec)] \times (Volt/cm)^{MUEPH0}]$	NMOS: 20.0e3 PMOS: 9.0e3
MUEPHL	Length dependence of phonon mobility reduction	None	0.0
MUEPLP	Length dependence of phonon mobility reduction	None	1.0
MUESR0	Surface-roughness scattering	None	2.0
MUESR1	Surface-roughness scattering	$[cm^2/(Volt\text{-}sec)] \times [(Volt/cm)^{MUESR0}]$	6.0e14
MUESRL	Length dependence of surface roughness mobility reduction	None	0.0
MUESLP	Length dependence of surface roughness mobility reduction	None	1.0
MUETMP	Temperature dependence of phonon scattering	None	1.5
NDEP	Depletion charge contribution on effective electric field	None	1.0
NDEPL	Modification of depletion charge contribution for short-channel case	None	0.0
NDEPLP	Modification of depletion charge contribution for short-channel case	None	1.0
NINV	Inversion charge contribution on effective electric field	None	0.5

Table 8: HiSIM HV Narrow Channel Effect Parameters

Model Parameter	**Description**	**Unit**	**Default**
WFC	Threshold voltage change due to capacitance change	Farad/(cm^2-Meter)	0.0
WVTH0	Threshold voltage shift	None	0.0
NSUBP0	Modification of pocket concentration for narrow width	cm^{-3}	0.0

NSUBWP	Modification of pocket concentration for narrow width	None	1.0
MUEPHW	Phonon-related mobility reduction	None	0.0
MUEPWP	Phonon-related mobility reduction	None	1.0
MUESRW	Change of surface-roughness-related mobility	None	0.0
MUESWP	Change of surface-roughness-related mobility	None	1.0
VTHSTI	Threshold voltage shift due to STI	None	0.0
VDSTI	Vds dependence of STI subthreshold	None	0.0
SCSTI1	The same effect as SC1 but at STI edge	None	0.0
SCSTI2	The same effect as SC2 but at STI edge	None	0.0
NSTI	Substrate-impurity concentration at the STI edge	cm^{-3}	5.0e17
WSTI	Width of the high-field region at the STI edge	Meter	0.0
WSTIL	Channel length dependence of WSTI	None	0.0
WSTILP	Channel length dependence of WSTI	None	1.0
WSTIW	Channel-width dependence of WSTI	None	0.0
WSTIWP	Channel-width dependence of WSTI	None	1.0
WL1	Threshold voltage shift of STI leakage due to narrow channel effect	None	0.0
WL1P	Threshold voltage shift of STI leakage due to narrow channel effect	None	1.0
NSUBPSTI1	Pocket concentration change due to diffusion-region length between gate and STI	Meter	0.0
NSUBPSTI2	Pocket concentration change due to diffusion-region length between gate and STI	Meter	0.0
NSUBPSTI3	Pocket concentration change due to diffusion-region length between gate and STI	Meter	1.0
MUESTI1	Mobility change due to diffusion-region length between gate and STI	None	0.0
MUESTI2	Mobility change due to diffusion-region length between gate and STI	None	0.0
MUESTI3	Mobility change due to diffusion-region length between gate and STI	None	1.0
SAREF	Length of diffusion between gate and STI	Meter	1e-6
SBREF	Length of diffusion between gate and STI	Meter	1e-6
NSUBCW	Parameter for narrow-channel effect	None	0.0

NSUBCWP	Parameter for narrow-channel effect	None	1.0

Table 9: HiSIM HV Small Size Effect Parameters

Model Parameter	Description	Unit	Default
WL2	Threshold voltage shift due to small size effect	None	0.0
WL2P	Threshold voltage shift due to small size effect	None	1.0
MUEPHS	Mobility modification due to small size effect	None	0.0
MUEPSP	Mobility modification due to small size effect	None	1.0
VOVERS	Modification of maximum velocity due to small size effect	None	0.0
VOVERSP	Modification of maximum velocity due to small size effect	None	0.0

Table 10: HiSIM HV Channel Length Modulation Parameters

Model Parameter	Description	Unit	Default
CLM1	Hardness coefficient of channel/contact junction	None	50.0e-3
CLM2	Coefficient for Q_B contribution	None	2.0
CLM3	Coefficient for Q_I contribution	None	1.0
CLM5	Effect of pocket implantation	None	1.0
CLM6	Effect of pocket implantation	None	0.0

Table 11: HiSIM HV Substrate Current Parameters

Model Parameter	Description	Unit	Default
SUB1	Substrate current coefficient of magnitude	$Volt^{-1}$	10
SUB1L	Lgate dependence of SUB1	Meter	2.5e-3
SUB1LP	Lgate dependence of SUB1	None	1.0
SUB2	Substrate current coefficient of exponential term	Volt	25
SUB2L	Lgate dependence of SUB2	Meter	2.0e-6
SVDS	Substrate current dependence on Vds	None	0.8
SLG	Substrate current dependence on Lgate	Meter	30e-9
SLGL	Substrate current dependence on Lgate	$Meter^{SLGLP}$	0.0
SLGLP	Substrate current dependence on Lgate	None	1.0

SVBS	Substrate current dependence on Vbs	None	0.5
SVBSL	Lgate dependence of SVBS	Meter^{SLBSLP}	0.0
SVBSLP	Lgate dependence of SVBS	None	1.0
SVGS	Substrate current dependence on Vgs	None	0.8
SVGSL	Lgate dependence of SVGS	Meter^{SVGSLP}	0.0
SVGSLP	Lgate dependence of SVGS	None	1.0
SVGSW	Wgate dependence of SVGS	Meter^{SVGSWP}	0.0
SVGSWP	Wgate dependence of SVGS	None	1.0

Table 12: HiSIM HV II-Induced Bulk Potential Change Parameters

Model Parameter	**Description**	**Unit**	**Default**
IBPC1	Impact-ionization induced bulk potential change	Volt/Ampere	0.0
IBPC1L	Impact-ionization induced bulk potential change	Volt/Ampere	0.0
IBPC1LP	Impact-ionization induced bulk potential change	Volt/Ampere	-1
IBPC2	Impact-ionization induced bulk potential change	Volt^{-1}	0.0

Table 13: HiSIM HV Impact Ionization Current Parameters

Model Parameter	**Description**	**Unit**	**Default**
SUBLD1L	Impact-ionization current in the drift region	Ampere	0.0
SUBLD1LP	Impact-ionization current in the drift region	Ampere	1.0
XPDV	Impact-ionization current in the drift region		0.0
XPVDTH	Impact-ionization current in the drift region		0.0
XPVDTHG	Impact-ionization current in the drift region		0.0

Table 14: HiSIM HV Gate Leakage Current Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
GLEAK1	Gate to channel current coefficient	Amp/(Volt$^{3/2}$ x °C)	50.0
GLEAK2	Gate to channel current coefficient	1/(V$^{0.5}$x Meter)	10e6

GLEAK3	Gate to channel current coefficient	None	60.0e-3
GLEAK4	Gate to channel current coefficient	1/Meter	4.0
GLEAK5	Gate to channel current coefficient (short channel correction)	Volt/Meter	7.5e3
GLEAK6	Gate to channel current coefficient (Vds dependence correction)	Volt	250e-3
GLEAK7	Gate to channel current coefficient (gate length and width dependence correction	Meter^2	1e-6
IGTEMP2	Temperature dependence of gate leakage	Volt-°K	0.0
IGTEMP3	Temperature dependence of gate leakage	Volt-°K^2	0.0
GLKSD1	Gate to source/drain current coefficient	Ampere-Meter/Volt^2	1e-15
GLKSD2	Gate to source/drain current coefficient	1/(Volt-Meter)	1e3
GLKSD3	Gate to source/drain current coefficient	1/Meter	1e-3
GLKB1	Gate to bulk current coefficient	Ampere/Volt^2	5.0e-16
GLKB2	Gate to bulk current coefficient	Meter/Volt	1.0
GLKB3	Flat-band shift for gate to bulk current	Volt	0.0
GLPART1	Partitioning ration of gate leakage current	None	0.5
FN1	Coefficient of Fowler-Nordheim current contribution	Meter^2/Volt$^{1.5}$	50
FN2	Coefficient of Fowler-Nordheim current contribution	1/(Meter-Volt$^{0.5}$)	170e-6
FN3	Coefficient of Fowler-Nordheim current contribution	Volt	0.0
FVBS	Vbs dependence of Fowler-Nordheim current	None	12e-3
EGIG	Parameter for gate current	None	0.0

Table 15: HiSIM HV GIDL Current Parameters

Model Parameter	**Description**	**Unit**	**Default**
GIDL1	Magnitude of GIDL	(Meter- Amp)/(Volt$^{3/2}$ - °C)	2.0
GIDL2	Field dependence of GIDL	V^{-2}x Meter^{-1}x Farad$^{-3/2}$	3.0e7
GIDL3	Vds dependence of GIDL	None	0.9
GIDL4	Threshold of Vds dependence	Volt	0.0
GIDL5	Correction of high-field contribution	None	0.2

Table 16: HiSIM HV Symmetry Conservation at Vds=0, Short Channel Model Parameters

Model Parameter	Description	Unit	Default
VZADD0	Symmetry conservation coefficient	Volt	10e-3
PZADD0	Symmetry conservation coefficient	Volt	5e-3
DDLTMAX	Smoothing coefficient for Vds	None	10.0
DDLTSLP	Lgate dependence of smoothing coefficient	None	0.0
DDLTICT	Lgate dependence of smoothing coefficient	None	10.0

Table 17: HiSIM HV Source/Bulk and Drain/Bulk Diode Parameters

Model Parameter	Description	Unit	Default
JS0	Saturation current density	Amp/Meter^2	0.5e-6
JS0SW	Sidewall saturation current density	Amp/Meter	0.0
NJ	Emission coefficient	None	1.0
NJSW	Sidewall emission coefficient	None	1.0
XTI	Temperature coefficient for forward current densities	None	2.0
XTI2	Temperature coefficient for forward current densities	None	0.0
DIVX	Reverse temperature coefficient	1/Volt	0.0
CTEMP	Temperature coefficient of reverse currents	None	0.0
CISB	Reverse-biased saturation current	Ampere	0.0
CISBK	Reverse-biased saturation current at low temperature	Ampere	0.0
CVB	Bias dependence coefficient of CISB	None	0.0
CVBK	Bias dependence coefficient of CISB at low temperature	None	CVB
CJ	Bottom junction capacitance per unit area at zero bias	Farad/Meter^2	5.0e-4
CJSW	Source-drain sidewall junction capacitance per unit length at zero bias	Farad/Meter	5.0e-10
CJSWG	Source-drain sidewall junction capacitance per unit length at zero bias	Farad/Meter	5.0e-10
MJ	Bottom junction capacitance grading coefficient	None	0.5
MJSW	Bulk junction sidewall grading coefficient	None	0.33

MJSWG	Source/drain sidewall junction capacitance grading coefficient	None	0.33
PB	Bulk junction built-in potential	Volt	1.0
PBSW	Source-drain sidewall junction built-in potential	Volt	1.0
PBSWG	Source-drain gate sidewall junction built-in potential	Volt	1.0
VDIFFJ	Diode threshold voltage between source/drain and substrate	Volt	0.6e-3
TCJBD	Temperature dependence of CJBD	None	0.0
TCJBS	Temperature dependence of CJBS	None	0.0
TCJBDSW	Temperature dependence of CJBDSW	None	0.0
TCJBSSW	Temperature dependence of CJBSSW	None	0.0
TCJBDSWG	Temperature dependence of CJBDSWG	None	0.0
TCJBSSWG	Temperature dependence of CJBSSWG	None	0.0

Table 18: HiSIM HV Diode Parameters for COASYM=1

Model Parameter	**Description**	**Unit**	**Default**
JS0D	Saturation current density for drain junction	Amp/Meter^2	JS0
JS0SWD	Sidewall saturation current density for drain junction	Amp/Meter	JS0SW
NJD	Emission coefficient for drain junction	None	NJ
NJSWD	Sidewall emission coefficient for drain junction	None	NJSW
XTID	Temperature coefficient for forward current densities for drain junction	None	XTI
XTI2D	Temperature coefficient for forward current densities for drain junction	None	XTI2
DIVXD	Reverse temperature coefficient for drain junction	1/Volt	DIVX
CTEMPD	Temperature coefficient of reverse currents for drain junction	None	CTEMP
CISBD	Reverse-biased saturation current for drain junction	Ampere	CISB
CISBKD	Reverse-biased saturation current at low temperature for drain junction	Ampere	CISBK

CVBD	Bias dependence coefficient of CISB for drain junction	None	CVB
CJD	Bottom junction capacitance per unit area at zero bias for drain junction	Farad/Meter^2	CJ
CJSWD	Source-drain sidewall junction capacitance per unit length at zero bias for drain junction	Farad/Meter	CJSW
CJSWGD	Source-drain sidewall junction capacitance per unit length at zero bias for drain junction	Farad/Meter	CJSWG
MJD	Bottom junction capacitance grading coefficient for drain junction	None	MJ
MJSWD	Bulk junction sidewall grading coefficient for drain junction	None	MJSW
MJSWGD	Source/drain sidewall junction capacitance grading coefficient for drain junction	None	MJSWG
PBD	Bulk junction built-in potential for drain junction	Volt	PB
PBSWD	Source-drain sidewall junction built-in potential for drain junction	Volt	PBSW
PBSWGD	Source-drain gate sidewall junction built-in potential for drain junction	Volt	PBSWG
VDIFFJD	Diode threshold voltage between source/drain and substrate for drain junction	Volt	VDIFFJ
JS0S	Saturation current density for source junction	Amp/Meter^2	JS0D
JS0SWS	Sidewall saturation current density for source junction	Amp/Meter	JS0SWD
NJS	Emission coefficient for source junction	None	NJD
NJSWS	Sidewall emission coefficient for source junction	None	NJSWD
XTIS	Temperature coefficient for forward current densities for source junction	None	XTID
XTI2S	Temperature coefficient for forward current densities for source junction	None	XTI2D
DIVXS	Reverse temperature coefficient for source junction	1/Volt	DIVXD
CTEMPS	Temperature coefficient of reverse currents for source junction	None	CTEMPD
CISBS	Reverse-biased saturation current for source	Ampere	CISBD

	junction		
CISBKS	Reverse-biased saturation current at low temperature for source junction	Ampere	CISBKD
CVBS	Bias dependence coefficient of CISB for source junction	None	CVBD
CJS	Bottom junction capacitance per unit area at zero bias for source junction	Farad/Meter^2	CJD
CJSWS	Source-drain sidewall junction capacitance per unit length at zero bias for source junction	Farad/Meter	CJSWD
CJSWGS	Source-drain sidewall junction capacitance per unit length at zero bias for source junction	Farad/Meter	CJSWGD
MJS	Bottom junction capacitance grading coefficient for source junction	None	MJD
MJSWS	Bulk junction sidewall grading coefficient for source junction	None	MJSWD
MJSWGS	Source/drain sidewall junction capacitance grading coefficient for source junction	None	MJSWGD
PBS	Bulk junction built-in potential for source junction	Volt	PBD
PBSWS	Source-drain sidewall junction built-in potential for source junction	Volt	PBSWD
PBSWGS	Source-drain gate sidewall junction built-in potential for source junction	Volt	PBSWGD
VDIFFJS	Diode threshold voltage between source/drain and substrate for source junction	Volt	VDIFFJD

Table 19: HiSIM HV 1/f Noise Model Parameters

Model Parameter	**Description**	**Unit**	**Default**
CIT	Capacitance caused by the interface trapped carriers	Farad/cm^2	0.0
NFALP	Contribution of the mobility fluctuation	Volt-sec	1.0e-19
NFTRP	Ratio of trap density to attenuation coefficient	Volt^{-1}x cm^{-2}	10.0e9

Table 20: HiSIM HV Non-Quasi-Static Model Parameters

Model Parameter	Description	Unit	Default
DLY1	Coefficient for delay due to diffusion of carriers	Second	100e-12
DLY2	Coefficient for delay due to conduction of carriers	None	0.7
DLY3	Coefficient for RC delay of bulk carriers	Ohm	0.8e-6

Table 21: HiSIM HV Capacitance Parameters

Model Parameter	Description	Unit	Default
CGDO	Gate-drain overlap capacitance	Farad/Meter	0.0
CGSO	Gate-source overlap capacitance	Farad/Meter	0.0
XQY	Distance from drain junction to maximum electric field point	Meter	0.0
XQY1	Vbs dependence of Qy	Farad-μm^{XQY2-1}	0.0
XQY2	Lgate dependence of Qy	None	2.0
NOVER	Impurity concentration in the overlap region	cm^{-3}	3e16
NOVERS	Impurity concentration in the overlap region at source, COSYM=1	cm^{-3}	1e17
OVSLP	Coefficient for overlap capacitance	None	2.1e-7
OVMAG	Coefficient for overlap capacitance	Volt	0.6
VFBOVER	Flatband voltage in overlap region	Volt	-0.5
RDOV11	Dependence coefficient for overlap length	None	0.0
RDOV12	Dependence coefficient for overlap length	None	1.0
RDSLP2	LDRIFT2 dependence of resistance for CORSRD=1	None	1.0
RDICT2	LDRIFT2 dependence of resistance for CORSRD=1	None	0.0

Table 22: HiSIM HV Parasitic Resistance Parameters

Model Parameter	Description	Unit	Default
RSH	Source/drain sheet resistance	(Volt-square)/Ampere	0.0
RSHG	Gate sheet resistance	(Volt-square)/Ampere	0.0
GBMIN	Substrate resistance network	None	1.0e-12

Table 23: HiSIM HV Miscellaneous Parameters

Model Parameter	Description	Unit	Default
XLDLD	Gate overlap length at drain side	Meter	1.0e-6
XWDLD	Widening of drift width	Meter	XWD
DLYOV	Coefficient for RC delay of carriers	Second/Farad	0
MPHDFM	NSUBCDFM dependence of phonon scattering for DFM		-0.3
RDVG12	Vgs dependence of RD for CORSRD=1,3	None	100.0
CTH0	Thermal capacitance	Watt-second/°K	1.0e-7
QDFTVD	Vd dependence of QDRIFT	None	1.0
RD20	RD23 boundary for CORSD=2,3	None	0.0
RD21	Vds dependence of RD for CORSD=2,3	None	1.0
RD22D	Vbs dependence of RD for CORSRD=2,3 with large Vds	None	0.0
RD25	Vgs dependence of RD for CORSD=2,3	Volt	0.0
RDVDL	Lgate dependence of RD for CORSD=1,3	None	0.0
RDVDLP	Lgate dependence of RD for CORSD=1,3	None	1.0
RDVDS	Small size dependence of RD for CORSD=1,3	None	0.0
RDVDSP	Small size dependence of RD for CORSD=1,3	None	1.0
RD23L	Lgate dependence of RD21 boundary for CORSD=2,3	None	0.0
RD23LP	Lgate dependence of RD21 boundary for CORSD=2,3	None	1.0
RD23S	Small size dependence of RD21 for CORSD=2,3	None	0.0
RD23SP	Small size dependence of RD21 for CORSD=2,3	None	1.0
RDS	Small size dependence of RD21 for CORSD=1,3	None	0.0
RDSP	Small size dependence of RD21 for CORSD=1,3	None	1.0
RDTEMP1	Temperature dependence of resistance for	None	0.0

	CORDRIFT=0		
RDTEMP2	Temperature dependence of resistance for CORDRIFT=0	None	0.0
RTH0R	Thermal dissipation	None	0.0
RDVDTEMP1	Temperature dependence of RDVD	None	0.0
RDVDTEMP2	Temperature dependence of RDVD	None	0.0
RTH0W	Width-dependence of RTH0	None	0.0
RTH0WP	Width-dependence of RTH0	None	1.0
RTH0NF	NF-dependence of RTH0	None	0.0
NINVD	Modification of VDSE dependence on Eeff	None	0.0
NINVDW	Coefficient of modification of VDSE dependence on Eeff	None	0.0
NINVDWP	Coefficient of modification of VDSE dependence on Eeff	None	1.0
NINVDT1	Coefficient of modification of VDSE dependence on Eeff	None	0.0
NINVDT2	Coefficient of modification of VDSE dependence on Eeff	None	0.0
VBSMIN	Minimum back-bias voltage to be treated in HSMH eva;luation	Volt	-10.5
RTHTEMP1	Thermal resistance	Ohm	0.0
RTHTEMP2	Thermal resistance	Ohm	0.0
PRATTEMP1	Temperature dependence of thermal dissipation	None	0.0
PRATTEMP2	Temperature dependence of thermal dissipation	None	0.0
RDVSUB	Model parameter for the substrate effect	None	1.0
RDVDSUB	Model parameter for the substrate effect	None	0.3
DDRIFT	Depth of the drift region	Meter	1e-6
VBISUB	Model parameter for the substrate effect	None	0.7
NSUBSUB	Model parameter for the substrate effect	None	1e15
RDRMUE	Field-dependent mobility in the drift region for CORDRIFT=1	None	1e3
RDRVMAX	Saturation velocity in the drift region for CORDRIFT=1	None	3e7

RDRMUETMP	Temperature dependence of resistance for CORDRIFT=1	None	0.0
RDRVTMP	Temperature dependence of resistance for CORDRIFT=1	None	0.0
RDRDJUNC	Junction depth at channel/drift region	Meter	1e-6
RDRCX	Exude of current flow from Xov	None	0.0
RDRCAR	High-field injection in drift region	None	1e-8
RDRDL1	Effective Ldrift of current in drift region	Meter	0.0
RDRDL2	Pinch-off length in drift region	Meter	0.0
RDRVMAXW	Saturation velocity Wgate dependence	None	0.0
RDRVMAXWP	Saturation velocity Wgate dependence	None	1.0
RDRVMAXL	Saturation velocity Lgate dependence	None	0.0
RDRVMAXLP	Saturation velocity Lgate dependence	None	1.0
RDRMUEL	Mobility in drift region Lgate dependence	None	0.0
RDRMUELP	Mobility in drift region Lgate dependence	None	1.0
RDRQOVER	Inclusion of the overlap charge into Rdrift	None	1e5
QOVADD	Parameter for additional Qover charge	None	0.0
SHEMAX	Maximum temperature rise for Self-Heating Effect	°K	500
VGSMIN	Minimal/maximal expected Vgs (NMOS/PMOS)	Volt	Calculated
GDSLEAK	Channel leakage conductance	Mho	0.0
RDRBB	Degradation of the mobility in the drift region	None	1
GMIN	Minimum conductance	Mho	GBMIN
RMIN	Minimum resistance for RS/RD	Ohm	1e-4

Table 24: HiSIM HV Binning Parameters

Model Parameter	**Description**	**Unit**	**Default**
LMIN	Minimum gate length	Meter	0.0
LMAX	Maximum gate length	Meter	1.0
WMIN	Minimum gate width	Meter	0.0
WMAX	Maximum gate width	Meter	1.0
LBINN			1.0

WBINN			1.0

Table 25: HiSIM HV Length Dependence Parameters

Model Parameter	Description	Unit	Default
LVMAX	Length dependence of Vmax	None	0.0
LBGTMP1	Length dependence of Bgtmp1	None	0.0
LBGTMP2	Length dependence of Bgtmp2	None	0.0
LEG0	Length dependence of Eg0	None	0.0
LVFBOVER	Length dependence of Vfbover	None	0.0
LNOVER	Length dependence of Nover	None	0.0
LNOVERS	Length dependence of Nover on source side	None	0.0
LWL2	Length dependence of WL2	None	0.0
LVFBC	Length dependence of Vfbc	None	0.0
LNSUBC	Length dependence of Nsubc	None	0.0
LNSUBP	Length dependence of Nsubp	None	0.0
LSCP1	Length dependence of Scp1	None	0.0
LSCP2	Length dependence of Scp2	None	0.0
LSCP3	Length dependence of Scp3	None	0.0
LSC1	Length dependence of Sc1	None	0.0
LSC2	Length dependence of Sc2	None	0.0
LSC3	Length dependence of Sc3	None	0.0
LPGD1	Length dependence of Pgd1	None	0.0
LNDEP	Length dependence of Ndep	None	0.0
LNINV	Length dependence of Ninv	None	0.0
LMUECB0	Length dependence of MUecb0	None	0.0
LMUECB1	Length dependence of MUecb1	None	0.0
LMUEPH1	Length dependence of MUeph1	None	0.0
LVTMP	Length dependence of Vtmp	None	0.0
LWVTH0	Length dependence of Wvth0	None	0.0
LMUESR1	Length dependence of MUesr1	None	0.0
LMUETMP	Length dependence of MUetmp	None	0.0

LSUB1	Length dependence of sub1	None	0.0
LSUB2	Length dependence of sub2	None	0.0
LSVDS	Length dependence of SVDS	None	0.0
LSVBS	Length dependence of SVBS	None	0.0
LSVGS	Length dependence of SVGS	None	0.0
LFN1	Length dependence of FN1	None	0.0
LFN2	Length dependence of FN2	None	0.0
LFN3	Length dependence of FN3	None	0.0
LFVBS	Length dependence of Vfbs	None	0.0
LNSTI	Length dependence of NSTI	None	0.0
LWSTI	Length dependence of Wsti	None	0.0
LSCSTI1	Length dependence of SCSTI1	None	0.0
LSCSTI2	Length dependence of SCSTI2	None	0.0
LVTHSTI	Length dependence of Vthsti	None	0.0
LMUESTI1	Length dependence of MUesti1	None	0.0
LMUESTI2	Length dependence of MUesti2	None	0.0
LMUESTI3	Length dependence of MUesti3	None	0.0
LNSUBPSTI1	Length dependence of Nsubpsti1	None	0.0
LNSUBPSTI2	Length dependence of Nsubpsti2	None	0.0
LNSUBPSTI3	Length dependence of Nsubpsti3	None	0.0
LCGSO	Length dependence of Cgso	None	0.0
LCGDO	Length dependence of Cgdo	None	0.0
LCLM1	Length dependence of Clm1	None	0.0
LCLM2	Length dependence of Clm2	None	0.0
LCLM3	Length dependence of Clm3	None	0.0
LWFC	Length dependence of Wfc	None	0.0
LGIDL1	Length dependence of GIDL1	None	0.0
LGIDL2	Length dependence of GIDL2	None	0.0
LGLEAK1	Length dependence of Gleak1	None	0.0
LGLEAK2	Length dependence of Gleak2	None	0.0
LGLEAK3	Length dependence of Gleak3	None	0.0
LGLEAK6	Length dependence of Gleak6	None	0.0

LGLKSD1	Length dependence of Glksd1	None	0.0
LGLKSD2	Length dependence of Glksd2	None	0.0
LGLKB1	Length dependence of Glkb1	None	0.0
LGLKB2	Length dependence of Glkb2	None	0.0
LNFTRP	Length dependence of Nftrp	None	0.0
LNFALP	Length dependence of Nfalp	None	0.0
LIBPC1	Length dependence of Ibpc1	None	0.0
LIBPC2	Length dependence of Ibpc2	None	0.0
LCGBO	Length dependence of CGBO	None	0.0
LCVDSOVER	Length dependence of CVDSOVER	None	0.0
LFALPH	Length dependence of FALPH	None	0.0
LNPEXT	Length dependence of NPEXT	None	0.0
LPOWRAT	Length dependence of POWRAT	None	0.0
LRD	Length dependence of RD	None	0.0
LRD22	Length dependence of RD22	None	0.0
LRD23	Length dependence of RD23	None	0.0
LRD24	Length dependence of RD24	None	0.0
LRDICT1	Length dependence of RDICT1	None	0.0
LRDOV13	Length dependence of RDOV13	None	0.0
LRDSLP1	Length dependence of RDSLP1	None	0.0
LRDVB	Length dependence of RDVB	None	0.0
LRDVD	Length dependence of RDVD	None	0.0
LRDVG11	Length dependence of RDVG11	None	0.0
LRS	Length dependence of RS	None	0.0
LRTH0	Length dependence of RTH0	None	0.0
LVOVER	Length dependence of VOVER	None	0.0
LJS0	Length dependence of Js0	None	0.0
LJS0SW	Length dependence of Js0sw	None	0.0
LNJ	Length dependence of Nj	None	0.0
LCISBK	Length dependence of Cisbk	None	0.0
LVDIFFJ	Length dependence of Vdiffj	None	0.0

LJS0D	Length dependence of Js0D	None	LJS0
LJS0SWD	Length dependence of Js0swD	None	LJS0SW
LNJD	Length dependence of NjD	None	LNJ
LCISBKD	Length dependence of CisbkD	None	LCISBK
LVDIFFJD	Length dependence of VdiffjD	None	LVDIFFJ
LJS0S	Length dependence of Js0S	None	LJS0D
LJS0SWS	Length dependence of Js0swS	None	LJS0SWD
LNJS	Length dependence of NjS	None	LNJD
LCISBKS	Length dependence of CisbkS	None	LCISBKD
LVDIFFJS	Length dependence of VdiffjS	None	LVDIFFJD

Table 26: HiSIM HV Width Dependence Parameters

Model Parameter	**Description**	**Unit**	**Default**
WVMAX	Width dependence of Vmax	None	0.0
WBGTMP1	Width dependence of Bgtmp1	None	0.0
WBGTMP2	Width dependence of Bgtmp2	None	0.0
WEG0	Width dependence of Eg0	None	0.0
WVFBOVER	Width dependence of Vfbover	None	0.0
WNOVER	Width dependence of Nover	None	0.0
WNOVERS	Width dependence of Nover on source side	None	0.0
WWL2	Width dependence of WL2	None	0.0
WVFBC	Width dependence of Vfbc	None	0.0
WNSUBC	Width dependence of Nsubc	None	0.0
WNSUBP	Width dependence of Nsubp	None	0.0
WSCP1	Width dependence of Scp1	None	0.0
WSCP2	Width dependence of Scp2	None	0.0
WSCP3	Width dependence of Scp3	None	0.0
WSC1	Width dependence of Sc1	None	0.0
WSC2	Width dependence of Sc2	None	0.0
WSC3	Width dependence of Sc3	None	0.0
WPGD1	Width dependence of Pgd1	None	0.0

WNDEP	Width dependence of Ndep	None	0.0
WNINV	Width dependence of Ninv	None	0.0
WMUECB0	Width dependence of MUecb0	None	0.0
WMUECB1	Width dependence of MUecb1	None	0.0
WMUEPH1	Width dependence of MUeph1	None	0.0
WVTMP	Width dependence of Vtmp	None	0.0
WWVTH0	Width dependence of Wvth0	None	0.0
WMUESR1	Width dependence of MUesr1	None	0.0
WMUETMP	Width dependence of MUetmp	None	0.0
WSUB1	Width dependence of sub1	None	0.0
WSUB2	Width dependence of sub2	None	0.0
WSVDS	Width dependence of SVDS	None	0.0
WSVBS	Width dependence of SVBS	None	0.0
WSVGS	Width dependence of SVGS	None	0.0
WFN1	Width dependence of FN1	None	0.0
WFN2	Width dependence of FN2	None	0.0
WFN3	Width dependence of FN3	None	0.0
WFVBS	Width dependence of Vfbs	None	0.0
WNSTI	Width dependence of NSTI	None	0.0
WWSTI	Width dependence of Wsti	None	0.0
WSCSTI1	Width dependence of SCSTI1	None	0.0
WSCSTI2	Width dependence of SCSTI2	None	0.0
WVTHSTI	Width dependence of Vthsti	None	0.0
WMUESTI1	Width dependence of MUesti1	None	0.0
WMUESTI2	Width dependence of MUesti2	None	0.0
WMUESTI3	Width dependence of MUesti3	None	0.0
WNSUBPSTI1	Width dependence of Nsubpsti1	None	0.0
WNSUBPSTI2	Width dependence of Nsubpsti2	None	0.0
WNSUBPSTI3	Width dependence of Nsubpsti3	None	0.0
WCGSO	Width dependence of Cgso	None	0.0
WCGDO	Width dependence of Cgdo	None	0.0

WCLM1	Width dependence of Clm1	None	0.0
WCLM2	Width dependence of Clm2	None	0.0
WCLM3	Width dependence of Clm3	None	0.0
WWFC	Width dependence of Wfc	None	0.0
WGIDL1	Width dependence of GIDL1	None	0.0
WGIDL2	Width dependence of GIDL2	None	0.0
WGLEAK1	Width dependence of Gleak1	None	0.0
WGLEAK2	Width dependence of Gleak2	None	0.0
WGLEAK3	Width dependence of Gleak3	None	0.0
WGLEAK6	Width dependence of Gleak6	None	0.0
WGLKSD1	Width dependence of Glksd1	None	0.0
WGLKSD2	Width dependence of Glksd2	None	0.0
WGLKB1	Width dependence of Glkb1	None	0.0
WGLKB2	Width dependence of Glkb2	None	0.0
WNFTRP	Width dependence of Nftrp	None	0.0
WNFALP	Width dependence of Nfalp	None	0.0
WIBPC1	Width dependence of Ibpc1	None	0.0
WIBPC2	Width dependence of Ibpc2	None	0.0
WCGBO	Width dependence of CGBO	None	0.0
WCVDSOVER	Width dependence of CVDSOVER	None	0.0
WFALPH	Width dependence of FALPH	None	0.0
WNPEXT	Width dependence of NPEXT	None	0.0
WPOWRAT	Width dependence of POWRAT	None	0.0
WRD	Width dependence of RD	None	0.0
WRD22	Width dependence of RD22	None	0.0
WRD23	Width dependence of RD23	None	0.0
WRD24	Width dependence of RD24	None	0.0
WRDICT1	Width dependence of RDICT1	None	0.0
WRDOV13	Width dependence of RDOV13	None	0.0
WRDSLP1	Width dependence of RDSLP1	None	0.0
WRDVB	Width dependence of RDVB	None	0.0
WRDVD	Width dependence of RDVD	None	0.0

WRDVG11	Width dependence of RDVG11	None	0.0
WRS	Width dependence of RS	None	0.0
WRTH0	Width dependence of RTH0	None	0.0
WVOVER	Width dependence of VOVER	None	0.0
WJS0	Width dependence of Js0	None	0.0
WJS0SW	Width dependence of Js0sw	None	0.0
WNJ	Width dependence of Nj	None	0.0
WCISBK	Width dependence of Cisbk	None	0.0
WVDIFFJ	Width dependence of Vdiffj	None	0.0
WJS0D	Width dependence of Js0D	None	WJS0
WJS0SWD	Width dependence of Js0swD	None	WJS0SW
WNJD	Width dependence of NjD	None	WNJ
WCISBKD	Width dependence of CisbkD	None	WCISBK
WVDIFFJD	Width dependence of VdiffjD	None	WVDIFFJ
WJS0S	Width dependence of Js0S	None	WJS0D
WJS0SWS	Width dependence of Js0swS	None	WJS0SWD
WNJS	Width dependence of NjS	None	WNJD
WCISBKS	Width dependence of CisbkS	None	WCISBKD
WVDIFFJS	Width dependence of VdiffjS	None	WVDIFFJD

Table 27: HiSIM HV Cross Dependence Parameters

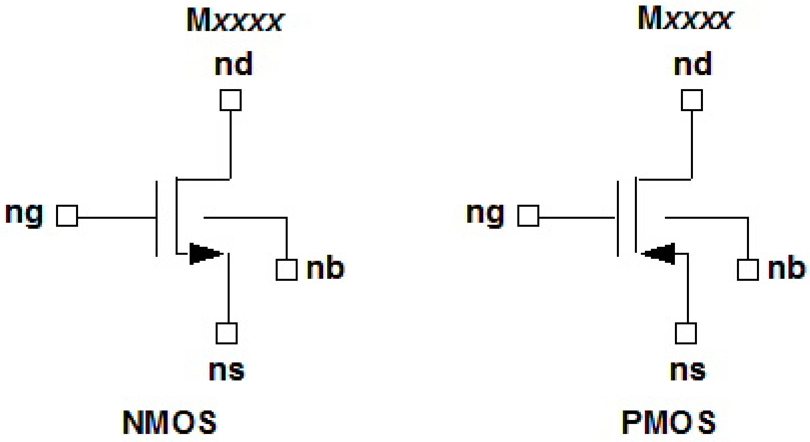
Model Parameter	**Description**	**Unit**	**Default**
PVMAX	Cross dependence of Vmax	None	0.0
PBGTMP1	Cross dependence of Bgtmp1	None	0.0
PBGTMP2	Cross dependence of Bgtmp2	None	0.0
PEG0	Cross dependence of Eg0	None	0.0
PVFBOVER	Cross dependence of Vfbover	None	0.0
PNOVER	Cross dependence of Nover	None	0.0
PNOVERS	Cross dependence of Nover on source side	None	0.0
PWL2	Cross dependence of WL2	None	0.0
PVFBC	Cross dependence of Vfbc	None	0.0

PNSUBC	Cross dependence of Nsubc	None	0.0
PNSUBP	Cross dependence of Nsubp	None	0.0
PSCP1	Cross dependence of Scp1	None	0.0
PSCP2	Cross dependence of Scp2	None	0.0
PSCP3	Cross dependence of Scp3	None	0.0
PSC1	Cross dependence of Sc1	None	0.0
PSC2	Cross dependence of Sc2	None	0.0
PSC3	Cross dependence of Sc3	None	0.0
PPGD1	Cross dependence of Pgd1	None	0.0
PNDEP	Cross dependence of Ndep	None	0.0
PNINV	Cross dependence of Ninv	None	0.0
PMUECB0	Cross dependence of MUecb0	None	0.0
PMUECB1	Cross dependence of MUecb1	None	0.0
PMUEPH1	Cross dependence of MUeph1	None	0.0
PVTMP	Cross dependence of Vtmp	None	0.0
PWVTH0	Cross dependence of Wvth0	None	0.0
PMUESR1	Cross dependence of MUesr1	None	0.0
PMUETMP	Cross dependence of MUetmp	None	0.0
PSUB1	Cross dependence of sub1	None	0.0
PSUB2	Cross dependence of sub2	None	0.0
PSVDS	Cross dependence of SVDS	None	0.0
PSVBS	Cross dependence of SVBS	None	0.0
PSVGS	Cross dependence of SVGS	None	0.0
PFN1	Cross dependence of FN1	None	0.0
PFN2	Cross dependence of FN2	None	0.0
PFN3	Cross dependence of FN3	None	0.0
PFVBS	Cross dependence of Vfbs	None	0.0
PNSTI	Cross dependence of NSTI	None	0.0
PWSTI	Cross dependence of Wsti	None	0.0
PSCSTI1	Cross dependence of SCSTI1	None	0.0
PSCSTI2	Cross dependence of SCSTI2	None	0.0
PVTHSTI	Cross dependence of Vthsti	None	0.0

PMUESTI1	Cross dependence of MUesti1	None	0.0
PMUESTI2	Cross dependence of MUesti2	None	0.0
PMUESTI3	Cross dependence of MUesti3	None	0.0
PNSUBPSTI1	Cross dependence of Nsubpsti1	None	0.0
PNSUBPSTI2	Cross dependence of Nsubpsti2	None	0.0
PNSUBPSTI3	Cross dependence of Nsubpsti3	None	0.0
PCGSO	Cross dependence of Cgso	None	0.0
PCGDO	Cross dependence of Cgdo	None	0.0
PCLM1	Cross dependence of Clm1	None	0.0
PCLM2	Cross dependence of Clm2	None	0.0
PCLM3	Cross dependence of Clm3	None	0.0
PWFC	Cross dependence of Wfc	None	0.0
PGIDL1	Cross dependence of GIDL1	None	0.0
PGIDL2	Cross dependence of GIDL2	None	0.0
PGLEAK1	Cross dependence of Gleak1	None	0.0
PGLEAK2	Cross dependence of Gleak2	None	0.0
PGLEAK3	Cross dependence of Gleak3	None	0.0
PGLEAK6	Cross dependence of Gleak6	None	0.0
PGLKSD1	Cross dependence of Glksd1	None	0.0
PGLKSD2	Cross dependence of Glksd2	None	0.0
PGLKB1	Cross dependence of Glkb1	None	0.0
PGLKB2	Cross dependence of Glkb2	None	0.0
PNFTRP	Cross dependence of Nftrp	None	0.0
PNFALP	Cross dependence of Nfalp	None	0.0
PIBPC1	Cross dependence of Ibpc1	None	0.0
PIBPC2	Cross dependence of Ibpc2	None	0.0
PCGBO	Cross dependence of CGBO	None	0.0
PCVDSOVER	Cross dependence of CVDSOVER	None	0.0
PFALPH	Cross dependence of FALPH	None	0.0
PNPEXT	Cross dependence of NPEXT	None	0.0
PPOWRAT	Cross dependence of POWRAT	None	0.0

PRD	Cross dependence of RD	None	0.0
PRD22	Cross dependence of RD22	None	0.0
PRD23	Cross dependence of RD23	None	0.0
PRD24	Cross dependence of RD24	None	0.0
PRDICT1	Cross dependence of RDICT1	None	0.0
PRDOV13	Cross dependence of RDOV13	None	0.0
PRDSLP1	Cross dependence of RDSLP1	None	0.0
PRDVB	Cross dependence of RDVB	None	0.0
PRDVD	Cross dependence of RDVD	None	0.0
PRDVG11	Cross dependence of RDVG11	None	0.0
PRS	Cross dependence of RS	None	0.0
PRTH0	Cross dependence of RTH0	None	0.0
PVOVER	Cross dependence of VOVER	None	0.0
PJS0	Cross dependence of Js0	None	0.0
PJS0SW	Cross dependence of Js0sw	None	0.0
PNJ	Cross dependence of Nj	None	0.0
PCISBK	Cross dependence of Cisbk	None	0.0
PVDIFFJ	Cross dependence of Vdiffj	None	0.0
PJS0D	Cross dependence of Js0D	None	PJS0
PJS0SWD	Cross dependence of Js0swD	None	PJS0SW
PNJD	Cross dependence of NjD	None	PNJ
PCISBKD	Cross dependence of CisbkD	None	PCISBK
PVDIFFJD	Cross dependence of VdiffjD	None	PVDIFFJ
PJS0S	Cross dependence of Js0S	None	PJS0D
PJS0SWS	Cross dependence of Js0swS	None	PJS0SWD
PNJS	Cross dependence of NjS	None	PNJD
PCISBKS	Cross dependence of CisbkS	None	PCISBKD
PVDIFFJS	Cross dependence of VdiffjS	None	PVDIFFJD

MOSFET Instance, UTSOI Local Model (Level 76)



UTSOI Local Model MOSFET Instance Netlist Syntax

The syntax for a Level 76 UTSOI local model MOSFET instance is:

```
Mxxxx nd ng ns nb modelname
[ADRAIN=val] [ASOURCE=val] [PDRAIN=val] [PSOURCE=val]
[MULT=val]
```

nd is the drain node, *ng* is the gate node, *ns* is the source node, and *nb* is the bulk or substrate node of the MOSFET. *modelname* is the name of a Level 76 UTSOI MOSFET local model (with model parameter **SWSCALE=0**) defined in a .MODEL statement elsewhere in the netlist.

Table 1: Level 76 UTSOI Local Model MOSFET Instance Parameters

Instance Parameter	Description	Unit	Default
ADRAIN	Drain region area	Meter^2	1.0e-12
ASOURCE	Source region area	Meter^2	1.0e-12
PDRAIN	Drain region perimeter	Meter	1.0e-6
PSOURCE	Source region perimeter	Meter	1.0e-6
MULT	Multiplier for multiple parallel transistors	None	1.0

UTSOI MOSFET Local Model (Level 76, SWSCALE=0)

The syntax for a Level 76 LETI-UTSOI local model MOSFET model is:

```
.MODELmodelname NMOS LEVEL=76 SWSCALE=0

+ [(][parameter=val] ... [)]
```

or

```
.MODELmodelname PMOS LEVEL=76 SWSCALE=0

+ [(][parameter=val] ... [)]
```

modelname is the name used by MOSFET instances to refer to this .MODEL statement. The **LEVEL=76** entry (plus the model parameter **SWSCALE=0**) selects the LETI-UTSOI MOSFET local model.

```
UTSOI Model Version 1.1.4
Ultra Thin Fully Depleted SOI MOSFET Model
Copyright CAE LETI 2012
```

This model is for undoped ultra-thin film SOI MOSFET. The model includes:

- Specific surface potential equations for FDSOI with interface coupling
- Specific current expression for FDSOI
- Field-dependent mobility including remote coulomb scattering
- Quantum effect
- Velocity saturation
- Conductance effects (CLM, DIBL, etc.)
- Series-resistance with gate voltage dependence
- Short-channel effects
- Overlap capacitances (SP-based)
- Gate leakage current
- Gate-induced drain/source leakage (GIDL, GISL)
- Self heating effect
- Global parameters (see Global Instance and Model)
- Narrow-width effects
- Stress model
- Noise (1/f, thermal, induced gate and shot noise)

Table 1: Level 76 UTSOI MOSFET Local Model Selector Parameters

Model Parameter	Description	Unit	Default
LEVEL	76 is required to select the UTSOI MOSFET model. The model parameter **SWSCALE=0** selects the local	None	1 (default if LEVEL

	model over the global model.		parameter is omitted)
TYPE	Channel type, +1 = NMOS, -1 = PMOS	None	+1
TR	Nominal reference temperature	°C	21.0
SWSCALE	Selector for model: 0=local, 1=global	None	0 is required to select the local model
VERSION	Model version	None	1.14
SWIGATE	Flag for gate current (0 = off)	None	0
SWGIDL	Flag for GIDL/GISL current (0 = off)	None	0
SWSHE	Selector for self-heating effect (0 = off)	None	0
SWRSMOD	Flag for access resistance (1 = with internal nodes, 0 = without internal nodes)	None	0
SWIGN	Flag for induced gate noise model (1 = with, 0 = without)	None	1

Table 2: Level 69 PSP 103.1 MOSFET Local Model Process Parameters

Model Parameter	**Description**	**Unit**	**Default**
VFB	Flat-band voltage at reference temperature	Volt	0.0
STVFB	Temperature dependence of flat-band voltage	Volt/°K	5.0e-4
TOX	Gate oxide thickness	Meter	2.0e-9
EPSROX	Relative permittivity of gate dielectric	None	3.9
TSI	Silicon film thickness	Meter	1e-8
EPSRSI	Relative permittivity of gate dielectric	None	11.8
EG	Band gap of silicon film at 300K	Volt	1.179
STEG1	1st temperature coefficient of EG	Volt/°C	9.025e-5
STEG2	2nd temperature coefficient of EG	Volt/ °C^2	3.05e-7
NI	Intrinsic doping of silicon film at 300K	cm^{-3}	1.45e10
STNI	Temperature dependence of NI	None	1.5
TBOX	Buried oxide thickness	Meter	1e-7
NSI	Lightly silicon film doping, 0 = undoped	cm^{-3}	0

NSUB	Substrate doping, (negative value = NMOS, positive value = PMOS)	1/cm^3	3.0e18
DVFBB	Offset of back-gate flat-band voltage	Volt	0
CT	Interface states factor	None	0.0
TOXOV	Overlap oxide thickness	Meter	2.0e-9
NOV	Effective doping of overlap-ldd region (0 = no doping effect)	1/cm^3	0

Table 3: Level 76 UTSOI MOSFET Local Model Quantum Effect Parameters

Model Parameter	Description	Unit	Default
QMC	Quantum correction factor	None	1

Table 4: Level 76 UTSOI MOSFET Local Model Interface Coupling Parameters

Model Parameter	Description	Unit	Default
CIC	Substrate bias dependence factor of interface coupling	None	1.0

Table 5: Level 76 UTSOI MOSFET Local Model Short Channel Effect Parameters

Model Parameter	Description	Unit	Default
PSCE	Short-channel effect parameter above threshold	None	0.0

Table 6: Level 76 UTSOI MOSFET Local Model DIBL Parameters

Model Parameter	Description	Unit	Default
CF	DIBL parameter	1/Volt	0.0
CFB	Substrate bias dependence of CF	1/Volt	0.0
STCF	Temperature dependence of CF	None	0.0

Table 7: Level 76 UTSOI MOSFET Local Model Mobility Parameters

Model Parameter	Description	Unit	Default

BETN	Product of channel aspect ratio and zero-field mobility at TR.	Meter ^{2}/Volt/Second	5.0e-2
STBET	Temperature dependence of BETN		1.0
MUE	Mobility reduction coefficient at reference temperature	Meter/Volt	0.5
STMUE	Temperature dependence of MUE	None	0.0
THEMU	Mobility reduction exponent at reference temperature	None	1.5
STTHEMU	Temperature dependence of mobility reduction exponent THEMU	None	1.5
CS	Coulomb scattering parameter at reference temperature	None	0.0
CSB	Substrate bias dependence of CS	None	0.0
THECS	Remote Coulomb scattering exponent at TR	None	1.5
STTHECS	Temperature dependence of THECS	None	1.5
STCS	Temperature dependence of CS	None	0.0
XCOR	Non-universality parameter	1/Volt	0.0
STXCOR	Temperature dependence of XCOR	None	0.0
FETA	Effective field parameter	None	1.0

Table 8: Level 76 UTSOI MOSFET Local Model Series Resistance Parameters

Model Parameter	**Description**	**Unit**	**Default**
RS	Source/drain series resistance at reference temperature	Ohm	30.0
RSG	Gate-bias dependence of RS	None	0.0
THERSG	Gate bias dependence exponent of RS	None	2.0
STRS	Temperature dependence of RS	None	1.0

Table 9: Level 76 UTSOI MOSFET Local Model Velocity Saturation Parameters

Model Parameter	**Description**	**Unit**	**Default**
THESAT	Velocity saturation parameter at reference temperature	1/Volt	0.0
STTHESAT	Temperature dependence of THESAT	None	1.0
THESATB	Back-bias dependence of velocity saturation	None	0.0

THESATG	Gate-bias dependence of velocity saturation	1/Volt	0.0

Table 10: Level 76 UTSOI MOSFET Local Model Saturation Voltage Parameter

Model Parameter	Description	Unit	Default
AX	Linear/saturation transition factor	None	10.0

Table 11: Level 76 UTSOI MOSFET Local Model Channel Length Modulation Parameters

Model Parameter	Description	Unit	Default
ALP	CLM prefactor		0.0
ALP1	CLM enhancement factor above threshold	Volt	0.0
VP	CLM logarithmic dependence factor	Volt	0.05

Table 12: Level 76 UTSOI MOSFET Local Model Gate Current Parameters

Model Parameter	Description	Unit	Default
GCO	Gate tunneling energy adjustment	None	0.0
IGINV	Gate to channel current prefactor in inversion	Ampere	0.0
IGOVINV	Gate to overlap current prefactor in inversion	Ampere	0.0
IGOVACC	Gate to overlap current prefactor in accumulation	Ampere	0.0
GC2CH	Gate current slope factor for gate to channel current	None	0.375
GC3CH	Gate current curvature factor for gate to channel current	None	0.063
GC2OV	Gate current slope factor for overlap currents	None	0.375
GC3OV	Gate current curvature factor for overlap currentsS	None	0.063
STIG	Temperature dependence of gate current	None	2.0
CHIB	Tunneling barrier height	Volt	3.1

Table 13: Level 76 UTSOI MOSFET Local Model Gate-Induced Drain Leakage Parameters

Model Parameter	Description	Unit	Default
AGIDL	GIDL prefactor	Ampere/Volt^3	0.0
BGIDL	GIDL probability factor at reference temperature	Volt	41.0
STBGIDL	Temperature dependence of BGIDL	Volt/°K	0.0
CGIDL	Back-bias dependence of GIDL	None	0.0

Table 14: Level 76 UTSOI MOSFET Local Model Charge Model Parameters

Model Parameter	Description	Unit	Default
COX	Oxide capacitance for intrinsic channel	Farad	1e-14
CBOX	Unit area buried oxide capacitance of drain/source region	Farad/Meter^2	5.0e-4
CGBOV	Oxide capacitance for gate-substrate overlap	Farad	0.0
COV	Overlap capacitance by side (Version 1.12 and later)	Farad	0.0
CFR	Outer fringe capacitance by side	Farad	0.0
CSDO	Outer drain-source capacitance for drain side	Farad	0.0
CSDBP	Drain/source to substrate perimeter capacitance	Farad/Meter	0.0

Table 15: Level 76 UTSOI MOSFET Local Model Self Heating Parameters

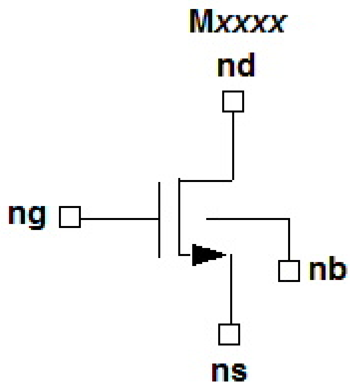
Model Parameter	Description	Unit	Default
RTH	Substrate thermal resistance	°C/W	1500
STRTH	Temperature dependence of RTH	None	0.0
CTH	Substrate thermal capacitance	W-s/°C	5e-10

Table 16: Level 69 PSP 103.1 MOSFET Local Model Noise Model Parameters

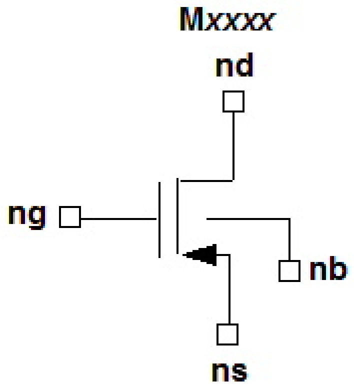
Model Parameter	Description	Unit	Default

FNT	Thermal noise coefficient	None	1.0
NFA	First coefficient of flicker noise	1/Volt-Meter^4	8.0e22
NFB	Second coefficient of flicker noise	1/Volt-Meter^2	3.0e7
NFC	Third coefficient of flicker noise	1/Volt	0.0
EF	Flicker noise frequency exponent	None	1.0

MOSFET Instance, UTSOI Global Model (Level 76)



NMOS



PMOS

UTSOI Global Model MOSFET Instance Netlist Syntax

The syntax for a Level 76 UTSOI global model MOSFET instance is:

```
Mxxxx nd ng ns nb modelname
[L=length] [W=width]
[ABSOURCE=val] [LSSOURCE=val] [LGSOURCE=val]
[ABDRAIN=val] [LSDRAIN=val] [LGDRAIN=val]
[SA=val] [SB=val] [SC=val] [SD=val]
[SCA=val] [SCB=val][SCC=val] [NRS=val] [NRD=val]
[DELVTO=val] [FACTUO=val] [NGCON=val] [XGW=val]
[NF=val] [MULT=val]
```

nd is the drain node, *ng* is the gate node, *ns* is the source node, and *nb* is the bulk or substrate node of the MOSFET. *modelname* is the name of a Level 76 UTSOI MOSFET global model (with model parameter **SWSCALE=1**) defined in a .MODEL statement elsewhere in the netlist.

Table 1: Level 76 UTSOI Geometric Model MOSFET Instance Parameters

Instance Parameter	Description	Unit	Default
L	Drawn channel length	Meter	1.0e-6
W	Drawn channel width	Meter	1.0e-6
ADRAIN	Drain region area	Meter 2	1.0e-12
ASOURCE	Source region area	Meter 2	1.0e-12
PDRAIN	Drain region perimeter	Meter	1.0e-6
PSOURCE	Source region perimeter	Meter	1.0e-6
DELVTO	Threshold voltage shift factor	V	0.0
FACTUO	Zero-field mobility prefactor	None	1
SA	Distance between OD-edge and poly at source side	Meter	0.0
SB	Distance between OD-edge and poly at drain side	Meter	0.0
SD	Distance between neighboring fingers	Meter	0
NF	Number of fingers; internally rounded to the nearest integer	None	1
MULT	Multiplier for multiple parallel transistors	None	1.0

UTSOI MOSFET Global Model (Level 76, SWSCALE=1)

The syntax for a Level 76 UTSOI global model MOSFET model is:

```
.MODELmodelname NMOS LEVEL=76 SWSCALE=1

+ [(][parameter=val] ... [)]
```

or

```
.MODELmodelname PMOS LEVEL=76 SWSCALE=1

+ [(][parameter=val] ... [)]
```

modelname is the name used by MOSFET instances to refer to this .MODEL statement. The **LEVEL=76** entry (plus the model parameter **SWSCALE=1**) selects the UTSOI MOSFET global model.

```
UTSOI Model Version 1.1.4
Ultra Thin Fully Depleted SOI MOSFET Model
Copyright CAE LETI 2012
```

This model is for undoped ultra-thin film SOI MOSFET. The model includes:

- Specific surface potential equations for FDSOI with interface coupling
- Specific current expression for FDSOI
- Field-dependent mobility including remote coulomb scattering
- Quantum effect
- Velocity saturation
- Conductance effects (CLM, DIBL, etc.)
- Series-resistance with gate voltage dependence
- Short-channel effects
- Overlap capacitances (SP-based)
- Gate leakage current
- Gate-induced drain/source leakage (GIDL, GISL)
- Self heating effect
- Global parameters
- Narrow-width effects
- Stress model
- Noise (1/f, thermal, induced gate and shot noise)

Table 1: Level 76 UTSOI MOSFET Global Model Selector Parameters

Model Parameter	Description	Unit	Default
LEVEL	76 is required to select the UTSOI MOSFET model. The model parameter **SWSCALE=0** selects the local model over the global model.	None	1 (default if LEVEL parameter is omitted)
TYPE	Channel type, +1 = NMOS, -1 = PMOS	None	+1
TR	Nominal reference temperature	°C	21.0
SWSCALE	Selector for model: 0=local, 1=global	None	1 is required to select the global model
VERSION	Model version	None	1.14
SWIGATE	Flag for gate current (0 = off)	None	0
SWGIDL	Flag for GIDL/GISL current (0 = off)	None	0

SWSHE	Selector for self-heating effect (0 = off)	None	0
SWRSMOD	Flag for access resistance (1 = with internal nodes, 0 = without internal nodes)	None	0
SWIGN	Flag for induced gate noise model (1 = with, 0 = without)	None	1

Table 2: Level 76 UTSOI MOSFET Global Model Scaling Parameters

Model Parameter	Description	Unit	Default
LVARO	Geometry-independent difference between physical and drawn gate length	Meter	0.0
LVARL	Length dependence of LPS	None	0.0
LVARW	Width dependence of LPS	None	0.0
LAP	Effective channel length reduction per side	Meter	0.0
WVARO	Geometry-independent difference between physical and drawn field-oxide opening	Meter	0.0
WVARL	Length dependence of WOD	None	0.0
WVARW	Width dependence of WOD	None	0.0
WOT	Effective channel width reduction per side	Meter	0.0
DLQ	Effective channel length offset for CV	Meter	0.0
DWQ	Effective channel width offset for CV	Meter	0.0

Table 3: Level 76 UTSOI Global Model MOSFET Stress Model Parameters

Model Parameter	Description	Unit	Default
SAREF	Reference distance between OD edge and poly from one side	Meter	1e-6
SBREF	Reference distance between OD edge and poly on the other side	Meter	1e-6
WLOD	Width parameter	Meter	0.0
KUO	Mobility degradation/enhancement coefficient	Meter	0.0
KVSAT	Saturation velocity degradation/enhancement parameter	Meter	0.0

TKUO	Temperature coefficient of KUO	None	0.0
LKUO	Length dependence of KUO	None	0.0
WKUO	Width dependence of KUO	None	0.0
PKUO	Cross-term dependence of KUO	None	0.0
LLODKUO	Length parameter for mobility stress effect	None	0.0
WLODKUO	Width parameter for mobility stress effect	None	0.0
KVTHO	Threshold shift parameter	Volt-Meter	0.0
LKVTHO	Length dependence of KVTHO	None	0.0
WKVTHO	Width dependence of KVTHO	None	0.0
PKVTHO	Cross-term dependence of KVTHO	None	0.0
LLODVTH	Length parameter for threshold voltage stress effect	None	0.0
WLODVTH	Width parameter for threshold voltage stress effect	None	0.0
STETAO	ETAO shift factor related to threshold voltage change	Meter	0.0
LODETAO	ETAO shift modification factor	None	1.0

Table 4: Level 76 UTSOI MOSFET Global Model Process Parameters

Model Parameter	**Description**	**Unit**	**Default**
VFBO	Geometry-independent flat-band voltage at reference temperature	Volt	0.0
VFBL	Length dependence of flat-band voltage	None	0.0
VFBLEXP	Exponent describing length dependence of VFB	None	1.0
VFBW	Width dependence of flat-band voltage	None	0.0
VFBLW	Area dependence of flat-band voltage	None	0.0
STVFBO	Geometry-independent temperature dependence of flat-band voltage	Volt/°K	5.0e-4
STVFBL	Length dependence of temperature dependence of flat-band voltage	None	0.0
STVFBW	Width dependence of temperature dependence of flat-band voltage	None	0.0
STVFBLW	Area dependence of temperature dependence of flat-band voltage	None	0.0

TOXO	Gate oxide thickness	Meter	2.0e-9
EPSROXO	Relative permittivity of gate dielectric	None	3.9
TSIO	Silicon film thickness	Meter	1e-8
EPSRSIO	Relative permittivity of gate dielectric	None	11.8
EGO	Band gap of silicon film at 300K	Volt	1.179
STEG1O	1st temperature coefficient of EG	Volt/°C	9.025e-5
STEG2O	2nd temperature coefficient of EG	Volt/$°C^2$	3.05e-7
NIO	Intrinsic doping of silicon film at 300K	cm^{-3}	1.45e10
STNIO	Temperature dependence of NI	None	1.5
TBOXO	Buried oxide thickness	Meter	1e-7
NSIO	Lightly silicon film doping, 0=intrinsic doping	cm^{-3}	0.0
NSUB0	Substrate doping (negative value = N-type, positive value = P-type	cm^{-3}	1e18
DVFBBO	Offset of back-gate flat-band voltage	Volt	0.0
CTO	Geometry-independent part of interface states factor CT	None	0.0
TOXOVO	Overlap oxide thickness	Meter	2.0e-9
LOV	Overlap length for overlap capacitance	Meter	0.0
NOVO	Effective doping of overlap region	$1/cm^3$	0.0

Table 5: Level 76 UTSOI MOSFET Global Model Quantum Effect Parameters

Model Parameter	**Description**	**Unit**	**Default**
QMC	Quantum correction factor	None	1

Table 6: Level 76 UTSOI Global Model MOSFET Interface Coupling Parameters

Model Parameter	**Description**	**Unit**	**Default**
CICO	Geometry-independent part of back-gate-bias dependenc3e factor of interface coupling	None	1.0
CICL	Length dependence of CIC	None	0.0

CICLEXP	Exponent describing length dependence of CIC	None	1.0
CICW	Width dependence of CIC	None	0.0
CICLW	Area dependence of CIC	None	0.0

Table 7: Level 76 UTSOI Global Model MOSFET SCE Parameters

Model Parameter	**Description**	**Unit**	**Default**
PSCEL	Length dependence of PSCE	None	0.0
PSCELEXP	Exponent describing length dependence of PSCE	None	1.0
PSCEW	Width dependence of PSCE	None	0.0

Table 8: Level 76 UTSOI Global Model MOSFET DIBL Parameters

Model Parameter	**Description**	**Unit**	**Default**
CFL	Length dependence of DIBL factor CF	1/Volt	0.0
CFLEXP	Exponent describing length dependence of CF	None	2.0
CFW	Width dependence of CF	None	0.0
CFBO	Substrate bias dependence of CF	None	0.0
STCFBO	Temperature dependence of CF	None	0.0

Table 9: Level 76 UTSOI Global Model MOSFET Mobility Parameters

Model Parameter	**Description**	**Unit**	**Default**
UO	Zero-field mobility at reference temperature	Meter ^{2} /Volt/Second	5.0e-2
BETNL	2nd-order length dependence of BETN	None	0.0
BETNLEXP	Exponent for 2nd-order length dependence of BETN	None	1.0
BETNW	2nd-order width dependence of BETN	None	0.0
STBETO	Geometry-independent temperature dependence of BETN	None	1.0
STBETL	Length dependence of temperature dependence of BETN	None	0.0
STBETW	Width dependence of temperature dependence of	None	0.0

	BETN		
STBETLW	Area dependence of temperature dependence of BETN	None	0.0
MUEO	Geometry-independent mobility reduction coefficient MUE at reference temperature	Meter/Volt	0.5
STMUEO	Temperature dependence of MUE	None	0.0
THEMUO	Mobility reduction exponent at reference temperature	None	1.5
STTHEMUO	Temperature dependence of mobility reduction exponent THEMU	None	1.5
CSO	Geometry-independent Coulomb scattering parameter CS at reference temperature	None	0.0
CSL	Length dependence of Coulomb scattering parameter CS	None	0.0
CSLEXP	Exponent for length dependence of CS	None	1.0
CSW	Width dependence of Coulomb scattering parameter CS	None	0.0
CSLW	Area dependence of Coulomb scattering parameter CS	None	0.0
CSBO	Back bias dependence of CS	None	0.0
THECSO	Remote Coulomb scattering exponent at TR	None	1.5
STCSO	Temperature dependence of CS	None	0.0
STTHECSO	Temperature dependence of THECS	None	1.5
XCORO	Geometry-independent non-universality parameter	1/Volt	0.0
XCORL	Length dependence of XCOR	None	0.0
XCORLEXP	Exponent describing length dependence of XCOR	None	1.0
XCORW	Width dependence of XCOR	None	0.0
XCORLW	Area dependence of XCOR	None	0.0
STXCORO	Temperature dependence of XCOR	None	0.0
FETAO	Effective field parameter	None	1.0

Table 10: Level 76 UTSOI Global Model MOSFET Series Resistance Parameters

Model Parameter	**Description**	**Unit**	**Default**
RSW1	Source/drain series resistance for a channel width of W_{EN} at	Ohm	30.0

	reference temperature		
RSW2	Higher-order width scaling of source/drain series resistance	None	0.0
STRSO	Temperature dependence of source/drain series resistance	None	1.0
RSGO	Gate-bias dependence of series resistance	None	0.0

Table 11: Level 76 UTSOI Global Model MOSFET Velocity Saturation Parameters

Model Parameter	**Description**	**Unit**	**Default**
THESATO	Geometry-independent velocity saturation parameter at reference temperature	1/Volt	0.0
THESATL	Length dependence of THESAT	None	0.0
THESATLEXP	Exponent for length dependence of THESAT	None	1.0
THESATW	Width dependence of THESAT	None	0.0
THESATLW	Area dependence of THESAT	None	0.0
THESATGO	Geometry-independent gate-bias dependence of velocity saturation parameter at reference temperature	1/Volt	0.0
STTHESATO	Geometry-independent temperature dependence of THESAT	None	1.0
STTHESATL	Length dependence of STTHESAT	None	0.0
STTHESATW	Width dependence of STTHESAT	None	0.0
STTHESATLW	Area dependence of STTHESAT	None	0.0
THESATBO	Back-bias dependence of THESAT	1/Volt	0.0

Table 12: Level 76 UTSOI Global Model MOSFET Saturation Voltage Parameters

Model Parameter	**Description**	**Unit**	**Default**
AXO	Geometry-independent linear/saturation transition parameter	None	10.0
AXL	Length dependence of AX	None	0.0
AXLEXP	Exponent for length dependence of AX	None	1.0

Table 13: Level 76 UTSOI Global Model MOSFET Channel Length Modulation Parameters

Model Parameter	Description	Unit	Default
ALPL1	Length dependence of CLM prefactor ALP	None	0.0
ALPLEXP	Exponent for length dependence of ALP	None	1.0
ALPL2	2nd-order length dependence of CLM prefactor ALP	None	0.0
ALPW	Width dependence of ALP	None	0.0
ALP1L1	Length dependence of CLM enhancement factor above threshold ALP1	Volt	0.0
ALP1LEXP	Exponent describing the length dependence of ALP1	None	0.5
ALP1L2	Second-order length dependence of ALP1	None	0.0
ALP1W	Width dependence of ALP1	None	0.0
VPO	CLM logarithmic dependence factor	Volt	0.05

Table 14: Level 76 UTSOI Global Model MOSFET Gate Current Parameters

Model Parameter	Description	Unit	Default
GCOO	Gate tunneling energy adjustment	None	0.0
IGINVLW	Gate channel current prefactor for a gate channel area of W_{EN} x L_{EN}	Ampere	0.0
IGOVINVW	Gate to overlap current prefactor in inversion for an overlap of W_{EN} x L_{OV}	Ampere	0.0
IGOVACCW	Gate to overlap current prefactor in accumulation for an overlap of W_{EN} x L_{OV}	Ampere	0.0
GC2CHO	Gate current slope factor for gate to channel current	None	0.375
GC3CHO	Gate current curvature factor for gate to channel current	None	0.063
GC2OVO	Gate current slope factor for overlap currents	None	0.375
GC3OVO	Gate current curvature factor for overlap currents	None	0.063
STIGO	Temperature dependence of all gate currents	None	2.0
CHIBO	Tunneling barrier height	Volt	3.1

Table 15: Level 76 UTSOI Global Model MOSFET Gate-Induced Drain Leakage Parameters

Model Parameter	Description	Unit	Default
AGIDLW	Width dependence of GIDL prefactor	Ampere/Volt^3	0.0
BGIDLO	GIDL probability factor at reference temperature	Volt	41.0
STBGIDLO	Temperature dependence of BGIDL	Volt/°K	0.0
CGIDLO	Back-bias dependence of GIDL	None	0.0

Table 16: Level 76 UTSOI Global Model MOSFET Charge Model Parameters

Model Parameter	Description	Unit	Default
CGBOVL	Oxide capacitance for gate-substrate overlap	Farad	0.0
CFRW	Outer fringe capacitance	Farad	0.0
CSDBPO	Drain/source to substrate perimeter capacitance	Farad/Meter	0.0

Table 17: Level 76 UTSOI MOSFET Global Model Self Heating Parameters

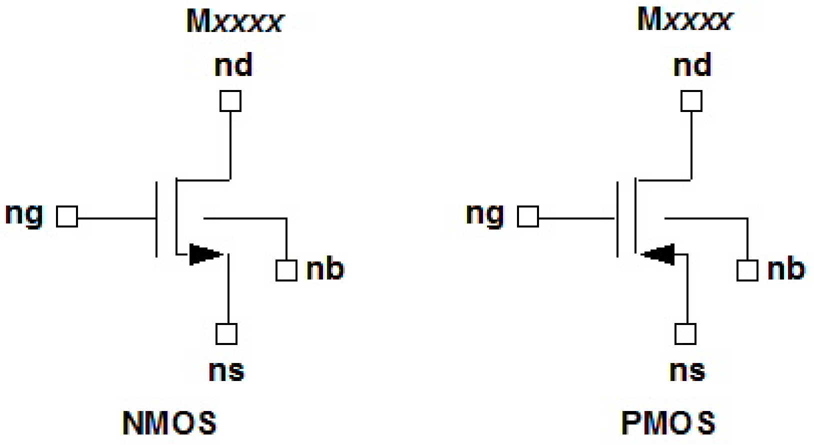
Model Parameter	Description	Unit	Default
RTHO	Geometry-independent part of substrate thermal resistance	°C/W	1500
RTHL	Length dependence of RTH	None	0.0
RTHW	Width dependence of RTH	None	0.0
RTHLW	Area dependence of RTH	None	0.0
CTHO	Geometry-independent part of substrate thermal capacitance	W-s/°C	5e-10
STRTHO	Temperature dependence of RTH	None	0.0

Table 18: Level 76 UTSOI Global Model MOSFET Noise Model Parameters

Model Parameter	Description	Unit	Default
FNTO	Thermal noise coefficient	None	1.0
NFALW	First coefficient of flicker noise	Volt^{-1}/Meter^4	8.0e22
NFBLW	Second coefficient of flicker noise	Volt^{-1}/Meter^2	3.0e7

NFCLW	Third coefficient of flicker noise	Volt^{-1}	0.0
EFO	Flicker noise frequency exponent	None	1.0

MOSFET Instance, Motorola MET LDMOS Model (Level 99)



Motorola MET LDMOS MOSFET Instance Netlist Syntax

Motorola Electro Thermal Laterally Diffused Metal Oxide Semiconductor (MET LDMOS) instances use the following netlist syntax:

```
Mxxxx nd ng ns [ndt] modelname [AREA=val] [N_FING=val]
```

nd is the drain node, *ng* is the gate node, *ns* is the source node, and *ndt* is the thermal node of the MOSFET. *modelname* is the name of a Level 99 MOSFET model defined in a .MODEL statement elsewhere in the netlist.

Table 1: Level 99 MOSFET Instance Parameters

Instance Parameter	Description	Unit	Default
AREA	Transistor area	Meter^2	1.0e-5
N_FING	Number of instances	None	1

Netlist Example

```
M213 55 56 57 58 mos_99 n_fing=2
```

Motorola MET LDMOS MOSFET Model, Level 99

The syntax for a Level 99 Motorola Electro Thermal Laterally Diffused MOSFET (MET LDMOS) model is:

```
.MODELmodelname NMOS LEVEL=99 [parameter=val] ...
```

or

```
.MODELmodelnamePMOSLEVEL=99 [parameter=val] ...
```

modelname is the name used by MOSFET instances to refer to this .MODEL statement. The **LEVEL=99** entry selects the Motorola MET LDMOS MOSFET model.

Table 1: Level 99 MOSFET Model Parameters

Model Parameter	Description	Unit	Default
LEVEL	99 is required to select the Motorola MET LDMOS MOSFET model	Integer	1 (default if LEVEL parameter is omitted)
AF	Flicker noise exponent	None	1.0
ALPHA	Ids equation coefficient	None	1.5
BETA_0 (**BETA0**)	Ids equation coefficient, BETA evaluated at Tnom	Ohm^{-1}	0.2
BETA_1 (**BETA1**)	Ids equation coefficient	1/(Ohm x °K)	-0.0002
BR	Reverse Ids equation coefficient	1/(Ohm x Volt)	0.5
CDS1	Cds equation coefficient	Farad	1.0e-12
CDS2	Cds equation coefficient	Farad	1.5e-12
CDS3	Cds equation coefficient	$1/\text{Volt}^2$	0.1
CDST	Cds temperature coefficient	1/°K	0.001
CGS1	Cgs equation coefficient	Farad	2.0e-12
CGS2	Cgs equation coefficient	Farad	1.0e-12
CGS3	Cgs equation coefficient	Volt	-4.0
CGS4	Cgs equation coefficient	None	1.0e-12
CGS5	Cgs equation coefficient	1/Volt	0.25
CGS6	Cgs equation coefficient	1/Volt	3.5
CGST	Cgs temperature coefficient	1/°K	0.001

CGD1	Cgd equation coefficient	Farad	4.0e-13
CGD2	Cgd equation coefficient	Farad	1.0e-13
CGD3	Cgd equation coefficient	1/Volt^2	0.1
CGD4	Cgd equation coefficient	Volt	4.0
CGDT	Cgd temperature coefficient	1/°K	0.0
CTH	Thermal capacitance	1/°C	0.0
DELTA	Ids equation coefficient	Volt	0.9
FFE	Flicker noise frequency exponent	None	1.0
GAMMA	Ids equation coefficient	None	-0.02
GGD	Gate to drain conductance	1/Ohm	1.0e5
GGS	Gate to source conductance	1/Ohm	1.0e5
ISR	Reverse diode leakage current	Ampere	1.0e-13
ISS	Forward diode leakage current	Ampere	1.0e-13
K1	Breakdown parameter	None	1.5
K2	Breakdown parameter	1/Volt	1.15
KF	Flicker noise coefficient	None	0.0
LAMBDA	Ids equation coefficient	1/Volt	-0.00025
M1	Breakdown parameter	None	9.5
M2	Breakdown parameter	1/Volt	1.2
M3	Breakdown parameter	None	0.001
N	Forward diode ideality	None	1.0
NR	Reverse diode ideality	None	1.0
RD_0 (**RD0**)	Drain resistance evaluated at Tnom	Ohm	1.5
RD_1 (**RD1**)	Drain resistance coefficient	Ohm/°K	0.0015
RDIODE_0 (**RDIODE0**)	Reverse diode series resistance evaluated at Tnom	Ohm	0.5
RDIODE_1 (**RDIODE1**)	Reverse diode series resistance coefficient	Ohm/°K	0.001
RG_0 (**RG0**)	Gate resistance evaluated at Tnom	Ohm	1.0
RG_1 (**RG1**)	Gate resistance coefficient	Ohm/°K	0.0001
RS_0 (**RS0**)	Source resistance evaluated at Tnom	Ohm	0.1
RS_1 (**RS1**)	Source resistance coefficient	Ohm/°K	0.0001

RTH	Thermal resistance	°C/Watt	10.0
TAU	Transit time under gate	Second	1.0e-12
TNOM	Temperature at which parameters are extracted	°K	298.0
TSNK	Heat sink temperature	°C	25.0
VBR_0 (**VBR0**)	Breakdown voltage evaluated at Tnom	Volt	75.0
VBR_1 (**VBR1**)	Breakdown voltage coefficient at Vgs=0V	Volt/°K	0.01
VGEXP	Ids equation coefficient	None	1.1
VK	Ids equation coefficient	Volt	7.0
VST	Subthreshold slope coefficient	Volt	0.15
VTO_0 (**VTO0**)	Forward threshold voltage evaluated at Tnom	Volt	3.5
VTO_1 (**VTO1**)	Forward threshold voltage coefficient	Volt/°K	-0.0001
VTO_R (**VTOR**)	Reverse threshold voltage coefficient	Volt	3.0

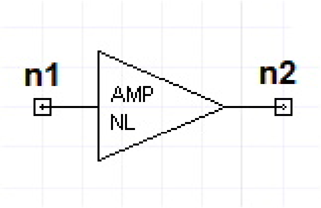
26 - Nonlinear RF Elements

This topic describes the following nonlinear RF elements:

"Nonlinear Amplifier" below

"Nonlinear Mixer" on the next page

Nonlinear Amplifier



Nonlinear Amplifier Instance Netlist Syntax

The nonlinear amplifier model supports both time and frequency domain analyses. The syntax for a nonlinear amplifier instance is:

```
ANLAMPxxxx n2 n2ref n1 n1ref
+ p1db=val gaindb=val oip2db=val
+ r1=val r2=val COMPONENT=nl_amp
```

n1 is the input node, *n2* is the output node of the amplifier. *n1ref* and *n2ref* are the reference or negative nodes for the input and output, respectively, and are typically grounded (node 0). The entry **COMPONENT=nl_amp** identifies the device.

Table 1: Nonlinear Amplifier Instance Parameters

Parameter	Description	Unit	Default
p1db	1dB compression point	dBm	10
gaindb	Gain	dB	10
oip2db	2nd-Order intercept	dBm	20
r1	source characteristic impedance	Ohm	50
r2	Load impedance	Ohm	50

Nonlinear Amplifier Netlist Example

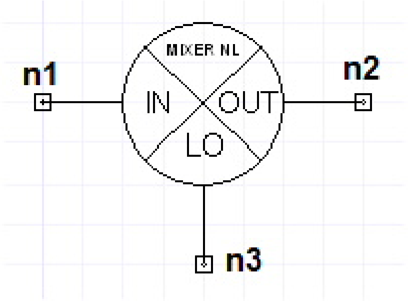
```
ANLAMP123 out 0 in 0

+ p1db=20 gaindb=10 oip2db=20 r1=50 r2=50
+ COMPONENT=nl_amp
```

Notes

1. OIP3(dBm) = P1dB(dBm) + 10.63 dB.

Nonlinear Mixer



Nonlinear Mixer Instance Netlist Syntax

The nonlinear mixer model supports both time and frequency domain analyses. The syntax for a nonlinear mixer instance is:

`ANLMIXERxxxx n2 n2ref n1 n1ref n3 n3ref cgdb=val r1=val r2=val r3=val COMPONENT=nl_mixer`

n1 is the RF input node, *n2* is the output node, and n3 is the LO input node of the amplifier. *n1ref*, *n2ref*, and *n3ref* are the reference or negative nodes for the IN, OUT, and LO signals, respectively, and are typically grounded (node 0). The entry **COMPONENT=nl_mixer** identifies the device.

Table 2: Nonlinear Mixer Instance Parameters

Parameter	Description	Unit	Default
cgdb	Conversion gain	dB	0
r1	Pin 1 (IN) impedance	Ohm	50
r2	Pin2 (OUT) impedance	Ohm	50
r3	Pin3 (LO) impedance	Ohm	50

Nonlinear Mixer Netlist Example

```
ANLMIXER123 out 0 in 0 lo 0 cgdb=10 r1=50 r2=50 r3=50
+ COMPONENT=nl_mixer
```

27 - Offset Stripline Elements

This topic describes the following offset stripline distributed elements available in Nexxim.

"Multi-Coupled Lines, Asymmetric" below

"Multi-Coupled Lines, Differential Pairs, Field Solver" on page 27-3

"Transmission Line, Physical Length" on page 27-5

"Transmission Line, Physical Length with Reference" on page 27-6

"Transmission Line, Field Solver" on page 27-8

This topic also describes the Offset Stripline substrate type.

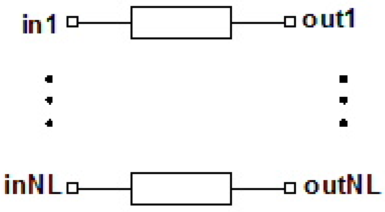
"Selecting None for the Initial Substrate" on page 27-10

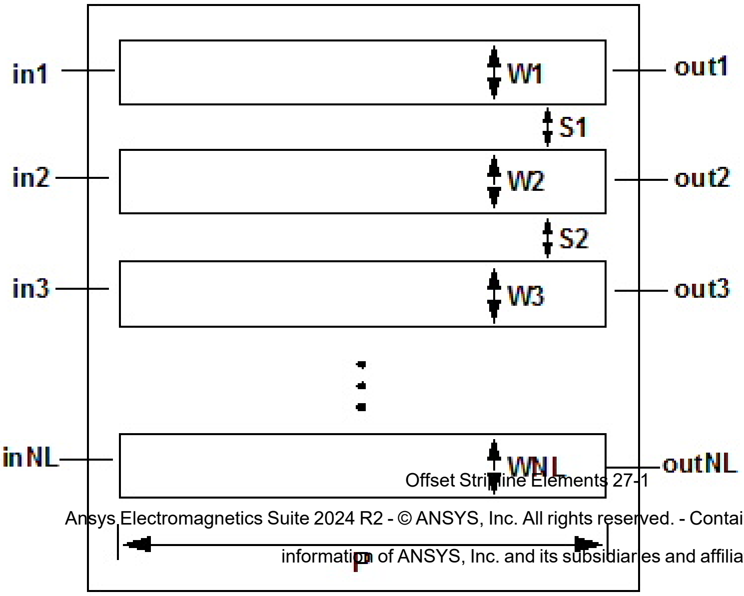
"Creating a Custom Offset Stripline Substrate" on page 27-10

"Selecting an Offset Stripline Substrate at the Component Level" on page 27-11

"Offset Stripline Substrate Model" on page 27-12

Multi-Coupled Lines, Asymmetric





Netlist Form

An asymmetric multiple coupled line, physical length instance has the following netlist syntax:

```
Axxx in1 [...inNL] out1 [...outNL]

NL=NumberofLines [P=length] [W=width] [SP=spacing]

COMPONENT=osl_mcpl_a SUBSTRATE=substrate_name
```

in1 through *inNL* are the names of the input nodes. *out1* through *outNL* are the corresponding output nodes. The entry **COMPONENT=osl_mcpl_a** identifies the element as an asymmetric multiple coupled line, physical length.

The **SUBSTRATE=***substrate_name* is the offset stripline substrate model name selected for the design (see "Offset Stripline Substrate Model" on page 27-12 for details.

Table 168: Asymmetric Multiple Coupled Line, Physical Length, Instance Parameters

Parameter	Description	Units	Default
NL	Number of signal lines	None	None
P	Physical length	Meter	1e-3
W1, **W2**, ...	Conductor widths	Meter	1e-3
S1, **S2**, ...	Spacing between conductors (S1 = spacing between 1 and 2, etc.)	Meter	1e-3

Netlist Example (3 Conductors)

```
A3 Port1 Port2 Port 3 Port 4 Port 5 Port 6 NL=3
+ P=15mm W1=0.75mm S1=0.4mm W2=1.3mm S2=0.6mm W3=1.1mm
+ COMPONENT=osl_mcpl_a SUBSTRATE=OSL1
```

where OSL1, the selected layout technology or substrate type, has a definition such as:

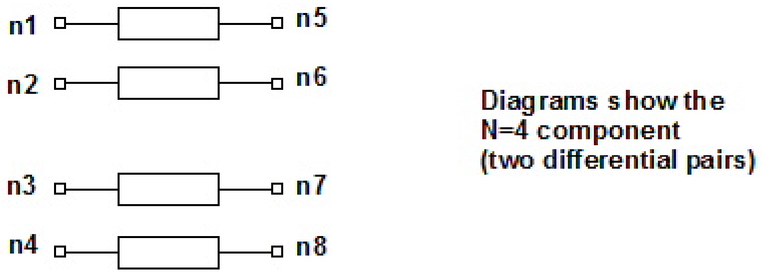
```
.SUB OSL1 OSL(
+ B=0.001524 Er=4.4 TAND=0.02 BL=2.5400e-004
+ MET1=1.724137931034483 T1=2.5400e-005
+ RGH=0)
```

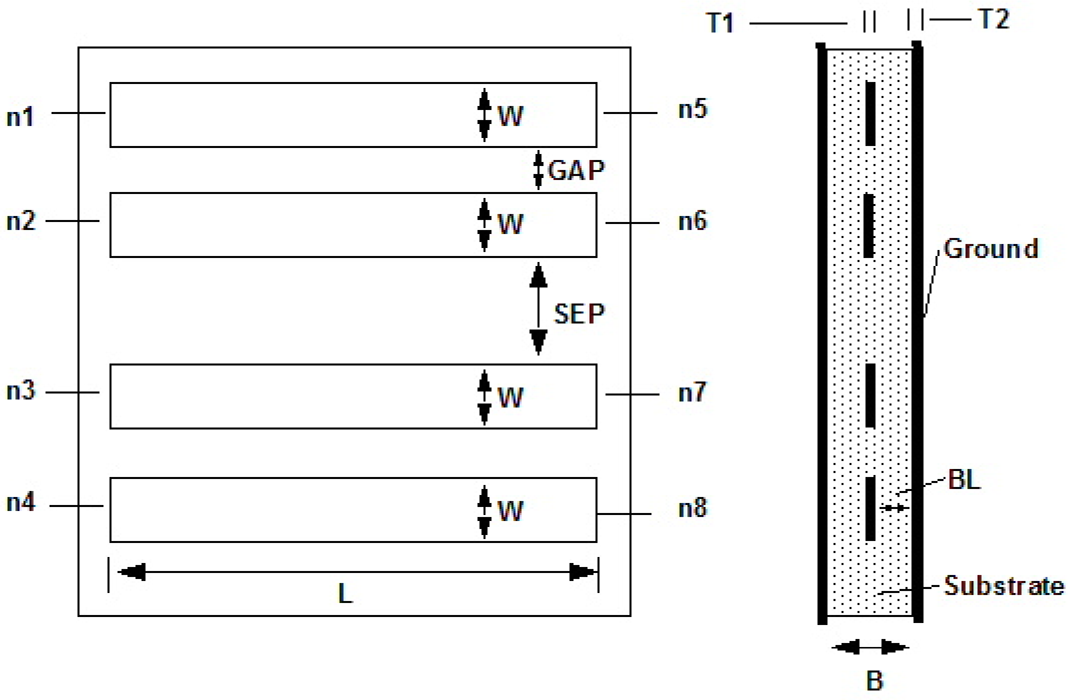
Notes

1. Surface roughness in the substrate definition is not supported in the MCPL implementation.

2. The asymmetric MCPL elements use the data on the SUBSTRATE definition, but internally the data is converted to W-element FIELD SOLVER format for solution.

Multi-Coupled Lines, Differential Pairs, Field Solver





A multicoupled line, two differential pairs, field solver instance has the following netlist syntax:

```
Wxxx n1 n2 n3 n4 0 n5 n6 n7 n8 0    N=4 [L=length]    FSmodel=modelname

.MATERIAL conductor METAL CONDUCTIVITY=conductivity

.MATERIAL dielectric DIELECTRIC ER=er LOSSTANGENT=losstangent
```

```
.SHAPE RECT1 RECTANGLE WIDTH=w HEIGHT=t1 // Conductors
.LAYERSTACK offsetstripline
+ LAYER=(cond1, t2) // Ground plane
+ LAYER=(dielectric, B)
+ LAYER=(cond1, t2)
.MODEL modelname W MODELTYPE=Fieldsolver
+ LAYERSTACK=offsetstripline
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=(0, 't2 + BL')
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=('w+gap', 't2 + BL'
+ MATERIAL=conductor, TYPE=REFERENCE)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=('2w+gap', 't2 + BL')
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT3, ORIGIN=('3w+2gap+sep', 't2 + BL')
+ MATERIAL=conductor, TYPE=REFERENCE)
```

n1, n2, *n3,* and *n4* are the names of the input nodes. *n5*, *n6*, *n7*, and *n8* are the corresponding output nodes. The entry **N=4** shows that this is a 4-conductor, 2-pair differential line.

The entry **FSmodel=***modelname* identifies the field solver offset stripline model.

Table 169: Multicoupled Line, Differential Pairs, Field Solver Instance Parameters

Parameter	Description	Units	Default
L	Physical length	Meter	1e-3
N	Number of lines	None	None
BL	Hieght of signal conductors above lower ground plane	Meter	B/2
conductor	Conductor material	None	cond1
conductivity	Conductivity of conductor material		57.6e6
dielectric	Dielectric material	None	diel1
B	Thickness of dielectric layer	Meter	1e-3
er	Dielectric constant		2.2
losstangent	Dielectric loss tangent		0
w	Width of conductor	Meter	1e-3
gap	Gap width between differential lines	Meter	1e-3
sep	Separation between pairs of lines	Meter	5e-3
T1	Thickness of conductors	Meter	0.001
T2	Thickness of ground planes	Meter	0.001

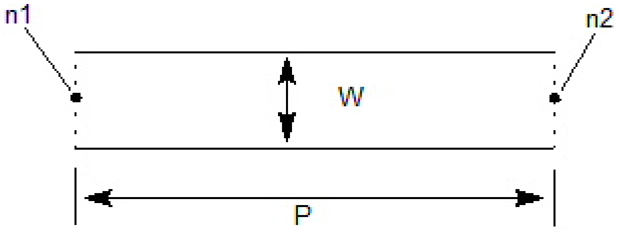
> **Note:** The default values for the differential coupled lines are the ones assigned when placing a component on the Component library in a schematic. There are NO defaults for netlist designs; all values must be specified.

Netlist Example

```
W3 Port1 Port2 0 net_1911 net_2 0 N=2 L=0.002 FSmodel=BCL1
```

```
.MATERIAL copper METAL CONDUCTIVITY=5.8e7
.MATERIAL dielectric DIELECTRIC ER=4.4 LOSSTANGENT=0.02
.SHAPE RECT1 RECTANGLE WIDTH=.002 HEIGHT=.001   // Conductors
.LAYERSTACK STACK1
+ LAYER=(PEC, .003) // Bottom ground
+ LAYER=(dielectric, .01)
+ LAYER=(AIR, .03)
.MODEL MSFS1 W MODELTYPE=Fieldsolver
+ LAYERSTACK=STACK1
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=(0, '.003+.01')
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=('.002+.004', '.003+.01’)
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=('2*.002+.004', '.003+.01')
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=('3*.002+2*.004', '.001+.01')
+ MATERIAL=conductor, TYPE=SIGNAL)
```

Transmission Line, Physical Length



Netlist Format

An instance of a transmission line with physical length has the following netlist syntax:

A`xxx n1 n2 [`**W=**`val] [`**P=**`val]` **COMPONENT=trl SUBSTRATE=**`substrate_name`

n1 and *n2* are the names of the nodes attached to the transmission line. The entry **COMPONENT=trl** identifies the element as a transmission line with physical length.

The **SUBSTRATE=***substrate_name* is the offset stripline substrate model name selected for the design (see "Offset Stripline Substrate Model" on page 27-12 for details. \

Table 170: Transmission Line with Physical Length, Instance Parameters

Parameter	Description	Units	Default
P	Physical length	Meter	1e-2
W	Conductor width	Meter	1e-3

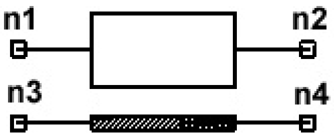
Netlist Example

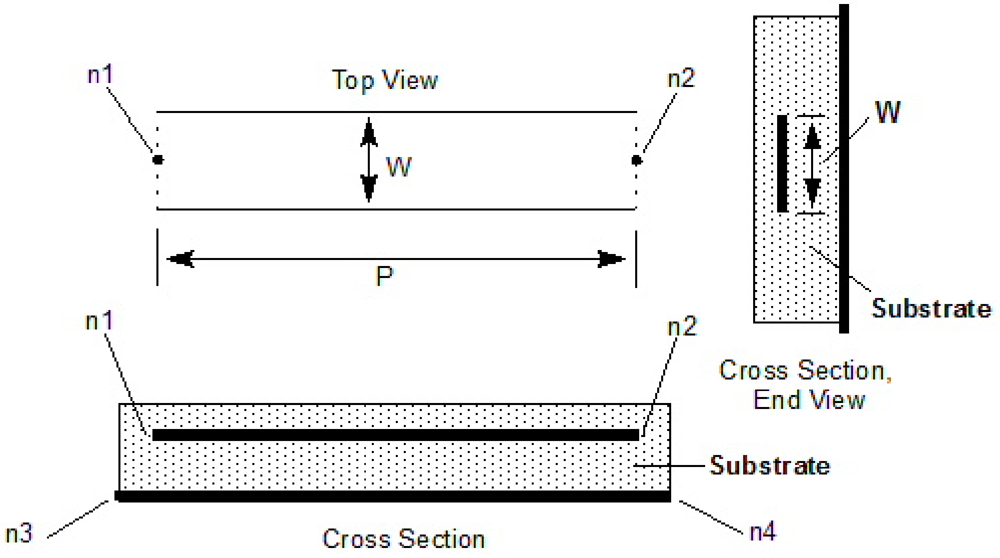
```
A23 Port1 Port2 W=1.2700e-004 P=0.001
+ COMPONENT=TRL   SUBSTRATE=OSL1
```

where OSL1, the selected layout technology or substrate type, has a definition such as:

```
.SUB OSL1 OSL(
+ B=0.001524 Er=4.4 TAND=0.02 BL=2.5400e-004
+ MET1=1.724137931034483 T1=2.5400e-005
+ RGH=0)
```

Transmission Line, Physical Length with Reference





Netlist Format

An instance of a transmission line with physical length and reference nodes has the following netlist syntax:

```
Axxx n1 n2 n3 n4 [W=val] [P=val]

COMPONENT=TRL SUBSTRATE=substrate_name
```

n1, *n2*, *n3*, and *n4* are the names of the nodes attached to the transmission line. The entry **COMPONENT=TRL** identifies the element as a transmission line with physical length.

The **SUBSTRATE=***substrate_name* is the offset stripline substrate model name selected for the design (see "Offset Stripline Substrate Model" on page 27-12 for details.

Table 171: Transmission Line with Physical Length and Reference Nodes, Instance Parameters

Parameter	Description	Units	Default
P	Physical length	Meter	1e-2
W	Conductor width	Meter	1e-3

Netlist Example

```
A5 Port1 Port2 0 0 W=0.001 P=0.01 COMPONENT=TRL SUBSTRATE=OSL1
```

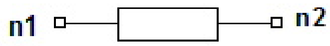
where OSL1, the selected layout technology or substrate type, has a definition such as:

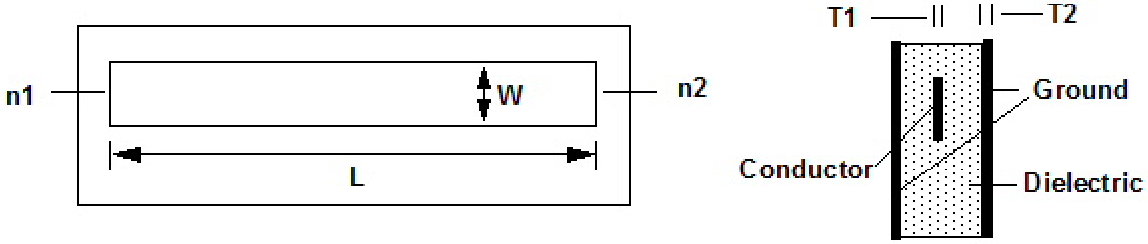
```
.SUB OSL1 OSL(
+ B=0.001524 Er=4.4 TAND=0.02 BL=2.5400e-004
+ MET1=1.724137931034483 T1=2.5400e-005
+ RGH=0)
```

Notes

1. [**Stripline**] For accurate results, the substrate definition should specify W/B <10.

Transmission Line, Field Solver





Netlist Format

A field solver offset stripline transmission line has the following netlist syntax:

W*xxx n1 n2* **0 N=1 W=***val* **L=***val* **FSmodel=***modelname*

```
.MATERIAL conductor METAL CONDUCTIVITY=val

.MATERIAL dielectric DIELECTRIC ER=val LOSSTANGENT=val

.SHAPE RECT1 RECTANGLE WIDTH=w HEIGHT=t1 // Conductors
.LAYERSTACK layerstack

+ LAYER=(conductor, t2) // Lower ground plane
+ LAYER=(dielectric, b) // Dielectric layer
```

```
+ LAYER=(conductor, t2) // Upper ground plane
.MODEL modelname W MODELTYPE=Fieldsolver
+ LAYERSTACK=layerstack

+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=(0, 't2 + bl')
```

n1, and *n2* are the names of the input and output nodes. The entry **N=1** shows that this is a single transmission line. The names for the *modelname*, *conductor*, *dielectric*, and *layerstack* are supplied by the user.

The entry **FSmodel=***modelname* identifies the field solver offset stripline W-model.

Table 172: Transmission Line, Field Solver Instance Parameters

Parameter	Description	Units	Default
W	Width of conductor	Meter	1e-3
L	Physical length	Meter	1e-3
N	Number of lines for W-model . Must be 1 for transmission line.	None	1
T1	Thickness of conductors	Meter	0.001
T2	Thickness of ground planes	Meter	0.001
B	Thickness of dielectric layer	Meter	1e-3
BL	Height of conductors above lower ground plane	Meter	B/2
CONDUCTIVITY	Conductivity of conductor material		57.6e6
ER	Dielectric constant		2.2
TAND	Dielectric loss tangent		0

> **Note:** The default values for the transmission line are the ones assigned when placing a component on the Component library in a schematic. There are NO defaults for netlist designs; all values must be specified.

Netlist Example

```
W3 Port1 Port2 0 N=1 W-0.0001 L=0.002 FSmodel=OSL1

.MATERIAL cond1 METAL CONDUCTIVITY=5.8e7
.MATERIAL diel1 DIELECTRIC ER=4.4 LOSSTANGENT=0.02
.SHAPE rect1 RECTANGLE WIDTH=.002 // Conductor width W
+ HEIGHT=.001   // Conductor height T1
.LAYERSTACK offsetstripline
```

```
+ LAYER=(cond1, .001) // Bottom ground T2
+ LAYER=(diel1, .01) // Dielectric B
+ LAYER=(cond1, .001) // Top ground, T2
.MODEL OSL1 W MODELTYPE=Fieldsolver
+ LAYERSTACK=offsetstripline
+ CONDUCTOR=(SHAPE=rect1, ORIGIN=(0, '.001 + .005') // T2 + BL
+ MATERIAL=cond1, TYPE=SIGNAL)
```

Selecting None for the Initial Substrate

For Nexxim designs that are created with the **Schematic Editor**, the initial selection of a global substrate type is made on the **Choose Layout Technology** window that appears when you select Insert Nexxim Circuit Design on the Project menu.

However, no offset stripline substrates are available in the **Choose Layout Technology** window.

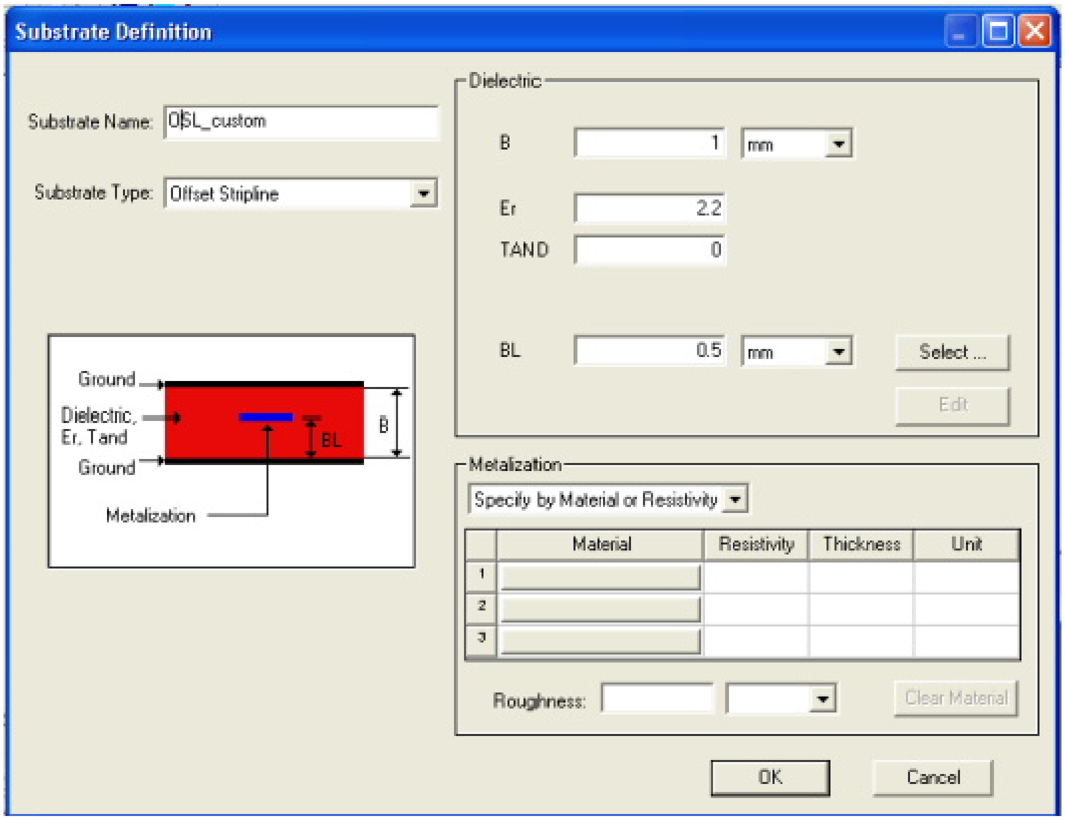
If you wish to use an offset stripline substrate, you must create it as a custom substrate type.

In the **Choose Layout Technology** window, click **None**. The design opens, but no substrate type is applied to instances of distributed elements until you create a custom substrate type.

See "Creating a Custom Offset Stripline Substrate" below for details.

Creating a Custom Offset Stripline Substrate

To create an offset stripline substrate definition, open the Nexxim design icon (e.g., “Nexxim1”, then right-click the **Data** field and select **Add Substrate Definition** to open the **Substrate Definition** window. Specify the name of your new substrate (the following example uses the name “OSL_custom”).



Substrate Name: OSL_custom

Substrate Type: Offset Stripline

B: 1 mm

Er: 2.2

TAND: 0

BL: 0.5 mm

Specify by Material or Resistivity

Roughness:

Select Offset Stripline as the Substrate Type. Complete the Dielectric and Metallization filed information. (See the "Offset Stripline Substrate Model" on the next page help topic for guidelines on defining offset stripline substrates.

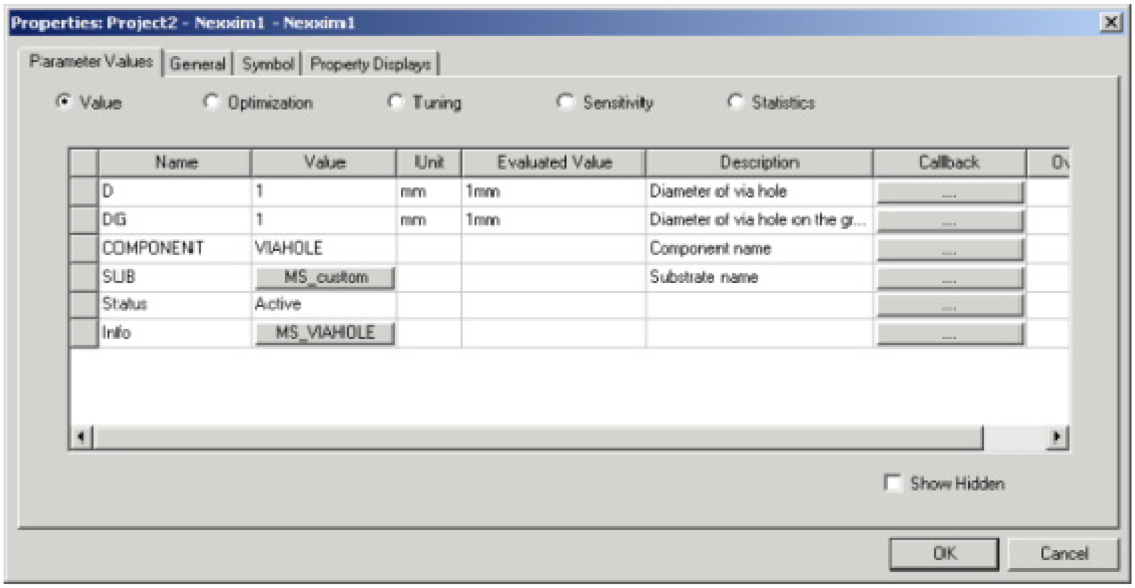
When the substrate definition is complete, click **OK**.

If you selected **None** for the global substrate type in the **Choose Layout Technology** window, the custom offset stripline substrate becomes the global substrate type.

When an element is instantiated , it includes a **SUBSTRATE=***substrate_name* entry in its netlist syntax. **Electronics Desktop** automatically inserts the global *substrate_name* into the internal netlist entry for the instantiated element.

Selecting an Offset Stripline Substrate at the Component Level

To specify a custom substrate type, or to change to a different predefined substrate type, you must make the assignment individually for each component. Double-click the distributed element to open the **Properties** window:



Properties: Project2 - Nexxim1 - Nexxim1

Parameter Values | General | Symbol | Property Displays

● Value ○ Optimization ○ Tuning ○ Sensitivity ○ Statistics

Name	Value	Unit	Evaluated Value	Description	Callback	Ov
D	1	mm	1mm	Diameter of via hole	...	
DIG	1	mm	1mm	Diameter of via hole on the gr...	...	
COMPONENT	VIAHOLE			Component name	...	
SUB	MS_custom			Substrate name	...	
Status	Active				...	
Info	MS_VIAHOLE				...	

☐ Show Hidden

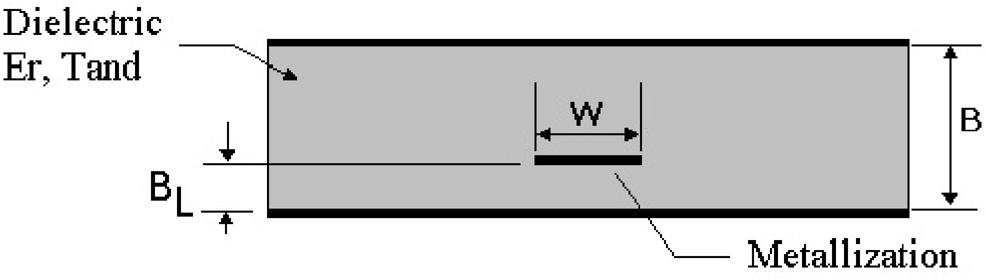
OK Cancel

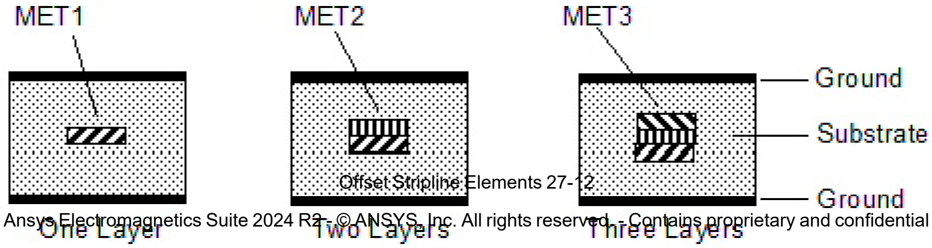
The **SUB** property identifies the substrate that is currently applied to the element. In the example above, a custom substrate type named “MS_custom” appears as the value of the **SUB** property.

To change to a different substrate type and click in the **SUB** Value field and select the appropriate substrate name as the value of the **SUB** property. Then click **OK**.

> **Note:** All distributed elements in a given design must use the same substrate type.

Offset Stripline Substrate Model





metallization

Defining an Offset Stripline Model

To add an offset stripline substrate model to a new Nexxim design, you must add the definition to the set of substrate models.

To add a new substrate definition to an existing design, expand the **Project** icon, the **Design** icon. Right-click the **Data** icon and select **Add Substrate Definition** to open the **Substrate Definition** window. Then add the substrate name and parameters as appropriate, and click **OK**. A substrate added in this manner requires you to specify the metallization parameters explicitly.

To edit the definition of a substrate, expand the **Project** icon, the **Design** icon, the **Data** icon. Click on the icon for the substrate you wish to edit to open the **Substrate Definition** window. Add or modify the substrate parameters as appropriate, then click **OK**.

Offset Stripline Substrate Model Netlist Format

The Offset Stripline substrate model has the following netlist format:

```
.SUBsubstrate_name OSL ( [B=val] BL= val [ER=val] [TAND=val]

[MET1=val] [T1=val] [MET2=val] [T2=val] [MET3=val]    [T3=val]

[RGH=val])
```

The *substrate_name* is the name for the substrate type used in distributed elements that refer to this substrate definition. The entry **OSL** is required to identify the Offset Stripline substrate type. The **OSL** identifier must immediately follow the *substrate_name*.

Inside the parentheses, the labeled parameters may be entered in any order.

Table 173: Offset Stripline Substrate Parameters

Parameter	Description	Unit	Default
B	Spacing between ground planes, B > 0	Meter	1e-3
BL	Spacing between stripline and lower ground plane	Meter	
ER	Dielectric constant of substrate, 1 ≤ ER ≤ 128	None	4.5
MET1, **MET2**, **MET3**	Resistivity of metal layer 1, 2, 3	μOhm-cm	0.0
RGH	RMS surface roughness	Meter	0.0
T1, **T2**, **T3**	Thickness of metal layer 1, 2, 3	Meter	0.0
TAND	Dielectric loss tangent, [0,0.1]	None	0.0

Stripline Substrate Model Netlist Example

```
.SUB OSL1 OSL(
+ B=0.001524 Er=4.4 TAND=0.02 BL=2.5400e-004
+ MET1=1.724137931034483 T1=2.5400e-005
+ RGH=0)
```

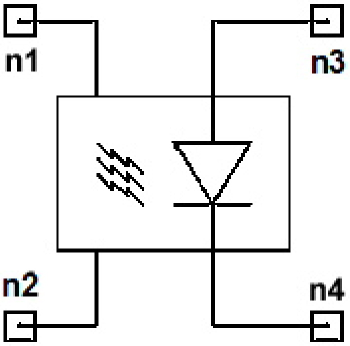
> **Note:** Surface roughness in the substrate definition is not supported in some MCPL implementations.

28 - Optoelectronic Elements

This topic describes the following optoelectronic elements:

"PIN Photodetector, Linear Model" below

PIN Photodetector, Linear Model



PIN Photodetector Instance Netlist Syntax

The syntax for the PIN photodetector, linear model instance is:

APINL*xxxx n1 n2 n3 n4* **RES=***val* **CS=***val* **RP=***val* **LP=***val* **CP=***val* **TAU=***val* **COMPONENT=pinl**

n1 and *n2* are the input nodes, *n3* and *n4* are the output nodes of the photodetector. The entry **COMPONENT=pinl** identifies the device.

Table 7: PIN Photodetector, Linear Model Instance Parameters

Instance Parameter	**Description**	**Unit**	**Default**
RES	Responsivitity	Watt/amp	0.0
CS	Chip capacitance	Farad	0.0
RP	Series resistance	Ohm	0.0
LP	Bondwire inductance	Henry	0.0
CP	Package capacitance	Farad	0.0
TAU	Carrier transit time	Second	0.0

PIN Photodetector, Linear Model, Netlist Example

```
APINL123 photo1 photo2 line1 line2 RES=0.6
+ COMPONENT=pinl
```

29 - Power Electronics Tools

This topic describes the following elements of the Power Electronics Tools:

Controllers

Power Semiconductors

Pulse Width Modulation

Space-Vector PWM 3-Phase 2-Level

Piecewise-linear Diode Model

Controllers

This topic describes the following elements of the Controllers:

Compensators

Motors

This topic describes the following elements of the Motor Models:

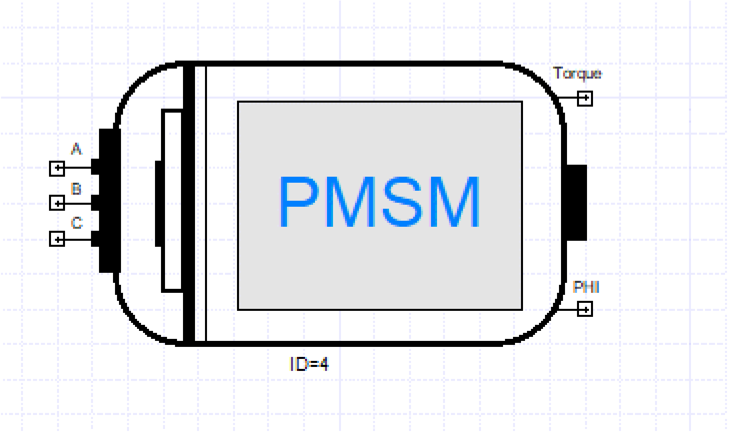
Synchronous Machines

Synchronous Machines

This topic describes the following elements of Synchronous Machines:

SYMP: Permanent Magnet Synchronous Machine

SYMP: Permanent Magnet Synchronous Machine



The permanent magnet synchronous machine aims to enable realistic motor modeling for power electronics designs.

Input Terminals

Name	Description
A, B, C	3-phase inputs to the star connected stator windings.

Input Parameters

Name	Description	Unit	Default Value
p	Number of pole pairs		2
r1	Stator resistance	Ohms	0.4
L1d	Stator inductance of d-axis	H	0.042
L1q	Stator inductance of q-axis	H	0.042
ke	Rotor flux	Wb	0.875
n	Input speed	rad/sec	0
phi0	Initial rotor position	rad	0

Output Terminals

Name	Description
Torque	Torque (n*m)
Angular Position	Angular Position (Rad)

Mathematical Description

Equation System

The equation system is implemented in a rotor-fixed (rotor-fixed and also rotor flux-fixed) coordinate system (d-q-coordinates). Index 1 represents the stator quantities. The phase quantities of the real three-phase synchronous machine are indicated with a, b, c. Ψ is the magnetic flux.

Voltage Equations

$$\begin{aligned} v_{1d}(t) &= R_1 \cdot i_{1d}(t) + \frac{d\Psi_{1d}(t)}{dt} - \omega_E \cdot \Psi_{1q}(t) \\ v_{1q}(t) &= R_1 \cdot i_{1q}(t) + \frac{d\Psi_{1q}(t)}{dt} + \omega_E \cdot \Psi_{1d}(t) \\ v_{10}(t) &= R_1 \cdot i_{10}(t) + \frac{d\Psi_{10}(t)}{dt} \end{aligned}$$

Flux Equations

$$\begin{aligned} \Psi_{1d}(t) &= L_1 \cdot i_{1d}(t) + \Psi_{Pm1fd} \\ \Psi_{1q}(t) &= L_1 \cdot i_{1q}(t) \\ \Psi_{10}(t) &= L_{10} \cdot i_{10} t \end{aligned}$$

Field Equation

$$\Psi_{Pm1fd} = \frac{k_e}{p}$$

Torque equation

$$m_{Int}(t) = \frac{3}{2} \cdot p \cdot (\Psi_{1d}(t) \cdot i_{1q}(t) - \Psi_{1q}(t) \cdot i_{1d}(t))$$

Rotation Matrix

$$R = \begin{bmatrix} \cos\gamma & \sin\gamma & 0 \\ -\sin\gamma & \cos\gamma & 0 \\ 0 & 0 & 1 \end{bmatrix}$$

Three-phase - two-phase and two-phase - three-phase transformation matrices

$$T_{32} = \begin{bmatrix} \frac{2}{3} & -\frac{1}{3} & -\frac{1}{3} \\ 0 & \frac{\sqrt{3}}{3} & -\frac{\sqrt{3}}{3} \\ \frac{1}{3} & \frac{1}{3} & \frac{1}{3} \end{bmatrix} \quad \text{and} \quad T_{23} = \begin{bmatrix} 1 & 0 & 1 \\ -\frac{1}{2} & \frac{\sqrt{3}}{2} & 1 \\ -\frac{1}{2} & -\frac{\sqrt{3}}{2} & 1 \end{bmatrix}$$

Reference frame transformation - stator voltages

$$\begin{bmatrix} v_{1\alpha} \\ v_{1\beta} \\ v_{10} \end{bmatrix} = T_{32} \cdot \begin{bmatrix} v_{1a} \\ v_{1b} \\ v_{1c} \end{bmatrix} \quad \text{and} \quad \begin{bmatrix} v_{1d} \\ v_{1q} \\ v_{10} \end{bmatrix} = R \cdot \begin{bmatrix} v_{1\alpha} \\ v_{1\beta} \\ v_{10} \end{bmatrix}$$

Reference frame transformation - stator currents

$$\begin{bmatrix} i_{1\alpha} \\ i_{1\beta} \\ i_{10} \end{bmatrix} = R^{-1} \cdot \begin{bmatrix} i_{1d} \\ i_{1q} \\ i_{10} \end{bmatrix} \quad \text{and} \quad \begin{bmatrix} i_{1a} \\ i_{1b} \\ i_{1c} \end{bmatrix} = T_{23} \cdot \begin{bmatrix} i_{1\alpha} \\ i_{1\beta} \\ i_{10} \end{bmatrix}$$

Power Semiconductors

This topic describes the following elements of the Power Semiconductors:

MOSFET

MOSFET

This topic describes the following MOSFET elements:

STMicroelectronics

UARK

STMicro Electronics

This topic describes the following STMicro Electronics components:

Automotive-grade silicon carbide 1200 V, 16 mΩ typ., 125 A Power MOSFET bare die in D8 packing

Automotive-grade silicon carbide 750 V, 10.5 mΩ typ., 167 A Power MOSFET bare die in D8 packing

Automotive-grade silicon carbide Power MOSFET 650 V, 40 mΩ typ., 30 A in an H²PAK-7 package

Silicon carbide Power MOSFET 1200 V, 21 mΩ typ., 91 A in an HiP247 package

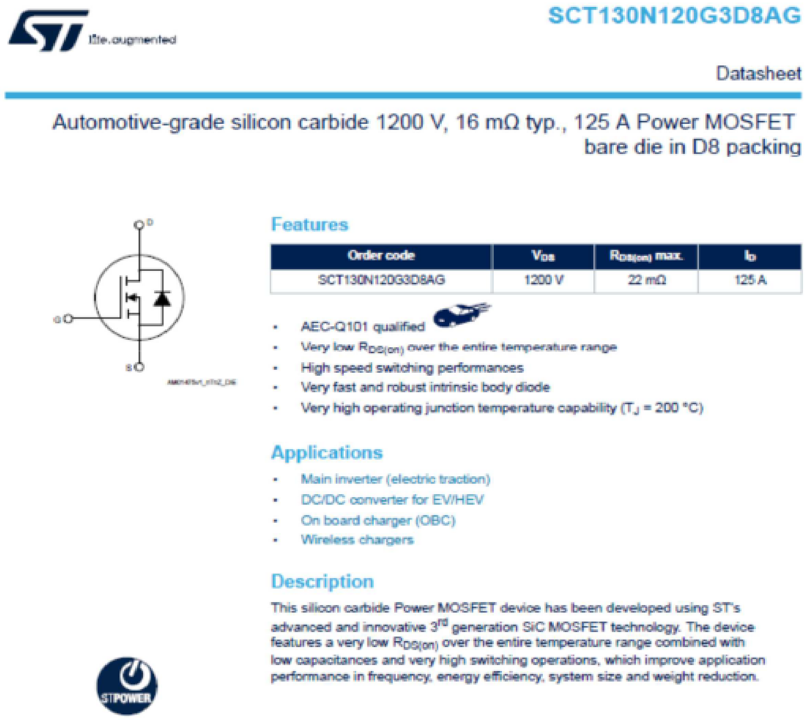
Silicon carbide Power MOSFET 1200 V, 35 mΩ typ., 60 A in an HiP247-4 package

Silicon carbide Power MOSFET 650 V, 116 A, 18 mΩ (typ., TJ = 25 °C) in an H²PAK-7 package

Silicon carbide Power MOSFET 650 V, 18 mΩ typ., 119 A in an HiP247-4 package

Silicon carbide Power MOSFET 650 V, 55 mΩ typ., 40 A in a PowerFLAT 8x8 HV package

Automotive-grade silicon carbide 1200 V, 16 mΩ typ., 125 A Power MOSFET bare die in D8 packing



SCT130N120G3D8AG

Datasheet

Automotive-grade silicon carbide 1200 V, 16 mΩ typ., 125 A Power MOSFET bare die in D8 packing

Features

Order code	V_{DS}	$R_{DS(on)}$ max.	I_D
SCT130N120G3D8AG	1200 V	22 mΩ	125 A

- AEC-Q101 qualified
- Very low $R_{DS(on)}$ over the entire temperature range
- High speed switching performances
- Very fast and robust intrinsic body diode
- Very high operating junction temperature capability (T_J = 200 °C)

Applications

- Main inverter (electric traction)
- DC/DC converter for EV/HEV
- On board charger (OBC)
- Wireless chargers

Description

This silicon carbide Power MOSFET device has been developed using ST's advanced and innovative 3rd generation SiC MOSFET technology. The device features a very low $R_{DS(on)}$ over the entire temperature range combined with low capacitances and very high switching operations, which improve application performance in frequency, energy efficiency, system size and weight reduction.

SCT130N120G3D8AG
Electrical ratings

1 Electrical ratings

Table 1. Absolute maximum ratings

Symbol	Parameter		Value	Unit
V_{GS}	Gate-source voltage		-10 to 22	V
	Gate-source voltage (recommended operating values)		-5 to 18	V
	Gate-source transient voltage, $t_p < 1$ μs, $t \leq 10$ hours over lifetime		-11 to 25	V
I_D[1]	Drain current (continuous), limited by T_J max. = 200 °C, V_{GS} = 18 V, R_{thJC} < 0.28 °C/W	T_C = 25 °C	125	A
		T_C = 100 °C	95	A
I_{DM}[1][2]	Drain current (pulsed)		378	A
T_{stg}	Storage temperature range		-55 to 200	°C
T_J	Operating junction temperature range			°C

1. *Specified by design, not tested in production.*
2. *Pulse width is limited by safe operating area.*

SCT130N120G3D8AG
Electrical characteristics

2 Electrical characteristics

T_C = 25 °C unless otherwise specified.

Table 2. On/off states

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{(BR)DSS}$	Drain-source breakdown voltage	V_{GS} = 0 V, I_D = 1 mA	1200			V
I_{DSS}	Zero gate voltage drain current	V_{GS} = 0 V, V_{DS} = 1200 V			10	µA
I_{GSS}	Gate-body leakage current	V_{DS} = 0 V, V_{GS} = -10 to 22 V			±100	nA
$V_{GS(th)}$	Gate threshold voltage	V_{DS} = V_{GS}, I_D = 5 mA (Bin 1)	2.0		2.5	V
		V_{DS} = V_{GS}, I_D = 5 mA (Bin 2)	2.5		3.0	V
		V_{DS} = V_{GS}, I_D = 5 mA (Bin 3)	3.0		3.5	V
		V_{DS} = V_{GS}, I_D = 5 mA (Bin 4)	3.5		4.3	V
$R_{DS(on)}$	Static drain-source on-resistance	V_{GS} = 18 V, I_D = 60 A		16	22	mΩ
		V_{GS} = 15 V, I_D = 60 A		20		
		V_{GS} = 18 V, I_D = 60 A, T_J = 200 °C		30		

Table 3. Dynamic (referred to the discrete package)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
C_{iss}	Input capacitance	V_{DS} = 1000 V, f = 1 MHz, V_{GS} = 0 V	-	3600	-	pF
C_{oss}	Output capacitance		-	167	-	pF
C_{rss}	Reverse transfer capacitance		-	30	-	pF
R_g	Gate input resistance	f = 1 MHz, I_D = 0 A	-	1.1	-	Ω
Q_g	Total gate charge	V_{DS} = 800 V, I_D = 60 A, V_{GS} = -5 V to 18 V	-	155	-	nC
Q_{gs}	Gate-source charge		-	41	-	nC
Q_{gd}	Gate-drain charge		-	60	-	nC

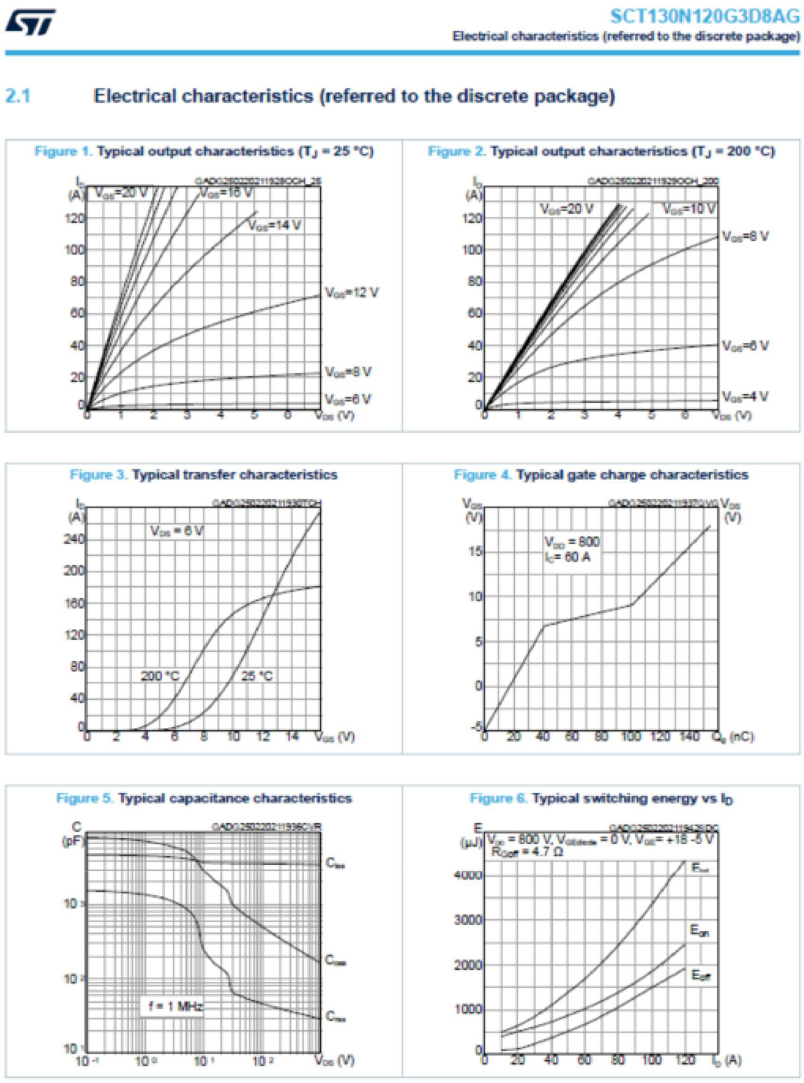
Table 4. Inductive load switching energy (referred to the discrete package)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
E_{on}	Turn-on switching energy	V_{DD} = 800 V, I_D = 60 A, R_g = 4.7 Ω, V_{GS} = -5 V to 18 V at T_C=25 °C	-	1000	-	µJ
E_{off}	Turn-off switching energy		-	670	-	µJ

Table 5. Reverse SiC diode characteristics (referred to the discrete package)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_{SD}	Diode forward voltage	I_{SD} = 100 A, V_{GS} = -5 V	-	5.2	-	V
t_{rr}	Reverse recovery time	V_{DD} = 800 V, I_D = 100 A, di/dt = 1000 A/ns	-	130	-	ns
Q_{rr}	Reverse recovery charge		-	750	-	nC
I_{RRM}	Reverse recovery current		-	18	-	A

ST Confidential



SCT130N120G3D8AG

Electrical characteristics (referred to the discrete package)

2.1 Electrical characteristics (referred to the discrete package)

Figure 1. Typical output characteristics (T_J = 25 °C)

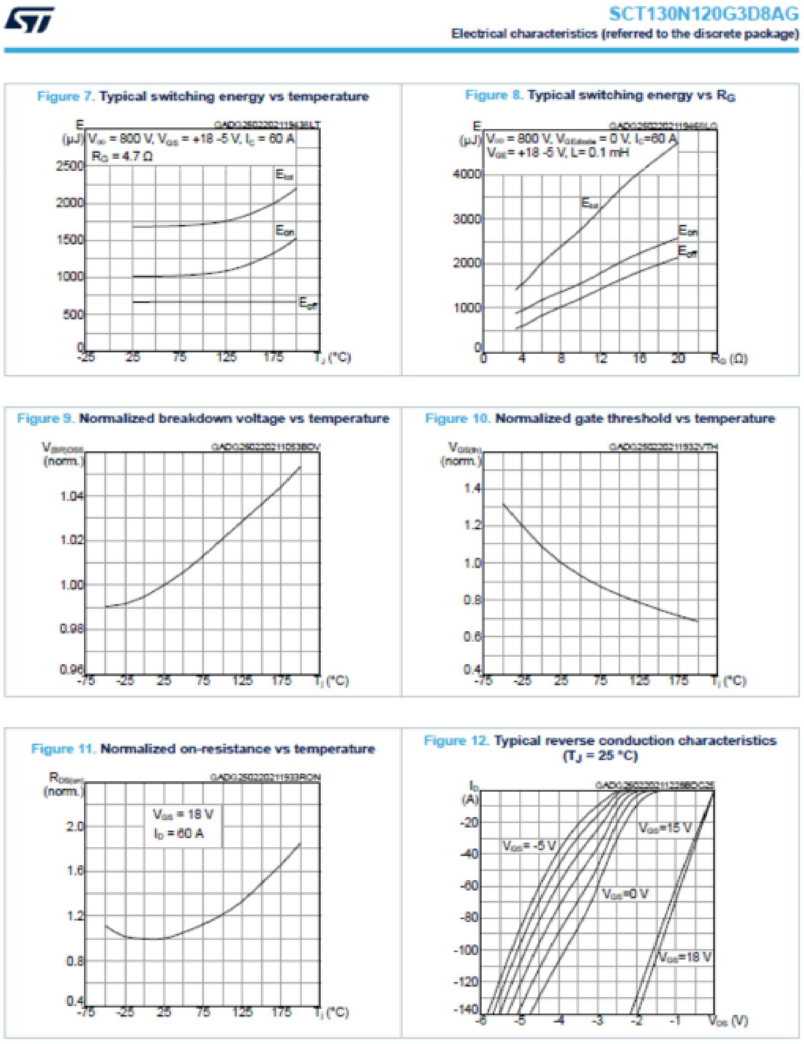
Figure 2. Typical output characteristics (T_J = 200 °C)

Figure 3. Typical transfer characteristics

Figure 4. Typical gate charge characteristics

Figure 5. Typical capacitance characteristics

Figure 6. Typical switching energy vs I_D



SCT130N120G3D8AG

Electrical characteristics (referred to the discrete package)

Figure 7. Typical switching energy vs temperature

Figure 8. Typical switching energy vs R_G

Figure 9. Normalized breakdown voltage vs temperature

Figure 10. Normalized gate threshold vs temperature

Figure 11. Normalized on-resistance vs temperature

Figure 12. Typical reverse conduction characteristics (T_J = 25 °C)

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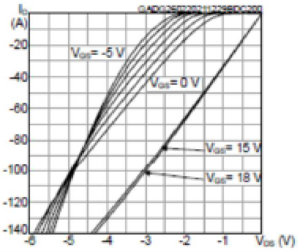
SCT130N120G3D8AG

Electrical characteristics (referred to the discrete package)

Figure 13. Typical reverse conduction characteristics (T_J = 200 °C)



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Automotive-grade silicon carbide 750 V, 10.5 mΩ typ., 167 A Power MOSFET bare die in D8 packing

SCT160N75G3D8AG

Datasheet

Automotive-grade silicon carbide 750 V, 10.5 mΩ typ., 167 A Power MOSFET bare die in D8 packing

Features

Order code	V_{DS}	$R_{DS(on)}$ max.	I_D
SCT160N75G3D8AG	750 V	14 mΩ	167 A

- AEC-Q101 qualified
- Very low $R_{DS(on)}$ over the entire temperature range
- High speed switching performances
- Very fast and robust intrinsic body diode
- Very high operating junction temperature capability (T_J = 200 °C)

Applications

- Main inverter (electric traction)
- DC/DC converter for EV/HEV
- On board charger (OBC)
- Wireless chargers

Description

This silicon carbide Power MOSFET device has been developed using ST's advanced and innovative 3rd generation SiC MOSFET technology. The device features a very low $R_{DS(on)}$ over the entire temperature range combined with low capacitances and very high switching operations, which improve application performance in frequency, energy efficiency, system size and weight reduction.

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SCT160N75G3D8AG
Electrical ratings

1 Electrical ratings

Table 1. Absolute maximum ratings

Symbol	Parameter		Value	Unit
V_{GS}	Gate-source voltage		-10 to 22	V
	Gate-source voltage (recommended operating values)		-5 to 18	
	Gate-source transient voltage, t_p < 1 µs, t ≤ 10 hours over lifetime		-11 to 25	
I_D(1)	Drain current (continuous), limited by T_J max. = 200 °C, V_{GS} = 18 V, R_{thJC} < 0.32 °C/W	T_C = 25 °C	167	A
		T_C = 100 °C	126	
I_{DM}(1)(2)	Drain current (pulsed)		505	A
T_{stg}	Storage temperature range		-55 to 200	°C
T_J	Operating junction temperature range			°C

1. *Specified by design, not tested in production.*
2. *Pulse width is limited by safe operating area.*

SCT160N75G3D8AG
Electrical characteristics

2 Electrical characteristics

(T_C = 25 °C unless otherwise specified)

Table 2. On/off states

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{(BR)DSS}$	Drain-source breakdown voltage	V_{GS} = 0 V, I_D = 1 mA	750			V
I_{DSS}	Zero gate voltage drain current	V_{GS} = 0 V, V_{DS} = 750 V		1	10	µA
		V_{GS} = 0 V, V_{DS} = 750 V, T_J = 200 °C		25		
I_{GSS}	Gate-body leakage current	V_{DS} = 0 V, V_{GS} = -10 to 22 V			±100	nA
$V_{GS(th)}$	Gate threshold voltage	V_{DS} = V_{GS}, I_D = 5 mA (Bin 1)	2.0		2.6	V
		V_{DS} = V_{GS}, I_D = 5 mA (Bin 2)	2.6		3.2	V
		V_{DS} = V_{GS}, I_D = 5 mA (Bin 3)	3.2		3.8	V
		V_{DS} = V_{GS}, I_D = 5 mA (Bin 4)	3.8		4.4	V
$R_{DS(on)}$	Static drain-source on-resistance	V_{GS} = 18 V, I_D = 80 A		10.5	14	mΩ
		V_{GS} = 18 V, I_D = 80 A, T_J = 200 °C		15		

Table 3. Dynamic (referred to the discrete package)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
C_{iss}	Input capacitance	V_{DS} = 400 V, f = 1 MHz, V_{GS} = 0 V	-	4050	-	pF
C_{oss}	Output capacitance		-	350	-	pF
C_{rss}	Reverse transfer capacitance		-	40	-	pF
R_g	Gate input resistance	f = 1 MHz, I_D = 0 A	-	1.5	-	Ω
Q_g	Total gate charge	V_{DS} = 400 V, V_{GS} = -5 V to 18 V, I_D = 80 A	-	160	-	nC
Q_{gs}	Gate-source charge		-	51	-	nC
Q_{gd}	Gate-drain charge		-	53	-	nC

Table 4. Inductive load switching energy (referred to the discrete package)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
E_{on}	Turn-on switching energy	V_{DD} = 400 V, I_D = 80 A, R_G = 5.6 Ω, V_{GS} = -5 V to 18 V	-	585	-	µJ
E_{off}	Turn-off switching energy		-	565	-	µJ

Table 5. Reverse SiC diode characteristics (referred to the discrete package)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_{SD}	Diode forward voltage	I_{SD} = 80 A, V_{GS} = 0 V	-	3.2	-	V
t_{rr}	Reverse recovery time	V_{DS} = 400 V, V_{GS} = -5 V to 18 V, di/dt = 1000 A/µs, I_D = 80 A, R_G = 5.6 Ω	-	29	-	ns
Q_{rr}	Reverse recovery charge		-	267	-	nC
I_{RRM}	Reverse recovery current		-	16	-	A

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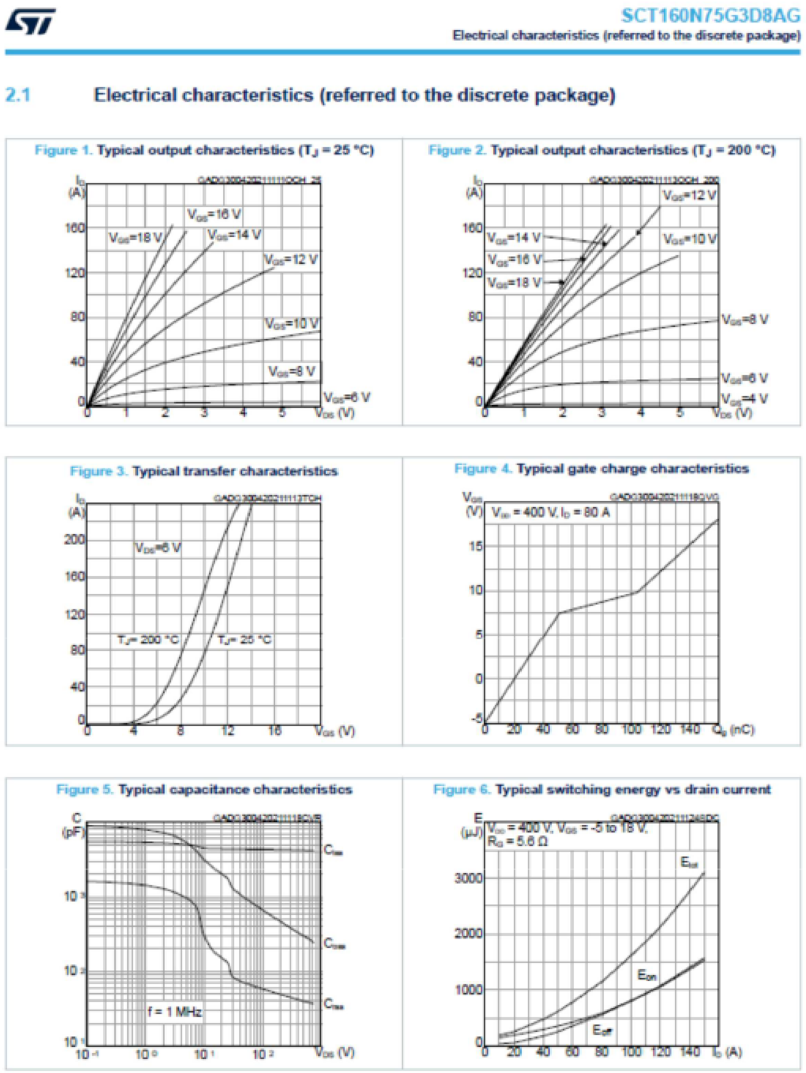

SCT160N75G3D8AG
Electrical characteristics (referred to the discrete package)

2.1 Electrical characteristics (referred to the discrete package)

Figure 1. Typical output characteristics (T_J = 25 °C)

Figure 2. Typical output characteristics (T_J = 200 °C)

Figure 3. Typical transfer characteristics

Figure 4. Typical gate charge characteristics

Figure 5. Typical capacitance characteristics

Figure 6. Typical switching energy vs drain current

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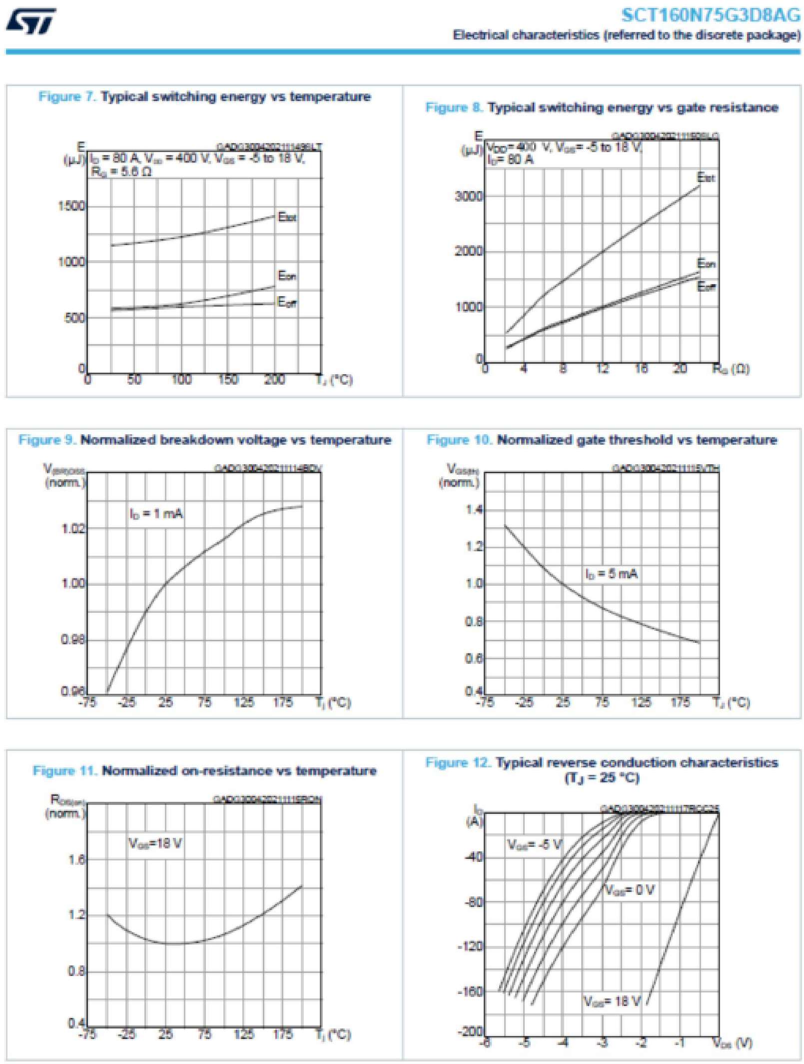


SCT160N75G3D8AG

Electrical characteristics (referred to the discrete package)

Figure 7. **Typical switching energy vs temperature**

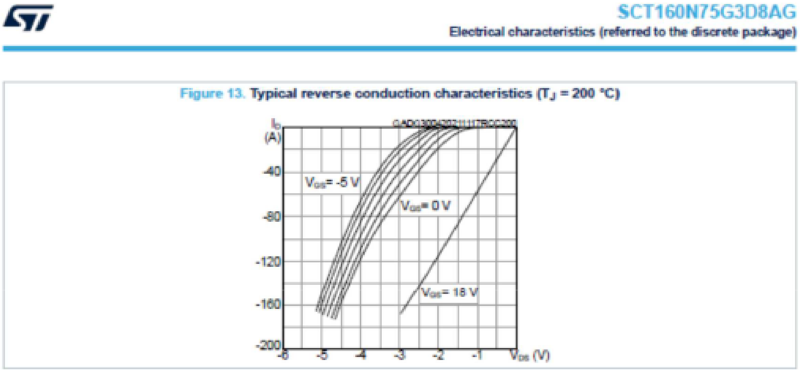
Figure 8. **Typical switching energy vs gate resistance**

Figure 9. **Normalized breakdown voltage vs temperature**

Figure 10. **Normalized gate threshold vs temperature**

Figure 11. **Normalized on-resistance vs temperature**

Figure 12. **Typical reverse conduction characteristics (T_J = 25 °C)**

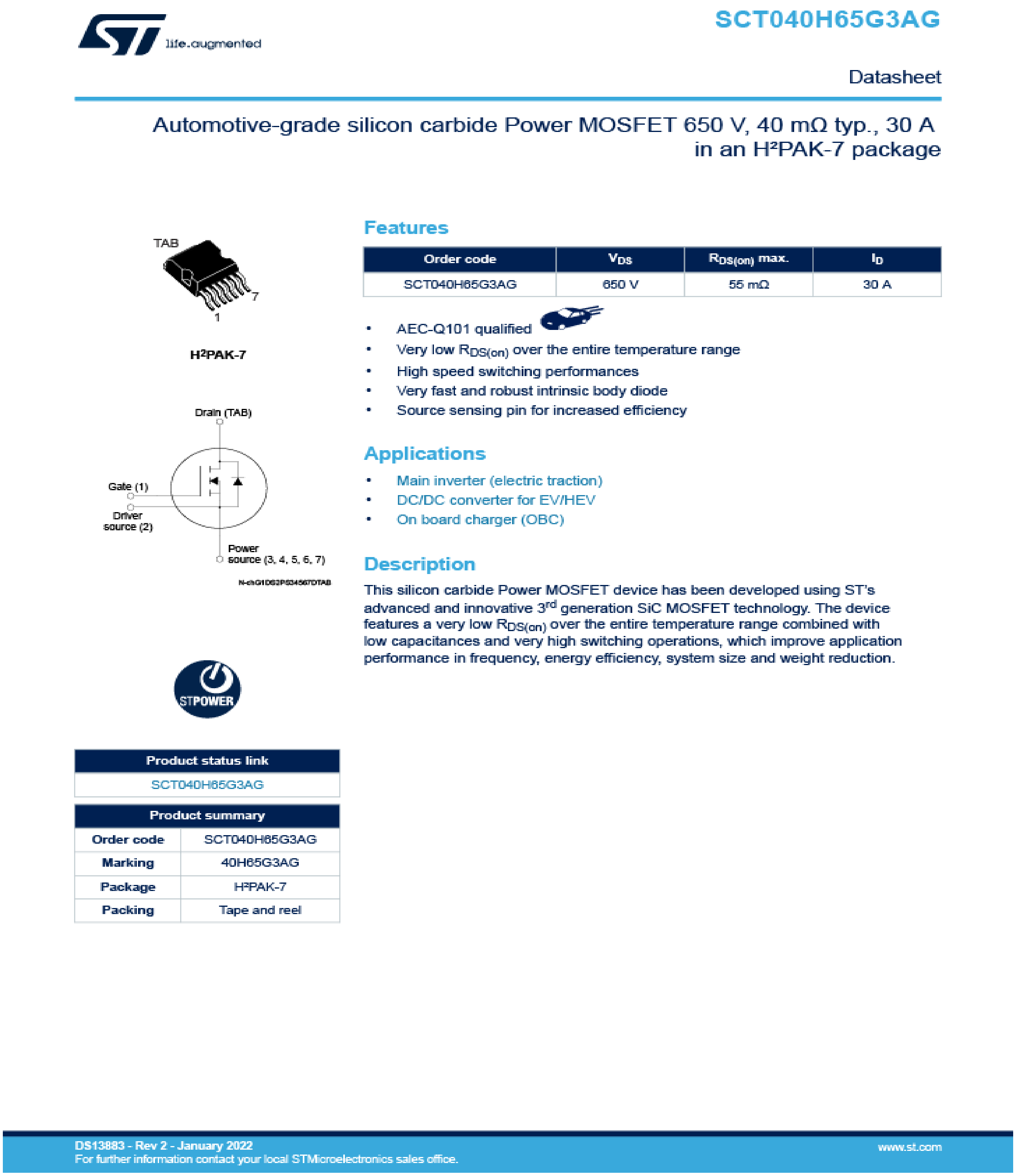


SCT160N75G3D8AG

Electrical characteristics (referred to the discrete package)

Figure 13. Typical reverse conduction characteristics (T_J = 200 °C)

Automotive-grade silicon carbide Power MOSFET 650 V, 40 mΩ typ., 30 A in an H²PAK-7 package



SCT040H65G3AG

Datasheet

Automotive-grade silicon carbide Power MOSFET 650 V, 40 mΩ typ., 30 A in an H²PAK-7 package

H^2PAK-7

Features

Order code	V_{DS}	$R_{DS(on)}$ max.	I_D
SCT040H65G3AG	650 V	55 mΩ	30 A

- AEC-Q101 qualified
- Very low $R_{DS(on)}$ over the entire temperature range
- High speed switching performances
- Very fast and robust intrinsic body diode
- Source sensing pin for increased efficiency

Applications

- Main inverter (electric traction)
- DC/DC converter for EV/HEV
- On board charger (OBC)

Description

This silicon carbide Power MOSFET device has been developed using ST's advanced and innovative 3rd generation SiC MOSFET technology. The device features a very low $R_{DS(on)}$ over the entire temperature range combined with low capacitances and very high switching operations, which improve application performance in frequency, energy efficiency, system size and weight reduction.

Product status link
SCT040H65G3AG

Product summary	
Order code	SCT040H65G3AG
Marking	40H65G3AG
Package	H²PAK-7
Packing	Tape and reel

DS13883 - Rev 2 - January 2022
For further information contact your local STMicroelectronics sales office.
www.st.com

1 Electrical ratings

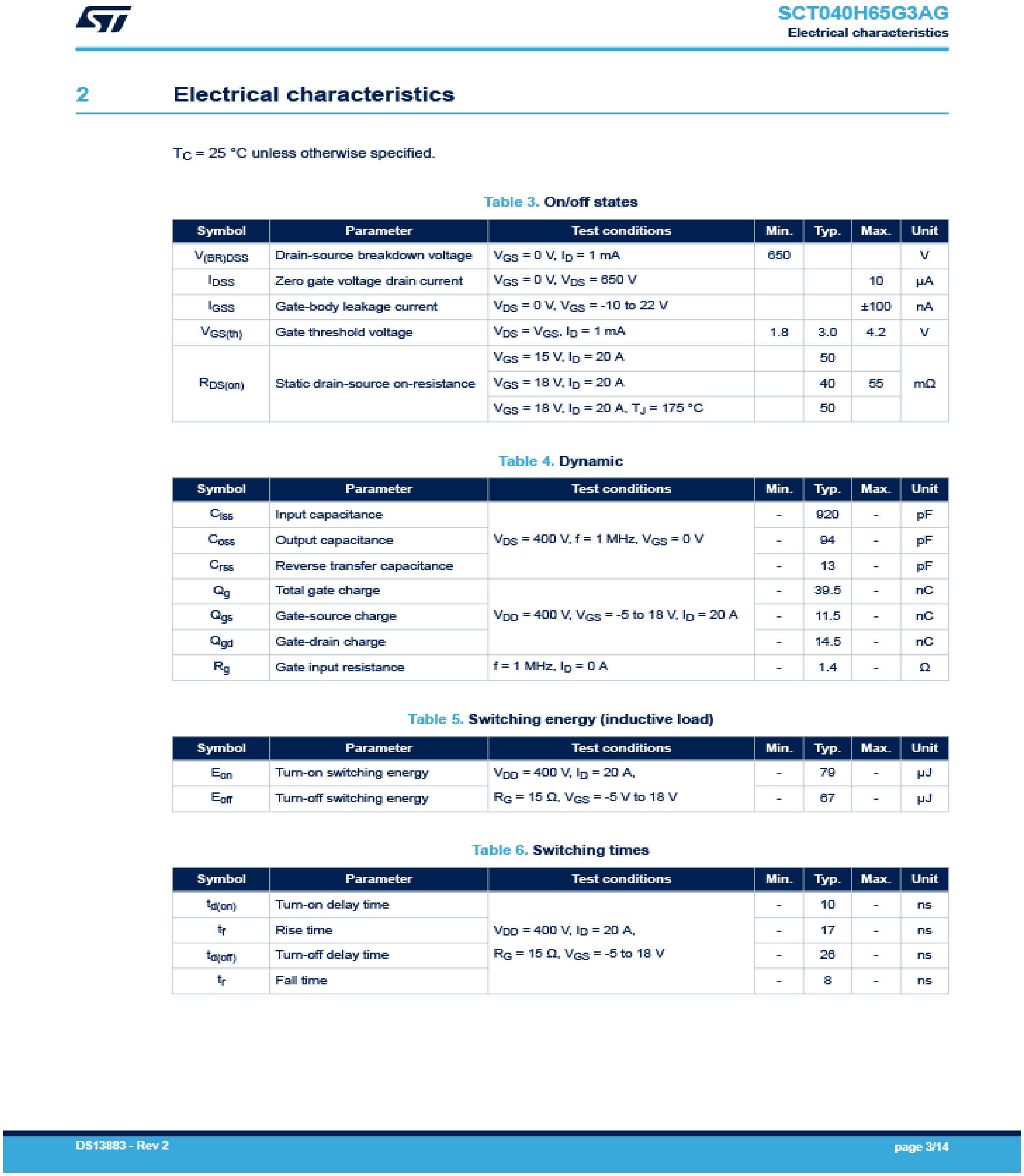
Table 1. **Absolute maximum ratings**

Symbol	Parameter	Value	Unit
V_{DS}	Drain-source voltage	650	V
V_{GS}	Gate-source voltage	-10 to 22	V
	Gate-source voltage (recommended operating values)	-5 to 18	
	Gate-source transient voltage, t_p < 1 µs, t ≤ 10 hours over lifetime	-11 to 25	
I_D (1)	Drain current (continuous) at T_C = 25 °C	30	A
	Drain current (continuous) at T_C = 100 °C	30	
I_{DM} (2)	Drain current (pulsed)	160	A
P_{TOT}	Total power dissipation at T_C = 25 °C	221	W
T_{stg}	Storage temperature range	-55 to 175	°C
T_J	Operating junction temperature range		°C

1. *I_D is limited by package.*
2. *Pulse width is limited by safe operating area.*

Table 2. **Thermal data**

Symbol	Parameter	Value	Unit
R_{thJC}	Thermal resistance, junction-to-case	0.68	°C/W
R_{thJA}	Thermal resistance, junction-to-ambient	50	°C/W



2 Electrical characteristics

T_C = 25 °C unless otherwise specified.

Table 3. On/off states

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{(BR)DSS}$	Drain-source breakdown voltage	V_{GS} = 0 V, I_D = 1 mA	650			V
I_{DSS}	Zero gate voltage drain current	V_{GS} = 0 V, V_{DS} = 650 V			10	µA
I_{GSS}	Gate-body leakage current	V_{DS} = 0 V, V_{GS} = -10 to 22 V			±100	nA
$V_{GS(th)}$	Gate threshold voltage	V_{DS} = V_{GS}, I_D = 1 mA	1.8	3.0	4.2	V
$R_{DS(on)}$	Static drain-source on-resistance	V_{GS} = 15 V, I_D = 20 A		50		mΩ
		V_{GS} = 18 V, I_D = 20 A		40	55	
		V_{GS} = 18 V, I_D = 20 A, T_J = 175 °C		50		

Table 4. Dynamic

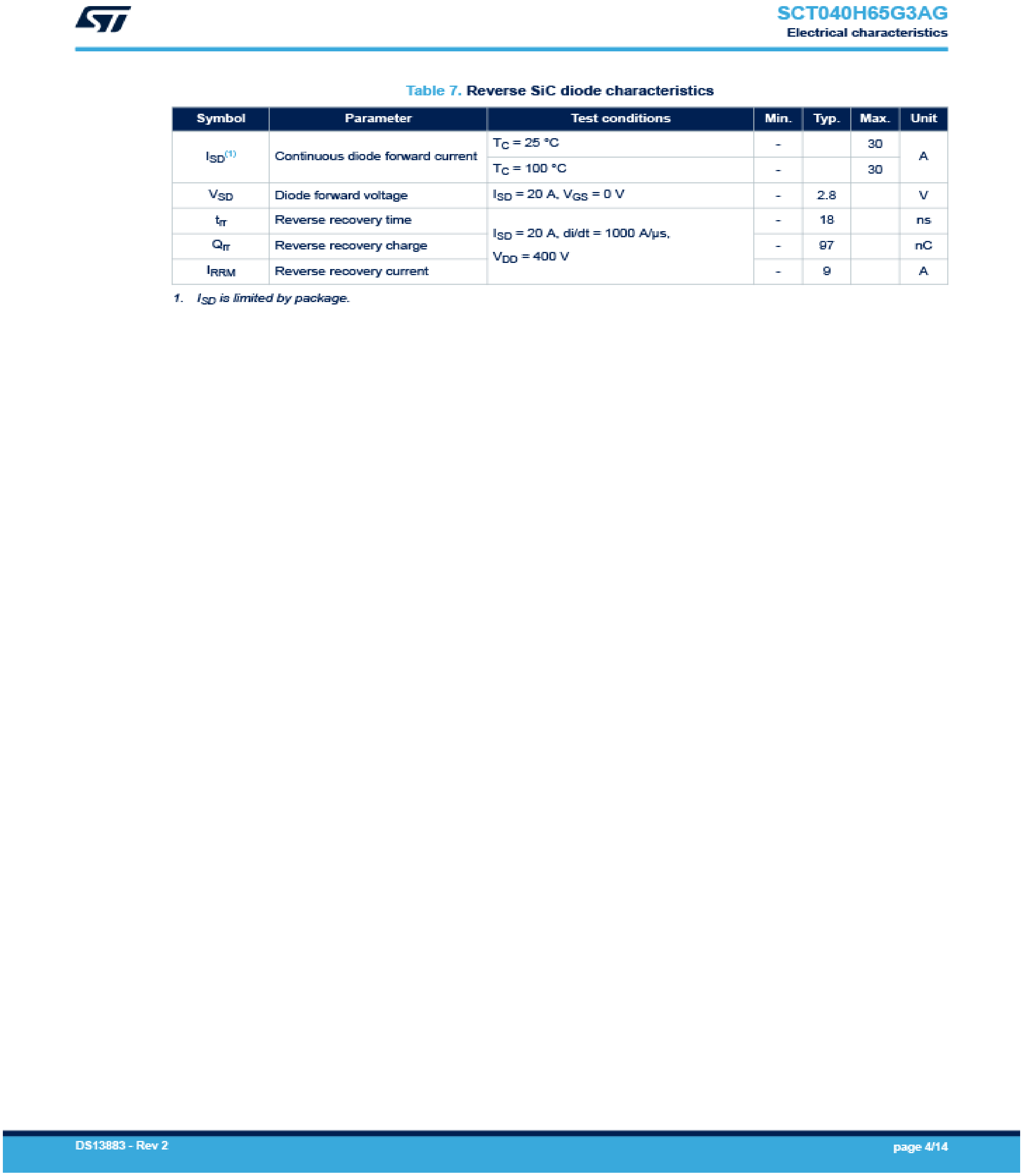
Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
C_{iss}	Input capacitance	V_{DS} = 400 V, f = 1 MHz, V_{GS} = 0 V	-	920	-	pF
C_{oss}	Output capacitance		-	94	-	pF
C_{rss}	Reverse transfer capacitance		-	13	-	pF
Q_g	Total gate charge	V_{DD} = 400 V, V_{GS} = -5 to 18 V, I_D = 20 A	-	39.5	-	nC
Q_{gs}	Gate-source charge		-	11.5	-	nC
Q_{gd}	Gate-drain charge		-	14.5	-	nC
R_g	Gate input resistance	f = 1 MHz, I_D = 0 A	-	1.4	-	Ω

Table 5. Switching energy (inductive load)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
E_{on}	Turn-on switching energy	V_{DD} = 400 V, I_D = 20 A, R_G = 15 Ω, V_{GS} = -5 V to 18 V	-	79	-	µJ
E_{off}	Turn-off switching energy		-	67	-	µJ

Table 6. Switching times

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$t_{d(on)}$	Turn-on delay time	V_{DD} = 400 V, I_D = 20 A, R_G = 15 Ω, V_{GS} = -5 to 18 V	-	10	-	ns
t_r	Rise time		-	17	-	ns
$t_{d(off)}$	Turn-off delay time		-	26	-	ns
t_f	Fall time		-	8	-	ns



SCT040H65G3AG

Electrical characteristics

Table 7. Reverse SiC diode characteristics

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
I_{SD}(1)	Continuous diode forward current	T_C = 25 °C	-		30	A
		T_C = 100 °C	-		30	
V_{SD}	Diode forward voltage	I_{SD} = 20 A, V_{GS} = 0 V	-	2.8		V
t_{rr}	Reverse recovery time	I_{SD} = 20 A, di/dt = 1000 A/µs, V_{DD} = 400 V	-	18		ns
Q_{rr}	Reverse recovery charge		-	97		nC
I_{RRM}	Reverse recovery current		-	9		A

1. *I_{SD} is limited by package.*

DS13883 - Rev 2 page 4/14

2.1 Electrical characteristics (curves)

Figure 1. Safe operating area

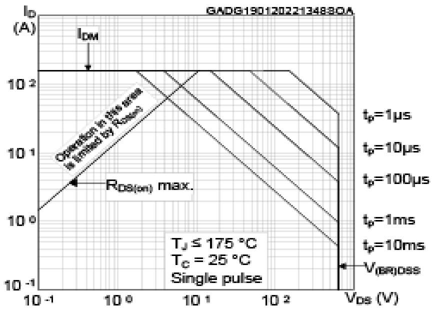


Figure 2. Maximum transient thermal impedance

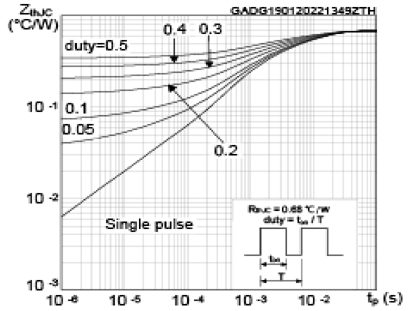


Figure 3. Typical output characteristics (T_J = 25 °C)

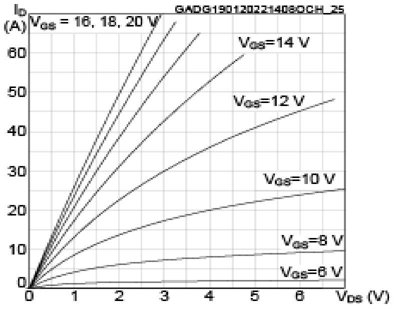


Figure 4. Typical output characteristics (T_J = 175 °C)

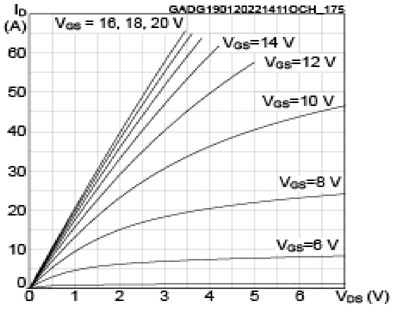


Figure 5. Typical transfer characteristics

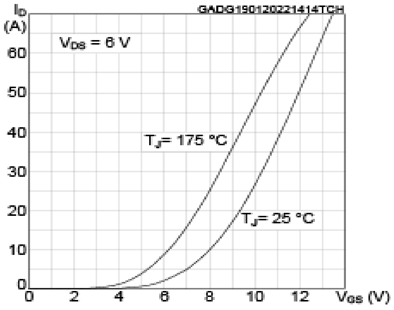
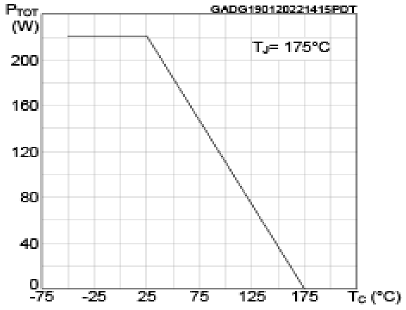
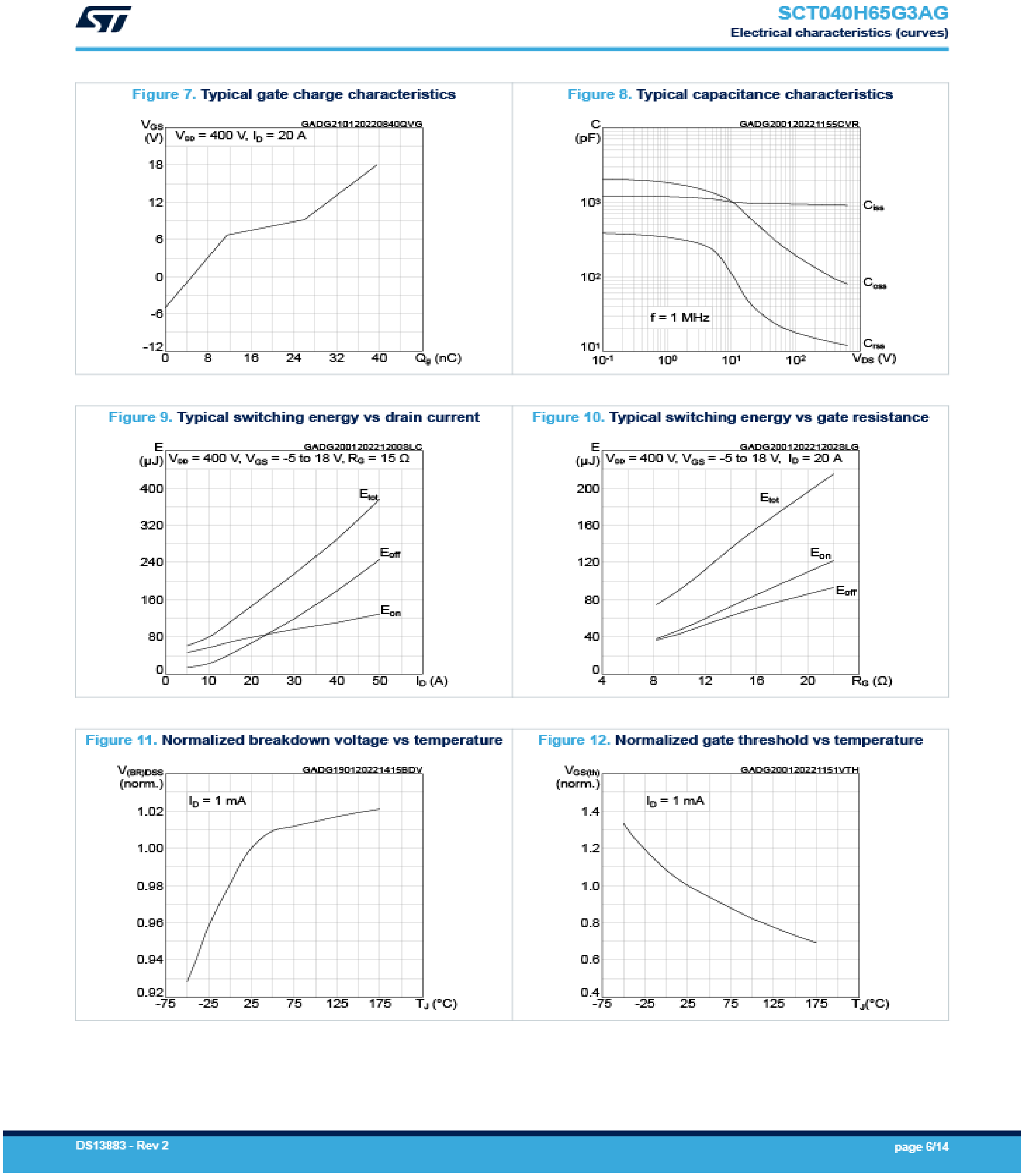


Figure 6. Total power dissipation





SCT040H65G3AG

Electrical characteristics (curves)

Figure 7. Typical gate charge characteristics

Figure 8. Typical capacitance characteristics

Figure 9. Typical switching energy vs drain current

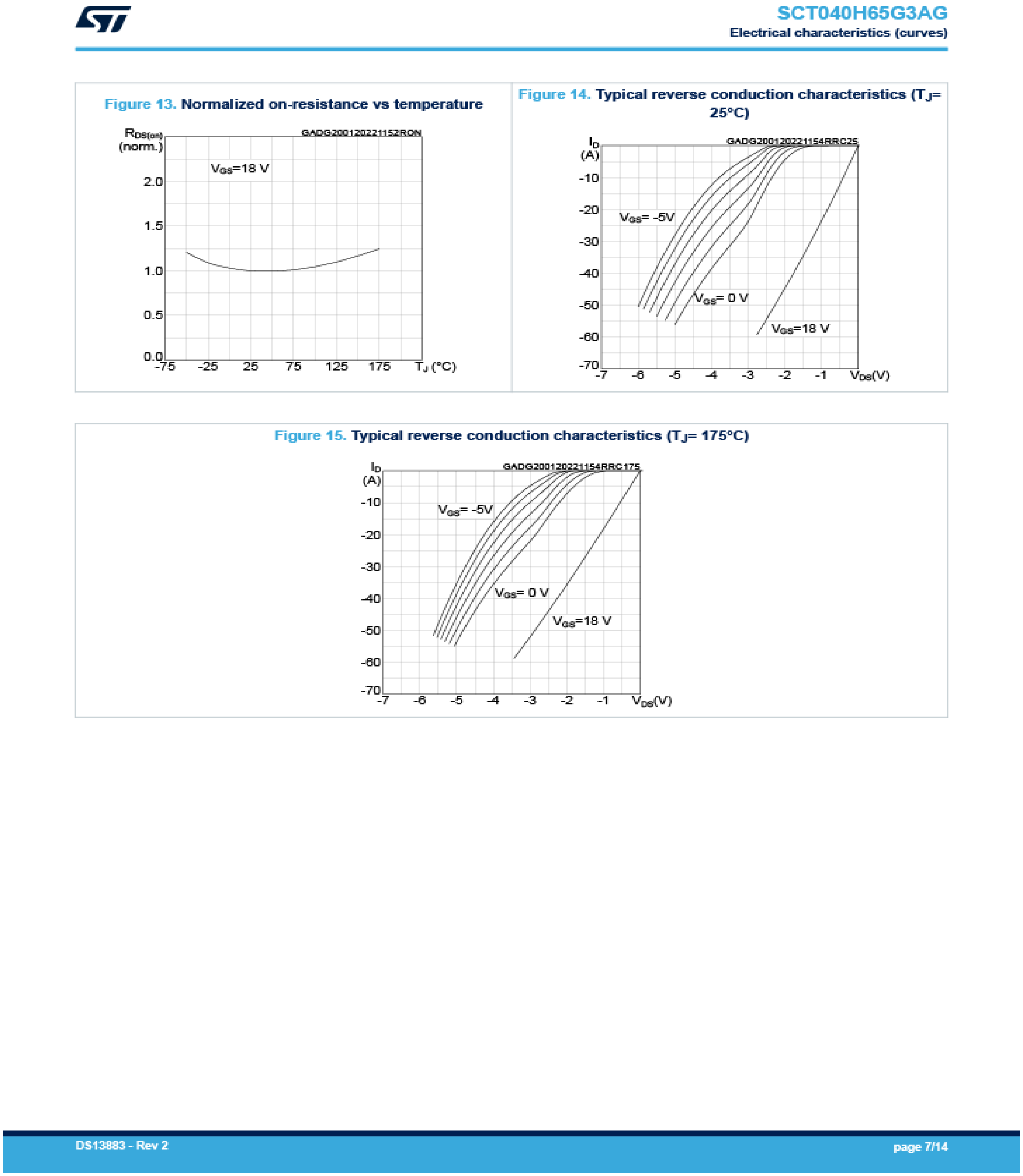
Figure 10. Typical switching energy vs gate resistance

Figure 11. Normalized breakdown voltage vs temperature

Figure 12. Normalized gate threshold vs temperature

DS13883 - Rev 2

page 6/14



SCT040H65G3AG

Electrical characteristics (curves)

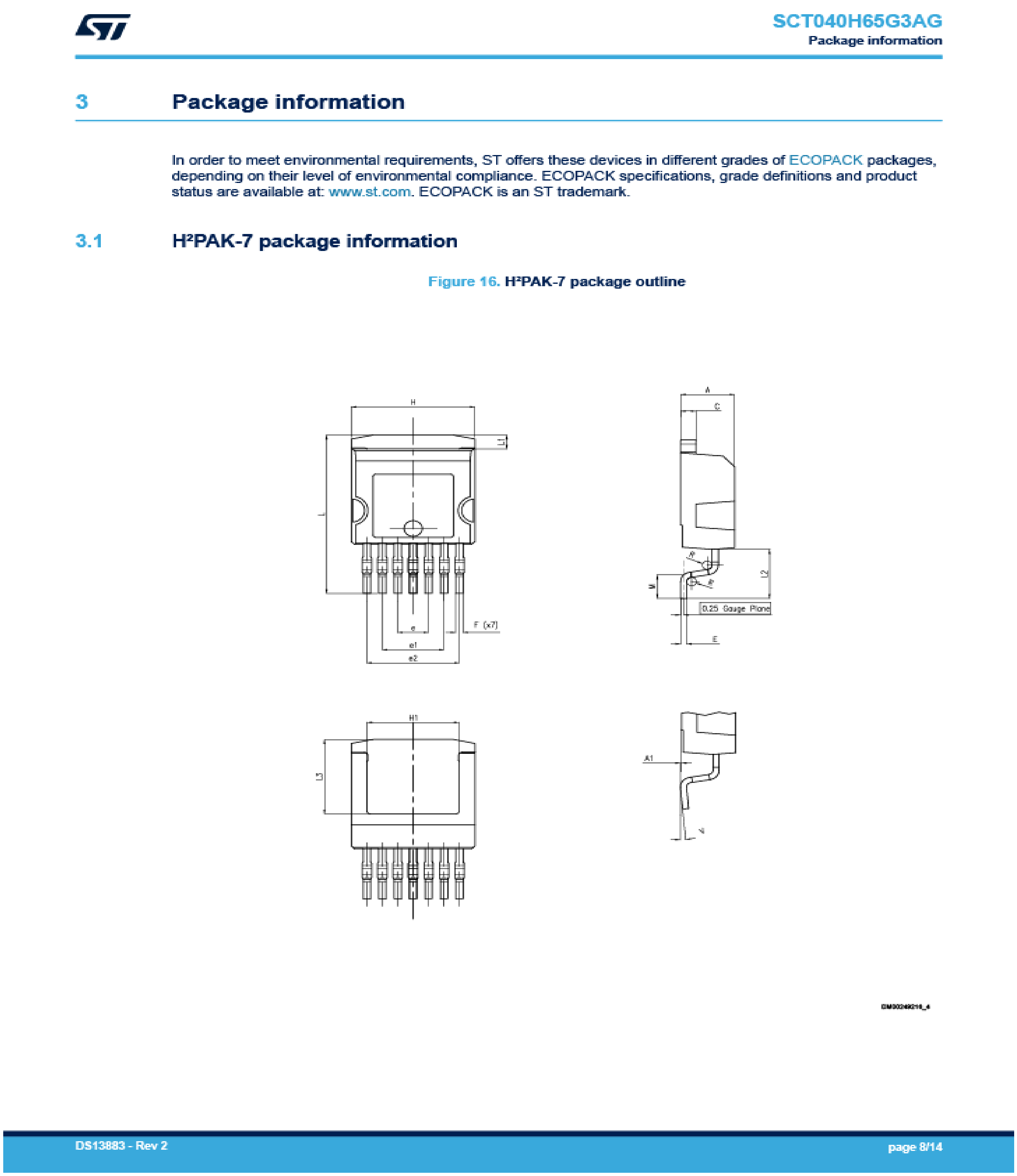
Figure 13. Normalized on-resistance vs temperature

Figure 14. Typical reverse conduction characteristics (TJ= 25°C)

Figure 15. Typical reverse conduction characteristics (TJ= 175°C)

DS13883 - Rev 2

page 7/14



3 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK packages, depending on their level of environmental compliance. ECOPACK specifications, grade definitions and product status are available at: www.st.com. ECOPACK is an ST trademark.

3.1 H²PAK-7 package information

Figure 16. H²PAK-7 package outline

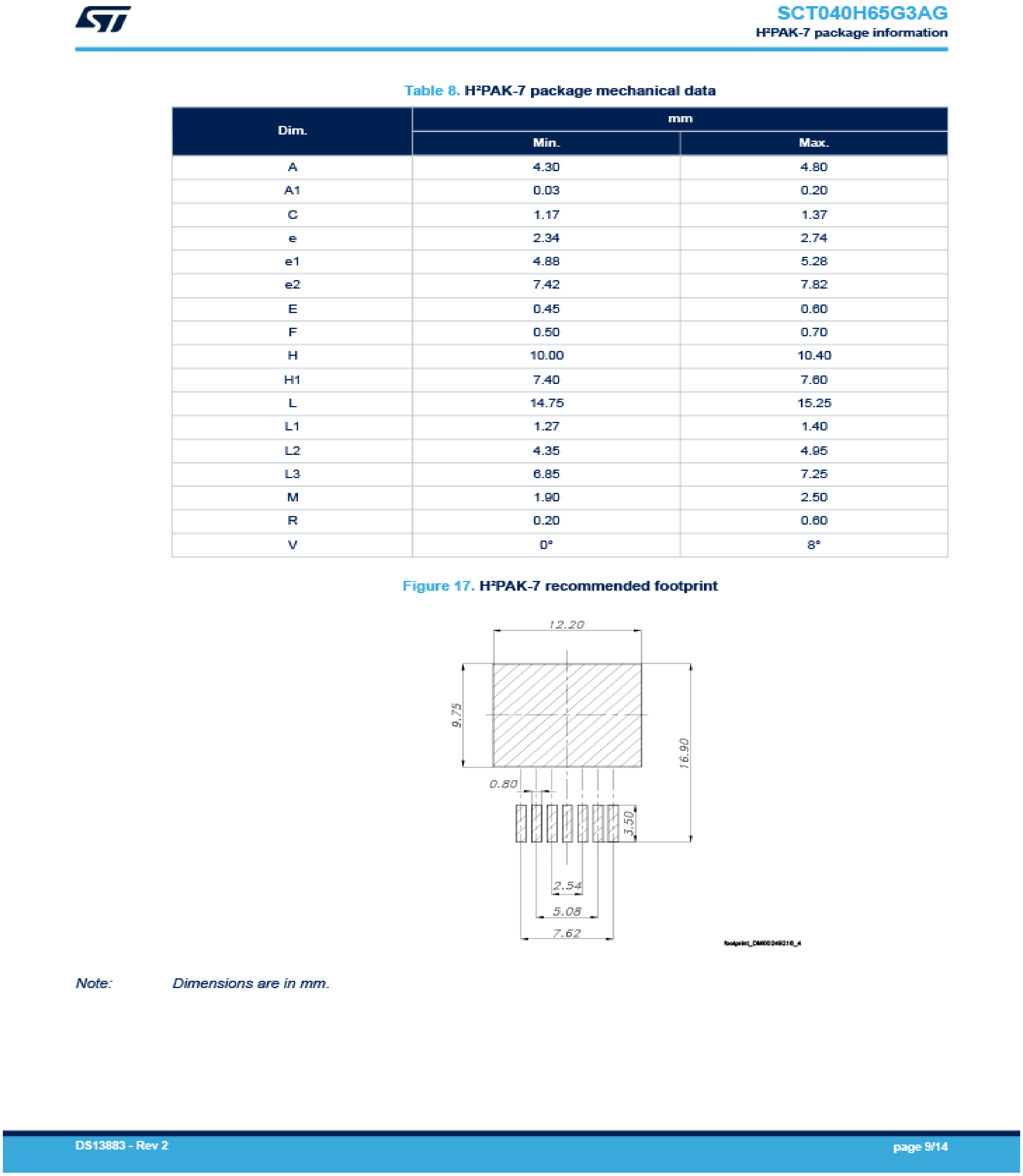


Table 8. **H²PAK-7 package mechanical data**

Dim.	mm	
	Min.	Max.
A	4.30	4.80
A1	0.03	0.20
C	1.17	1.37
e	2.34	2.74
e1	4.88	5.28
e2	7.42	7.82
E	0.45	0.60
F	0.50	0.70
H	10.00	10.40
H1	7.40	7.60
L	14.75	15.25
L1	1.27	1.40
L2	4.35	4.95
L3	6.85	7.25
M	1.90	2.50
R	0.20	0.60
V	0°	8°

Figure 17. **H²PAK-7 recommended footprint**

Note: Dimensions are in mm.

3.2 Packing information

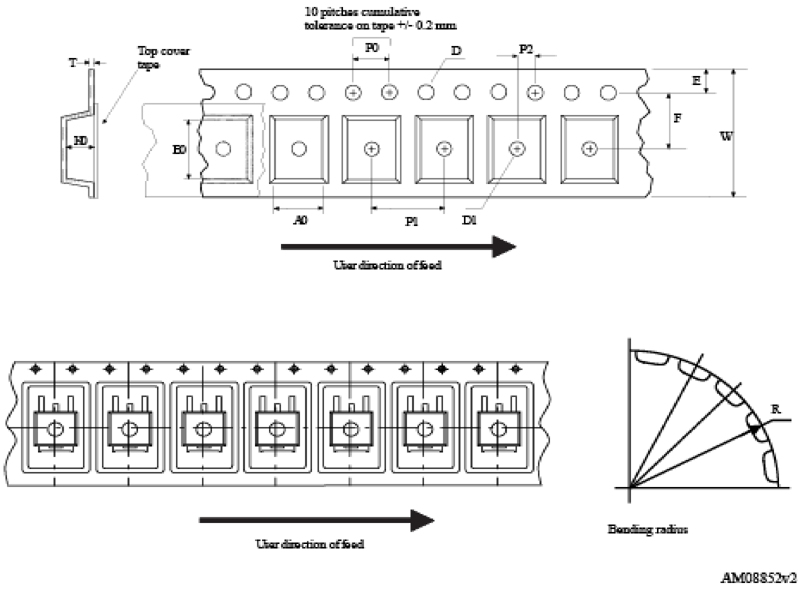


Figure 18. Tape outline

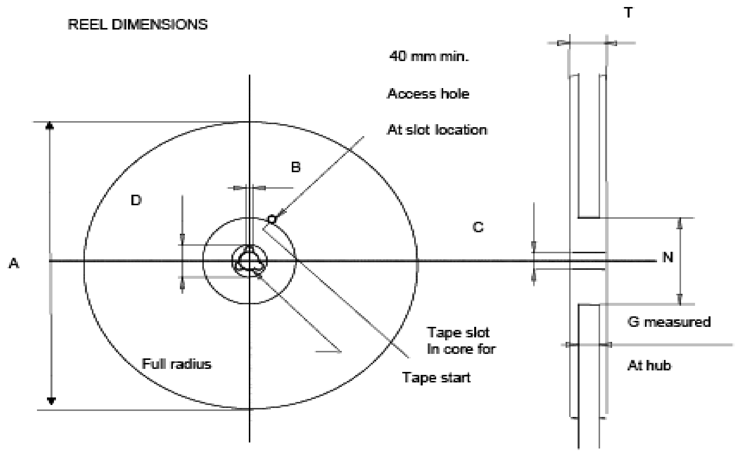


Figure 19. Reel outline

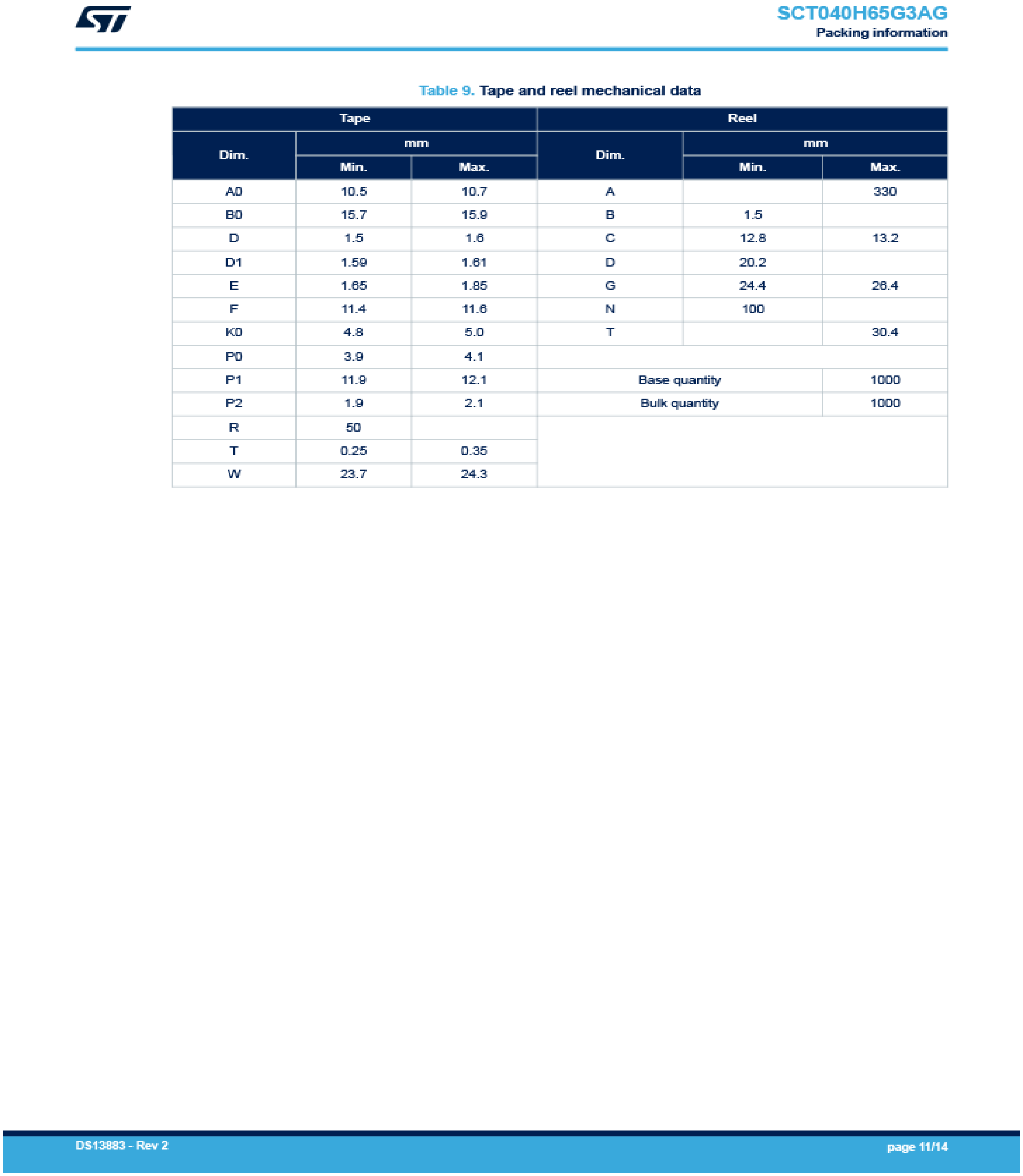
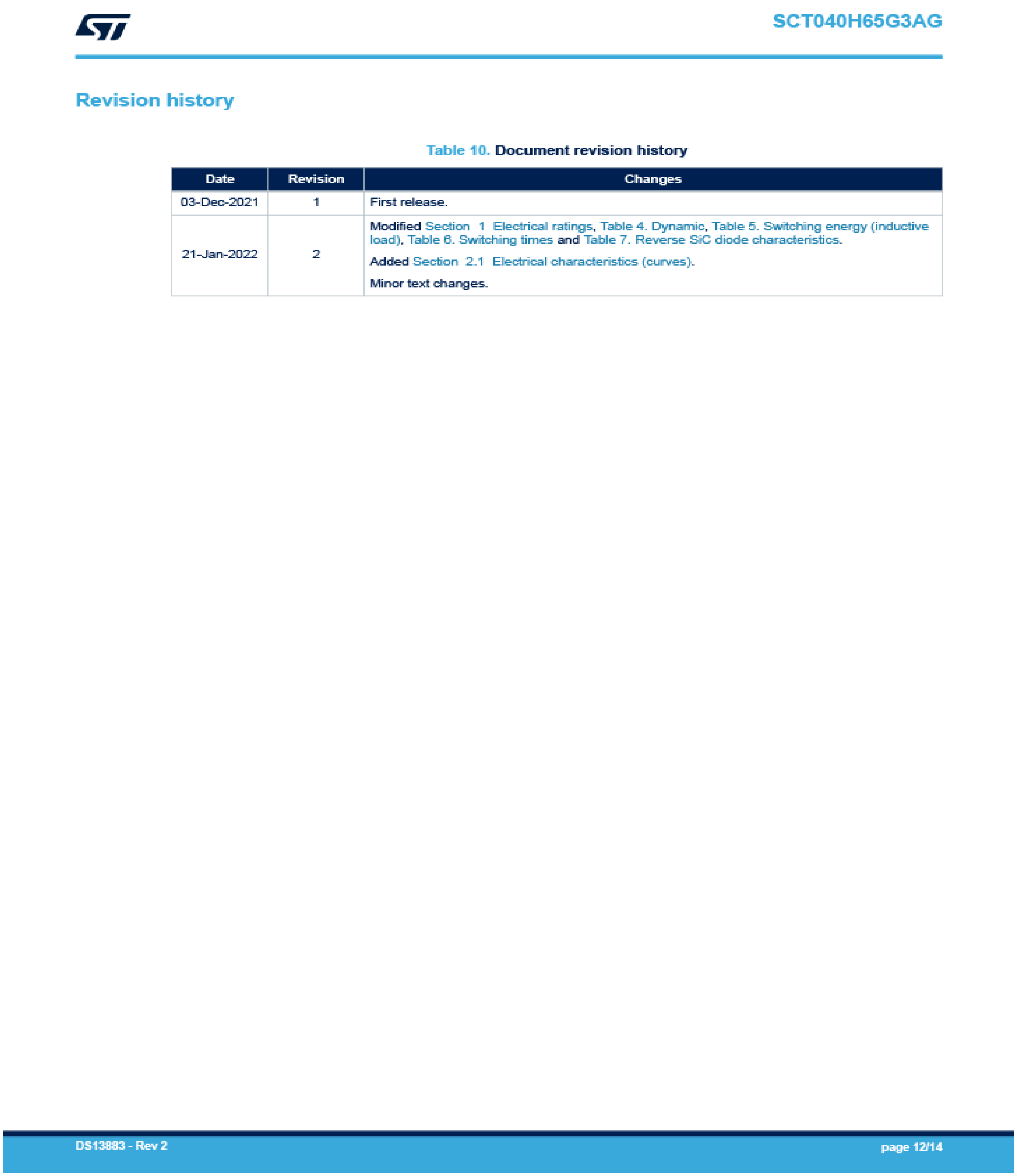


Table 9. Tape and reel mechanical data

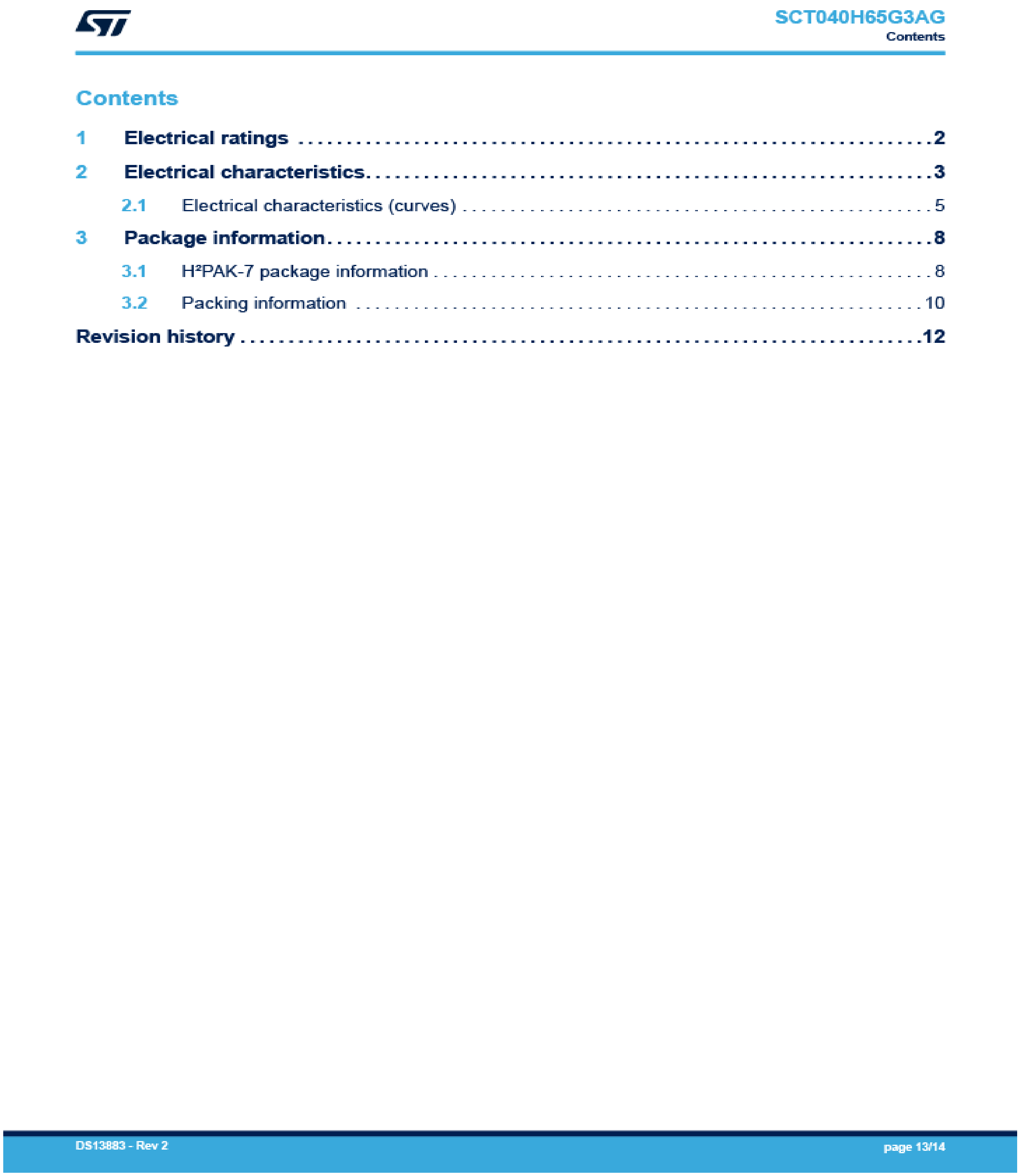
Tape			Reel		
Dim.	mm		Dim.	mm	
	Min.	Max.		Min.	Max.
A0	10.5	10.7	A		330
B0	15.7	15.9	B	1.5	
D	1.5	1.6	C	12.8	13.2
D1	1.59	1.61	D	20.2	
E	1.65	1.85	G	24.4	26.4
F	11.4	11.6	N	100	
K0	4.8	5.0	T		30.4
P0	3.9	4.1			
P1	11.9	12.1	Base quantity		1000
P2	1.9	2.1	Bulk quantity		1000
R	50				
T	0.25	0.35			
W	23.7	24.3			



Revision history

Table 10. **Document revision history**

Date	Revision	Changes
03-Dec-2021	1	First release.
21-Jan-2022	2	Modified Section 1 Electrical ratings, Table 4. Dynamic, Table 5. Switching energy (inductive load), Table 6. Switching times and Table 7. Reverse SiC diode characteristics. Added Section 2.1 Electrical characteristics (curves). Minor text changes.



Contents

SCT040H65G3AG

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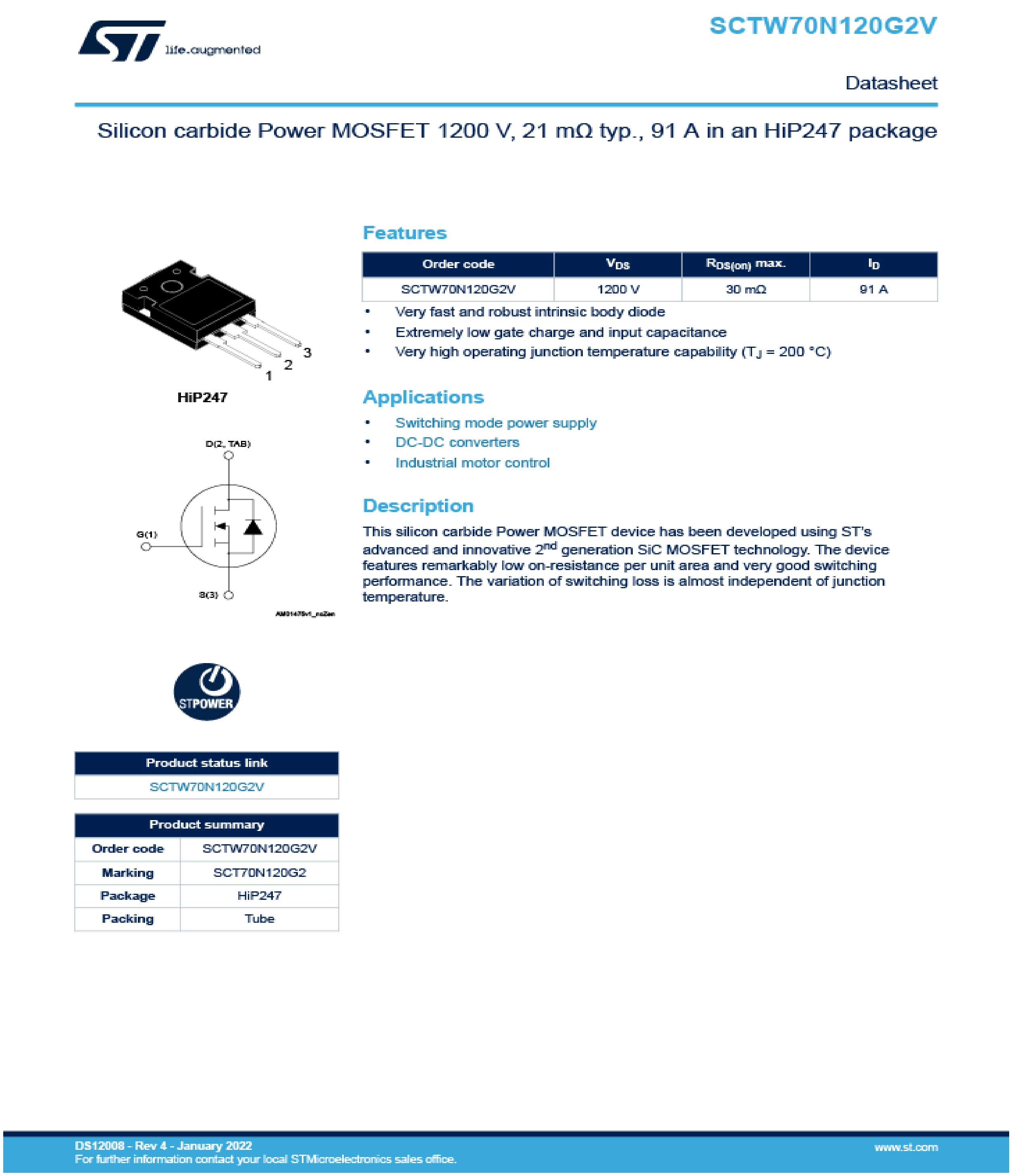
Silicon carbide Power MOSFET 1200 V, 21 mΩ typ., 91 A in an HiP247 package



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SCTW70N120G2V

Datasheet

Silicon carbide Power MOSFET 1200 V, 21 mΩ typ., 91 A in an HiP247 package

HiP247

STPOWER

Product status link
SCTW70N120G2V

Product summary	
Order code	SCTW70N120G2V
Marking	SCT70N120G2
Package	HiP247
Packing	Tube

Features

Order code	V_{DS}	$R_{DS(on)}$ max.	I_D
SCTW70N120G2V	1200 V	30 mΩ	91 A

- Very fast and robust intrinsic body diode
- Extremely low gate charge and input capacitance
- Very high operating junction temperature capability (T_J = 200 °C)

Applications

- Switching mode power supply
- DC-DC converters
- Industrial motor control

Description

This silicon carbide Power MOSFET device has been developed using ST's advanced and innovative 2nd generation SiC MOSFET technology. The device features remarkably low on-resistance per unit area and very good switching performance. The variation of switching loss is almost independent of junction temperature.

DS12008 - Rev 4 - January 2022
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1 Electrical ratings

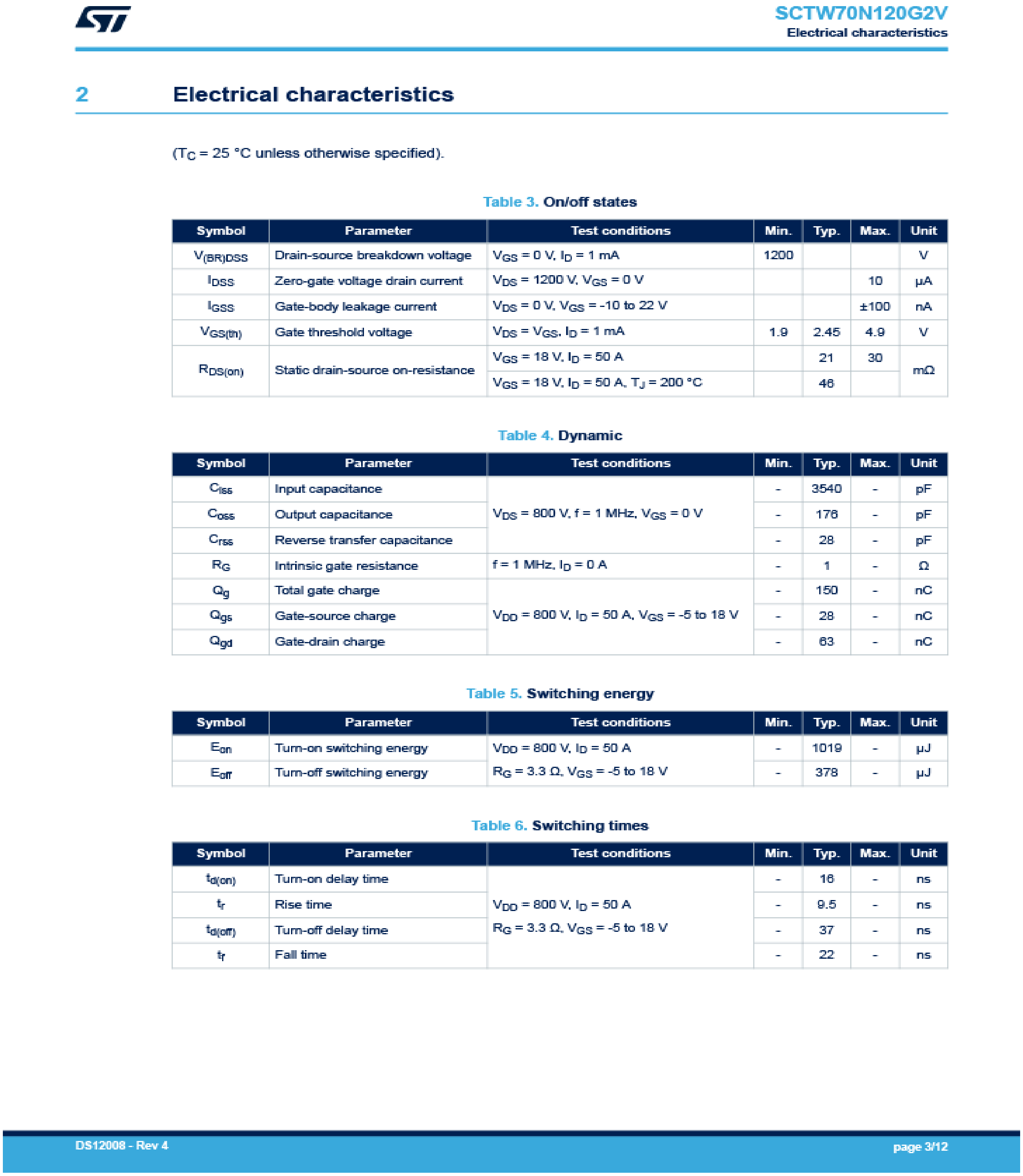
Table 1. **Absolute maximum ratings**

Symbol	Parameter	Value	Unit
V_{DS}	Drain-source voltage	1200	V
V_{GS}	Gate-source voltage	-10 to 22	V
	Gate-source voltage (recommended operating values)	-5 to 18	
I_D	Drain current (continuous) at T_C = 25 °C	91	A
	Drain current (continuous) at T_C = 100 °C	69	
I_{DM}[(1)]	Drain current (pulsed)	274	A
P_{TOT}	Total power dissipation at T_C = 25 °C	547	W
T_{stg}	Storage temperature range	-55 to 200	°C
T_J	Operating junction temperature range		

1. *Pulse width is limited by safe operating area.*

Table 2. **Thermal data**

Symbol	Parameter	Value	Unit
R_{thJC}	Thermal resistance, junction-to-case	0.32	°C/W
R_{thJA}	Thermal resistance, junction-to-ambient	40	°C/W



2 Electrical characteristics

(T_C = 25 °C unless otherwise specified).

Table 3. **On/off states**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{(BR)DSS}$	Drain-source breakdown voltage	V_{GS} = 0 V, I_D = 1 mA	1200			V
I_{DSS}	Zero-gate voltage drain current	V_{DS} = 1200 V, V_{GS} = 0 V			10	µA
I_{GSS}	Gate-body leakage current	V_{DS} = 0 V, V_{GS} = -10 to 22 V			±100	nA
$V_{GS(th)}$	Gate threshold voltage	V_{DS} = V_{GS}, I_D = 1 mA	1.9	2.45	4.9	V
$R_{DS(on)}$	Static drain-source on-resistance	V_{GS} = 18 V, I_D = 50 A		21	30	mΩ
		V_{GS} = 18 V, I_D = 50 A, T_J = 200 °C		46		

Table 4. **Dynamic**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
C_{iss}	Input capacitance	V_{DS} = 800 V, f = 1 MHz, V_{GS} = 0 V	-	3540	-	pF
C_{oss}	Output capacitance		-	176	-	pF
C_{rss}	Reverse transfer capacitance		-	28	-	pF
R_G	Intrinsic gate resistance	f = 1 MHz, I_D = 0 A	-	1	-	Ω
Q_g	Total gate charge	V_{DD} = 800 V, I_D = 50 A, V_{GS} = -5 to 18 V	-	150	-	nC
Q_{gs}	Gate-source charge		-	28	-	nC
Q_{gd}	Gate-drain charge		-	63	-	nC

Table 5. **Switching energy**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
E_{on}	Turn-on switching energy	V_{DD} = 800 V, I_D = 50 A R_G = 3.3 Ω, V_{GS} = -5 to 18 V	-	1019	-	µJ
E_{off}	Turn-off switching energy		-	378	-	µJ

Table 6. **Switching times**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$t_{d(on)}$	Turn-on delay time	V_{DD} = 800 V, I_D = 50 A R_G = 3.3 Ω, V_{GS} = -5 to 18 V	-	16	-	ns
t_r	Rise time		-	9.5	-	ns
$t_{d(off)}$	Turn-off delay time		-	37	-	ns
t_f	Fall time		-	22	-	ns

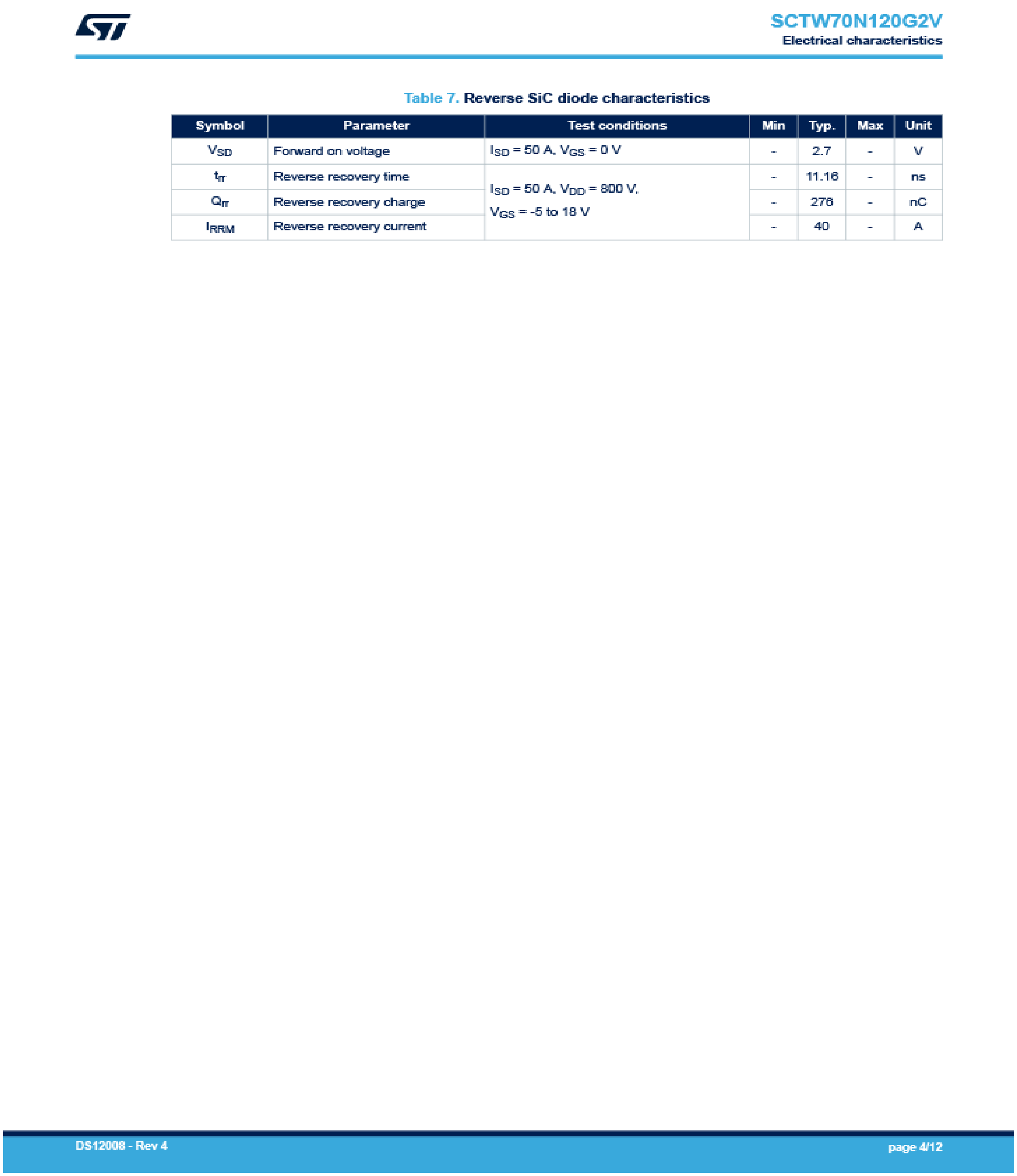
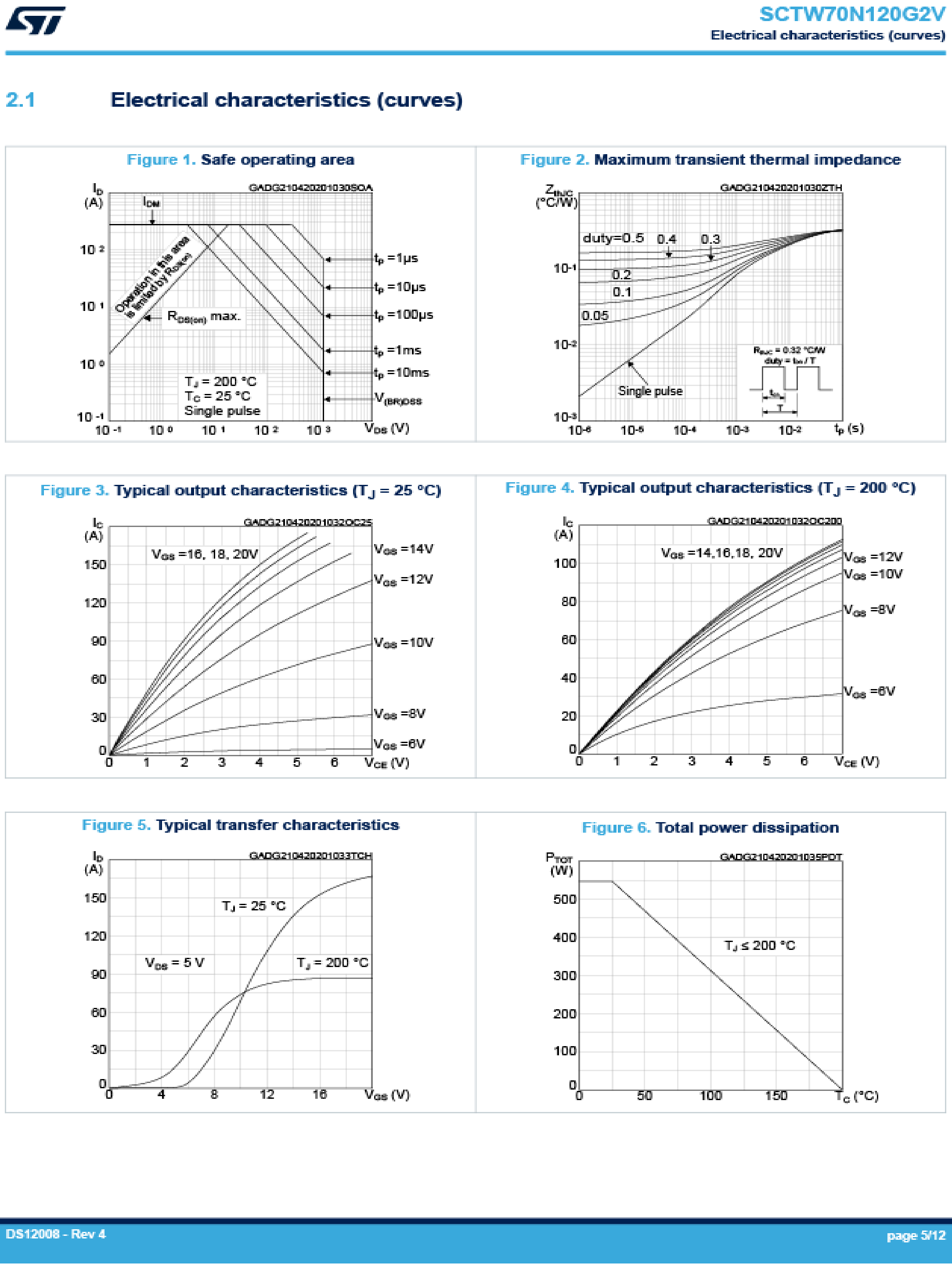


Table 7. Reverse SiC diode characteristics

Symbol	Parameter	Test conditions	Min	Typ.	Max	Unit
V_{SD}	Forward on voltage	I_{SD} = 50 A, V_{GS} = 0 V	-	2.7	-	V
t_{rr}	Reverse recovery time	I_{SD} = 50 A, V_{DD} = 800 V, V_{GS} = -5 to 18 V	-	11.16	-	ns
Q_{rr}	Reverse recovery charge		-	276	-	nC
I_{RRM}	Reverse recovery current		-	40	-	A



SCTW70N120G2V
Electrical characteristics (curves)
2.1 Electrical characteristics (curves)
Figure 1. Safe operating area
GADG210420201030SOA
I_D (A)
I_{DM}
Operation in this area is limited by $R_{DS(on)}$
$R_{DS(on)}$ max.
t_p =1µs
t_p =10µs
t_p =100µs
t_p =1ms
t_p =10ms
$V_{(BR)DSS}$
T_J = 200 °C
T_C = 25 °C
Single pulse
10^2
10^1
10^0
10^{-1}
10^{-1} 10^0 10^1 10^2 10^3
V_{DS} (V)
Figure 2. Maximum transient thermal impedance
GADG210420201030ZTH
Z_{thJC} (°C/W)
duty=0.5 0.4 0.3
0.2
0.1
0.05
Single pulse
R_{thJC} = 0.32 °C/W
duty = t_{on} / T
t_{on}
T
10^{-1}
10^{-2}
10^{-3}
10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2}
t_p (s)
Figure 3. Typical output characteristics (T_J = 25 °C)
GADG210420201032OC25
I_C (A)
V_{GS} =16, 18, 20V
V_{GS} =14V
V_{GS} =12V
V_{GS} =10V
V_{GS} =8V
V_{GS} =6V
150 120 90 60 30 0
0 1 2 3 4 5 6
V_{CE} (V)
Figure 4. Typical output characteristics (T_J = 200 °C)
GADG210420201032OC200
I_C (A)
V_{GS} =14,16,18, 20V
V_{GS} =12V
V_{GS} =10V
V_{GS} =8V
V_{GS} =6V
100 80 60 40 20 0
0 1 2 3 4 5 6
V_{CE} (V)
Figure 5. Typical transfer characteristics
GADG210420201033TCH
I_D (A)
T_J = 25 °C
V_{DS} = 5 V
T_J = 200 °C
150 120 90 60 30 0
0 4 8 12 16
V_{GS} (V)
Figure 6. Total power dissipation
GADG210420201035PDT
P_{TOT} (W)
T_J ≤ 200 °C
500 400 300 200 100 0
0 50 100 150
T_C (°C)
DS12008 - Rev 4
page 5/12

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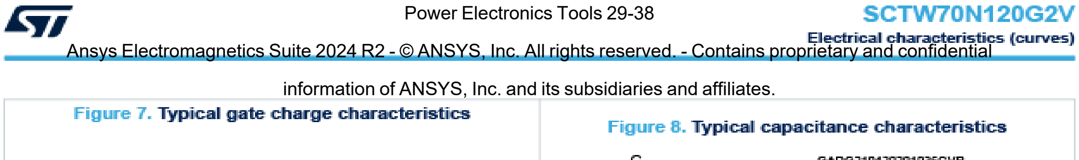
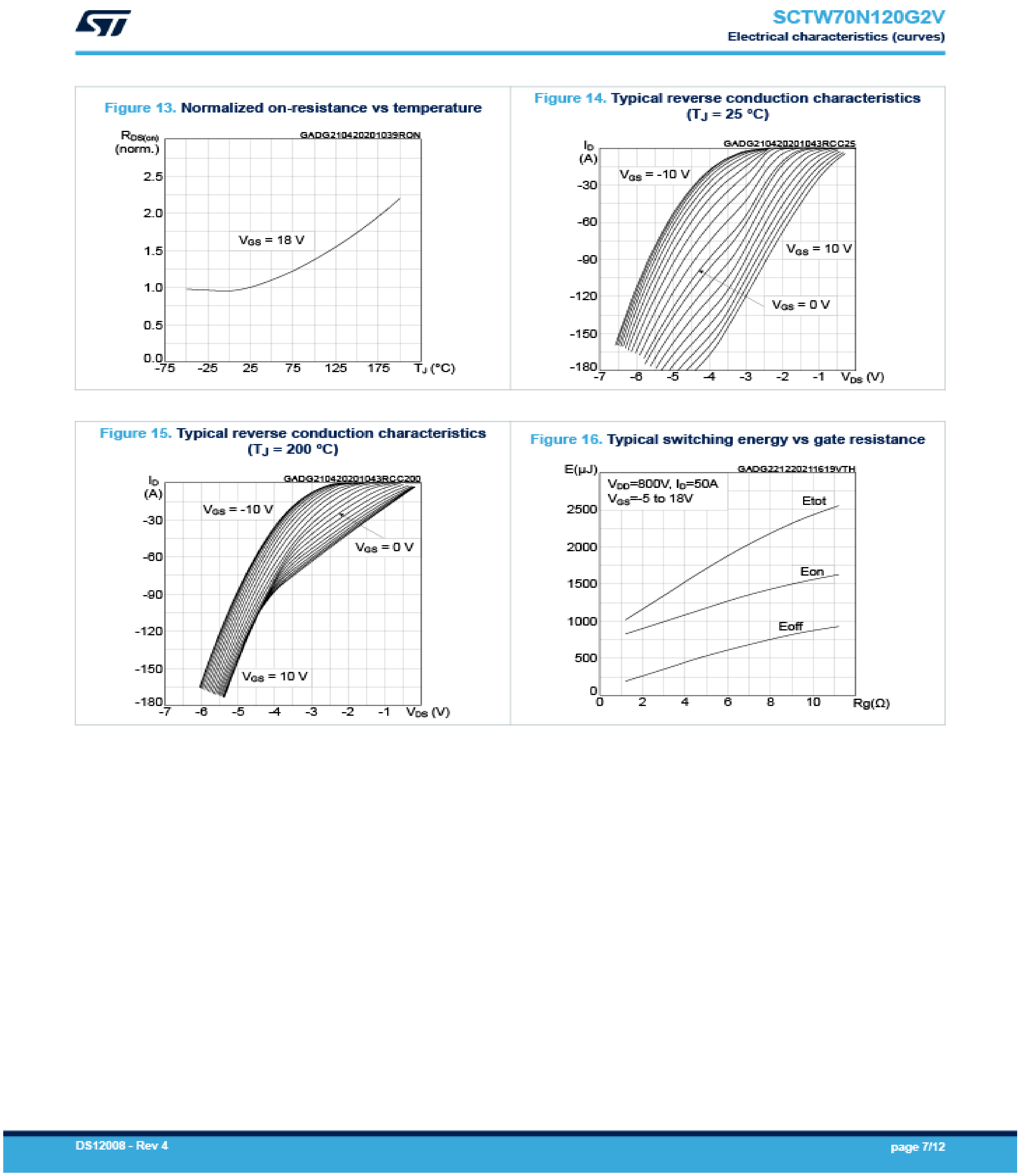


SCTW70N120G2V
Electrical characteristics (curves)
Figure 7. Typical gate charge characteristics
Figure 8. Typical capacitance characteristics



SCTW70N120G2V

Electrical characteristics (curves)

Figure 13. Normalized on-resistance vs temperature

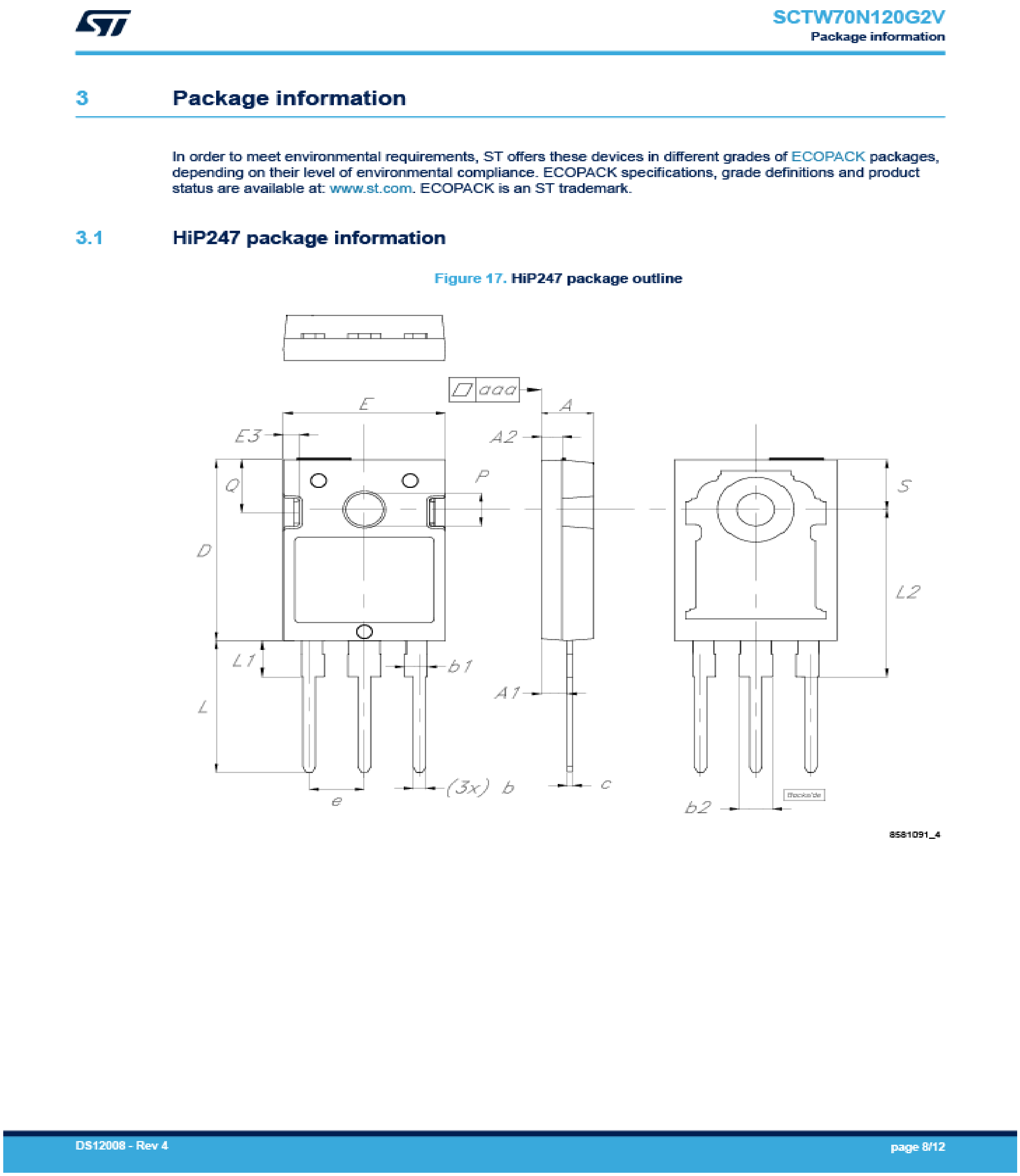
Figure 14. Typical reverse conduction characteristics (T_J = 25 °C)

Figure 15. Typical reverse conduction characteristics (T_J = 200 °C)

Figure 16. Typical switching energy vs gate resistance

DS12008 - Rev 4

page 7/12

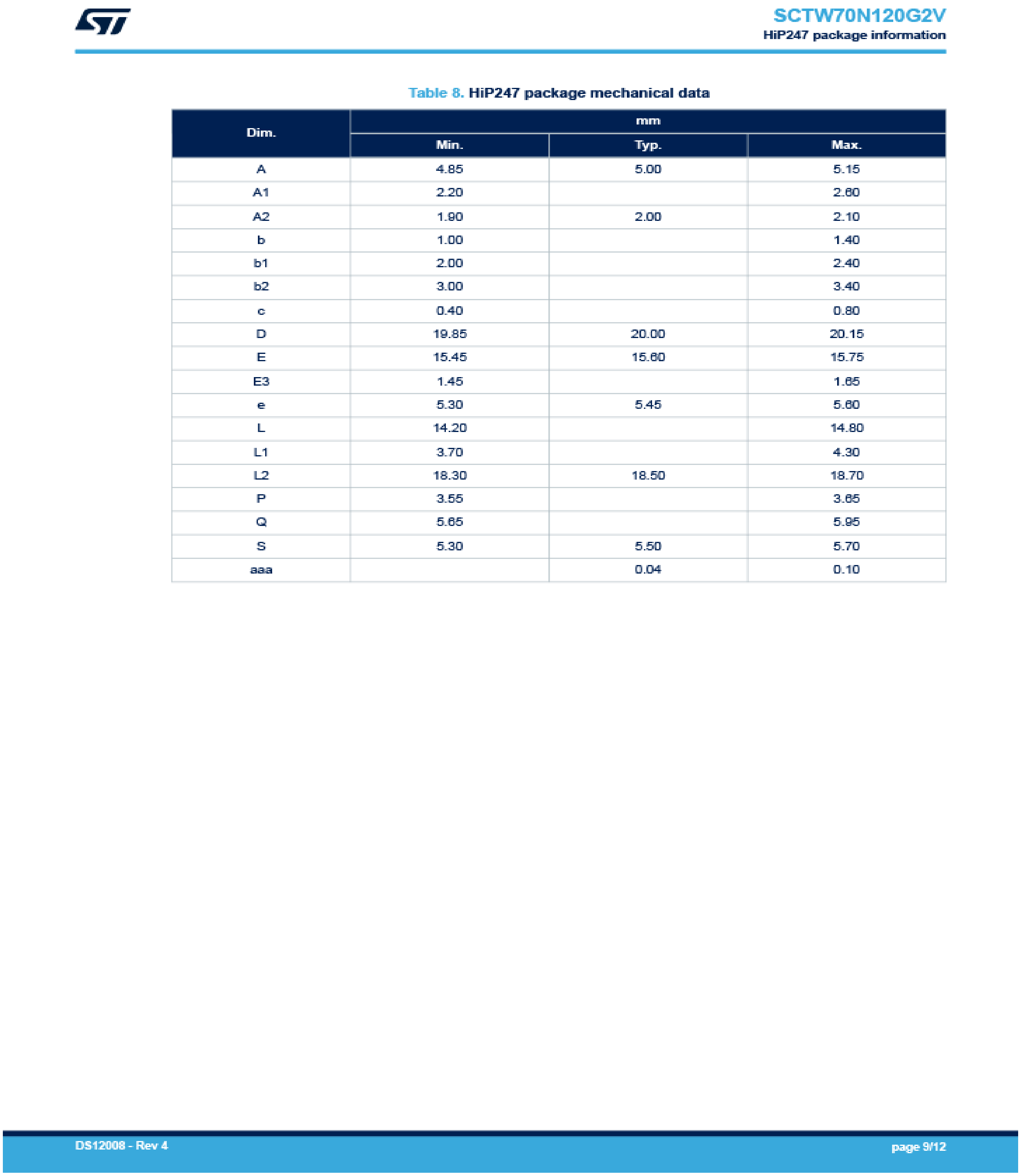


3 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK packages, depending on their level of environmental compliance. ECOPACK specifications, grade definitions and product status are available at: www.st.com. ECOPACK is an ST trademark.

3.1 HiP247 package information

Figure 17. **HiP247 package outline**



SCTW70N120G2V

HiP247 package information

Table 8. **HiP247 package mechanical data**

Dim.	mm		
	Min.	Typ.	Max.
A	4.85	5.00	5.15
A1	2.20		2.60
A2	1.90	2.00	2.10
b	1.00		1.40
b1	2.00		2.40
b2	3.00		3.40
c	0.40		0.80
D	19.85	20.00	20.15
E	15.45	15.60	15.75
E3	1.45		1.65
e	5.30	5.45	5.60
L	14.20		14.80
L1	3.70		4.30
L2	18.30	18.50	18.70
P	3.55		3.65
Q	5.65		5.95
S	5.30	5.50	5.70
aaa		0.04	0.10

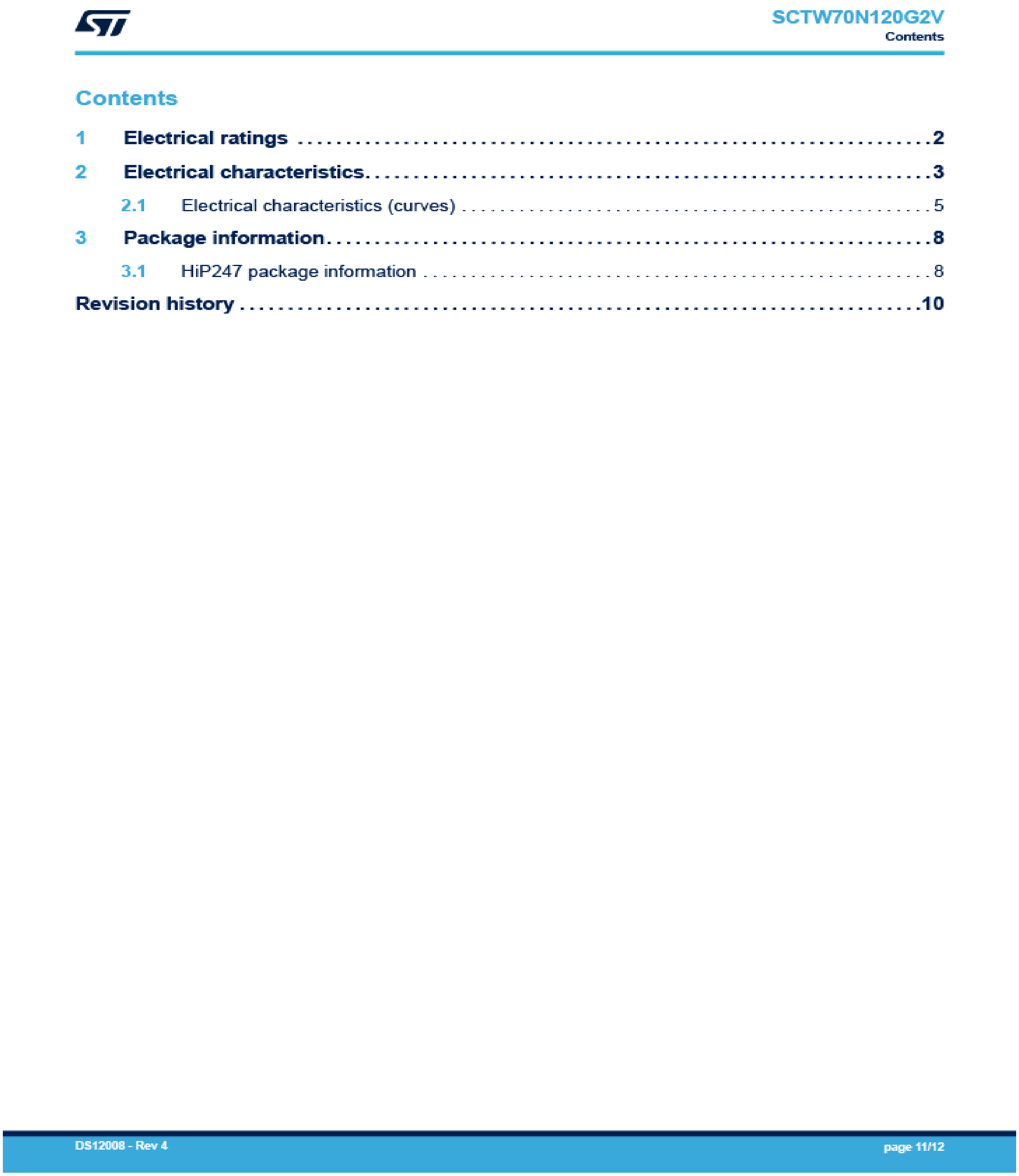
DS12008 - Rev 4

page 9/12

Revision history

Table 9. **Document revision history**

Date	Revision	Changes
26-Jan-2017	1	First release
22-May-2020	2	Updated *Title, Internal schematic, Features, Description* and *Device summary* in cover page. Updated *Section 1 Electrical ratings.* Updated *Section 2 Electrical characteristics.* Updated *Section 2.1 Electrical characteristics (curves).* Updated *Section 3 Package information.*
31-Aug-2020	3	Modified Table 7. Reverse SiC diode characteristics. Modified Figure 9. Typical switching energy vs drain current.
07-Jan-2022	4	Updated Section 2.1 Electrical characteristics (curves). Minor text changes.



Contents

SCTW70N120G2V

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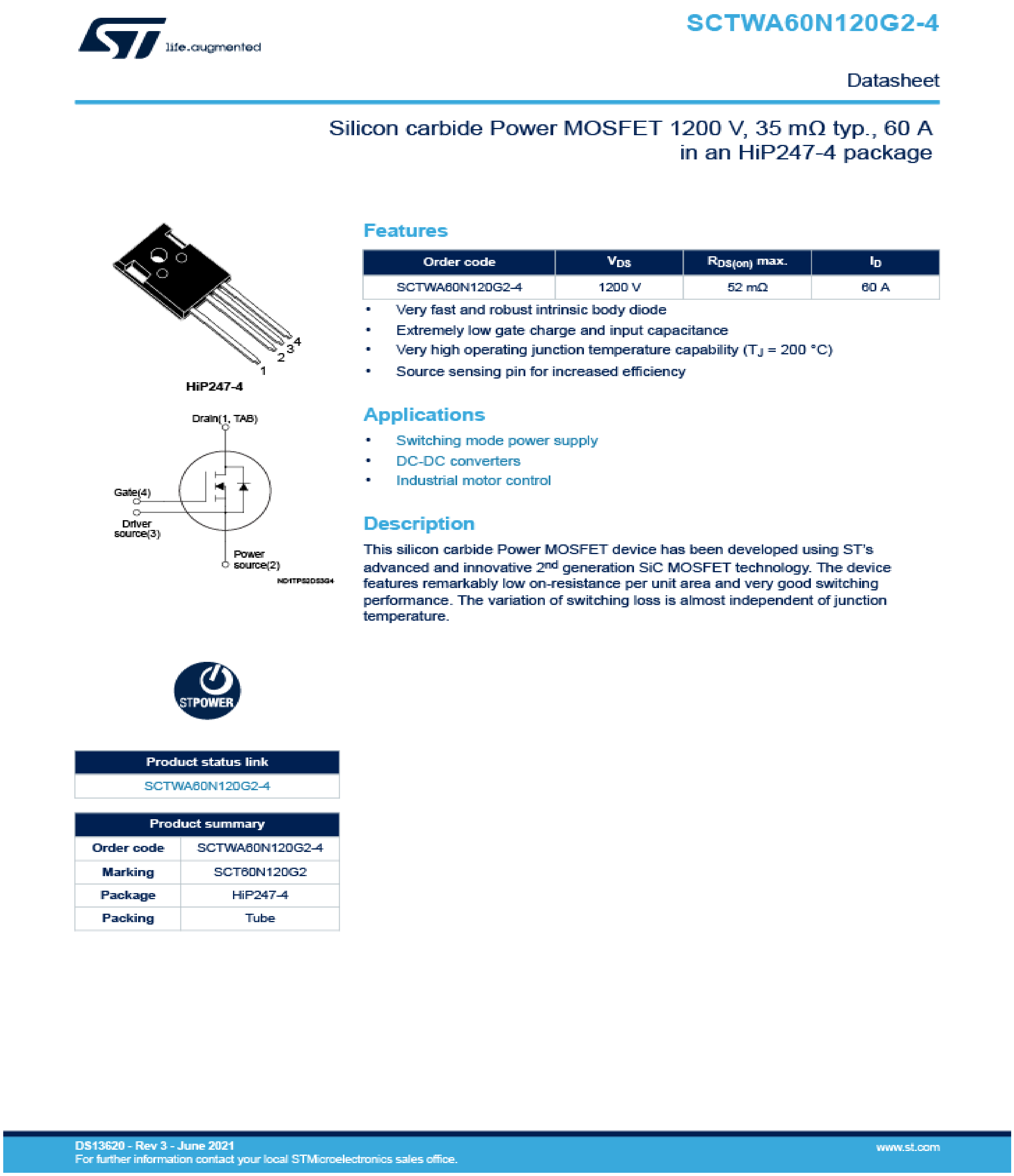
Silicon carbide Power MOSFET 1200 V, 35 mΩ typ., 60 A in an HiP247-4 package



SCTWA60N120G2-4

Datasheet

Silicon carbide Power MOSFET 1200 V, 35 mΩ typ., 60 A in an HiP247-4 package

HiP247-4

Features

Order code	V_{DS}	$R_{DS(on)}$ max.	I_D
SCTWA60N120G2-4	1200 V	52 mΩ	60 A

- Very fast and robust intrinsic body diode
- Extremely low gate charge and input capacitance
- Very high operating junction temperature capability (T_J = 200 °C)
- Source sensing pin for increased efficiency

Applications

- Switching mode power supply
- DC-DC converters
- Industrial motor control

Description

This silicon carbide Power MOSFET device has been developed using ST's advanced and innovative 2nd generation SiC MOSFET technology. The device features remarkably low on-resistance per unit area and very good switching performance. The variation of switching loss is almost independent of junction temperature.

STPOWER

Product status link
SCTWA60N120G2-4

Product summary	
Order code	SCTWA60N120G2-4
Marking	SCT60N120G2
Package	HiP247-4
Packing	Tube

DS13620 - Rev 3 - June 2021
For further information contact your local STMicroelectronics sales office.

www.st.com

1 Electrical ratings

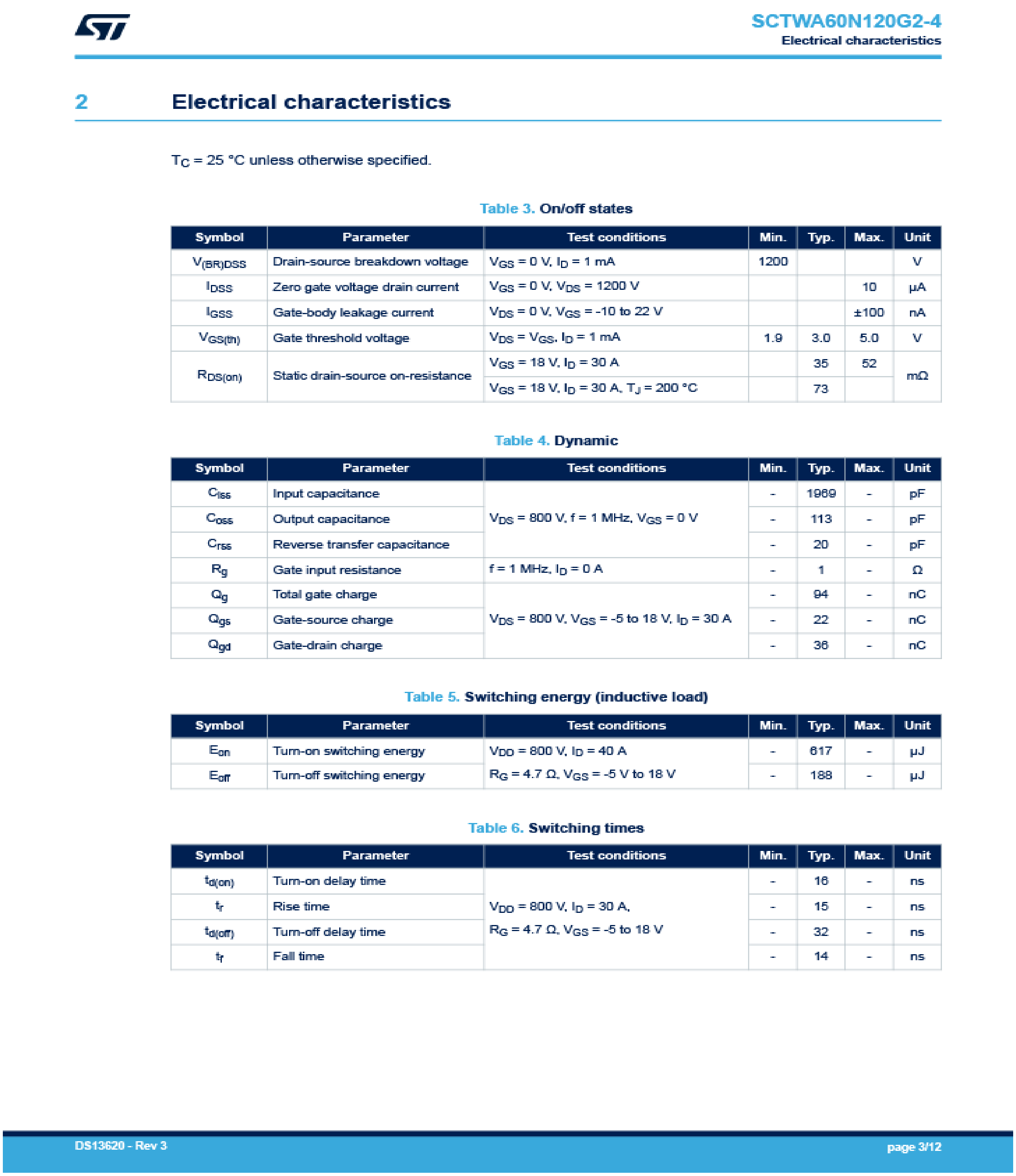
Table 1. **Absolute maximum ratings**

Symbol	Parameter	Value	Unit
V_{DS}	Drain-source voltage	1200	V
V_{GS}	Gate-source voltage	-10 to 22	V
	Gate-source voltage (recommended operational values)	-5 to 18	
I_D	Drain current (continuous) at T_C = 25 °C	60	A
	Drain current (continuous) at T_C = 100 °C	45	
I_{DM}(1)	Drain current (pulsed)	177	A
P_{TOT}	Total power dissipation at T_C = 25 °C	389	W
T_{stg}	Storage temperature range	-55 to 200	°C
T_J	Operating junction temperature range		°C

1. *Pulse width is limited by safe operating area.*

Table 2. **Thermal data**

Symbol	Parameter	Value	Unit
R_{thJC}	Thermal resistance, junction-to-case	0.45	°C/W
R_{thJA}	Thermal resistance, junction-to-ambient	40	°C/W



2 Electrical characteristics

T_C = 25 °C unless otherwise specified.

Table 3. On/off states

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{(BR)DSS}$	Drain-source breakdown voltage	V_{GS} = 0 V, I_D = 1 mA	1200			V
I_{DSS}	Zero gate voltage drain current	V_{GS} = 0 V, V_{DS} = 1200 V			10	µA
I_{GSS}	Gate-body leakage current	V_{DS} = 0 V, V_{GS} = -10 to 22 V			±100	nA
$V_{GS(th)}$	Gate threshold voltage	V_{DS} = V_{GS}, I_D = 1 mA	1.9	3.0	5.0	V
$R_{DS(on)}$	Static drain-source on-resistance	V_{GS} = 18 V, I_D = 30 A		35	52	mΩ
		V_{GS} = 18 V, I_D = 30 A, T_J = 200 °C		73		

Table 4. Dynamic

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
C_{iss}	Input capacitance	V_{DS} = 800 V, f = 1 MHz, V_{GS} = 0 V	-	1969	-	pF
C_{oss}	Output capacitance		-	113	-	pF
C_{rss}	Reverse transfer capacitance		-	20	-	pF
R_g	Gate input resistance	f = 1 MHz, I_D = 0 A	-	1	-	Ω
Q_g	Total gate charge	V_{DS} = 800 V, V_{GS} = -5 to 18 V, I_D = 30 A	-	94	-	nC
Q_{gs}	Gate-source charge		-	22	-	nC
Q_{gd}	Gate-drain charge		-	36	-	nC

Table 5. Switching energy (inductive load)

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
E_{on}	Turn-on switching energy	V_{DD} = 800 V, I_D = 40 A R_G = 4.7 Ω, V_{GS} = -5 V to 18 V	-	617	-	µJ
E_{off}	Turn-off switching energy		-	188	-	µJ

Table 6. Switching times

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$t_{d(on)}$	Turn-on delay time	V_{DD} = 800 V, I_D = 30 A, R_G = 4.7 Ω, V_{GS} = -5 to 18 V	-	16	-	ns
t_r	Rise time		-	15	-	ns
$t_{d(off)}$	Turn-off delay time		-	32	-	ns
t_f	Fall time		-	14	-	ns

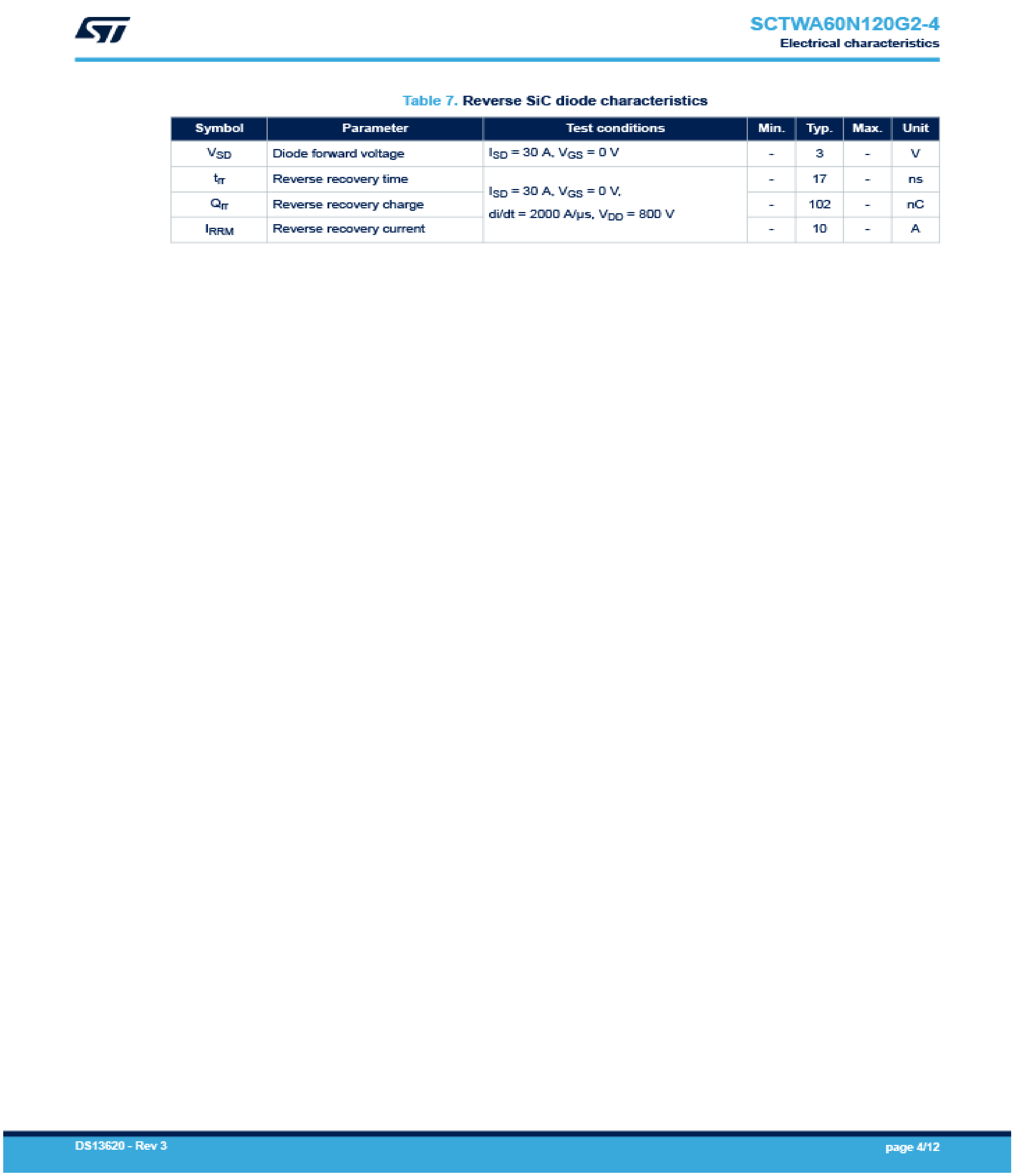
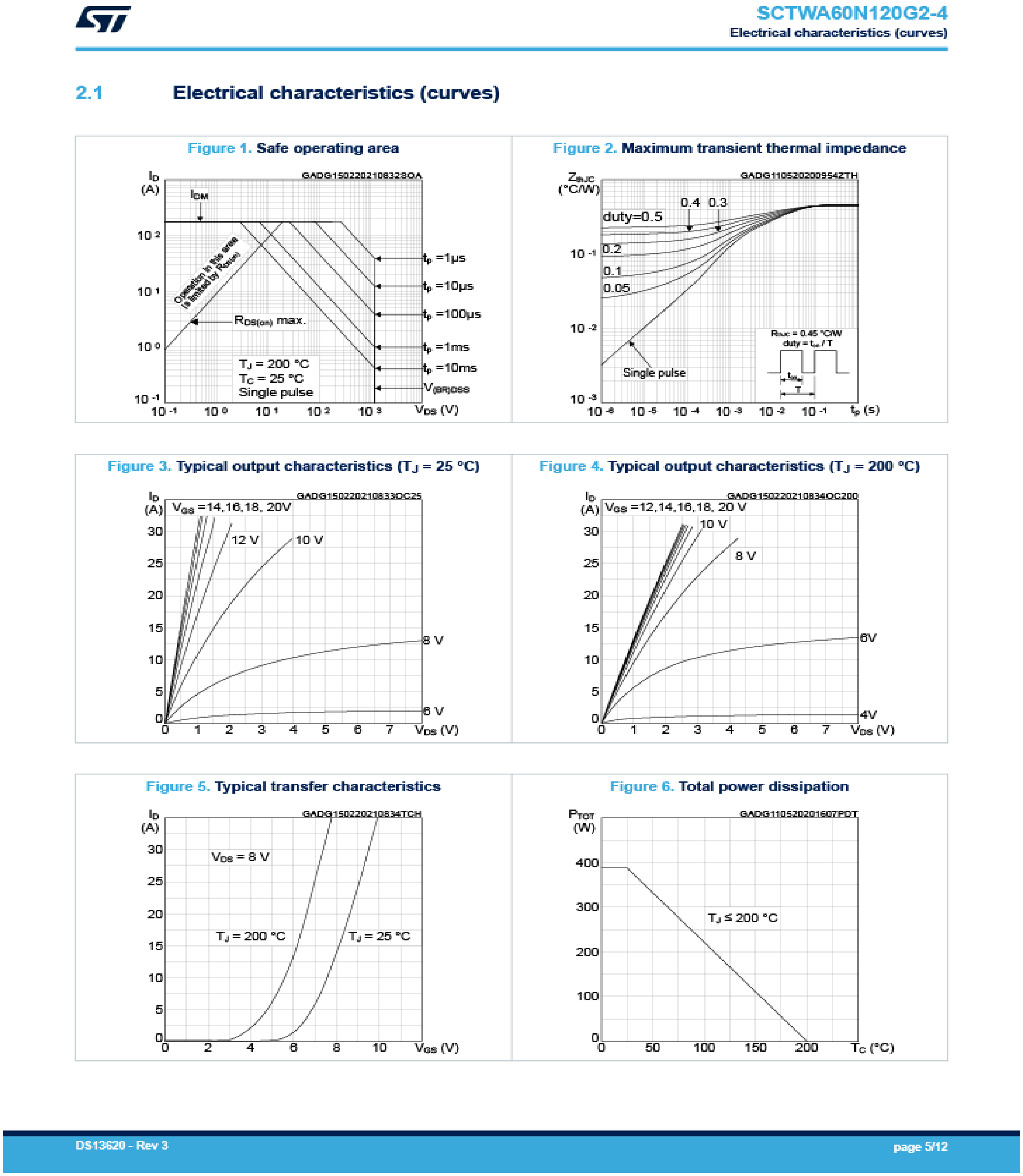


Table 7. **Reverse SiC diode characteristics**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_{SD}	Diode forward voltage	I_{SD} = 30 A, V_{GS} = 0 V	-	3	-	V
t_{rr}	Reverse recovery time	I_{SD} = 30 A, V_{GS} = 0 V, di/dt = 2000 A/µs, V_{DD} = 800 V	-	17	-	ns
Q_{rr}	Reverse recovery charge		-	102	-	nC
I_{RRM}	Reverse recovery current		-	10	-	A



SCTWA60N120G2-4
Electrical characteristics (curves)

2.1 Electrical characteristics (curves)

Figure 1. Safe operating area

Figure 2. Maximum transient thermal impedance

Figure 3. Typical output characteristics (T_J = 25 °C)

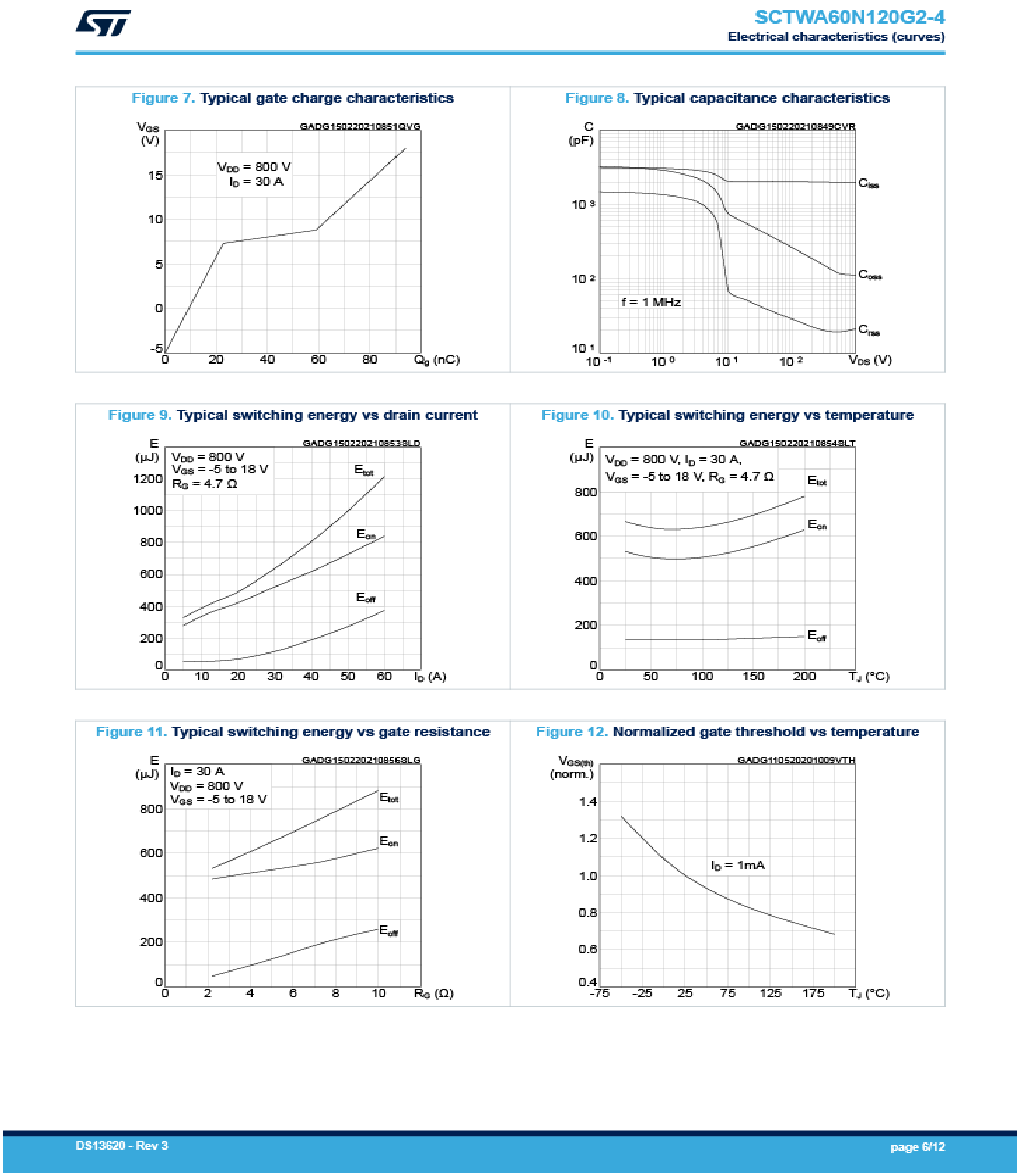
Figure 4. Typical output characteristics (T_J = 200 °C)

Figure 5. Typical transfer characteristics

Figure 6. Total power dissipation

DS13620 - Rev 3

page 5/12



SCTWA60N120G2-4

Electrical characteristics (curves)

Figure 7. **Typical gate charge characteristics**

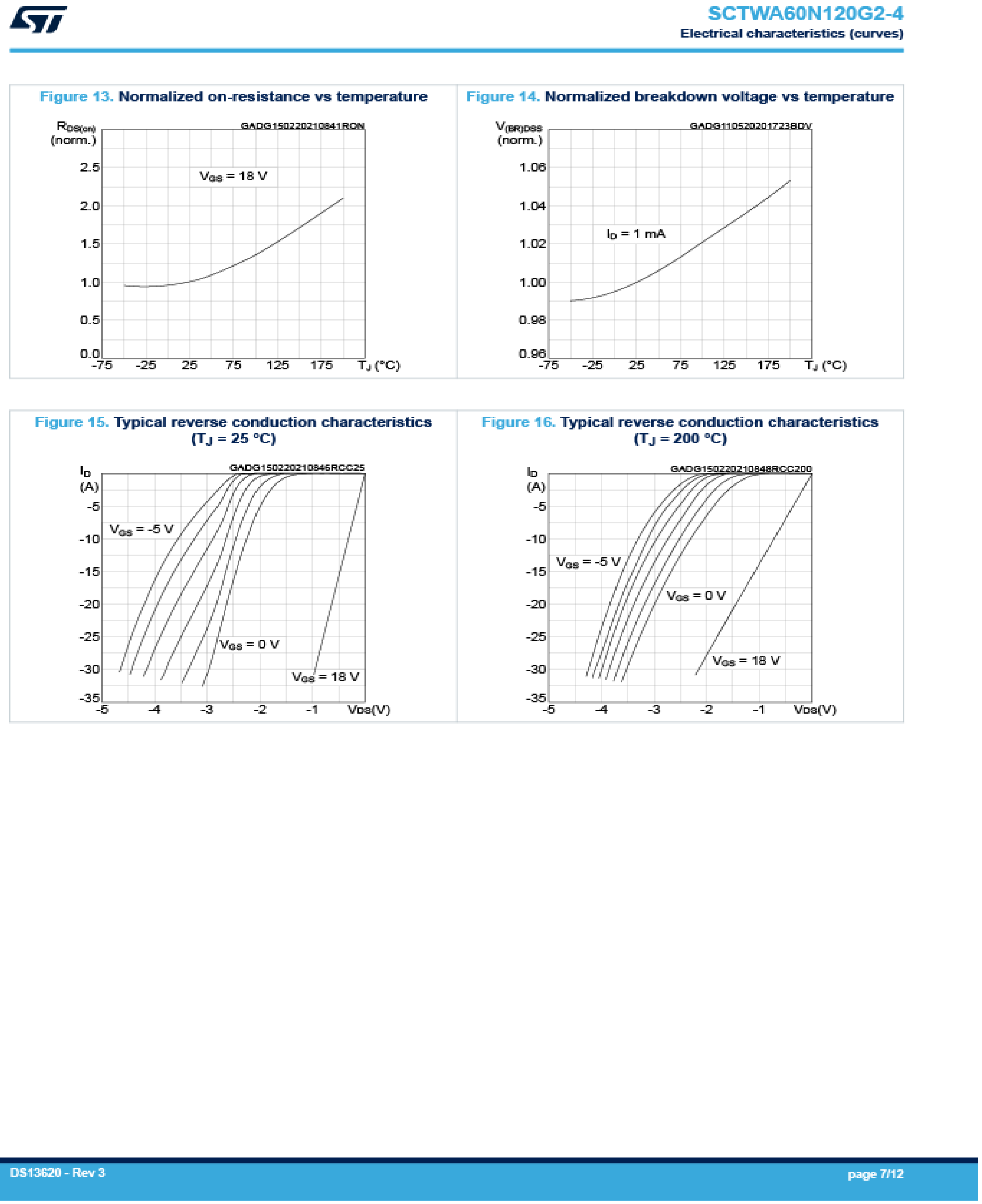
Figure 8. **Typical capacitance characteristics**

Figure 9. **Typical switching energy vs drain current**

Figure 10. **Typical switching energy vs temperature**

Figure 11. **Typical switching energy vs gate resistance**

Figure 12. **Normalized gate threshold vs temperature**



SCTWA60N120G2-4

Electrical characteristics (curves)

Figure 13. Normalized on-resistance vs temperature

Figure 14. Normalized breakdown voltage vs temperature

Figure 15. Typical reverse conduction characteristics (T_J = 25 °C)

Figure 16. Typical reverse conduction characteristics (T_J = 200 °C)

DS13620 - Rev 3

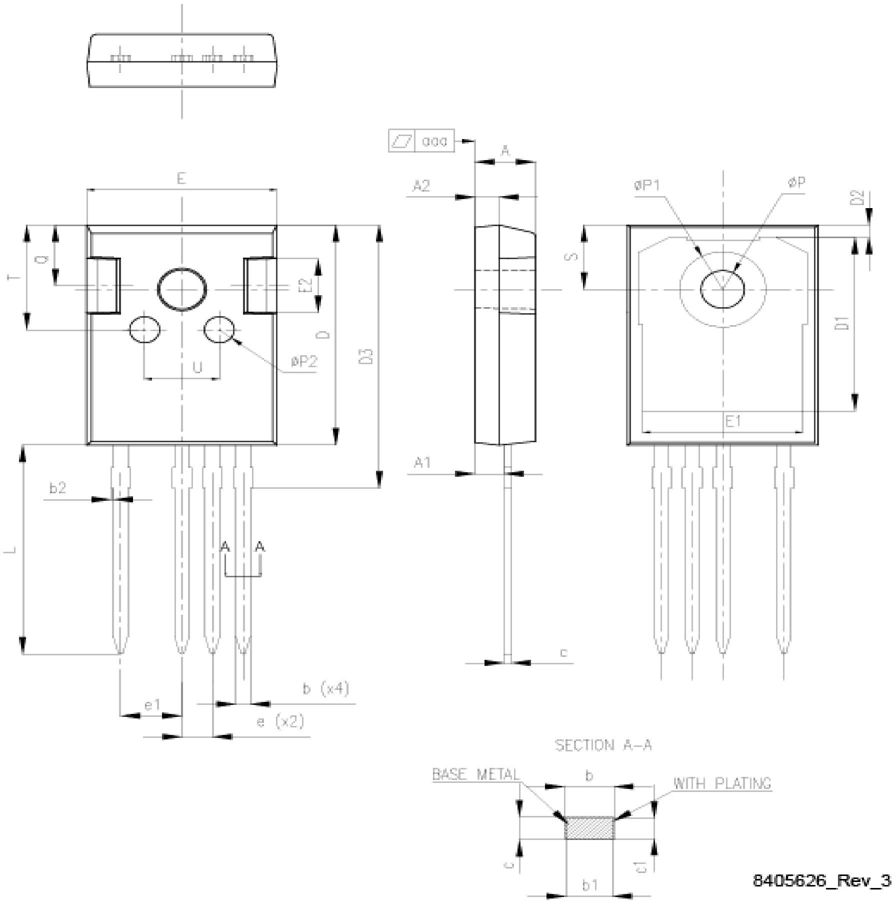
page 7/12

3 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK packages, depending on their level of environmental compliance. ECOPACK specifications, grade definitions and product status are available at: www.st.com. ECOPACK is an ST trademark.

3.1 HiP247-4 package information

Figure 17. **HiP247-4 package outline**



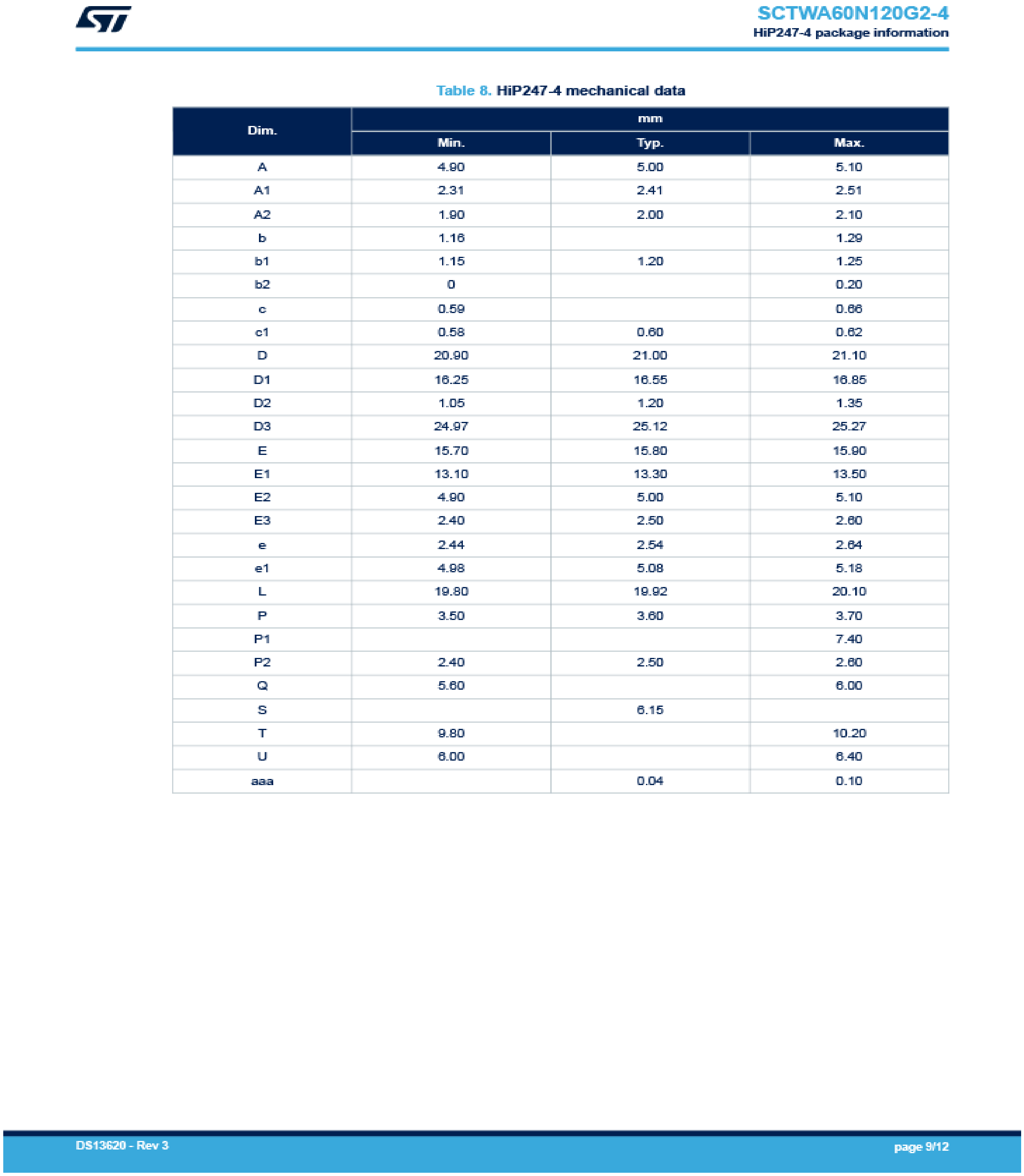
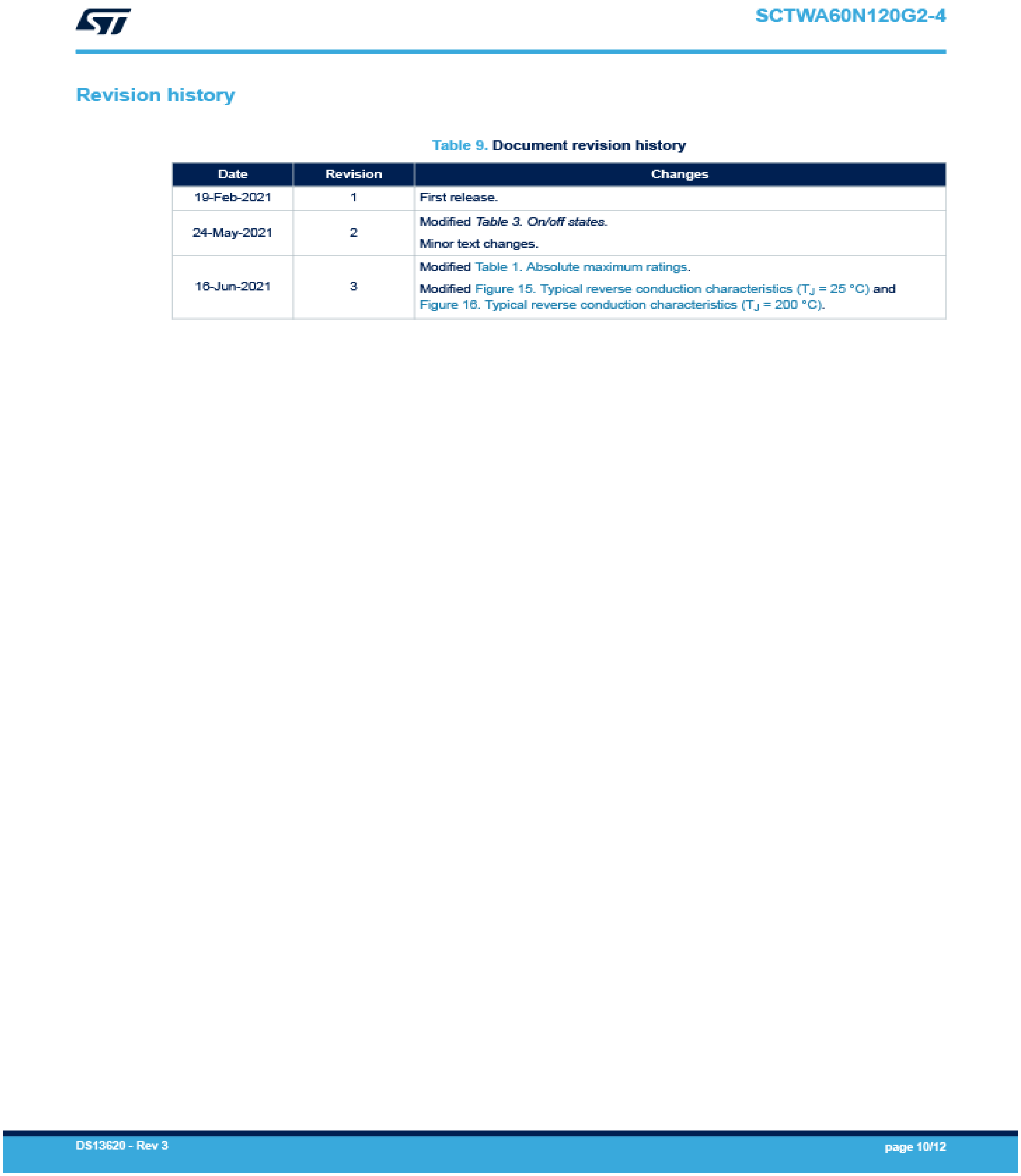


Table 8. **HiP247-4 mechanical data**

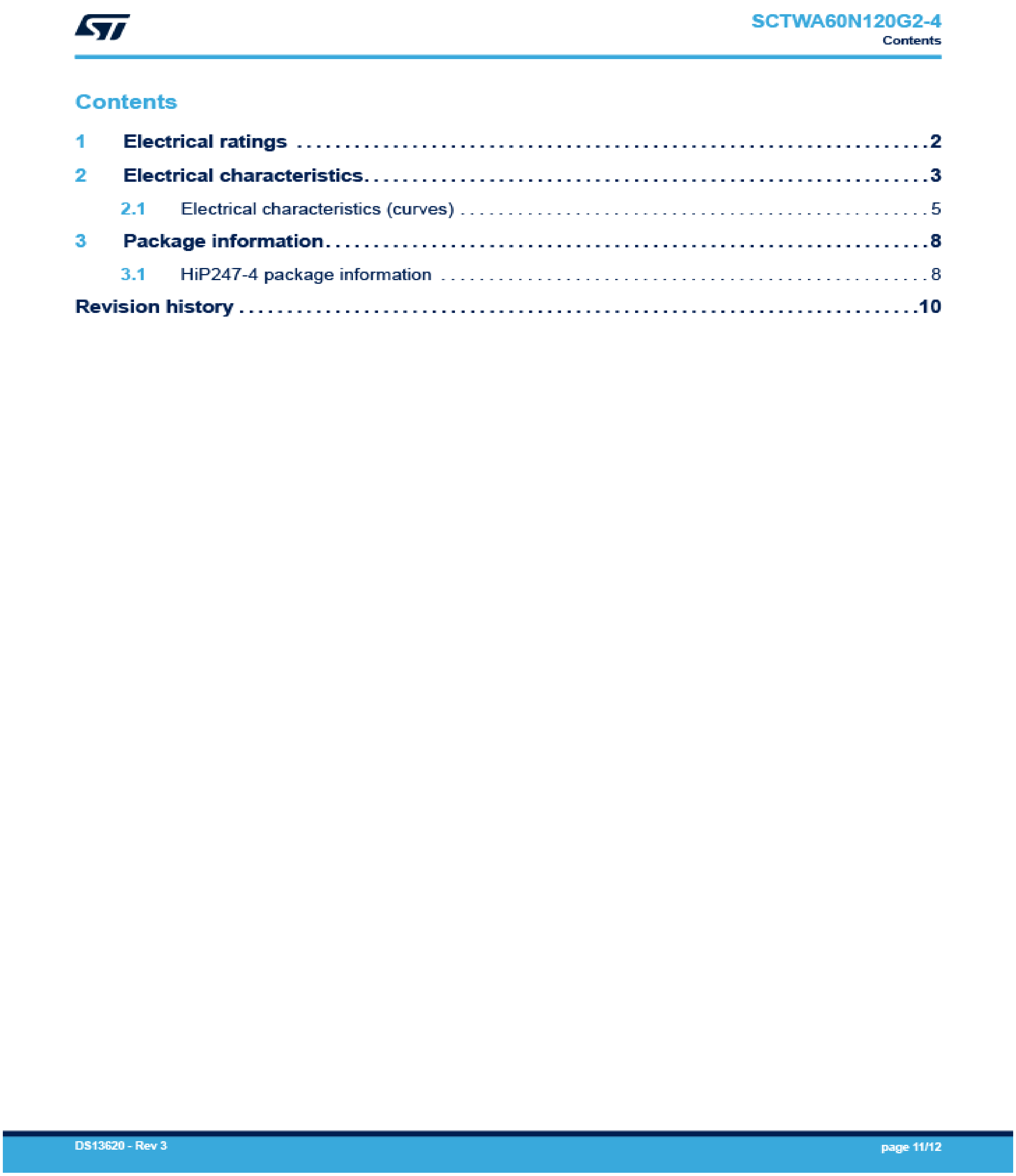
Dim.	mm		
	Min.	Typ.	Max.
A	4.90	5.00	5.10
A1	2.31	2.41	2.51
A2	1.90	2.00	2.10
b	1.16		1.29
b1	1.15	1.20	1.25
b2	0		0.20
c	0.59		0.66
c1	0.58	0.60	0.62
D	20.90	21.00	21.10
D1	16.25	16.55	16.85
D2	1.05	1.20	1.35
D3	24.97	25.12	25.27
E	15.70	15.80	15.90
E1	13.10	13.30	13.50
E2	4.90	5.00	5.10
E3	2.40	2.50	2.60
e	2.44	2.54	2.64
e1	4.98	5.08	5.18
L	19.80	19.92	20.10
P	3.50	3.60	3.70
P1			7.40
P2	2.40	2.50	2.60
Q	5.60		6.00
S		6.15	
T	9.80		10.20
U	6.00		6.40
aaa		0.04	0.10



Revision history

Table 9. **Document revision history**

Date	Revision	Changes
19-Feb-2021	1	First release.
24-May-2021	2	Modified *Table 3. On/off states.* Minor text changes.
16-Jun-2021	3	Modified Table 1. Absolute maximum ratings. Modified Figure 15. Typical reverse conduction characteristics (T_J = 25 °C) and Figure 16. Typical reverse conduction characteristics (T_J = 200 °C).



Contents

SCTWA60N120G2-4

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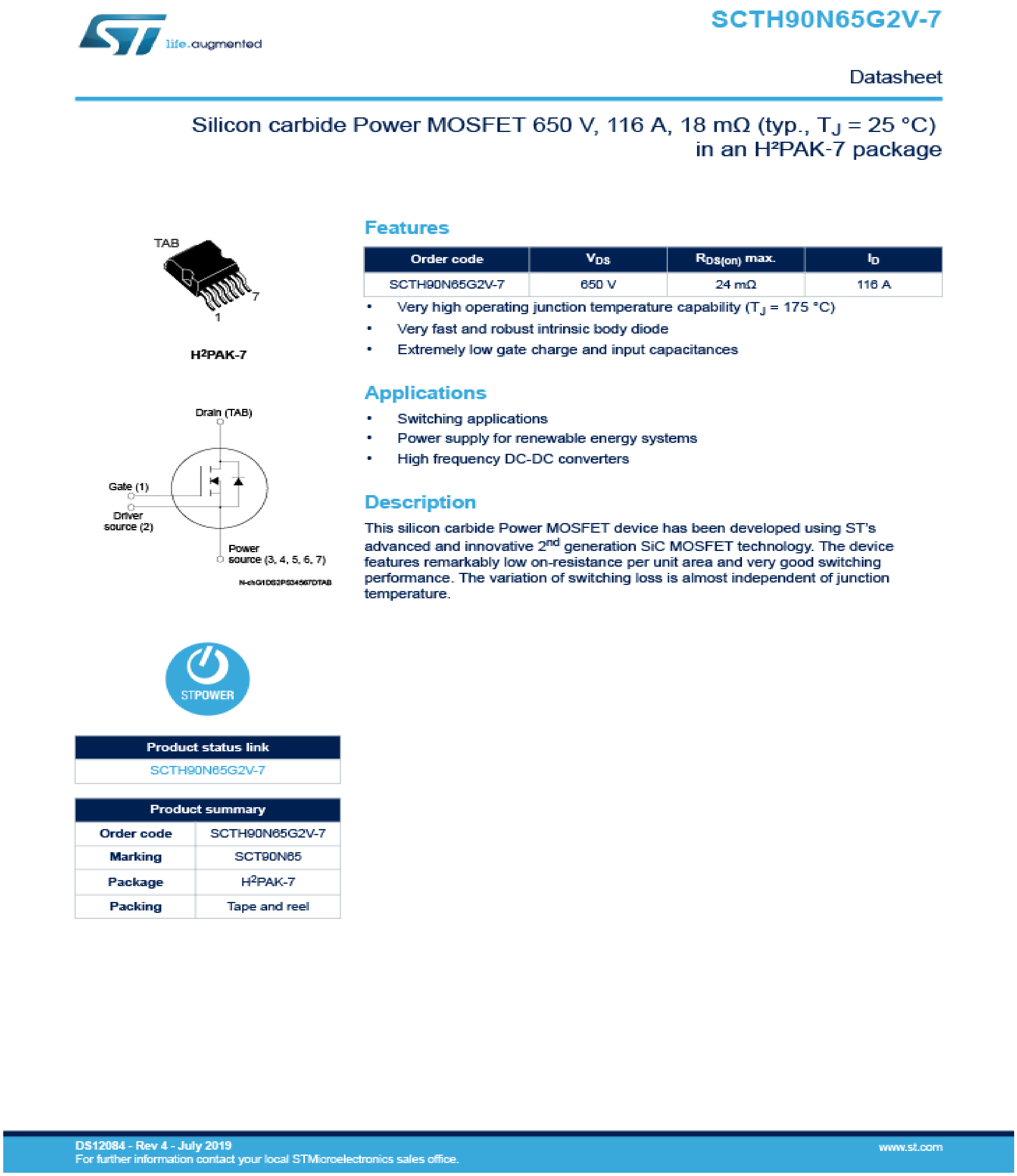
DS13620 - Rev 3

page 12/12

Silicon carbide Power MOSFET 650 V, 116 A, 18 mΩ (typ., TJ = 25 °C) in an H²PAK-7 package



SCTH90N65G2V-7

Datasheet

Silicon carbide Power MOSFET 650 V, 116 A, 18 mΩ (typ., T_J = 25 °C) in an H²PAK-7 package

H^2PAK-7

Features

Order code	V_{DS}	$R_{DS(on)}$ max.	I_D
SCTH90N65G2V-7	650 V	24 mΩ	116 A

- Very high operating junction temperature capability (T_J = 175 °C)
- Very fast and robust intrinsic body diode
- Extremely low gate charge and input capacitances

Applications

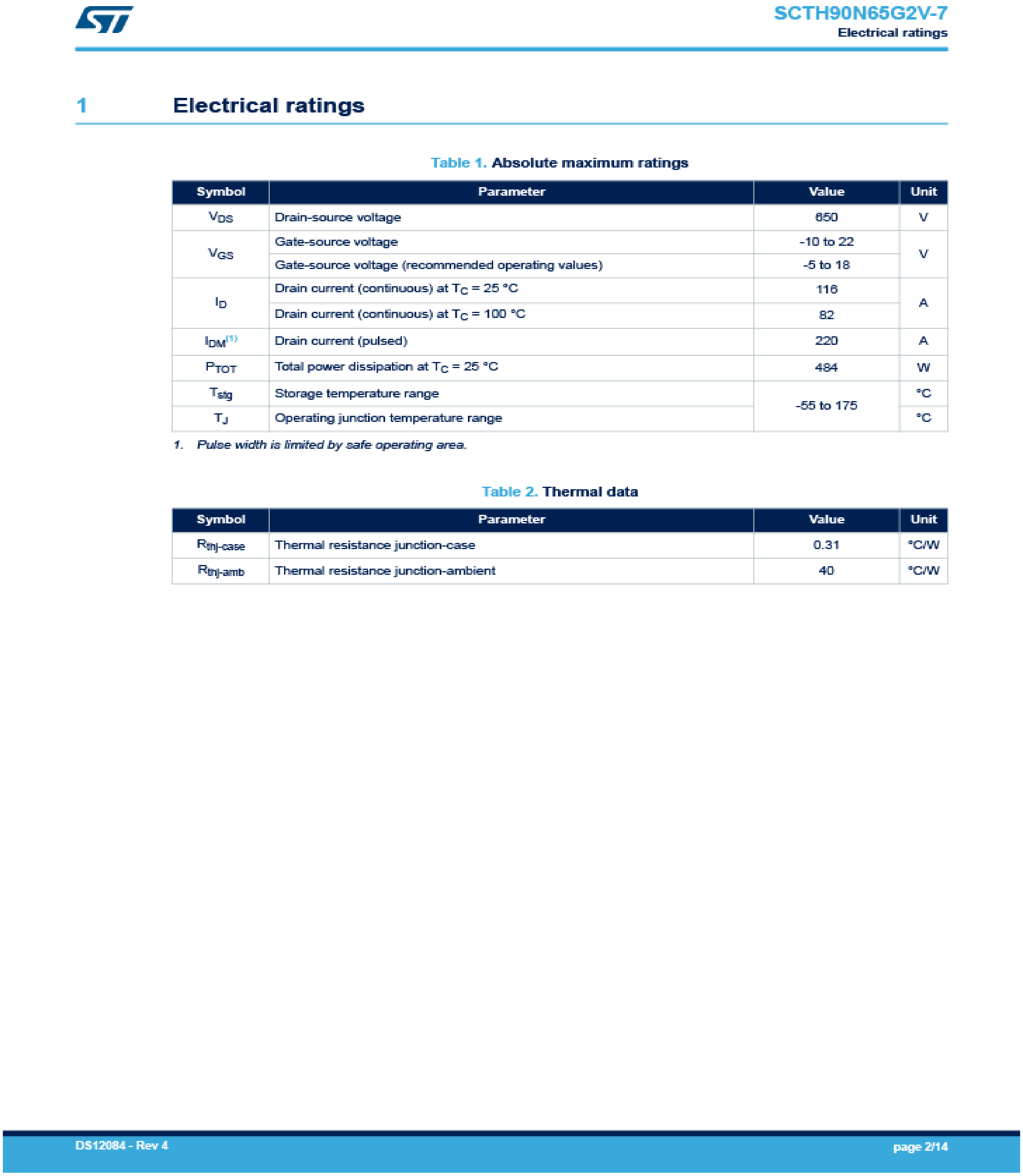
- Switching applications
- Power supply for renewable energy systems
- High frequency DC-DC converters

Description

This silicon carbide Power MOSFET device has been developed using ST's advanced and innovative 2nd generation SiC MOSFET technology. The device features remarkably low on-resistance per unit area and very good switching performance. The variation of switching loss is almost independent of junction temperature.

Product status link
SCTH90N65G2V-7

Product summary	
Order code	SCTH90N65G2V-7
Marking	SCT90N65
Package	H^2PAK-7
Packing	Tape and reel



1 Electrical ratings

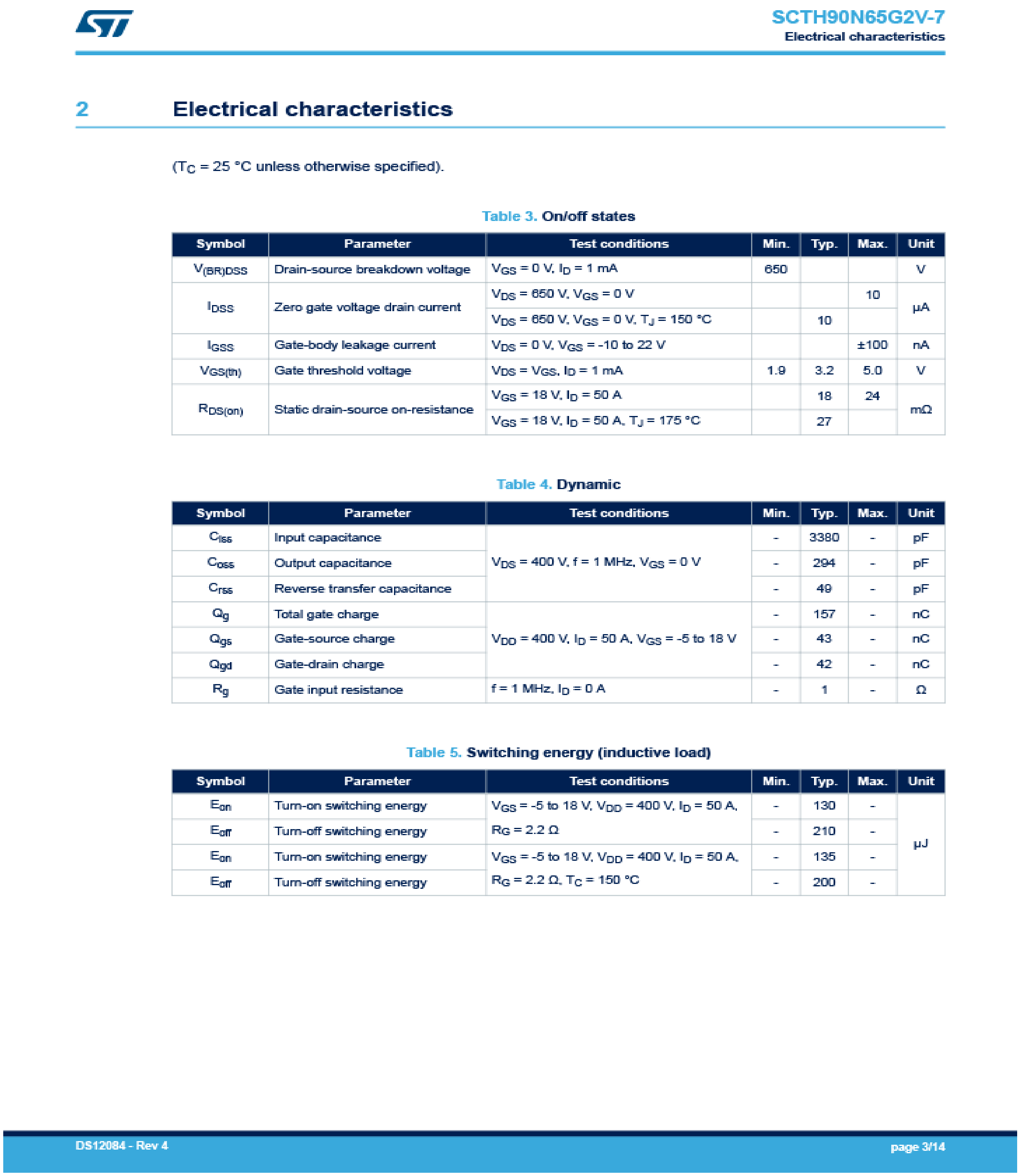
Table 1. **Absolute maximum ratings**

Symbol	Parameter	Value	Unit
V_{DS}	Drain-source voltage	650	V
V_{GS}	Gate-source voltage	-10 to 22	V
	Gate-source voltage (recommended operating values)	-5 to 18	
I_D	Drain current (continuous) at T_C = 25 °C	116	A
	Drain current (continuous) at T_C = 100 °C	82	
I_{DM}(1)	Drain current (pulsed)	220	A
P_{TOT}	Total power dissipation at T_C = 25 °C	484	W
T_{stg}	Storage temperature range	-55 to 175	°C
T_J	Operating junction temperature range		°C

1. *Pulse width is limited by safe operating area.*

Table 2. **Thermal data**

Symbol	Parameter	Value	Unit
$R_{thj\text{-}case}$	Thermal resistance junction-case	0.31	°C/W
$R_{thj\text{-}amb}$	Thermal resistance junction-ambient	40	°C/W



2 Electrical characteristics

(T_C = 25 °C unless otherwise specified).

Table 3. **On/off states**

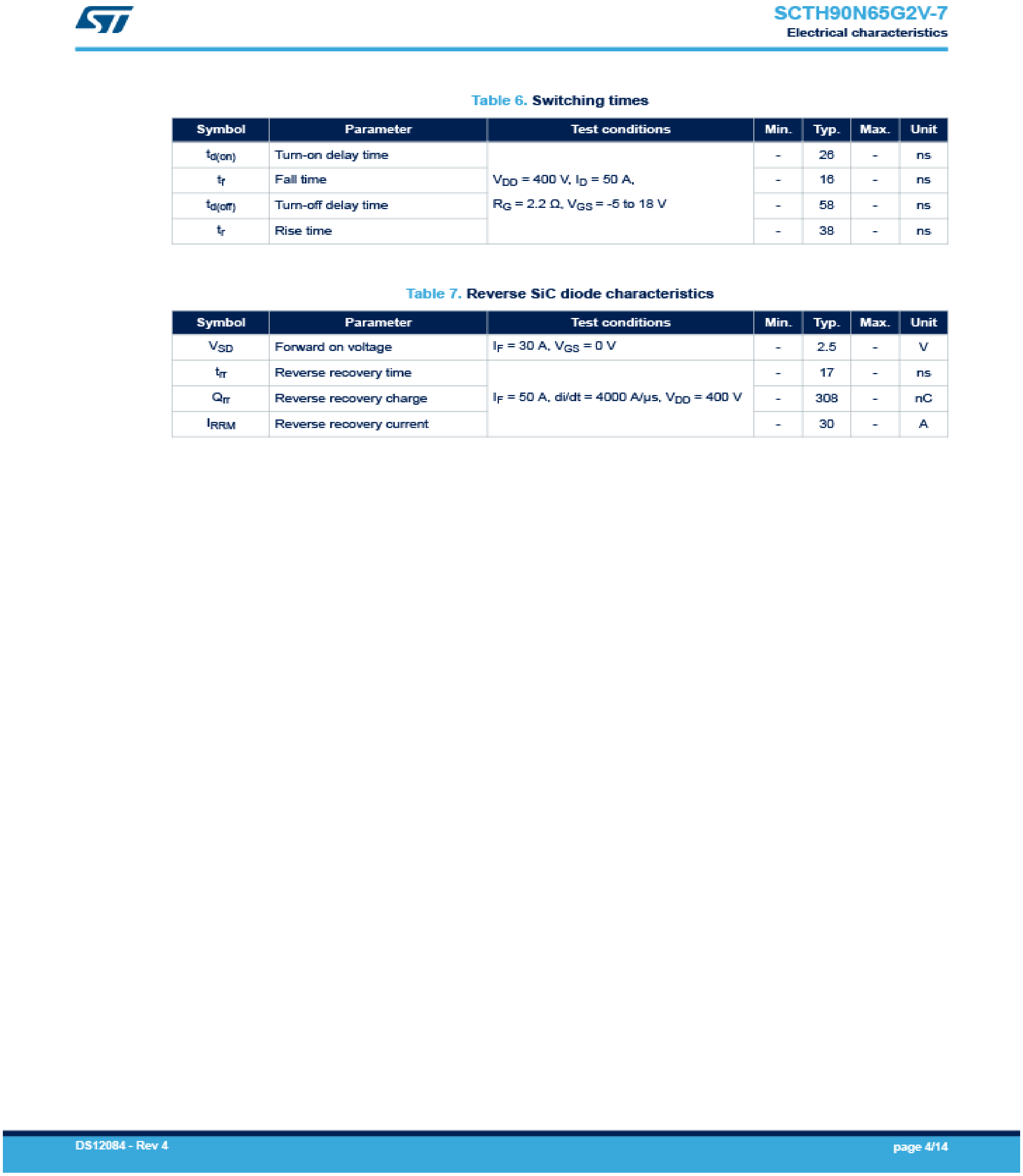
Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{(BR)DSS}$	Drain-source breakdown voltage	V_{GS} = 0 V, I_D = 1 mA	650			V
I_{DSS}	Zero gate voltage drain current	V_{DS} = 650 V, V_{GS} = 0 V			10	µA
		V_{DS} = 650 V, V_{GS} = 0 V, T_J = 150 °C		10		
I_{GSS}	Gate-body leakage current	V_{DS} = 0 V, V_{GS} = -10 to 22 V			±100	nA
$V_{GS(th)}$	Gate threshold voltage	V_{DS} = V_{GS}, I_D = 1 mA	1.9	3.2	5.0	V
$R_{DS(on)}$	Static drain-source on-resistance	V_{GS} = 18 V, I_D = 50 A		18	24	mΩ
		V_{GS} = 18 V, I_D = 50 A, T_J = 175 °C		27		

Table 4. **Dynamic**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
C_{iss}	Input capacitance	V_{DS} = 400 V, f = 1 MHz, V_{GS} = 0 V	-	3380	-	pF
C_{oss}	Output capacitance		-	294	-	pF
C_{rss}	Reverse transfer capacitance		-	49	-	pF
Q_g	Total gate charge	V_{DD} = 400 V, I_D = 50 A, V_{GS} = -5 to 18 V	-	157	-	nC
Q_{gs}	Gate-source charge		-	43	-	nC
Q_{gd}	Gate-drain charge		-	42	-	nC
R_g	Gate input resistance	f = 1 MHz, I_D = 0 A	-	1	-	Ω

Table 5. **Switching energy (inductive load)**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
E_{on}	Turn-on switching energy	V_{GS} = -5 to 18 V, V_{DD} = 400 V, I_D = 50 A, R_G = 2.2 Ω	-	130	-	µJ
E_{off}	Turn-off switching energy		-	210	-	
E_{on}	Turn-on switching energy	V_{GS} = -5 to 18 V, V_{DD} = 400 V, I_D = 50 A, R_G = 2.2 Ω, T_C = 150 °C	-	135	-	
E_{off}	Turn-off switching energy		-	200	-	



SCTH90N65G2V-7
Electrical characteristics

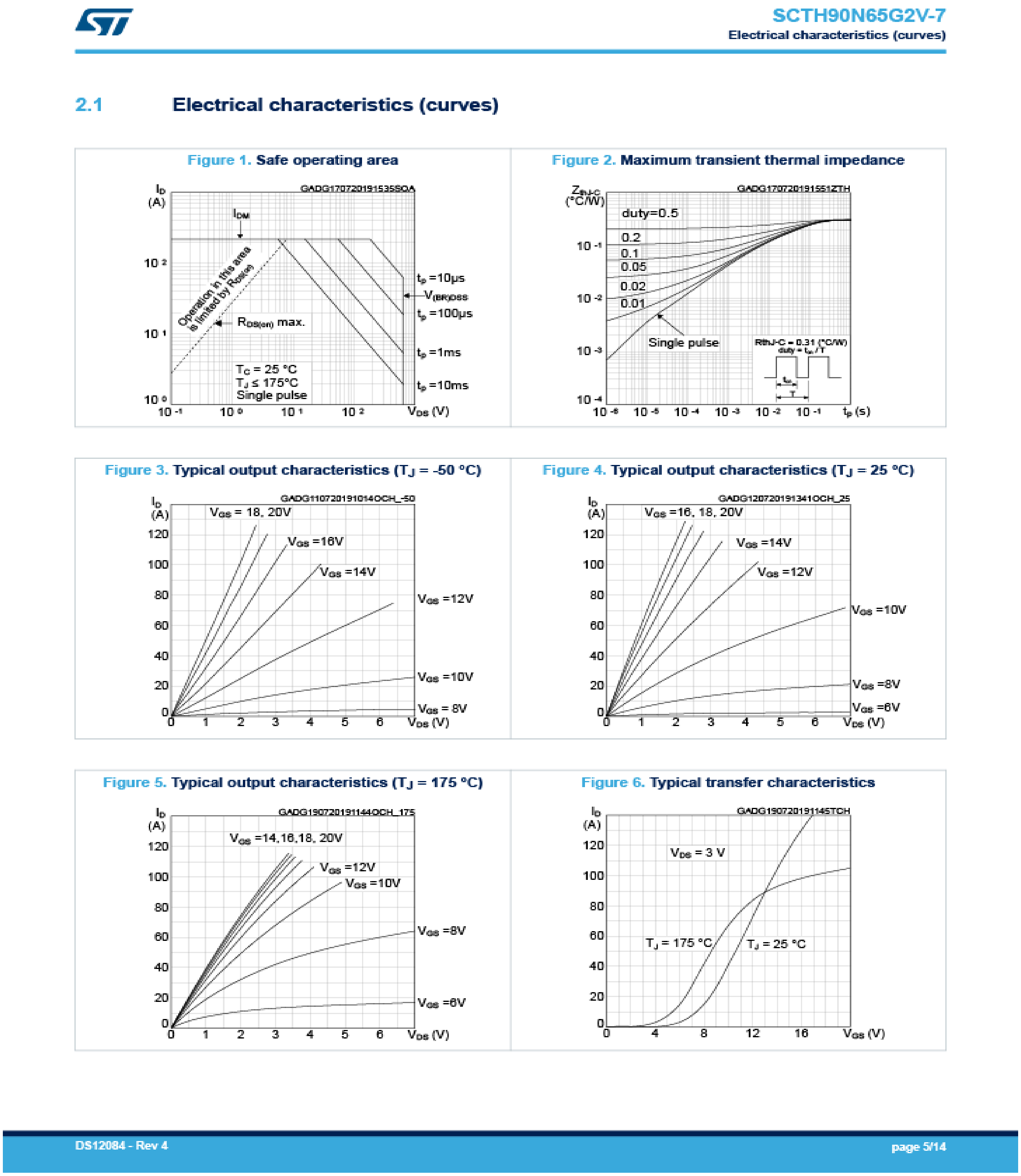
Table 6. Switching times

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$t_{d(on)}$	Turn-on delay time	V_{DD} = 400 V, I_D = 50 A, R_G = 2.2 Ω, V_{GS} = -5 to 18 V	-	26	-	ns
t_f	Fall time		-	16	-	ns
$t_{d(off)}$	Turn-off delay time		-	58	-	ns
t_r	Rise time		-	38	-	ns

Table 7. Reverse SiC diode characteristics

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_{SD}	Forward on voltage	I_F = 30 A, V_{GS} = 0 V	-	2.5	-	V
t_{rr}	Reverse recovery time	I_F = 50 A, di/dt = 4000 A/µs, V_{DD} = 400 V	-	17	-	ns
Q_{rr}	Reverse recovery charge		-	308	-	nC
I_{RRM}	Reverse recovery current		-	30	-	A

DS12084 - Rev 4 page 4/14



SCTH90N65G2V-7

Electrical characteristics (curves)

2.1 Electrical characteristics (curves)

Figure 1. Safe operating area

Figure 2. Maximum transient thermal impedance

Figure 3. Typical output characteristics (T_J = -50 °C)

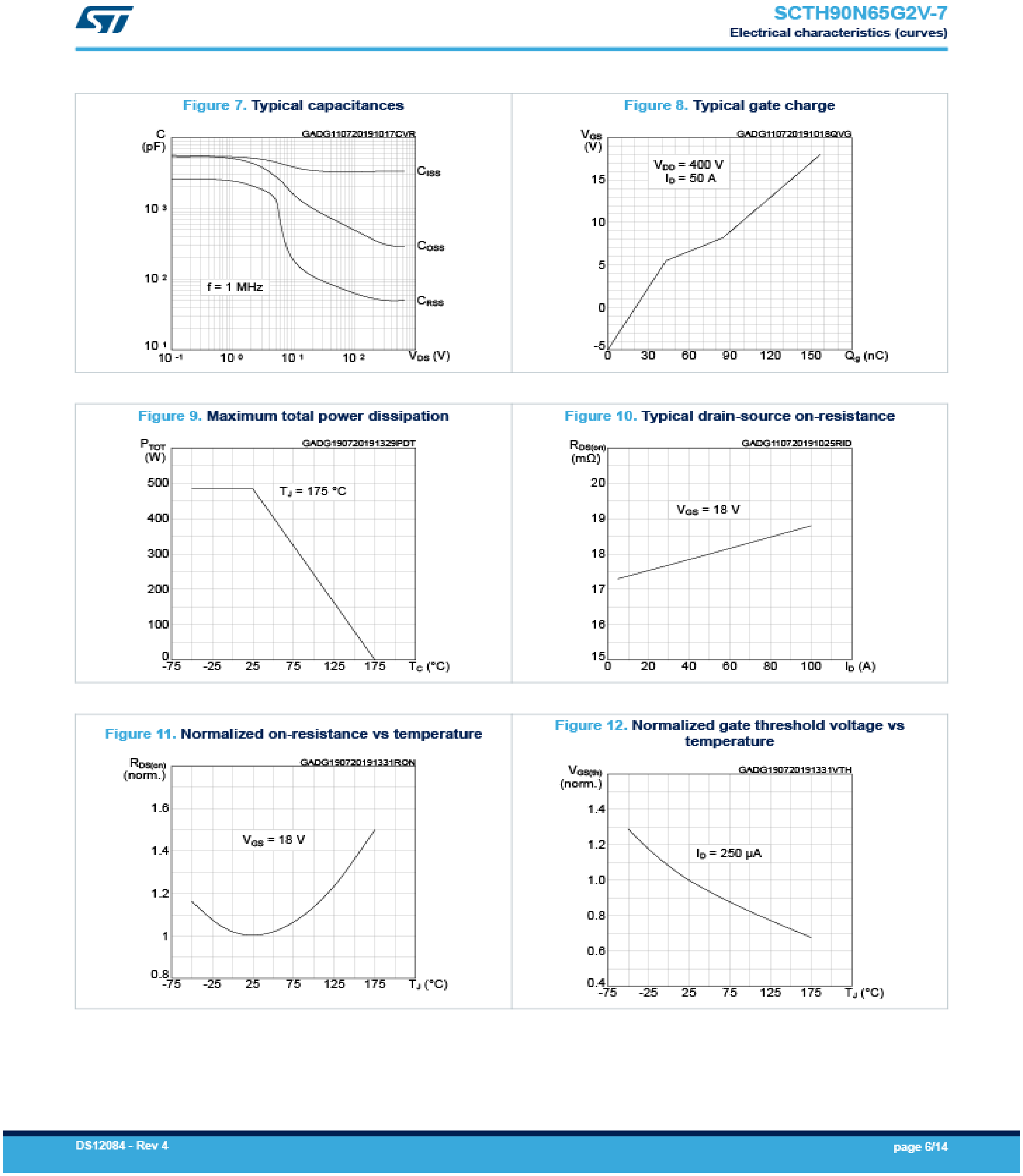
Figure 4. Typical output characteristics (T_J = 25 °C)

Figure 5. Typical output characteristics (T_J = 175 °C)

Figure 6. Typical transfer characteristics

DS12084 - Rev 4

page 5/14



SCTH90N65G2V-7

Electrical characteristics (curves)

Figure 7. **Typical capacitances**

Figure 8. **Typical gate charge**

Figure 9. **Maximum total power dissipation**

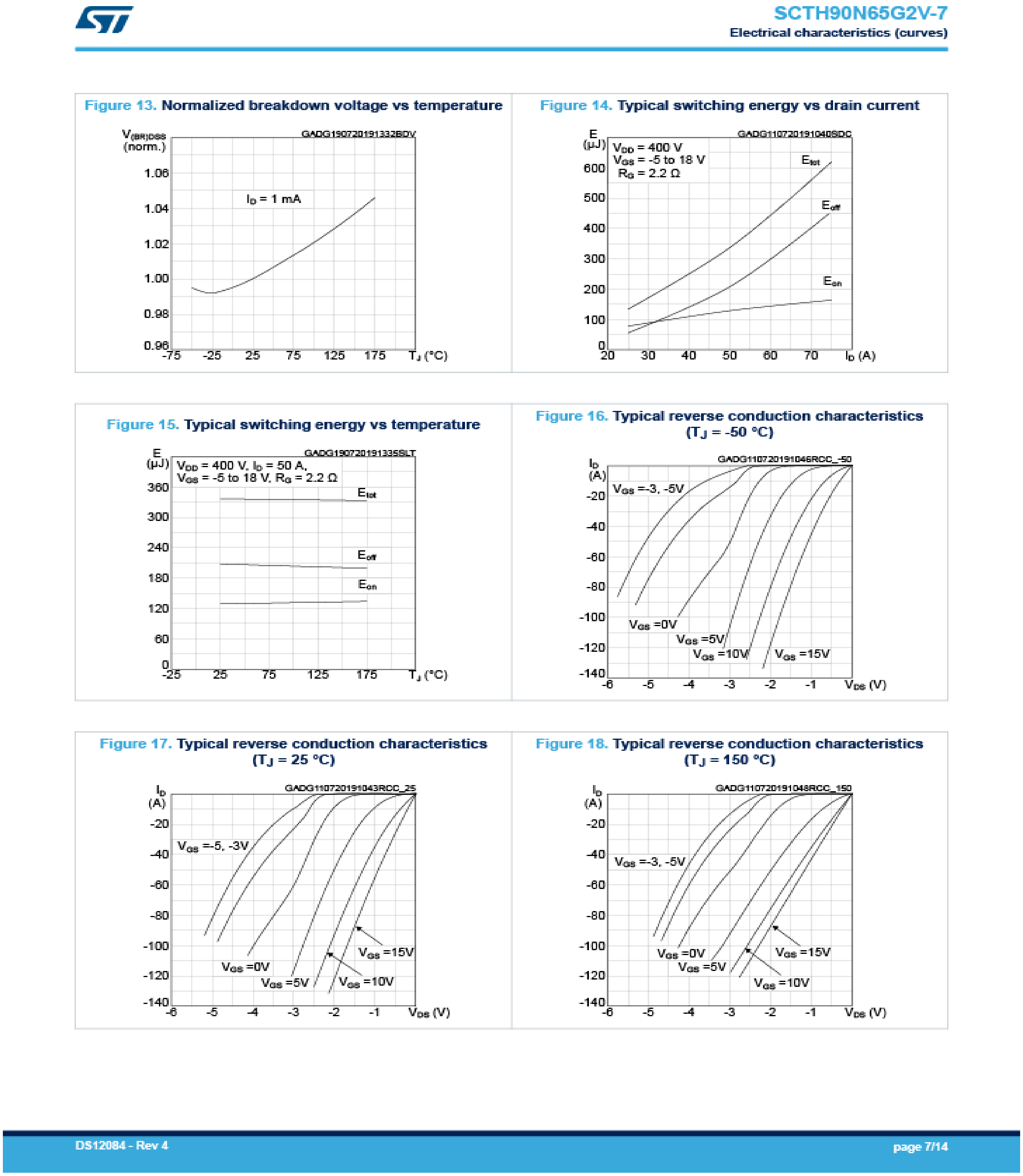
Figure 10. **Typical drain-source on-resistance**

Figure 11. **Normalized on-resistance vs temperature**

Figure 12. **Normalized gate threshold voltage vs temperature**

DS12084 - Rev 4

page 6/14



SCTH90N65G2V-7

Electrical characteristics (curves)

Figure 13. **Normalized breakdown voltage vs temperature**

Figure 14. **Typical switching energy vs drain current**

Figure 15. **Typical switching energy vs temperature**

Figure 16. **Typical reverse conduction characteristics (T_J = -50 °C)**

Figure 17. **Typical reverse conduction characteristics (T_J = 25 °C)**

Figure 18. **Typical reverse conduction characteristics (T_J = 150 °C)**

DS12084 - Rev 4

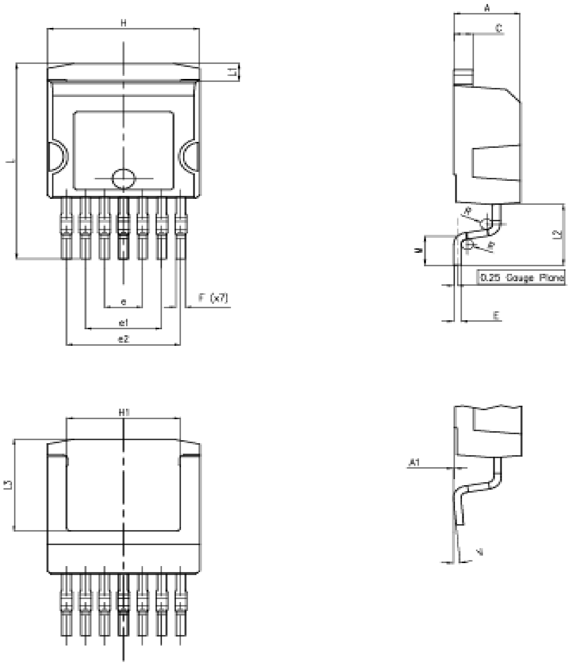
page 7/14

3 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK packages, depending on their level of environmental compliance. ECOPACK specifications, grade definitions and product status are available at: www.st.com. ECOPACK is an ST trademark.

3.1 H²PAK-7 package information

Figure 19. **H²PAK-7 package outline**



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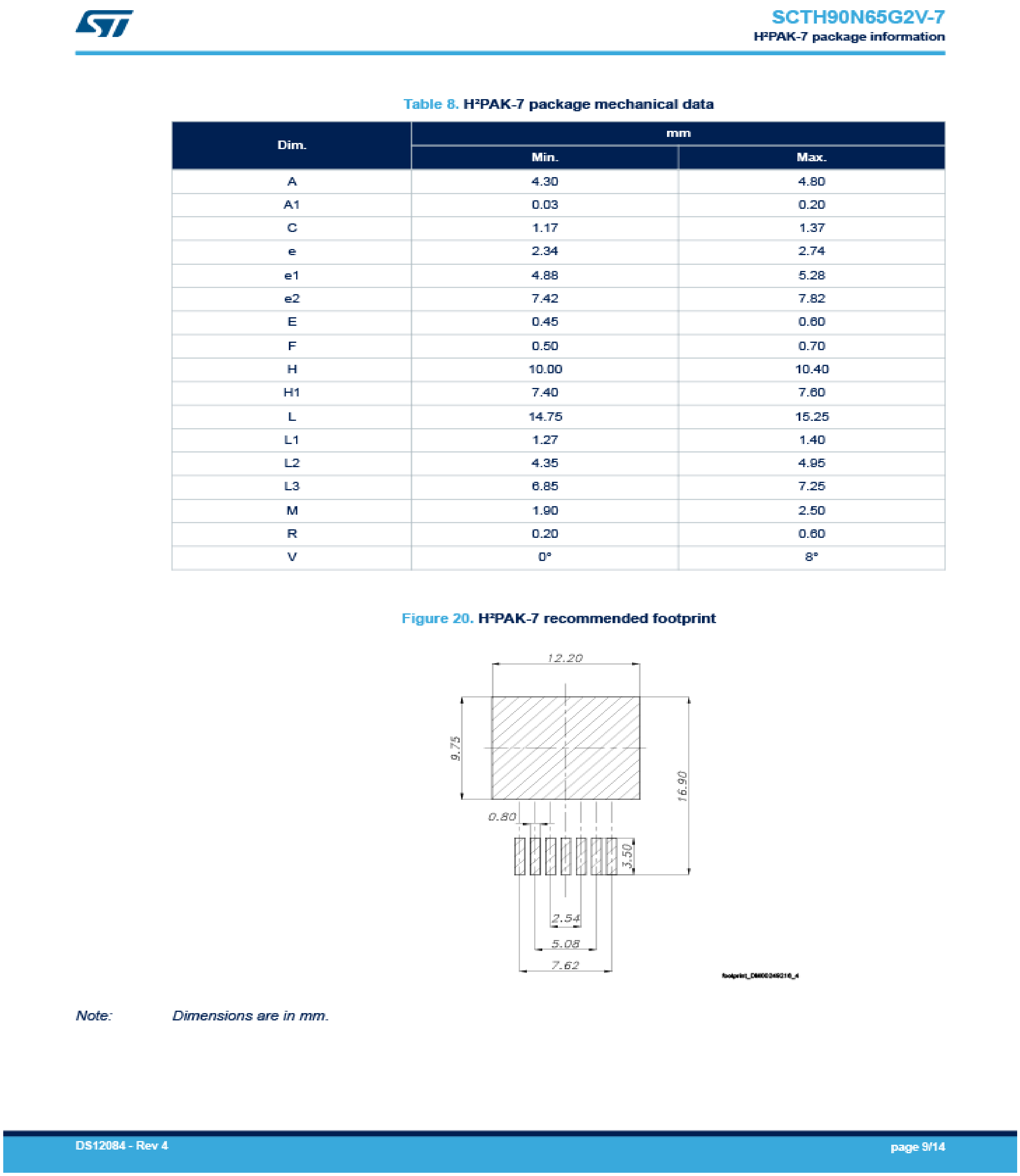


SCTH90N65G2V-7

H²PAK-7 package information

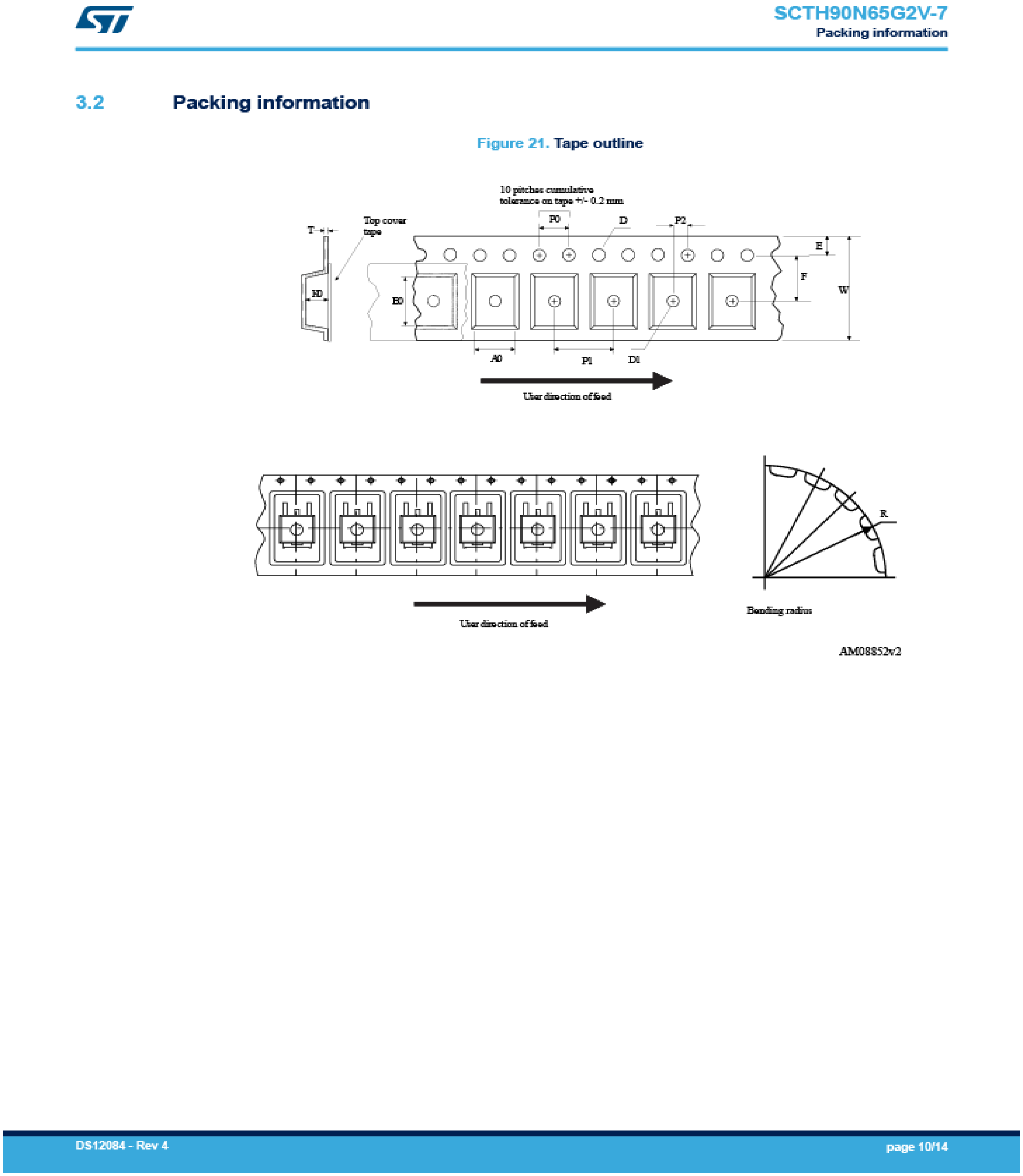
Table 8. **H²PAK-7 package mechanical data**

Dim.	mm	
	Min.	Max.
A	4.30	4.80
A1	0.03	0.20
C	1.17	1.37
e	2.34	2.74
e1	4.88	5.28
e2	7.42	7.82
E	0.45	0.60
F	0.50	0.70
H	10.00	10.40
H1	7.40	7.60
L	14.75	15.25
L1	1.27	1.40
L2	4.35	4.95
L3	6.85	7.25
M	1.90	2.50
R	0.20	0.60
V	0°	8°

Figure 20. **H²PAK-7 recommended footprint**

Note: *Dimensions are in mm.*

DS12084 - Rev 4 **page 9/14**



3.2 Packing information

Figure 21. Tape outline

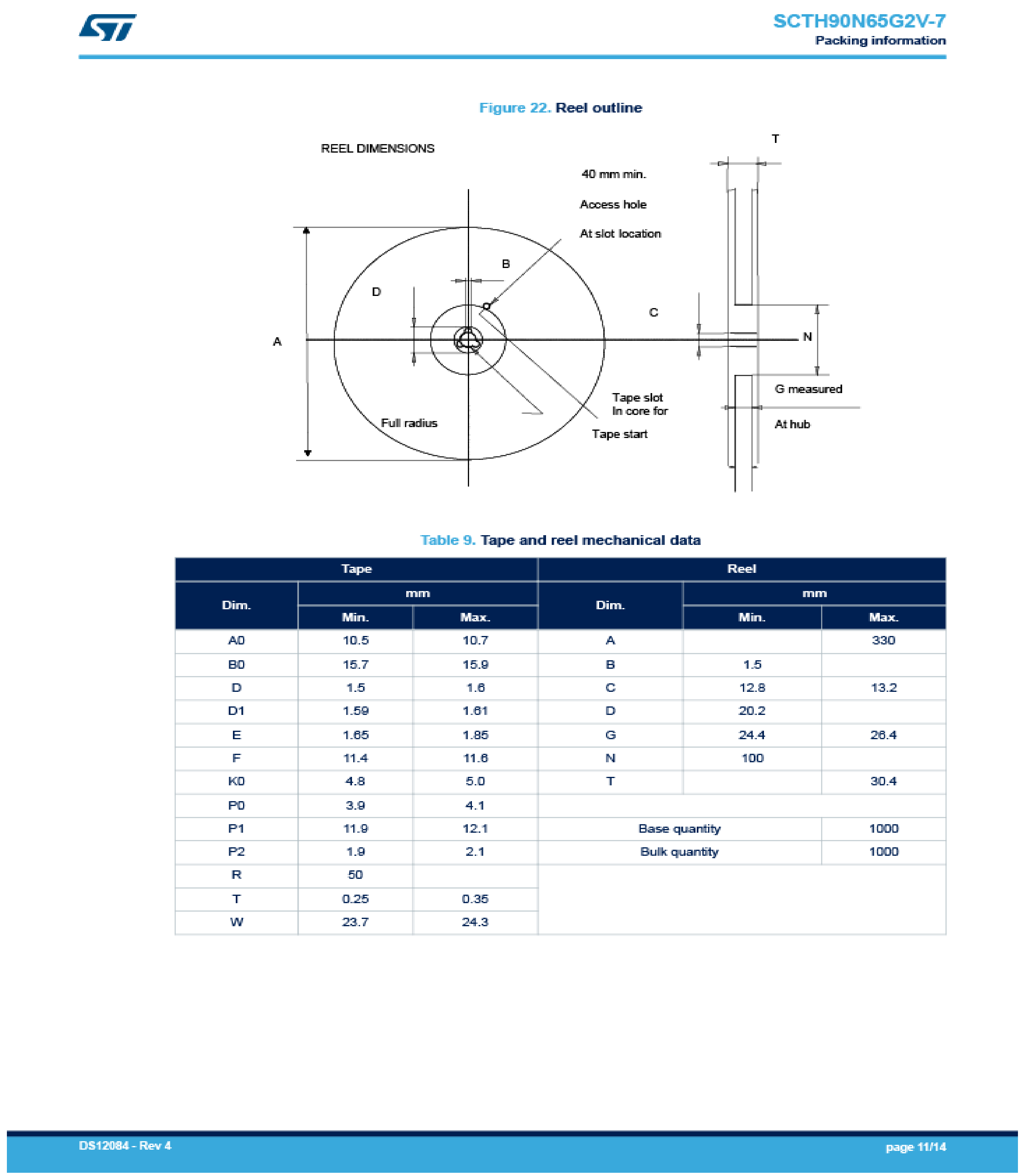


Figure 22. Reel outline

Table 9. Tape and reel mechanical data

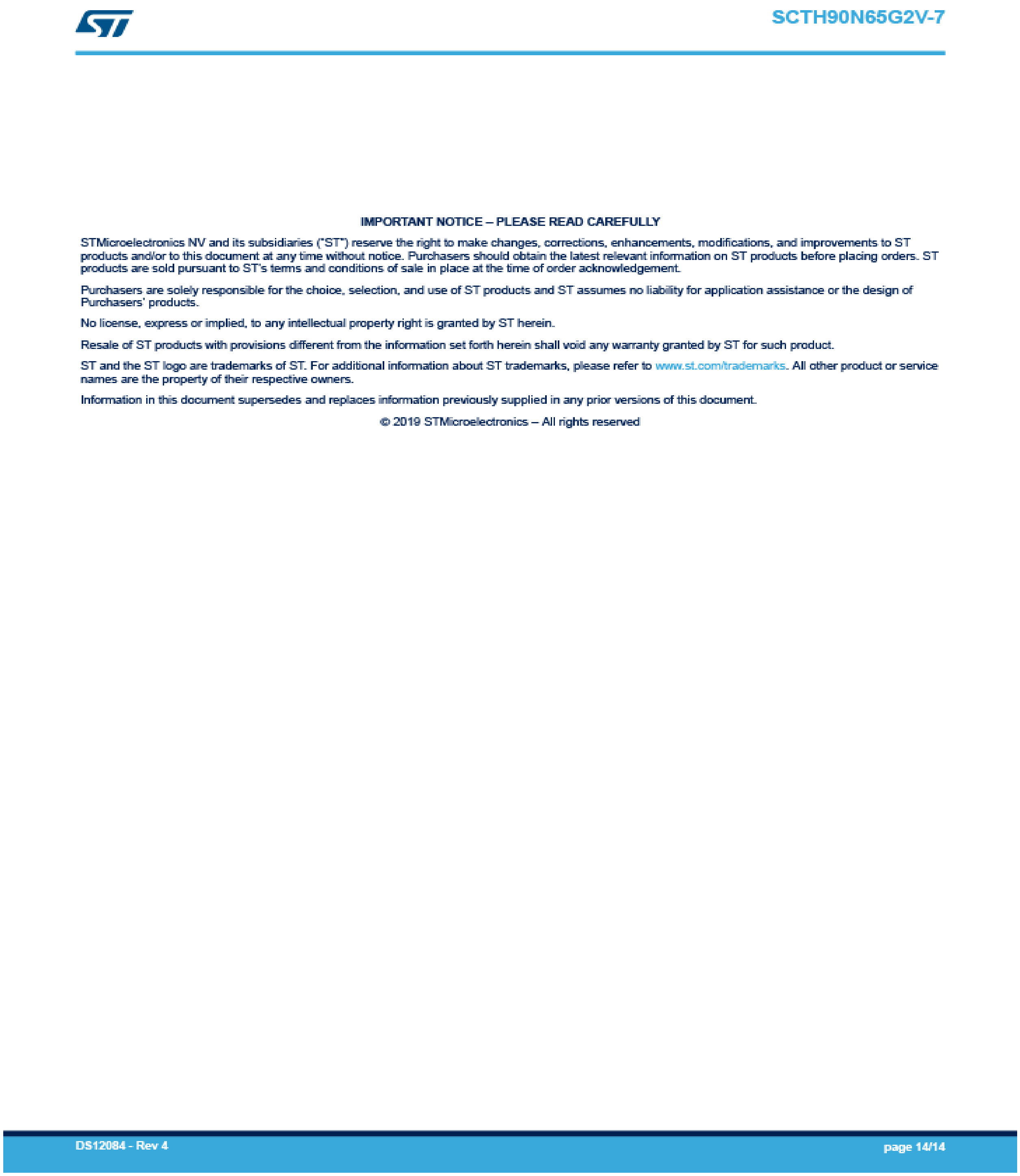
Tape			Reel		
Dim.	mm		Dim.	mm	
	Min.	Max.		Min.	Max.
A0	10.5	10.7	A		330
B0	15.7	15.9	B	1.5	
D	1.5	1.6	C	12.8	13.2
D1	1.59	1.61	D	20.2	
E	1.65	1.85	G	24.4	26.4
F	11.4	11.6	N	100	
K0	4.8	5.0	T		30.4
P0	3.9	4.1			
P1	11.9	12.1	Base quantity		1000
P2	1.9	2.1	Bulk quantity		1000
R	50				
T	0.25	0.35			
W	23.7	24.3			

Revision history

Table 10. **Document revision history**

Date	Revision	Changes
30-Mar-2017	1	First release
28-Jun-2018	2	Updated cover page. Updated *Section 2 Electrical characteristics* and *Section 3 Package information*. Minor text changes.
22-Jan-2019	3	Updated title and *features* on cover page. Updated *Table 1. Absolute maximum ratings*. Updated *Section 2 Electrical characteristics* and *Section 2.1 Electrical characteristics (curves)*. Minor text changes.
19-Jul-2019	4	Updated Section 1 Electrical ratings. Updated Section 2 Electrical characteristics and Section 2.1 Electrical characteristics (curves). Minor text changes.

Contents



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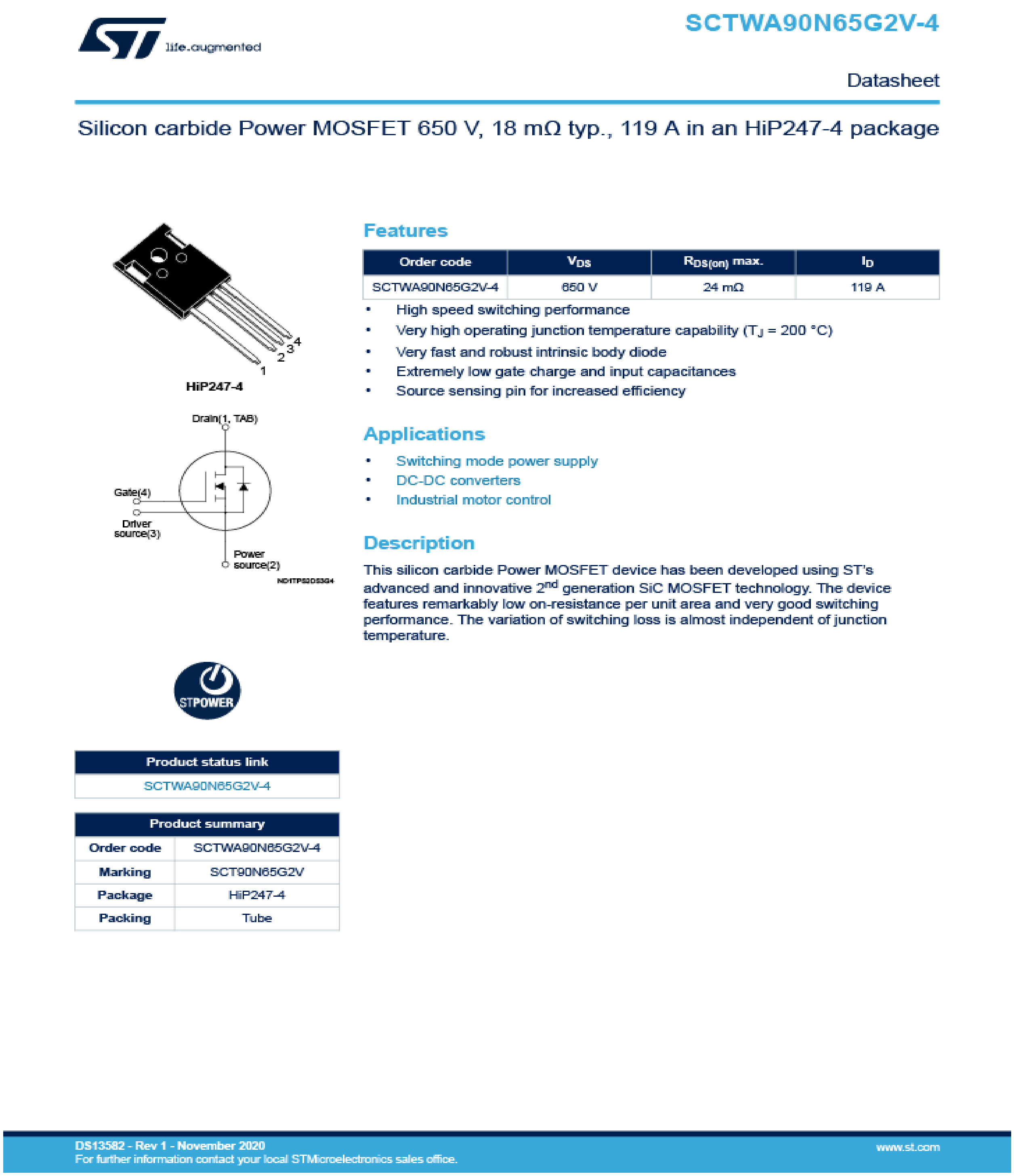
Information in this document supersedes and replaces information previously supplied in any prior versions of this document.

Silicon carbide Power MOSFET 650 V, 18 mΩ typ., 119 A in an HiP247-4 package



SCTWA90N65G2V-4

Datasheet

Silicon carbide Power MOSFET 650 V, 18 mΩ typ., 119 A in an HiP247-4 package

Features

Order code	V_{DS}	$R_{DS(on)}$ max.	I_D
SCTWA90N65G2V-4	650 V	24 mΩ	119 A

- High speed switching performance
- Very high operating junction temperature capability (T_J = 200 °C)
- Very fast and robust intrinsic body diode
- Extremely low gate charge and input capacitances
- Source sensing pin for increased efficiency

Applications

- Switching mode power supply
- DC-DC converters
- Industrial motor control

Description

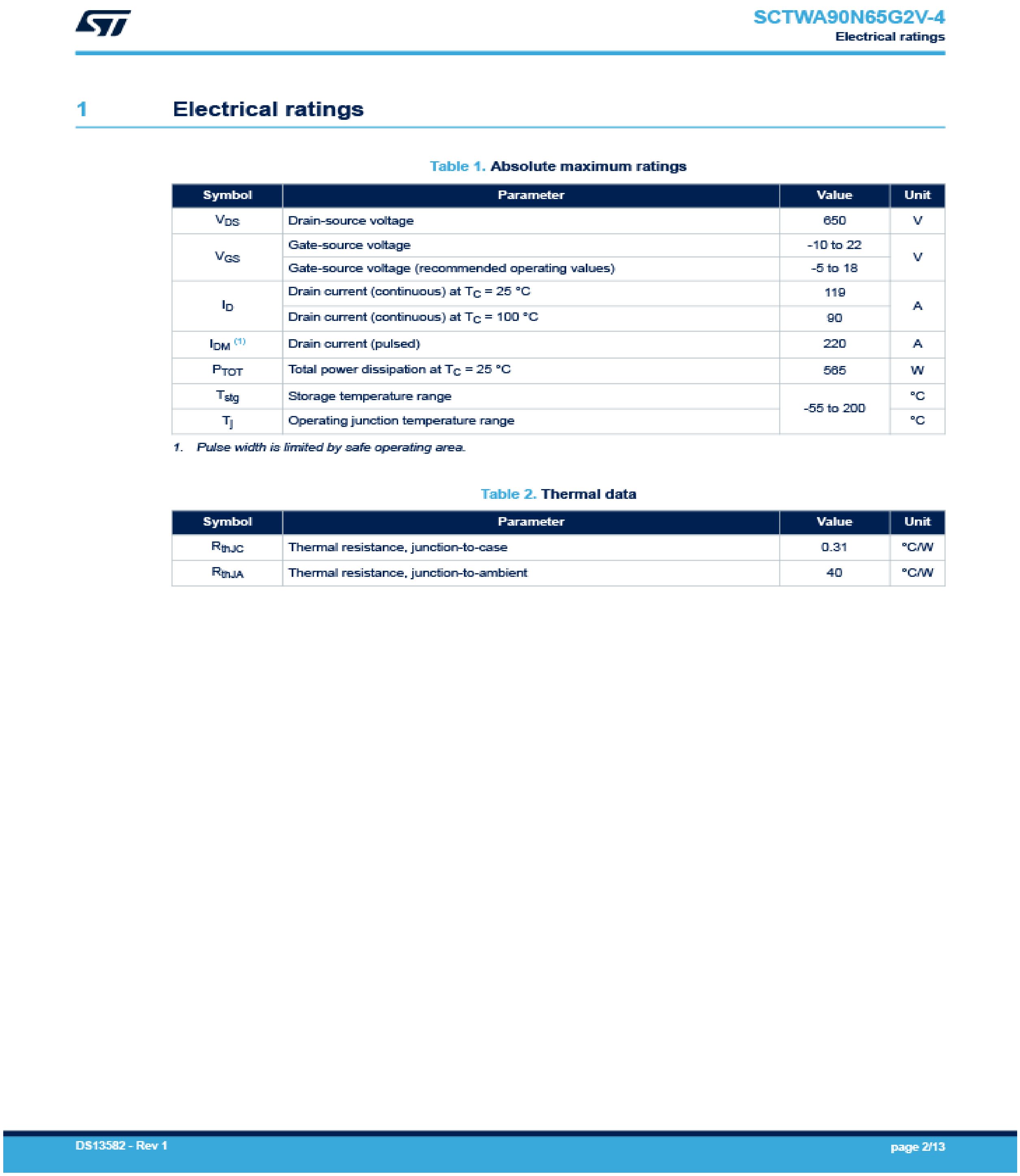
This silicon carbide Power MOSFET device has been developed using ST's advanced and innovative 2nd generation SiC MOSFET technology. The device features remarkably low on-resistance per unit area and very good switching performance. The variation of switching loss is almost independent of junction temperature.

Product status link
SCTWA90N65G2V-4

Product summary	
Order code	SCTWA90N65G2V-4
Marking	SCT90N65G2V
Package	HiP247-4
Packing	Tube

DS13582 - Rev 1 - November 2020
For further information contact your local STMicroelectronics sales office.

www.st.com



1 Electrical ratings

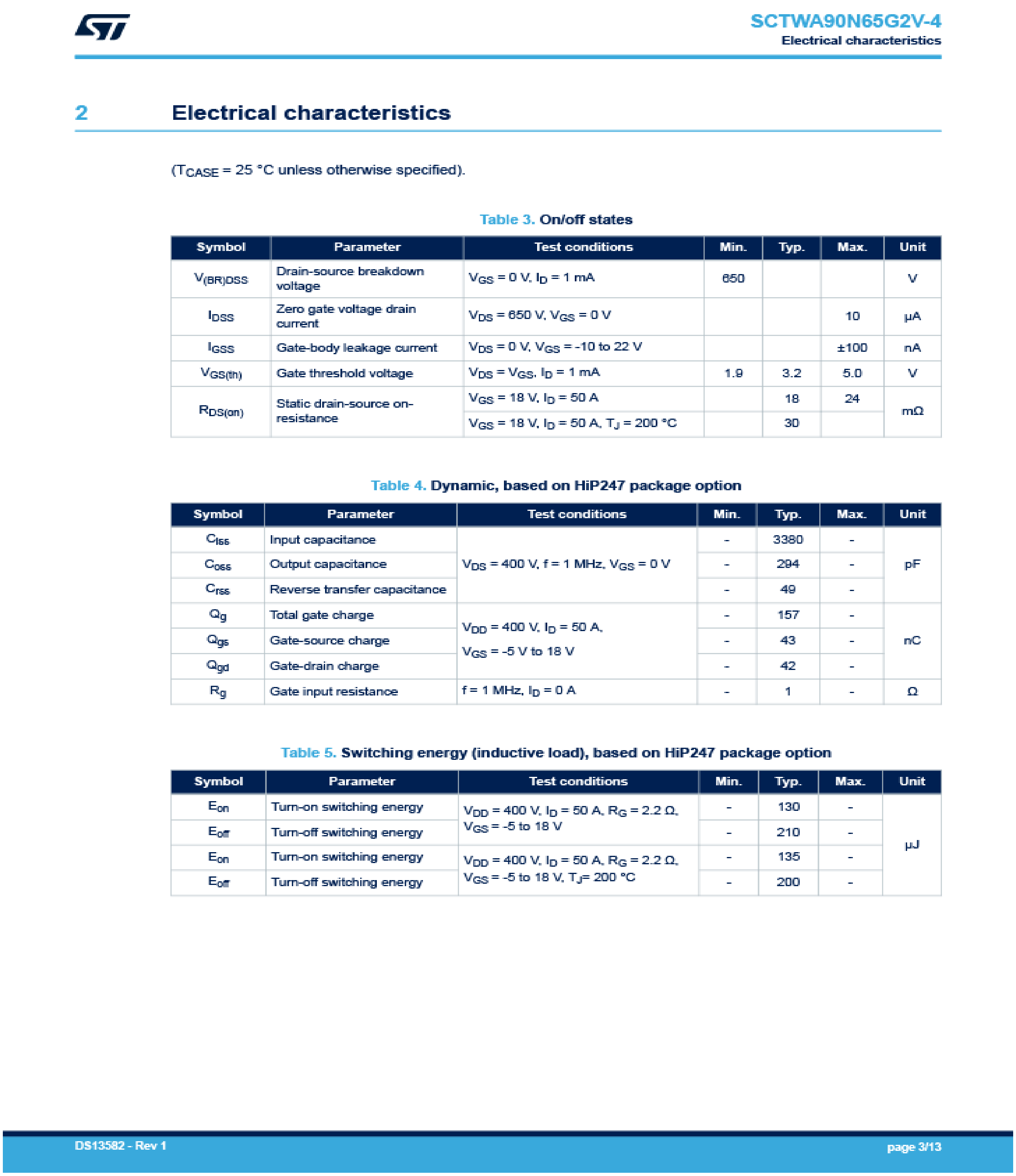
Table 1. **Absolute maximum ratings**

Symbol	Parameter	Value	Unit
V_{DS}	Drain-source voltage	650	V
V_{GS}	Gate-source voltage	-10 to 22	V
	Gate-source voltage (recommended operating values)	-5 to 18	
I_D	Drain current (continuous) at T_C = 25 °C	119	A
	Drain current (continuous) at T_C = 100 °C	90	
I_{DM} (1)	Drain current (pulsed)	220	A
P_{TOT}	Total power dissipation at T_C = 25 °C	565	W
T_{stg}	Storage temperature range	-55 to 200	°C
T_J	Operating junction temperature range		°C

1. *Pulse width is limited by safe operating area.*

Table 2. **Thermal data**

Symbol	Parameter	Value	Unit
R_{thJC}	Thermal resistance, junction-to-case	0.31	°C/W
R_{thJA}	Thermal resistance, junction-to-ambient	40	°C/W



SCTWA90N65G2V-4
Electrical characteristics

2 Electrical characteristics

(T_{CASE} = 25 °C unless otherwise specified).

Table 3. **On/off states**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{(BR)DSS}$	Drain-source breakdown voltage	V_{GS} = 0 V, I_D = 1 mA	650			V
I_{DSS}	Zero gate voltage drain current	V_{DS} = 650 V, V_{GS} = 0 V			10	µA
I_{GSS}	Gate-body leakage current	V_{DS} = 0 V, V_{GS} = -10 to 22 V			±100	nA
$V_{GS(th)}$	Gate threshold voltage	V_{DS} = V_{GS}, I_D = 1 mA	1.9	3.2	5.0	V
$R_{DS(on)}$	Static drain-source on-resistance	V_{GS} = 18 V, I_D = 50 A		18	24	mΩ
		V_{GS} = 18 V, I_D = 50 A, T_J = 200 °C		30		

Table 4. **Dynamic, based on HiP247 package option**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
C_{iss}	Input capacitance	V_{DS} = 400 V, f = 1 MHz, V_{GS} = 0 V	-	3380	-	pF
C_{oss}	Output capacitance		-	294	-	
C_{rss}	Reverse transfer capacitance		-	49	-	
Q_g	Total gate charge	V_{DD} = 400 V, I_D = 50 A, V_{GS} = -5 V to 18 V	-	157	-	nC
Q_{gs}	Gate-source charge		-	43	-	
Q_{gd}	Gate-drain charge		-	42	-	
R_g	Gate input resistance	f = 1 MHz, I_D = 0 A	-	1	-	Ω

Table 5. **Switching energy (inductive load), based on HiP247 package option**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
E_{on}	Turn-on switching energy	V_{DD} = 400 V, I_D = 50 A, R_G = 2.2 Ω, V_{GS} = -5 to 18 V	-	130	-	µJ
E_{off}	Turn-off switching energy		-	210	-	
E_{on}	Turn-on switching energy	V_{DD} = 400 V, I_D = 50 A, R_G = 2.2 Ω, V_{GS} = -5 to 18 V, T_J= 200 °C	-	135	-	
E_{off}	Turn-off switching energy		-	200	-	

DS13582 - Rev 1

page 3/13

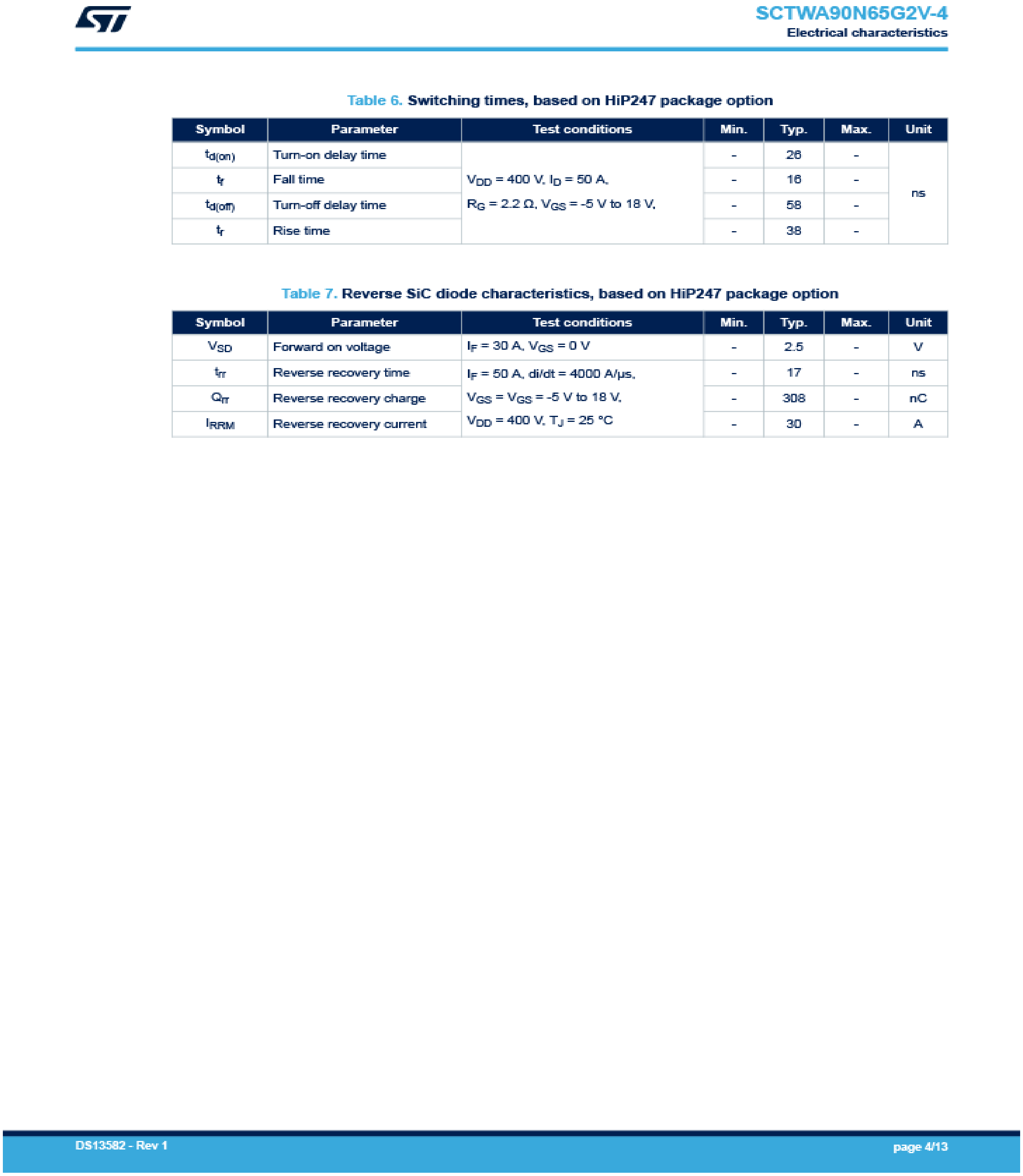
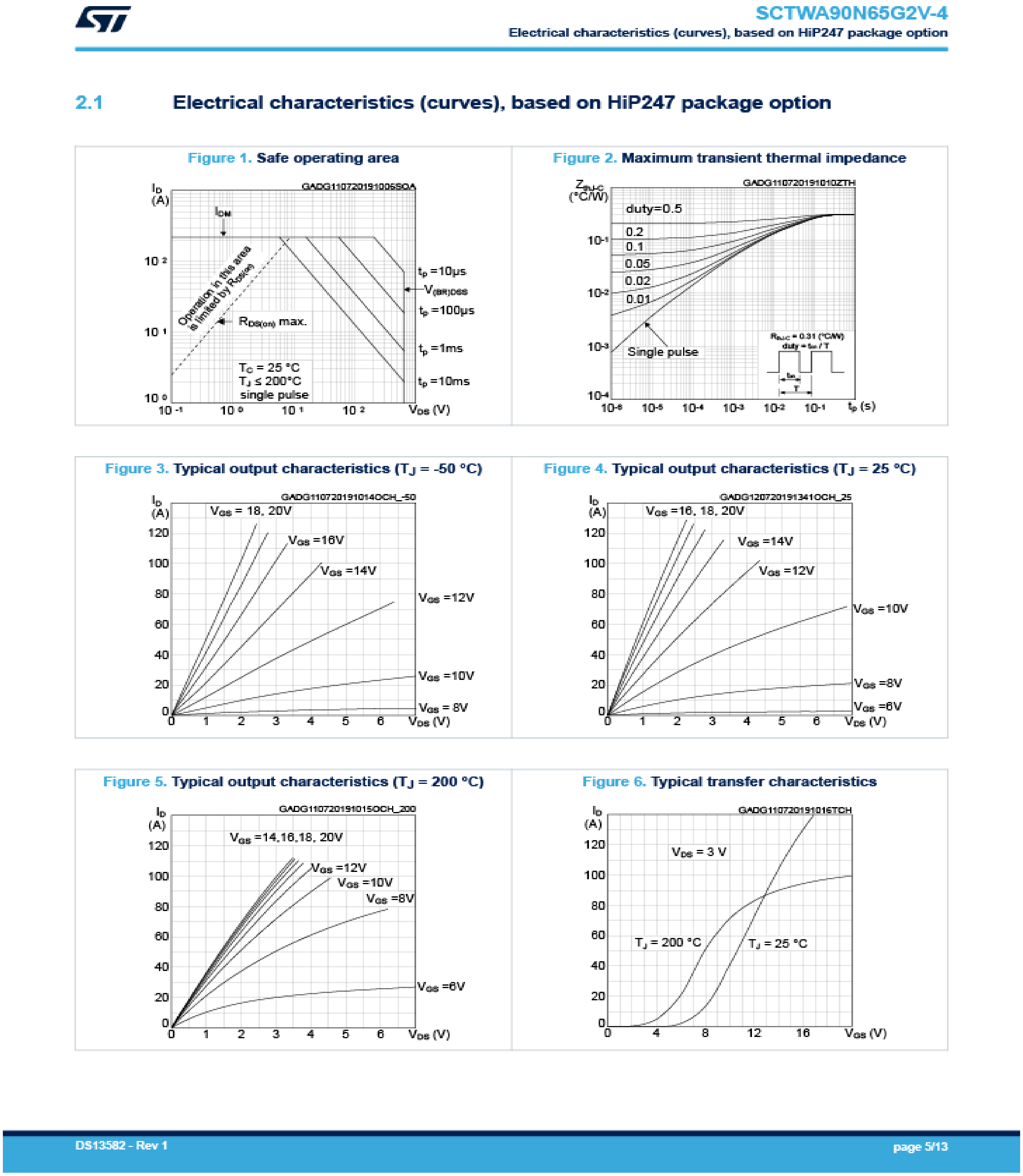


Table 6. **Switching times, based on HiP247 package option**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$t_{d(on)}$	Turn-on delay time	V_{DD} = 400 V, I_D = 50 A, R_G = 2.2 Ω, V_{GS} = -5 V to 18 V,	-	26	-	ns
t_f	Fall time		-	16	-	
$t_{d(off)}$	Turn-off delay time		-	58	-	
t_r	Rise time		-	38	-	

Table 7. **Reverse SiC diode characteristics, based on HiP247 package option**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_{SD}	Forward on voltage	I_F = 30 A, V_{GS} = 0 V	-	2.5	-	V
t_{rr}	Reverse recovery time	I_F = 50 A, di/dt = 4000 A/μs, V_{GS} = V_{GS} = -5 V to 18 V, V_{DD} = 400 V, T_J = 25 °C	-	17	-	ns
Q_{rr}	Reverse recovery charge		-	308	-	nC
I_{RRM}	Reverse recovery current		-	30	-	A



2.1 Electrical characteristics (curves), based on HiP247 package option

Figure 1. **Safe operating area**

Figure 2. **Maximum transient thermal impedance**

Figure 3. **Typical output characteristics (T_J = -50 °C)**

Figure 4. **Typical output characteristics (T_J = 25 °C)**

Figure 5. **Typical output characteristics (T_J = 200 °C)**

Figure 6. **Typical transfer characteristics**

Figure 7. **Typical capacitances**

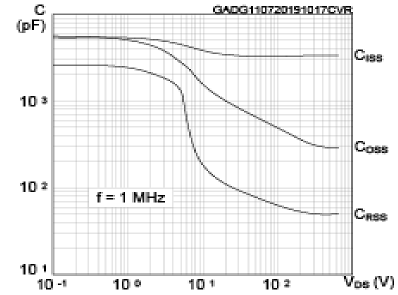


Figure 8. **Typical gate charge**

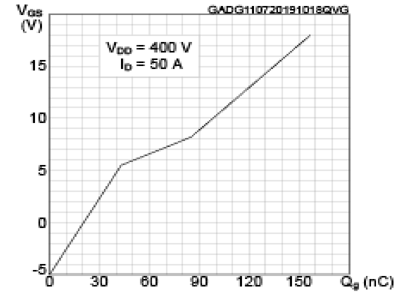


Figure 9. **Maximum total power dissipation**

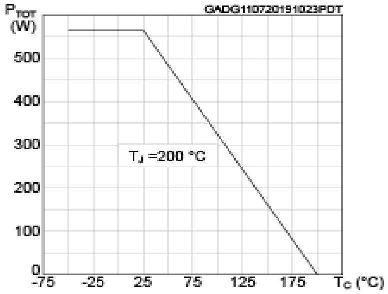


Figure 10. **Typical drain-source on-resistance**

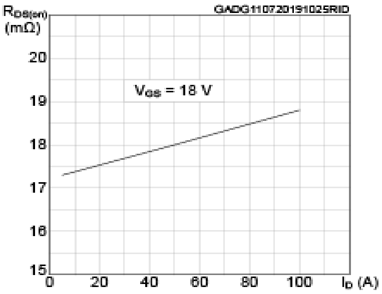


Figure 11. **Normalized on-resistance vs temperature**

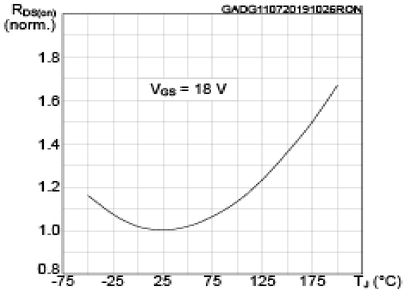
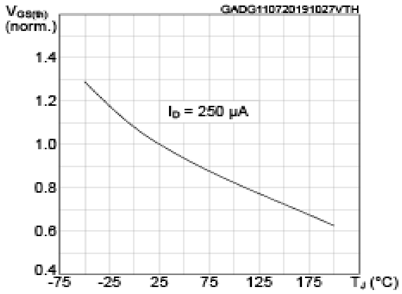


Figure 12. **Normalized gate threshold voltage vs temperature**



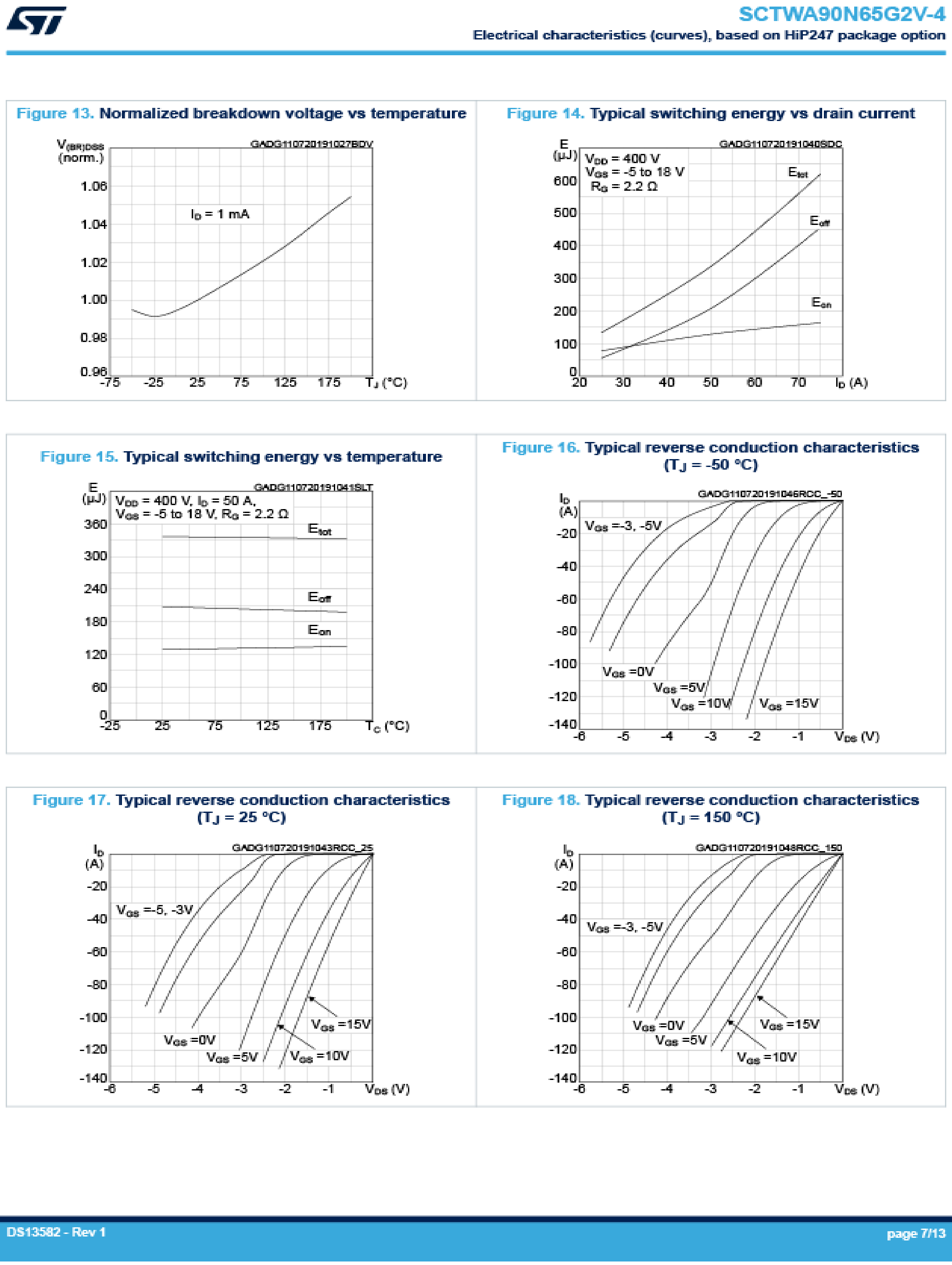


Figure 13. Normalized breakdown voltage vs temperature

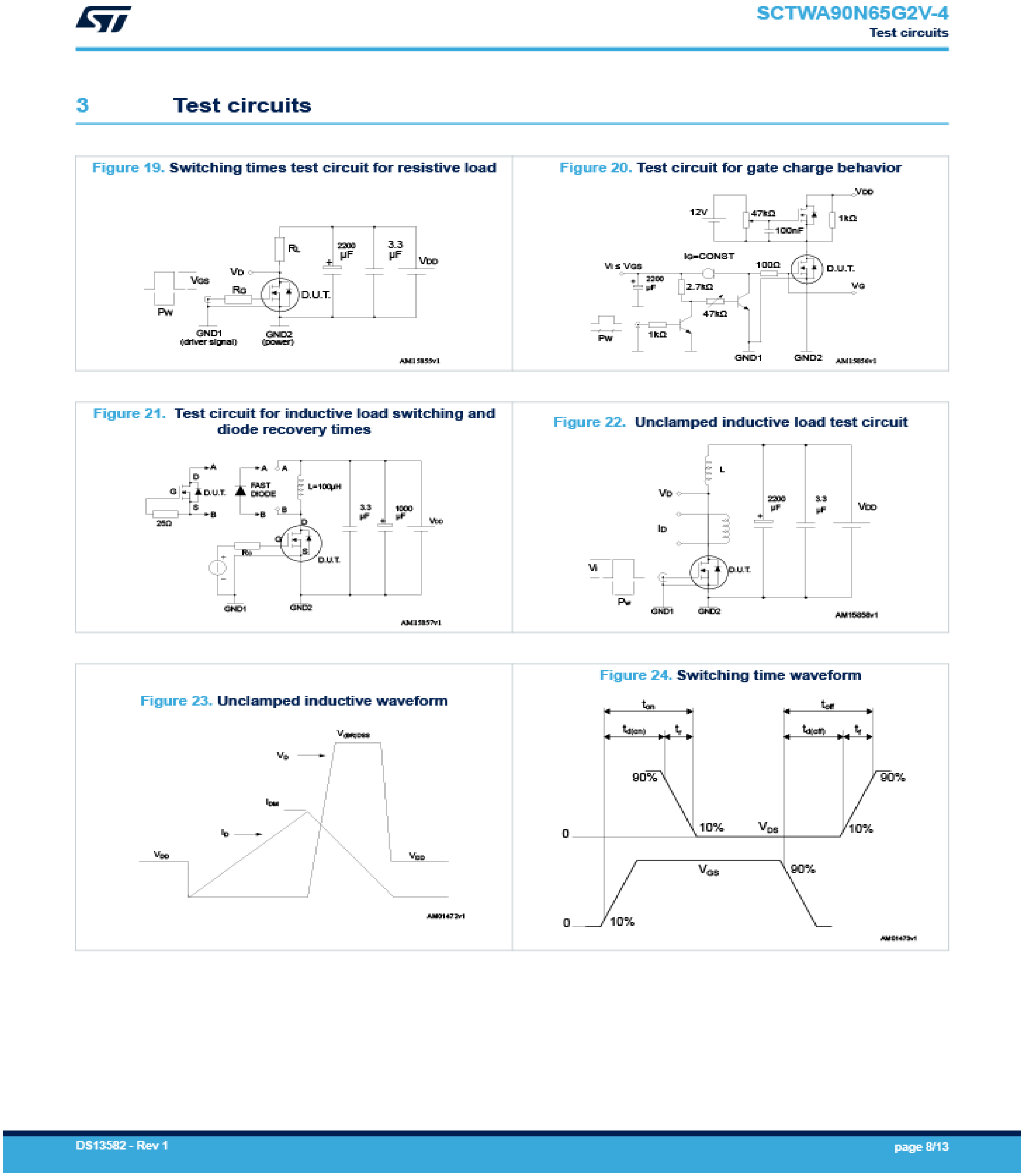
Figure 14. Typical switching energy vs drain current

Figure 15. Typical switching energy vs temperature

Figure 16. Typical reverse conduction characteristics (T_J = -50 °C)

Figure 17. Typical reverse conduction characteristics (T_J = 25 °C)

Figure 18. Typical reverse conduction characteristics (T_J = 150 °C)



SCTWA90N65G2V-4
Test circuits

3 Test circuits

Figure 19. Switching times test circuit for resistive load

Figure 20. Test circuit for gate charge behavior

Figure 21. Test circuit for inductive load switching and diode recovery times

Figure 22. Unclamped inductive load test circuit

Figure 23. Unclamped inductive waveform

Figure 24. Switching time waveform

DS13582 - Rev 1

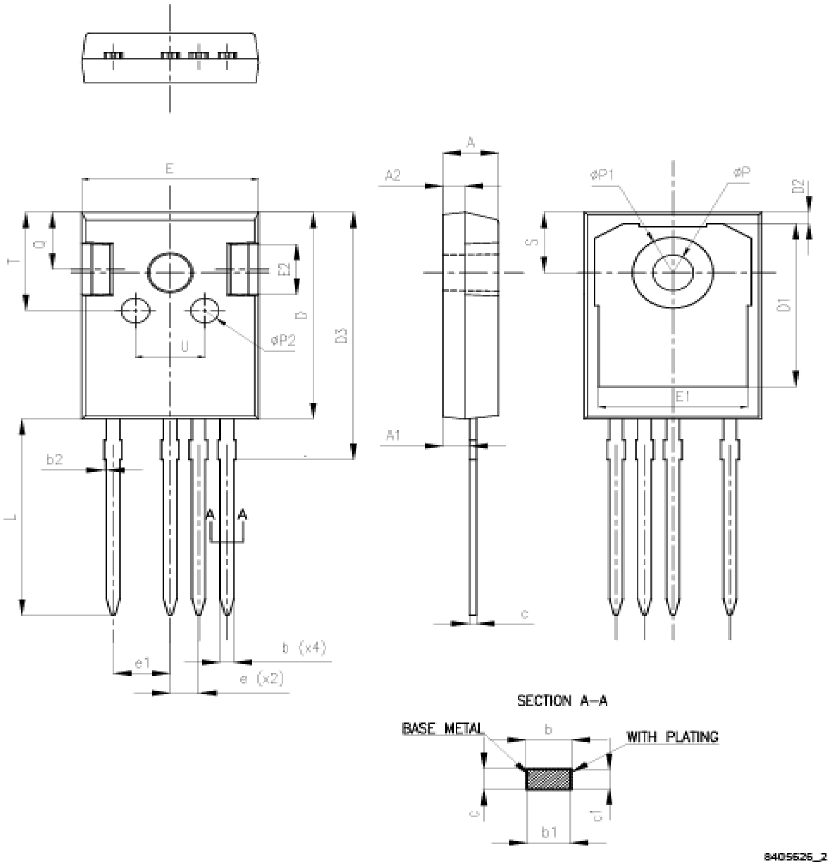
page 8/13

4 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK packages, depending on their level of environmental compliance. ECOPACK specifications, grade definitions and product status are available at: www.st.com. ECOPACK is an ST trademark.

4.1 HiP247-4 package information

Figure 25. **HiP247-4 package outline**



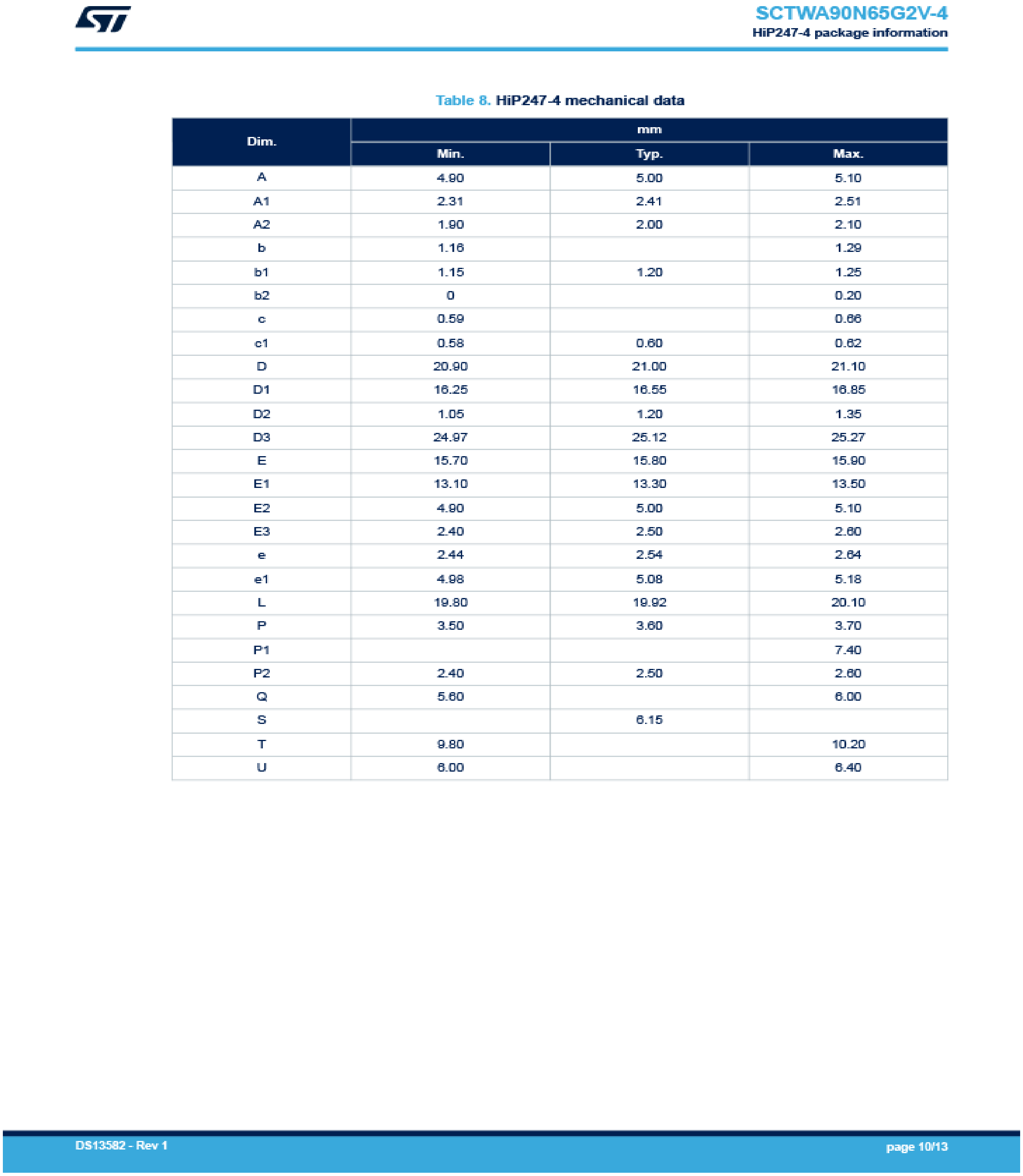
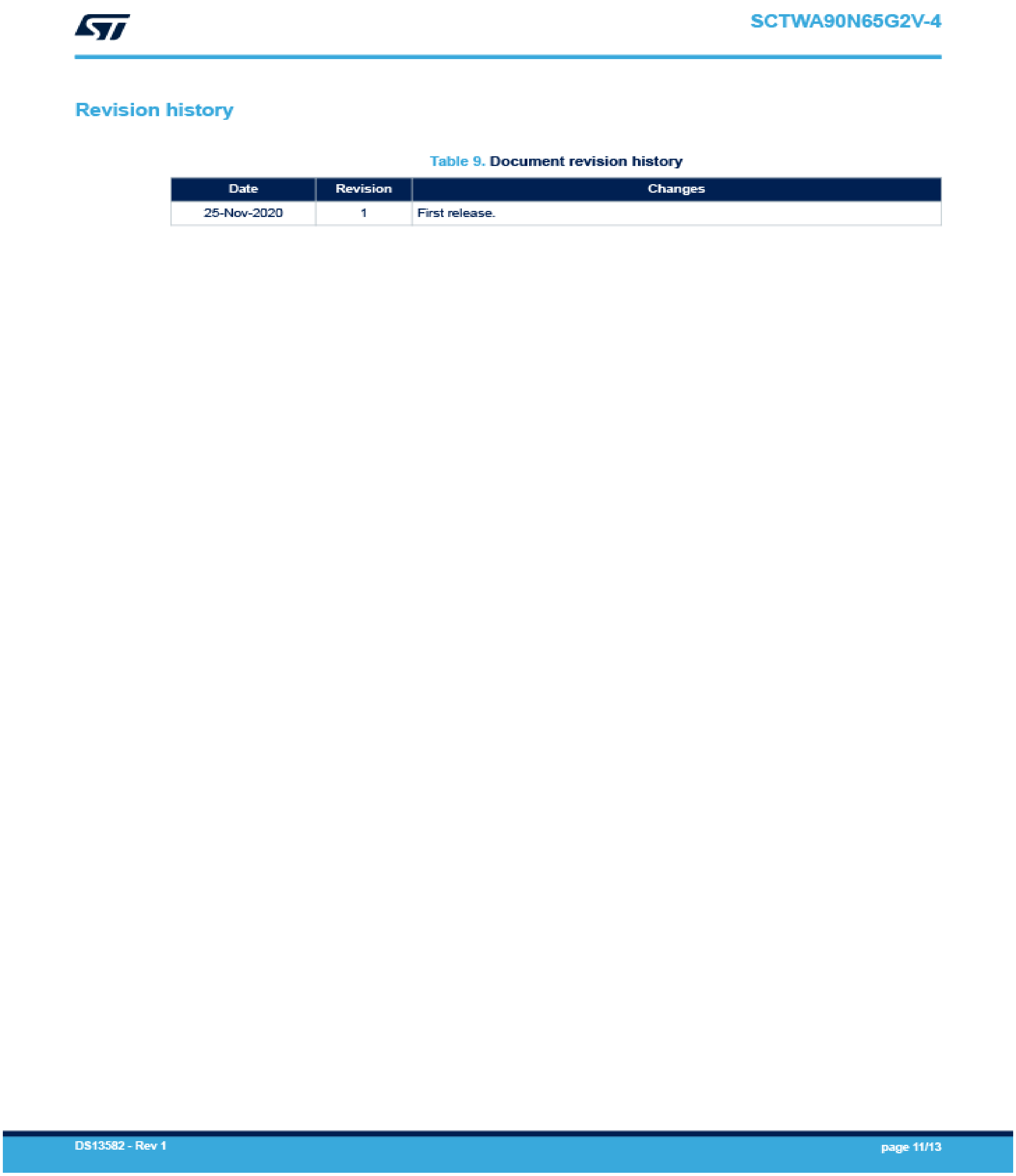


Table 8. **HiP247-4 mechanical data**

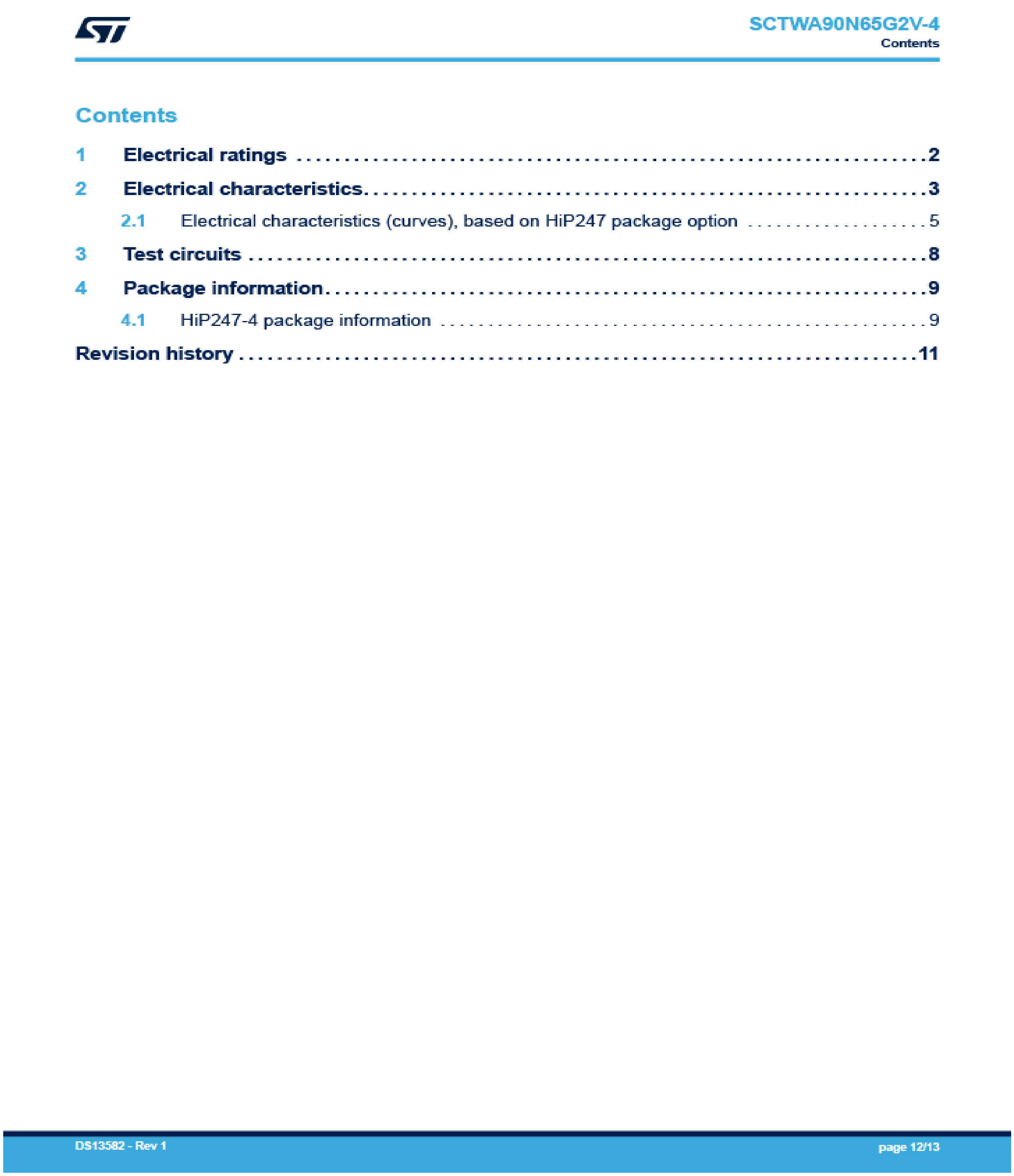
Dim.	mm		
	Min.	Typ.	Max.
A	4.90	5.00	5.10
A1	2.31	2.41	2.51
A2	1.90	2.00	2.10
b	1.16		1.29
b1	1.15	1.20	1.25
b2	0		0.20
c	0.59		0.66
c1	0.58	0.60	0.62
D	20.90	21.00	21.10
D1	16.25	16.55	16.85
D2	1.05	1.20	1.35
D3	24.97	25.12	25.27
E	15.70	15.80	15.90
E1	13.10	13.30	13.50
E2	4.90	5.00	5.10
E3	2.40	2.50	2.60
e	2.44	2.54	2.64
e1	4.98	5.08	5.18
L	19.80	19.92	20.10
P	3.50	3.60	3.70
P1			7.40
P2	2.40	2.50	2.60
Q	5.60		6.00
S		6.15	
T	9.80		10.20
U	6.00		6.40



Revision history

Table 9. **Document revision history**

Date	Revision	Changes
25-Nov-2020	1	First release.



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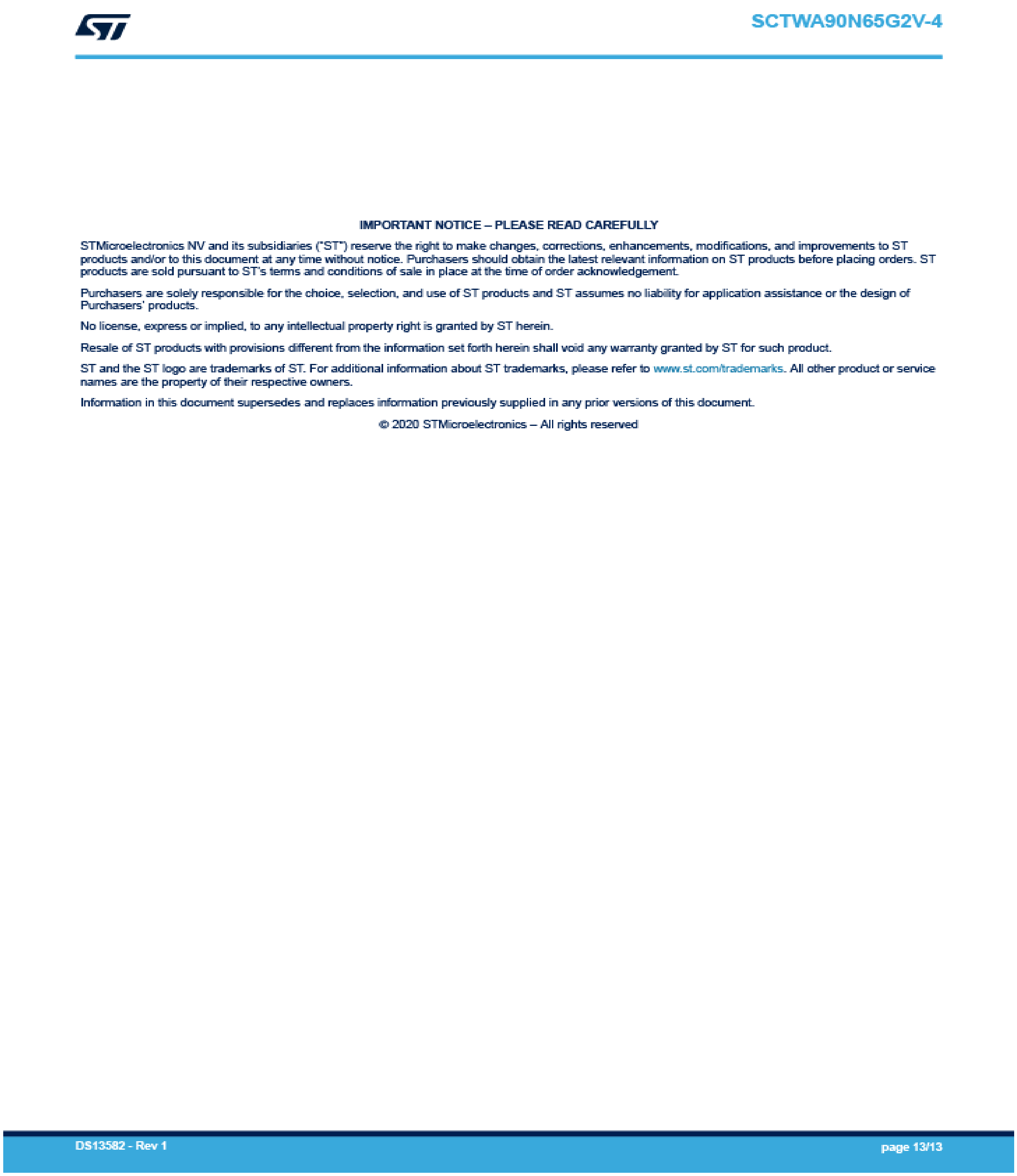

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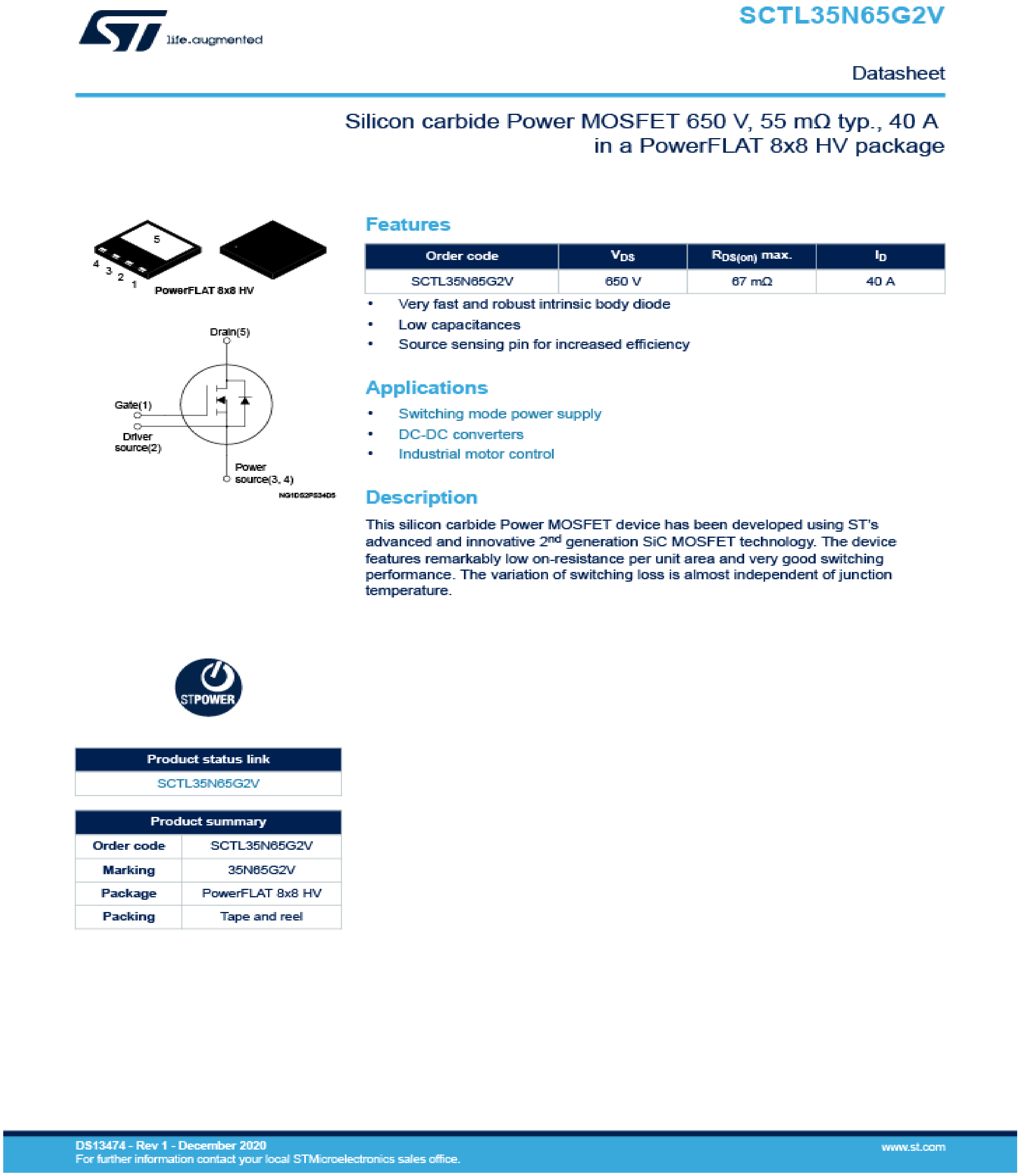
Silicon carbide Power MOSFET 650 V, 55 mΩ typ., 40 A in a PowerFLAT 8x8 HV package



SCTL35N65G2V

Datasheet

Silicon carbide Power MOSFET 650 V, 55 mΩ typ., 40 A in a PowerFLAT 8x8 HV package

Features

Order code	V_{DS}	$R_{DS(on)}$ max.	I_D
SCTL35N65G2V	650 V	67 mΩ	40 A

- Very fast and robust intrinsic body diode
- Low capacitances
- Source sensing pin for increased efficiency

Applications

- Switching mode power supply
- DC-DC converters
- Industrial motor control

Description

This silicon carbide Power MOSFET device has been developed using ST's advanced and innovative 2nd generation SiC MOSFET technology. The device features remarkably low on-resistance per unit area and very good switching performance. The variation of switching loss is almost independent of junction temperature.

Product status link
SCTL35N65G2V

Product summary	
Order code	SCTL35N65G2V
Marking	35N65G2V
Package	PowerFLAT 8x8 HV
Packing	Tape and reel

DS13474 - Rev 1 - December 2020
For further information contact your local STMicroelectronics sales office.

www.st.com

1 Electrical ratings

Table 1. **Absolute maximum ratings**

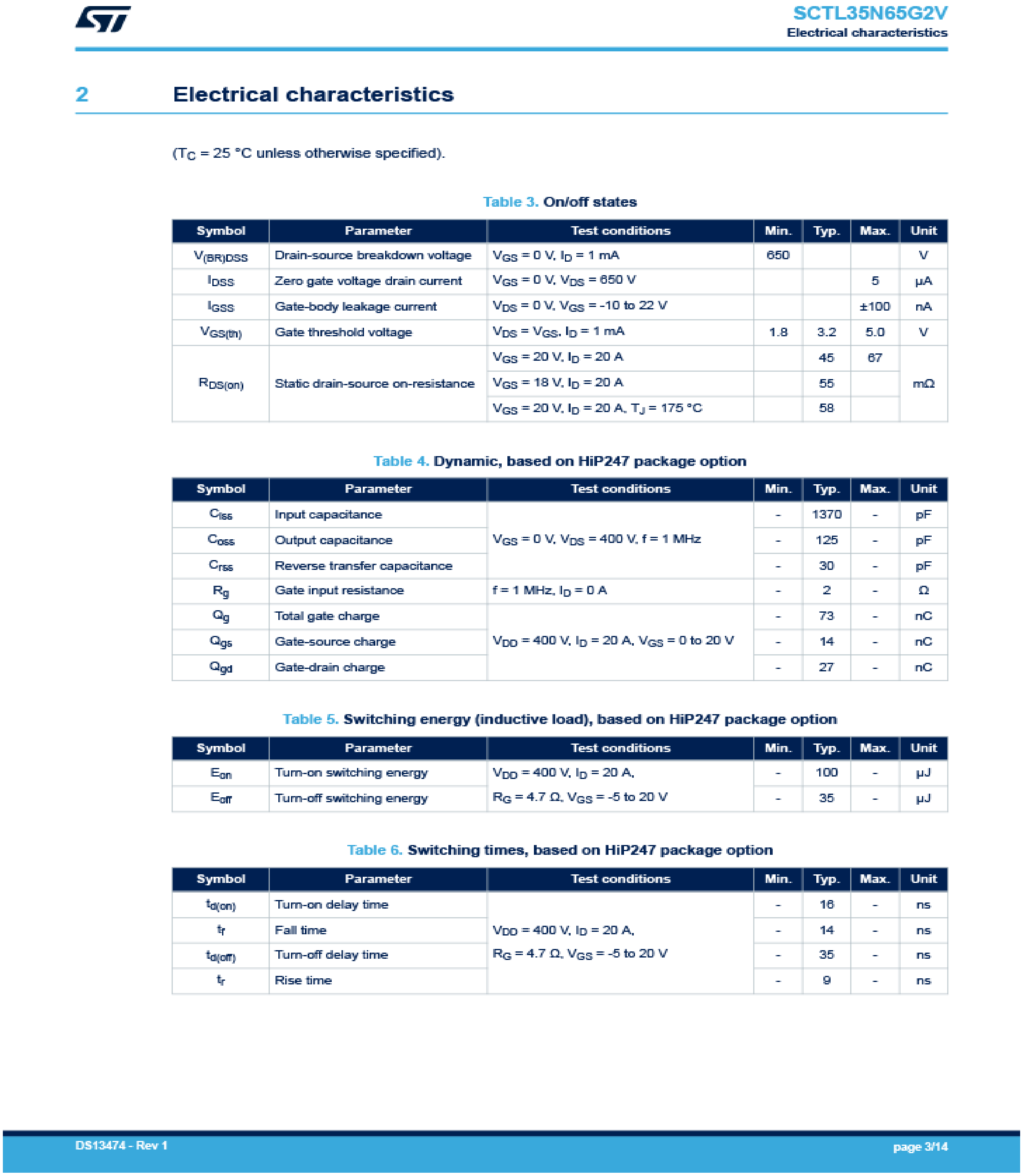
Symbol	Parameter	Value	Unit
V_{DS}	Drain-source voltage	650	V
V_{GS}	Gate-source voltage	-10 to 22	V
	Gate-source voltage (recommended operating range)	-5 to 20	
I_D (1)	Drain current (continuous) at T_C = 25 °C	40	A
	Drain current (continuous) at T_C = 100 °C	40	
I_{DM} (2)	Drain current (pulsed)	160	A
P_{TOT}	Total power dissipation at T_C = 25 °C	417	W
T_{stg}	Storage temperature range	-55 to 175	°C
T_J	Operating junction temperature range		°C

1. *Value limited by package.*
2. *Pulse width is limited by safe operating area.*

Table 2. **Thermal data**

Symbol	Parameter	Value	Unit
R_{thJC}	Thermal resistance, junction-to-case	0.36	°C/W
R_{thJB} (1)	Thermal resistance, junction-to-board	45	°C/W

1. *When mounted on an 1-inch² FR-4, 2 Oz copper board.*



2 Electrical characteristics

(T_C = 25 °C unless otherwise specified).

Table 3. On/off states

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$V_{(BR)DSS}$	Drain-source breakdown voltage	V_{GS} = 0 V, I_D = 1 mA	650			V
I_{DSS}	Zero gate voltage drain current	V_{GS} = 0 V, V_{DS} = 650 V			5	µA
I_{GSS}	Gate-body leakage current	V_{DS} = 0 V, V_{GS} = -10 to 22 V			±100	nA
$V_{GS(th)}$	Gate threshold voltage	V_{DS} = V_{GS}, I_D = 1 mA	1.8	3.2	5.0	V
$R_{DS(on)}$	Static drain-source on-resistance	V_{GS} = 20 V, I_D = 20 A		45	67	mΩ
		V_{GS} = 18 V, I_D = 20 A		55		
		V_{GS} = 20 V, I_D = 20 A, T_J = 175 °C		58		

Table 4. Dynamic, based on HiP247 package option

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
C_{iss}	Input capacitance	V_{GS} = 0 V, V_{DS} = 400 V, f = 1 MHz	-	1370	-	pF
C_{oss}	Output capacitance		-	125	-	pF
C_{rss}	Reverse transfer capacitance		-	30	-	pF
R_g	Gate input resistance	f = 1 MHz, I_D = 0 A	-	2	-	Ω
Q_g	Total gate charge	V_{DD} = 400 V, I_D = 20 A, V_{GS} = 0 to 20 V	-	73	-	nC
Q_{gs}	Gate-source charge		-	14	-	nC
Q_{gd}	Gate-drain charge		-	27	-	nC

Table 5. Switching energy (inductive load), based on HiP247 package option

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
E_{on}	Turn-on switching energy	V_{DD} = 400 V, I_D = 20 A, R_G = 4.7 Ω, V_{GS} = -5 to 20 V	-	100	-	µJ
E_{off}	Turn-off switching energy		-	35	-	µJ

Table 6. Switching times, based on HiP247 package option

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
$t_{d(on)}$	Turn-on delay time	V_{DD} = 400 V, I_D = 20 A, R_G = 4.7 Ω, V_{GS} = -5 to 20 V	-	16	-	ns
t_f	Fall time		-	14	-	ns
$t_{d(off)}$	Turn-off delay time		-	35	-	ns
t_r	Rise time		-	9	-	ns

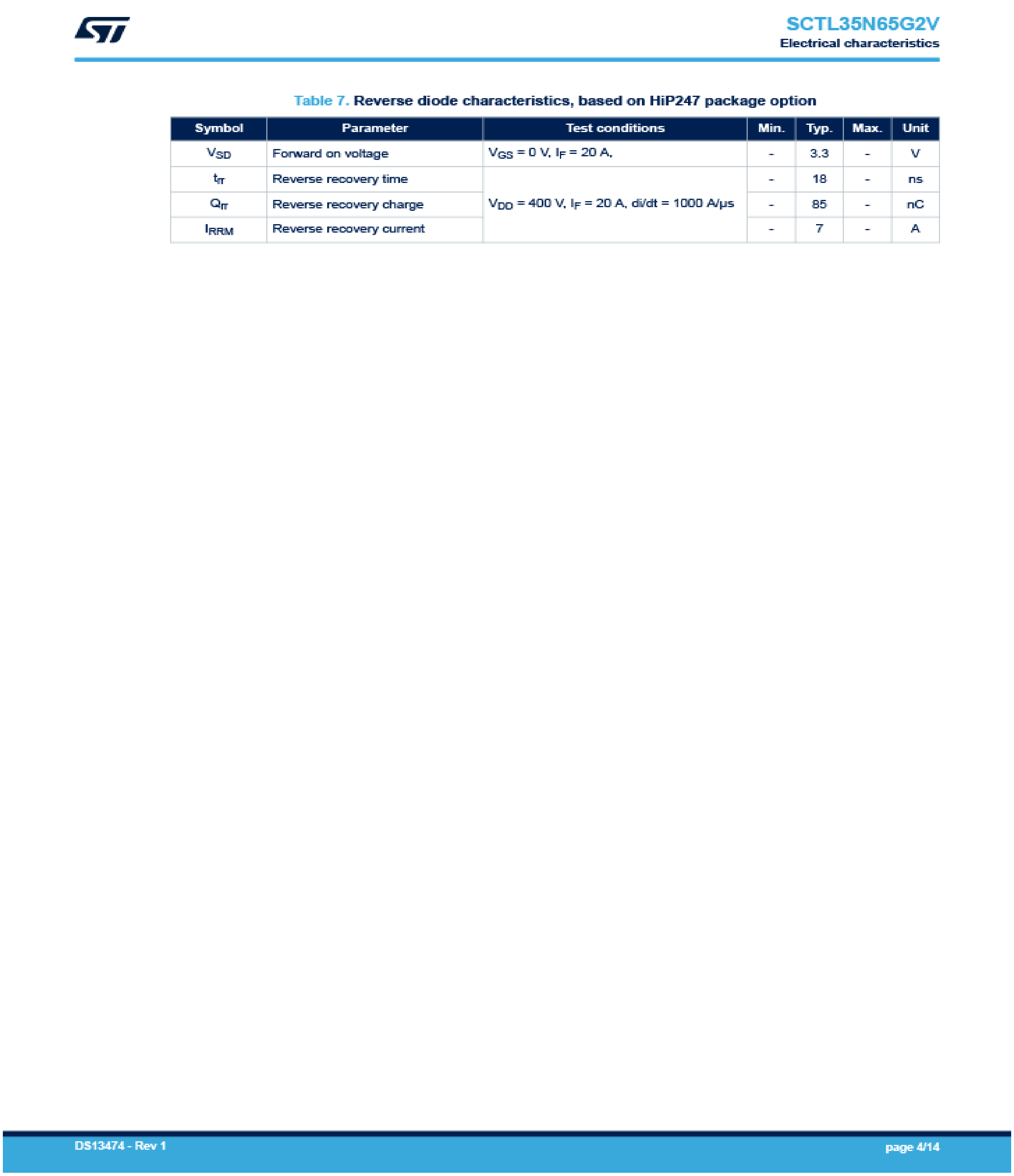
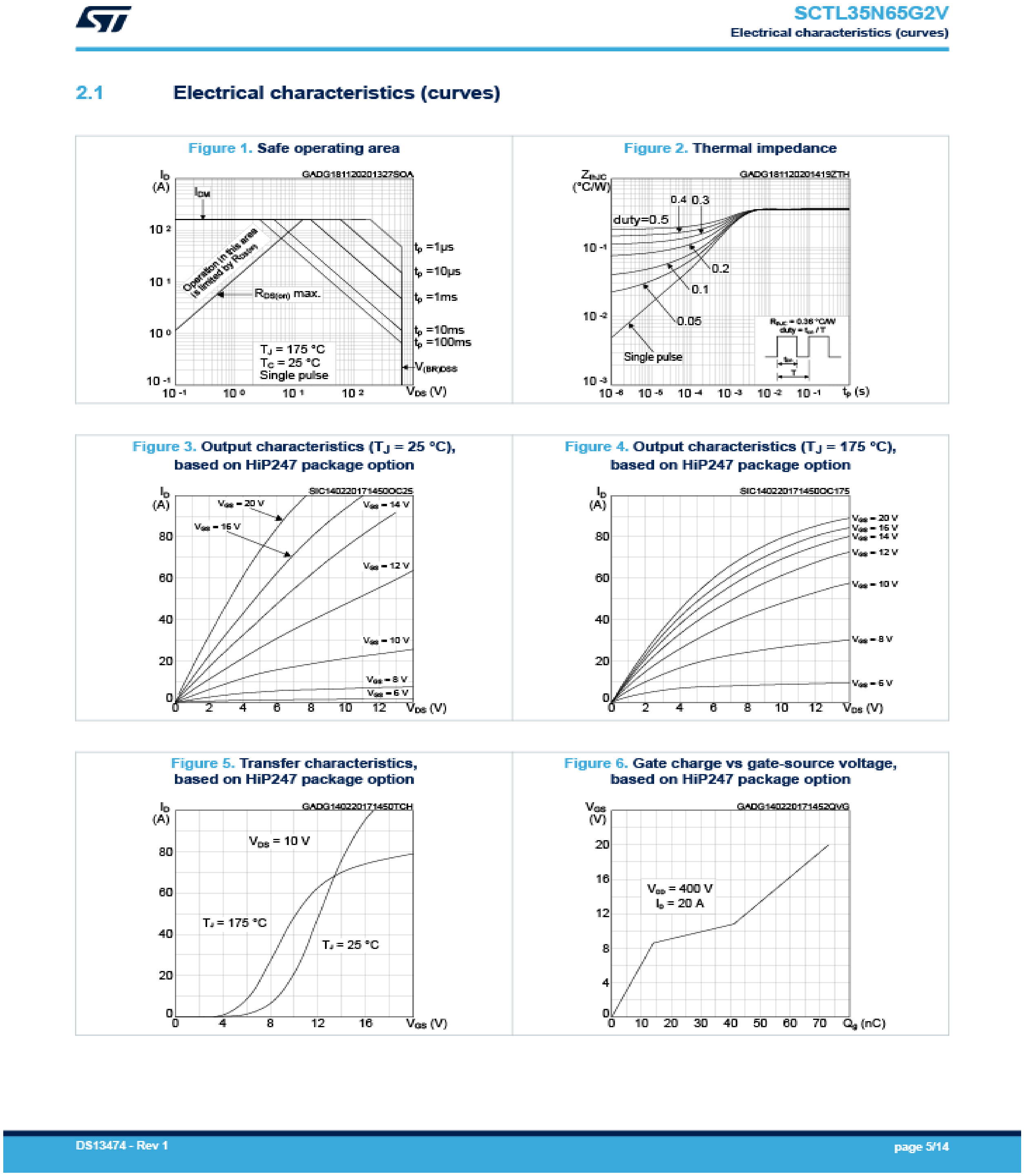


Table 7. **Reverse diode characteristics, based on HiP247 package option**

Symbol	Parameter	Test conditions	Min.	Typ.	Max.	Unit
V_{SD}	Forward on voltage	V_{GS} = 0 V, I_F = 20 A,	-	3.3	-	V
t_{rr}	Reverse recovery time	V_{DD} = 400 V, I_F = 20 A, di/dt = 1000 A/µs	-	18	-	ns
Q_{rr}	Reverse recovery charge		-	85	-	nC
I_{RRM}	Reverse recovery current		-	7	-	A



2.1 Electrical characteristics (curves)

Figure 1. Safe operating area

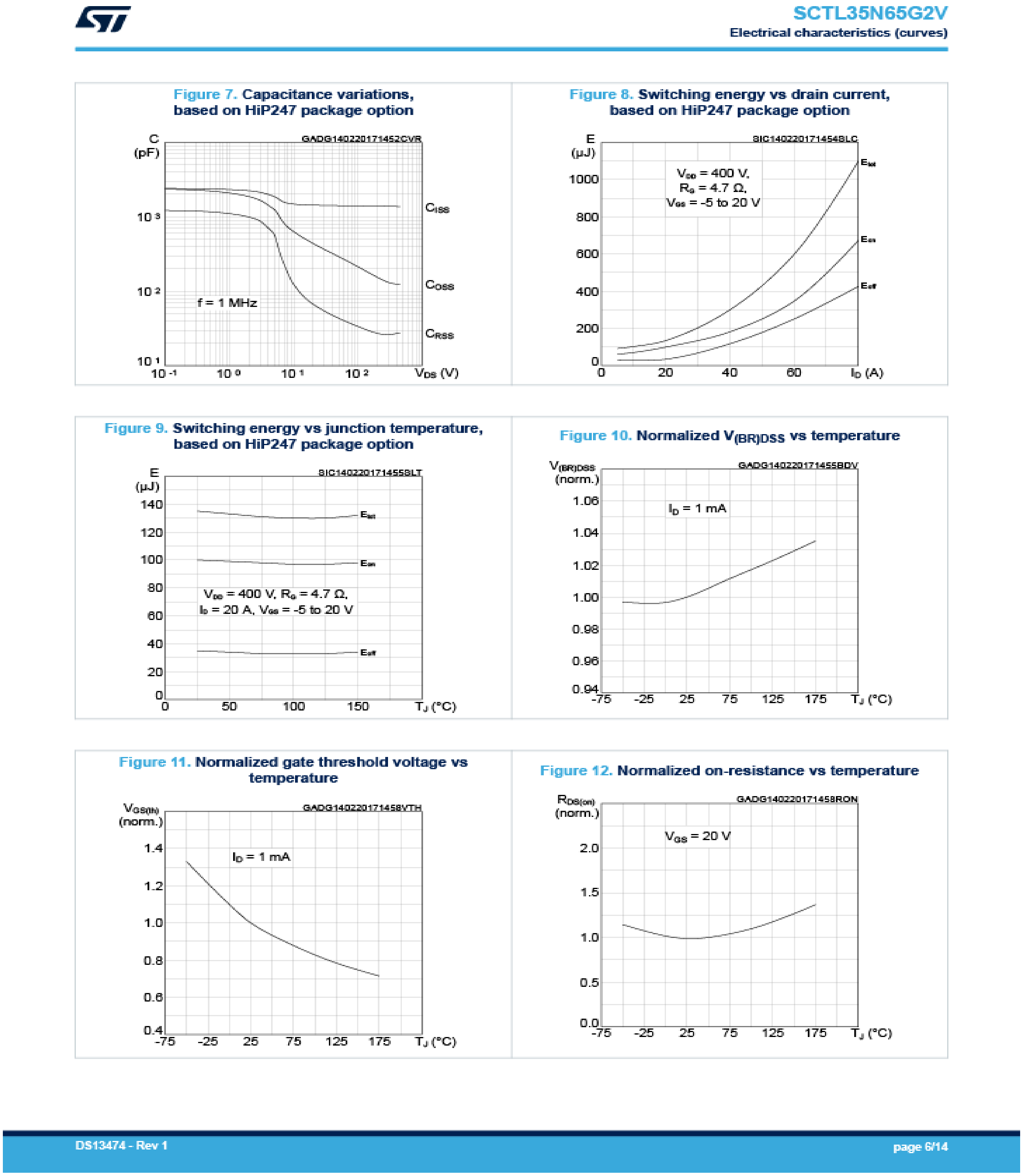
Figure 2. Thermal impedance

Figure 3. Output characteristics (T_J = 25 °C), based on HiP247 package option

Figure 4. Output characteristics (T_J = 175 °C), based on HiP247 package option

Figure 5. Transfer characteristics, based on HiP247 package option

Figure 6. Gate charge vs gate-source voltage, based on HiP247 package option



SCTL35N65G2V

Electrical characteristics (curves)

Figure 7. Capacitance variations, based on HiP247 package option

Figure 8. Switching energy vs drain current, based on HiP247 package option

Figure 9. Switching energy vs junction temperature, based on HiP247 package option

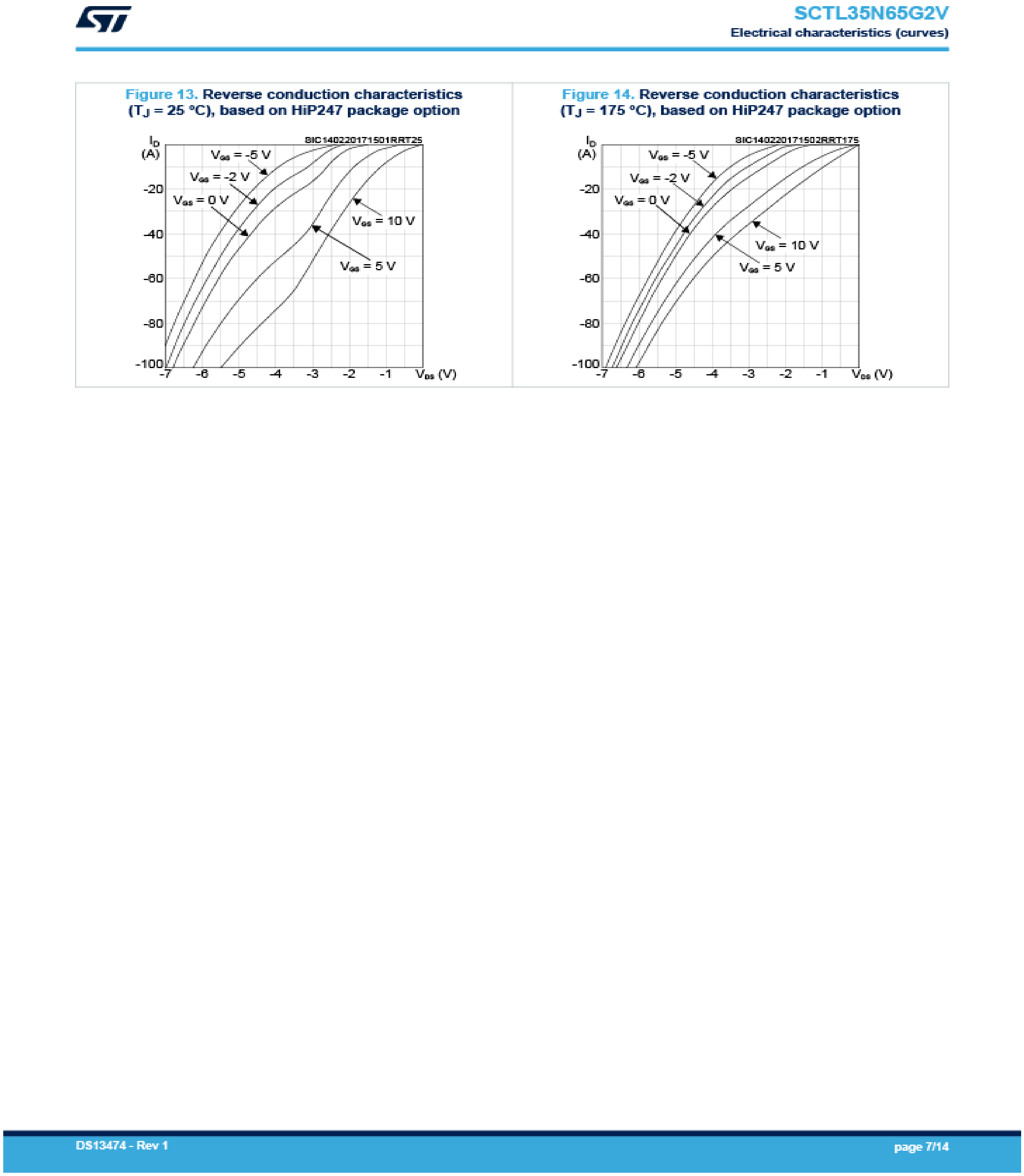
Figure 10. Normalized $V_{(BR)DSS}$ vs temperature

Figure 11. Normalized gate threshold voltage vs temperature

Figure 12. Normalized on-resistance vs temperature

DS13474 - Rev 1

page 6/14



SCTL35N65G2V

Electrical characteristics (curves)

Figure 13. Reverse conduction characteristics (T_J = 25 °C), based on HiP247 package option

Figure 14. Reverse conduction characteristics (T_J = 175 °C), based on HiP247 package option

DS13474 - Rev 1

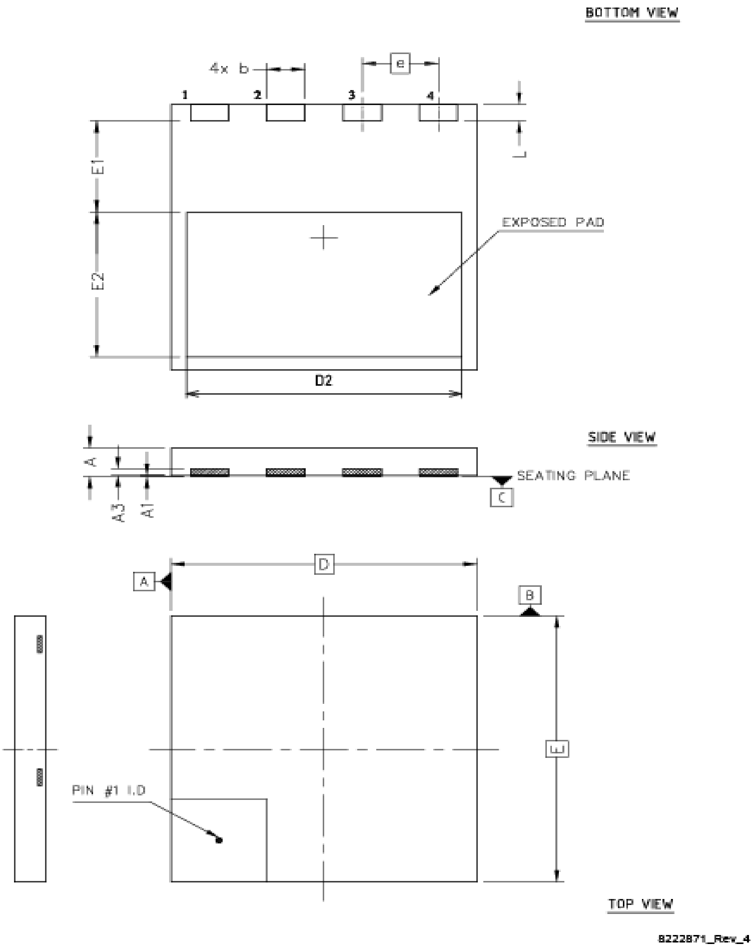
page 7/14

3 Package information

In order to meet environmental requirements, ST offers these devices in different grades of ECOPACK packages, depending on their level of environmental compliance. ECOPACK specifications, grade definitions and product status are available at: www.st.com. ECOPACK is an ST trademark.

3.1 PowerFLAT 8x8 HV type A package information

Figure 15. PowerFLAT 8x8 HV type A package outline



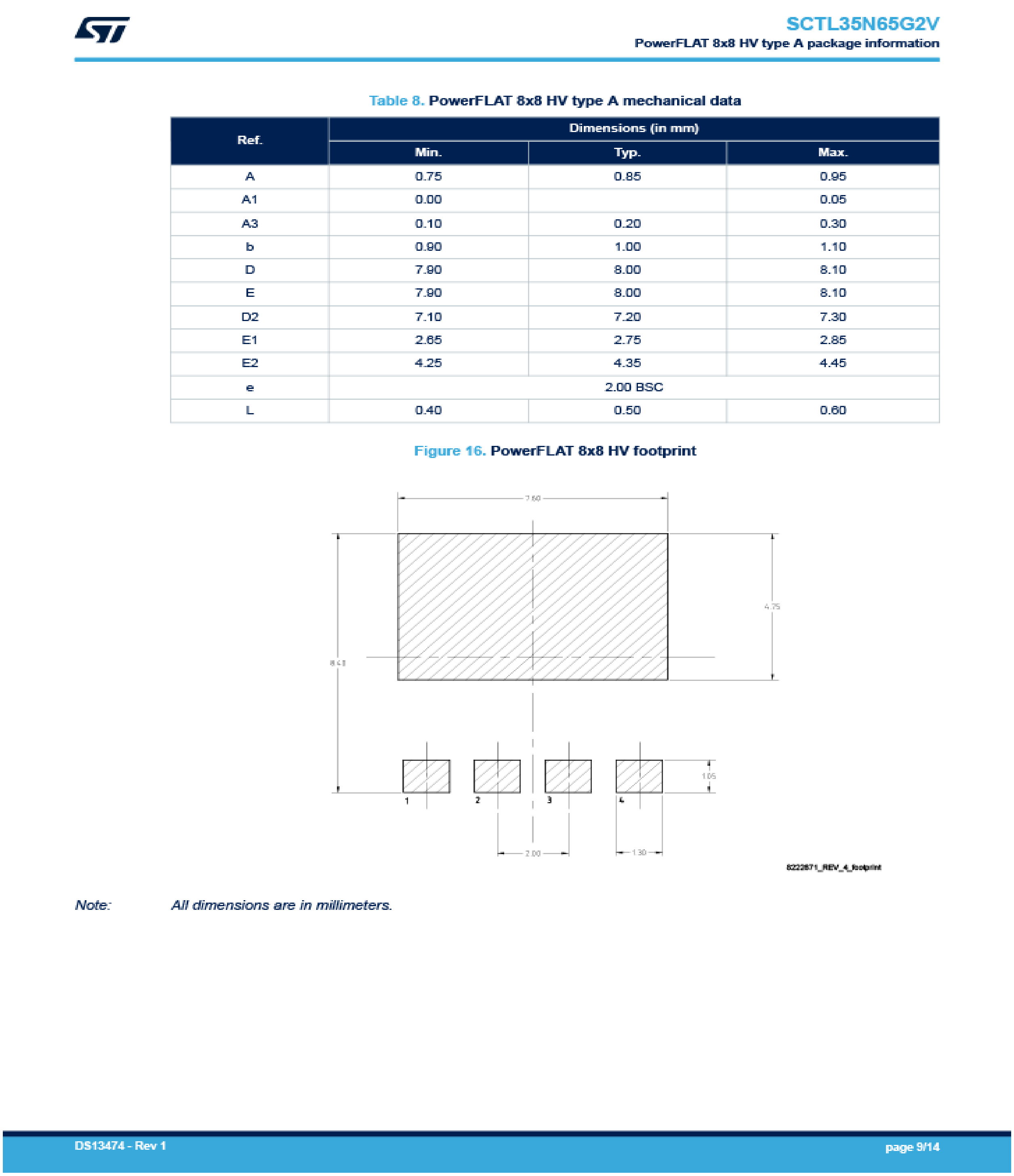


Table 8. **PowerFLAT 8x8 HV type A mechanical data**

Ref.	Dimensions (in mm)		
	Min.	Typ.	Max.
A	0.75	0.85	0.95
A1	0.00		0.05
A3	0.10	0.20	0.30
b	0.90	1.00	1.10
D	7.90	8.00	8.10
E	7.90	8.00	8.10
D2	7.10	7.20	7.30
E1	2.65	2.75	2.85
E2	4.25	4.35	4.45
e		2.00 BSC	
L	0.40	0.50	0.60

Figure 16. **PowerFLAT 8x8 HV footprint**

Note: *All dimensions are in millimeters.*

3.2 PowerFLAT 8x8 HV packing information

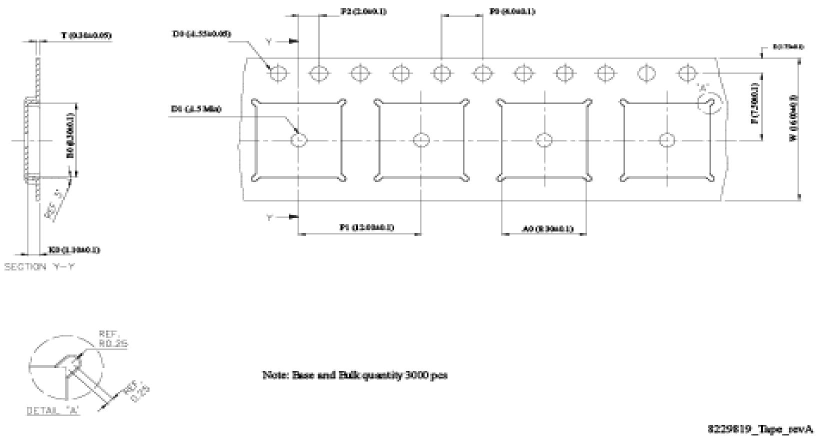
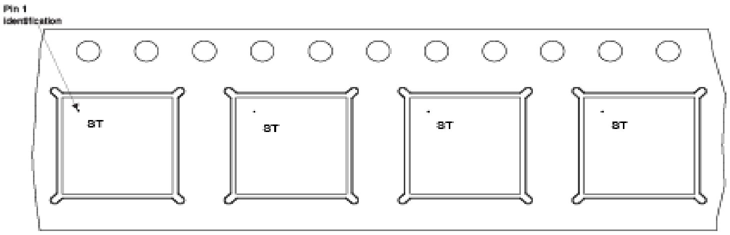
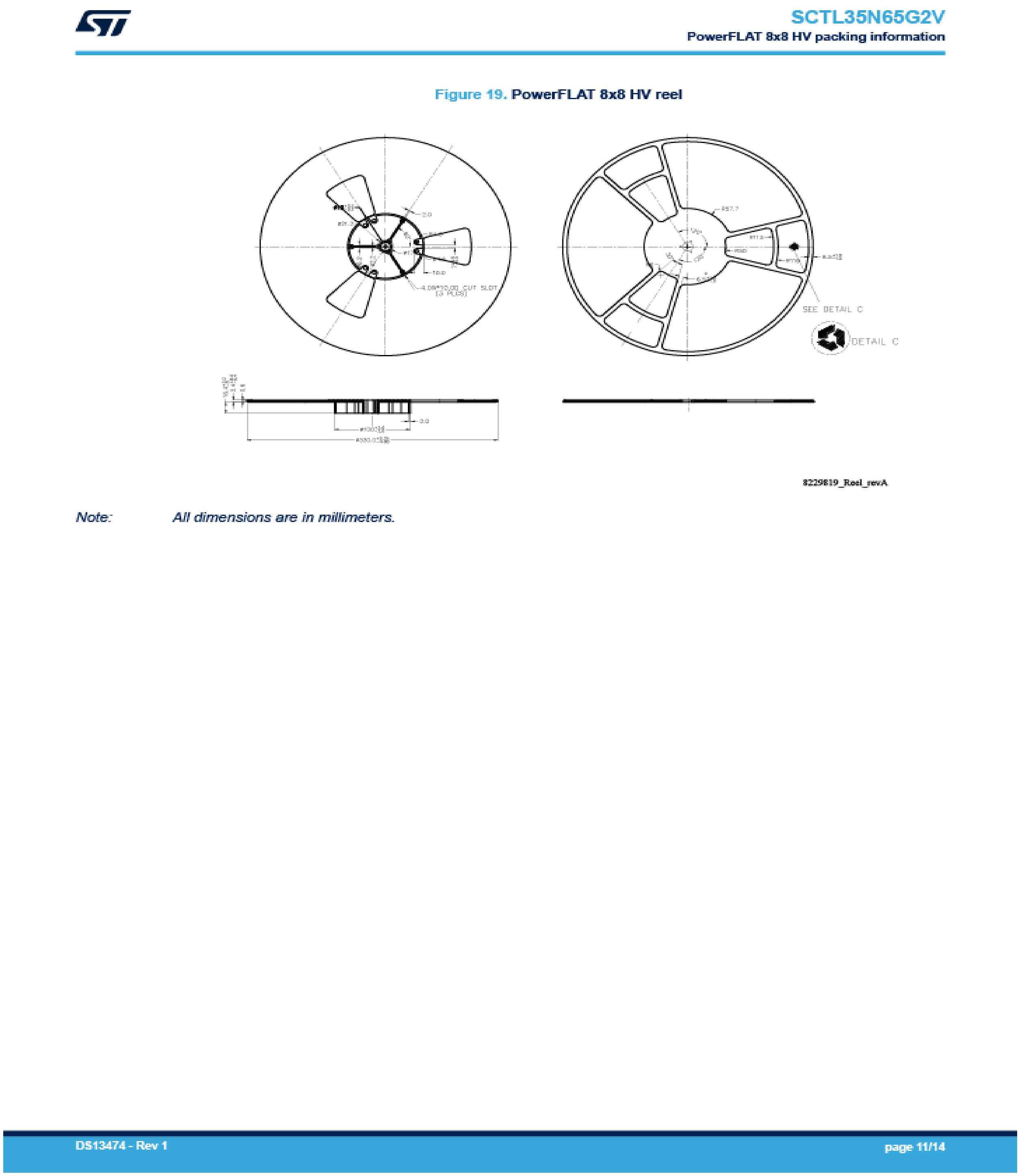


Figure 17. PowerFLAT 8x8 HV tape

Note: *All dimensions are in millimeters.*

Figure 18. PowerFLAT 8x8 HV package orientation in carrier tape





SCTL35N65G2V

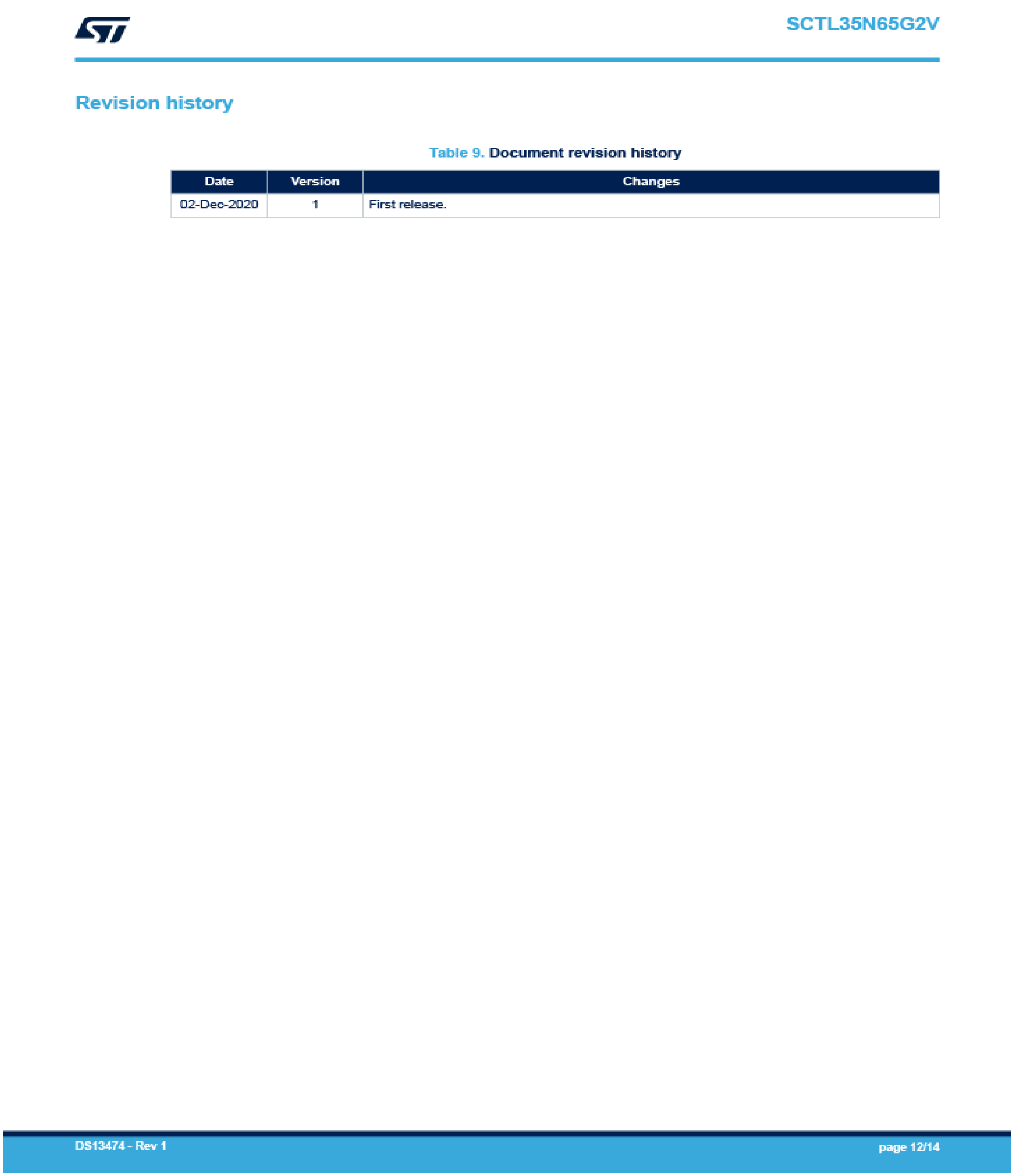
PowerFLAT 8x8 HV packing information

Figure 19. **PowerFLAT 8x8 HV reel**

Note: *All dimensions are in millimeters.*

DS13474 - Rev 1

page 11/14



SCTL35N65G2V

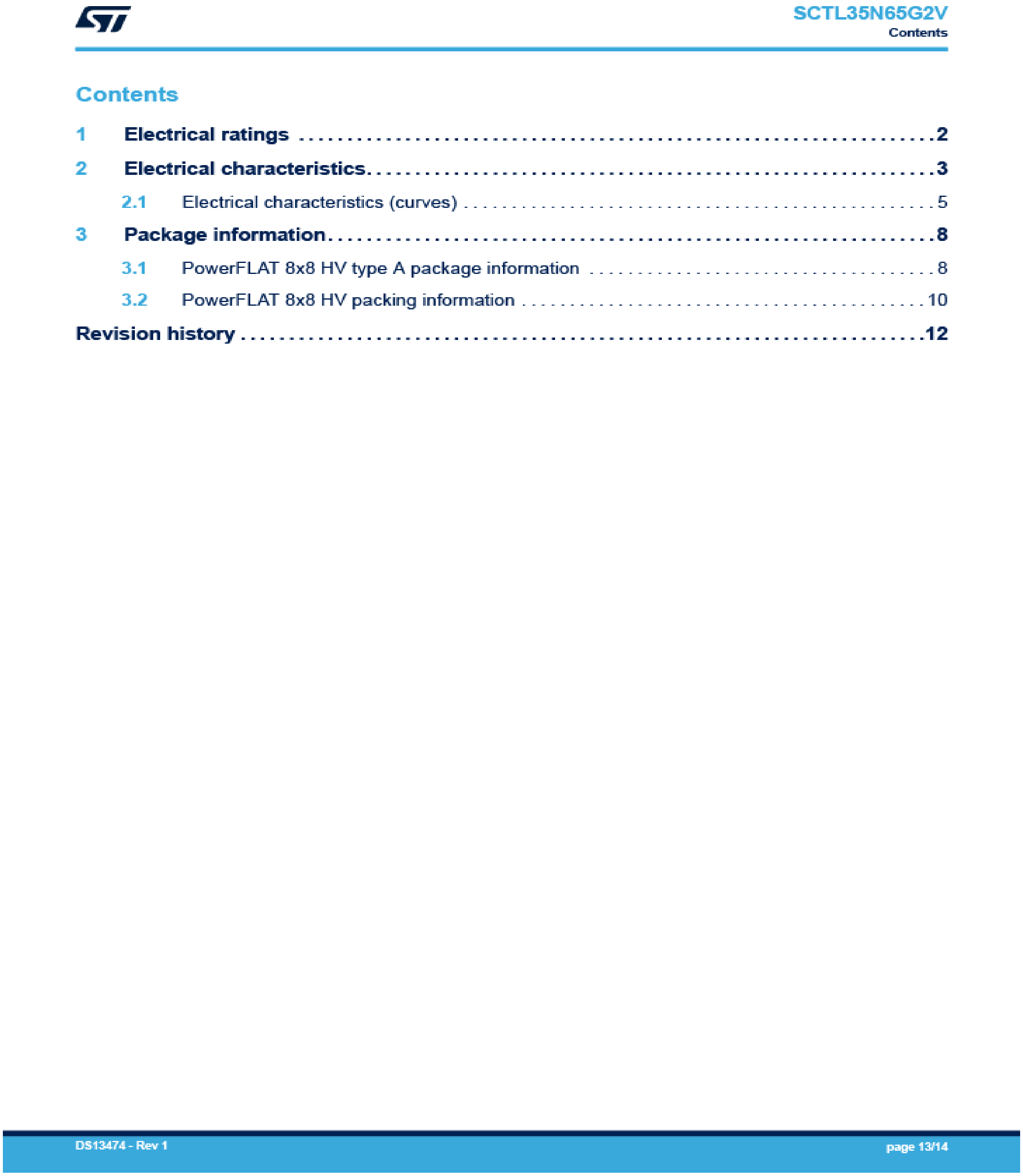
Revision history

Table 9. **Document revision history**

Date	Version	Changes
02-Dec-2020	1	First release.

DS13474 - Rev 1

page 12/14



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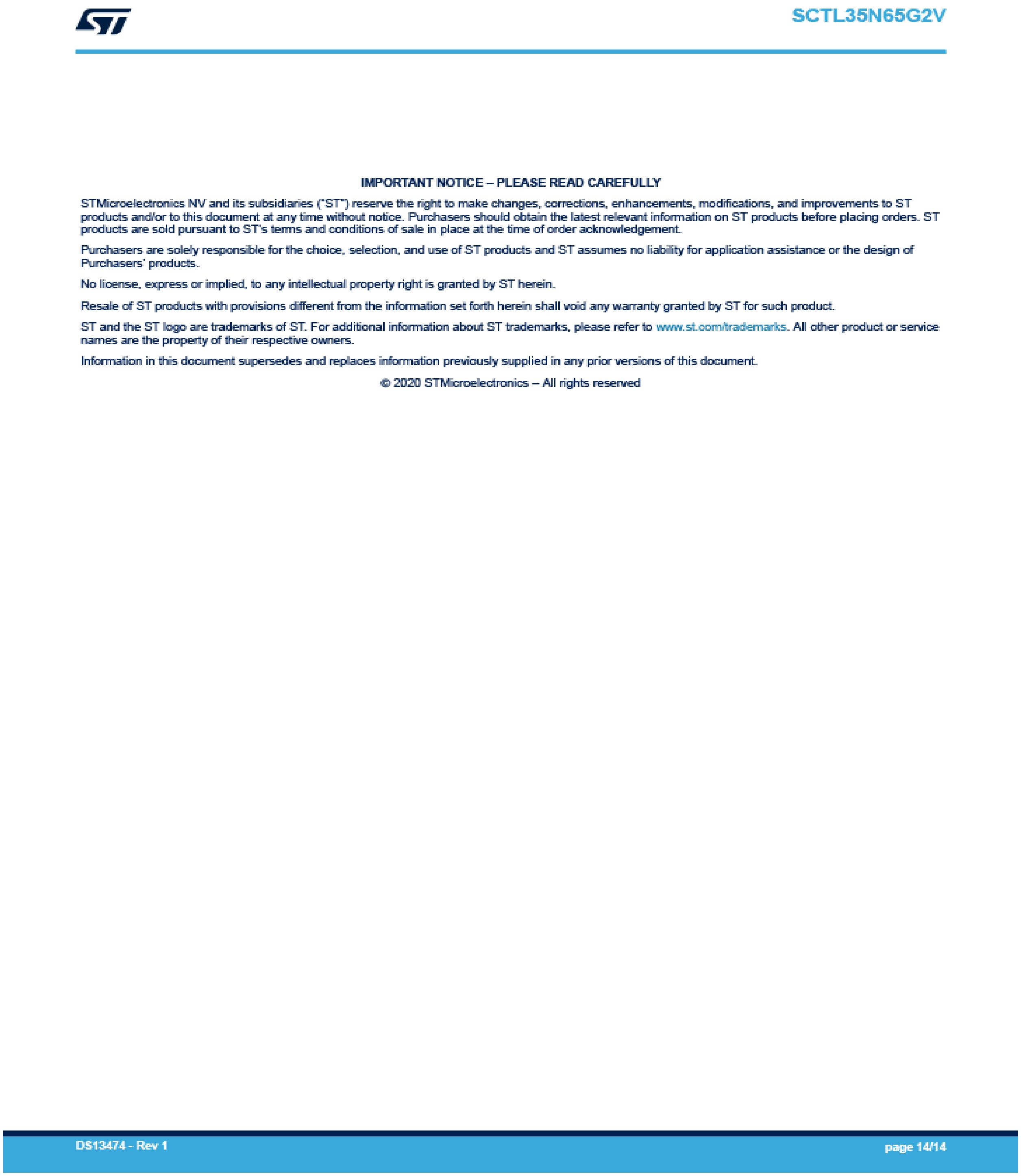


SCTL35N65G2V

IMPORTANT NOTICE – PLEASE READ CAREFULLY

DS13474 - Rev 1

page 14/14

UARK

This topic describes the following components:

Instance, University of Arkansas SiC Power MOSFET

University of Arkansas SiC MOSFET Model

University of Arkansas SiC Power MOSFET

The netlist syntax for a University of Arkansas SiC Power MOSFET instance is:

Mxxxx nd ng ns modelname [[**DTEMP =**] *val*]

nd is the drain node, *ng* is the gate node, *ns* is the source node. *modelname* is the name of a UARK SiC Power MOSFET model defined in a .MODEL statement elsewhere in the netlist.

Table: UARK SiC Power MOSFET Instance Parameters

Instance Parameter	Description	Unit	Default
DTEMP	Difference between the element temperature and the circuit temperature in Celsius	°C	0.0

Refer to Semiconductor Characterization Process for procedure support.

References:

1. M. Mudholkar, S. Ahmed, M. N. Ericson, S. S. Frank, C. L. Britton and H. A. Mantooth, "Datasheet Driven Silicon Carbide Power MOSFET Model," in IEEE Transactions on Power Electronics, vol. 29, no. 5, pp. 2220-2228, May 2014.
2. A. U. Rashid, M. M. Hossain, A. I. Emon and H. A. Mantooth, "Datasheet-Driven Compact Model of Silicon Carbide Power MOSFET Including Third-Quadrant Behavior," in IEEE Transactions on Power Electronics, vol. 36, no. 10, pp. 11748-11762, Oct. 2021.
3. M. M. Hossain, L. Ceccarelli, A. U. Rashid, R. M. Kotecha and H. A. Mantooth, "An Improved Physics-based LTSpice Compact Electro-Thermal Model for a SiC Power MOSFET with Experimental Validation," IECON 2018 - 44th Annual Conference of the IEEE Industrial Electronics Society, Washington, DC, USA, 2018, pp. 1011-1016.

University of Arkansas SiC MOSFET Model

The netlist syntax for a University of Arkansas SiC MOSFET Model is:

.model *modelname* **NMOS UARK=1** [**(**][*parameter real* **=***val*] ... [**)**]

modelname is the name used by UARK NMOS instances to refer to this .MODEL statement.

Table: UARK NMOS Basic Model Parameters

Model Parameter	Description	Unit	Default
mtrlmod	Material type. "0" corresponds to Si and "1" corresponds to SiC	None	1
syncmod	Synchronous mode type. "0" corresponds to disable and "1" corresponds to enable the synchronous rectification	None	1
cgs	Gate to source capacitance	F	6.2e-10
cds	Drain to source zero bias capacitance	F	10e-10
cgd0	Gate drain overlap capacitance	F	1.1e-12
coxd	Gate oxide capacitance	F	1.67e-10
vtd	Gate drain overlap depletion threshold voltage	V	0.01
vtdtco	Temp. coefficient of vtd	V/K	0
fc	Forward-bias depletion capacitance coefficient	None	0
m	Junction grading coefficient	None	0.001
wb	Metallurgical drift region width	cm	150e-6
nb	Base doping concentration	cm^{-3}	1.3e+15
a	Device active area	cm^2	0.1667
agd	Gate drain overlap active area	cm^2	0.004
thetal	Empirical parameter to model transconductance reduction low gate-source voltage	None	0.0002
thetah	Empirical parameter to model transconductance reduction for high gate-source voltage	None	0.0001
thetaltexp	Temperature exponent for thetal	m/s	26.9482
thetahtexp	Temperature exponent for thetah	V	0
rs	Parasitic drain resistance	Ohms	1e-3
kfl	Transconductance parameter to scale current in triode region and low threshold voltage region	None	1.65
kfh	Transconductance parameter to scale current in triode region and high threshold voltage region	None	10
kpl	Transconductance parameter to scale current in triode and saturation region and low threshold voltage region	None	1.8
kph	Transconductance parameter to scale current in triode and saturation region and high threshold voltage	None	4.89

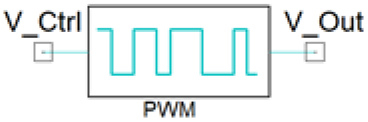
	region		
kfltexp	Temp. exponent for kfl	None	0
kfhtexp	Temp. exponent for kfh	None	6.4242
kpltexp	Temp. exponent for kpl	None	-4.6188
kphtexp	Temp. exponent for kph	None	0.2419
vtl	Low current threshold voltage	V	2.5
vth	High current threshold voltage	V	5.8
vtltco	Temp. coefficient of vtl	V/K	0.0033
vthtco	Temp. coefficient of vth	V/K	-0.026
vbigd	Gate-drain neck region built-in potential	None	0.1
pvf	Pinch-off voltage parameter to adjust drain-source saturation voltage	None	480e-3
fxjbe	Fraction depletion charge at gate-drain overlap edge	F/cm^2	0.5
fxjbm	Fraction depletion charge at gate-drain overlap middle	F/cm^2	0.75
slmin	Minimum slope for MOSFET current	A/V	1.0e-9
is_body	Body diode reverse bias saturation current	A	1e-10
id0	Leakage current at breakdown voltage	A	0
vb	Breakdown voltage of the device	V	1200
tnom	Nominal temperature	°C	27
rd	Parasitic drain resistance	Ohms	0.035
rdiode	Body diode resistance	Ohms	0.003
rdvd	Drain voltage coefficient of drift resistance	Ohms/V	0.015
rdvg11	First gate voltage coefficient of drift resistance	Ohms/V	0.001
rdvg12	Second gate voltage coefficient of drift resistance	Ohms/V	5
rdtemp1	First temperature coefficient of rd	Ohms/K	0.0
rdtemp2	Second temperature coefficient of rd	Ohms/K	0.0
rdvdtemp1	First temperature coefficient of rdvd	Ohms/V.K	0
rdvdtemp2	Second temperature coefficient of rd	Ohms/V.K	-3.3049e-7
kvsg1	Gate bias dependent first body diode parameter	1/V	1.0
kvsg2	Gate bias dependent second body diode parameter	1/V	1
nd	Emission coefficient of body diode	None	3.3

Refer to Semiconductor Characterization Process for procedure support.

References:

1. M. Mudholkar, S. Ahmed, M. N. Ericson, S. S. Frank, C. L. Britton and H. A. Mantooth, "Datasheet Driven Silicon Carbide Power MOSFET Model," in IEEE Transactions on Power Electronics, vol. 29, no. 5, pp. 2220-2228, May 2014.
2. A. U. Rashid, M. M. Hossain, A. I. Emon and H. A. Mantooth, "Datasheet-Driven Compact Model of Silicon Carbide Power MOSFET Including Third-Quadrant Behavior," in IEEE Transactions on Power Electronics, vol. 36, no. 10, pp. 11748-11762, Oct. 2021.
3. M. M. Hossain, L. Ceccarelli, A. U. Rashid, R. M. Kotecha and H. A. Mantooth, "An Improved Physics-based LTSpice Compact Electro-Thermal Model for a SiC Power MOSFET with Experimental Validation," IECON 2018 - 44th Annual Conference of the IEEE Industrial Electronics Society, Washington, DC, USA, 2018, pp. 1011-1016.

Pulse Width Modulation



This component aims to emulate the effect of a PWM driven circuit for EMC testing without having to design the necessary control circuit. It is a single-input single-output component that takes a control input and outputs a pulse width modulated signal.

Based on the type of output that is required, you may choose either an inverted or a non-inverted output.

Table 36: Pulse Width Modulation Parameters

Parameter	**Description**
VC_max	Maximum value that the control voltage takes
VC_min	Minimum value that the control voltage takes
IPWM_max	Maximum output voltage
PWM_min	Minimum output voltage
Frequency	Reference voltage frequency

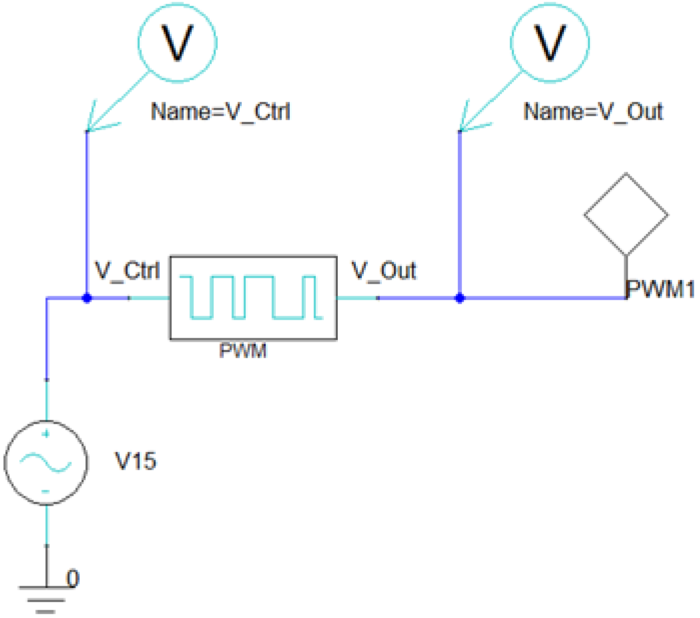


Figure 29-1 PWM Test Circuit

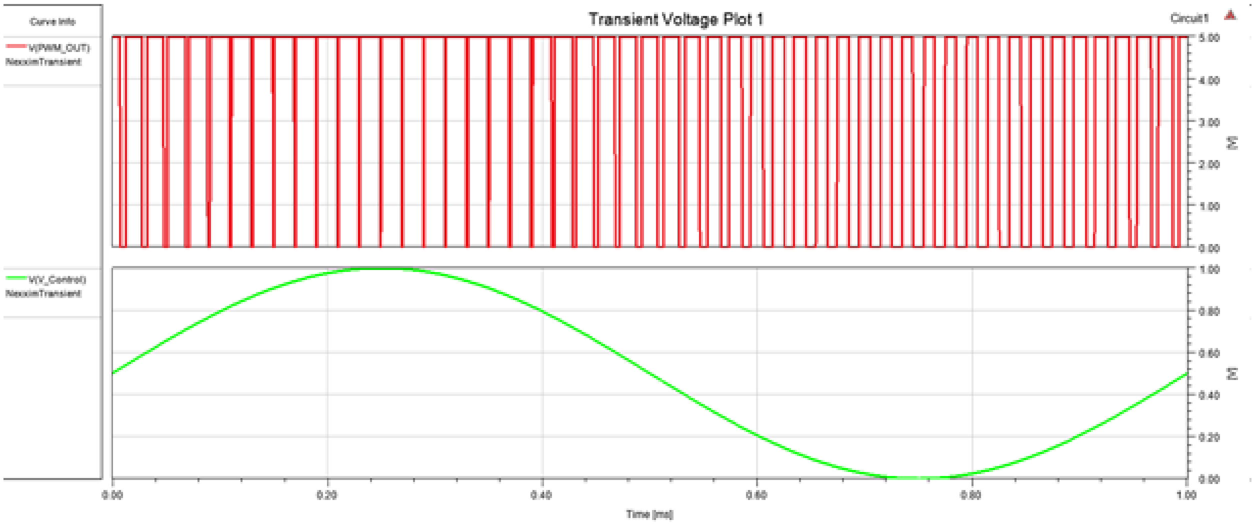


Figure 29-2 PWM Test Circuit Output

Sinusoidal PWM: Sinusoidal PWM 3-phase 2-level

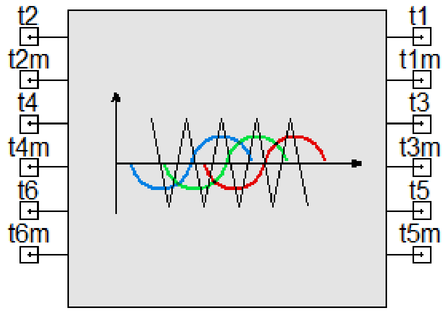


Table: Sinusoidal PWM 3-Phase 2-Level

Parameter	Description	Default Value [Unit]
freq1	Carrier frequency	1000 [Hz]
freq2	Input sinusoid frequency	50 [Hz]
dead_time	Switching dead time	1 [us]
Vm	Input sinusoid amplitude	0.8 [V]
Phase	Input sinusoid initial phase	0 [degrees]
vc_m	Carrier initial voltage	-1 [V]
vc_p	Carrier final voltage	1 [V]
vout_mag	Magnitude of switching output	1 [V]

There are six isolated voltage source outputs: t1, t3, t5 and their complements t2, t4, t6. The reference terminal for each is identified with a 'm' subscript.

SVPWM: Space-Vector PWM 3-Phase 2-Level

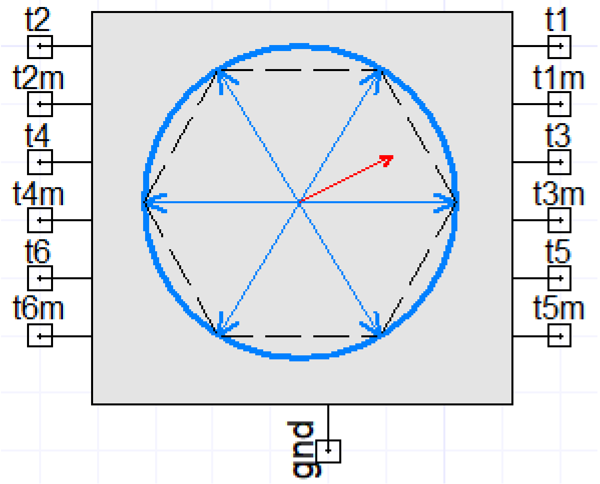


Table: Space-Vector PWM 3 Phase 2-Level

Parameter	Description	Default Value [Unit]
freq1	Carrier frequency	1000 [Hz]
freq2	Input sinusoid frequency	500 [Hz]
dead_time	Switching dead time	1 [us]
Vm	Input sinusoid amplitude	0.8 [V]
Phase	Input sinusoid initial phase	0 [degrees]
Vdc	DC voltage	1 [V]
vc_m	Carrier initial voltage	0 [V]
vc_p	Carrier final voltage	1 [V]
vout_mag	Magnitude of switching output	1 [V]

Space-Vector PWM is a special switching sequence of the upper three power transistors of a three-phase power inverter. It generates less harmonic distortion in output voltages and currents that are applied to the phases of an AC motor. The SVPWM also uses supply voltage more efficiently than sinusoidal modulation technique.

There are six isolated voltage source outputs: t1, t3, t5 and their complements t2, t4, t6. The reference terminal for each is identified with a 'm' subscript.

The Space-Vector PWM works in three steps:

1. Determine V_d, V_q, V_{ref}, and angle (α)

$$V_d = V_{an} - \frac{V_{bn}}{2} - \frac{V_{cn}}{2}$$

$$V_q = V_{an} + \frac{V_{bn}\sqrt{3}}{2} - \frac{V_{cn}\sqrt{3}}{2}$$

$$|\overline{V_{ref}}| = \sqrt{V_d^2 + V_q^2}$$

$$\alpha = tan^{-1}\left(\frac{V_q}{V_d}\right) = \omega t = 2\pi ft\ where\ f = fundamental\ frequency$$

2. Determine time durations T_1, T_2, and T_0

$$T_1 = T_z \cdot a \cdot \frac{sin(\pi/3 - \alpha)}{sin(\pi/3)}$$

$$T_2 = T_z \cdot a \cdot \frac{sin(\alpha)}{sin(\pi/3)}$$

$$T_0 = T_z - (T_1 + T_2)\ where\ T_z = \frac{1}{f_z}\ and\ a = \frac{3|\overline{V_{ref}}|}{2V_{dc}}$$

3. Determine the switching time of each transistor, S1 to S6

$$T_1 = \frac{\sqrt{3}\cdot T_z \cdot |\overline{V_{ref}}|}{V_{dc}}\left(sin\left(\frac{n\pi}{3}\right) - \alpha\right)$$

$$T_2 = \frac{\sqrt{3}\cdot T_z \cdot |\overline{V_{ref}}|}{V_{dc}}\left(sin\left(\alpha - \frac{(n-1)\pi}{3}\right)\right)$$

$$T_0 = T_z - T_1 - T_2\ where\ n = 1\ through\ 6\ (Sector\ 1\ to\ 6)\ \ 0 \leqslant \alpha \leqslant 60^{\circ}$$

Table: Switching Time Calculation at Each Sector

Sector	**Upper Switches(S_1, S_3, S_5**	**Lower Switches (S_4, S_6, S_2)**
1	$S_1 = T_1 + T_2 + T_0/2$ $S_3 = T_2 + T_0/2$ $S_5 = T_0/2$	$S_4 = T_0/2$ $S_6 = T_1 +$

		$T_0/2$ $S_2 = T_1 + T_2 + T_0/2$
2	$S_1 = T_1 + T_0/2$ $S_3 = T_1 + T_2 + T_0/2$ $S_5 = T_0/2$	$S_4 = T_2 + T_0/2$ $S_6 = T_0/2$ $S_2 = T_1 + T_2 + T_0/2$
3	$S_1 = T_0/2$ $S_3 = T_1 + T_2 + T_0/2$ $S_5 = T_2 + T_0/2$	$S_4 = T_1 + T_2 + T_0/2$ $S_6 = T_0/2$ $S_2 = T_1 + T_0/2$
4	$S_1 = T_0/2$ $S_3 = T_1 + T_0/2$ $S_5 = T_1 + T_2 + T_0/2$	$S_4 = T_1 + T_2 + T_0/2$ $S_6 = T_2 + T_0/2$ $S_2 = T_0/2$
5	$S_1 = T_2 + T_0/2$ $S_3 = T_0/2$ $S_5 = T_1 + T_2 + T_0/2$	$S_4 = T_1 + T_0/2$ $S_6 = T_1 + T_2 + T_0/2$ $S_2 = T_0/2$
6	$S_1 = T_1 + T_2 + T_0/2$ $S_3 = T_0/2$ $S_5 = T_1 + T_0/2$	$S_4 = T_0/2$ $S_6 = T_1 + T_2 + T_0/2$ $S_2 = T_2 + T_0/2$

PWL Diode: Piecewise-linear Diode Model

The PWL Diode model is a linear model of the operating regions of a real semiconductor diode with limits available for the maximum forward and reverse currents. The model is conduction current only and no charge effects are considered.

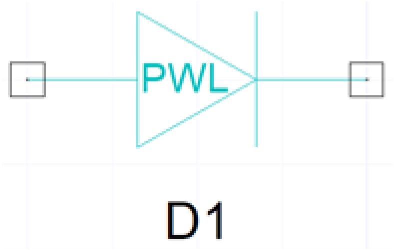
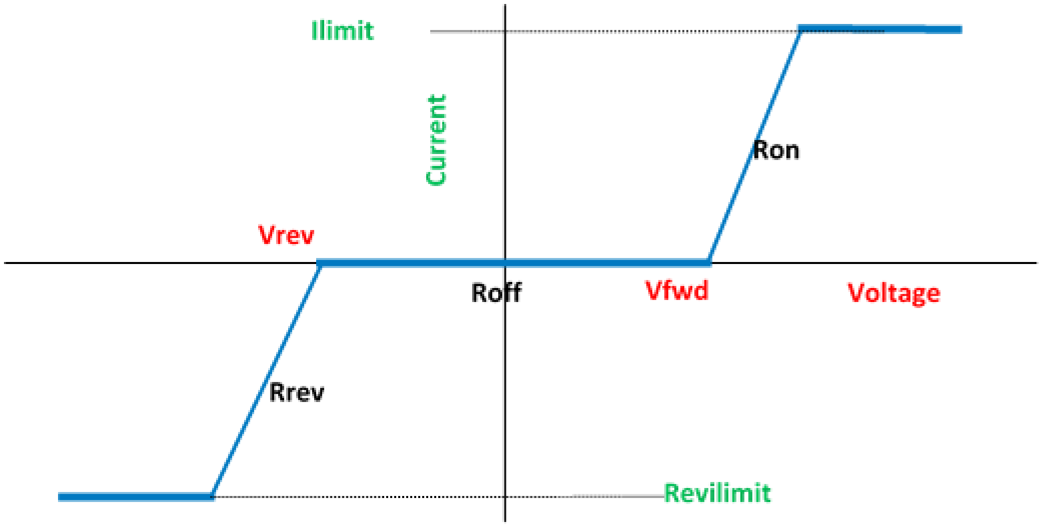


Table: PWL Diode Model Parameters

Parameter	Description	Default Value [Unit]
Ron	ON resistance	1 [Ohm]
Roff	OFF resistance	1e6 [Ohm]
Vfwd	Threshold voltage	0 [V]
Vrev	Breakdown voltage	Specify the absolute value of Vrev [V]
Rrev	Breakdown resistance	1 [Ohm]
Ilimit	Forward current limit	1e6 [Amp]
Revlimit	Reverse current limit	1e6 [Amp]

Figure 29-3 Figure: I-V curve of PWL diode model



Semiconductor Characterization Process

The semiconductor characterization tool enables users to create physics-based models of various power electronics devices to operate to a desired characteristic. Currently, the tool supports modeling of SiC power MOSFET devices, however characterization support for other devices will be added in future releases.

The tool employs the UARK model for modeling of SiC Power MOSFET; this model is based on the analytical equations from multiple publications, referenced at the bottom of this page. The model has multiple parameters that can be adjusted to achieve desired behavior. In other words, the characteristics of the device, such as the Capacitance vs Drain-Source voltage (CV) curves and Drain current vs Drain-Source voltage (Id-Vd/Output characteristics) curves, can be modified by adjusting parameters of the UARK model.

However, adjusting these parameters can be a challenging task. The parameter determination procedures rely on commonly available data in the datasheet, including Capacitance vs Drain-Source voltage curves, Drain current vs Drain-Source voltage (Id-Vd/Output Characteristics) curves at nominal and elevated temperature, etc. To guide the user through the parameter extraction procedure, an example is provided which guides users to determine all the necessary parameters to achieve desired characteristics. The overall procedure can be divided into the following steps:

1. **Obtain data**: Data on Capacitance vs Drain-Source voltage (CV) curves, Drain current vs Drain-Source voltage (Id-Vd/) curves at nominal and elevated temperature are required. This data can be obtained from the datasheet or through measurements.
2. **UARK model**: The model can be accessed from Component Library > Power Electronics Tools > Power-Semiconductor > MOSFET > UARK.
3. **UARK model parameter extraction/adjustment**: Various parameters in the UARK model are required to be adjusted. The procedure is divided into three main steps, which are explained in detail in the guide. Moreover, the file can be accessed from the following location.

   Example Path: Examples\Circuit\Power Electronics\Semiconductor Characterization\UARK Model

Once the device is characterized, users verify the transient behavior of the model. This may include verifying the rise/fall time, switching losses, conduction losses etc. It's important to note that parasitics affect the behavior of the model, and users may need to include them in their analysis. For such investigations Double Pulse Test (DPT) can be performed, an example circuit for simplified DPT can be found.

DPT circuit Path: Extraction\Characterization_UARK.aedtExamples\Circuit\Power Electronics\Semiconductor Characterization\Double Pulse Test\Double_Pulse_Test.aedt

References:

1. M. Mudholkar, S. Ahmed, M. N. Ericson, S. S. Frank, C. L. Britton and H. A. Mantooth, "Datasheet Driven Silicon Carbide Power MOSFET Model," in IEEE Transactions on Power Electronics, vol. 29, no. 5, pp. 2220-2228, May 2014.
2. A. U. Rashid, M. M. Hossain, A. I. Emon and H. A. Mantooth, "Datasheet-Driven Compact Model of Silicon Carbide Power MOSFET Including Third-Quadrant Behavior," in IEEE Transactions on Power Electronics, vol. 36, no. 10, pp. 11748-11762, Oct. 2021.
3. M. M. Hossain, L. Ceccarelli, A. U. Rashid, R. M. Kotecha and H. A. Mantooth, "An Improved Physics-based LTSpice Compact Electro-Thermal Model for a SiC Power MOSFET with Experimental Validation," IECON 2018 - 44th Annual Conference of the IEEE Industrial Electronics Society, Washington, DC, USA, 2018, pp. 1011-1016.

Power Electronics Tools Compensators

This topic describes the following compensators in the Power Electronics Tools:

Type I Compensator (Integral Controller)

Type II Compensator

Type III Compensator (PID)

Type I Compensator (Integral Controller)

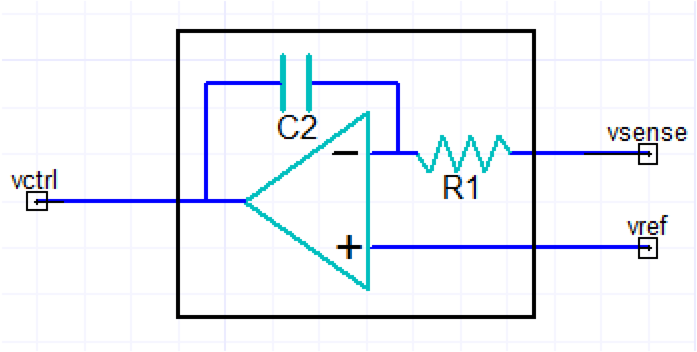


Table: Type I Compensator Parameters

Parameter	Description	Data Type	Default Value [Unit]
C1	Capacitance 1 Value	real	1e-7 [F]
R1	Resistor 1 Value	real	1000 [Ohm]
Vmin	Minimum output voltage	real	-15 [V]
Vmax	Maximum output voltage	real	15 [V]

Since optimum performance is obtained from maximizing low frequency gain and minimizing high frequency gain, it stands to reason that an integrator is the logical starting choice for an error amplifier. The transfer function of this type of amplifier has one pole (at the origin), so for reference purposes call this a Type 1 amplifier.

Figure shows the schematic of the traditional Op-Amp with Type I configuration. The operational amplifier (the traditional Op-Amp) represents the basis of the closed-loop system. Its function, in a feedback system, is to amplify the error detected between a fixed and stable reference level and the monitored state variable. In this Type I configuration, derive H(s) by dividing the capacitor impedance (C1) by the upper resistor. The transfer function is given as follows:

$$\mathrm{Gain}_{\mathrm{TypeI}} = -\frac{1}{sR_1C_1}$$

$$f_c = \frac{1}{2\pi R_1 C_1}$$

The transfer function of a Type 1 amplifier falls at a –1 slope at all frequencies (–20 dB per decade), crossing unity gain at the frequency where the reactance of C1 is equal in magnitude to the resistance of R1. The Type I compensation network has –270° (−180° phase shift with the inverting compensation network included) of phase shift throughout the –1 slope region. Type I compensation network is used for systems where the phase shift of the modulator is minimal.

Type 1 is used where no phase boost is necessary at crossover. If a 45° φ_m is OK, a Type 1 can be used where arg *H(fc)* < 45°:

- Power Factor Correction circuits
- Current mode power supplies in CCM, DCM, or BCM
- Voltage-mode power supplies in DCM
- Pure integrator, brings output overshoot

So, selecting f_{po} depends on the wanted gain at crossover. Crossover frequency selection depends on several factors:

Switching Frequency: theoretical limit is = $F_{SW}/2$

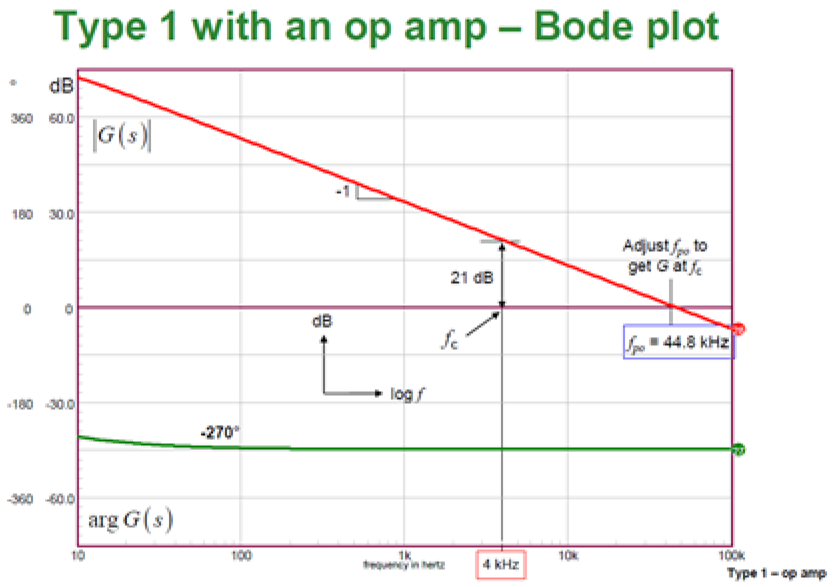
In practice, it is recommended to stay below 1/5 of F_{SW} for noise concerns. Say,

$$|G(4kHz)| = 21\,\mathrm{dB}$$

$$|G(4\,\mathrm{kHz})| = 10^{|G|/20}$$

$$|G(5\,\mathrm{kHz})| = 10^{|21|/20}$$

$$f_{\mathrm{po}} \;=\; G_{\mathrm{fc}} \;*\, f_{z1} \;=\; 10^{|21|/20} \;*\, 4k \;=\; 44.8\ \mathrm{kHz}$$



The following example illustrates how to set up small signal analysis and transient analysis for Type I compensator in **Electronics Desktop** Circuits.

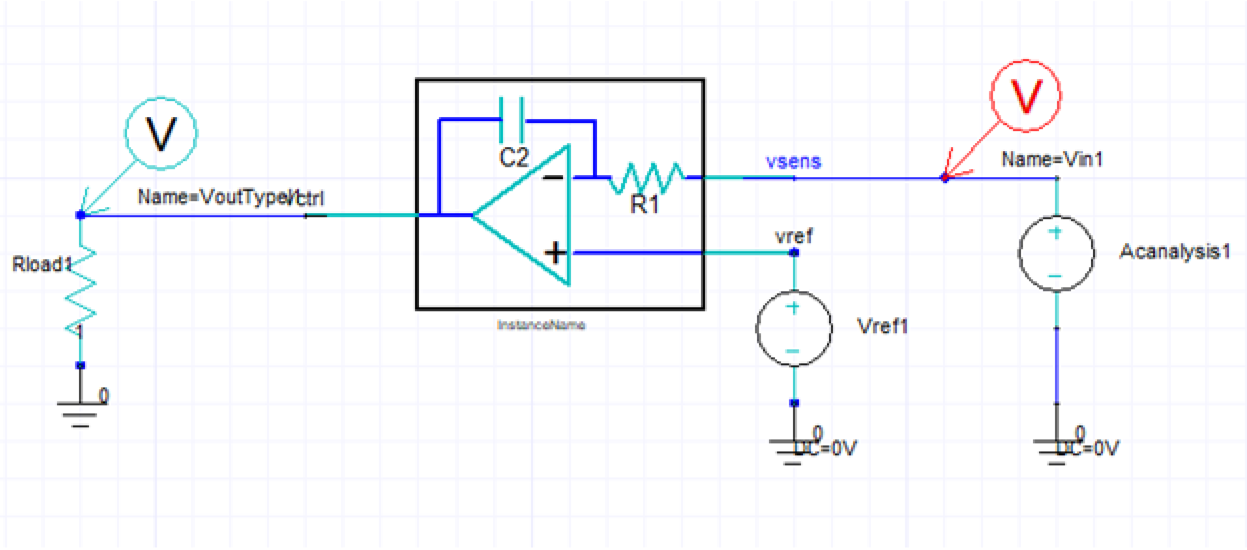
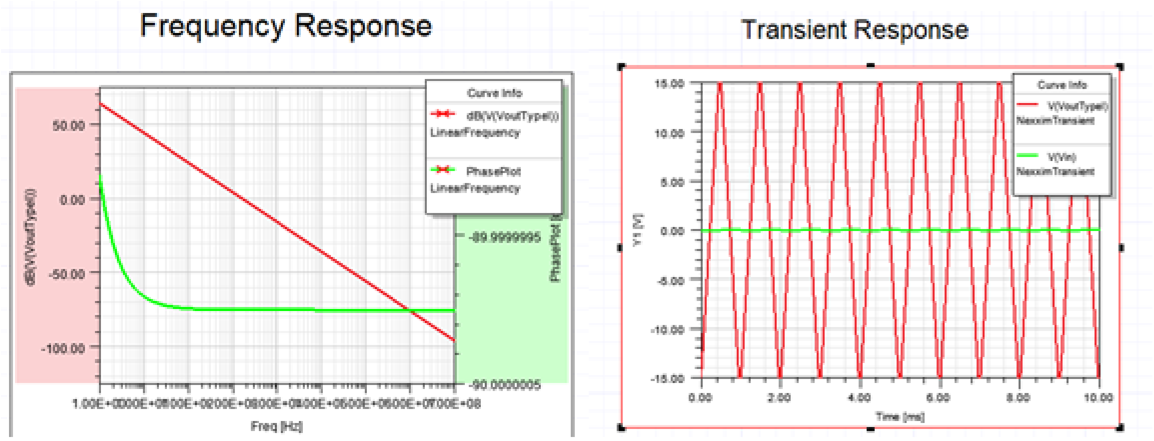


Table: Type-I Compensator Parameters

	Parameter	Default Value [Unit]

Type I Integral Controller I_CONT1	C1	1e-009 [F]
	R1	750 [Ohm]
	Vmin	-15 [V]
	Vmax	15 [V]
Voltage Source E1	EMF Value	0[V]
Voltage Source E2	EMF Value	TRAPEZ1.VAL
Resistor R1	Resistance	1000[Ohm]
Trapezoidal Wave TRAPEZ1	TRISE	1e-006 [s]
	TFALL	1e-006 [s]
	PWIDTH	0.0005 [s]
	TPERIO	0.000502 [s]
	OFFSET	-0.05

Figure 29-4 Results



Type II Compensator

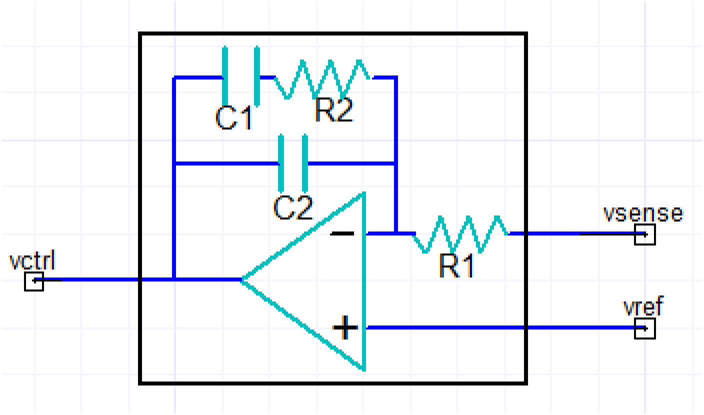


Table: Type II Compensator Parameters

Parameter	Description	Data Type	Default Value [Unit]
C1	Capacitance 1 Value	real	1e-8 [F]
R1	Resistor 1 Value	real	1000 [Ohm]
C2	Capacitance 2 Value	real	1e-8 [F]
R2	Resistor 2 Value	real	1000 [Ohm]
Vmin	Minimum output voltage	real	-15 [V]
Vmax	Maximum output voltage	real	15 [V]

Type II compensators are widely used in the control loops for power converters. A Type II compensator has two poles (one at the origin) and one zero, and the zero is placed somewhere between the poles. Designers use this type of compensator to provide a phase boost to the control loop. It is known that the compensator reaches its maximum phase boost at the geometric mean of the zero's frequency and the second pole's frequency. To design this type of compensator, the popular approach is to place the appropriate loop crossover frequency at the geometric mean of the zero and pole.

Transfer function for Type II compensation network can be written as:

$$\mathrm{Gain}_{\mathrm{TypeII}} = -\frac{1}{R_1 C_2}\frac{\left(s+\frac{1}{R_2 C_1}\right)}{s\left(s+\frac{C_1+C_2}{R_2 C_1 C_2}\right)}$$

This transfer function has two poles and one zero. The poles and zeros are positioned so as to obtain a phase boost of 90° (ideally) with respect to the converter’s transfer function, and their values are summarized in the following table.

Parameter	**Value**
Pole 1	0 Hz
Zero 1	$\frac{1}{2\pi R_2 C_1}$
Pole 2	$\frac{C_1 + C_2}{2\pi R_2 C_1 C_2}$

Placement of Poles and Zeroes

Say,

f_c (Crossover Frequency) = 5kHz, with gain deficiency is -18dB and required phase boost is +68deg.

Therefore,

$$f_{p1} = \left[\tan(\text{boost}) + \text{sqrt}\left(\tan^2(\text{boost}) + 1\right)\right]^{*}\text{fc} = 5.14{*}5K = 25.7\,\text{kHz} = f_{z1} = \frac{f_c}{f_{p1}} = 25k/25.7k = 970\,\text{Hz}$$

A +18dB gain is necessary at 5kHz:

$$|G(5kHz)| = 18\,\text{dB}$$

$$|G(5\,\text{kHz})| = 10^{|G|/20} \approx 8$$

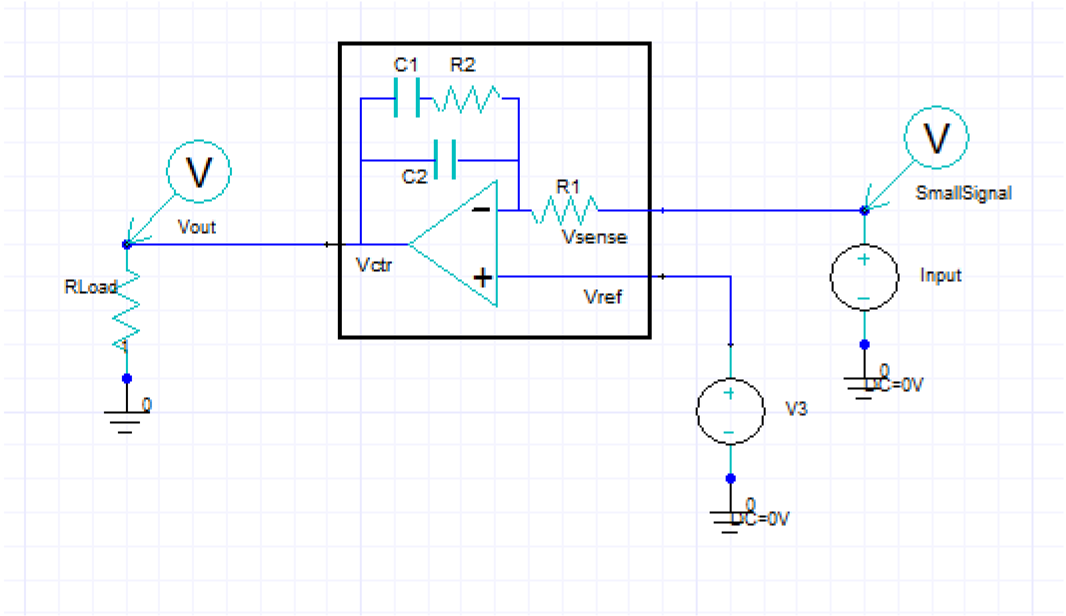
$$f_{po} = 8 * f_{z1} = 7.8\,kHz$$

Once all the appropriate frequencies are defined, the following equations can be used to calculate component values:

Step	**Component**	**Formula**
1	R1	Assume to be 1k
2	R2	$\left(\frac{F_{ESR}}{F_{LC}}\right)^2 \frac{DBW}{F_{ESR}} \frac{V_{OSC}}{V_{IN}} R_1$
3	C1	$\frac{10}{2\pi R_2 F_{LC}}$

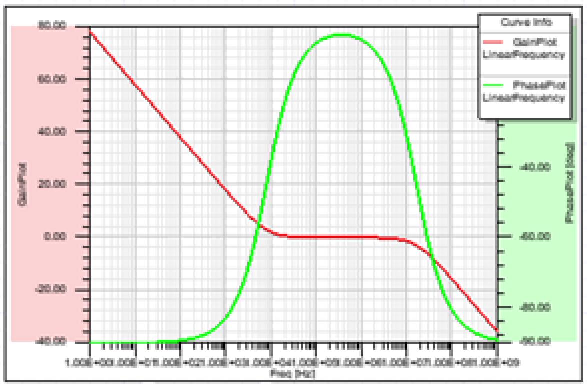
4	C2	$\frac{C_i}{(\pi R_2 C_1 F_{SW}) - 1}$

The following example illustrates how to set up small signal analysis and transient analysis for Type II compensator in **Electronics Desktop** Circuits.

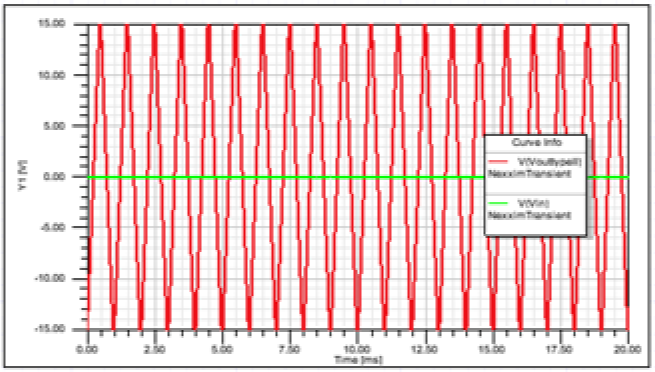


Component	Parameter	Default Value [Unit]
Type II Controller	C1	1e-009 [F]
	R1	750 [Ohm]
	C2	1e-012 [F]
	R2	1000 [Ohm]
	Vmin	-15 [V]
	Vmax	15 [V]
Voltage Source	DC Value	0[V]
Voltage Source (Small Signal)	AC Value	1[V]

Figure 29-5 Results



Frequency Response



Transient Response

Figure 29-6 References

[1] Amir M. Rahimi, Parviz Parto, and Peyman Asadi, ‘Compensator Design Procedure for Buck Converter with Voltage-Mode Error-Amplifier’, International Rectifier Application Note

[2] D. Venable, Venable Technical Paper #3, Optimum feedback amplifier design for control systems

Type III Compensator (PID)

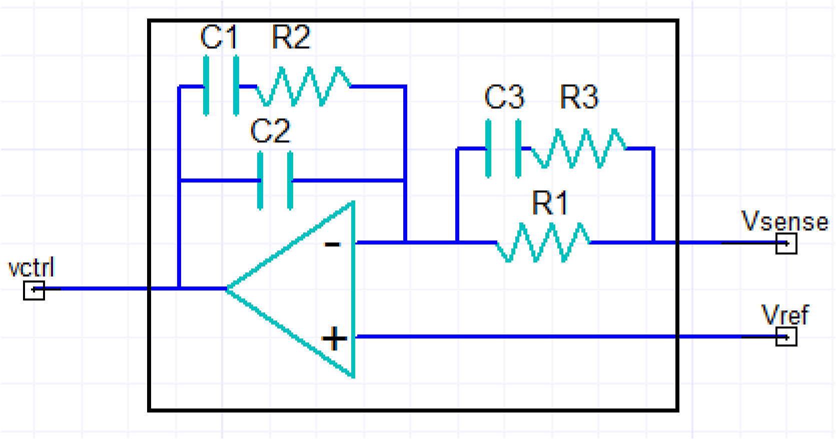


Table: Type III Compensator Parameters

Parameter	Description	Data Type	Default Value [Unit]
C1	Capacitance 1 Value	real	1e-7 [F]
R1	Resistor 1 Value	real	1000 [Ohm]
C2	Capacitance 2 Value	real	1e-7 [F]
R2	Resistor 2 Value	real	1000 [Ohm]
C3	Capacitance 3 Value	real	1e-7 [F]
R3	Resistor 3 Value	real	1000 [Ohm]
Vmin	Minimum output voltage	real	-15 [V]
Vmax	Maximum output voltage	real	15 [V]

Type II compensators are widely used in the control loops for power converters. However, there are cases where the phase lag of a power converter can approach 180 degrees, while the maximal phase from a Type II compensator at any frequencies is at most zero degree. Thus in these cases, the Type II compensator cannot provide enough phase margin to keep the loop stable, and this is where a Type III compensator is needed. A Type III compensator can have a phase plot going above zero degree at some frequencies, and therefore it can provide the required phase boost to maintain a reasonable phase margin.

Type III compensation network places its poles and zeros in such a way that it adjusts the transfer function to have a appropriate bandwidth and give a 180° phase. The goal with this type of compensation is to achieve low DC error and high bandwidth for a quick responding system. Usually Type III is used when location of frequencies is like F_{LC} < DBW < F_{ESR} < $F_{SW}/2$, or F_{LC} < DBW < $F_{SW}/2$ < F_{ESR}.

The transfer function for Type III compensation network can be written as:

$$\mathrm{Gain}_{\mathrm{TypeIII}} = -\frac{R_1 + R_3}{R_1 R_3 C_2} \frac{\left(s + \frac{1}{R_2 C_1}\right)\left(s + \frac{1}{(R_1+R_3)C_3}\right)}{s\left(s + \frac{C_1+C_2}{R_2 C_1 C_2}\right)\left(s + \frac{1}{R_3 C_3}\right)}$$

This transfer function has three poles and two zero. Values of these poles, zeros are positioned so as to obtain a phase boost of 180° with respect to the converter’s transfer function. Their values are summarized in the following table.

Parameter	Value
Pole 1	0 Hz
Zero 1	$\frac{1}{2\pi R_2 C_1}$
Zero 2	$\frac{1}{2\pi (R_1 + R_3) C_3}$
Pole 2	$\frac{1}{2\pi R_2 \left(\frac{C_1 C_2}{C_1 + C_2}\right)}$
Pole 3	$\frac{1}{2\pi R_3 C_3}$

Placement of Poles and Zeroes

Say,

f_c (Crossover Frequency) = 5kHz, with gain deficiency is +10dB and required phase boost is +158deg.

$$\mathrm{Boost} = 2\left[\arctan\left(\frac{f_p}{f_c}\right) - \arctan\left(\frac{f_c}{f_p}\right)\right]$$

$$f_c = 5kHz = \sqrt{f_z f_p}$$

$$f_{p1,2} = \frac{f_c}{tan\left(45 - \frac{Boost}{4}\right)} = \frac{5k}{96.3m} \approx 52kHz$$

$$f_{z1,2} = \frac{f_c^2}{f_{p1,2}} = \frac{25k}{52k} \approx 480\ Hz$$

A +10dB gain is necessary at 5kHz:

$$|G(5\,\mathrm{kHz})| = 10\,\mathrm{dB}$$

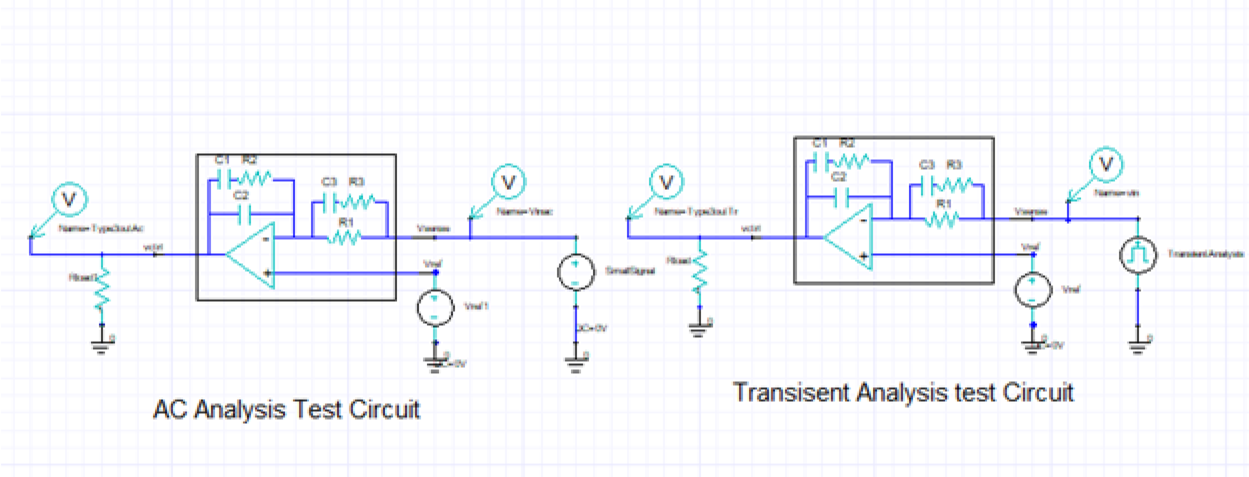
$$|G(5\,\mathrm{kHz})| = 10^{|G|/20} \approx 3.2$$

$$f_{po} = G_{fc} * \frac{f_{z1,2}^2}{f_c} = 147Hz$$

Once all the appropriate frequencies are defined the following equations can be used to calculate component values:

Step	Component	Formula
1	R1	Assume to be 1k
2	R2	$\frac{DBW}{F_{LC}} \frac{\Delta V_{OSC}}{V_{IN}} R_1$
3	C2	$\frac{1}{\pi R_2 F_{\mathrm{LC}}}$
4	C1	$\frac{C_2}{(2\pi R_2 C_2 F_{\mathrm{ESR}}) - 1}$
5	R3	$\frac{R_1}{\left(\frac{F_{SW}}{2F_{LC}}\right) - 1}$
6	C3	$\frac{1}{\pi R_3 F_{SW}}$

The following example illustrates how to set up small signal analysis and Transient Analysis for Type III compensator in **Electronics Desktop** Circuits.



The following example illustrates how to set up small signal analysis and transient analysis for Type III compensator in **Electronics Desktop** Circuits.

Table: Type-III Compensator Parameters

	Parameter	**Default Value [Unit]**
Type III_Comp	C1	1e-006 [F]
	R1	100000 [Ohm]
	C2	1e-007 [F]
	R2	1000 [Ohm]
	C3	1e-008 [F]
	R3	v
	Vmin	-15 [V]
	Vmax	15 [V]
Voltage Source	DC Value	0[V]
Voltage Source (small signal)	AC Value	1[V]
Resistor R1	Resistance	1000[Ohm]
Square Voltage(Transient Analysis)	DC Value	-0.2 to 0.2[V]

Figure 29-7 Results

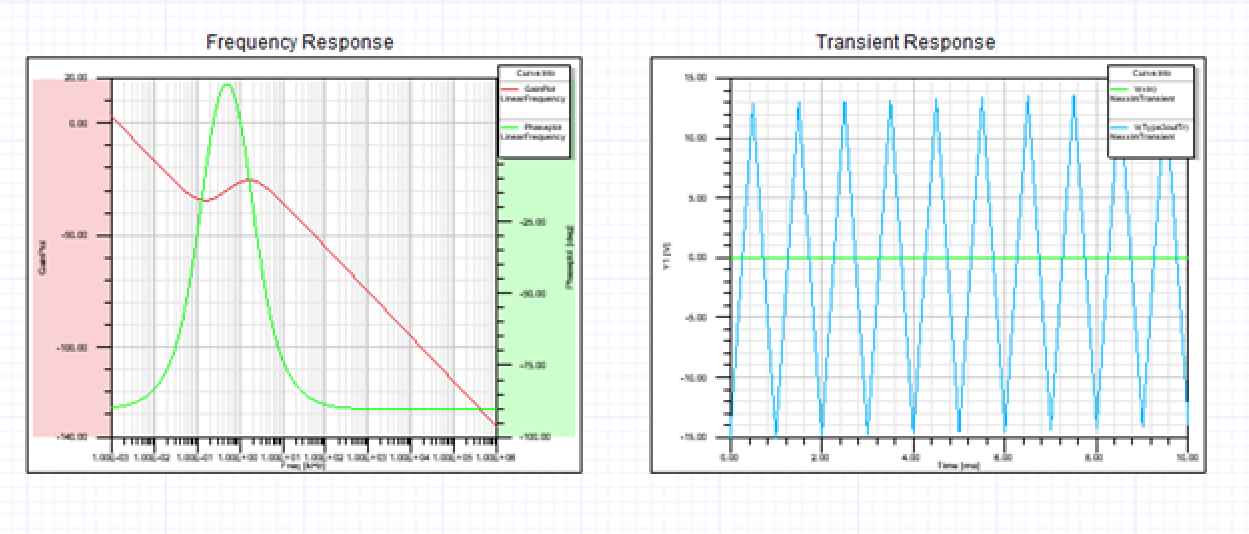


Figure 29-8 References

[1] Amir M. Rahimi, Parviz Parto, and Peyman Asadi, ‘Compensator Design Procedure for Buck Converter with Voltage-Mode Error-Amplifier’, International Rectifier Application Note

[2] D. Venable, Venable Technical Paper #3, Optimum feedback amplifier design for control systems.

[3] K. I. Hwu, Wen-Zhuang Jiang, Jenn-Jong Shieh, “Analysis and Design of Type 3 Compensator for the Buck Converter Based on PSIM”, *2018 13th IEEE Conference on Industrial Electronics and Applications (ICIEA)*

30 - Probes

Probes are inserted into the schematic at points where circuit values can be reported. This topic describes the following voltage and current probes:

AMI Probe

Current Probe

Dynamic Current Probe

Dynamic Voltage Probe

Eye Probe, Single-Ended, Differential, and Externally Triggered

Eye Scope, Single-Ended and Differential

MATLAB Probe

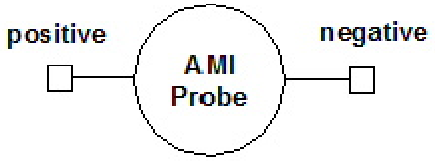
MIPI-CPHY Receiver

Oscillator Probe

Time Domain Reflectometer

Voltage Probe, Single-Ended and Differential

AMI Probe (Receiver)



AMI Probe Netlist Format

> **Note:** The AMI Probe can be used to simulate an AMI receiver, when only an IBIS AMI Transmitter model has been imported. See *IBIS Library Support* in the Circuit Design help topics.

The AMI Probe implements the user’s AMI receiver model in an Algorithmic Modeling Interface simulation. The netlist syntax is:

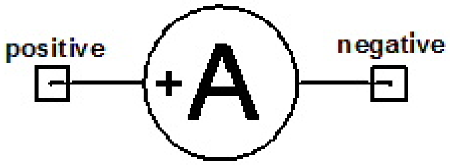
AAMIPROBE*xxxxpositivenegative***COMPONENT=AMI_PROBE**
 \+ **LIBRARY=**'*file-reference*'
 \+ **PARAMETERS_FILE=**'*file-reference*'

positive and *negative* are the nodes connected to the AMI probe. The AMI probe should connect to the same signal lines as the corresponding AMI source without any direct connection to ground. The entry **COMPONENT=AMI_PROBE** identifies the element. The **LIBRARY** entry gives the path and name of the the AMI model library file. The **PARAMETERS_FILE** entry gives the name of the file containing the model parameters to be used in the analysis.

AMI Probe Netlist Example

```
AAMIPROBE1 net_34 net_27 COMPONENT=AMI_PROBE
+ LIBRARY='my_AMI_lib'
+ PARAMETERS_FILE='my_parameters'
```

Current Probe



Current Probe Netlist Format

A zero-voltage voltage source with the following format is automatically inserted in the netlist for a current probe that is added in the schematic:

V*xxx positive negative*

positive and *negative* are the nodes connected to the current probe.

In addition, when an analysis is performed, a .PRINT statement with the following syntax is inserted in the netlist to create the output variable for the report:

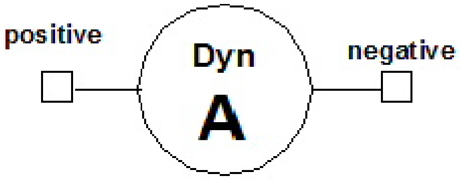
.PRINT*analysis* **I(***Vxxx***)**

The analysis is the analysis type, DC, TRAN, HB, or LNA. *Vxxx* is the name of the voltage source instantiated for the current probe.

Current Probe Netlist Example

```
Vprobe1 net_34 net_27
```

Dynamic Current Probe



Dynamic Current Probe Netlist Format

A zero-voltage voltage source with the following format is inserted in the netlist to serve as a dynamic current probe in the schematic. The dynamic probe enables reports to be updated in “real time” rather than waiting for the entire set of results to be calculated.

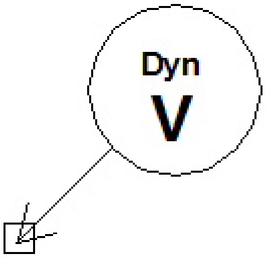
`APROBE``xxx positive negative` **`component=dyn_probe_i id=`**`xxx`

positive and *negative* are the nodes connected to the dynamic current probe.

Dynamic Current Probe Netlist Example

```
APROBE2 net_34 net_27 COMPONENT=DYN_PROB_I ID=2
```

Dynamic Voltage Probe



Dynamic Voltage Probe Netlist Format

A dynamic voltage probe inserted in a schematic enables reports to be updated in “real time” rather than waiting for the entire set of results to be calculated. The netlist format is:

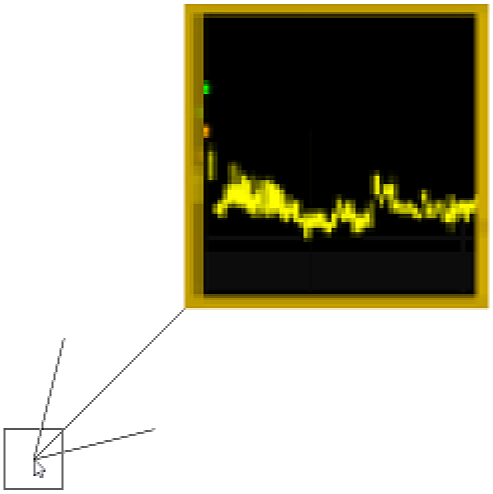
`APROBE``xxx positive negative` **`component=dyn_probe_v id=`**`xxx`

positive and *negative* are the nodes connected to the dynamic voltage probe.

Dynamic Voltage Probe Netlist Example

```
APROBE3 net_22 net_81 COMPONENT=DYN_PROB_V ID=3
```

EMI Receiver Probe



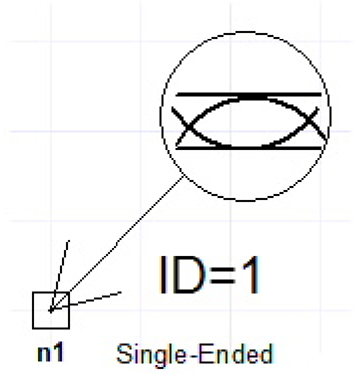
The virtual EMI receiver probe is a post-processing probe that provides a report of the signals recognized after the completion of transient analysis. The probe does not appear in the netlist but .print statements are added in the netlist for the signals probed.

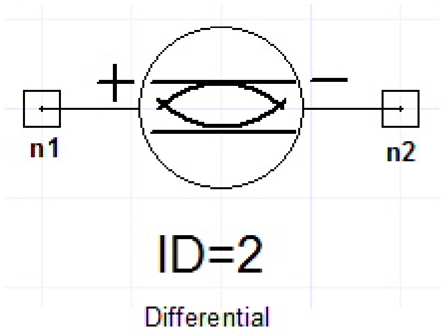
> **Note:** The EMI receiver probe is a post-processing application. Refer to Creating a Transient EMI Receiver Probe Report for instructions.

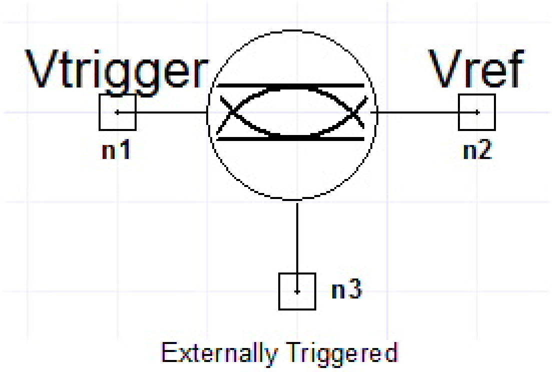
Related Topics:

Technical Note: Virtual EMI Receiver Probe

Eye Probe







Single-Ended and Differential Eye Probe Netlist Format

An Eye probe is inserted in a schematic to perform VerifEye analysis, Quick Eye analysis, or Transient analysis in combination with an associated Eye source.

The netlist syntax for the Single-Ended and Differential Eye Probes is:

```
AEYEPROBExxxx n1 [n2] COMPONENT=EYE_PROBE
+ SOURCE_NAME='source_name'
+ DFE_TAPS=val
+ DFE_LOCS=[locations ]
+ DFE_WEIGHTS=[weights ] (or DFE_WEIGHT_LBS=[val val ...] DFE_WEIGHT_UBS=[val val ...])
+ DECISION_HIGH=val
+ DECISION_LOW=val
+ THRESHOLDS=[val (val...) ]
+ CTLE_FIRST_POLE=val
+ CTLE_SECOND_POLE=val
+ CTLE_ZERO=val
+ CTLE_ALLOWED_GAIN=[val ...]
```

```
+ CTLE_FILE="file_reference"
+ CTLE_RELTOL=val
+ TF_NUM=val
+ CTLE_POLES=[pole1 ... ]
+ CTLE_ZEROS=[ zero1 ... ]
+ CTLE_AC_GAIN=val
```

n1 is the node connected to the single-ended probe. *n2* is the second node on a differential probe. The Eye probe should connect to the same signal line or lines as the corresponding Eye Source without any direct connection to ground. The entry **COMPONENT=EYE_PROBE** is required.

For more information on Decision-Feedback Equalization (DFE) and Continuous-Time Linear Equalization, (CTLE) see *Quick Eye and VerifEye Technical Notes*.

> **Note:** If there are multiple sources of CTLE data present in the netlist, the order of precedence is:
> (ctle_file, ctle_reltol, tf_num) > (ctle_poles, ctle_zeros, ctle_ac_gain) > ctle_first_pole, ctle_second_pole, ctle_zero).

Table 1: Single-Ended and Differential Eye Probe Parameters

Parameter	Description	Unit	Default
SOURCE_ NAME	Name of the associated eye source enclosed in quotes	None	None
DFE_TAPS	Number of Decision-Feedback Equalization (DFE) taps	None	0
DFE_LOCS	Bit locations of DFE taps	None	None
DFE_WEIGHTS	DFE weights	None	None
DFE_WEIGHT_ LBS	DFE weight lower bounds	None	None
DFE_WEIGHT_ UBS	DFE weight upper bounds	None	None
DECISION_ HIGH	Decision high value. Set to the expected high level at the receiver after attenuation.	Volt	None
DECISION_ LOW	Decision low value. Set to the expected low level at the receiver after attenuation.	Volt	None
THRESHOLDS	Vector of decision threshold voltages. NRZ transmissions use a single threshold voltage, PAM4 tranmissions use three threshold voltages, one for each of the three eyes. Multiple voltage thresholds	Volt	Calculated

Parameter	Description	Unit	Default
	may be in ascending or descending order. The legacy parameter **decision_threshold** is recognized in existing netlists.		
CTLE_FIRST_ POLE	Frequency of first pole in Continuous-Time Linear Equalization (CTLE) transfer function. (Setting CTLE_ FIRST_POLE enables CTLE_FIRST_POLE, CTLE_ SECOND_POLE, CTLE_ZERO, and CTLE_ ALLOWED_GAIN as CTLE data source. See **Note**).	Hz	-1e30 (Equivalent to no data)
CTLE_ SECOND_ POLE	Frequency of second pole in CTLE transfer function (optional). Ignored if CTLE_FIRST_POLE is not set.	Hz	-1e30 (Equivalent to no data)
CTLE_ZERO	Zero frequency, where response begins to rise (optional). Ignored if CTLE_FIRST_POLE is not set.	Hz	-1e30 (Equivalent to no data)
CTLE_ ALLOWED_ GAIN	Bracketed list of one or more allowable gain values separated by spaces. If CTLE_ALLOWED_GAIN is not present, Nexxim calculates the optimum gain between -infinity dB and 0 dB (linear values 0 to 1). Ignored if CTLE_FIRST_POLE is not set.	dB	Calculated
CTLE_FILE	File name for the CTLE transfer function data. (Setting CTLE_FILE enables CTLE_FILE, CTLE_RELTOL, and TF_NUM as CTLE data source. See **Note**).	None	None
CTLE_RELTOL	Fitting error for the fit of the transfer function data.	None	1e-2
TF_NUM	Select one transfer function from a file containing multiple transfer functions over the frequency range. With the default value of 0, Nexxim tries each transfer function from the file, selecting the one that yields the maximum eye height. If **tf_num** exceeds the number of functions in the file, an error occurs.	None	0
CTLE_POLES	Vector of pole frequencies. (Setting CTLE_POLES enables CTLE_POLEs, CTLE_ZEROS, and CTLE_ AC_GAIN as CTLE data source. See **Note**).	Hz	None
CTLE_ZEROS	Vector of zero frequencies. Number of zeros must be less than the number of poles.	Hz	None
CTLE_AC_ GAIN	High frequency peak gain. Maximum value of transfer function.	dB	0

Single_Ended Eye Probe Netlist Example

```
AEYEPROBE4 Port1 0 COMPONENT=eye_probe SOURCE_NAME='EYESOURCE1'
```

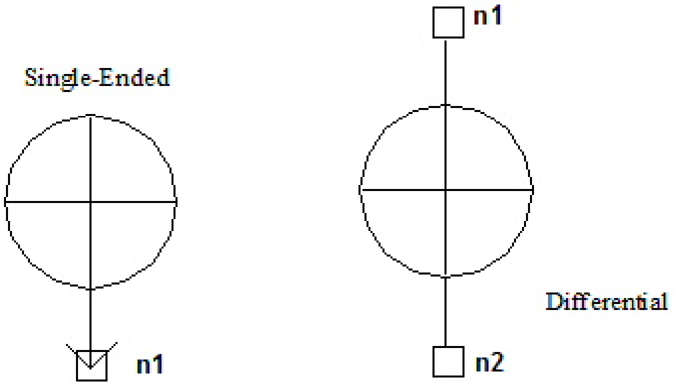
Externally-Triggered Eye Probe Parameters

The externally-triggered eye probe does not have a netlist. The eye diagram is generated directly on the solution data. Node *n1* is connected to the triggering voltage signal. Node *n2* is connected to the reference voltage signal. Node *n3* is connected to the signal being probed. When the selected edge event on the triggering signal crosses the reference, the plot of the probed signal begins the next eye trace at the start of the eye.

Table 2: Externally-Triggered Eye Probe Parameters

Parameter	Description	Unit	Default
NAME	Name of the eye probe enclosed in quotes	None	Required
Triggering	Edges used to trigger event (Rising, Falling, Both)	None	Both

Eye Scope



Eye Scope Netlist Format

An eye scope is inserted in a schematic to tell transient analysis to generate an eye diagram for the signal at that location. If in addition the transient option **Tran.skipresult=1** is set, only the data necessary for the requested eye are stored, saving on the time needed to generate the report.

Warning	If no eye scope is present when **Tran.skipresult=1** is

	set, the transient results file is empty with no error or warning message.

The netlist syntax for the Eye Scope is:

```
AEYESCOPExxxx n1 [n2] COMPONENT=EYE_SCOPE
+ UI=val
+ DELAY=val
+ NO_UI_BINS=val
+ NO_V_BINS=val
+ APPROX_VMIN=val
+ APPROX_VMAX=val
```

n1 is the node connected to the single-ended scope. *n2* is the second node on a differential scope. The entry **COMPONENT=EYE_SCOPE** is required**.**

Table 3: Eye Scope Parameters

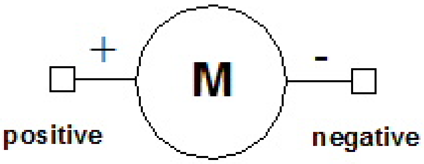
Parameter	**Description**	**Unit**	**Default**
UI	Period to repeat	Second	1e-9
DELAY	Delay to start of recording	Second	1e-9
NO_UI_BINS	Time resolution	None	100
NO_V_BINS	Voltage resolution	None	100
APPROX_VMIN	Approximate minimum voltage	Volt	0.0
APPROX_VMAX	Approximate maximum voltage	Volt	1.0

Eye Scope Netlist Example

```
AEYESCOPEE4 Port1 0 COMPONENT=eye_scope

+ UI=2.3e-9 DELAY=0 APPROX_VMAX=2.0
```

MATLAB Probe



MATLAB Probe Netlist Format

A MATLAB probe allows the user to pass transient analysis data to a MATLAB script (MATLAB™ is a trademark of The Mathworks, Inc.). The netlist syntax is:

```
AMATLABPROBExxxxpositivenegativeCOMPONENT=MATLAB_PROBE
 + SCRIPTFILE='file-reference'
 + BITSOURCE=name
+ BITWIDTH=val
+ TYPE=0|1
 + STEP_SIZE=val
+ [Param1=[val [,val]...]]
+ [Param2=[val [,val]...]]

+ ...
 + [Param10=[val [,val]...]]
```

positive and *negative* are the nodes connected to the AMI probe. The entry **COMPONENT=AMI_PROBE** identifies the element.

Table 4: MATLAB Scope Parameters

Parameter	Description	Unit	Default
SCRIPTFILE	File containing MATLAB script	None	None
BITSOURCE	Netlist name of the source for the bit pattern for transient analysis to use	None	None
BITWIDTH	Bit width or unit interval	Second	1e-9
TYPE	Data format type. 0 = time, voltage 1=Fibre Channel standard	None	0
STEP_SIZE	For Fibre Channel data only. Fixed step size to interpolate transient result. **STEP_SIZE** must be set >0 for Fibre Channel.	Second	0.0 (Simulation does not run with the default value)
Param1 ... Param10	Up to ten parameters. Each parameter can be a single numeric or string value, or vector of numeric or string data.	None	None

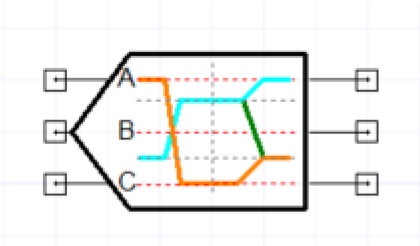
.

MATLAB Probe Netlist Example

```
AMATLABPROBE1 net_34 net_27 COMPONENT=MATLAB_PROBE
+ SCRIPTFILE='my_MATLAB_script'
+ BITSOURCE=V1
+ BITWIDTH=1ns
+ TYPE=1
+ STEPSIZE=0.01ns
+ Param1=0
+ Param2='true'
+ Param3=[0, 1, 2, 3]
+ Param4=['true', 'false']
```

NOTE: For Matlab components to work, you must ensure that a path to the libeng.dll file is added to the PATH system environment variable. Typically, the path to libeng.dll is "C:\Program Files\MATLAB\R2017a\bin\win64".

MIPI-CPHY Receiver



A MIPI-CPHY Receiver is a group of 3 differential line receivers. It takes in signals from line A, B, and C of a CPHY lane, and outputs pair-wise differences. The signs of these differential signals are decoded into 0’s or 1’s and the symbols sent at the transmitter can be determined. The 3 nodes on the left of the schematic are connected to 3 input lines, the 3 nodes on the right are the output nodes from the receiver.

The receiver equalizer defined in the MIPI C-PHY specification is a second order continuous time linear filter with the following transfer function:

$$H(s) = \frac{A_{DC}\omega_{P1}\omega_{P2}}{\omega_Z} \cdot \frac{s+\omega_Z}{(s+\omega_{P1})(s+\omega_{P2})}$$

Where:

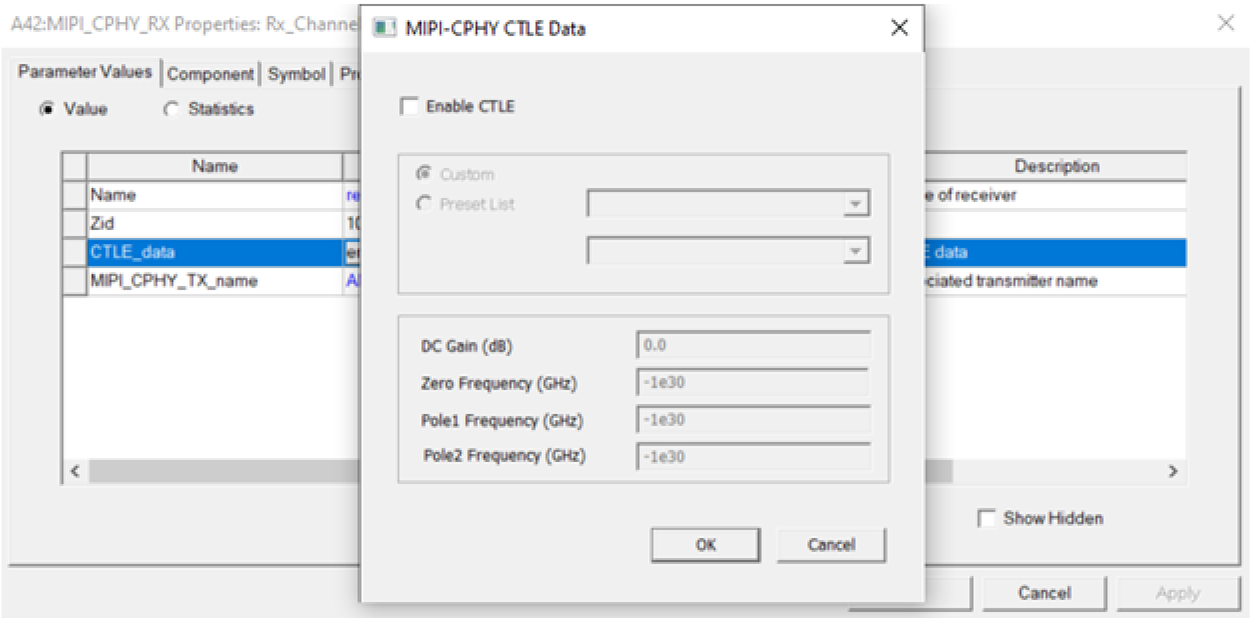
A_{DC}	is the DC gain
$\omega_{P1}= 2\pi f_{P1}$	f_{P1} is the first pole frequency
$\omega_{P2}= 2\pi f_{P2}$	f_{P2} is the first pole frequency
$\omega_{Z}= 2\pi f_{Z}$	f_{Z} is the first pole frequency

MIPI-CPHY Receiver Parameters

Parameter	Description	Unit	Default
Zid	Differential input impedance	Ohm	100
CTLE_data1	Enable and define CTLE parameters	NA	NA
MIPI_CPHY_TX_name^2	Name of the associated MIPI-CPHY Tx	NA	NA

Notes:

1. Click the **Value** field for the **CTLE_data** parameter to open the MIPI-CPHY CTLE Data dialog.



☐ Enable CTLE

● Custom
○ Preset List

DC Gain (dB) 0.0
Zero Frequency (GHz) -1e30
Pole1 Frequency (GHz) -1e30
Pole2 Frequency (GHz) -1e30

Check the **Enable CTLE** box to choose between **Custom** or **Preset List** methods. Once selected, the respective parameter for Custom or Preset List become editable.

Custom enables the following parameters:

Custom Method Parameters

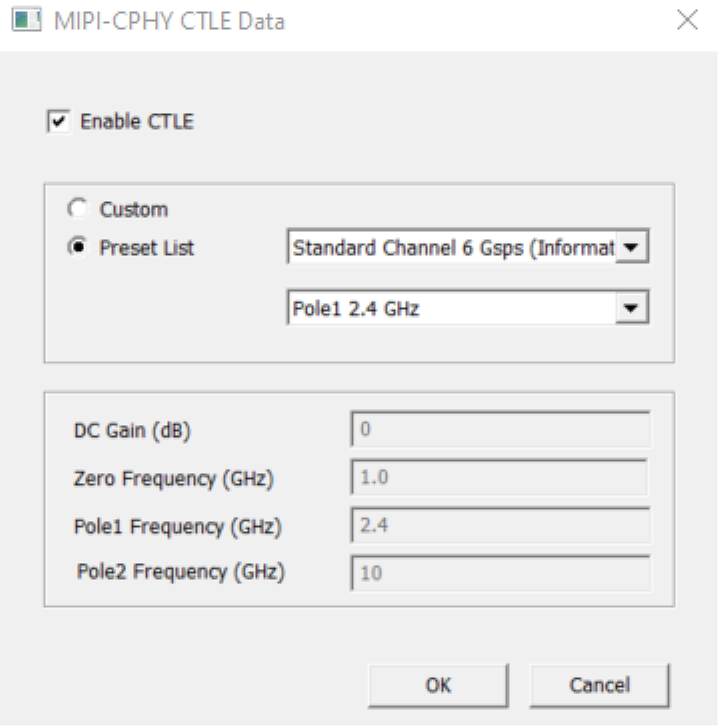
Parameters	Description	Unit	Default
DC Gain	DC Gain	dB	0
Zero Frequency	Zero Frequency	GHz	-1e-30
Pole1 Frequency	First pole frequency	GHz	-1e-30
Pole2 Frequency	Second pole frequency	GHz	-1e-30

Additionally, when **Custom** is enabled, the CTLE parameters take scalar form in the netlist:

```
ctle_first_pole=-1e30 ctle_second_pole=-1e30 ctle_zero=-1e30
ctle_allowed_gain=0.0
```

When **Preset List** is selected, users can further choose **Short**, **Standard** or **Long channel** type, as well as the corresponding **Pole1** value from the drop-down menus. The DC Gain, zero frequency, Pole1 and Pole2 frequencies are automatically set to preset values given in MIPI-CPHY specification v2.1.

The following figure shows the default setting when **Preset List** is chosen:



MIPI-CPHY CTLE Data

☑ Enable CTLE

○ Custom

● Preset List Standard Channel 6 Gsps (Informat

Pole1 2.4 GHz

DC Gain (dB) 0

Zero Frequency (GHz) 1.0

Pole1 Frequency (GHz) 2.4

Pole2 Frequency (GHz) 10

Additionally, when **Preset List** method is selected, CTLE parameters take vector form in the netlist:

```
ctle_poles=[1.6 10] ctle_zeros=[0.8] ctle_allowed_gain=[0]
```

2. Click the **Value** field for the **MIPI_CPHY_TX_name** property, to populate a list of all the MIPI-CPHY transmitters present in the underlined circuit. Users can pick the right Tx to pair with the current Rx.

MIPI-CPHY Receiver Netlist Format

```
AMIPI_CPHY_RXxx net_1 net_2 net_3 net_4 net_5 net_6 COMPONENT=MIPI_CPHY_RECEIVER +ZID=100

+MIPI_CPHY_TX_NAME=val

(+enable_CTLE=1 ctle_poles=[val1 val2] ctle_zeros=[val] ctle_allowed_gain=[val]
```

or

```
+enable_CTLE=1 ctle_first_pole=val ctle_second_pole=val ctle_zero=val ctle_allowed_gain=val
```

or

```
+enable_CTLE=0)
```

When all parameters take default values, the receiver netlist is as follows:

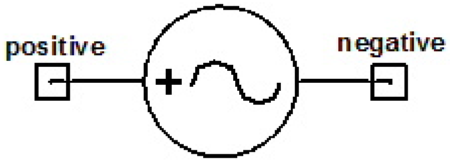
```
AMIPI_CPHY_RXxx net_1 net_2 net_3 net_4 net_5 net_6 COMPONENT=MIPI_CPHY_RECEIVER +ZID=100

+MIPI_CPHY_TX_NAME=val
```

MIPI-CPHY Receiver Netlist Example

```
AMIPI_CPHY_RX35 net_1 net_2 net_3 net_8 net_9 net_10 COMPONENT=MIPI_CPHY_RECEIVER ZID=100 MIPI_CPHY_TX_NAME=AMIPI_CPHY_Tx1 enable_CTLE=1 ctle_poles=[1.6 10] ctle_zeros=[0.8] ctle_allowed_gain=[0]
```

Oscillator Probe



Oscillator Probe Netlist Format

To enable oscillator analysis, the circuit must include an oscillator probe device. The netlist syntax for this device is:

```
Rxxx positive negative OSC_PROBE=1 A=val FREQ=val
 [T=val peak_current=val]
```

The oscillator probe element can have any name beginning with "**R** ". Positive is the positive node and negative is the negative node.

The **OSC_PROBE=1** parameter is required to distinguish the oscillator probe from a resistor.

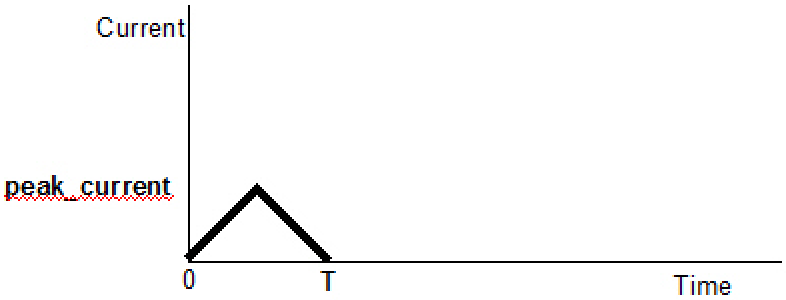
The probe behaves like an oscillating voltage source with voltage amplitude given by the parameter **A** at the frequency given by the parameter **FREQ**. At all other frequencies, the probe current is zero. The default for parameter **A** is zero volts. The default for parameter **FREQ** is 1e6Hz.

The oscillator probe is a frequency domain element; in the time domain (e.g., in transient and DC analyses) the oscillator probe behaves like an open circuit.

The oscillator probe applies a small voltage at a known frequency. The initial guess at the circuit oscillating frequency is controlled by the **initial_guess** option . The voltage given by parameter **A** is always used as the initial probe voltage. The simulator adjusts the frequency and voltage until both the real and imaginary components of the probe current (Iprobe) are zero, that is, Re (Iprobe) = 0 and Im(Iprobe) = 0. The frequency where this occurs is the oscillating frequency.

For more information, see *Initial Guess for Oscillator Frequency* in the Circuit Design help topics.

Parameters **T** and **peak_current** are specific to transient analysis and need to be set only when an oscillator circuit does not begin oscillation during time-domain analysis. Choosing a non-zero **peak_current** (Amperes) and positive **T** (seconds) adds a temporary triangular noise current source with a peak value of **peak_current** and duration **T**, starting at time = 0.



The PWL current source acts as extra noise which helps the oscillation to start and reach steady state soon. This current source does not affect the period of oscillation or any other quantity of interest in an oscillator analysis.

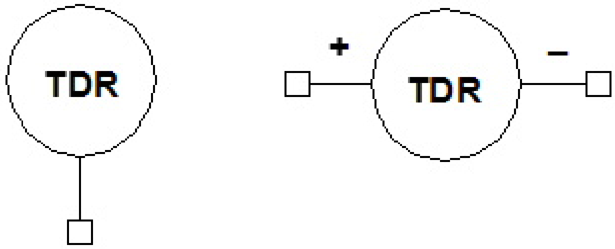
Table 5: Oscillator Probe Parameters

Parameter	Description	Unit	Default
A	Probe initial voltage amplitude	Volt	0.0
FREQ	Probe initial frequency	Hertz	1e6
T	Time duration of triangular noise wave (transient only)	Second	0.0
peak_ current	Maximum current amplitude of triangular noise wave (transient only)	Ampere	0.0

Oscillator Probe Netlist Example

```
Rprobe1 net_34 net_27 OSC_PROBE=1 A=0.005 FREQ=3e6 T=1e-12 peak_
current=0.001
```

Time Domain Reflectometer



The Time Domain Reflectometer (TDR) isolates faults in long runs of inaccessible cables and transmission lines. A pulse is injected into the line and the reflections are captured in the time domain. The fault location is determined on the timing of the reflections and the propagation delay in the channel.

The result at the TDR is a graph of impedance vs. time. The data is available in the **Report** window under the **Device Properties** category. For the single-ended TDR, the report shows the reflected impedance vs. time. For the differential TDR, the data can show the impedance at the positive node, the impedance at the negative node, and the impedance difference between the two nodes.

The single-ended TDR consists of a pulse source, an internal impedance of Z0 ohm, a reference length of lossless transmission line (Z0-ohm impedance, 0.5ns delay), and two voltage probes, Vexcited_pos for the step voltage and Vdetected_pos for the reflected voltage.

The netlist syntax for the single-ended TDR is:

```
ATDRxxxx n1 COMPONENT=TDR_Single_Ended type=Trapezoidal or Smoothstep
RISE_TIME=val
PULSE_WIDTH=val PULSE_REPETITION=val TIME_DELAY=val Z0=val
b=RiseInterval Val
```

```
.PRINT TRAN V(ATDRxxxx) O(ATDRxxxx,zl)
```

n1 is the node connected to the single-ended TDR. The entry **COMPONENT=TDR_Single_Ended** identifies the element. The **.PRINT** line generates the output data.

The differential TDR consists of two channels, each with a pulse source, an internal impedance equal to 0.5Z0 ohm, a transmission line (0.5Z0-ohm impedance, 0.5ns delay), and two voltage probes, Vexcited_pos or Vexcited_neg for the step voltage and Vdetected_pos or Vdetected_neg for the reflected voltage.

The netlist syntax for the differential TDR is:

```
ATDRxxxx positive negative COMPONENT=TDR_Differential_Ended
type=Trapezoidal or Smoothstep RISE_TIME=val PULSE_WIDTH=val PULSE_
REPETITION=val
TIME_DELAY=val Z0=val b=RiseInterval Val
```

```
.PRINT TRAN V(ATDRxxxx) O(ATDRxxxx,zpos) O(ATDRxxxx,zneg)
O(ATDRxxxx,zdiff)
```

Positive and *negative* are the nodes connected to the differential TDR. The entry **COMPONENT=TDR_Differential_Ended** identifies the element. The **.PRINT** line generates the output data.

TDR Parameters

Name	Description	Unit	Default
Choose Pulse Type	Trapezoidal or Smooth Step excitation signal type.		Trapezoidal
Common Parameters			
RISE_TIME	Rise time for voltage pulse	Sec	35ps
Z0	For the single-ended TDR, Z0 is the internal impedance of the single unit pulse source and also the characteristic impedance of the lossless transmission line in series with the source impedance. For the differential TDR, (Z0 x 0.5) is the internal	Ohm	Single-ended: 50 Differential-ended: 100

Name	Description	Unit	Default
	impedance of each of the two unit pulse sources and also the characteristic impedance of each of the lossless transmission lines (positive and negative) in series with the source impedances.		
TIME_DELAY	Delay of the single internal transmission line in single-ended TDR or the two internal transmission lines in differential-ended TDR.	Sec	0.5ns
Trapezoidal Parameters			
PULSE_WIDTH	Width of voltage pulse	Sec	1e-5
PULSE_ REPETITION	Period of repetition for the voltage pulse	Sec	2e-5
Smooth Step Parameters			
RISEINTERVAL	Measurement of the signal's rise time, either 10%-90% (80%) or 20%-80% (60%)	%	80
T50	Time-shift; marks the 50% point of smoothstep. The default value of 1ns works well for rise times below 1ns. Larger rise times will require a further shift forward to ensure a smooth, continuous function. There is an automatic method built into the TDR probe that evaluates the need for a further shift and applies it in increments of 1 ns. The final value of T50 will be reported as an informational message in the Message Manager. Use this value to interpret the TDR Impedance Plots. The T50 value can be user-specified by enabling Show Hidden Parameters; the model will not override a user-specified T50 value. However, if the built-in method identifies more shift is required, a warning message will be issued which will show the recommended value.	Sec	1e-09

Time Domain Reflectometer Netlist Examples

```
ATDR1 net_34 COMPONENT=TDR_Single_Ended
+ RISE_TIME=25e-6 PULSE_WIDTH=5e-6 PULSE_REPETITION=1e-5
```

```
.PRINT TRAN V(ATDR1) O(ATDR1,zl)
```

```
ATDR110 net_34 COMPONENT=TDR_Differential_Ended
+ RISE_TIME=25e-6 PULSE_WIDTH=5e-6 PULSE_REPETITION=1e-5
```

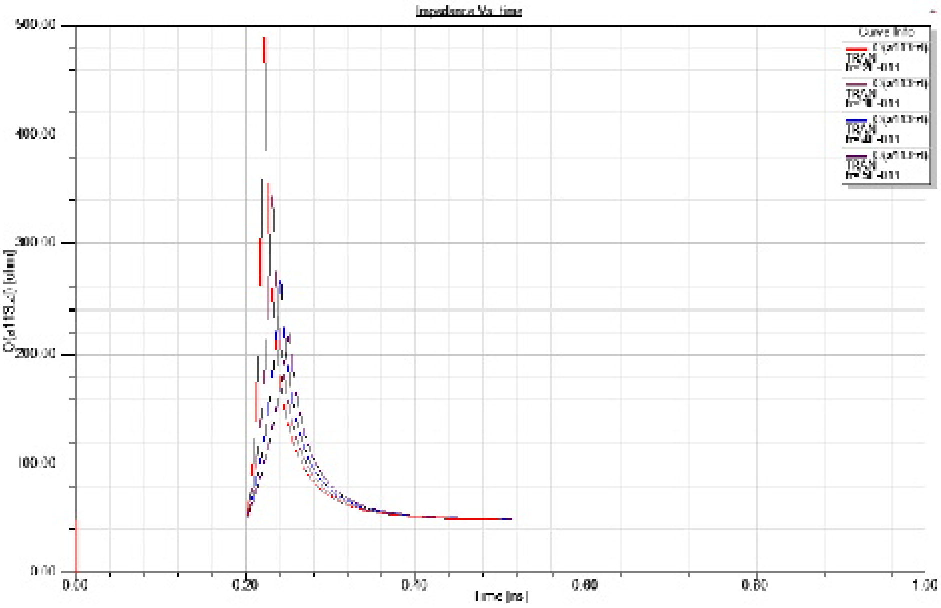
```
.PRINT TRAN V(ATDR110) O(ATDR110,zpos) O(ATDR110,zneg)
+ O(ATDR110,zdiff)
```

```
A82 unconnected2 COMPONENT=TDR_Single_Ended type=SmoothStep
enabled=enabled_A82 b=80 t50=1n
```

```
A83 unconnected3 unconnected4 COMPONENT=TDR_Differential_Ended
type=SmoothStep enabled=enabled_A83 b=80 t50=1n
```

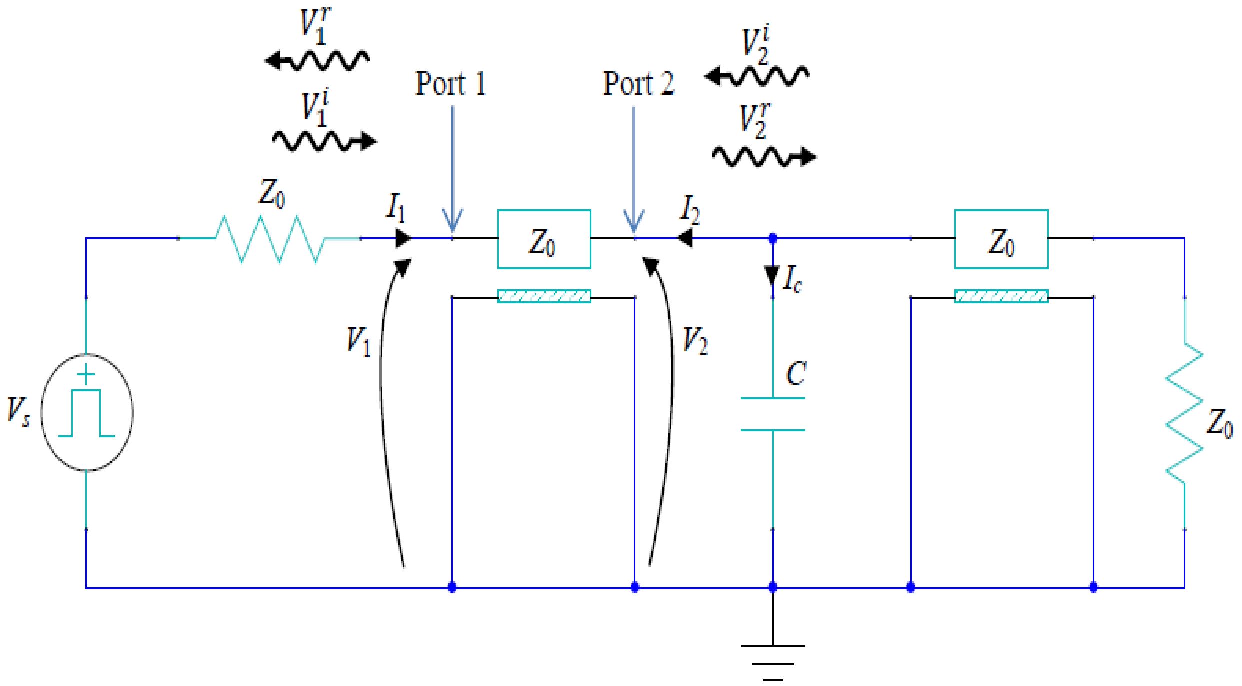
Extracting the Equivalent Reactance from Time Domain Reflectometer Waveforms

In time-domain reflectometry (TDR), a voltage pulse is launched into a device under test (DUT) and the reflections are used to assess discontinuities in the DUT. Typically, the DUT is a transmission line, and the discontinuities are due to elements such as bends, vias, or test-pads. To simulate a TDR measurement in schematic, place a TDR component at one end, run a transient simulation, and plot the time-dependent impedance Z1(t) seen by the TDR component at Port 1, the head end of the line. Discontinuities in the transmission line result in abrupt changes in Z_1(t). A capacitive obstacle such as a test-pad or SMA launch results in a trough. An inductive obstacle such as an electrically shorter and thinner section of a microstrip trace results in a peak. The height and shape of the peak or trough depend on the rise-time (see the following figure), and therefore it is important to set the rise-time of the TDR component to that of the driver connected to the transmission line in the actual design.



To assess the severity of the transmission line discontinuity, an equivalent shunt capacitance (for troughs) or series inductance (for peaks) can be computed. After running the time domain analysis of the TDR circuit, the equivalent reactance can be displayed in the Report generator, using a pair of trace characteristics. See Displaying Equivalent Reactance for TDR Results.

Note that the computed equivalent inductance L should be the same for all the plots of $Z_1(t)$ in the graph above, despite the difference in rise times. The lumped C and L are, respectively, electrostatic and magnetostatic characteristics of the discontinuity and are not influenced by the rise time. The circuit in the following figure serves as our example.



The diagram illustrates a capacitive discontinuity in a transmission line. Port 1 is the beginning of the line. Port 2 represents the point of the discontinuity.

The source voltage V_s(t) is a step voltage switched on at t=0, with rise time Tr and steady-state voltage V_0.

The source and termination impedance is Z_0, which is also the characteristic impedance of the transmission line.

Equations (1) through (4) give the formulas in summary form. A brief derivation follows the summary.

The time-dependence impedance at Port 1 is given by:

$$Z_1(t) = \frac{V_1(t)}{I_1(t)}$$

(1)

The time-dependent reflection coefficient at port 1 is given by:

$$\Gamma_1(t) = \frac{Z_1(t) - Z_0}{Z_1(t) + Z_0}$$

(2)

The equivalent capacitance for a discontinuity has the formula:

$$C = -\frac{2}{Z_0}\int_0^{\infty}\Gamma_1(t)dt$$

(3)

The equivalent inductance for a discontinuity has the formula:

$$L = 2Z_0\int_0^{\infty}\Gamma_1(t)dt$$

(4)

Here is a brief derivation for equation (3), using standard formulas (an alternative derivation is given in [1]). A similar argument derives equation (4).

The capacitance C is defined as the ratio of the charge that accumulates on the capacitor to the steady-state voltage across it. At steady state, the capacitor is fully charged, and therefore the voltage across it is determined by the voltage divider consisting of the source and load impedances. Since these impedances are equal, the steady-state voltage across the capacitor is $V_0/2$, resulting in:

$$C = \frac{2Q}{V_0}$$

(5)

The charge is defined as the time integral of the current through the capacitor:

$$Q = \int_0^{\infty} I_c(t)dt$$

(6)

We need to represent the charge and thus the capacitance in terms of the quantities shown in the circuit diagram.

Applying Kirchhoff’s current law to Port 2:

$$I_c = \frac{V_2}{Z_0} + I_2$$

(7)

We can express the capacitor current in terms of the incident voltage at port 2, which is defined as:

$$V_2^{\,i} \equiv \frac{V_2 + Z_0 I_2}{2}$$

(8)

Rearranging (8) to solve for V_2:

$$V_2 = 2V_2^{\,i} - Z_0 I_2$$

(9)

Substituting for V_2 in equation (7) and simplifying produces:

$$I_c = -\frac{Z_0 V_2^{\,i}}{2}$$

(10)

The next step is to derive a formula for the incident voltage at port 2.

Since the transmission line is assumed to be lossless, the voltage incident on port 2 is an advanced version of the voltage reflected from port 1. Represent the time delay for the transmission line segment as Δ.

$$V_2^{\,i}(t) = V_1^{\,r}(t + \Delta)$$

(11)

The reflected voltage at port 1 is related to the incident voltage at port 1 by the reflection coefficient defined in equation (2).

$$V_1^{\,r}(t) = \Gamma_1(t) V_1^{\,i}(t)$$

(12)

In turn, the incident voltage at port 1 is defined as

$$V_1^{\ i} \equiv \frac{V_1 + Z_0 I_1}{2}$$

(13)

The next step is to express the incident voltage in terms of the supply voltage V_s.

Applying Kirchhoff’s voltage law at Port 1:

$$V_1 + Z_0 I_1 \ = \ V_s$$

(14)

Substituting (14) into (13) yields:

$$V_1^{\ i} \ = \ \frac{V_s}{2}$$

(15)

Then, substituting (15) into (12), express the reflected voltage in terms of the source voltage.

$$V_1^{\ r}(t) \ = \ \frac{\Gamma_1(t) V_s(t)}{2}$$

(16)

Now substitute (16) into (11) to develop the formula for the incident voltage at port 2:

$$V_2^{\ i}(t) \ = \ \frac{\Gamma_1(t+\Delta) V_s(t+\Delta)}{2}$$

(17)

Now find the formula for the capacitor current. Substitute (17) into (10) and simplify to obtain:

$$I_c(t) \ = \ -\frac{1}{Z_0}(\Gamma_1(t+\Delta) V_s(t+\Delta))$$

(18)

Next, substitute (18) into (6) to get the formula for the charge:

$$Q \ = \ -\frac{1}{Z_0}\int_0^{\infty} \Gamma_1(t+\Delta) V_s(t+\Delta) dt$$

(19)

Then, substituting equation (19) for Q into equation (5), to get the following formula for the capacitance:

$$C = -\frac{2}{V_0 Z_0}\int_0^{\infty}\Gamma_1(t+\Delta)V_s(t+\Delta)\,dt$$

(20)

We can simplify equation (20) as it applies to the physical problem. By causality, $\Gamma_1 = 0$ for any $t<2\Delta$. Moreover, assume that rise time T_r is smaller than 2Δ, so for $t>2\Delta$, $V_s(t)$ is essentially equal to V_0.

Applying these assumptions, simplify equation (20) to produce the formula for the equivalent capacitance for a discontinuity given earlier as equation (3):

$$C = -\frac{2}{Z_0}\int_0^{\infty}\Gamma_1(t)\,dt$$

(21)

Replace the shunt capacitor with a series inductor so a similar derivation yields the equivalent inductance for a discontinuity (see equation 4):

$$L = 2Z_0\int_0^{\infty}\Gamma_1(t)\,dt$$

(22)

Guidance for Equivalent Reactance Extraction

The formulas derived in this topic are standard formulas for reactance extraction, which is derived (differently) in [1]. The extracted values for the shunt capacitance should be interpreted as follows, “if the trough between the markers are obtained for a reactive element between two transmission lines with characteristic impedance Z_0, the shunt capacitance is as computed.” Similarly, “if the peak between the markers are obtained for a reactive element between two transmission lines with characteristic impedance Z_0, the series inductance is as computed.”

If the circuit probed by the TDR probe is not a pair of ideal Z_0 transmission-lines with a reactive element between them, the computed value may differ on the actual capacitance or reactance. In particular, losses, multiple reflections, and differences in the impedances surrounding the reactive element may contribute to inaccuracies in the result.

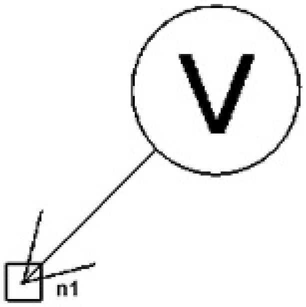
As the calculation assumes that the impedances are the same on either side of the reactive element, it is recommended that the markers be placed on points for which $Z(t)$ is the same. This value should be used in the trace characteristic computation.

Lastly, the accuracy of the trace characteristic computation may be verified by building a small equivalent circuit with the extracted reactance and transmission lines of appropriate delay. Then, running a transient analysis on the equivalent circuit and superposing its TDR response on that of the original circuit can give a sense of the accuracy of the equivalent circuit.

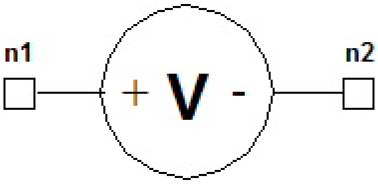
TDR References

[1] D. J. Dascher, “Measuring parasitic capacitance and inductance using TDR,” Hewlett Packard Journal, vol. 47, pp. 83–96, 1996.

Voltage Probe



Single-Ended



Differential

Voltage Probe Netlist Format

A .PRINT statement is automatically inserted in the netlist for a voltage probe that is added in the schematic. The PRINT statement appears only when there is an analysis defined for the design.

```
.PRINTanalysis_type V (n1) // Single-ended
```

```
.PRINTanalysis_type V (n1, n2) // Differential
```

n1 is the node to which the single-ended voltage probe is attached. *n1* and *n2* are the positive and negative nodes attached to a differential voltage probe. *Analysis _type* identifies the analysis.

NOTE: The single-ended voltage probe and differential voltage probe are supported for all analysis_types. For LNA analysis, the probes are ignored unless a source is specified in one of the ports. (see *PRINT Statements with Simple Values* in the Circuit Design help topics for additional information on the .PRINT statement with Nexxim analyses.

31 - Rectangular Waveguide Elements

This topic describes the following rectangular waveguide distributed elements available in Nexxim.

"Rectangular Waveguide, TE10 Mode" below

"Rectangular Waveguide Termination" on the next page

This topic also describes the rectangular waveguide substrate type.

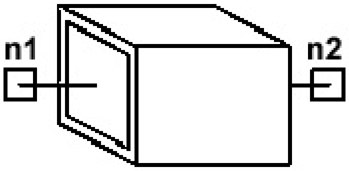
"Selecting None for the Initial Substrate" on page 31-4

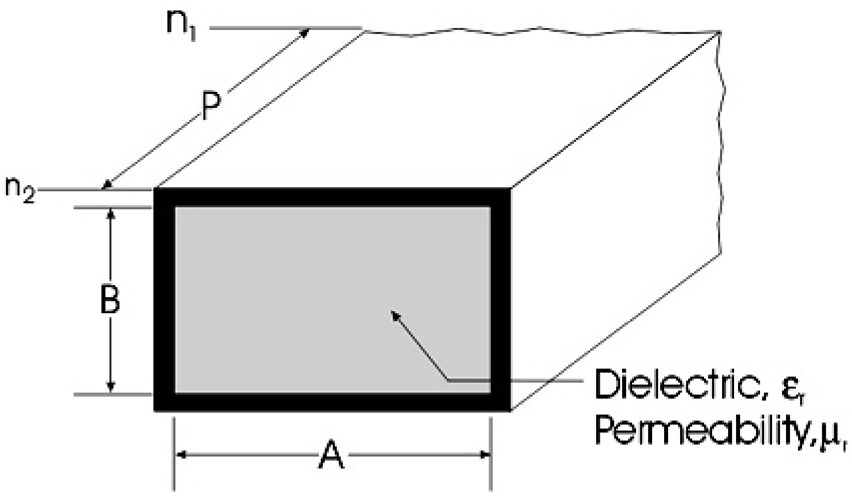
"Creating a Custom Rectangular Waveguide Substrate" on page 31-4

"Selecting a Rectangular Waveguide Substrate at the Component Level" on page 31-6

"Rectangular Waveguide Substrate Model" on page 31-6

Rectangular Waveguide, TE10 Mode





Netlist Format

An instance of a rectangular waveguide, TE10 mode has the following netlist syntax:

A*xxx n1 n2* [**A=***val*] [**B=***val*] [**P=***val*]
COMPONENT=rectangular_waveguide **SUBSTRATE=***substrate_name*

n1 and *n2* are the nodes attached to the waveguide. The entry **COMPONENT=rectangular_waveguide** identifies the element.

The **SUBSTRATE=***substrate_name* is the rectangular waveguide substrate model name selected for the design (see "Selecting None for the Initial Substrate" on page 31-4 for details.

Table 5: Rectangular Waveguide, TE10 Mode Instance Parameters

Parameter	Description	Units	Default
A	Inside width	Meter	24.13e-3
B	Inside height	Meter	11.43e-3
P	Physical length	Meter	254e-3

Netlist Example

```
A23 Port1 Port2 A=24.13e-003 B=11.43e-3 P=254e-3
+ COMPONENT=rectangular_waveguide   SUBSTRATE=RWG1
```

where RWG1, the selected layout technology or substrate type, has a definition such as:

```
.SUB RWG1 RWG(
+ UR=0.01 ER=4.4 TAND=0.02
+ MET1=1.724137931034483 T1=2.5400e-005
+ RGH=0)
```

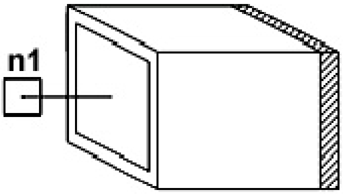
Notes

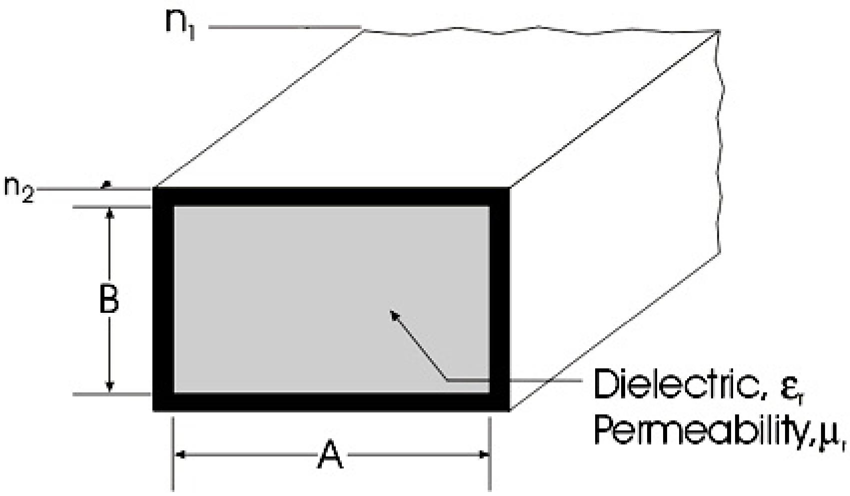
1. The program considers only the dominant **TE$_{10}$** mode, which has a cut-off wavelength of kc =2a, where a is the greater inside dimension.

References

[1] David M. Pozar, *Microwave Engineering*, John Wiley & Sons, Inc., New Jersey, Fourth Edition, 2012.

Rectangular Waveguide Termination





Netlist Format

An instance of a rectangular waveguide termination has the following netlist syntax:

A*xxx n1 n2* [**A=***val*] [**B=***val*]
COMPONENT=rectangular_waveguide_termination SUBSTRATE=*substrate_name*

n1 and *n2* arethe nodes attached to the open stub. The entry **COMPONENT=rectangular_ waveguide_termination** identifies the element.

The **SUBSTRATE=***substrate_name* is the rectangular waveguide substrate model name selected for the design (see "Selecting None for the Initial Substrate" on the next page for details.

Table 6: Rectangular Waveguide Termination, Instance Parameters

Parameter	Description	Units	Default

A	Inside width	Meter	24.13e-3
B	Inside height	Meter	11.43e-3

Netlist Example

```
A23 Port1 Port2 A=24.13e-003 B=11.43e-3
+ COMPONENT=rectangular_waveguide_termination   SUBSTRATE=RWG1
```

where RWG1, the selected layout technology or substrate type, has a definition such as:

```
.SUB RWG1 RWG(
+ UR=0.01 ER=4.4 TAND=0.02
+ MET1=1.724137931034483 T1=2.5400e-005
+ RGH=0)
```

Selecting None for the Initial Substrate

For Nexxim designs that are created with the **Schematic Editor**, the initial selection of a global substrate type is made on the **Choose Layout Technology** window that appears when you select Insert Nexxim Circuit Design on the Project menu.

However, no rectangular waveguide substrates are available in the **Choose Layout Technology** window.

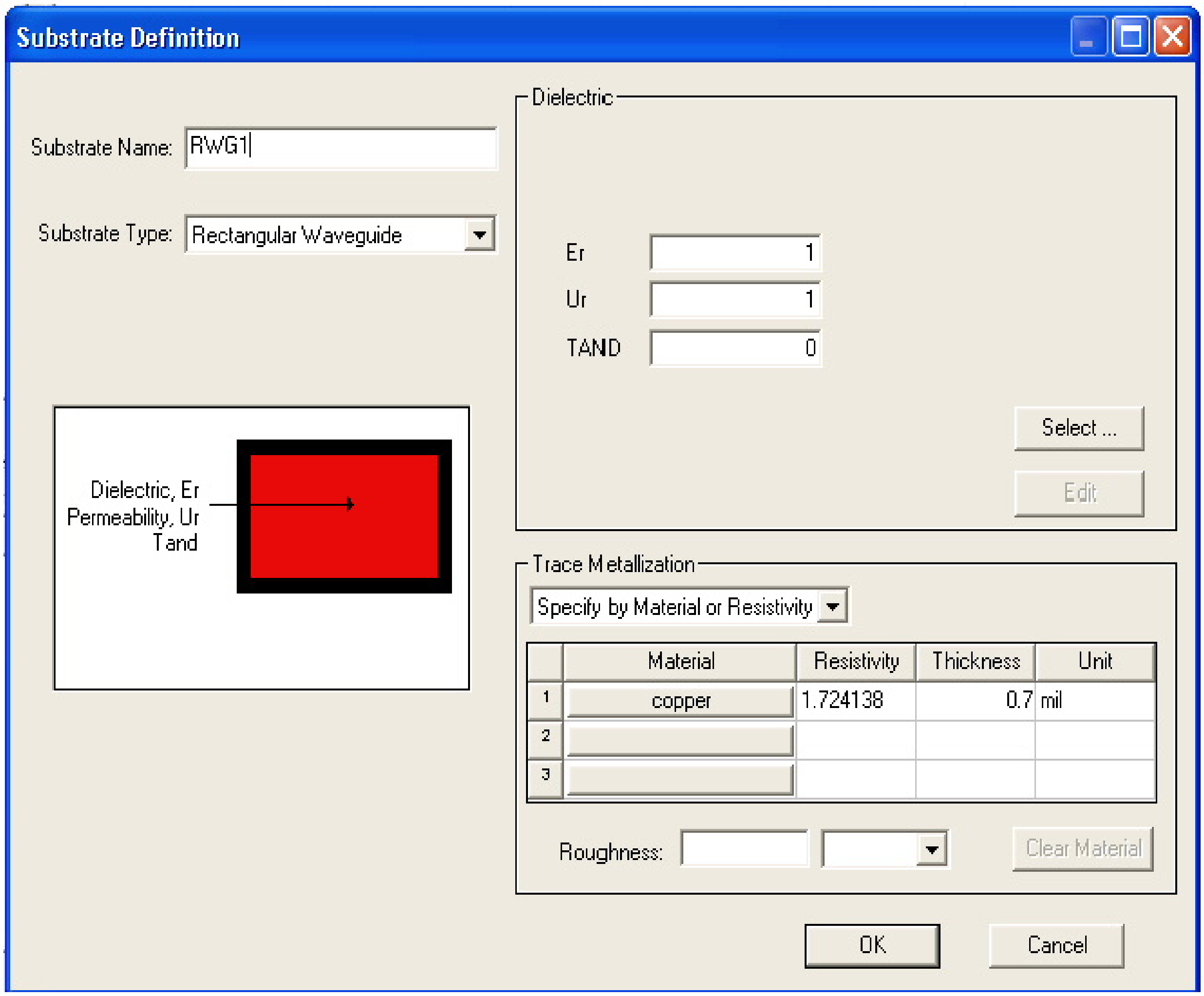
If you wish to use an rectangular waveguide substrate, you must create it as a custom substrate type.

In the **Choose Layout Technology** window, click **None**. The design opens, but no substrate type is applied to instances of distributed elements until you create a custom substrate type.

See "Creating a Custom Rectangular Waveguide Substrate" below for details.

Creating a Custom Rectangular Waveguide Substrate

To create a rectangular waveguide substrate definition, open the Nexxim design icon (e.g., “Nexxim1”, then right-click the **Add Reference Data** field. Select **Add Substrate Definition** to open the **Substrate Definition** window. Specify the name of your new substrate (the following example uses the name “RWG1”):



Substrate Name: RWG1

Substrate Type: Rectangular Waveguide

Er 1

Ur 1

TAND 0

Trace Metallization

Specify by Material or Resistivity

	Material	Resistivity	Thickness	Unit
1	copper	1.724138	0.7	mil
2				
3				

Select **Rectangular Waveguide** as the Substrate Type. Complete the Dielectric and Metallization field information. (see the "Rectangular Waveguide Substrate Model" on the next page help topic for guidelines on defining rectangular waveguide substrates.

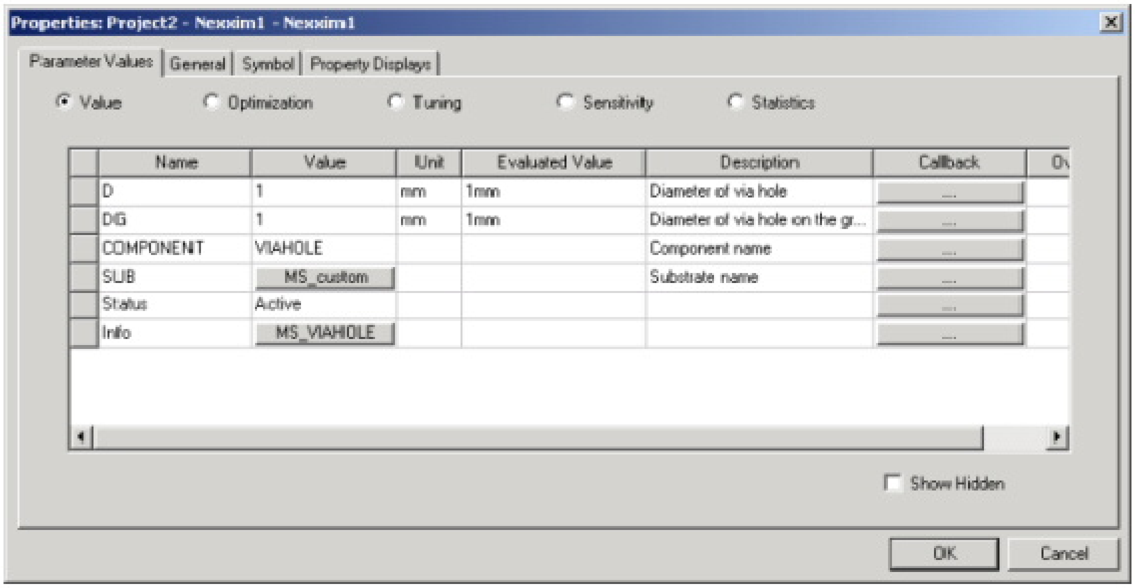
When the substrate definition is complete, click **OK**.

If you selected **None** for the global substrate type in the **Choose Layout Technology** window, the custom slotline substrate becomes the global substrate type.

When an element is instantiated , it includes a **SUBSTRATE=***substrate_name* entry in its netlist syntax. **Electronics Desktop** automatically inserts the global *substrate_name* into the internal netlist entry for the instantiated element.

Selecting a Rectangular Waveguide Substrate at the Component Level

To specify a custom substrate type, or to change to a different predefined substrate type, you must make the assignment individually for each component. Double-click the distributed element to open the **Properties** window:



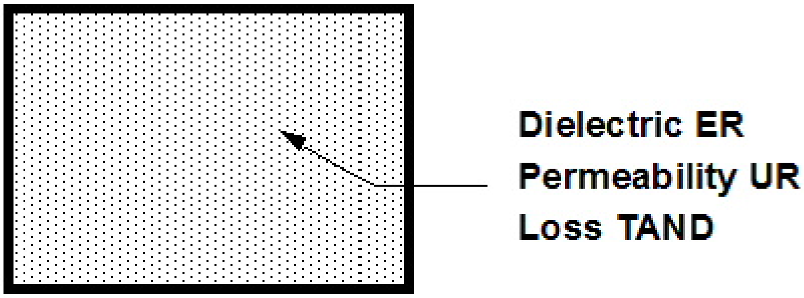
Name	Value	Unit	Evaluated Value	Description	Callback	O
D	1	mm	1mm	Diameter of via hole	...	
DIG	1	mm	1mm	Diameter of via hole on the gr...	...	
COMPONENT	VIAHOLE			Component name	...	
SUB	MS_custom			Substrate name	...	
Status	Active				...	
Info	MS_VIAHOLE				...	

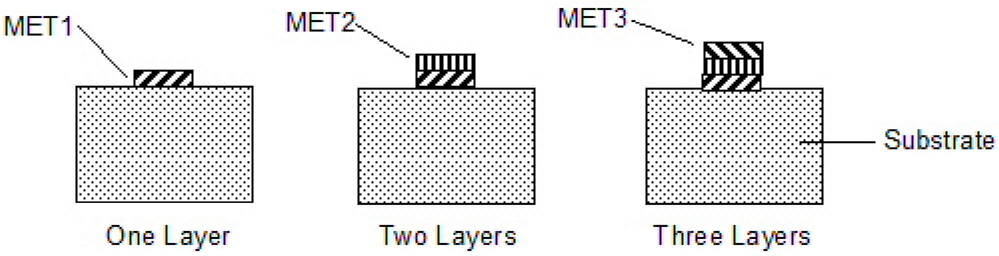
The **SUB** property identifies the substrate that is currently applied to the element. In the example above, a custom substrate type named “MS_custom” appears as the value of the **SUB** property.

To change to a different substrate type, click in the **SUB** Value field and select the appropriate substrate name as the value of the **SUB** property. Then click **OK**.

> **Note:** All distributed elements in a given design must use the same substrate type.

Rectangular Waveguide Substrate Model





metallization

Defining a Rectangular Waveguide Model

To add a rectangular waveguide substrate model to a new Nexxim design, you must add the definition to the set of substrate models.

To add a new substrate definition to an existing design, expand the **Project** icon, the **Design** icon. Right-click the **Data** icon and select **Add Substrate Definition** to open the **Substrate Definition** window. Then add the substrate name and parameters as appropriate, and click **OK**. A substrate added in this manner requires you to specify the metallization parameters explicitly.

To edit the definition of a substrate, expand the **Project** icon, the **Design** icon, the **Data** icon. Click on the icon for the substrate you wish to edit to open the **Substrate Definition** window. Add or modify the substrate parameters as appropriate, then click **OK**.

Rectangular Waveguide Substrate Model Netlist Format

The rectangular waveguide substrate model has the following netlist format:

```
.SUBsubstrate_name RWG ( [ER=val] [TAND=val] [UR=val]
+ [MET1=val] [T1=val] [MET2=val] [T2=val] [MET3=val]   [T3=val]
+ [RGH=val])
```

The *substrate_name* is the name for the substrate type used in distributed elements that refer to this substrate definition. The entry **RWG** is required to identify the rectangular waveguide substrate type. The **RWG** identifier must immediately follow the *substrate_name*.

Inside the parentheses, the labeled parameters may be entered in any order.

Table 7: Rectangualr Waveguide Substrate Parameters

Parameter	**Description**	**Unit**	**Default**
ER	Dielectric constant of substrate	None	4.5
UR	Permeability	None	1.0
TAND	Dielectric loss tangent	None	0.0
T1, **T2**, **T3**	Thickness of metal layer 1, 2, 3	Meter	0.0
MET1, **MET2**, **MET3**	Resistivity of metal layer 1, 2, 3	μOhm-cm	0.0
RGH	RMS surface roughness	Meter	0.0

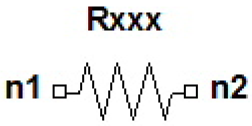
Rectangular Waveguide Substrate Model Netlist Example

```
.SUB RWG1 RWG(
+ UR=0.01 ER=4.4 TAND=0.02
+ MET1=1.724137931034483 T1=2.5400e-005
+ RGH=0)
```

32 - Resistors

This topic describes the following resistors:

Resistor



Resistor Instance Netlist Syntax

This basic resistor is available in the **Electronics Desktop** Schematic Editor. The basic resistor has only the resistance (**R**) parameter, and does not have a corresponding resistor model. Netlist versions should use the "Resistor Device" on the next page instance.

The form for the basic resistor instance is:

`R`*`xxxx n1 n2`* `[[`**`R=`**`]`*`val`*`] [`**`NOISE=0`**`|`**`1`**`] [`**`DTEMP=`***`val`*`]`

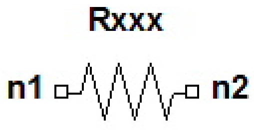
n1 is the positive node and *n2* is the negative node of the resistor. The resistance defaults to 50 Ohms in **Electronics Desktop** schematics. In a netlist, the default resistance is calculated. Optionally, set **NOISE=1** to generate noise data. Optionally, set **DTEMP** to the difference between the device temperature and the circuit temperature.

An expression can be used for the resistance value. In a netlist, the Nexxim expression parser handles the expression. See *Names, Number, Constructs, and Expressions* in the Circuit Design Technical Notes for information on expressions in Nexxim. From the component Properties window in AED, an internal parser handles the expression. See *Displaying and Editing*

Component Properties in the **Schematic Editor** topic for information on expressions in the Property window.

In a Nexxim netlist, the expression for resistance can include the special token 'HERTZ' denoting the operating frequency. When this token is detected, Nexxim uses the "Resistor, Frequency-Dependent (Netlist Only)" on page 32-8 rather than the simple resistor. From the component Property window, use the special token 'f' (or 'F') to designate the frequency. When the **Electronics Desktop** internal parser sees 'f' or 'F' in the expression, it converts the token to 'HERTZ' and passes the expression to the netlist where it is handled by the Nexxim expression parser, and Nexxim uses the frequency-dependent resistor definition.

Resistor Device



Resistor Device Instance Netlist Syntax

The general form for a resistor instance is:

R*xxxx n1 n2* [*modelname*] [[**R=**]*val*]

[[**TC1=**]*val*] [[**TC2=**]*val*]

[**M=***val*] [**DTEMP=***val*] [**SCALE=***val*]

[**L=***val*] [**W=***val*] [**C=** val] [**NOISE=***val*]

n1 is the positive node and *n2* is the negative node of the resistor. The current is assumed to flow from *n1* through the resistor to *n2*. If a model statement is provided for the resistor, the *modelname* is its name.

Table 4: Resistor Instance Parameters

Instance Parameter	Description	Unit	Default
C	Parasitic capacitance	Farad	0.0
DTEMP	Temperature difference between resistor and circuit	°C	0.0
L	Resistor length	Meter	0.0
M	Multiplier: simulates parallel	None	1.0

	resistors		
NOISE	1 = generate noise data 0 = no noise data	None	1
R	Resistance	Ohm	Calculated from geometry or set to RES (model parameter)
SCALE	Scale factor for resistance	None	1.0
TC1	Linear temperature coefficient	$°K^{-1}$	TC1R (model parameter)
TC2	Quadratic temperature coefficient	$°K^{-2}$	TC2R (model parameter)
W	Resistor width	Meter	0.0

Notes

1. In the syntax above, both *modelname* and the resistance value are shown as optional, but at least one of the two must be supplied. The *modelname* is identified by matching it to the **.MODEL** statements in the netlist. The label **R=** is optional, but the presence or absence of the **R=** label affects the interpretation of other unlabeled entries in the statement. The first unlabeled value after a *modelname* is taken to be the resistance value.
2. The syntax above shows the labels **TC1=** and **TC2=** as optional, but this option depends on the presence or absence of the resistance value, labeled or unlabeled.

- When the *modelname* is present without a resistance value, the label **TC1=** or **TC2=** must be used.
- When both *modelname* and the resistance value are present but the resistance value does not have the **R=** label, the next two unlabeled values are taken to be **TC1**, then **TC2**. To specify a value for **TC2**, either a value for **TC1** must be given as well, or the label **TC2=** must be used.
- When the resistance value is present with the **R=** label, the labels **TC1=** and **TC2=** are required.

3. Minimum Resistance Values

The minimum positive or negative resistance value is determined by the global option **RESMIN**. The default value for **RESMIN** is 1e-5 Ohm. The value can be changed only in a netlist design. Schematic designs always use the default value. **RESMIN** always has a positive value.

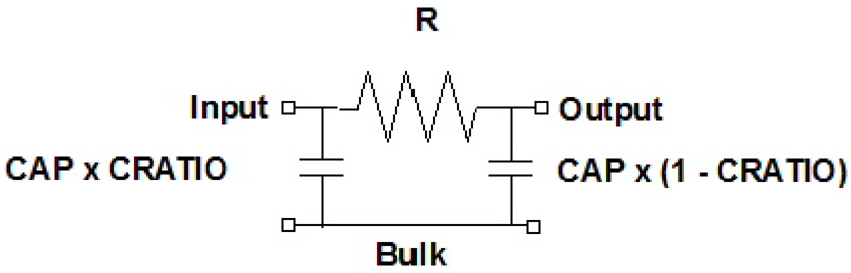
- When a resistor has been given a positive resistance less than **RESMIN**, a warning is given and the resistance is set to **RESMIN**.
- When a resistor has been given a negative value whose absolute magnitude is less than **RESMIN**, a warning is given and the resistance is set to **-RESMIN**.

- When a resistor has been given a zero value, a warning is given. If the **DEVICE_ CLEANUP** option has been set, the zero-valued resistor is replaced with a short circuit. Otherwise, the resistance is set to **RESMIN**.

See *Global Device Options* for more information on the global options.

Resistor Model

A resistor model allows for the inclusion of parasitic capacitances. If a parasitic capacitance is required, the equivalent circuit is as in the following figure:



The syntax for the resistor .MODEL statement is:

```
.MODELmodelname R [modelparameter=val] ...
```

Table 5: Resistor Model Parameters

Model Parameter	Description	Unit	Default
BULK	Reference node for parasitic capacitance	None	0 (Ground)
CAP	Default parasitic capacitance	Farad	0.0
CAPSW	Sidewall fringing capacitance	Farad/Meter	0.0
COX	Bottomwall capacitance	Farad/Meter^2	0.0
CRATIO	Parasitic capacitance allocation ratio	None	0.5
DI	Relative dielectric constant	None	0.0
DLR	Difference between physical length and drawn length	Meter	0.0
DW	Difference between physical width and drawn width	Meter	0.0
RES	Default resistance	Ohm	0.0

RSH	Sheet resistance per square	Ohm/square	0.0
SCALM	Width and length scaling factor	None	1.0
SHRINK	Reduction scale factor	None	1.0
TC1C	1st-order temperature coefficient for capacitance	°K^{-1}	0.0
TC1R	1st-order temperature coefficient for resistance	°K^{-1}	0.0
TC2C	2nd-order temperature coefficient for capacitance	°K^{-2}	0.0
TC2R	2nd-order temperature coefficient for resistance	°K^{-2}	0.0
THICK	Dielectric thickness	Meter	0.0
TNOM	Nominal temperature	°C	25.0

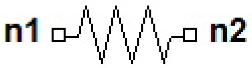
Resistor Model Netlist Example

```
R1 1 2 resistor1 R=500 dtemp=30

.MODEL resistor1 R cratio=0.75 cap=10e-12

Rspan node35 node423 R=100 TC1R=0.1 TC2R=0.05
```

Chip Resistor



Netlist Syntax

The form for a chip resistor instance is:

A*xxxx n1 n2* **R=***val* [**FESR=***val*] [**TEMP=***val*] [**TC=***val*]

COMPONENT=chipres

n1 is the positive node and *n2* is the negative node of the resistor. The current is assumed to flow from *n1* through the resistor to *n2*.

The entry **COMPONENT=chipres** identifies the element.

Table 6: Chip Resistor Instance Parameters

Instance Parameter	Description	Unit	Default
R	Resistance	Ohm	50.0
FESR	Chip resonant frequency	Hertz	1.0e9
TEMP	Temperature difference between resistor and circuit	°C	0.0
TC	Temperature coefficient	Celsius	0.0

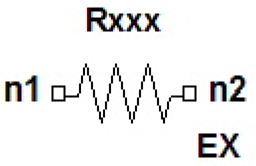
Netlist Example

```
Achipres1 1 2 R=50 FESR=2.1e9 COMPONENT=chipres
```

Notes

1. This chip resistor employs an internal model that is noncausal. The noncausal model can lead to fitting problems during transient analysis.

Resistor, Expression-Based (Netlist Only)



Instead of the standard resistor syntax with a specified resistance value, you can define the resistance by an expression, using the syntax given in this section.

> **Note:** The expression-based resistor is available for use in netlists, but is not supported in the Components window of the **Electronics Desktop Schematic Editor**.

Expression-Based Resistor Instance Netlist Syntax

```
Rxxxx n1 n2 [modelname] [R=]'expression'

[[TC1=]val]   [[TC2=]val]

[M=val]   [DTEMP=val] [SCALE=val]

[L=val] [W=val] [C= val]
```

n1 is the positive node and *n2* is the negative node of the resistor. The current is assumed to flow from *n1* through the resistor to *n2*. If a model statement is provided for the resistor, the *modelname* is its name.

The expression defines the resistance as a function of voltages and currents in the netlist. The expression should be enclosed in single quotation marks. The label **R=** is optional. The first unlabeled value after a *modelname* is taken to be the resistance value.

The syntax above shows the labels **TC1=** and **TC2=** as optional, but this option depends on the presence or absence of the resistance value, labeled or unlabeled:

- When both *modelname* and the resistance value are present but the resistance value does not have the **R=** label, the next two unlabeled values are taken to be **TC1**, then **TC2**. To specify a value for **TC2**, either a value for **TC1** must be given as well, or the label **TC2=** must be used.
- When the resistance value is present with the **R=** label, the labels **TC1=** and **TC2=** are required.

Table 7: Expression-Based Resistor Instance Parameters

Instance Parameter	Description	Unit	Default
C	Parasitic capacitance	Farad	No parasitic capacitance
DTEMP	Temperature difference between resistor and circuit	°C	0.0
L	Resistor length	Meter	0.0
M	Multiplier: simulates parallel resistors	None	1.0
SCALE	Scale factor for resistance	None	1.0
TC1	Linear temperature coefficient	$°K^{-1}$	TC1R (model parameter)
TC2	Quadratic temperature coefficient	$°K^{-2}$	TC2R (model parameter)
W	Default resistor width	Meter	0.0

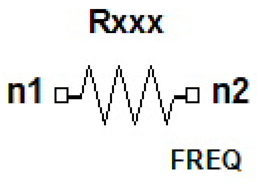
Expression-Based Resistor Instance Netlist Example

```
R25 IN1 N23 R='V(IN1,N23)/2.0e-5'
```

Expression-Based Resistor Model

The model netlist syntax and parameters for the expression-based resistor are identical to those for the standard resistor (see Resistor Model).

Resistor, Frequency-Dependent (Netlist Only)



Instead of the standard resistor syntax with a specified resistance value, define the resistance by an expression involving the frequency, using the syntax given in this topic.

> **Note:** The frequency-dependent resistor is available for use in netlists, but is not supported in the Components window of the **Electronics Desktop Schematic Editor**.
>
> Parasitic capacitance is ignored in this implementation.
>
> The frequency-dependent resistor is supported only for frequency-domain analyses such as AC and LNA. To run a time-domain analysis such as TRAN on a circuit including a frequency-dependent resistor , set the **TRAN_EVAL_FREQ** parameter to a constant frequency value.

Frequency-Dependent Resistor Instance Netlist Syntax

The general form for a frequency-dependent resistor instance is:

```
Rxxxx n1 n2 [modelname] [R=]'freq-dependent-expr'

[[TC1=]val]   [[TC2=]val] [M=val]   [SCALE=val]

[TRAN_EVAL_FREQ=val]
```

n1 is the positive node and *n2* is the negative node of the resistor. The current is assumed to flow from *n1* through the resistor to *n2*. If a model statement is provided for the resistor, the *modelname* is its name. The *modelname* is identified by matching it to the **.MODEL** statements in the netlist.

The frequency-dependent expression should be enclosed in single quotation marks. The token **HERTZ** can be used in the expression to indicate the frequency as supplied by the analysis. The circuit frequency is available to the model each time the model equations are evaluated. The label **R=** is optional. The first unlabeled value after a *modelname* is taken to be the resistance.

The syntax above shows the labels **TC1=** and **TC2=** as optional, but this option depends on the presence or absence of the resistance value, labeled or unlabeled:

- When both *modelname* and the resistance value are present but the resistance value does not have the **R=** label, the next two unlabeled values are taken to be **TC1**, then **TC2**. To specify a value for **TC2**, either a value for **TC1** must be given as well, or the label **TC2=** must be used.
- When the resistance value is present with the **R=** label, the labels **TC1=** and **TC2=** are required.

The frequency-dependent resistance expression is evaluated by the Nexxim expression parser, and follows the rules for operands defined in *Names, Number, Constructs, and Expressions* in the Circuit Design Technical Notes. In particular, the Nexxim parser cannot accept complex numbers as operands or arguments to built-in functions.

When the parameter **TRAN_EVAL_FREQ** is provided, Nexxim can run a transient (time-domain) analysis, substituting the value of **TRAN_EVAL_FREQ** for the variable **HERTZ** to produce a constant frequency value for the transient analysis.

Table 8: Frequency-Dependent Resistor Instance Parameters

Instance Parameter	Description	Unit	Default
L	Resistor length	Meter	0.0
M	Multiplier: simulates parallel resistors	None	1.0
R	Resistance	Ohm	Calculated from geometry or set to RES (model parameter)
SCALE	Scale factor for resistance	None	1.0
TC1	Linear temperature coefficient	$°K^{-1}$	TC1R (model parameter)
TC2	Quadratic temperature coefficient	$°K^{-2}$	TC2R (model parameter)
TRAN_EVAL_FREQ	Frequency to use for transient analysis	Hertz	0.0
W	Resistor width	Meter	0.0

Frequency-Dependent Resistor Instance Netlist Examples

Frequency-domain analysis:

```
R1 1 2 resistor1 R='1e-9*HERTZ + 50' dtemp=30
.LNA POI 4 -1e9 -1e6 1e6 1e9
```

Time-domain analysis:

```
R1 1 2 resistor1 R='1e-9*HERTZ + 50' TRAN_EVAL_FREQ=50e9
.TRAN 0.01ns 10ns
```

Frequency-Dependent Resistor Model

The model netlist syntax and parameters for the frequency-dependent resistor are identical to those for the standard resistor (see Resistor Model).

Resistor, Ideal Tuner (Netlist Only)

> **Note:**
> 1. The ideal tuner resistor is required in a netlist-based design only for Load-Pull Analysis, where it is necessary to use a port with a variable reflection coefficient. For schematic designs created within Ansys Electronics Desktop, the load-pull analysis setup creates an ideal tuner automatically on the selected schematic port. For this reason, no Ideal Tuner element is available in the Schematic Editor interface.

Netlist Format

The ideal tuner defines a port for Load-Pull Analysis. The ideal tuner syntax is based on the Resistor device:

```
Rxxxx n1 n2 PORTNUM= val
[GAMMA_REAL=val GAMMA_IMAG=val]

GAMMA_MAG=val GAMMA_ANG=val

[REF_REAL=val] [REF_IMAG=val]
[TUNER_FREQS=[val [,val...]]]
[Z_FREQS=[val [,val...]]]
[Z_REAL=[val [,val...]]]
[Z_IMAG=[val [,val...]]]
[RDEF= val] [XDEF= val]
[RDC= val]
```

n1 is the positive node and *n2* is the negative node of the tuner. The current is assumed to flow from *n1* through the tuner to *n2*.

The reflection coefficient gamma (Γ) can be specified using EITHER the **GAMMA_REAL** /**GAMMA_IMAG** parameters OR the **GAMMA_MAG** /**GAMMA_ANG** parameters, but not both. Typically, the **GAMMA_MAG** /**GAMMA_ANG** parameters are used.

In the syntax above, the bold brackets **[ ]** are required when the list of values contains more than one element.

Table 9: Ideal Tuner Instance Parameters

Instance Parameter	Description	Unit	Default
PORTNUM	Port number (must be nonnegative integer)	None	None
GAMMA_REAL	Real part of reflection coefficient	Ohm	0.0
GAMMA_IMAG	Imaginary part of reflection coefficient	Ohm	0.0
GAMMA_MAG	Magnitude of reflection coefficient	Ohm	None
GAMMA_ANG	Angle of reflection coefficient	Radian	None
REF_REAL	Real part of reference impedance	Ohm	50.0
REF_IMAG	Imaginary part of reference impedance	Ohm	0.0
TUNER_FREQS	Tuner frequencies	Hertz	0.0
Z_FREQS	Cluster frequencies	Hertz	None
Z_REAL	Real parts of cluster impedances	Ohm	None
Z_IMAG	Imaginary parts of cluster impedances	Ohm	None
RDEF	Default resistance of tuner	Ohm	50
XDEF	Default reactance of tuner	Ohm	0.0
RDC	DC resistance of tuner	Ohm	50

Ideal Tuner Netlist Example

The netlist sets up a load-pull analysis by defining netlist parameters ZRho (sample impedance) and ZAng (angle of sample impedance), using these netlist parameters to set an ideal tuner element, and setting up sweeps of the ZRho and ZAng parameters as part of the HB analysis statement. The bolded lines in the following netlist show the additions for the load-pull analysis, including the ideal tuner element.

```
* Nexxim Load-Pull Netlist Example

.PARAM Freq1=1.5e9
.PARAM Freq2=2.2e9
```

```
.PARAM ZRho=1 // Sample impedance for load-pull

.PARAM ZAng=0 // Sample impedance angle



V1 net_0 0 DC=0.5 SIN(0 0.5 Freq1 0 0 0)

V2 net_0 0 DC=0.5 SIN(0 0.5 Freq2 0 0 0)

R2 net_0 Port1 1000



RPort1 Port1 0 PORTNUM=1 // Ideal tuner element

+ GAMMA_MAG=ZRho GAMMA_ANG=ZAng // Reflection coefficient

+ REF_REAL=50 REF_IMAG=0 // Reference impedance
+ TUNER_FREQS=[Freq1, Freq2] // Main tuner frequencies
+ Z_FREQS=['2*Freq1-Freq2', '2*Freq2-Freq1'] // Cluster freqs
+ Z_REAL=[100, 100] Z_IMAG=[0.5, 0.5] // Cluster impedances
+ RDC=50 // Tuner Resistance at DC
+ RDEF=50 XDEF=0 // Default tuner impedance for all frequencies



.HB

+ TONES=[Freq1, Freq2] MAXK=[2, 2]

+ SWEEP // Sweeps of ZRho and ZAng implement the load-pull

+ ZRho LIN 11 0 1

+ ZAng LIN 13 0 6.283185307

.END
```

Notes

1. The ideal tuner resistor is required in a netlist-based design only for Load-Pull Analysis, where it is necessary to use a port with a variable reflection coefficient. For schematic

designs created within Ansys Electronics Desktop, the load-pull analysis setup creates an ideal tuner automatically on the selected schematic port. For this reason, no Ideal Tuner element is available in the Schematic Editor interface.

2. At the frequencies specified by the **TUNER_FREQS** list, Nexxim load-pull analysis computes the input impedance Z of an ideal tuner on the following formula:

$$Z = Z_r \times \frac{(1-\Gamma)}{(1+\Gamma)}$$

Where Γ is the reflection coefficient and Z_r is the reference impedance of the tuner. The tuner instance parameters define Γand Z_r. The impedance calculation is performed over a combined sweep of **GAMMA_MAG** and **GAMMA_ANG**. **GAMMA_MAG** is typically swept over a range from zero to one, and **GAMMA_ANG** is swept over a range of zero to 2π (6.283185307) radians. At each sweep point, a harmonic balance is performed to solve for the circuit responses at the calculated tuner impedance.

3. At the frequencies specified in the **Z_FREQS** list, the impedance is taken on the corresponding **Z_REAL** and **Z_IMAG** lists.
4. When no tuner frequency or cluster freqeuency matches the current HB frequency, the default impedance given by **RDEF** and **XDEF** is used.
5. The DC resistance is given by **RDC** for time-domain analyses.

Resistor, Port Impedance (Netlist Only)

Netlist Format

The port impedance resistor defines an input/output port for Linear Network Analysis (LNA) in a netlist design.

The netlist form for a port impedance resistor instance is:

```
Rxxxx n1 n2 PORTNUM= val [RZ=val IZ=val]
[NOISE=val [NOISEVEC=[f1,psd1,... fn,psdn]] [NOISETEMP= val]]
```

n1 is the positive node and *n2* is the negative node of the resistor. The current is assumed to flow from *n1* through the resistor to *n2*.

Table 10: Port Impedance Resistor Instance Parameters

Instance Parameter	Description	Unit	Default
PORTNUM	Port number (must be nonnegative integer)	None	Required
RZ	Real part of port impedance	Ohm	50.0

IZ	Imaginary part of port impedance	Ohm	0.0
NOISE	1 = generate noise data 0 = no noise data	None	0
NOISEVEC	List of shot noise frequencies (f1...fn) and corresponding noise power spectral densities (psd1...psdn), in pairs. The sequence of frequencies must be monotonically non-decreasing.	Hertz, Volt ^{2} /Hertz	None
NOISETEMP	Temperature for thermal noise data	°C	16.85
W	Resistor width	Meter	0.0

Port Impedance Resistor Instance Netlist Example

```
Rport1 IN1 0 PORTNUM=1 RZ=50 IZ=1e-3
+ NOISE=1 NOISEVEC=[1e3,1e-22,5e9,43e-22] NOISETEMP=25
```

```
Rport2 IN1 0 PORTNUM=2 RZ=50 IZ=0
```

```
.OPTIONS ZERO_PORT_VALUES=1
```

Notes

1. The port impedance resistor is required in a netlist-based design only for Linear Network Analysis, where it is necessary to represent a port as an impedance. For schematic designs created within Ansys Electronics Desktop, the interface port element inserts a port impedance resistor automatically. For this reason, no Port Impedance Resistor element is available in the **Schematic Editor** interface.
2. Each port impedance resistor must be oriented in the circuit so the direction of current flow is outward from the circuit at every port. Reversing this orientation can lead to undesirable results such as reversing the sign of the S-parameters.
3. The **PORTNUM** parameter specifies the port number, which can be any nonnegative integer.
4. **RZ** and **IZ** are the real and imaginary parts of the port impedance. If they are omitted, the default is RZ = 50 Ohms, IZ = 0. **RZ** and **IZ** are valid for all the small-signal analyses (AC, HB, LNA, and Noise). **IZ** is ignored by DC and Transient analyses.
5. The **NOISE** parameter turns noise calculations on (1) or off (0). When **NOISE** is on, the resistor syntax can include the **NOISEVEC** and **NOISETEMP** parameters. The total noise is the sum of shot noise and thermal noise.
6. The **NOISEVEC** group box specifies the frequencies and power spectral densities for the shot noise component for a TV noise or oscillator phase noise analysis. The list must contain an even number of values inside the brackets, so each frequency has a corresponding power spectral density value. An odd number of values generates an error.

The sequence of frequencies must be monotonically non-decreasing. If a frequency is not greater than or equal to the previous one in the list, an error occurs. If **NOISEVEC** is omitted, the shot noise behavior is similar to that of a standard resistor.

7. The **NOISETEMP** parameter specifies the temperature at which thermal noise is calculated, using the formula [4*K*×**NOISETEMP** /**RZ**], where *K* is Boltzmann’s constant, **NOISETEMP** and **RZ** are the parameter values.

The default value of **NOISETEMP** (290° K) is the IEEE standard 16.85° C. To deactivate thermal noise, set **NOISETEMP** to 0 (zero).

8. When port impedance resistors are present, the option **ZERO_PORT_VALUES=1** must be set in the netlist to obtain a correct LNA. When the option **ZERO_PORT_VALUES=1** is in effect, the port impedance is shorted.

33 - S-Parameter Elements

This topic describes the frequency-dependent S-parameter element, the SP model for frequency-dependent elements, the S model for frequency-dependent elements described in Touchstone files, and the chain-based ABCD element.

Related Topics:

"S-Element" below

"SP Frequency Dependent Data Model" on page 33-6

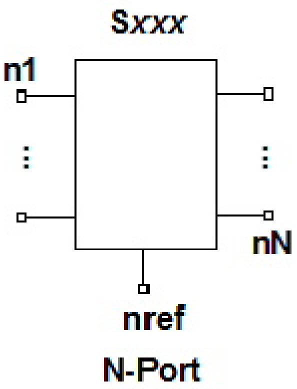
"S Frequency Dependent Data Model" on page 33-13

S-Element Options Reference

"Equation Based S Parameter Element " on page 33-25

"Chain-Based ABCD Element (Netlist Only) " on page 33-26

S-Element



S-Element Instance Netlist Format

The S-element is an N-port (N+1 terminal) element characterized by a set of frequency-dependent scattering (S) parameters. The Nexxim netlist parser recognizes several netlist formats for the S-element, to allow for variations in models and in reference nodes.

(see *Importing Network Design Data* in the **Schematic Editor** documentation for details on the use of the N-port element.

S Model or SP Model, Common Reference Node

The first format references either an S-model or an SP-model, using a common reference for all ports:

```
Sxxx n1 ... nN nref FQMODEL=modelname [Zo=val[,val ...]]
[M=val] [PASSIVE=val] [NOISEMODEL=external|internal|none]
[unused_nodes=[(node,val),...]] [DELAYHANDLE=0|1]
[LOWPASS=0|1|2|10|14|15|16]
```

n1 through *nN* are the N signal nodes. *nref* is the voltage reference node common to all signal nodes.

FQMODEL Parameter

FQMODEL indicates that *modelname* is the name of an SP or S model defined elsewhere in the netlist. The SP model specifies the frequency-dependent data (see "SP Frequency Dependent Data Model" on page 33-6). The S model references frequency-dependent data from a file in the Touchstone® format (Touchstone® is a registered trademark of Agilent Corporation.) See "S Frequency Dependent Data Model" on page 33-13. The **FQMODEL** format is the one used for netlists generated from schematics.

Zo Parameter

Zo is a comma-separated list of reference impedances for the ports in the device. When only one value is supplied, it is used as the frequency-independent reference impedance for all ports. Multiple values are applied to the ports in the order of the listing. The default for **Zo** is 50 ohms.

M Parameter

M is a device multiplier, in effect creating multiple, parallel N-ports with identical node connections. The default for parameter **M** is 1.

PASSIVE Parameter

PASSIVE controls passivity checking and enforcement. By default, the input S-parameter data is checked for passivity by doing a singular value decomposition at each frequency point. If any of the singular values are greater than unity, the worst violation is reported in a warning message, along with the frequency at which it occurs.

- When **PASSIVE=1** has been set, the passivity violations are reported in terms of the minimum eigenvalue of **I - S' * S**, and violations larger than 0.01% cause an error message.
- When **PASSIVE=2** has been set, the passivity of the state-space fit to the data is checked, and if there are any violations of passivity, the worst errors are reported.

NOISEMODEL Parameter

NOISEMODEL controls noise calculations for DC Analysis and for frequency-domain analyses such as Harmonic Balance. Time-domain analyses do not use **NOISEMODEL**.

- With the default setting, **NOISEMODEL=external**, Nexxim uses external noise data on the Touchstone file or dynamic link object when it is available. If no external noise data is available, Nexxim uses its internal noise model.
- With the setting **NOISEMODEL=internal**, Nexxim uses its internal noise model. External data is ignored.
- With the setting **NOISEMODEL=none**, no noise calculation is done. External data is ignored.

The S-Element option **NOISEMODEL** sets the noise model for all S-Element instances. The **NOISEMODEL** parameter on an S-Element instance overrides the global option.

See *Noise in S-Parameter Elements* in the Circuit Design help topics.

Unused_nodes Parameter

The parameter **unused_nodes** enables port reduction, excluding unconnected device ports on the calculations. Brackets open and close the list of unconnected ports. Each entry in the list is a parenthesized pair, (*node*, *val*). The *node* item is the name of the unconnected port or terminal on the component symbol, and the *val* item specifies the resistance to ground, using the following conventions:

- 0 = Connect directly to ground.
- -1 = Leave open (connect to infinite resistance)
- Any other value = Resistance to ground in ohms

The port reduction algorithm takes into consideration any termination for unconnected ports specified on the Terminals tab when the component is edited.

See *Components Terminals Tab* in the Circuit Design help topics for details.

The **unused_node** s parameter enables port reduction only for unconnected ports. The related **s_element.reduce** option eliminates any ports on the component that are connected directly to ground in the netlist, saving additional compute time. See .

DELAYHANDLE Parameter

DELAYHANDLE controls the processing of delays when the Convolution method is being used. By default, **DELAYHANDLE=0** or **OFF**, so S-elements do not process delays from incoming sources. When the **convolution=1** method is used to process S-parameter data, delay handling can be enabled (the HSPICE S-model parameter **DELAYHANDLE=1** or **ON** is the same as **convolution=1**). Setting **DELAYHANDLE=1** on an S-element conditions that S-element to process delays.

LOWPASS Parameter

LOWPASS controls the extrapolation method for low-frequency data points that are not supplied in the Touchstone file.

Table 8: S-Element LOWPASS Parameter

LOWPASS	Description
0	Cut off
1	Use the magnitude of the lowest point
2	Linear interpolation using the magnitude of the two lowest points
10	Linear interpolation using magnitude and phase of the two lowest points
14	Spline interpolation using all the points, including negative frequencies
15	Causal interpolation using all the points, including negative frequencies
16	LOWPASS=15 for transient analysis, LOWPASS=10 for LNA-based analyses

The default for **LOWPASS** is **16**. With this setting, the default for transient analysis is **LOWPASS=15**, the default for Linear Network Analysis (LNA) or Harmonic Balance is **LOWPASS=10**.

With **LOWPASS=0**, **1**, **2**, or **10**, interpolation extends down to and including 0 Hz. With **LOWPASS=14** or **15**, Nexxim calculates the S-parameters at negative frequencies and uses interpolation to estimate the missing data points. Low-frequency S-parameters estimated by spline interpolation (**LOWPASS=14**) are noncausal, potentially yielding inaccurate results.

S Model, Common Reference Node

A second syntax references an S-model (Touchstone file model), using a common reference node for all the ports:

```
Sxxx n1 ... nN nref MNAME=Smodelname [M=val] [PASSIVE=val]
[unused_nodes=[(node,val),...]]
```

n1 through *nN* are the N signal nodes or ports. *nref* is the voltage reference node common to all signal nodes. With the keyword **MNAME**, the *Smodelname* is the name of an S model defined elsewhere in the netlist. **M** is a device multiplier, **PASSIVE** controls the reporting of passivity violations, and **unused_nodes** controls port reduction, as discussed above.

S Model, Ground Reference

A third format references an S-model (Touchstone file model), using system ground as a voltage reference for all ports:

```
Sxxx n1 ... nN MNAME=modelname [Zo=val[,val ...]] [M=val]
[PASSIVE=val] [unused_nodes=[(node,val),...]]
```

n1 through *nN* are the N signal nodes. Node zero (system ground) becomes the voltage reference node common to all signal nodes. Node zero is understood, and is not shown in the syntax.

With the keyword **MNAME**, the *Smodelname* is the name of an S model defined elsewhere in the netlist. The S model references frequency-dependent data from a file in the Touchstone® format (Touchstone® is a registered trademark of Agilent Corporation.) See "S Frequency Dependent Data Model" on page 33-13.

Zo is a list of reference impedances for the ports in the device. When only one value is supplied, it is used as the frequency-independent reference impedance for all ports. Multiple values are applied to the ports in the order of the listing. The default for **Zo** is 50 ohms.

M is a device multiplier, **PASSIVE** controls the reporting of passivity violations, and **unused_nodes** controls port reduction, as discussed above.

S Model, Multiple References

A fourth syntax references an S-model (Touchstone file model) using multiple reference nodes, one for each port:

```
Sxxx n1 ref1 n2 ref2 [ ... nN refN] MNAME=Smodelname [M=val]
[PASSIVE=val] [unused_nodes=[(node,val),...]]
```

n1 through *nN* are the N signal nodes or ports. *ref1* through *refN* are the N voltage reference nodes, one reference node for each signal node. With the keyword **MNAME**, the *Smodelname* is the name of an S model defined elsewhere in the netlist. The S-model in turn references a Touchstone file that specifies the number of ports. (See "S Frequency Dependent Data Model" on page 33-13.) With this syntax, the total number of nodes must be twice the number of ports (i.e., it must specify a separate reference node for each port).

M is a device multiplier, **PASSIVE** controls the reporting of passivity violations, and **unused_nodes** controls port reduction, as discussed above.

> **Note:** The S-element syntax with multiple reference nodes should be used with care. Like all circuit simulators, Nexxim requires a DC path to ground from all nodes. Since the S-element is defined in terms of voltage differences between ports only, it does not provide any DC paths to ground. Therefore, either users must provide a DC path to ground from every positive and negative terminal of the S-element, or Nexxim adds large resistors as part of the DC alpha-beta continuation. In either case, having significant sections of a circuit separated by large resistances puts a strain on Nexxim's transient solver, and can lead to inaccurate answers or convergence difficulties.

S-Element Instance Netlist Examples

```
S1 1 0 FQMODEL=SP_1port Zo=50
```

```
S2 4 5 0 MNAME=S_2port
```

SP Frequency Dependent Data Model

The SP model provides frequency-dependent data in matrix form for S-element or W-element models. The SP model is implemented as the standard frequency response model described in the follow section.

Frequency Response Model

The SP frequency response model has the following netlist format.

```
.MODELmodelname SP [SPACING=LINEAR|NONUNIFORM]

[N=matrix_dimension] [VALTYPE=CARTESIAN|POLAR|DECIBEL|REAL]

[MATRIX=SYMMETRIC|HERMITIAN|NONSYMMETRIC]

FSTART=freq0 FSTOP=freqN

DATA=[num_freqs matrix_data]| DATAFILE=file_reference
```

Spacing between frequency points is linear or uniform, with a frequency increment of

(*freq0* - *freqN*)/(*num_freqs* - 1)

All frequencies are specified in hertz.

The frequency response model specifies the frequency-dependent response of the element with a sequence of matrices, one for each frequency. Parameter **N** is the number of signals or ports, which determines the full dimension of each matrix, N × N. The default is N=1.

DATA Entry

The frequency-dependent data can be provided in a **DATA** entry that is part of the .MODEL statement, or in a separate file identified in a **DATAFILE** reference in the .MODEL statement. The use of a separate data file is discussed in the later section Data Files.

The structure of the **DATA** entry depends on the number of frequencies given by the *num_freqs* entry, the type of the data matrices as specified by the **MATRIX** parameter, and on the type of the data, real or complex. In the definitions that follow, use the following algebraic conventions:

q = *num_freqs*, the number of frequencies.

h*ij*(s*k*) = the response at port *i* due to the input at port *j*, at the *k*th frequency s,

where $1 \le i,j \le N$ and $1 \le k \le q$

hij_{re} = real part of h*ij*, hij_{im} = imaginary part of h*ij*.

Spaces or commas may be used as the delimiters.

MATRIX=SYMMETRIC is the default. In a symmetric matrix, h*ij* = h*ji* for all *i*,*j*. The DATA points specify only the lower-triangular portion of each matrix, i.e., the portion of the matrix for which $j \leq i$, where *i* is the row number and *j* is the column number.

The structure of the **DATA** entry for a linear symmetric matrix of real data is:

```
DATA=[ q

+ h11(s1)

+ ...

+ hN1(s1) ... hNN(s1)

...

+ h11(sq)

+ ...

+ hN1(sq) ... hNN(sq)

+ ]
```

For example, for a two-port system with symmetric linear real response over two frequencies, the .MODEL statement has the structure:

```
.MODEL twop1 SP SPACING=LINEAR N=2 MATRIX=SYMMETRIC

FSTART=1.0e+3 FSTOP=2.0e+3

DATA=[ 2

+ h11(s1)

+ h21(s1) h22(s1)

+ h11(s2)

+ h21(s2) h22(s2)

+ ]
```

The structure of the **DATA** entry for a linear symmetric matrix of complex data is:

```
DATA=[ q

+ h11_re(s1) h11_im(s1)

+ ...
```

+ hN1$_{re}$(s1) hN1$_{im}$(s1) ... hNN$_{re}$(s1) hNN$_{re}$(s1)

...

+ h11$_{re}$(sq) h11$_{im}$(sq)

+ ...

+ hN1$_{re}$(sq) hN1$_{im}$(sq) ... hNN$_{re}$(sq) hNN$_{re}$(sq)

+]

For example, for a two-port system with symmetric linear complex response over two frequencies, the .MODEL statement has the structure:

```
.MODEL twop2 SP SPACING=LINEAR N=2 MATRIX=SYMMETRIC

FSTART=1.0e+3 FSTOP=2.0e+3

DATA=[ 2
```

+ h11$_{re}$(s1) h11$_{im}$(s1)

+ h21$_{re}$(s1) h21$_{im}$(s1) h22$_{re}$(s1) h22$_{re}$(s1)

+ h11$_{re}$(s2) h11$_{im}$(s2)

+ h21$_{re}$(s2) h21$_{im}$(s2) h22$_{re}$(s2) h22$_{re}$(s2)

+]

MATRIX=HERMITIAN. In a hermitian matrix, the data is complex and h*ij* = h*ji** for all *i*,*j*, where * denotes the complex conjugate. As with symmetric matrices, the DATA points for a hermitian matrix specify only the lower-triangular portion of each matrix, i.e., the portion of the matrix for which $j \le i$, where *i* is the row number and *j* is the column number. The DATA structure is the same as the one given above for the symmetric matrix of complex data.

MATRIX=NONSYMMETRIC. For nonsymmetric matrices, the DATA must specify the full matrix of real or complex data.

The structure of the **DATA** entry for a nonsymmetric matrix of real linear data is:

```
DATA=[ q

+ h11(s1) ... h1N(s1)

+ ...

+ hN1(s1) ... hNN(s1)

...

+ h11(sq) ... h1N(sq)
```

```
+ ...

+ hN1(sq) ... hNN(sq)

+ ]
```

For example, for a two-port system with nonsymmetric linear real response over two frequencies, the .MODEL statement has the structure:

```
.MODEL twop3 SP SPACING=LINEAR N=2 MATRIX=NONSYMMETRIC

FSTART=1.0e+3 FSTOP=2.0e+3

DATA=[ 2

+ h11(s1) h12(s1)

+ h21(s1) h22(s1)

+ h11(s2) h12(s2)

+ h21(s2) h22(s2)

+ ]
```

The structure of the **DATA** entry for a nonsymmetric matrix of complex linear data is:

DATA=[q

+ $h11_{re}$(s1) $h11_{im}$(s1) ... $h1N_{re}$(s1) $h1N_{im}$(s1)

+ ...

+ $hN1_{re}$(s1) $hN1_{im}$(s1) ... hNN_{re}(s1) hNN_{re}(s1)

...

+ $h11_{re}$(sq) $h11_{im}$(sq) ... $h1N_{re}$(sq) $h1N_{im}$(sq)

+ ...

+ $hN1_{re}$(sq) $hN1_{im}$(sq) ... hNN_{re}(sq) hNN_{re}(sq)

+]

For example, for a two-port system with nonsymmetric linear complex response over two frequencies, the .MODEL statement has the structure:

```
.MODEL twop4 SP SPACING=LINEAR N=2 MATRIX=NONSYMMETRIC

FSTART=1.0e+3 FSTOP=2.0e+3

DATA=[ 2
```

+ $h11_{re}$(s1) $h11_{im}$(s1) $h12_{re}$(s1) $h12_{im}$(s1)

+ $h21_{re}$(s1) $h21_{im}$(s1) $h22_{re}$(s1) $h22_{re}$(s1)

+ $h11_{re}$(s2) $h11_{im}$(s2) $h12_{re}$(s2) $h12_{im}$(s2)

+ $h21_{re}$(s2) $h21_{im}$(s2) $h22_{re}$(s2) $h22_{re}$(s2)

+]

The structure of the DATA entry for a NONUNIFORM frequency distribution is:

```
DATA=[ q
+ f1 h11(s1) ... h1N(s1)
+ ...
+    hN1(s1) ... hNN(s1)
...
+ fq h11(sq) ... h1N(sq)
+ ...
+    hN1(sq) ... hNN(sq)
+ ]
```

For example, for a two-port system with nonuniform linear real response over two frequencies, the .MODEL statement has the structure:

```
.MODEL twop3 SP SPACING=NONUNIFORM N=2 MATRIX=NONSYMMETRIC
DATA=[ 2
+ 1.0e+3 h11(s1) h12(s1) h21(s1) h22(s1)
+ 2.0e+3 h11(s2) h12(s2) h21(s2) h22(s2)
+ ]
```

Data Files

The frequency response model can reference a separate file containing the response data, instead of using data supplied in-line in the .MODEL statement. Instead of the **DATA** entry, the netlist syntax contains an entry of the form:

DATAFILE=*file_reference*

The *file_reference* identifies an external file containing the data.

See *File References* in the Circuit Design help topics for details.

The data file must contain only the numeric data, with entries separated by spaces, commas, tabs, or end-of-lines. No comments are allowed.

An example of a model statement using a data file reference is:

```
.MODEL fmod SP N=2 SPACING=LINEAR FSTART=0 FSTOP=40

+ MATRIX=NONSYMMETRIC

+ DATAFILE="c:\circuits\s_element.dat"
```

The corresponding data file, for a two-input S-parameter device over two frequency points (0.0 Hz and 40 Hz), in complex Cartesian form, has data such as the following:

```
2,

0,0,1,0,1,0,0,0

0,0,2,0,2,0,0,0
```

This encodes the following data points:

```
f=0: h11=0.0+j0.0, h12=1.0+j0.0, h21=1.0+j0.0, h22=0.0+j0.0

f=40: h11=0.0+j0.0, h12=2.0+j0.0, h21=2.0+j0.0, h22=0.0+j0.0
```

Imported Data from Touchstone Files

In a schematic, an N-port element or other element that uses the S-model or W-model can directly import S-parameter data from a Touchstone file. **Electronics Desktop** creates an SP model with the data. The Touchstone file can contain noise data. To import the data in the correct format, select the Noise Data tab on the N-Port Data window box and ensure the Option field has the default setting:

`Fmin Mag(Gopt) Ang(gopt) Rn`

Here is an example Touchstone file:

```
!2-port S-parameter file with noise data

# GHZ S RI R 50.0

!freq   ReS11 ImS11  ReS21  ImS21  ReS12  ImS12  ReS22 ImS22

1.000   0.393 -0.121 -0.001 -0.002 -0.001 -0.002 0.393 -0.121

2.000   0.352 -0.305 -0.010 -0.030 -0.010 -0.030 0.352 -0.305

10.000  0.342 -0.334 -0.013 -0.038 -0.013 -0.038 0.342 -0.334

!Noise Parameters (Nfreq Fmin MGopt PGopt Rnoise)
```

```
4 0.7 0.64 69 0.38

8 2.7 0.46 -33 0.40
```

Here is the .MODEL statement that Ansys Electronics Desktop creates for this file (some trailing zeros have been deleted for brevity):

```
.model NportData SP N=2 SPACING=NONUNIFORM MATRIX=NONSYMMETRIC

+ INTERPOLATION=LINEAR INTDATTYP=RI  HIGHPASS=10  LOWPASS=10
DATA=(

+3

+ 1.00E+009   3.93E-001   -1.21E-001  -1.00E-003  -2.00E-003

+ -1.00E-003  -2.00E-003  3.93E-001   -1.21E-001

+

+ 2.00E+009   3.52E-001   -3.05E-001  -1.00E-002  -3.00E-002

+ -1.00E-002  -3.00E-002  3.52E-001   -3.05E-001

+

+ 1.00E+010   3.42E-001   -3.34E-001  -1.30E-002  -3.80E-002

+ -1.30E-002  -3.80E-002  3.42E-001   -3.34E-001

+

+)

+ NOISE_FREQUENCY = (

+ 4.000000E+009   ,8.000000E+009   )

+ NOISE_FIGURE = (

+ 7.000000E-001   ,2.700000E+000   )

+ GAMMA_MAG = (

+ 6.400000E-001   ,4.600000E-001   )

+ GAMMA_ANG = (

+ 6.900000E+001   ,-3.300000E+001  )

+ NOISE_RESISTANCE = (

+ 3.800000E-001   ,4.000000E-001   )
```

S Frequency Dependent Data Model

The S model provides frequency-dependent data in the Touchstone® format. Touchstone is a registered trademark of Agilent Technologies.

(see the *Touchstone File Format Specification* in the Circuit Design help topics for information on this format.

The S model has the following netlist syntax.

.MODEL*modelname* **S TSTONEFILE=**" [*pathname*]*filename*"

[**INTERPOLATION=LINEAR**|**STEP**] [**INTDATTYP=MA**|**RI**|**DBA**]

[**HIGHPASS=***val*] [**LOWPASS=***val*]

[**CONVOLUTION=0**|**1**|**2**] [**RELTOL=***val*] [**MOR=***val*] [**MAX_STATES=***val*]

[**CACHE_STATE_SPACE=***val*] [**BY_ENTRY=***val*]

[**G_TO_GND=***val*] [**Q_LIMIT=***val*]

[**DELAYHANDLE=0**|**1**] **[ERRORIF=0|1]**
[**ENSURE_ACCURATE_ZFIT=0**|**1**|**2**]

The *file_reference* specifies the directory and file name for the Touchstone file.

> **Note:** If the reference normalization impedance is not specified in the Touchstone file, 50 ohms is the default.

A W-element can be described by S-parameter data from a Touchstone file. Additional S-model parameters for W-elements follow. When Nexxim encounters one of these parameters in an S-Model definition, it looks in the circuit for the corresponding W-element. If the W-element is found, the S-model calculates the W model. If no W-element is found, these parameters are ignored.

XLINELENGTH=*val*

[**ER=***val*]

[**MAX_ER=***val*]

The **XLINELENGTH** parameter on the S-Model specifies a unit length (default 1 meter). Nexxim computes the equivalent RLGC or TABLE model for that unit length on the S-parameter data. The parameter **L** on the W-Element specifies the actual length of transmission line to simulate using the calculated model.

The parameter **ER** is the dielectric constant of the substrate for the W-element. If **ER** is not known, or if there are multiple substrates, use **MAX_ER** to provide an estimate that is greater than the probable maximum value. If both **ER** and **MAX_ER** are given, the larger of the two values is used. If neither parameter is supplied, a dielectric constant of 15 is used. An accurate RLGC or TABLE model is always be produced as long as no actual dielectric constant is larger than the one used in the calculation.

> **Note:**
>
> Parameters ER and MAX_ER are Nexxim-specific. The XLINELENGTH parameter is HSPICE-compatible.

Table 9: S Model Parameters

Parameter	Description	Unit	Default
BY_ENTRY	Error tolerance method 0=absolute 1=relative	None	0
CACHE_STATE_ SPACE	0= do not cache 1 = cache	None	1
CONVOLUTION	Transient analysis method 0: state-space 1: convolution using PWL waveform 2: Convolution using reverse FFT 3: Convolution using linear interpolation of reverse FFT.	None	0
DELAYHANDLE	Transient analysis method 0: state-space, 1: convolution NOTE: DELAYHANDLE is supported as a model parameter for HSPICE compatibility only. Use the CONVOLUTION model parameter instead. DELAYHANDLE=1 is the same as CONVOLUTION=1. When **convolution=1**, **2**, or **3** is in effect (either by global option or by model parameter), any **DELAYHANDLE=0** model parameters are ignored.	None	0

ERRORIF	1=Reject state-space model if error is above 10% 0=No rejection	None	1
G-TO-GND	Conductance between all terminal nodes and ground	Siemens	0.0
INTERPOLATION	Interpolation method LINEAR: Piecewise linear STEP: Take value on the closest table entry that is lower in frequency	None	LINEAR
INTDATTYP	Complex data type for linear interpolation MA: Magnitude-phase RI: Real-imaginary DBA: Decibel-phase	None	MA
HIGHPASS	Extrapolation method for points above the given frequency range 0: Forced to zero 1: Forced to highest frequency point in the table 2: Linear extrapolation 10: Hold the highest magnitude, linearly extrapolate the phase	None	10
LOWPASS	How a DC point is generated if none exists in the input data (always real) 0: Set to zero 1: Magnitude and sign equal to those of the lowest given point 2: Real part of linear extrapolation to DC 10: Magnitude equal to the lowest given point, phase linearly extrapolated and forced to be a multiple of pi 11: All signal lines open circuited (S-parameter matrix is identity matrix) 12: All signal lines shorted together 13: All signal lines shorted to ground (S-parameter	None	10

	matrix is negative identity matrix)		
MAX_STATES	Maximum number of states per entry in the state-space formulation	None	128
MOR	Model-order reduction 0=none 1=entire matrix 2=MOR of rows individually, plus final MOR for combination 3=MOR of rows individually, no final MOR 4=MOR of columns individually, plus final MOR for combination 5=MOR of columns individually, no final MOR	None	0
Q-LIMIT	Limit of quality factor of poles in rational fit	None	5e-3
RELTOL	Tolerance for state-space fit		
ENSURE_ ACCURATE_ZFIT	Selects enhanced or legacy methods for fitting S-, Y-, and Z-parameter data. 0=Legacy method, best for S-parameters but less good for Y- and Z-parameters. 1= Fitting accuracy is similar for S-, Y-, and Z-parameters. 2= Fitting accuracy is similar for S-, Y-, and Z-parameters, with enhancement for handling large numbers of frequencies	None	2

Table 10: S Model Parameters for W-Elements

Parameter	Description	Unit	Default
XLINELENGTH	Unit length for computing RLGC or Table model for W element	Meter	1
ER	Exact dielectric constant.	None	None
MAX_ER	Maximum dielectric constant	None	15

S Model Netlist Examples

Here is an example of an S model netlist statement:

```
.MODEL S_2port S TSTONEFILE=”C:/fdata/tsdata.s2p”
```

Here is an example of a two-port S-parameter file with three frequency points, in real-imaginary format, adapted on the *Touchstone File Format Specification*:

```
!2-port S-parameter file, three frequency points

# GHZ S RI R 50.0

!freq   ReS11 ImS11  ReS21  ImS21  ReS12  ImS12  ReS22 ImS22

1.000   0.393 -0.121 -0.001 -0.002 -0.001 -0.002 0.393 -0.121

2.000   0.352 -0.305 -0.010 -0.030 -0.010 -0.030 0.352 -0.305

10.000  0.342 -0.334 -0.013 -0.038 -0.013 -0.038 0.342 -0.334
```

Here is an example of a four-port S-parameter file with three frequency points, in magnitude-angle format, adapted on the *Touchstone File Format Specification*:

```
! 4-port S-parameter data, three frequency points

# GHZ S MA R 50

!freq   MS11  AS11    MS12  AS12    MS13  AS13    MS14  AS14
!       MS21  AS21    MS22  AS22    MS23  AS23    MS24  AS24
!       MS31  AS31    MS32  AS32    MS33  AS33    MS34  AS34
!       MS41  AS41    MS42  AS42    MS43  AS43    MS44  AS44

5.000   0.60  161.24  0.40  -42.20  0.42  -66.58  0.53  -79.34
        0.40  -42.20  0.60  161.20  0.53  -79.34  0.42  -66.58
        0.42  -66.58  0.53  -79.34  0.60  161.24  0.40  -42.20
        0.53  -79.34  0.42  -66.58  0.53  -79.34  0.60  161.24

6.000   0.57  150.37  0.40  -44.34  0.41  -81.24  0.57  -95.77
        0.40  -44.34  0.57  150.37  0.40  -44.34  0.41  -81.24
        0.41  -81.24  0.57  -95.77  0.57  150.37  0.40  -44.34
        0.57  -95.77  0.41  -81.24  0.57  -95.77  0.57  150.37

7.000   0.50  136.69  0.45  -46.41  0.37  -99.09  0.62  -114.19
        0.45  -46.41  0.50  136.69  0.62  -114.19 0.37  -99.09
        0.37  -99.09  0.62  -114.19 0.50  136.69  0.45  -46.41
        0.62  -114.19 0.37  -99.09  0.45  -46.41  0.50  136.69
```

S-Element Options Reference

The following options are for S-parameter elements. All of these options have the **s_element.** prefix.

Table 13: Nexxim S-Element Options

Option	Default Value	Description
s_element.auto_ enforce_passivity	1	**This option is supported only for legacy designs.** Use the Global Analysis option **auto_enforce_passivity=1** to enable automatic passivity enforcement for both S-elements and W-elements. When the Global option is unavailable (set to 0), the **auto_enforce_passivity** option set in a W-element or S-element is ignored. 1=If transient fails with a passivity violation, and passivity enforcement is not enabled, automatically restart transient with passivity enforcement enabled (**s_element.enforce_ passivity=7**). 0=No restart after transient fails **auto_enforce_passivity** is valid only in a transient simulation and is ignored in a frequency-domain analysis (HB or LNA).
s_element.by_entry	0	0=State-Space fitting error is the maximum absolute error of fit over all frequencies with respect to the S-parameter data. 1=Fitting error is the maximum relative error of fit, the maximum absolute fit with respect to the data divided by the maximum S-parameter value over all frequencies in the data. This option may be used when there is a need for higher accuracy on small S-parameters. This option is ignored when FastFit is used.
s_element.cache_ state_space	1	1=Enables caching of the state space fitting information (see Note on Caching). 0=no caching
s_element.causality_ check	0	1=Enable causality checking of Touchstone data 0=No causality checking
s_element.causality_	0.025	Maximum acceptable causality error. Default is 5 times the

Option	Default Value	Description
checker_tolerance		default value for target fitting error, that is, 5 times s_element.reltol.
s_element.column_fit	2	0=Fit each entry separately, then combine them at the end 1=Fit one column at a time 2=Do the entire matrix at once This option is ignored when FastFit is used. (FastFit fits the entire matrix at once.)
s_element.compute_runtimecc	0	1=Calculate and display runtime in seconds for causality checker. 0=Turn off runtime calculation This option is primarily for internal use.
s_element.convolution	0	Sets Nexxim to use convolution rather than state-space matrices to model the behavior of S-parameter elements during transient analysis. 0: The state-space method is used. 1: Convolution is used. The impulse response is a piecewise linear waveform, with breakpoints chosen to exactly match the given frequency-domain data. This setting gives the most accurate response. 2: Convolution is used. The impulse response is a train of impulses in the time domain, given by the inverse Fast Fourier Transform. This setting yields an impulse response that is accurate in-band and usually passive. However, the transient waveforms may have discontinuity effects. 3: Convolution is used. The impulse response is the linear interpolation of the inverse FFT results. This setting yields an impulse response with a low probability of passivity violations, but there is significant filtering toward the top of the frequency range of the input data.
s_element.coupling_threshold	N/A	Set a coupling threshold (in dB) to determine the coupling ports of the s_element model. Achieves model order reduction.
s_element.disable_fastfit	0	0=Use FastFit algorithm for fitting state-space data (option **s_element.twa** is ignored)

Option	Default Value	Description
		1=Use fitting method selected by **s_element.twa** option
s_element.do_fast_passivity_enforcement	1	1=Use faster method for enforcing passivity. 0=Use legacy method.
s_element.enable_cc_continuation	0	1=Automatic continuation after inconclusive causality check (cannot determine that data is definitely causal or definitely noncausal). Causality checker starts with **interpolation_typecc=1** and **integration_typecc=1**. If the test is inconclusive, causality checker automatically continues with **interpolation_typecc=2** and **integration_typecc=2**. 0=Turn off automatic continuation.
s_element.enforce_causality	0	1=Perform causality check on Touchstone data, perform compensation to replace non-causal data with causal reconstruction estimate 0=No checking or compensation
s_element.enforce_passivity	0	0=No passivity enforcement 1=Enforce the passivity of the state-space model during transient analysis of S-parameter element 2= Use a point-by-point method for enforcing passivity. Use this option in cases with large numbers of ports (more than about 30). 6=Use a passivity by perturbation algorithm 7=Use Iterated Fitting of Passivity Violations (IFPV) algorithm 8=Use Iterated Fitting of Passivity Violations Low Frequency (IFPVLF) algorithm Setting **enforce_passivity=2** automatically sets **mor=3**, since this passivity enforcement algorithm requires this model-order reduction strategy. Settings **enforce_passivity=8** build upon the existing IFPV while ensuring a better fit to “Z” at DC and low frequencies.
s_element.ensure_accurate_zfit	2	Selects enhanced or legacy methods for fitting S-, Y-, and Z-parameter data.

Option	Default Value	Description
		0=Legacy method, best for S-parameters but less good for Y- and Z-parameters. 1=Fitting accuracy is similar for S-, Y-, and Z-parameters. 2=Fitting accuracy is similar for S-, Y-, and Z-parameters, with enhancement for handling large numbers of frequencies.
s_element.errorif	1	1 = Reject state-space model if error is above 10%. 0 = No rejection.
s_element.g_to_gnd	0	Conductance between all terminal nodes of all S-elements and ground
s_element.integration_typecc	1	1=numerical 2=analytical When **integration_typecc=2** is selected, **interpolation_typecc=** 2 should also be used. See also **enable_cc_continuation**.
s_element.interpolation_typecc	1	1=cubic spline 2=rational function See also **enable_cc_continuation**.
s_element.max_states	10000 for FastFit and TWA 128 for IRF	Sets the maximum number of states per entry in the state-space formulation
s_element.mor	0	0=No model order reduction (MOR) 1=MOR of entire matrix at once 2=MOR of rows of matrix individually, then final MOR for the combination 3=MOR of rows of matrix individually, no final MOR 4=MOR of columns of matrix individually, then final MOR for the combination 5=MOR of columns of matrix individually, no final MOR This option is ignored when FastFit is used.

Option	Default Value	Description
s_element.mor_sp	0	1=Use singular perturbation MOR. Preserves DC fit.
s_element.noisemodel	external	external=use external data if present, else use internal noise model internal=use internal noise model. External data is ignored none=no noise calculation Noisemodel applies to frequency domain analyses, not to time domain.
s_element.q_limit	1e4	Sets the limit of the quality factor of poles in the rational fit. The default is 1e4. Limiting the quality factor can be useful in avoiding overfitting, which can lead to severe passivity violations. The value should be a positive number greater than 0.5 (generally much greater). This option is ignored when FastFit is used.
s_element.rational_ fitting_iteration_limit	2	Increasing the limit improves the fit on certain complicated S-parameter cases, at the cost of extra CPU time.
s_element.reduce	0	Port reduction. 1=eliminate ports tied to ground directly. Does not affect unconnected ports or ports tied to ground through a resistor. See **Note 1** for more about port reduction.
s_element.reltol	5e-3	Tolerance for state-space fit.
s_element.test_sss	1	1 = Test existing .sss file for goodness of fit with given S-parameter data. **Mainly for internal use**
s_element.twa	1	Selects state-space fitting algorithm when option **s_ element.disable_fastfit** =1. Option s_element.twa is ignored when **s_element.disable_fastfit** =0 0=Use rational fitting 1=Use Tsuk-White algorithm (TWA) for state-space fitting.
s_element.wide_ dynamic_range	0	Set **wide_dynamic_range** to 1 when the S-parameter data contains a wide dynamic range within single entries (e.g., with values around 1 at low frequencies but approaching 10^{-5} at high frequencies, and the smallest values must be fitted precisely). This option is ignored when FastFit is used.

Option	Default Value	Description
s_element.zo_from_file	1	0=Port impedances are determined on the S-element instance line, or on the Touchstone file per the Touchstone 1.0 or 2.0 Specification. 1=Touchstone file contains a (non-standard) list of port impedances on the option line, one for each port in the device, as in the following example for a four-port model: # GHZ S MA R 50 50 100 50 **Note:** Add the **s_element.zo_from_file=1** option in the **Additional Options** field under **Solution Options** in the analysis setup (DC, Transient, LNA, etc.), NOT in the N-Port Data Dialog Options tab.

Note on Caching Operation during State-Space Fitting

By default, the Nexxim state-space fitter caches (saves) the fitting results in a state-space (.sss) file. The option **s_element.cache_state_space=1** (the default) enables caching.

When state-space fitting is performed with caching enabled, Nexxim checks to see if there is an existing .sss file for the element. If no cache exists, Nexxim calculates the fit and caches the result in a new .sss file. If there is an existing .sss file, Nexxim tries to validate the cached result.

- If any of the supported fitting options has changed value on the previous fitting, the cache is invalid.
- If the frequency-dependent input data has changed, the cache is invalid.

If the cache is valid, the .sss file is read in and no additional fitting calculations are done. If the cache is invalid, Nexxim calculates a new fit and rewrites the .sss file.

Setting **s_element.cache_state_space=0** turns off caching. When caching is deactivated, no attempt is made to validate an existing .sss file, and no .sss files are written or rewritten.

Notes

1. Port Reduction

Port reduction is a technique that reduces the size of the S-element data to accelerate subsequent analyses. A mathematical formula is used to transform the data into a smaller set that corresponds to a device having only the ports that are connected in the schematic. The transformed data is the same as what is obtained by running a linear network analysis (LNA) on the schematic at the frequencies present in the data. This transformed data then completely replaces the original data of the S-element for the purpose of any analyses.

Nodes of the S-element that are left unconnected in the schematic are reduced. To deactivate port reduction at a node, it can be connected to a short lead that is left floating. In addition, if the .reduce option is set to 1, nodes that are grounded are also reduced.

Note that port reduction can result in (typically slight) differences compared to a case in which no port reduction is used. This is because for frequencies not present in the data, an interpolation between the transformed data is performed, as opposed to an interpolation between the original S-element data.

2. Cache-Invalidating S-Element Options

The following S-element fitting options are automatically checked to see if they have changed since the last fitting calculation, modifying the fitting results and invalidating the cache.

by_entry

column_fit

enforce_causality

max_states

mor

mor_sp

q_limit

rational_fitting_iteration_limit

reltol

twa

twa_conserve_memory

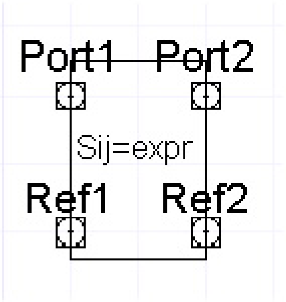
twa_adjust_tolerance

wide_dynamic_range

The option **enforce_passivity** is also checked for a changed value. However, a cached .sss file contains a flag to indicate that it is known to contain a passive model. If a passive cached .sss file is found in the project folder, Nexxim uses that passive macromodel, even if **enforce_passivity** has changed its setting. To force Nexxim to create a new cache, you must delete the existing .sss file.

Other fitting-related options require the user to deactivate caching (**s_element.cache_state_space=0**) if their value has changed on the default. Examples: **ensure_accurate_zfit**, **do_fast_passivity_enforcement**.

Equation Based S Parameter Element



Netlist Format

The equation-based S-parameter element has the following Nexxim netlist syntax:

```
Axxxn1 ref1 n2 ref2

+ s11_mag='expr' s11_ang='expr'

 + s12_mag='expr' s12_ang='expr'

 + s21_mag='expr' s21_ang='expr'

 + s22_mag='expr' s22_ang='expr'

 + COMPONENT=equation_based_two_port_s_parameter
```

n1 and *n2* are the signal nodes attached to the S-parameter element. *ref1* and *ref2* are the corresponding reference nodes.

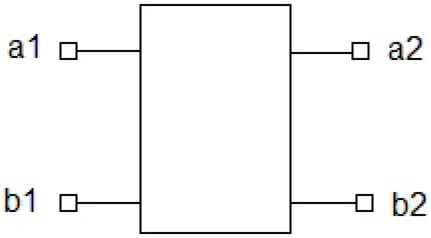
The entry **COMPONENT=equation_based_two_port_s_parameter** is required.

Table 12: Equation-Based S-Parameter Element Parameters

Instance Parameter	Description	Unit	Default
s11_mag	Magnitude of S11. The value is an expression in quotation	None	None

	marks		
s11_ang	Angle of S11 in radians. The value is an expression in quotation marks	None	None
s12_mag	Magnitude of S12. The value is an expression in quotation marks	None	None
s12_ang	Angle of S12 in radians. The value is an expression in quotation marks	None	None
s21_mag	Magnitude of S21. The value is an expression in quotation marks	None	None
s21_ang	Angle of S21 in radians. The value is an expression in quotation marks	None	None
s22_mag	Magnitude of S22. The value is an expression in quotation marks	None	None
s22_ang	Angle of S22 in radians. The value is an expression in quotation marks	None	None
Z0	Reference impedance	Ohm	50

Chain-Based ABCD Element (Netlist Only)



Netlist Format

The chain-based ABCD element has the following Nexxim netlist syntax:

```
Axxx a1 b1 a2 b2 [CHAIN_PARAM=val] [DELAYHANDLE=val]
+ A_real='expr' A_imag='expr'

 + B_real='expr' B_imag='expr'

 + C_real='expr' C_imag='expr'

 + D_real='expr' D_imag='expr'
```

```
+ COMPONENT=chain_based_abcd
```

a1, *a2*, *b1*, and *b2* are the nodes attached to the ABCD element.

The entry **COMPONENT=chain_based_abcd** is required.

Table 13: Chain-Based ABCD Element Parameters

Instance Parameter	Description	Unit	Default
CHAIN_PARAM	Number of identical elements to be chained minus one (zero = one element)	None	0
DELAYHANDLE	0 = state-space, 1 = convolution	None	1
A_real, **A_imag**	Real and imaginary parts of A parameter. The values are entered as expressions in quotation marks	None	Required
B_real, **B_imag**	Real and imaginary parts of B parameter. The values are entered as expressions in quotation marks	None	Required
C_real, **C_imag**	Real and imaginary parts of C parameter. The values are entered as expressions in quotation marks	None	Required
D_real, **D_imag**	Real and imaginary parts of A parameter. The values are entered as expressions in quotation marks	None	Required

Notes

1. The ABCD element is available for use in netlists, but is not supported in the Components window of the AED **Schematic Editor**.
2. Nodes a1, a2, b1, and b2 are related by the ABCD parameters according to the following formula:

$$\begin{bmatrix} b_1 \\ a_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} a_2 \\ b_2 \end{bmatrix}$$

3. The **CHAIN_PARAM** entry specifies the number of identical copies (minus one) of the ABCD matrix to be chained (matrix multiplied):

$$\begin{bmatrix} b_1 \\ a_1 \end{bmatrix} = \begin{bmatrix} A & B \\ C & D \end{bmatrix} \cdots \begin{bmatrix} A & B \\ C & D \end{bmatrix} \begin{bmatrix} a_2 \\ b_2 \end{bmatrix}$$

An entry of **CHAIN_PARAM=0** (the default) uses one ABCD matrix.

34 - Slotline Elements

This topic describes the following slotline distributed elements available in Nexxim.

"Open Stub, Physical Length" below

"Open Stub, Electrical Length" on the next page

"Shorted Stub, Physical Length" on page 34-4

"Shorted Stub, Electrical Length" on page 34-5

"Transmission Line, Physical Length" on page 34-6

"Transmission Line, Electrical Length" on page 34-8

Coupled Lines, Full-Wave Model

This topic also describes the Slotline substrate type.

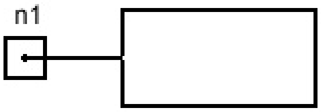
"Selecting None for the Initial Substrate" on page 34-11

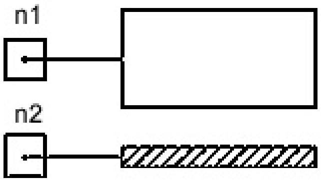
"Creating a Custom Slotline Substrate" on page 34-11

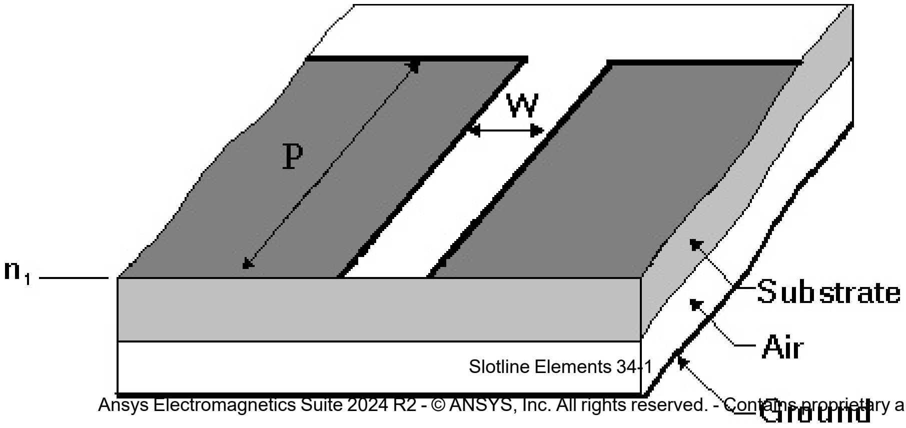
"Selecting a Slotline Substrate at the Component Level" on page 34-13

"Slotline Substrate Model" on page 34-13

Open Stub, Physical Length







Netlist Format

An instance of a slotline open stub with physical length has the following netlist syntax:

```
Axxx n1 [n2]   [W=val] [P=val] COMPONENT=slotline_open_stub
SUBSTRATE=substrate_name
```

n1 is node attached to the open stub. *n2* is the optional reference node. The entry **COMPONENT=slotline_open_stub** identifies the element.

The **SUBSTRATE=***substrate_name* is the slotline substrate model name selected for the design (see "Selecting None for the Initial Substrate" on page 34-11 for details.

Table 5: Slotline Open Stub with Physical Length, Instance Parameters

Parameter	Description	Units	Default
P	Physical length	Meter	1e-3
W	Center conductor width	Meter	.762e-3

Netlist Example

```
A23 Port1 0 W=.5e-003 P=0.001
+ COMPONENT=slotline_open_stub   SUBSTRATE=SLOT1
```

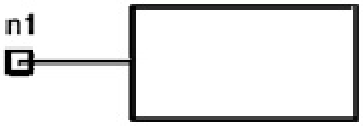
where SLOT1, the selected layout technology or substrate type, has a definition such as:

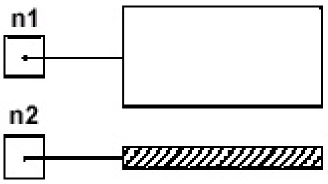
```
.SUB SLOT1 SLOT(
+ B=0.001524 Er=4.4 TAND=0.02 H=0.5e-3 HU=2.54e-003
+ MET1=1.724137931034483 T1=2.5400e-005
+ RGH=0)
```

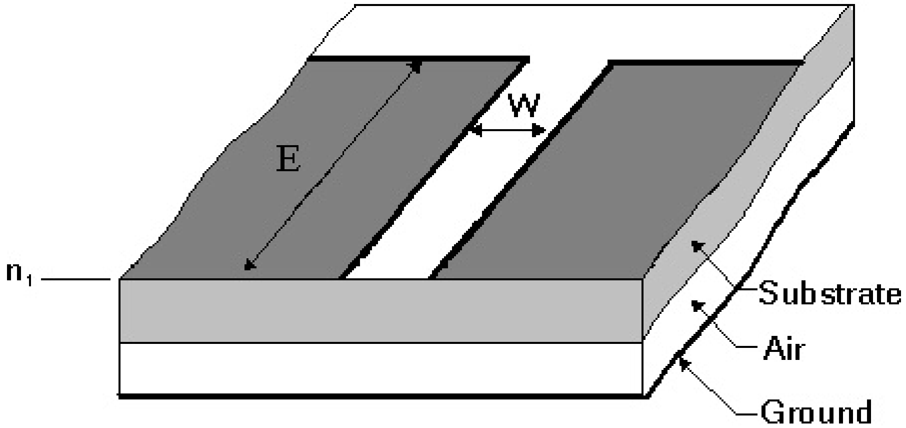
Notes

1. [**Slotline**] The slotline open stub model is equivalent to a transmission line model followed by an ideal open. When a negative length is used for de-embedding, the open stub model is equivalent to a transmission line with negative length terminated by an open.

Open Stub, Electrical Length







Netlist Format

An instance of a slotline open stub with electrical length has the following netlist syntax:

A*xxx n1 [n2]* **W=***val* **E=***val* **F=***val*
COMPONENT=slotline_open_stub_electrical SUBSTRATE=*substrate_name*

n1 is node attached to the open stub. *n2* is the optional reference node. The entry **COMPONENT=slotline_open_stub_electrical** identifies the element.

The **SUBSTRATE=***substrate_name* is the slotline substrate model name selected for the design (see "Selecting None for the Initial Substrate" on page 34-11 for details.

Table 6: Slotline Open Stub with Electrical Length, Instance Parameters

Parameter	Description	Units	Default
W	Conductor width	Meter	.762e-3
E	Electrical length	Degree	45
F	Reference frequency for E	Hz	1e9

Netlist Example

```
A7 Port1 0 W=0.005 E=45 F=5000000000
+ COMPONENT=slotline_open_stub_electrical SUBSTRATE=SLOT1
```

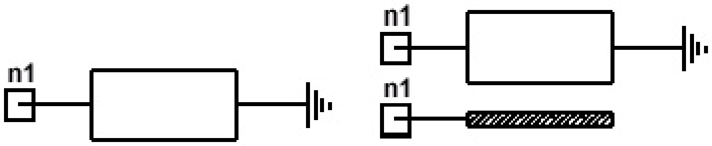
where SLOT1, the selected layout technology or substrate type, has a definition such as:

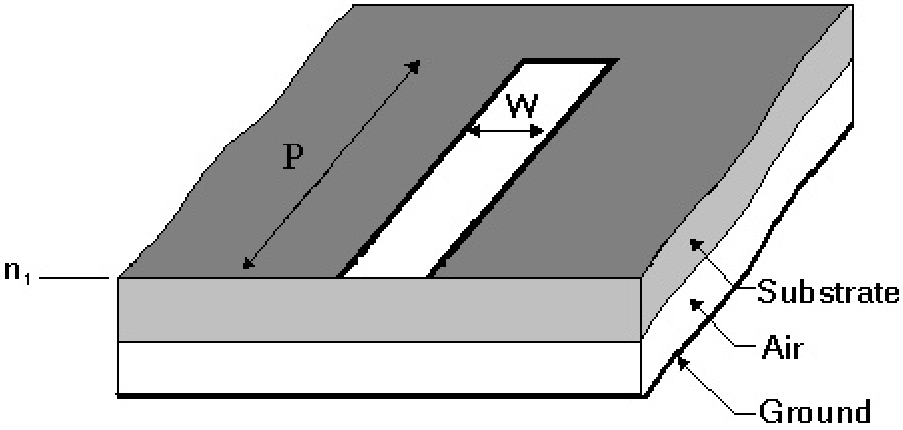
```
.SUB SLOT1 SLOT(
+ B=0.001524 Er=4.4 TAND=0.02 H=0.5e-3 HU=2.54e-003
+ MET1=1.724137931034483 T1=2.5400e-005
+ RGH=0)
```

Notes

1. [**Slotline**] The slotline open stub electrical model is equivalent to a transmission line model followed by an ideal open.

Shorted Stub, Physical Length





Netlist Format

An instance of a slotline shorted stub with physical length has the following netlist syntax:

A*xxx n1* [*n2*]   [**W=***val*] [**P=***val*] **COMPONENT=slotline_short_stub SUBSTRATE=***substrate_name* *n1* is node attached to the shorted stub. *n2* is the optional reference node. The entry **COMPONENT=slotline_short_stub** identifies the element.

The **SUBSTRATE=***substrate_name* is the slotline substrate model name selected for the design (see "Selecting None for the Initial Substrate" on page 34-11 for details.

Table 7: Slotline Shorted Stub with Physical Length, Instance Parameters

Parameter	Description	Units	Default
P	Physical length	Meter	1e-3
W	Center conductor width	Meter	.762e-3

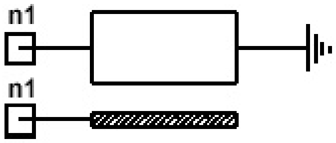
Netlist Example

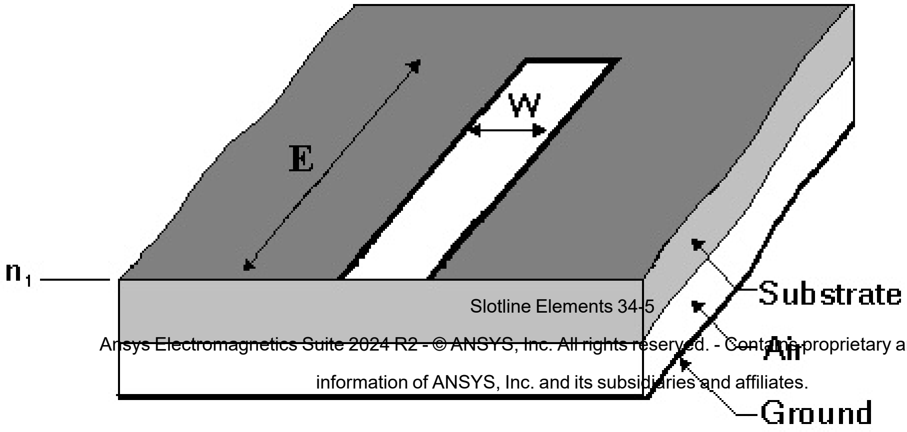
```
A23 Port1 0 W=.5e-003 P=0.001
+ COMPONENT=slotline_short_stub   SUBSTRATE=SLOT1
```

where SLOT1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SLOT1 SLOT(
+ B=0.001524 Er=4.4 TAND=0.02 H=0.5e-3 HU=2.54e-003
+ MET1=1.724137931034483 T1=2.5400e-005
+ RGH=0)
```

Shorted Stub, Electrical Length





Netlist Format

An instance of a slotline shorted stub with electrical length has the following netlist syntax:

```
Axxx n1 [n2]   W=val E=val F=val
COMPONENT=slotline_short_stub_electrical SUBSTRATE=substrate_name
```

n1 is node attached to the shorted stub. *n2* is the optional reference node. The entry **COMPONENT=slotline_short_stub_electrical** identifies the element.

The **SUBSTRATE=***substrate_name* is the slotline substrate model name selected for the design (see "Selecting None for the Initial Substrate" on page 34-11 for details.

Table 8: Slotline Shorted Stub with Electrical Length, Instance Parameters

Parameter	Description	Units	Default
W	Conductor width	Meter	.762e-3
E	Electrical length	Degree	45
F	Reference frequency for E	Hz	1e9

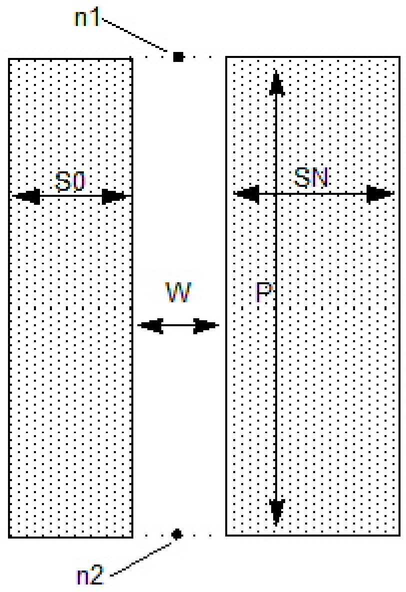
Netlist Example

```
A7 Port1 0 W=0.005 E=45 F=5000000000
+ COMPONENT=slotline_shorted_stub_electrical SUBSTRATE=SLOT1
```

where SLOT1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SLOT1 SLOT(
+ B=0.001524 Er=4.4 TAND=0.02 H=0.5e-3 HU=2.54e-003
+ MET1=1.724137931034483 T1=2.5400e-005
+ RGH=0)
```

Transmission Line, Physical Length



Netlist Format

An instance of a transmission line with physical length has the following netlist syntax:

A*xxx n1 n2* [**W=***val*] [**P=***val*] **COMPONENT=slottrl SUBSTRATE=***substrate_name*

n1 and *n2* are the names of the nodes attached to the transmission line. The entry **COMPONENT=slottrl** identifies the element as a transmission line with physical length.

The **SUBSTRATE=***substrate_name* is the slotline substrate model name selected for the design (see "Selecting None for the Initial Substrate" on page 34-11 for details.

Table 9: Transmission Line with Physical Length, Instance Parameters

Parameter	Description	Units	Default
P	Physical length	Meter	1e-2
W	Conductor width	Meter	1e-4

Netlist Example

```
A23 Port1 Port2 W=1.2700e-004 P=0.001
+ COMPONENT=SLOTTRL   SUBSTRATE=SLOT1
```

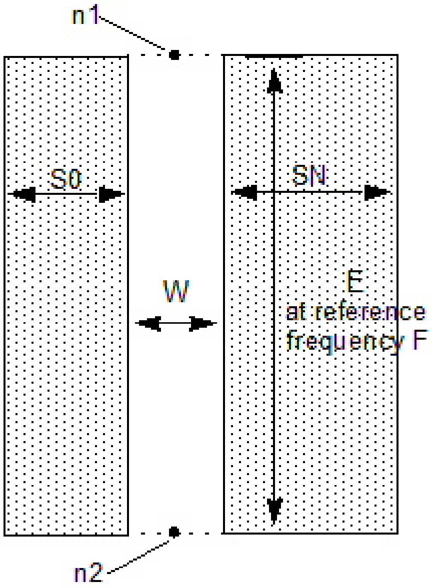
where SLOT1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SLOT1 SLOT(
+ B=0.001524 Er=4.4 TAND=0.02 H=0.5e-3 HU=2.54e-003
+ MET1=1.724137931034483 T1=2.5400e-005
+ RGH=0)
```

Notes

1. [**Slotline**] The MCPL is used to analyze the slotline.

Transmission Line, Electrical Length



Netlist Format

An instance of a transmission line with electrical length has the following netlist syntax:

A*xxx n1 n2* **W=***val* **E=***val* **F=***val* **COMPONENT=slottrle SUBSTRATE=***substrate_name* *n1* and *n2* are the names of the nodes attached to the transmission line. The entry **COMPONENT=slottrle** identifies the element as a transmission line with electrical length.

The **SUBSTRATE=***substrate_name* is the slotline substrate model name selected for the design (see "Selecting None for the Initial Substrate" on page 34-11 for details.

Table 10: Transmission Line with Electrical Length, Instance Parameters

Parameter	Description	Units	Default
W	Conductor width	Meter	0.0001
E	Electrical length	Degree	45
F	Reference frequency for E	Hz	1e9

Netlist Example

```
A7 Port1 Port2 W=0.001 E=45 F=5000000000
+ COMPONENT=slottrle SUBSTRATE=SLOT1
```

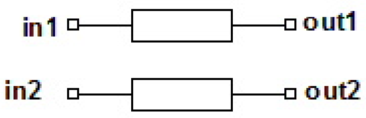
where SLOT1, the selected layout technology or substrate type, has a definition such as:

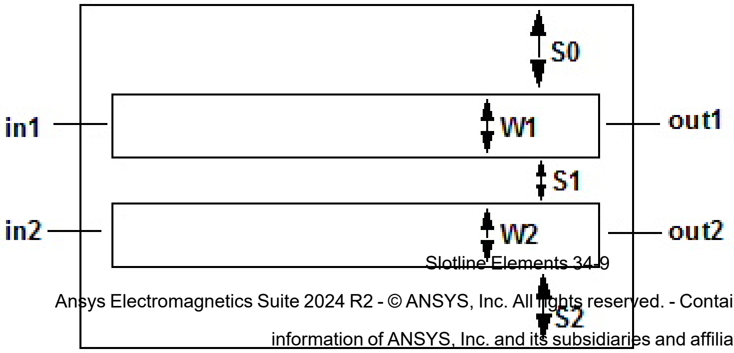
```
.SUB SLOT1 SLOT(
+ B=0.001524 Er=4.4 TAND=0.02 H=0.5e-3 HU=2.54e-003
+ MET1=1.724137931034483 T1=2.5400e-005
+ RGH=0)
```

Notes

1. [**Slotline**] The MCPL is used to analyze the slotline.

Coupled Lines, Full-Wave Model





Netlist Form

A two-conductor multicoupled line, full-wave instance has the following netlist syntax:

```
Axxx in1 in2 out1 out2 NL=2 W1=val S1=val W2=val P=val

[S0=val] [SN=val]
[NBAS=val] [NSUM=val][CERR=val] [STEP=val] [FO=val]

COMPONENT=slotmcpl SUBSTRATE=substrate_name
```

in1 and *in2* are the names of the input nodes. *out1* and *out2* are the corresponding output nodes. The entry **COMPONENT=slotmcpl** is required.

The **SUBSTRATE=***substrate_name* is the slotline substrate model name selected for the design (see "Selecting None for the Initial Substrate" on the facing page for details.

Table 11: Slotline Coupled Lines, Full-Wave Model, Instance Parameters

Parameter	Description	Units	Default
NL	Number of signal lines	None	Must be 2
P	Physical length	Meter	1e-3
S1	Spacing between slot 1 and 2	Meter	1e-3
W1, W2	Slot widths	Meter	1e-3
S0	Spacing from left enclosure to the first slot	Meter	0
SN	Spacing from right enclosure wall to the second slot	Meter	0
NBAS	Number of basis functions to use in the expansions	None	3
NSUM	Number of summations to use in the expansions	None	700
CERR	Calculation tolerance error (minimum value 1.0e-14)	None	1e-7
STEP	Root-searching algorithm step size	None	0.01
FO	Semi-dynamic mode calculation frequency (see Notes)	Hertz	-1 (Full-wave mode

Netlist Example

```
A3 Port1 Port3 Port2 Port4 NL=2
+ W1=1.25e-3 S1=1.5e-3 W2=1.25e-3 P=3e-3
+ COMPONENT=slotmcpl SUBstrate=SLOT1
```

where SLOT1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SLOT1 SLOT(
+ B=0.001524 Er=4.4 TAND=0.02 H=0.5e-3 HU=2.54e-003
+ MET1=1.724137931034483 T1=2.5400e-005
+ RGH=0)
```

Notes

1. This model uses a proprietary full-wave spectral domain algorithm. The parameters NBAS, NSUM, CERR, and STEP control the model solver. If there is difficulty finding roots, try changing the values of parameters as follows:
   - Gradually increase NSUM (maximum of 1500) until roots can be found.
   - Gradually decrease CERR (minimum 1e-14).
   - When S0 and S2 wall spacings are comparable to S1, reduce NSUM to 500 or less.
2. The parameter FO is required for semi-dynamic mode computation only. In this mode, the effective dielectric constants and characteristic impedances are computed only once at the FO frequency. This data is then used to compute the model for all other frequencies. The semi-dynamic mode offers a fast solution with a close approximation to the full-wave solution. Typically FO is specified at the center of the frequency range of interest with values exceeding 1GHz minimum. If this value is not specified, it is automatically computed at the center frequency of the frequency range specified by the user.

Selecting None for the Initial Substrate

For Nexxim designs that are created with the **Schematic Editor**, the initial selection of a global substrate type is made on the **Choose Layout Technology** window that appears when you select Insert Nexxim Circuit Design on the Project menu.

However, no slotline substrates are available in the **Choose Layout Technology** window.

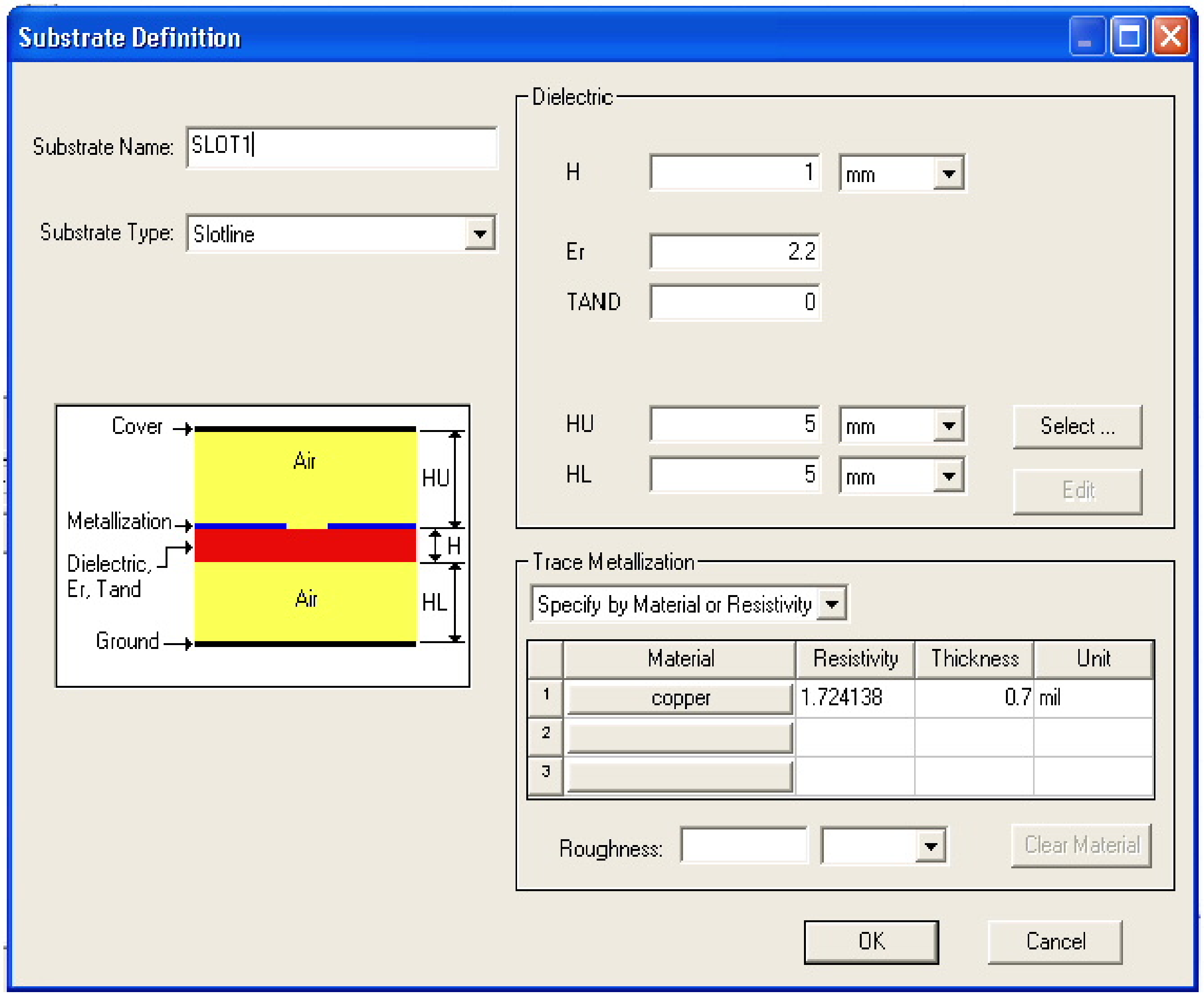
If you wish to use an slotline substrate, you must create it as a custom substrate type.

In the **Choose Layout Technology** window, click **None**. The design opens, but no substrate type is applied to instances of distributed elements until you create a custom substrate type.

See "Creating a Custom Slotline Substrate" belowfor details.

Creating a Custom Slotline Substrate

To create a slotline substrate definition, open the Nexxim design icon (e.g., “Nexxim1”, then right-click the **Add Reference Data** field. Select **Add Substrate Definition** to open the **Substrate Definition** window. Specify the name of your new substrate (the following example uses the name “SLOT1”):



Substrate Name: SLOT1

Substrate Type: Slotline

Dielectric

H 1 mm

Er 2.2

TAND 0

HU 5 mm

HL 5 mm

Trace Metallization

Specify by Material or Resistivity

	Material	Resistivity	Thickness	Unit
1	copper	1.724138	0.7	mil
2				
3				

Roughness:

Select **Slotline** as the Substrate Type. Complete the Dielectric and Metallization field information. Refer to the "Slotline Substrate Model" on the facing page help topic for guidelines on defining slotline substrates.

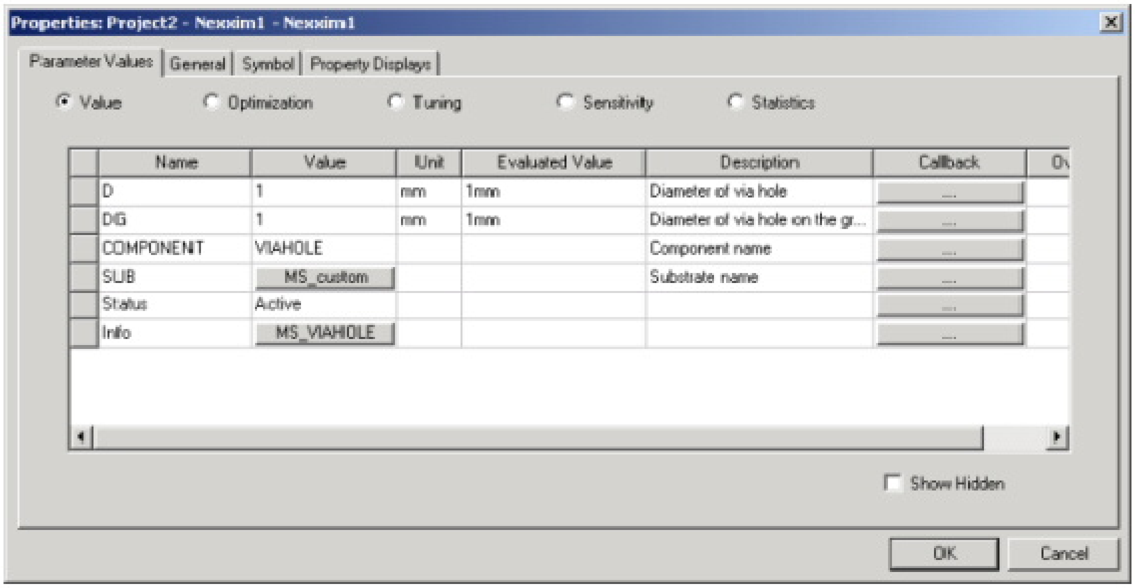
When the substrate definition is complete, click **OK**.

If you selected **None** for the global substrate type in the **Choose Layout Technology** window, the custom slotline substrate becomes the global substrate type.

When an element is instantiated , it includes a **SUBSTRATE=***substrate_name* entry in its netlist syntax. **Electronics Desktop** automatically inserts the global *substrate_name* into the internal netlist entry for the instantiated element.

Selecting a Slotline Substrate at the Component Level

To specify a custom substrate type, or to change to a different predefined substrate type, you must make the assignment individually for each component. Double-click the distributed element to open the **Properties** window:



● Value

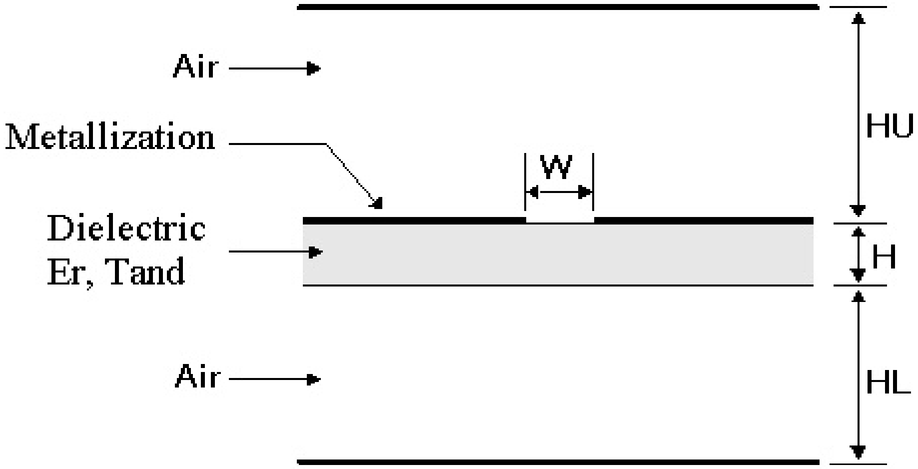
Name	Value	Unit	Evaluated Value	Description	Callback	Ov
D	1	mm	1mm	Diameter of via hole	...	
DIG	1	mm	1mm	Diameter of via hole on the gr...	...	
COMPONENT	VIAHOLE			Component name	...	
SUB	MS_custom			Substrate name	...	
Status	Active				...	
Info	MS_VIAHOLE				...	

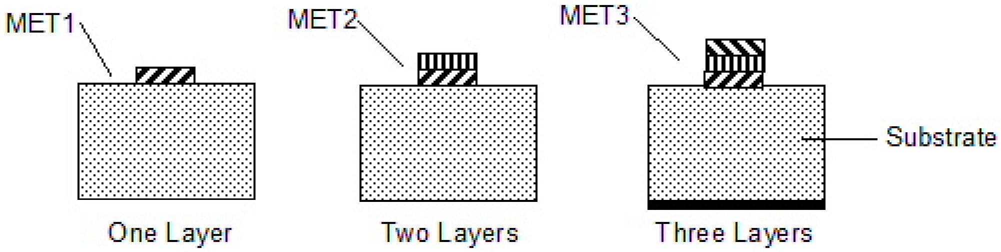
The **SUB** property identifies the substrate that is currently applied to the element. In the example above, a custom substrate type named “MS_custom” appears as the value of the **SUB** property.

To change to a different substrate type, click in the **SUB** Value field and select the appropriate substrate name as the value of the **SUB** property. Then click **OK**.

> **Note:** All distributed elements in a given design must use the same substrate type.

Slotline Substrate Model





metallization

Defining a Slotline Model

To add an slotline substrate model to a new Nexxim design, you must add the definition to the set of substrate models.

To add a new substrate definition to an existing design, expand the **Project** icon, the **Design** icon. Right-click the **Data** icon and select **Add Substrate Definition** to open the **Substrate Definition** window. Then add the substrate name and parameters as appropriate, and click **OK**. A substrate added in this manner requires you to specify the metallization parameters explicitly.

To edit the definition of a substrate, expand the **Project** icon, the **Design** icon, the **Data** icon. Click on the icon for the substrate you wish to edit to open the **Substrate Definition** window. Add or modify the substrate parameters as appropriate, then click **OK**.

Slotline Substrate Model Netlist Format

The Slotline substrate model has the following netlist format:

```
.SUBsubstrate_name SLOT ( [ER=val] [TAND=val]
+ [H=val] [HU=val] [HL=val]
+ [MET1=val] [T1=val] [MET2=val] [T2=val] [MET3=val] [T3=val]
+ [RGH=val])
```

The *substrate_name* is the name for the substrate type used in distributed elements that refer to this substrate definition. The entry **SLOT** is required to identify the Slotline substrate type. The **SLOT** identifier must immediately follow the **substrate_name**.

Inside the parentheses, the labeled parameters may be entered in any order.

Table 12: Slotline Substrate Parameters

Parameter	Description	Unit	Default
ER	Dielectric constant of substrate, 1 ≤ ER ≤ 128	None	4.5
H	Dielectric height	Meter	1e-3
HU	Height of upper air layer	Meter	0
HL	Height of lower air layer	Meter	0
MET1, **MET2**, **MET3**	Resistivity of metal layer 1, 2, 3	µOhm-cm	0.0
RGH	RMS surface roughness	Meter	0.0
T1, **T2**, **T3**	Thickness of metal layer 1, 2, 3	Meter	0.0
TAND	Dielectric loss tangent, [0,0.1]	None	0.0

Slotline Substrate Model Netlist Example

```
.SUB SLOT1 SLOT(
+ B=0.001524 Er=4.4 TAND=0.02 H=0.5e-3 HU=2.54e-003
+ MET1=1.724137931034483 T1=2.5400e-005
+ RGH=0)
```

35 - Stripline Elements

This topic describes the following distributed elements, which can be implemented in Nexxim with the Stripline substrate type.

General Components

Bends

Coupled Bends

Coupled Lines

Couplers

Cross Junctions

Gaps

Open-Ended Lines

Shorted Stubs

Tapered Lines

Transmission Lines

This topic also describes the following substrate types which can be used to implement distributed elements. Each element help topic documents the substrate types that can be used to implement it.

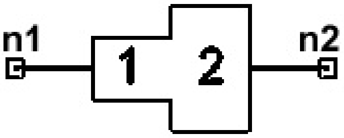
"Selecting a Stripline Substrate" on page 35-63

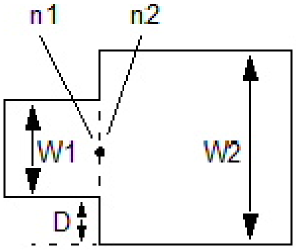
"Creating a Custom Stripline Substrate" on page 35-64

"Selecting a Substrate at the Component Level" on page 35-65

"Stripline Substrate Model" on page 35-66

Step





Netlist Format

A step instance has the following netlist format:

```
Axxx n1 n2 W1=val W2=val D=val [NSUM=val]
```

```
COMPONENT=step SUBSTRATE=substrate_name
```

n1 and *n2* are the names of the nodes attached to the step. The entry **COMPONENT=step** identifies the element as a step.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 9: Step Instance Parameters

Parameter	Description	Unit	Default

W1	Width of line connected to node n1	Meter	1e-3
W2	Width of line connected to node n2	Meter	1e-3
D	Offset between lines	Meter	(W2-W1)/2

Netlist Example

```
A23 Port1 Port2 W1=1e-3 W2=2e-3 D=0.5e-3

+ COMPONENT=STEP SUBSTRATE=SL1
```

where SL1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

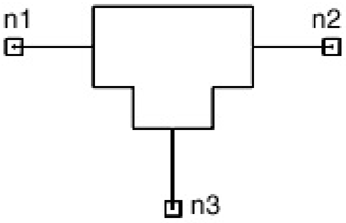
Notes

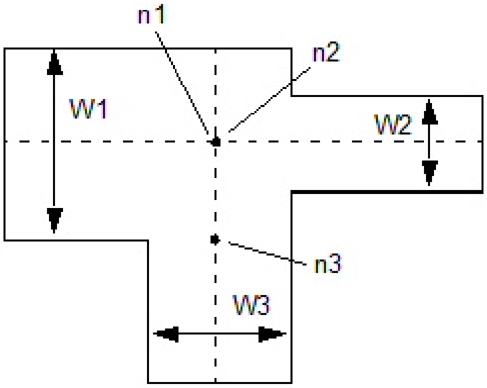
1. [**Stripline**] The following condition should be satisfied to get accurate results: $\max(W1,W2)/\lambda_g \leq 1.0$, where λ_g is the guide wavelength

References

1. R. Hoffmann, *Handbook of Microwave Integrated Circuits*, Artech House, 1987.

Tee, Reference Planes at Center





Netlist Format

A tee instance has the following netlist format:

```
Axxx n1 n2 n3 W1=val W2=val W3=val [NSUM=val]

COMPONENT=tee SUBSTRATE=substrate_name
```

n1, *n2*, and *n3* are the names of the nodes attached to the tee. The entry **COMPONENT=tee** identifies the element as a tee.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 10: Tee Instance Parameters

Parameter	Description	Unit	Default
W1	Width of line connected to node n1	Meter	1e-3
W2	Width of line connected to node n2	Meter	1e-3
W3	Width of line connected to node n3	Meter	1e-3
NSUM	Number of modes considered in the field expansion	None	3

Netlist Example

```
A23 Port1 Port2 Port3 W1=1e-3 W2=2e-3 W3=3e-3
+ COMPONENT=TEE SUBSTRATE=SL1
```

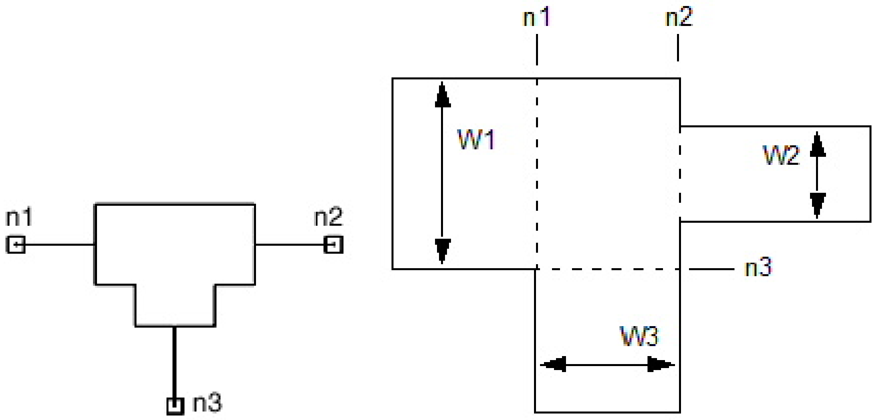
where SL1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] The collinear lines are connected to nodes *n1* and *n2* and have widths **W1** and **W2** ; the perpendicular line is connected to node *n3* and has width **W3**.
2. [**All substrates**] The *n1*, *n2* reference plane is centered on the width of the line connected to node *n3* (width **W3**).
3. [**All substrates**] If W1 > W2: Node *n3* is collinear with W1.
4. [**All substrates**] If W2 > W1: Node *n3* is collinear with W2.
5. [**Stripline**] To get accurate results, the following condition should be satisfied: $B/\lambda_g << 1$, where λ_g is the guide wavelength in the substrate dielectric.

Tee, Reference Planes at Edge



Netlist Format

A tee instance has the following netlist format:

```
Axxx n1 n2 n3 W1=val W2=val W3=val [NSUM=val]

COMPONENT=tee_edge_referenced SUBSTRATE=substrate_name
```

n1, *n2*, and *n3* are the names of the nodes attached to the tee. The entry **COMPONENT=tee_edge_referenced** identifies the element.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 11: Tee Instance Parameters

Parameter	Description	Unit	Default
W1	Width of line connected to node n1	Meter	1e-3
W2	Width of line connected to node n2	Meter	1e-3
W3	Width of line connected to node n3	Meter	1e-3
NSUM	Number of modes considered in the field expansion	None	3

Netlist Example

```
A23 Port1 Port2 Port3 W1=1e-3 W2=2e-3 W3=3e-3
+ COMPONENT=tee_edge_referenced SUBSTRATE=SL1
```

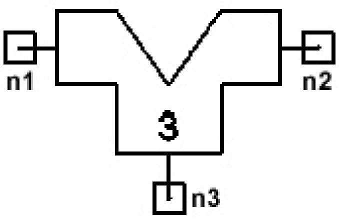
where SL1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] The collinear lines are connected to nodes n1 and n2 and have widths W1 and W2; the perpendicular line is connected to node n3 and has width W3.
2. [**All substrates**] If W1 > W2: Node n3 is collinear with W1.
3. [**All substrates**] If W2 > W1: Node n3 is collinear with W2.
4. [**Stripline**] To get accurate results, the following condition should be satisfied: $B/\lambda_g << 1$, where λ_g is the guide wavelength in the substrate dielectric.

Compensated TEE



NOTE: There is no netlist form for this component. It is available for Planar EM simulation only.

n1, *n2*, and *n3* are the names of the nodes attached to the tee.

Table 12: Compensated TEE Instance Parameters

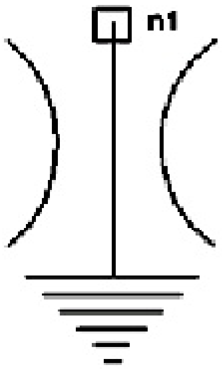
Parameter	Description	Unit	Default
W	Conductor width at ports 1 and 2	Meter	0.001
W3	Conductor width at port 3	None	0.001
D	Notch depth	Meter	0.001
ANG	Notch angle	Degree	45

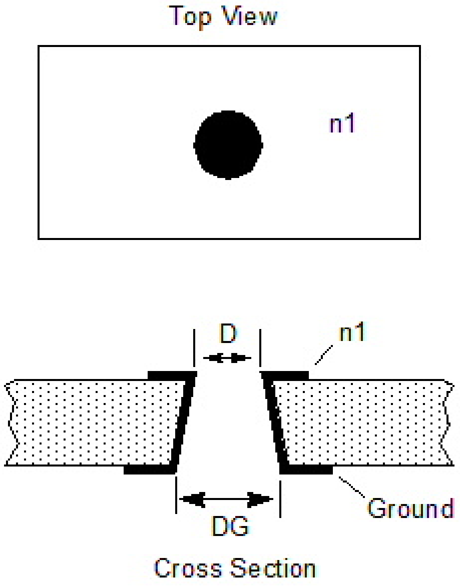
Notes

1. This model is available for Planar EM simulation only.
2. The notch angle coincides with the center of the line on port 3.

3. The structure is de-embedded to the reference planes that coincide with the edges of W and W3, respectively, unless the notch angle or depth causes the edges of the notch to fall outside the rectangle transcribed by the physical dimensions W and W3. In that case, the reference planes are transferred to the outermost corners of the notch.
4. If a substrate is not defined for the component, the Layout stackup or Footprint stackup may be used.

Via Through Hole





Netlist Format

A via hole instance has the following netlist format:

```
Axxx n1 [D=val] [DG=val]
```

```
COMPONENT=viahole SUBSTRATE=substrate_name
```

n1 is the name of the node attached to the via through hole. The other node is ground, and is not specified in the syntax. The entry **COMPONENT=viahole** identifies the element as a via through hole.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 13: Via Through Hole Instance Parameters

Parameter	Description	Unit	Default
D	Diameter of upper via hole	Meter	1e-3
DG	Diameter of lower via hole	Meter	D

Netlist Example

```
A19 Port1 D=0.001 COMPONENT=viahole SUBSTRATE=SL1
```

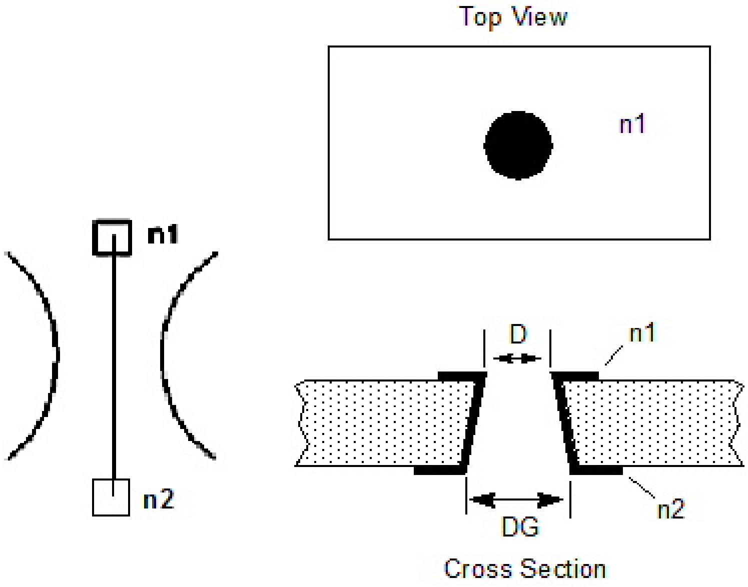
where SL1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] If metallization is not specified in the referenced substrate definition, the via element behaves as an inductance only.

Via Through Hole with Reference



Netlist Format

A via hole instance has the following netlist format:

```
Axxx n1 n2 [D=val] [DG=val] COMPONENT=viahole
SUBSTRATE=substrate_name
```

n1 and *n2* are the names of the node attached to the via through hole. The entry **COMPONENT=viahole** identifies the element as a via through hole.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 14: Via Through Hole Instance Parameters

Parameter	Description	Unit	Default
D	Diameter of upper via hole	Meter	1e-3
DG	Diameter of lower via hole	Meter	D

Netlist Example

```
A21 Port1 net_31 D=0.001 COMPONENT=viahole SUBSTRATE=SL1
```

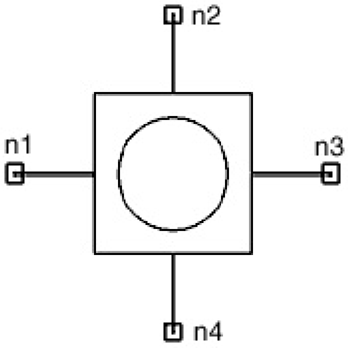
where SL1, the selected layout technology or substrate type, has a definition such as:

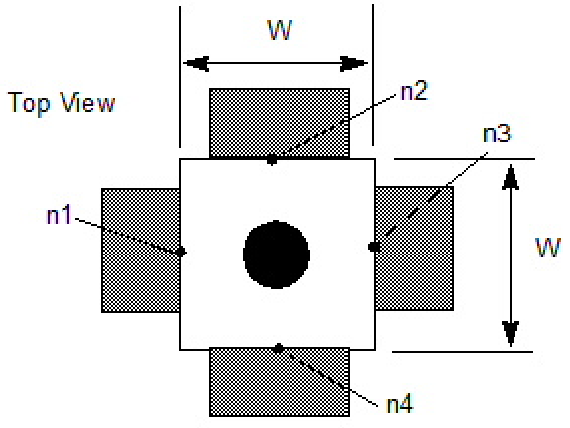
```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

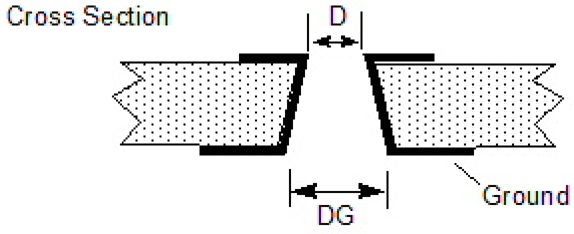
Notes

1. [**All substrates**] If metallization is not specified in the referenced substrate definition, the via element behaves as an inductance only.

Via Pad







Netlist Format

A via pad instance has the following netlist format:

```
Axxx n1 [n2 n3 n4] [D=val] [DG=val] [W=val] COMPONENT=viapad

SUBSTRATE=substrate_name
```

n1 through *n4* are the names of the nodes attached to the via pad. Any nodes not specified are modeled as open stubs. A fifth node is connected to ground, and is not shown in the syntax. The entry **COMPONENT=viapad** identifies the element as a via pad.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 15: Via Through Hole Instance Parameters

Parameter	Description	Unit	Default
D	Diameter of upper via hole	Meter	0.5e-3
DG	Diameter of lower via hole	Meter	D
W	Width and length of square pad	Meter	1e-3

Netlist Example

```
A23 Port1 Port2 Port3 Port4 D=0.0005 W=0.001
+ COMPONENT=viapad SUBSTRATE=SL1
```

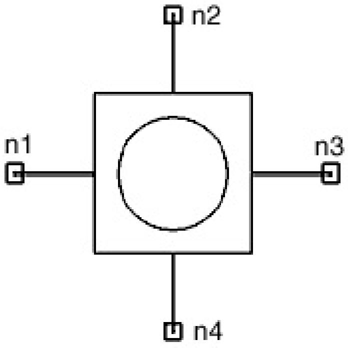
where SL1, the selected layout technology or substrate type, has a definition such as:

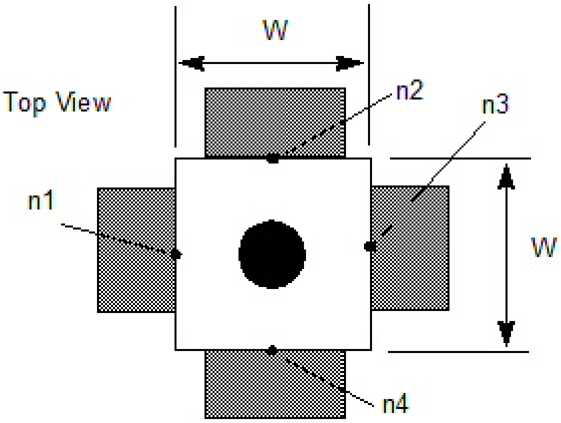
```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

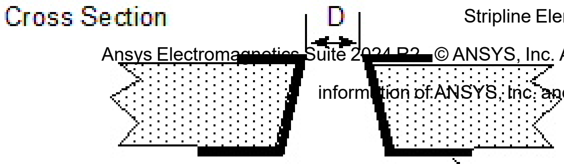
Notes

1. [**All substrates**] The pad is connected through a via to a ground.
2. [**All substrates**] The pad is square.
3. [**All substrates**] Unconnected nodes are considered to be open.
4. [**All substrates**] Transitions to connected transmission lines are not included in this model.

Via Pad with Reference







Netlist Format

A via pad instance has the following netlist format:

```
Axxx n1 [n2 n3 n4 n5] [D=val] [DG=val] [W= val]
```

```
COMPONENT=viapad SUBSTRATE=substrate_name
```

n1 through *n5* are the names of the nodes attached to the via pad. Any nodes not specified are modeled as open stubs. The entry **COMPONENT=viapad** identifies the element as a via pad.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 16: Via Through Holewith Reference, Instance Parameters

Parameter	Description	Unit	Default
D	Diameter of upper via hole	Meter	0.5e-3
DG	Diameter of lower via hole	Meter	D
W	Width and length of square pad	Meter	1e-3

Netlist Example

```
A24 Port1 Port2 Port3 Port4 net_49 D=0.0005 W=0.001
+ COMPONENT=viapad SUBSTRATE=SL1
```

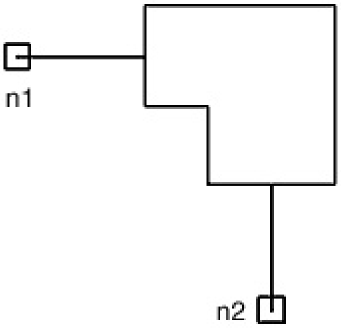
where SL1, the selected layout technology or substrate type, has a definition such as:

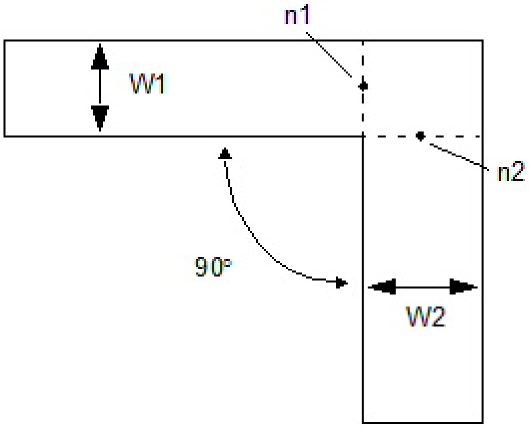
```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] The pad is connected through a via to a ground.
2. [**All substrates**] The pad is square.
3. [**All substrates**] Unconnected nodes are considered to be open.
4. [**All substrates**] Transitions to connected transmission lines are not included in this model.

Bend, Unmitered





Netlist Form

A*xxxx n1 n2* **W1=***val* **W2=***val* [**NSUM=***val*]

COMPONENT=unmitered_bend SUBSTRATE=*substrate_name*

n1 and *n2* are the names of the nodes attached to the unmitered bend. The entry **COMPONENT=unmitered_bend** identifies the element as an unmitered bend.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 17: Unmitered Bend Instance Parameters

Parameter	Description	Unit	Default
W1	Width of line 1	Meter	0.001
W2	Width of line 2	Meter	0.001
NSUM	Number of modes considered in the field expansion	None	3

Netlist Example

```
A23 Port1 Port2 W1=3e-4 W2=5e-3 NSUM=3
+ COMPONENT=unmitered_bend SUBSTRATE=SL1
```

where SL1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

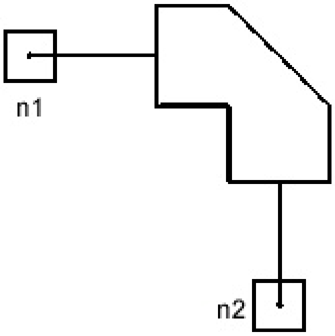
Notes

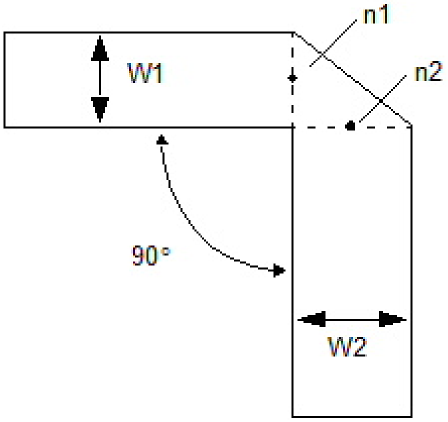
1. [**All substrates**] This element refers to a right angle bend, where the two intersecting lines can be defined with different widths. The outer corner of the bend is not mitered.
2. [**All substrates**] Reference planes coincide with the inside vertex of the corner.

References

1. Wolff, G. Kompa, and R. Mehran, “Calculation method for microstrip discontinuities and T-junctions,” Electron. Lett., Vol. 8, 1972, pp. 177-179.
2. G. Kompa, and R. Mehran, “Planar waveguide model for calculating microstrip components,” Electron. Lett., Vol. 11, 1975, pp. 459-460.
3. T. Okoshi, Planar Circuits for Microwaves and Lightwaves, Springer-Verlag, Berlin, New York, 1983.

Bend, Mitered





Netlist Form

A*xxxx n1 n2* **W1=***val* **W2=***val* [**NSUM=***val*]

COMPONENT=mitered_bend SUBSTRATE=*substrate_name*

n1 and *n2* are the names of the nodes attached to the mitered bend. The entry **COMPONENT=mitered_bend** identifies the element as a mitered bend.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 18: Mitered Bend Instance Parameters

Parameter	Description	Unit	Default
W1	Width of line 1	Meter	0.001
W2	Width of line 2	Meter	0.001
NSUM	Number of modes considered in the field expansion	None	3

Netlist Example

```
A23 Port1 Port2 w1=3e-4 w2=5e-3
+ COMPONENT=mitered_bend SUBSTRATE=SL1
```

where SL1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

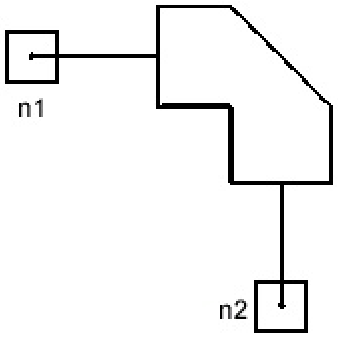
Notes

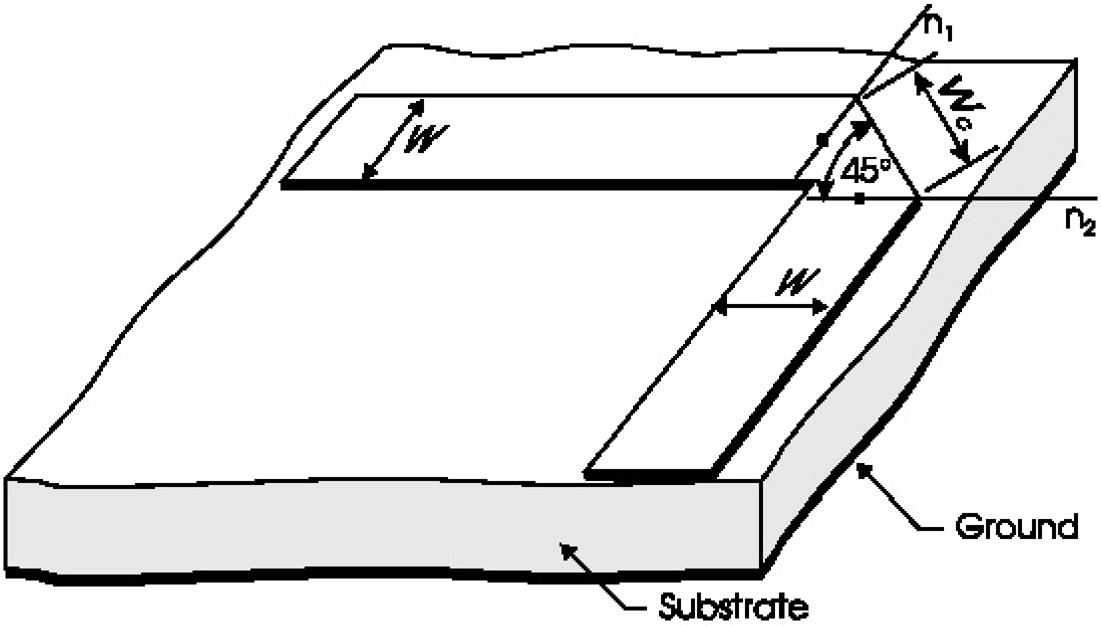
1. [**All substrates**] This element corresponds to the case where the outer corner of the right-angle bend is mitered at an angle, such that the edges of the cut are on the intersection of the reference planes and the outer edges of the bend. In the case W1=W2, the angle of the cut is 45° and the miter ratio is 0.5.
2. [**All substrates**] Reference planes coincide with the inside vertex of the corner.

References

1. Wolff, G. Kompa, and R. Mehran, “Calculation method for microstrip discontinuities and T-junctions,” *Electron. Lett.*, Vol. 8, 1972, pp. 177-179.
2. G. Kompa, and R. Mehran, “Planar waveguide model for calculating microstrip components,” *Electron. Lett.*, Vol. 11, 1975, pp. 459-460.
3. T. Okoshi, *Planar Circuits for Microwaves and Lightwaves*, Springer-Verlag, Berlin, New York, 1983.

Bend, Optimally Mitered





Netlist Form

A*xxxx n1 n2* **W1=***val* **COMPONENT=optimally_mitered_bend SUBSTRATE=***substrate_name*

n1 and *n2* are the names of the nodes attached to the mitered bend. The entry **COMPONENT=optimally mitered_bend** identifies the element as a mitered bend.

The entry **SUBSTRATE=** substrate_name identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 19: Mitered Bend Instance Parameters

Parameter	Description	Unit	Default
W	Width of line	Meter	0.001

Netlist Example

```
A23 Port1 Port2 W1=3e-4
+ COMPONENT=optimally_mitered_bend SUBSTRATE=SL1
```

where SL1, the selected layout technology or substrate type, has a definition such as:

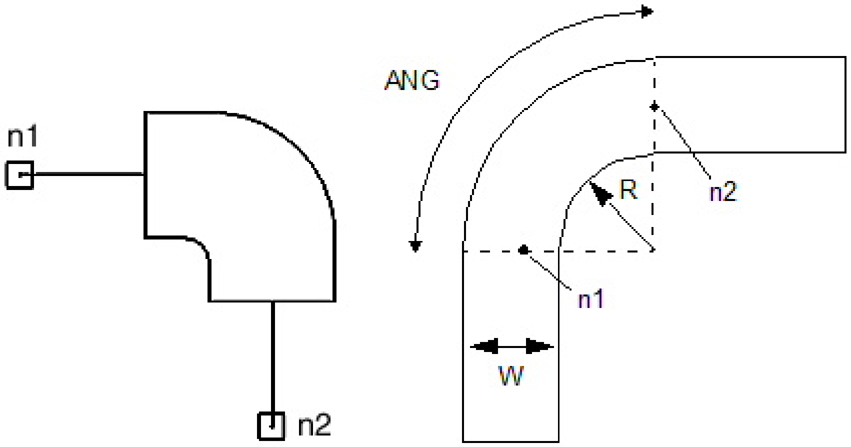
```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] Conditions for accurate results: Frequency ≤ 18 GHz, $2.2 \leq \varepsilon_r \leq 25$, $W/H \geq 0.25$
2. [**All substrates**] The miter is 45º and the length W_c is given by

$$\frac{W_c}{W} = 2\sqrt{2} \times \left(0.52 + 0.65 \times e^{\frac{-135W}{W}} \right)$$

Bend, Radial



Netlist Form

A*xxxx n1 n2* **W1=***val* **R=***val* [**ANG=***val*]

COMPONENT=radial_bend SUBSTRATE=*substrate_name*

n1 and *n2* are the names of the nodes attached to the radial bend. The entry **COMPONENT=radial_bend** identifies the element as a radial bend.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 20: Radial Bend Instance Parameters

Parameter	Description	Unit	Default
W	Width of line	Meter	0.001
R	Inner radius of bend	Meter	1e-20
ANG	Angle of bend	Degree	90

Netlist Example

```
A23 Port1 Port2 W=1e-3 R=1e-6 ANG=75
+ COMPONENT=radial_bend SUBSTRATE=SL1
```

where SL1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

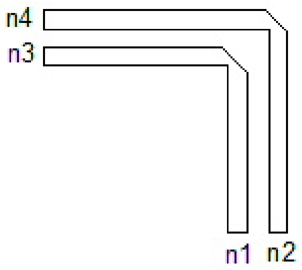
Notes

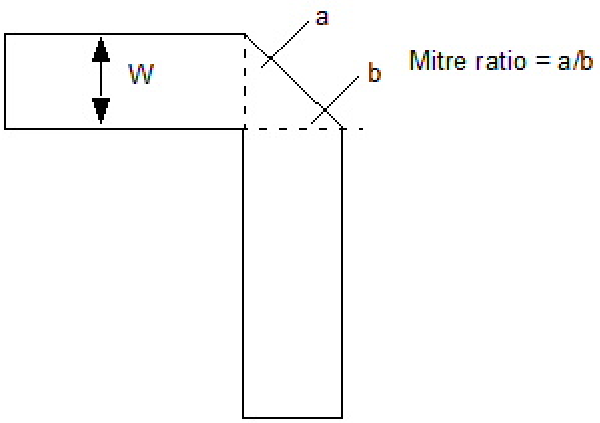
1. [**All substrates**] This element corresponds to the case where the outer corner of the right-angle bend is mitered at an angle, such that the edges of the cut are on the intersection of the reference planes and the outer edges of the bend. In the case W1=W2, the angle of the cut is 45° and the miter ratio is 0.5.
2. [**All substrates**] Reference planes coincide with the inside vertex of the corner.

References

1. Wolff, G. Kompa, and R. Mehran, “Calculation method for microstrip discontinuities and T-junctions,” *Electron. Lett.*, Vol. 8, 1972, pp. 177-179.
2. G. Kompa, and R. Mehran, “Planar waveguide model for calculating microstrip components,” *Electron. Lett.*, Vol. 11, 1975, pp. 459-460.
3. T. Okoshi, *Planar Circuits for Microwaves and Lightwaves*, Springer-Verlag, Berlin, New York, 1983.

Coupled Bend





NOTE: There is no netlist form for this component. It is available for Planar EM simulation only.

n1 and *n2* are the names of the input nodes attached to the coupled bend. *n3* and *n4* are the output nodes.

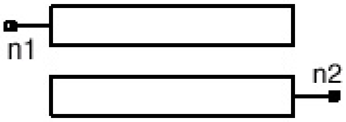
Table 21: Coupled Bend Instance Parameters

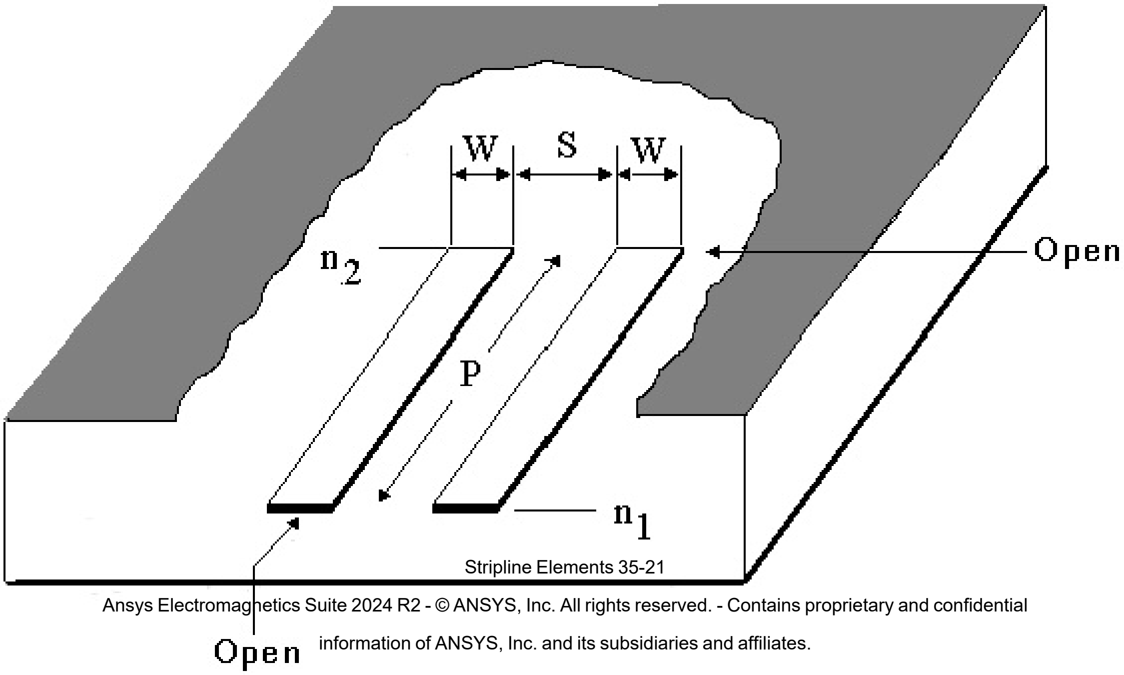
Parameter	Description	Unit	Default
W	Conductor width	Meter	0.001
M	Mitre ratio (**a** /**b** in the reference diagram)	None	1
S	Conductor spacing	Meter	0.001
L1	Shift in reference plane 1	Meter	0
L2	Shift in reference plane 2	Meter	0

Notes

1. This model is available for Planar EM simulation only.
2. The default reference plane is typically coincident with the opposing transmission line edge, but is extended if the miter ratio moves the outside edge further out. The reference plane is shifter even further through the use of the L1 and L2 parameters.
3. If a substrate is not defined for the component, the Layout stackup or Footprint stackup may be used.

Coupled Lines, Open Ends





Netlist Form

A multiple coupled line, physical length instance has the following netlist syntax:

A*xxx n1 n2* **W=***width* **P=***length* **S=***spacing*

COMPONENT=mcplo SUBSTRATE=*substrate_name*

n1 and *n2* are the input and output nodes. The entry **COMPONENT=mcplo** identifies the element as a coupled line, open ends.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 22: Multiple Coupled Line, Physical Length, Instance Parameters

Parameter	Description	Units	Default
P	Physical length	Meter	1e-2
S	Spacing between conductors (NL>1)	Meter	1e-3
W	Conductor width	Meter	1e-3

Netlist Example

```
A3 Port1 Port2 W=3.2004e-004 P=1 S=4.5720e-004
+ COMPONENT=MCPLO SUBSTRATE=SL1
```

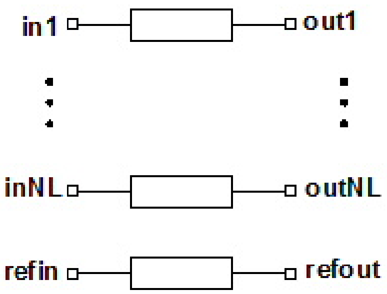
where SL1, the selected layout technology or substrate type, has a definition such as:

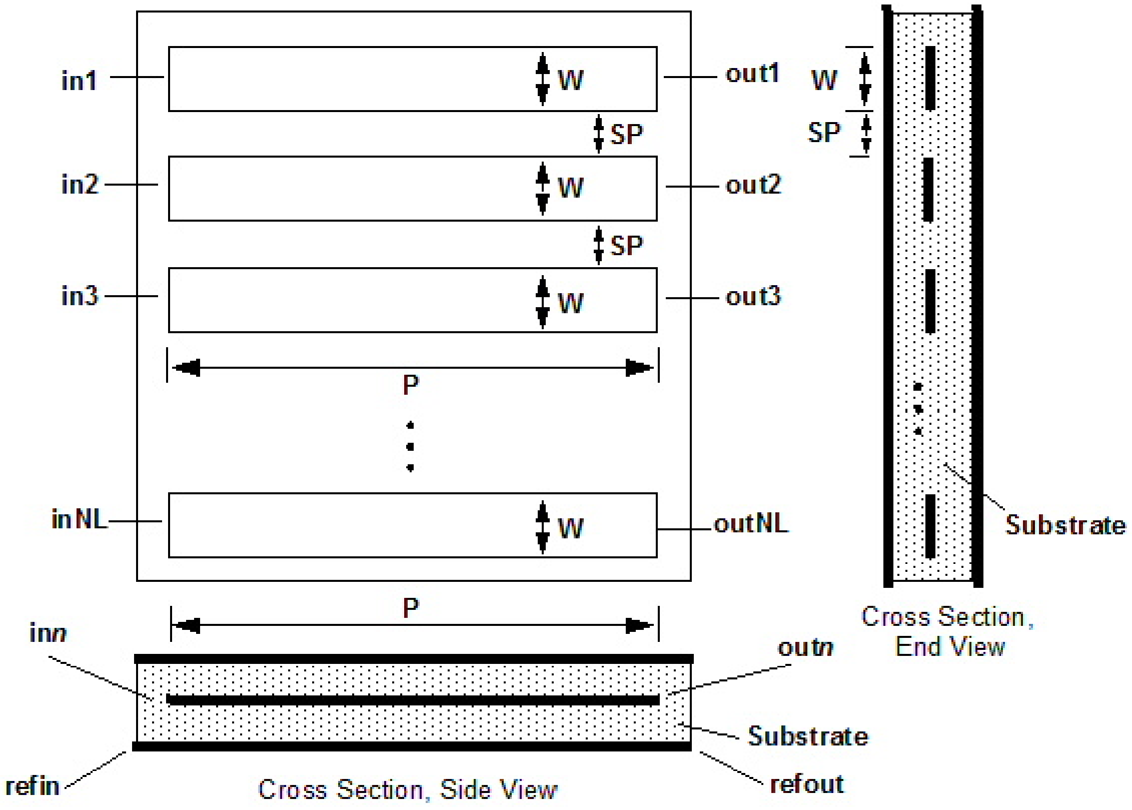
```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**Stripline**] This model includes the even and odd mode equivalent fringing lengths at the open ends. If P=0, only the end extension effect is considered.

Multi-Coupled Lines, Physical Length





Netlist Form

A multiple coupled line, physical length instance has the following netlist syntax:

```
Axxx in1 [...inNL] refin out1 [...outNL] refout

NL=NumberofLines [W=width] [P=length] [SP=spacing]

COMPONENT=MCPL SUBSTRATE=substrate_name
```

in1 through *inNL* are the names of the input nodes. *out1* through *outNL* are the corresponding output nodes. refin and refout are the input and output reference nodes. The entry **COMPONENT=MCPL** identifies the element as a multiple coupled line.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 23: Multiple Coupled Line, Physical Length, Instance Parameters

Parameter	Description	Units	Default
NL	Number of signal lines	None	1
P	Physical length	Meter	1e-2
SP	Spacing between conductors (NL>1)	Meter	1e-3
W	Conductor width	Meter	1e-3

Netlist Example

```
A3 Port1 Port2 0 net_1911 net_1911 0
+ W=3.2004e-004 P=1 nl=2 sp=4.5720e-004
+ COMPONENT=MCPL SUBSTRATE=SL1
```

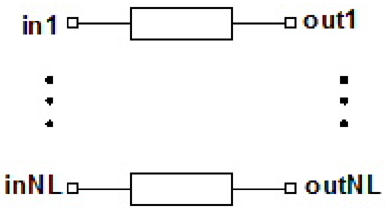
where SL1, the selected layout technology or substrate type, has a definition such as:

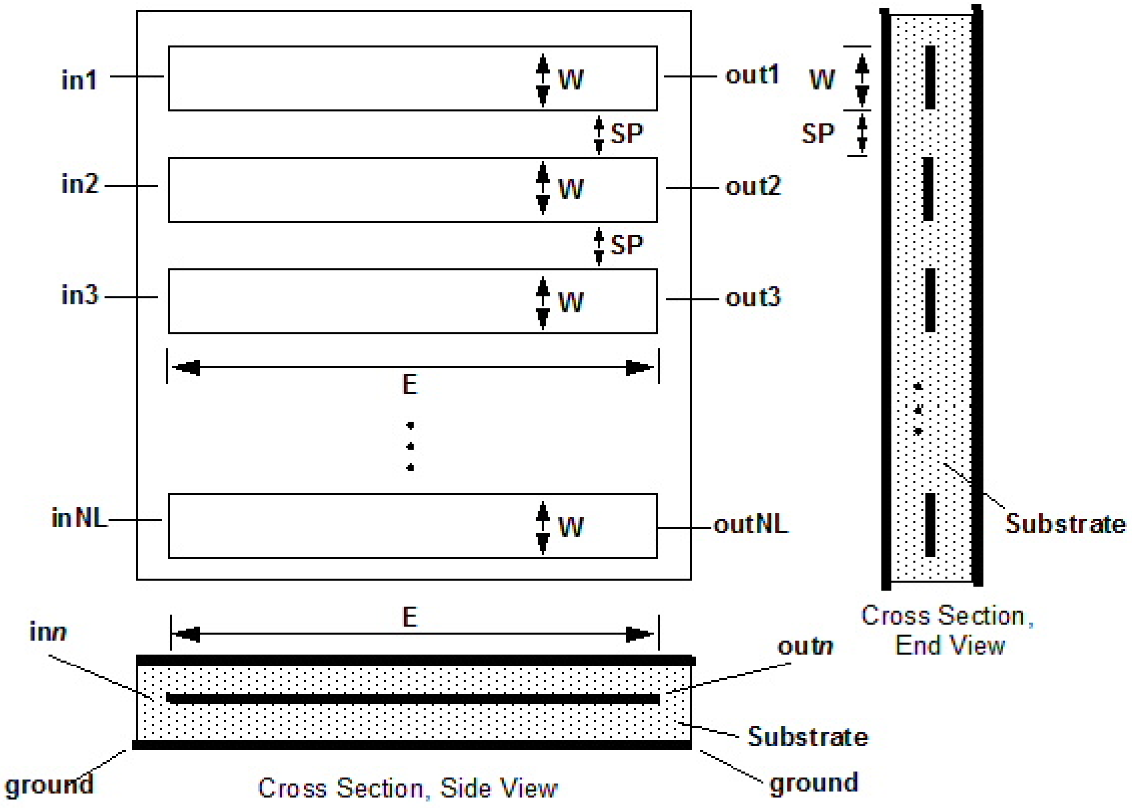
```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005)
```

Notes

1. Surface roughness in the substrate definition is not supported in the MCPL implementation.

Multi-Coupled Lines, Electrical Length





Netlist Form

A multiple coupled line, electrical length instance has the following netlist syntax:

`Axxx in1 [...inNL] out1 [...outNL]`

`NL=NumberofLines`

`[W=width] [SP=spacing] [E=length] [F=freq]`

`COMPONENT=MCPL SUBSTRATE=substrate_name`

in1 through *inNL* are the names of the input nodes. *out1* through *outNL* are the corresponding output nodes. The entry **COMPONENT=MCPL** identifies the element as a multiple coupled line.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the Stripline (SL) Substrate for information on this substrate type.

Table 24: Multiple Coupled Line, Electrical Length Instance Parameters

Parameter	Description	Units	Default
E	Electrical length	Degree	45.0
F	Reference frequency for electrical length	Hertz	1e9
NL	Number of signal lines	None	1
SP	Spacing between conductors (NL>1)	Meter	1e-3
W	Conductor width	Meter	1e-3

Netlist Example

```
A3 Port1 Port2 net_1911 net_1911
+ W=3.2004e-004 NL=2 sp=4.5720e-004 E=45 F=1e9
+ COMPONENT=MCPL SUBSTRATE=SL1
```

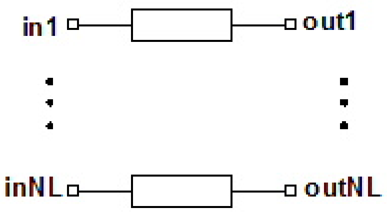
where SL1, the selected layout technology or substrate type, has a definition such as:

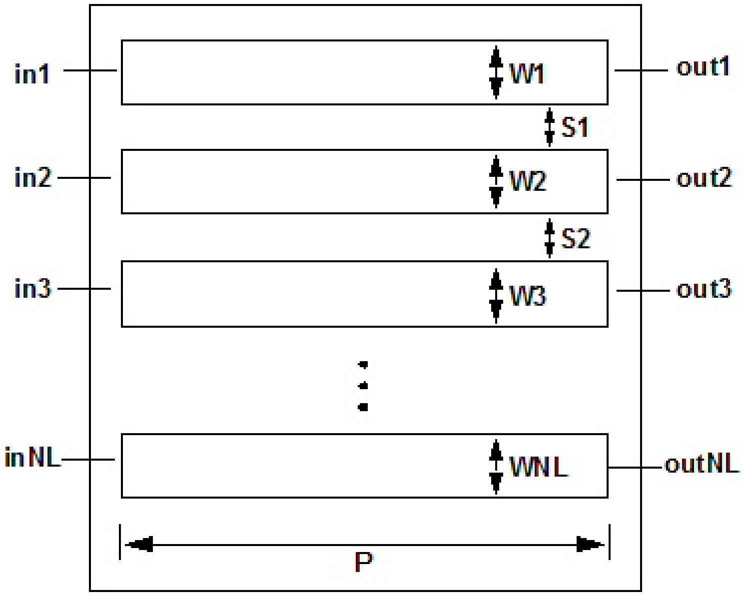
```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005)
```

Notes

1. Surface roughness in the substrate definition is not supported in the MCPL implementation.

Multi-Coupled Lines, Asymmetric





Netlist Form

An asymmetric multiple coupled line, physical length instance has the following netlist syntax:

```
Axxx in1 [...inNL] out1 [...outNL]

NL=NumberofLines [P=length] [W=width] [SP=spacing]

COMPONENT=sl_mcpl_a SUBSTRATE=substrate_name
```

in1 through *inNL* are the names of the input nodes. *out1* through *outNL* are the corresponding output nodes. The entry **COMPONENT=sl_mcpl_a** identifies the element as an asymmetric multiple coupled line, physical length.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 25: Asymmetric Multiple Coupled Line, Physical Length, Instance Parameters

Parameter	Description	Units	Default
NL	Number of signal lines	None	None
P	Physical length	Meter	1e-3
W1, **W2**, ...	Conductor widths	Meter	1e-3

S1, **S2**, ...	Spacing between conductors (S1 = spacing between 1 and 2, etc.)	Meter	1e-3

Netlist Example (3 Conductors)

```
A3 Port1 Port2 Port 3 Port 4 Port 5 Port 6 NL=3
+ P=15mm W1=0.75mm S1=0.4mm W2=1.3mm S2=0.6mm W3=1.1mm
+ COMPONENT=sl_mcpl_a SUBSTRATE=SL1
```

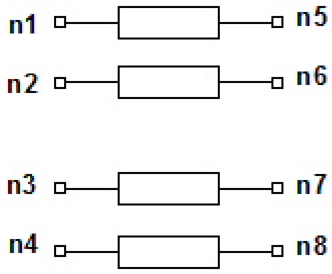
where SL1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005)
```

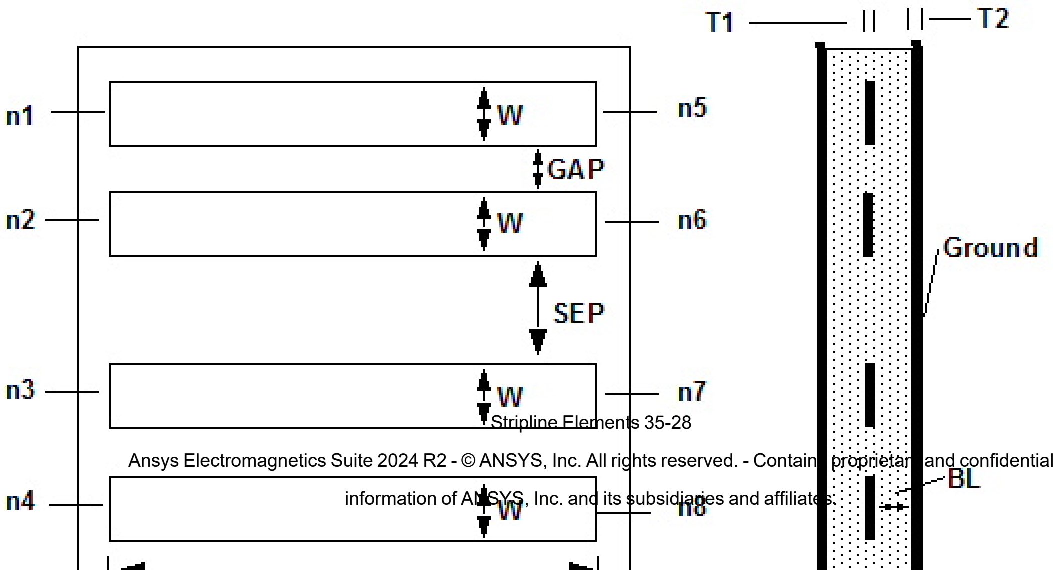
Notes

1. Surface roughness in the substrate definition is not supported in the MCPL implementation.
2. The asymmetric MCPL elements use the data on the SUBSTRATE definition, but internally the data is converted to W-element FIELD SOLVER format for solution.

Multi-Coupled Lines, Differential Pairs, Field Solver



Diagrams show the
N=4 component
(two differential pairs)



A multicoupled line, two differential pairs, field solver instance has the following netlist syntax:

```
Wxxx n1 n2 n3 n4 0 n5 n6 n7 n8 0   N=4 [L=length]   FSmodel=modelname
```

```
.MATERIAL conductor METAL CONDUCTIVITY=conductivity

.MATERIAL dielectric DIELECTRIC ER=er LOSSTANGENT=losstangent

.SHAPE RECT1 RECTANGLE WIDTH=w HEIGHT=t1 // Conductors
.LAYERSTACK stripline
+ LAYER=(cond1, t2) // Ground plane
+ LAYER=(dielectric, B)
+ LAYER=(cond1, t2)
.MODEL modelname W MODELTYPE=Fieldsolver
+ LAYERSTACK=stripline
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=(0, 't2 + B*0.5')
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=('w+gap', 't2 + B*0.5'
+ MATERIAL=conductor, TYPE=REFERENCE)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=('2w+gap', 't2 + B*0.5')
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT3, ORIGIN=('3w+2gap+sep', 't2 + B*0.5')
+ MATERIAL=conductor, TYPE=REFERENCE)
```

n1, n2, *n3,* and *n4* are the names of the input nodes. *n5*, *n6*, *n7*, and *n8* are the corresponding output nodes. The entry **N=4** shows that this is a 4-conductor, 2-pair differential line.

The entry **FSmodel=***modelname* identifies the field solver stripline model.

Table 169: Multicoupled Line, Differential Pairs, Field Solver Instance Parameters

Parameter	Description	Units	Default
L	Physical length	Meter	1e-3
N	Number of lines	None	None
conductor	Conductor material	None	cond1
conductivity	Conductivity of conductor material		57.6e6
dielectric	Dielectric material	None	diel1
B	Thickness of dielectric layer	Meter	1e-3
er	Dielectric constant		2.2
losstangent	Dielectric loss tangent		0
w	Width of conductor	Meter	1e-3

gap	Gap width between differential lines	Meter	1e-3
sep	Separation between pairs of lines	Meter	5e-3
T1	Thickness of conductors	Meter	0.001
T2	Thickness of ground planes	Meter	0.001

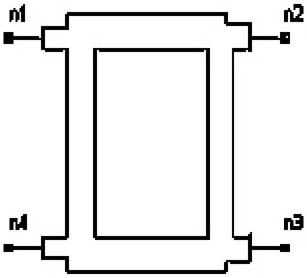
> **Note:** The default values for the differential coupled lines are the ones assigned when placing a component on the Component library in a schematic. There are NO defaults for netlist designs; all values must be specified.

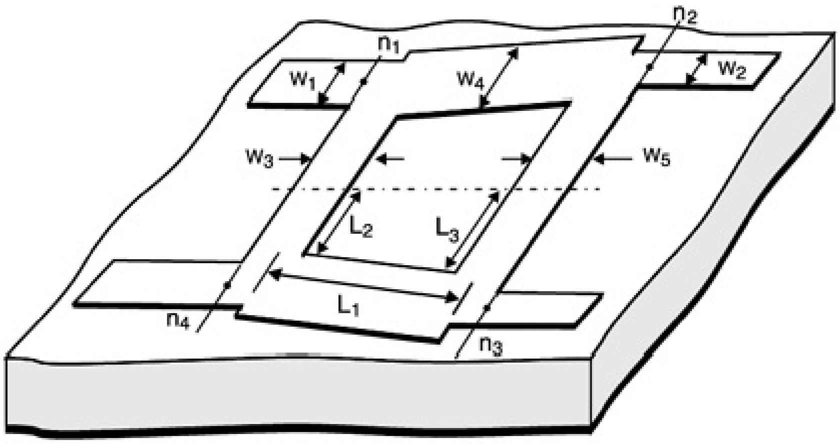
Netlist Example

```
W3 Port1 Port2 0 net_1911 net_2 0 N=2 L=0.002 FSmodel=BCL1
```

```
.MATERIAL copper METAL CONDUCTIVITY=5.8e7
.MATERIAL dielectric DIELECTRIC ER=4.4 LOSSTANGENT=0.02
.SHAPE RECT1 RECTANGLE WIDTH=.002 HEIGHT=.001   // Conductors
.LAYERSTACK STACK1
+ LAYER=(PEC, .003) // Bottom ground
+ LAYER=(dielectric, .01)
+ LAYER=(AIR, .03)
.MODEL MSFS1 W MODELTYPE=Fieldsolver
+ LAYERSTACK=STACK1
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=(0, '.003+.01*0.5')
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=('.002+.004', '.003+.01*0.5')
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=('2*.002+.004', '.003+.01*0.5')
+ MATERIAL=conductor, TYPE=SIGNAL)
+ CONDUCTOR=(SHAPE=RECT1, ORIGIN=('3*.002+2*.004', '.001+.01*0.5')
+ MATERIAL=conductor, TYPE=SIGNAL)
```

Branch Line Coupler





Netlist Format

A branch line coupler instance has the following netlist format:

ASLCOUPB*xxx n1 n2 n3 n4* **W1=***val* **W2=***val* **W3=***val* **W4=***val* **W5=***val* **L1=***val* **L2=***val* **L3=***val* **COMPONENT=branch_coupler SUBSTRATE=***substrate_name*

n1, *n2*, *n3*, and *n4* are the names of the nodes attached to the coupler. The entry **COMPONENT=branch_coupler** identifies the element.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 26: Branch Line Coupler Instance Parameters

Parameter	Description	Unit	Default
W1	Width of lines connected to nodes n1 and n4	Meter	0.5e-3

W2	Width of lines connected to nodes n2 and n3	Meter	0.5e-3
W3	Width of line from n1 to n4	Meter	0.5e-3
W4	Width of line from n1 to n2 Width of line from n3 to n4	Meter	0.5e-3
W5	Width of line from n2 to n3	Meter	0.5e-3
L1	Length along center line of W4	Meter	2e-3
L2	Half length along center line of W3	Meter	2e-3
L3	Half length along center line of W5	Meter	0

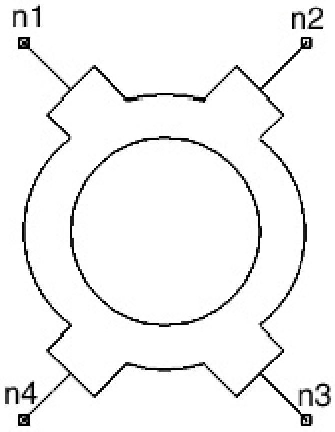
Netlist Example

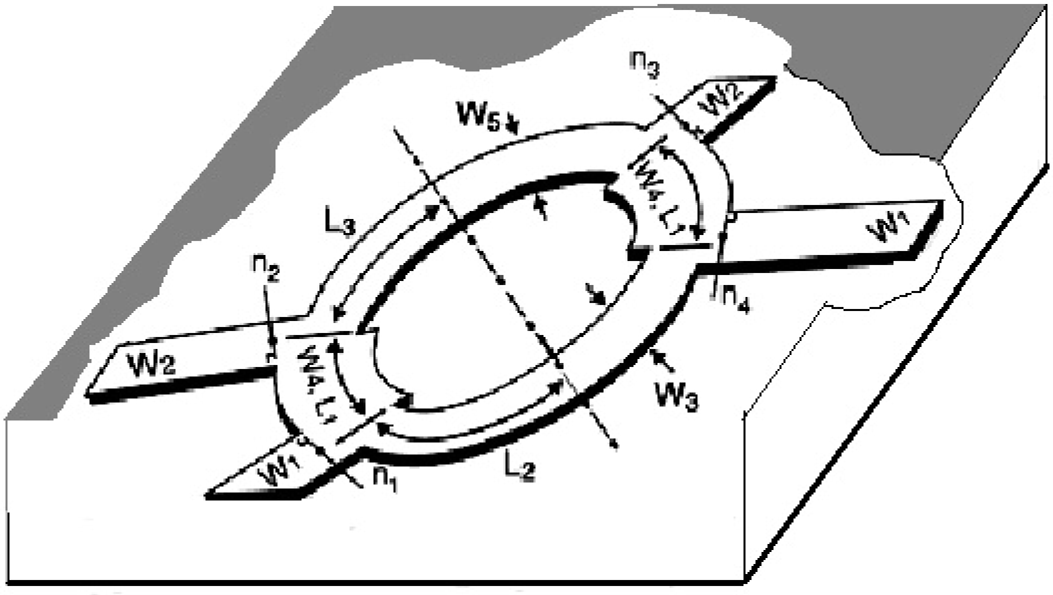
```
ASLCOUPB1 net1 Port2 net3 Port4 W1=1e-3 W2=.2e-3 W3=.7e-3
+ W4=.4e-3 L1=1.8e-3 L2=1.5e-3 L3=1.5e-3
+ COMPONENT=branch_coupler SUBSTRATE=SL1
```

where SL1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Ring Coupler





Netlist Format

A ring coupler instance has the following netlist format:

```
ASLCOUPRxxx n1 n2 n3 n4 W1=val W2=val W3=val W4=val W5=val
L1=val L2=val L3=val COMPONENT=ring_coupler
SUBSTRATE=substrate_name
```

n1, *n2*, *n3*, and *n4* are the names of the nodes attached to the coupler. The entry **COMPONENT=ring_coupler** identifies the element.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 27: Ring Coupler Instance Parameters

Parameter	Description	Unit	Default
W1	Width of lines connected to nodes n1 and n4	Meter	0.5e-3
W2	Width of lines connected to nodes n2 and n3	Meter	0.5e-3
W3	Width of line from n1 to n4	Meter	0.5e-3
W4	Width of line from n1 to n2 Width of line from n3 to n4	Meter	0.5e-3

W5	Width of line from n2 to n3	Meter	0.5e-3
L1	Length along center line of W4	Meter	2e-3
L2	Half length along center line of W3	Meter	2e-3
L3	Half length along center line of W5	Meter	0

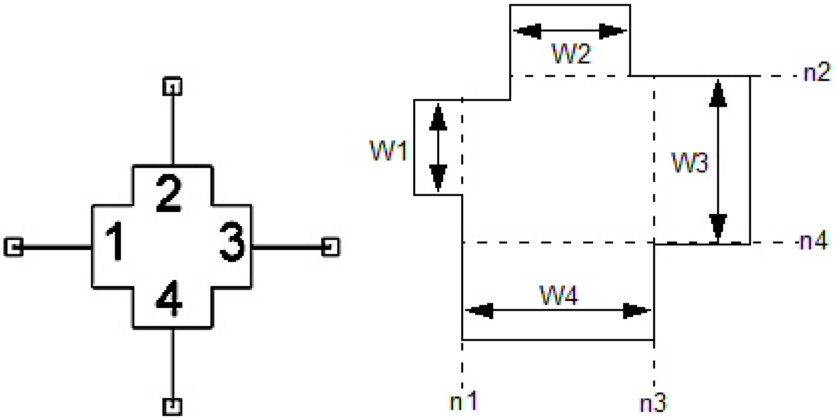
Netlist Example

```
ASLCOUPR1 net1 Port2 net3 Port4 W1=1e-3 W2=.2e-3 W3=.7e-3
+ W4=.4e-3 L1=1.8e-3 L2=1.5e-3 L3=1.5e-3
+ COMPONENT=ring_coupler SUBSTRATE=SL1
```

where SL1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Cross Junction



Netlist Format

A cross instance has the following netlist format:

A*xxx n1 n2 n3 n4* **W1=***val* **W2=***val* **W3=***val* **W4=***val* [**NSUM=***val*]

COMPONENT=cross SUBSTRATE=*substrate_name*

n1, *n2*, *n3*, and *n4* are the names of the nodes attached to the cross. The entry **COMPONENT=cross** identifies the element as a cross.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 28: Cross Instance Parameters

Parameter	Description	Unit	Default
W1	Width of line connected to node n1	Meter	1e-3
W2	Width of line connected to node n2	Meter	1e-3
W3	Width of line connected to node n3	Meter	1e-3
W4	Width of line connected to node n4	Meter	1e-3
NSUM	Number of modes considered in the field expansion	None	4

Netlist Example

```
Across1 Port1 Port2 Port3 Port4 W1=1e-3 W2=2e-3 W3=3e-3 W4=4e-3
+ COMPONENT=cross SUBSTRATE=SL1
```

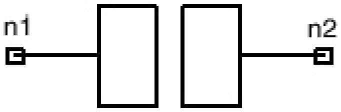
where SL1, the selected layout technology or substrate type, has a definition such as:

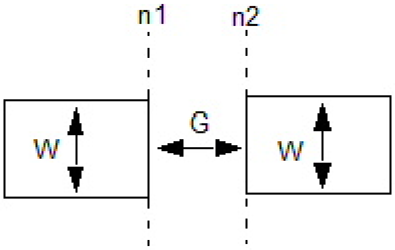
```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] The angle between intersecting lines is 90°.
2. [**All substrates**] Increasing NSUM improves the accuracy but increases the analysis time.

Gap, Symmetric





Netlist Format

A symmetric gap instance has the following netlist syntax:

A*xxx n1 n2* **W=***val* **G=***val* **COMPONENT=symmetric_gap SUBSTRATE=***substrate_name*

n1 and *n2* are the names of the nodes attached to the symmetric gap. The entry **COMPONENT=symmetric_gap** identifies the element as a symmetric gap.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 29: Symmetric Gap Instance Parameters

Parameter	Description	Units	Default
W	Line width	Meter	1e-3
G	Gap spacing	Meter	1e-4

Netlist Example

```
A23 Port1 Port2 W=5e-3 G=3e-4
+ COMPONENT=symmetric_gap SUBSTRATE=SL1
```

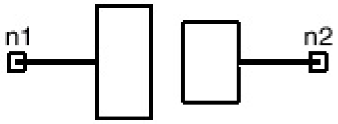
where SL1, the selected layout technology or substrate type, has a definition such as:

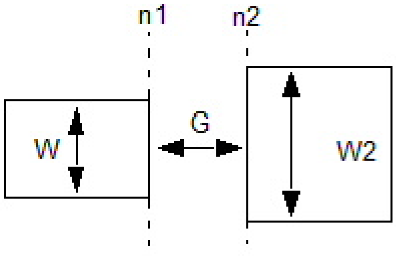
```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**Stripline**] The substrate definition should satisfy the following conditions:
   $G/B \leq 100$,
   $B/\lambda_g < 1.0$, where B is the distance between the ground planes and λ_g is the guide wavelength.

Gap, Asymmetric





Netlist Format

An asymmetric gap instance has the following netlist syntax:

A*xxx n1 n2* **W=***val* **W2=***val* **G=***val* **COMPONENT=asymmetric_gap SUBSTRATE=***substrate_name*

n1 and *n2* are the names of the nodes attached to the asymmetric gap. The entry **COMPONENT=asymmetric_gap** identifies the element as an asymmetric gap.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 30: Asymmetric Gap Instance Parameters

Parameter	Description	Units	Default
W1	Line width of the conductor at node 1	Meter	1e-3
W2	Line width of the conductor at node 2	Meter	1e-3
G	Gap spacing	Meter	1e-4

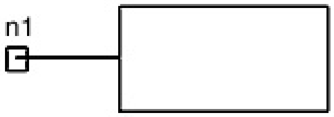
Netlist Example

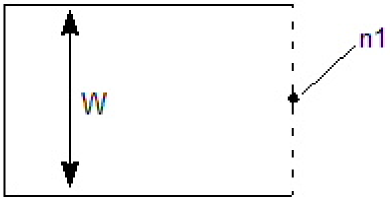
```
A23 Port1 Port2 W1=5e-3 W2=7e-3 G=3e-4
+ COMPONENT=asymmetric_gap SUBSTRATE=SL1
```

where SL1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Open End Effect





Netlist Form

An open end effect instance has the following netlist syntax:

```
Axxx n1 W=val [OPEN=POS|NEG] COMPONENT=open_end SUBSTRATE=substrate_name
```

n1 is the name of the node attached to the open end effect. The entry **COMPONENT=open_end** identifies the element as an open end effect.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 31: Open End Effect Instance Parameters

Parameter	Description	Units	Default
W	Line width	Meter	1e-3
OPEN	POS means a positive open-end effect is applied NEG means a negative open-end effect is applied (used for de-embedding)	None	POS

Netlist Example

```
A12 1 2 W=.0025 COMPONENT=open_end SUBSTRATE=SL1
```

where SL1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

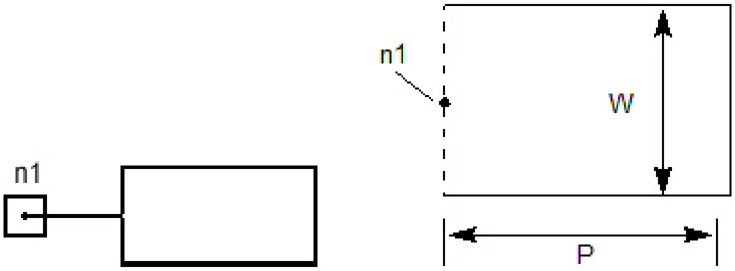
Notes

1. [**All substrates**] The transmission line is extended by a ΔL length, which is a function of the dielectric constant, frequency, and physical dimensions of the line. If the OPEN

parameter is set to NEG, a negative effect is applied. This holds true for the length extension ΔL, and the associated dielectric losses.

2. [**Stripline**] For maximum accuracy (where B is the ground-to-ground distance and E_R is the dielectric constant of the substrate):
   F[GHz] < 708/B[MILS]
   $E_R \le 50$
   $0.01 \le W/B \le 100$

Open Stub, Physical Length



Netlist Form

An instance of an open stub with physical length has the following netlist syntax:

`A``*xxx n1*` **`W=`**`*val*` **`P=`**`*val*` **`COMPONENT=open_stub SUBSTRATE=`**`*substrate_name*`

n1 is the name of the node attached to the open stub. The entry **COMPONENT=open_stub** identifies the element as an open stub with physical length.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 32: Open Stub with Physical Length, Instance Parameters

Parameter	**Description**	**Units**	**Default**
W	Line width	Meter	1e-3
P	Physical length	Meter	10e-3

Netlist Example

```
A44 Port1 W=0.001 P=10e-3 COMPONENT=open_stub SUBSTRATE=SL1
```

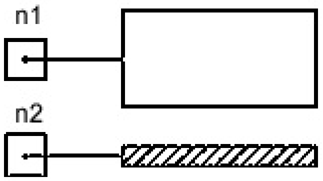
where SL1, the selected layout technology or substrate type, has a definition such as:

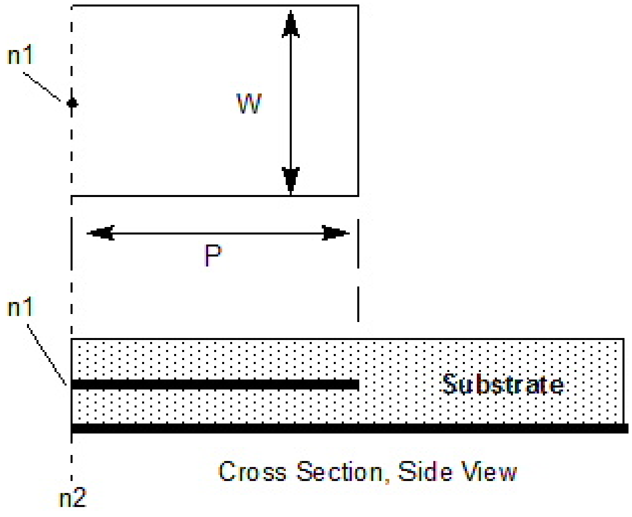
```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] The physical model using physical length includes the open end length correction.
2. [**All substrates**] The open stub model is equivalent to a transmission line model followed by an open model. This is also true in the case of negative length specifications, which are used for de-embedding purposes. Note that in the latter case, the open stub model is equivalent to the transmission line model with a negative length terminated by an open.

Open Stub, Physical Length with Reference





Netlist Form

An instance of an open stub, physical length with reference node has the following netlist syntax:

```
Axxx n1 n2 W=val P=val COMPONENT=open_stub SUBSTRATE=substrate_name
```

n1 is the name of the node attached to the open stub. *n2* is the name of the reference node. The entry **COMPONENT=open_stub** identifies the element as an open stub, physical length with or without a reference node.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 33: Open Stub, Physical Length with Reference, Instance Parameters

Parameter	Description	Units	Default
W	Line width	Meter	1e-3
P	Physical length	Meter	10e-3

Netlist Example

```
A44 Port1 Port3  W=0.001 P=10e-3
+ COMPONENT=open_stub SUBSTRATE=SL1
```

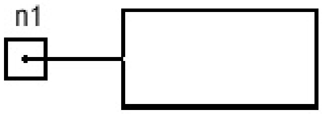
where SL1, the selected layout technology or substrate type, has a definition such as:

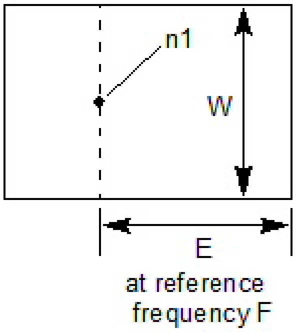
```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] The physical model using physical length includes the open end length correction.
2. [**All substrates**] The open stub model is equivalent to a transmission line model followed by an open model. This is also true in the case of negative length specifications, which are used for deembedding purposes. Note that in the latter case, the open stub model is equivalent to the transmission line model with a negative length terminated by an open.

Open Stub, Electrical Length





Netlist Format

An instance of an open stub with electrical length has the following netlist syntax:

`A``xxx n1` **`W=`**`val` **`E=`**`val` **`F=`**`val` **`COMPONENT=open_stub_e SUBSTRATE=`**`substrate_name`

n1 is the name of the node attached to the open stub. A reference node of ground (node 0) is automatically supplied, and is not shown in the netlist. The entry **COMPONENT=open_stub_e** identifies the element as an open stub with electrical length.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 34: Open Stub with Electrical Length, Instance Parameters

Parameter	Description	Units	Default
W	Line width	Meter	1e-3
E	Electrical length	Degree	45
F	Reference frequency for E	Hz	1e9

Netlist Example

```
A44 Port1 W=1.0e-3 E=45 F=1.0e9
+ COMPONENT=open_stub_e SUBSTRATE=SL1
```

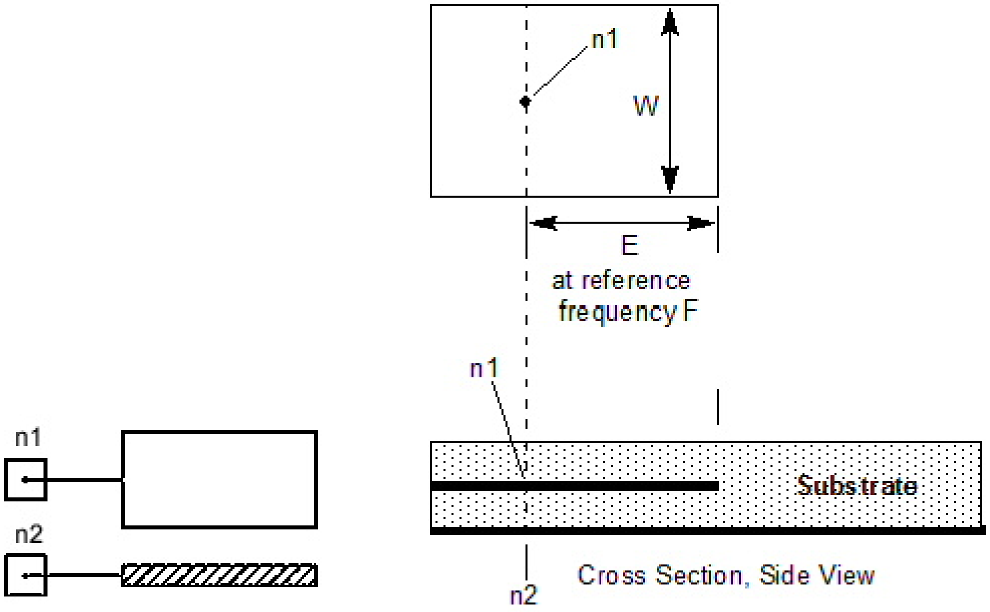
where SL1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] The open stub, electrical length model is equivalent to a transmission line model followed by an open model. This is also true in the case of negative length specifications, which are used for deembedding purposes. Note that in the latter case, the open stub model is equivalent to the transmission line model with a negative length terminated by an open.
2. [**Microstrip**] This model includes radiation effects if a cover height is not supplied (i.e., open structure.)
3. [**Microstrip**] The following limit applies (H is the thickness of the dielectric):
   0.01 ≤ **W/H** ≤ 100

Open Stub, Electrical Length with Reference



Netlist Format

An instance of an open stub, electrical length with reference has the following netlist syntax:

```
Axxx n1 n2 W=val E=val F=val COMPONENT=open_stub_e
SUBSTRATE=substrate_name
```

n1 is the name of the node attached to the open stub. *n2* is the name of the reference node. The entry **COMPONENT=open_stub_e** identifies the element as an open stub, electrical length, with or without a reference node.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 35: Open Stub, Electrical Length with Reference, Instance Parameters

Parameter	Description	Units	Default
W	Line width	Meter	1e-3
E	Electrical length	Degree	45
F	Reference frequency for E	Hz	1e9

Netlist Example

```
A44 Port1 Port2 W=1.0e-3 E=45 F=1.0e9
+ COMPONENT=open_stub_e SUBSTRATE=SL1
```

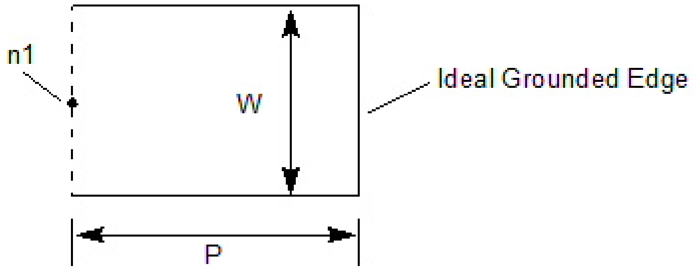
where SL1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] The open stub, electrical length model is equivalent to a transmission line model followed by an open model. This is also true in the case of negative length specifications, which are used for de-embedding purposes. Note that in the latter case, the open stub model is equivalent to the transmission line model with a negative length terminated by an open.

Shorted Stub, Physical Length



Netlist Form

An instance of a shorted stub with physical length has the following netlist syntax:

```
Axxx n1 W=val P=val COMPONENT=shorted_stub_physical
SUBSTRATE=substrate_name
```

n1 is the name of the node attached to the shorted stub. The entry **COMPONENT=shorted_stub_physical** identifies the element as a shorted stub, physical length.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 36: Shorted Stub, Physical Length, Instance Parameters

Parameter	Description	Units	Default
W	Line width	Meter	1e-3
P	Physical length	Meter	10e-3

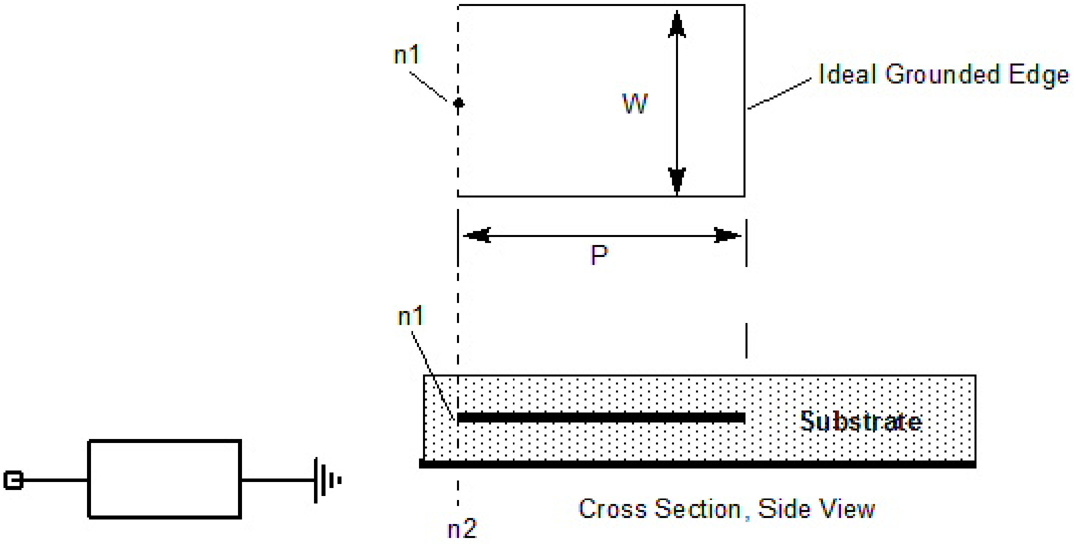
Netlist Example

```
A44 Port1 W=0.001 P=10e-3
+ COMPONENT=shorted_stub_physical SUBSTRATE=SL1
```

where SL1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Shorted Stub, Physical Length with Reference



Netlist Form

An instance of a shorted stub, physical length with reference node has the following netlist syntax:

A*xxx n1 n2* **W=***val* **P=***val* **COMPONENT=shorted_stub_physical SUBSTRATE=***substrate_name*

n1 is the name of the node attached to the shorted stub. *n2* is the reference node. The entry **COMPONENT=shorted_stub_physical** identifies the element as a shorted stub, physical length with or without a reference node.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 37: Shorted Stub, Physical Length with Reference, Instance Parameters

Parameter	Description	Units	Default
W	Line width	Meter	1e-3
P	Physical length	Meter	10e-3

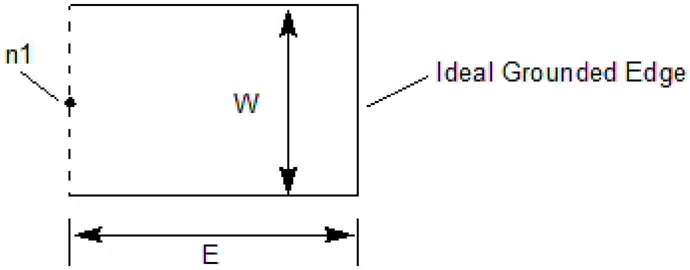
Netlist Example

```
A44 Port1 Port3 W=0.001 P=10e-3
+ COMPONENT=shorted_stub_physical SUBSTRATE=SL1
```

where SL1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Shorted Stub, Electrical Length



Netlist Format

An instance of a shorted stub with electrical length has the following netlist syntax:

A*xxx n1* **W=***val* **E=***val* **F=***val* **COMPONENT=shorted_stub_electrical SUBSTRATE=***substrate_name*

n1 is the name of the node attached to the shorted stub. A reference node of ground (node 0) is automatically supplied, and is not shown in the netlist. The entry **COMPONENT=shorted_stub_electrical** identifies the element as a shorted stub with electrical length.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 38: Shorted Stub with Electrical Length, Instance Parameters

Parameter	Description	Units	Default

W	Line width	Meter	1e-3
E	Electrical length	Degree	45
F	Reference frequency for E	Hz	1e9

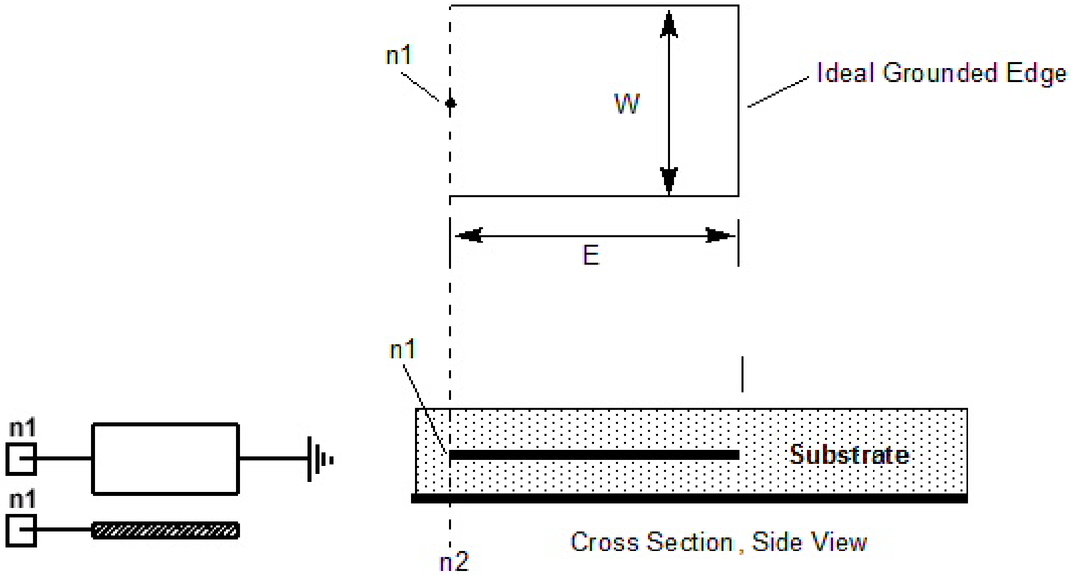
Netlist Example

```
A44 Port1 W=1.0e-3 E=45 F=1.0e9
+ COMPONENT=shorted_stub_electrical SUBSTRATE=SL1
```

where SL1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Shorted Stub, Electrical Length with Reference



Netlist Format

An instance of a shorted stub, electrical length with reference has the following netlist syntax:

A*xxx n1 n2* **W=***val* **E=***val* **F=***val* **COMPONENT=shorted_stub_electrical SUBSTRATE=***substrate_name*

n1 is the name of the node attached to the shorted stub. *n2* is the reference node. The entry **COMPONENT=shorted_stub_electrical** identifies the element as a shorted stub, electrical length with or without a reference node.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 39: Shorted Stub, Electrical Length with Reference, Instance Parameters

Parameter	Description	Units	Default
W	Line width	Meter	1e-3
E	Electrical length	Degree	45
F	Reference frequency for E	Hz	1e9

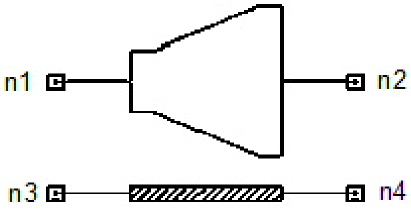
Netlist Example

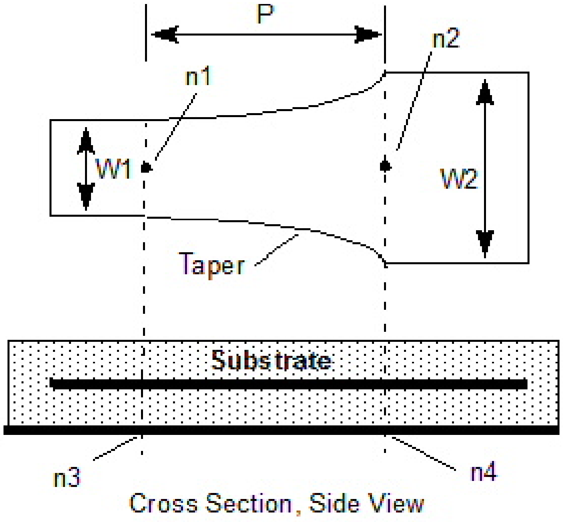
```
A44 Port1 Port 2 W=1.0e-3 E=45 F=1.0e9
+ COMPONENT=shorted_stub_electrical SUBSTRATE=SL1
```

where SL1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Tapered Line, W Specified, with Reference





Netlist Format

An instance of a tapered line, W specified, with reference has the following netlist syntax:

`A`*`xxx n1 n2 n3 n4`* `W1=`*`val`* `W2=`*`val`* `P=`*`val`*

`TAPER=LinImp|ExpImp|LinWidth|ExpWidth`

`COMPONENT=taper_width_specified SUBSTRATE=`*`substrate_name`*

n1 and *n2* are the names of the nodes attached to the tapered line, *n3* and *n4* are the reference nodes. The entry **COMPONENT=taper_width_specified** identifies the element as a tapered line, W specified, with reference node.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 40: Tapered Line, W Specified, with Reference, Instance Parameters

Parameter	Description	Units	Default
P	Physical length	Meter	1e-2
W1	Width of line at node 1	Meter	1e-3
W2	Width of line at node 2	Meter	1e-3
TAPER	Taper type: LinWidth—Linear Width	None	LinWidth

	ExpWidth—Exponential Width LinImp—Linear Impedance ExpImp—Exponential Impedance		

Netlist Example

```
A2 Port1 Port2 W1=0.001 W2=0.003 P=0.01 TAPER=ExpWidth

+ COMPONENT=taper_width_specified   SUBSTRATE=SL1
```

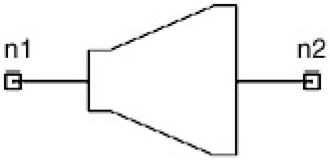
where SL1, the selected layout technology or substrate type, has a definition such as:

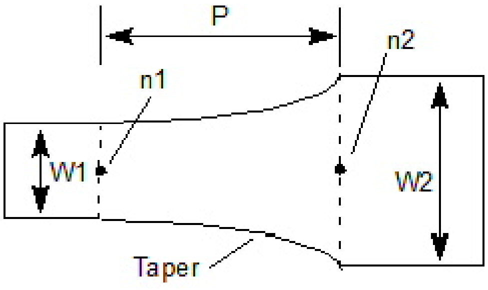
```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] Node numbers can be reversed, so *n1* and associated width **W1** are at the wide end of the taper.
2. [**All substrates**] The Tapered Line with Reference syntax is supported in netlists only. See the next three topics for the tapered line elements available in schematics.
3. [**Stripline**] The substrate definition should satisfy the following conditions: $0.01 \le W/B \le 100$, $\max(W1,W2) \le 0.5\lambda_g$, where λ_g is the guide wavelength.

Tapered Line, W Specified, Impedance Taper





Netlist Format

An instance of a tapered line, W specified, impedance taper has the following netlist syntax:

```
Axxx n1 n2 n3 n4 W1=val W2=val P=val TAPER=LinImp|ExpImp

 COMPONENT=taper_width_specified SUBSTRATE=substrate_name
```

n1 and *n2* are the names of the nodes attached to the tapered line, *n3* and *n4* are the reference nodes. The entry **COMPONENT=taper_width_specified** identifies the element as a tapered line, W specified.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 41: Tapered Line, W Specified, Impedance Taper, Instance Parameters

Parameter	Description	Units	Default
P	Physical length	Meter	1e-2
W1	Width of line at node 1	Meter	1e-3
W2	Width of line at node 2	Meter	1e-3
TAPER	Taper type: LinImp—Linear Impedance ExpImp—Exponential Impedance	None	ExpImp

Netlist Example

```
A2 Port1 Port2 W1=0.001 W2=0.003 P=0.01 TAPER=ExpImp

+ COMPONENT=taper_width_specified   SUBSTRATE=SL1
```

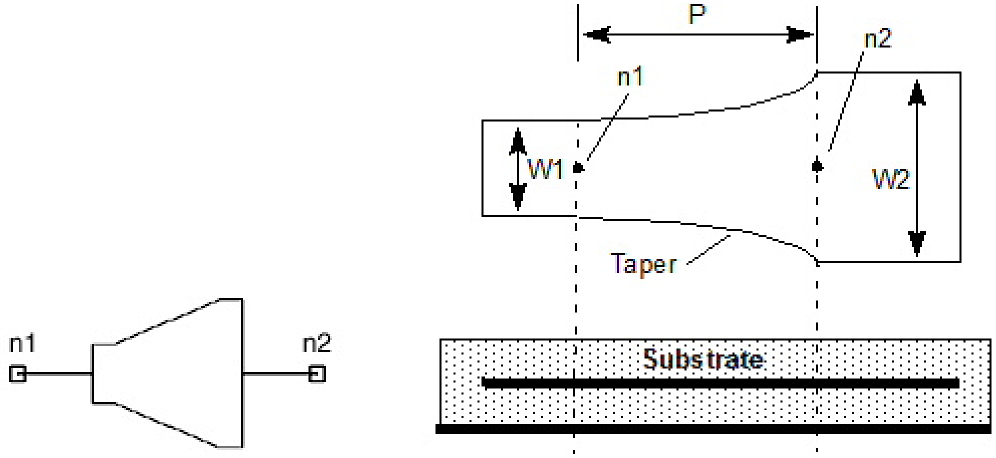
where SL1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] Node numbers can be reversed, so *n1* and associated width **W1** are at the wide end of the taper.
2. [**All substrates**] The Nexxim impedance tapered line element does not have a physical footprint in Ansys Electronics Desktop.
3. [**Stripline**] The substrate definition should satisfy the following conditions: $0.01 \le W/B \le 100$, $\max(W1,W2) \le 0.5\lambda_g$, where λ_g is the guide wavelength.

Tapered Line, W Specified, Exponential Width Taper



Netlist Format

An instance of a tapered line, W specified, exponential width taper has the following netlist syntax:

A*xxx n1 n2 n3 n4* **W1=***val* **W2=***val* **P=***val* **TAPER=ExpWidth COMPONENT=taper_width_specified SUBSTRATE=***substrate_name*

n1 and *n2* are the names of the nodes attached to the tapered line, *n3* and *n4* are the reference nodes. The entry **COMPONENT=taper_width_specified** identifies the element as a tapered line, W specified.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 42: Tapered Line, W Specified, Exponential Width Taper, Instance Parameters

Parameter	Description	Units	Default
P	Physical length	Meter	1e-2
W1	Width of line at node 1	Meter	1e-3
W2	Width of line at node 2	Meter	1e-3
TAPER	Taper type: Must be ExpWidth—Exponential Width	None	ExpWidth

Netlist Example

```
A2 Port1 Port2 W1=0.001 W2=0.003 P=0.01 TAPER=ExpWidth

+ COMPONENT=taper_width_specified   SUBSTRATE=SL1
```

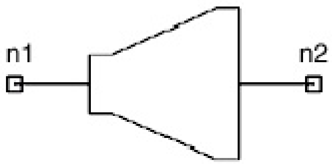
where SL1, the selected layout technology or substrate type, has a definition such as:

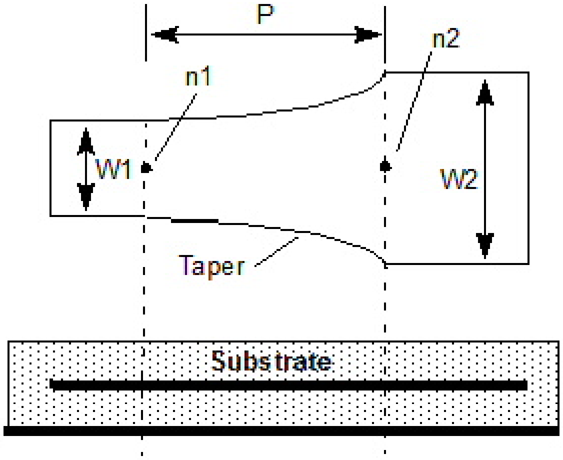
```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**All substrates**] Node numbers can be reversed, so *n1* and associated width **W1** are at the wide end of the taper.
2. [**All substrates**] The Nexxim exponential width tapered line element has a physical footprint in Ansys Electronics Desktop.
3. [**Stripline**] The substrate definition should satisfy the following conditions: $0.01 \le W/B \le 100$, $\max(W1,W2) \le 0.5\lambda_g$, where λ_g is the guide wavelength.

Tapered Line, W Specified, Linear Width Taper





Netlist Format

An instance of a tapered line, W specified, linear width taper has the following netlist syntax:

```
Axxx n1 n2 n3 n4 W1=val W2=val P=val TAPER=LinWidth
COMPONENT=taper_width_specified SUBSTRATE=substrate_name
```

n1 and *n2* are the names of the nodes attached to the tapered line, *n3* and *n4* are the reference nodes. The entry **COMPONENT=taper_width_specified** identifies the element as a tapered line, W specified.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 43: Tapered Line, W Specified, Linear Width Taper, Instance Parameters

Parameter	Description	Units	Default
P	Physical length	Meter	1e-2
W1	Width of line at node 1	Meter	1e-3
W2	Width of line at node 2	Meter	1e-3
TAPER	Taper type: Must be LinWidth—Linear Width	None	LinWidth

Netlist Example

```
A2 Port1 Port2 W1=0.001 W2=0.003 P=0.01 TAPER=LinWidth

+ COMPONENT=taper_width_specified   SUBSTRATE=SL1
```

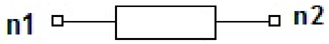
where SL1, the selected layout technology or substrate type, has a definition such as:

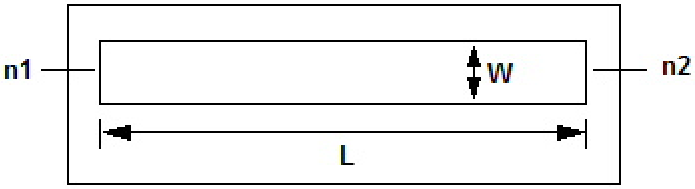
```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

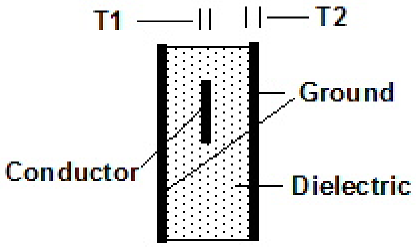
Notes

1. [**All substrates**] Node numbers can be reversed, so *n1* and associated width **W1** are at the wide end of the taper.
2. [**All substrates**] The Nexxim linear width tapered line element has a physical footprint in Ansys Electronics Desktop.
3. [**Stripline**] The substrate definition should satisfy the following conditions: $0.01 \le W/B \le 100$, $\max(W1,W2) \le 0.5\lambda_g$, where λ_g is the guide wavelength.

Transmission Line, Field Solver







Netlist Format

A field solver stripline transmission line has the following netlist syntax:

```
Wxxx n1 n2 0 N=1 W=val L=val FSmodel=modelname
.MATERIAL conductor METAL CONDUCTIVITY=val

.MATERIAL dielectric DIELECTRIC ER=val LOSSTANGENT=val

.SHAPE rect1 RECTANGLE WIDTH=w HEIGHT=t1 // Conductors
.LAYERSTACK layerstack

+ LAYER=(conductor, t2) // Upper ground plane
+ LAYER=(dielectric, b)
+ LAYER=(conductor, t2) // Lower ground plane
.MODEL modelname W MODELTYPE=Fieldsolver
+ LAYERSTACK=layerstack

+ CONDUCTOR=(SHAPE=rect1, ORIGIN=(0, 't2 + b * 0.5')
```

n1, and *n2* are the names of the input and output nodes. The entry **N=1** shows that this is a single transmission line. The names for the *modelname*, *conductor*, *dielectric*, and *layerstack* are supplied by the user.

The entry **FSmodel=***modelname* identifies the field solver stripline W-model.

Table 44: Transmission Line, Field Solver Instance Parameters

Parameter	Description	Units	Default

W	Width of conductor	Meter	1e-3
L	Physical length	Meter	1e-3
N	Number of lines for W-model . Must be 1 for transmission line.	None	1
T1	Thickness of conductors	Meter	0.001
T2	Thickness of ground planes	Meter	0.001
B	Thickness of dielectric layer	Meter	1e-3
CONDUCTIVITY	Conductivity of conductor material		57.6e6
ER	Dielectric constant		2.2
TAND	Dielectric loss tangent		0

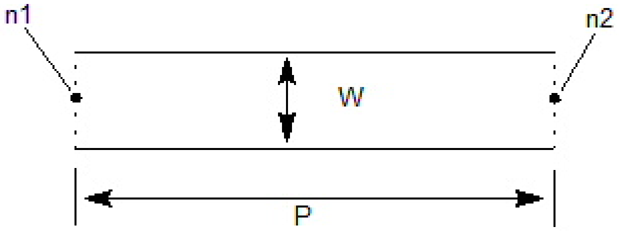
> **Note:**
>
> The default values for the transmission line are the ones assigned when placing a component on the Component library in a schematic. There are NO defaults for netlist designs; all values must be specified.

Netlist Example

```
W3 Port1 Port2 0 N=1 W-0.0001 L=0.002 FSmodel=SL1
```

```
.MATERIAL cond1 METAL CONDUCTIVITY=5.8e7
.MATERIAL diel1 DIELECTRIC ER=4.4 LOSSTANGENT=0.02
.SHAPE rect1 RECTANGLE WIDTH=.002 // Conductor width W
+ HEIGHT=.001   // Conductor height T1
.LAYERSTACK tstripline
+ LAYER=(cond1, .001) // Bottom ground T2
+ LAYER=(diel1, .01) // Dielectric B
+ LAYER=(cond1, .001) // Top ground, T2
.MODEL SL1 W MODELTYPE=Fieldsolver
+ LAYERSTACK=stripline
+ CONDUCTOR=(SHAPE=rect1,
+ ORIGIN=(0, '.005 + .01 * 0.5') // T2 + B/2
+ MATERIAL=cond1, TYPE=SIGNAL)
```

Transmission Line, Physical Length



Netlist Format

An instance of a transmission line with physical length has the following netlist syntax:

```
Axxx n1 n2 [W=val] [P=val] COMPONENT=TRL SUBSTRATE=substrate_name
```

n1 and *n2* are the names of the nodes attached to the transmission line. The entry **COMPONENT=TRL** identifies the element as a transmission line with physical length.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 45: Transmission Line with Physical Length, Instance Parameters

Parameter	Description	Units	Default
P	Physical length	Meter	1e-2
W	Conductor width	Meter	1e-3

Netlist Example

```
A2 Port1 Port2 W=0.001 P=0.01 COMPONENT=TRL   SUBSTRATE=SL1
```

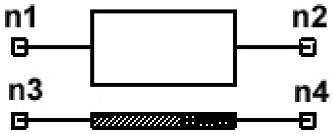
where SL1, the selected layout technology or substrate type, has a definition such as:

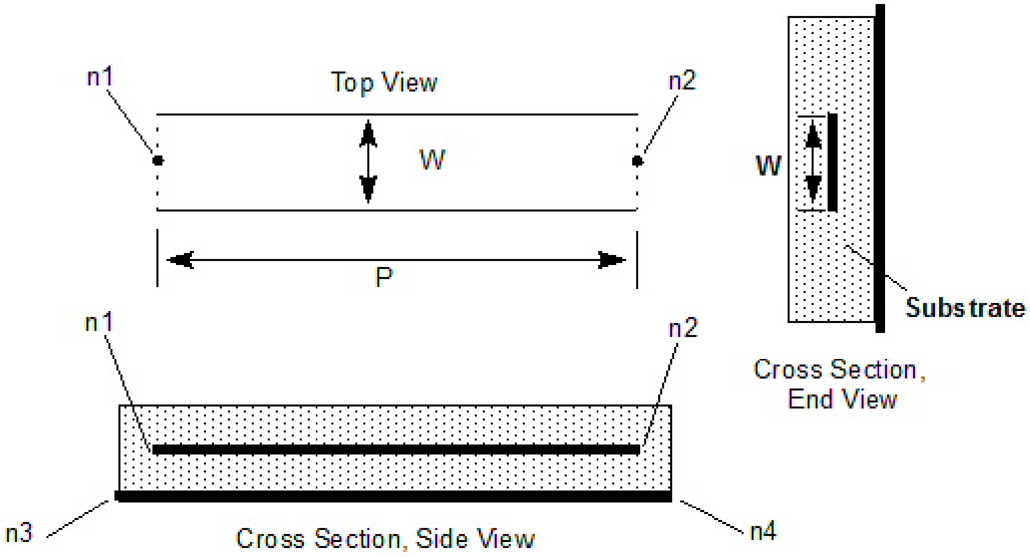
```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**Stripline**] For accurate results, the substrate definition should have W/B <10.

Transmission Line, Physical Length with Reference





Netlist Format

An instance of a transmission line with physical length and reference nodes has the following netlist syntax:

```
Axxx n1 n2 n3 n4 [W=val] [P=val]
```

```
COMPONENT=TRL SUBSTRATE=substrate_name
```

n1, *n2*, *n3*, and *n4* are the names of the nodes attached to the transmission line. The entry **COMPONENT=TRL** identifies the element as a transmission line with physical length.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 46: Transmission Line with Physical Length and Reference Nodes, Instance Parameters

Parameter	Description	Units	Default
P	Physical length	Meter	10e-3
W	Conductor width	Meter	1e-3

Netlist Example

```
A5 Port1 Port2 0 0 W=0.001 P=0.01
+ COMPONENT=TRL SUBSTRATE=SL1
```

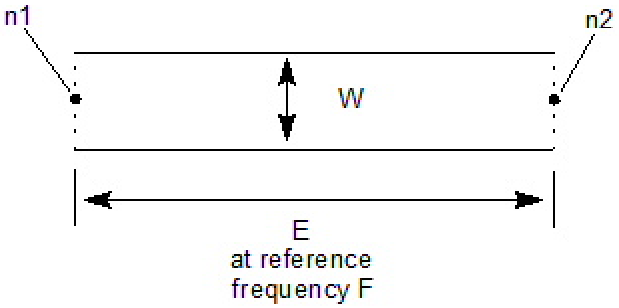
where SL1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**Stripline**] For accurate results, the substrate definition should have W/B <10.

Transmission Line, Electrical Length



Netlist Format

An instance of a transmission line with electrical length has the following netlist syntax:

A*xxx n1 n2* **W=***val* **E=***val* **F=***val* **COMPONENT=TRL_E SUBSTRATE=***substrate_name*

n1 and *n2* are the names of the nodes attached to the transmission line. The entry **COMPONENT=TRL_E** identifies the element as a transmission line with electrical length.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on page 35-63). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 47: Transmission Line with Electrical Length, Instance Parameters

Parameter	Description	Units	Default
W	Conductor width	Meter	0.001
E	Electrical length	Degree	45
F	Reference frequency for E	Hz	1e9

Netlist Example

```
A7 Port1 Port2 W=0.001 E=45 F=5000000000
+ COMPONENT=TRL_E SUBSTRATE=SL1
```

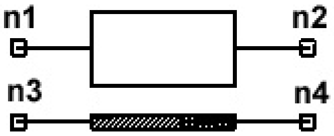
where SL1, the selected layout technology or substrate type, has a definition such as:

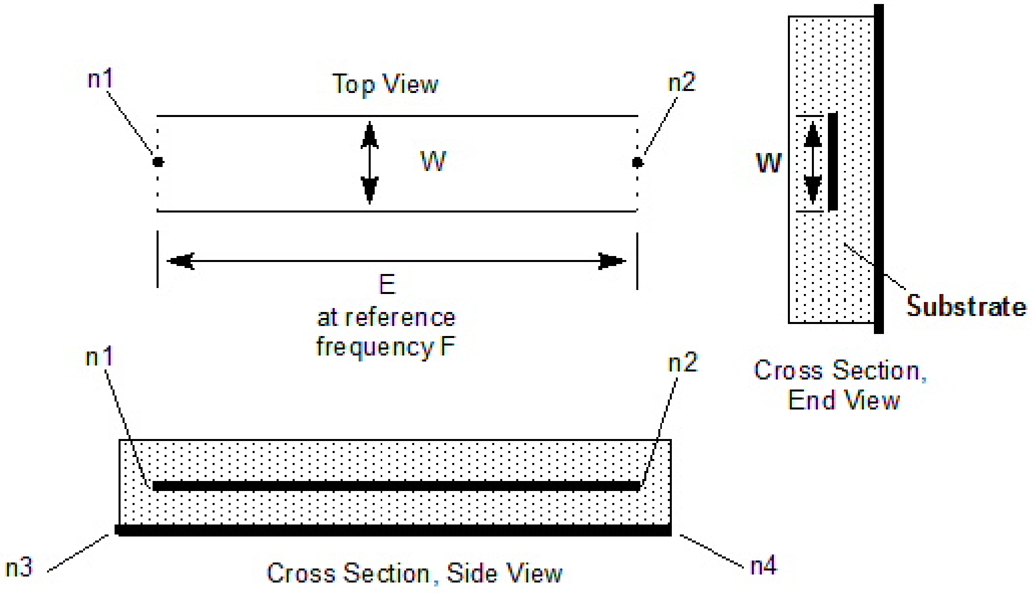
```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**Stripline**] For accurate results, W/B <10.

Transmission Line, Electrical Length with Reference





Netlist Format

An instance of a transmission line with electrical length and reference nodes has the following netlist syntax:

A*xxx n1 n2 n3 n4* **W=***val* **E=***val* **F=***val* **COMPONENT=TRL_E**
SUBSTRATE=*substrate_name*

n1, *n2*, *n3*, and *n4* are the names of the nodes attached to the transmission line. The entry **COMPONENT=TRL_E** identifies the element as a transmission line with electrical length.

The entry **SUBSTRATE=***substrate_name* identifies the Stripline substrate model name selected for the design (see "Selecting a Stripline Substrate" on the facing page). See the "Stripline Substrate Model" on page 35-66 for information on this substrate type.

Table 48: Transmission Line with Electrical Length and Reference Nodes, Instance Parameters

Parameter	Description	Units	Default
W	Conductor width	Meter	0.001
E	Electrical length	Degree	45
F	Reference frequency for E	Hz	10^9

Netlist Example

```
A10 Port1 Port2 0 0 W=0.001 E=45 F=5000000000
+ COMPONENT=TRL_E SUBSTRATE=SL1
```

where SL1, the selected layout technology or substrate type, has a definition such as:

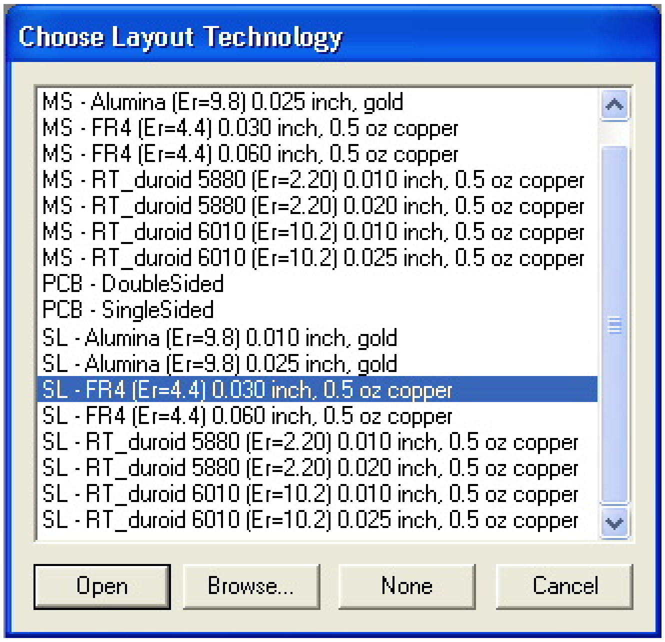
```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

Notes

1. [**Stripline**] For accurate results, W/B <10.

Selecting a Stripline Substrate

For Nexxim designs that are created with the **Schematic Editor**, select a predefined microstrip, stripline, or other substrate, to apply to all distributed elements instantiated in a design. The selection of a global technology is made on the **Choose Layout Technology** window that appears when you select Insert Nexxim Circuit Design on the Project menu:



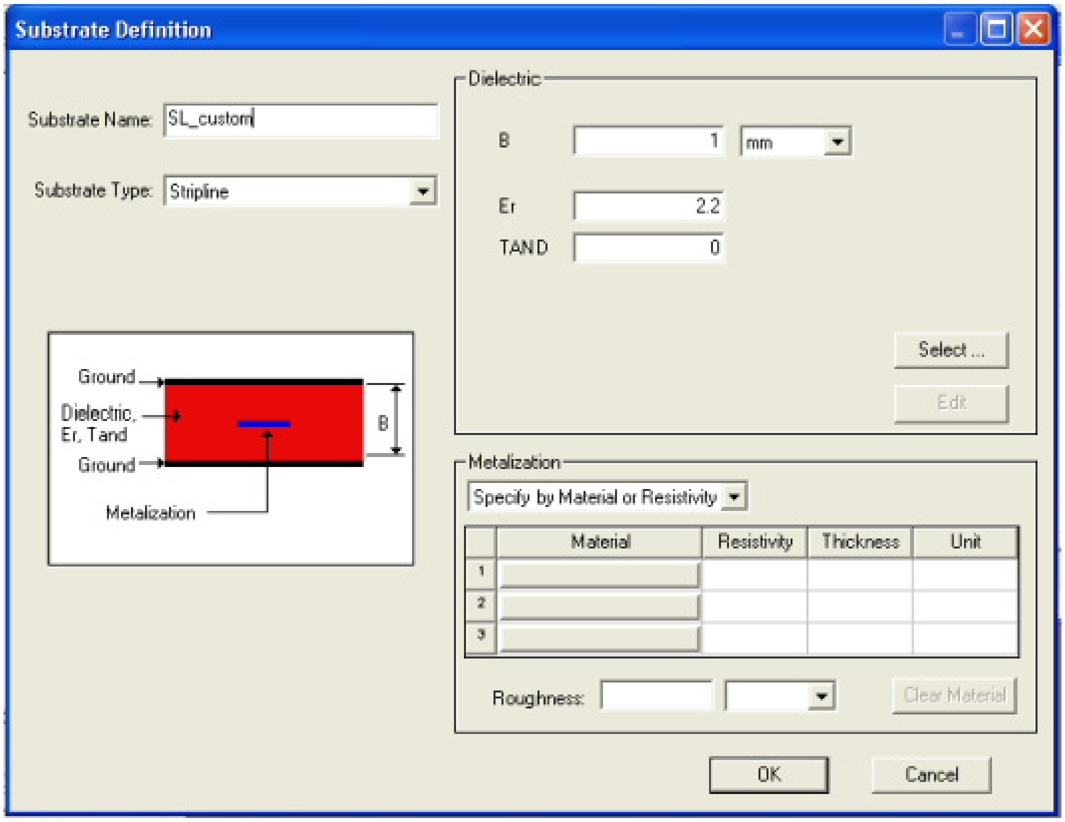
Select the appropriate substrate technology and click **Open**. To choose a technology that is not on the list, click **Browse**. Using the explorer window, browse to and select the Technology (**.asty**) file that contains the technology you want to use. Then click **Open**. When a substrate has been selected, Ansys Electronics Desktop creates a .SUB entry for this substrate type in the internal netlist representing the schematic design.

Then, when an element is instantiated that includes a **SUBSTRATE=***substrate_name* entry in its netlist syntax, **Electronics Desktop** automatically inserts the *substrate_name* that was selected on the **Choose Layout Technology** window (**FR4** in the example pictured above) into the internal netlist entry for the instantiated element.

If you wish to use a custom substrate type (or no substrate type) instead of one of the predefined types, click **None**. The design opens, but no substrate type is applied to instances of distributed elements unless you either create a custom substrate type or select a predefined type on a component-by-component basis.

Creating a Custom Stripline Substrate

To create a new, custom substrate definition, open the Nexxim design icon (e.g., “Nexxim1”, then right-click the **Data** field. Select **Add Substrate Definition** to open the **Substrate Definition** window. Specify the name of your new substrate (the following example uses the name “SL_custom”):



Substrate Name: SL_custom

Substrate Type: Stripline

B 1 mm

Er 2.2

TAND 0

Specify by Material or Resistivity

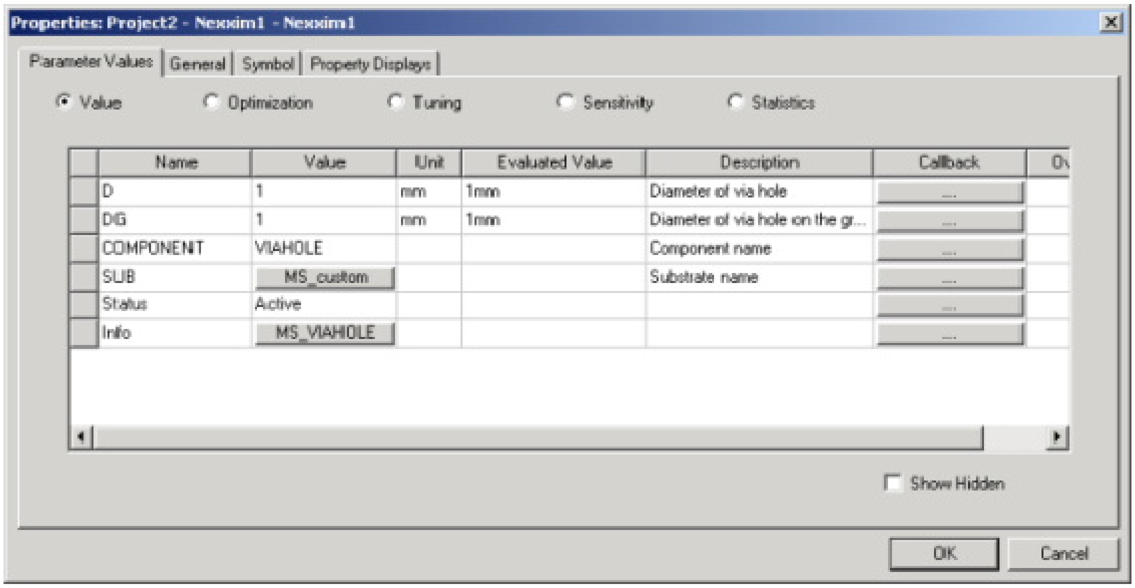
(see the "Stripline Substrate Model" on the next page help topic for guidelines on defining substrates.

When the substrate definition is complete, click **OK**.

If you selected **None** for the global substrate type in the **Choose Layout Technology** group box, the custom substrate becomes the global substrate type.

Selecting a Substrate at the Component Level

To specify a custom substrate type, or to change to a different predefined substrate type, you must make the assignment individually for each component. Double-click the distributed element to open the **Properties** window:



● Value ○ Optimization ○ Tuning ○ Sensitivity ○ Statistics

	Name	Value	Unit	Evaluated Value	Description	Callback	Ov
	D	1	mm	1mm	Diameter of via hole	...	
	DIG	1	mm	1mm	Diameter of via hole on the gr...	...	
	COMPONENT	VIAHOLE			Component name	...	
	SUB	MS_custom			Substrate name	...	
	Status	Active				...	
	Info	MS_VIAHOLE				...	

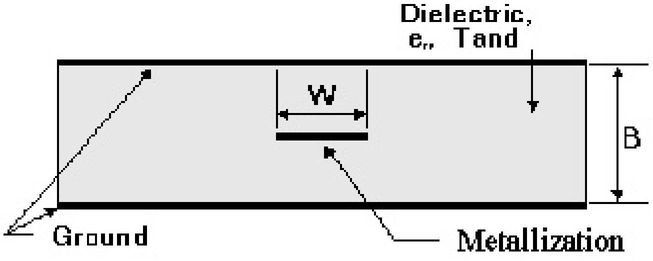
☐ Show Hidden

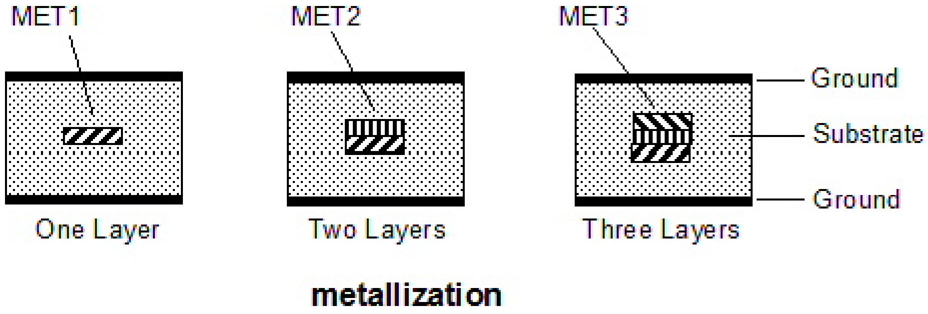
The **SUB** property identifies the substrate that is currently applied to the element. In the example above, there is a defined custom substrate type named “MS_custom”, which appears as the value of the **SUB** property.

To change to a different substrate type, enter the appropriate substrate name as the value of the **SUB** property, and click **OK**.

> **Note:**
>
> All distributed elements in a given design must use the same substrate type.

Stripline Substrate Model





Defining a Stripline Model

To add a stripline substrate model to a new Nexxim design, select one of the SL substrate types on the **Choose Layout Technology** window that appears when you select **Insert Nexxim Circuit Design** on the **Project** drop-down menu. A substrate that is added from this window has a default substrate name and metallization parameters.

To add a new substrate to an existing design, expand the **Project** icon, the **Design** icon. Right-click the **Data** icon and select **Add Substrate Definition** to open the **Substrate Definition** window. Then add the substrate name and parameters as appropriate, and click **OK**. A substrate added in this manner requires you to specify the metallization parameters explicitly.

To edit the definition of a substrate, expand the **Project** icon, the **Design** icon, the **Data** icon. Click on the icon for the substrate you wish to edit to open the **Substrate Definition** window. Add or modify the substrate parameters as appropriate, then click **OK**.

Stripline Substrate Model Netlist Format

The Stripline substrate model has the following netlist format:

```
.SUBsubstrate_name SL ( [B=val] [ER=val] [TAND=val]
```

[**MET1=***val*] [**T1=***val*] [**MET2=***val*] [**T2=***val*] [**MET3=***val*] [**T3=***val*]

[**RGH=***val*]**)**

The *substrate_name* is the name for the substrate type used in distributed elements that refer to this substrate definition. The entry **SL** is required to identify the Stripline substrate type. The **SL** identifier must immediately follow the *substrate_name*.

Inside the parentheses, the labeled parameters may be entered in any order.

Table 49: Stripline Substrate Parameters

Parameter	Description	Unit	Default
B	Spacing between ground planes, B > 0	Meter	1e-3
ER	Dielectric constant of substrate, 1 ≤ ER ≤ 128	None	4.5
MET1, **MET2**, **MET3**	Resistivity of metal layer 1, 2, 3	µOhm-cm	0.0
RGH	RMS surface roughness	Meter	0.0
T1, **T2**, **T3**	Thickness of metal layer 1, 2, 3	Meter	0.0
TAND	Dielectric loss tangent, [0,0.1]	None	0.0

Stripline Substrate Model Netlist Example

```
.SUB SL1 SL( B=0.001524 Er=4.40000000000000
+ TAND=0.0200000000000000 MET1=1.72413793103448
+ T1=1.7145e-005 RGH=0mil)
```

> **Note:** Surface roughness in the substrate definition is not supported in MCPL implementations.

36 - Suspended Stripline Elements

This topic describes the following suspended stripline distributed elements available in Nexxim.

General Components

Bends

Coupled Lines

Couplers

Open-Ended Lines

Shorted Stubs

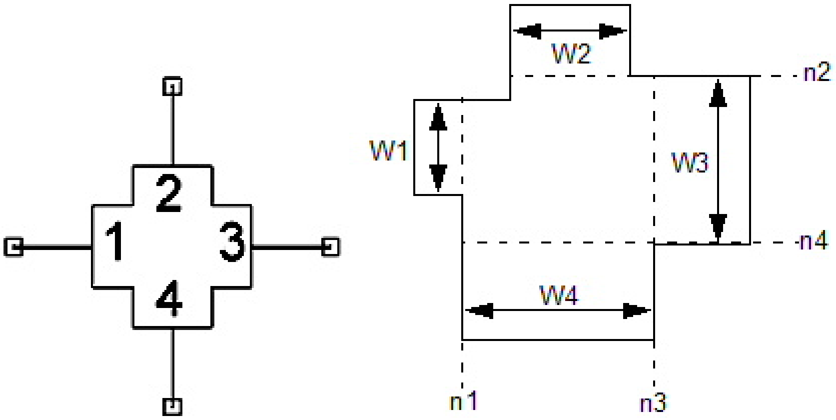
Transmission Lines

This section also contains information on the Suspended Stripline substrate type.

"Selecting a Suspended Stripline Substrate at the Component Level" on page 36-25

"Suspended Stripline (SS) Substrate Model" on page 36-26

Cross Junction



Netlist Format

A cross instance has the following netlist format:

A*xxx n1 n2 n3 n4* **W1=***val* **W2=***val* **W3=***val* **W4=***val* [**NSUM=***val*]

COMPONENT=cross SUBSTRATE=*substrate_name*

n1, *n2*, *n3*, and *n4* are the names of the nodes attached to the cross. The entry **COMPONENT=cross** identifies the element as a cross.

The entry **SUBSTRATE=***substrate_name* identifies the suspended stripline substrate model name selected for the design (see "Selecting None for the Initial Substrate" on page 36-23). See the "Suspended Stripline (SS) Substrate Model" on page 36-26 for information on this substrate type.

Table 39: Cross Instance Parameters

Parameter	Description	Unit	Default
W1	Width of line connected to node n1	Meter	1e-3
W2	Width of line connected to node n2	Meter	1e-3
W3	Width of line connected to node n3	Meter	1e-3
W4	Width of line connected to node n4	Meter	1e-3
NSUM	Number of modes considered in the field expansion	None	4

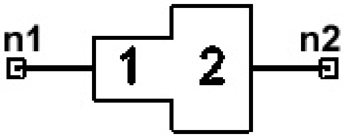
Netlist Example

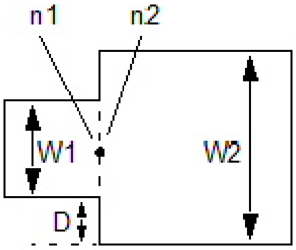
```
Across1 Port1 Port2 Port3 Port4 W1=1e-3 W2=2e-3 W3=3e-3 W4=4e-3
+ COMPONENT=cross SUBSTRATE=SS1
```

where SS1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SS1 SS (
+ Er=4.4 H=0.5e-3 HU=2.54e-003
+ MET1=1.7241379 T1=2.5400e-005
+ RGH=0 )
```

Step





Netlist Format

A step instance has the following netlist format:

A*xxx n1 n2* **W1=***val* **W2=***val* **D=***val*

COMPONENT=step SUBSTRATE=*substrate_name*

n1 and *n2* are the names of the nodes attached to the step. The entry **COMPONENT=step** identifies the element as a step.

The entry **SUBSTRATE=***substrate_name* identifies the suspended stripline substrate model name selected for the design (see "Selecting None for the Initial Substrate" on page 36-23). See the "Suspended Stripline (SS) Substrate Model" on page 36-26 for information on this substrate type.

Table 40: Step Instance Parameters

Parameter	Description	Unit	Default
W1	Width of line connected to node n1	Meter	1e-3
W2	Width of line connected to node n2	Meter	2e-3
D	Offset between lines	Meter	(W2-W1)/2

Netlist Example

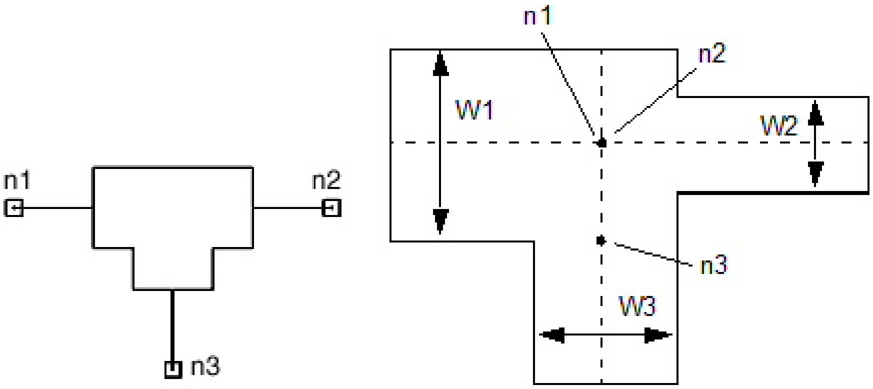
```
A23 Port1 Port2 W1=1e-3 W2=2e-3 D=0.5e-3
```

```
+ COMPONENT=STEP SUBSTRATE=SS1
```

where SS1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SS1 SS (
+ Er=4.4 H=0.5e-3 HU=2.54e-003
+ MET1=1.7241379 T1=2.5400e-005
+ RGH=0 )
```

Tee, Reference Planes at Center



Netlist Format

A tee instance has the following netlist format:

```
Axxx n1 n2 n3 W1=val W2=val W3=val [NSUM=val]
```

```
COMPONENT=tee SUBSTRATE=substrate_name
```

n1, *n2*, and *n3* are the names of the nodes attached to the tee. The entry **COMPONENT=tee** identifies the element as a tee.

The entry **SUBSTRATE=***substrate_name* identifies the suspended stripline substrate model name selected for the design (see "Selecting None for the Initial Substrate" on page 36-23). See the "Suspended Stripline (SS) Substrate Model" on page 36-26 for information on this substrate type.

Table 41: Tee Instance Parameters

Parameter	Description	Unit	Default
W1	Width of line connected to node n1	Meter	1e-3
W2	Width of line connected to node n2	Meter	1e-3
W3	Width of line connected to node n3	Meter	1e-3
NSUM	Number of modes considered in the field expansion	None	3

Netlist Example

```
A23 Port1 Port2 Port3 W1=1e-3 W2=2e-3 W3=3e-3
+ COMPONENT=TEE SUBSTRATE=SS1
```

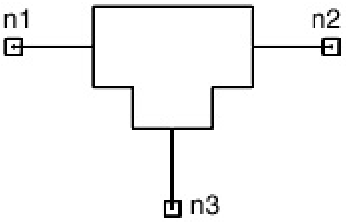
where SS1, the selected layout technology or substrate type, has a definition such as:

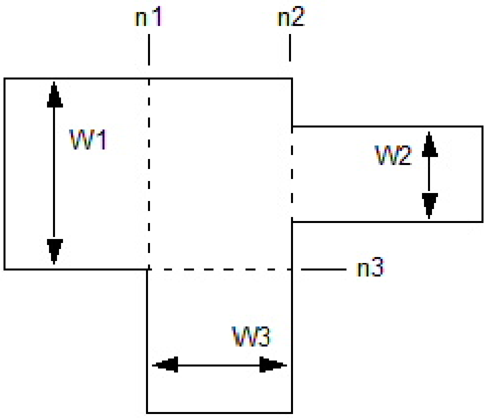
```
.SUB SS1 SS (
+ Er=4.4 H=0.5e-3 HU=2.54e-003
+ MET1=1.7241379 T1=2.5400e-005
+ RGH=0 )
```

Notes

1. [**All substrates**] The collinear lines are connected to nodes n1 and n2 and have widths W1 and W2; the perpendicular line is connected to node n3 and has width W3.
2. [**All substrates**] The n1, n2 reference plane is centered on the width of the line connected to node n3 (width W3).
3. [**All substrates**] If W1 > W2: Node n3 is collinear with W1.
4. [**All substrates**] If W2 > W1: Node n3 is collinear with W2.
5. [**Stripline**] To get accurate results, the following condition should be satisfied: $B/\lambda_g << 1$, where λ_g is the guide wavelength in the substrate dielectric.

Tee, Reference Planes at Edge





Netlist Format

A tee instance has the following netlist format:

```
Axxx n1 n2 n3 W1=val W2=val W3=val [NSUM=val]

COMPONENT=tee_edge_referenced SUBSTRATE=substrate_name
```

n1, *n2*, and *n3* are the names of the nodes attached to the tee. The entry **COMPONENT=tee_edge_referenced** identifies the element.

The entry **SUBSTRATE=***substrate_name* identifies the suspended stripline substrate model name selected for the design (see "Selecting None for the Initial Substrate" on page 36-23). See the "Suspended Stripline (SS) Substrate Model" on page 36-26 for information on this substrate type.

Table 42: Tee Instance Parameters

Parameter	Description	Unit	Default
W1	Width of line connected to node n1	Meter	1e-3
W2	Width of line connected to node n2	Meter	1e-3
W3	Width of line connected to node n3	Meter	1e-3
NSUM	Number of modes considered in the field expansion	None	3

Netlist Example

```
A23 Port1 Port2 Port3 W1=1e-3 W2=2e-3 W3=3e-3
+ COMPONENT=tee_edge_referenced SUBSTRATE=SS1
```

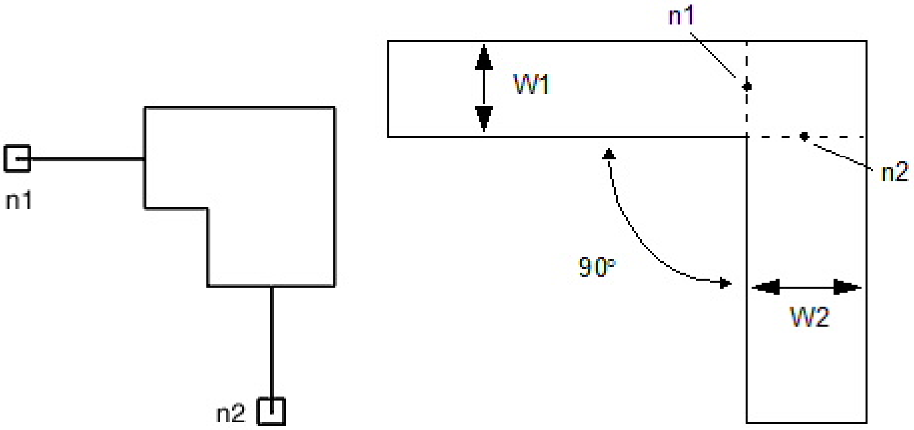
where SS1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SS1 SS (
+ Er=4.4 H=0.5e-3 HU=2.54e-003
+ MET1=1.7241379 T1=2.5400e-005
+ RGH=0 )
```

Notes

1. [**All substrates**] The collinear lines are connected to nodes n1 and n2 and have widths W1 and W2; the perpendicular line is connected to node n3 and has width W3.
2. [**All substrates**] If W1 > W2: Node n3 is collinear with W1.
3. [**All substrates**] If W2 > W1: Node n3 is collinear with W2.
4. [**Stripline**] To get accurate results, the following condition should be satisfied: $B/\lambda_g << 1$, where λ_g is the guide wavelength in the substrate dielectric.

Bend, Unmitered



Netlist Form

A*xxxx n1 n2* **W1=** *val* **W2=** *val* [**NSUM=***val*]

COMPONENT=unmitered_bend SUBSTRATE=*substrate_name*

n1 and *n2* are the names of the nodes attached to the unmitered bend. The entry **COMPONENT=unmitered_bend** identifies the element as an unmitered bend.

The entry **SUBSTRATE=***substrate_name* identifies the suspended stripline substrate model name selected for the design (see "Selecting None for the Initial Substrate" on page 36-23). See the "Suspended Stripline (SS) Substrate Model" on page 36-26 for information on this substrate type.

Table 43: Unmitered Bend Instance Parameters

Parameter	Description	Unit	Default
W1	Width of line 1	Meter	0.001
W2	Width of line 2	Meter	0.001
NSUM	Number of modes considered in the field expansion	None	3

Netlist Example

```
A23 Port1 Port2 W1=3e-4 W2=5e-3 NSUM=3
+ COMPONENT=unmitered_bend SUBSTRATE=SS1
```

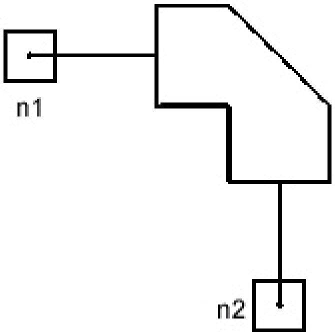
where SS1, the selected layout technology or substrate type, has a definition such as:

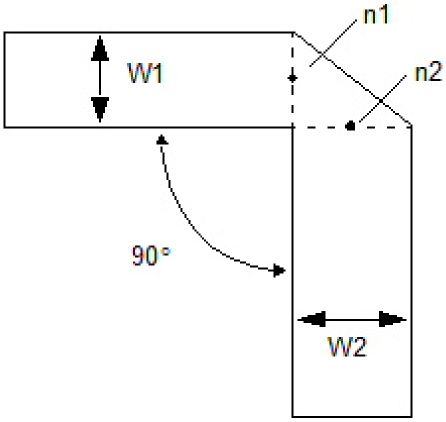
```
.SUB SS1 SS (
+ Er=4.4 H=0.5e-3 HU=2.54e-003
+ MET1=1.7241379 T1=2.5400e-005
+ RGH=0 )
```

Notes

1. [**All substrates**] This element refers to a right angle bend, where the two intersecting lines can be defined with different widths. The outer corner of the bend is not mitered.
2. [**All substrates**] Reference planes coincide with the inside vertex of the corner.

Bend, Mitered





Netlist Form

```
Axxxx n1 n2 W1=val W2=val [NSUM=val]
```

```
COMPONENT=mitered_bend SUBSTRATE=substrate_name
```

n1 and *n2* are the names of the nodes attached to the mitered bend. The entry **COMPONENT=mitered_bend** identifies the element as a mitered bend.

The entry **SUBSTRATE=***substrate_name* identifies the suspended stripline substrate model name selected for the design (see "Selecting None for the Initial Substrate" on page 36-23). See the "Suspended Stripline (SS) Substrate Model" on page 36-26 for information on this substrate type.

Table 44: Mitered Bend Instance Parameters

Parameter	Description	Unit	Default
W1	Width of line 1	Meter	0.001
W2	Width of line 2	Meter	0.001
NSUM	Number of modes considered in the field expansion	None	3

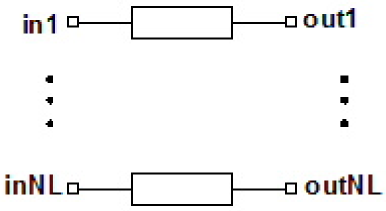
Netlist Example

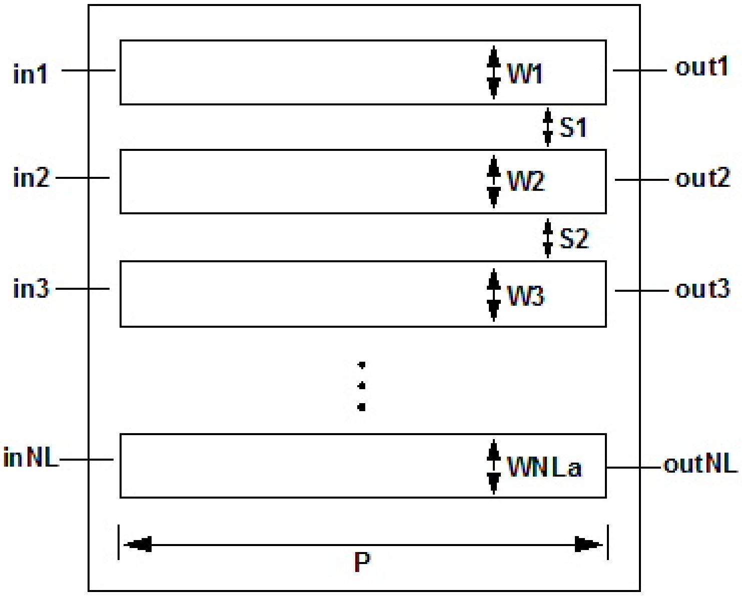
```
A23 Port1 Port2 w1=3e-4 w2=5e-3
+ COMPONENT=mitered_bend SUBSTRATE=SS1
```

where SS1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SS1 SS (
+ Er=4.4 H=0.5e-3 HU=2.54e-003
+ MET1=1.7241379 T1=2.5400e-005
+ RGH=0 )
```

Multi-Coupled Lines, Asymmetric





Netlist Form

An asymmetric multiple coupled line, physical length instance has the following netlist syntax:

```
Axxx in1 [...inNL] out1 [...outNL]

NL=NumberofLines [P=length] [W=width] [SP=spacing]

COMPONENT=ss_mcpl_a SUBSTRATE=substrate_name
```

in1 through *inNL* are the names of the input nodes. *out1* through *outNL* are the corresponding output nodes. The entry **COMPONENT=ss_mcpl_a** identifies the element as an asymmetric multiple coupled line, physical length.

The entry **SUBSTRATE=***substrate_name* identifies the suspended stripline substrate model name selected for the design (see "Selecting None for the Initial Substrate" on page 36-23). See the "Suspended Stripline (SS) Substrate Model" on page 36-26 for information on this substrate type.

Table 45: Asymmetric Multiple Coupled Line, Physical Length, Instance Parameters

Parameter	Description	Units	Default
NL	Number of signal lines	None	None
P	Physical length	Meter	1e-3

W1, **W2**, ...	Conductor widths	Meter	1e-3
S1, **S2**, ...	Spacing between conductors (S1 = spacing between 1 and 2, etc.)	Meter	1e-3

Netlist Example (3 Conductors)

```
A3 Port1 Port2 Port 3 Port 4 Port 5 Port 6 NL=3
+ P=15mm W1=0.75mm S1=0.4mm W2=1.3mm S2=0.6mm W3=1.1mm
+ COMPONENT=ss_mcpl_a SUBSTRATE=SS1
```

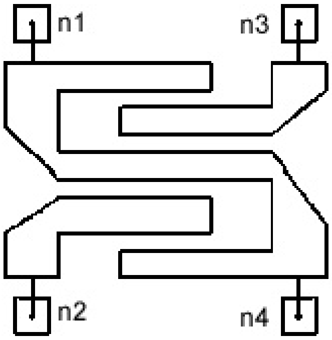
where SS1, the selected layout technology or substrate type, has a definition such as:

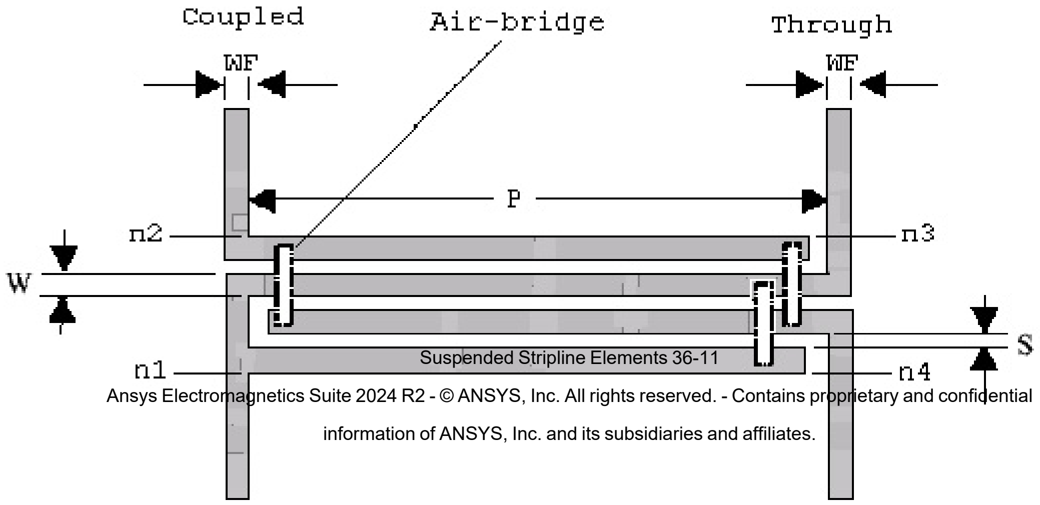
```
.SUB SS1 SS (
+ Er=4.4 H=0.5e-3 HU=2.54e-003
+ MET1=1.7241379 T1=2.5400e-005
+ RGH=0 )
```

Notes

1. The asymmetric MCPL elements use the data on the SUBSTRATE definition, but internally the data is converted to W-element FIELD SOLVER format for solution.

Lange Coupler, Physical Length





Netlist Format

A Lange coupler, physical length instance has the following netlist format:

ASSLANG*xxx n1 n2 n3 n4* **N=4 W=***val* **S=***val* **P=***val* **WF=***val* **WA=***val* **HA=***val* **COMPONENT=sslange_physical SUBSTRATE=***substrate_name*

n1, *n2*, *n3*, and *n4* are the names of the nodes attached to the coupler. The entry **COMPONENT=sslange_physical** identifies the element.

The entry **SUBSTRATE=***substrate_name* identifies the suspended stripline substrate model name selected for the design (see "Selecting None for the Initial Substrate" on page 36-23). See the "Suspended Stripline (SS) Substrate Model" on page 36-26 for information on this substrate type.

Table 46: Lange Coupler, Physical Length Instance Parameters

Parameter	Description	Unit	Default
N	Number of lines. Must be 4.	None	4
W	Conductor width	Meter	1e-3
S	Conductor spacing	Meter	1e-3
P	Physical length	Meter	2e-3
WF	Center conductor width of feeding lines	Meter	0.5e-3
WA	Width of air bridges	Meter	25e-6
HA	Height of air bridges	Meter	25e-6

Netlist Example

```
ASSLANG1 net1 Port2 net3 Port4 N=4 W=1e-3 S=.2e-3 P=10e-3
+ COMPONENT=sslange_physical SUBSTRATE=SS1
```

where SS1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SS1 SS (
+ Er=4.4 H=0.5e-3 HU=2.54e-003
+ MET1=1.7241379 T1=2.5400e-005
+ RGH=0 )
```

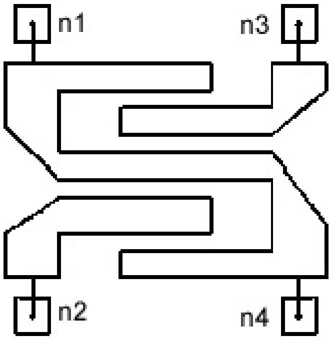
Notes

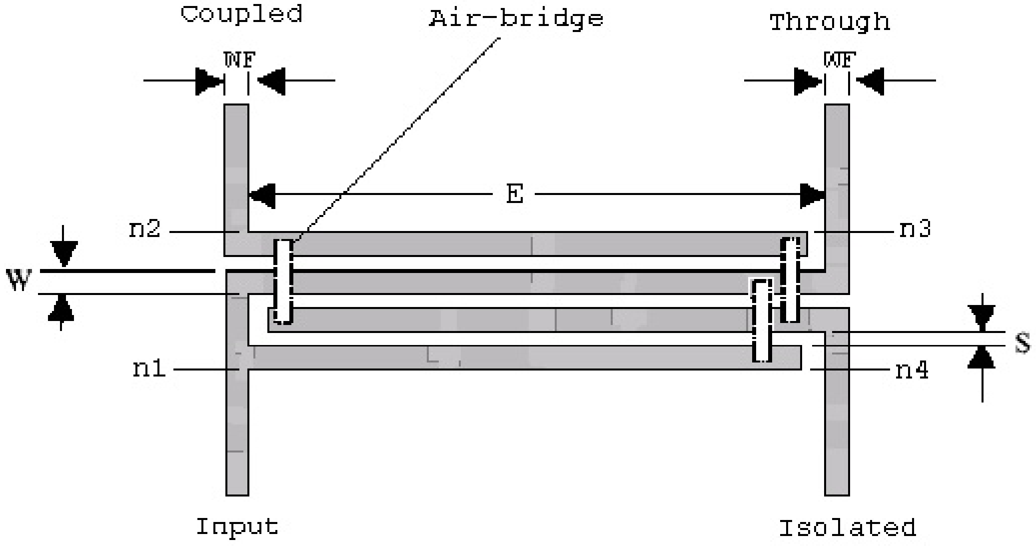
1. The conductor width of all fingers is W. The distance between all fingers is S.
2. The number of fingers, N, must be 4.
3. Port 1 is the input port, port 2 is the coupled port, port 3 is the through port, and port 4 is

the isolated port.

4. The length of air bridges used to approximate their parasitic effects, is 2*(W+S).

Lange Coupler, Electrical Length





Netlist Format

A Lange coupler, electrical length instance has the following netlist format:

ASSLANGE*xxx n1 n2 n3 n4* **N=4 W=***val* **S=***val* **E=***val* **F=***val* **WF=***val* **WA=***val* **HA=***val* **COMPONENT=sslange_electrical SUBSTRATE=***substrate_name* *n1*, *n2*, *n3*, and *n4* are the names of the nodes attached to the coupler. The entry **COMPONENT=sslange_electrical** identifies the element.

The entry **SUBSTRATE=***substrate_name* identifies the suspended stripline substrate model name selected for the design (see "Selecting None for the Initial Substrate" on page 36-23). See the "Suspended Stripline (SS) Substrate Model" on page 36-26 for information on this substrate type.

Table 47: Lange Coupler, Electrical Length Instance Parameters

Parameter	Description	Unit	Default
N	Number of lines. Must be 4.	None	4
W	Conductor width	Meter	1e-3
S	Conductor spacing	Meter	1e-3
E	Electrical length	Degree	90
F	Frequency at which E is taken	Hz	1e9
WF	Center conductor width of feeding lines	Meter	0.5e-3
WA	Width of air bridges	Meter	25e-6
HA	Height of air bridges	Meter	25e-6

Netlist Example

```
ASSLANGE1 net1 Port2 net3 Port4 N=4 W=1e-3 S=.2e-3 E=75
+ COMPONENT=sslange_electrical SUBSTRATE=SS1
```

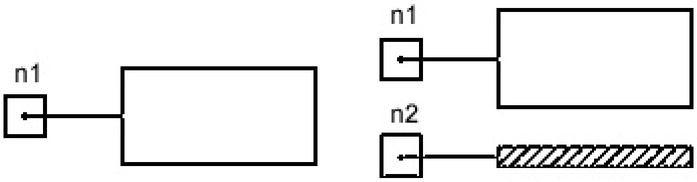
where SS1, the selected layout technology or substrate type, has a definition such as:

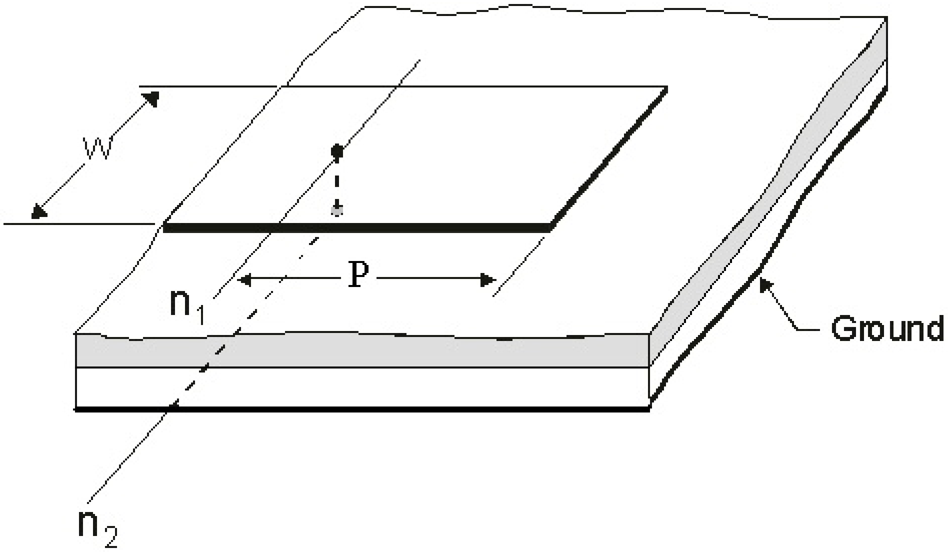
```
.SUB SS1 SS (
+ Er=4.4 H=0.5e-3 HU=2.54e-003
+ MET1=1.7241379 T1=2.5400e-005
+ RGH=0 )
```

Notes

1. The conductor width of all fingers is W. The distance between all fingers is S.
2. The number of fingers, N, must be 4.
3. Port 1 is the input port, port 2 is the coupled port, port 3 is the through port, and port 4 is the isolated port.
4. The length of air bridges used to approximate their parasitic effects, is 2*(W+S).

Open Stub, Physical Length





Netlist Format

An instance of a suspended stripline open stub with physical length has the following netlist syntax:

```
Axxx n1 [n2]   [W=val] [P=val] COMPONENT=open_stub
SUBSTRATE=substrate_name
```

n1 is node attached to the open stub. *n2* is the optional reference node. The entry **COMPONENT=open_stub** identifies the element.

The entry **SUBSTRATE=***substrate_name* identifies the suspended stripline substrate model name selected for the design (see "Selecting None for the Initial Substrate" on page 36-23). See the "Suspended Stripline (SS) Substrate Model" on page 36-26 for information on this substrate type.

Table 48: Suspended Stripline Open Stub with Physical Length, Instance Parameters

Parameter	Description	Units	Default
P	Physical length	Meter	10e-3
W	Center conductor width	Meter	1e-3

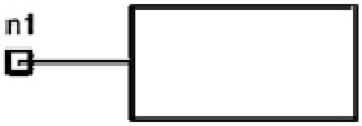
Netlist Example

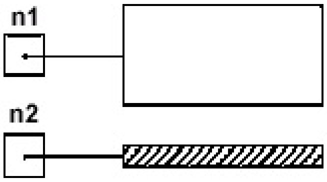
```
A23 Port1 0 W=.5e-003 P=0.001
+ COMPONENT=open_stub   SUBSTRATE=SS1
```

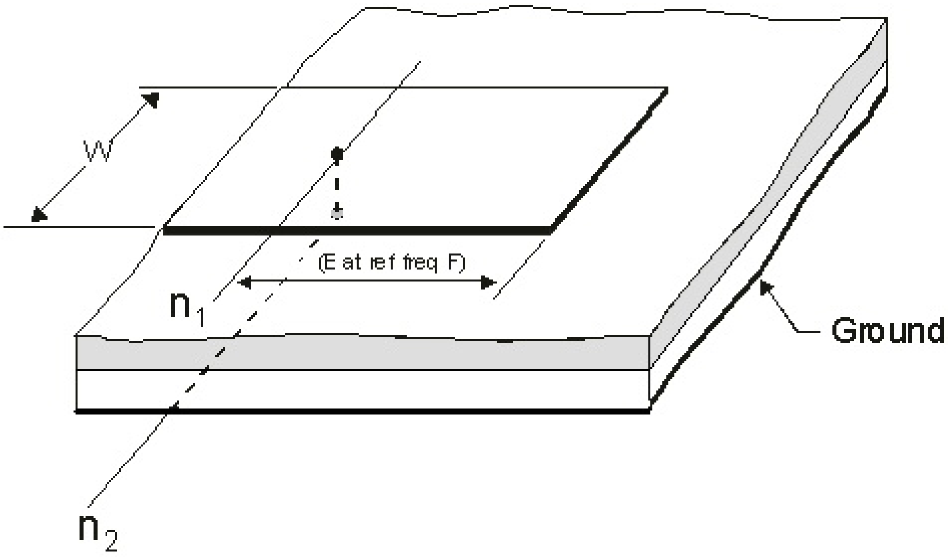
where SS1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SS1 SS (
+ Er=4.4 H=0.5e-3 HU=2.54e-003
+ MET1=1.7241379 T1=2.5400e-005
+ RGH=0 )
```

Open Stub, Electrical Length







Netlist Format

An instance of a suspended stripline open stub with electrical length has the following netlist syntax:

```
Axxx n1 [n2]   W=val E=val F=val COMPONENT=open_stub_e
SUBSTRATE=substrate_name
```

n1 is node attached to the open stub. *n2* is the optional reference node. The entry **COMPONENT=open_stub_e** identifies the element.

The entry **SUBSTRATE=***substrate_name* identifies the suspended stripline substrate model name selected for the design (see "Selecting None for the Initial Substrate" on page 36-23). See the "Suspended Stripline (SS) Substrate Model" on page 36-26 for information on this substrate type.

Table 49: Suspended Stripline Open Stub with Electrical Length, Instance Parameters

Parameter	Description	Units	Default
W	Conductor width	Meter	1e-3
E	Electrical length	Degree	45
F	Reference frequency for E	Hz	1e9

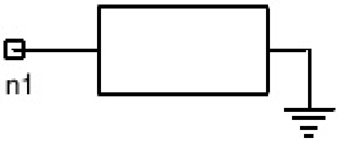
Netlist Example

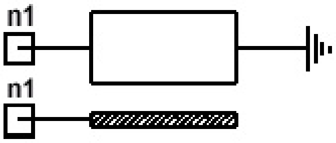
```
A7 Port1 0 W=0.005 E=45 F=5000000000
+ COMPONENT=open_stub   SUBSTRATE=SS1
```

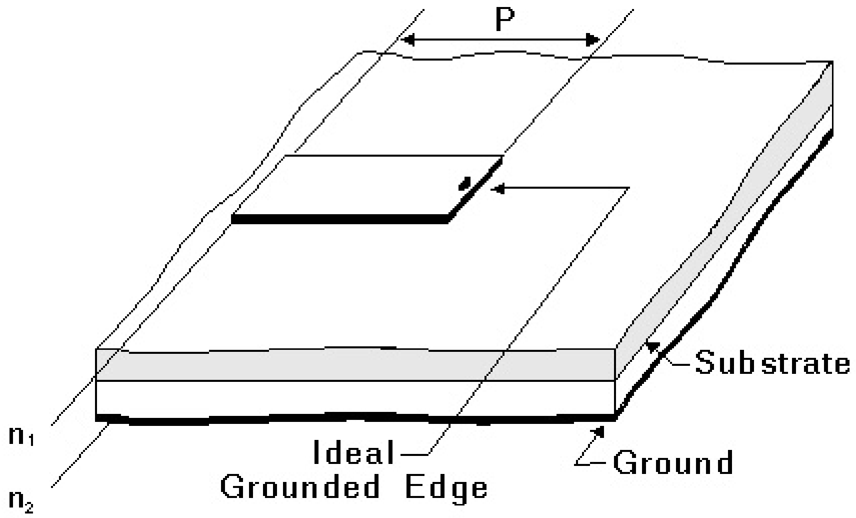
where SS1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SS1 SS (
+ Er=4.4 H=0.5e-3 HU=2.54e-003
+ MET1=1.7241379 T1=2.5400e-005
+ RGH=0 )
```

Shorted Stub, Physical Length







Netlist Format

An instance of a suspended stripline shorted stub with physical length has the following netlist syntax:

A*xxx n1* [*n2*] [**W=***val*] [**P=***val*] **COMPONENT=short_stub_physical SUBSTRATE=***substrate_name*

n1 is node attached to the shorted stub. *n2* is the optional reference node. The entry COMPONENT=short_stub_physical identifies the element.

The entry **SUBSTRATE=***substrate_name* identifies the suspended stripline substrate model name selected for the design (see "Selecting None for the Initial Substrate" on page 36-23). See the "Suspended Stripline (SS) Substrate Model" on page 36-26 for information on this substrate type.

Table 50: Suspended Stripline Shorted Stub with Physical Length, Instance Parameters

Parameter	Description	Units	Default
P	Physical length	Meter	10e-3
W	Center conductor width	Meter	1e-3

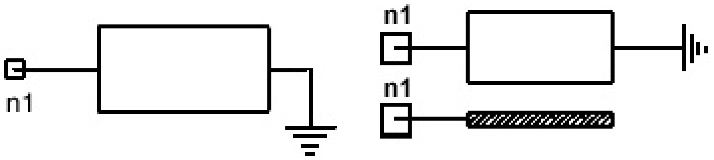
Netlist Example

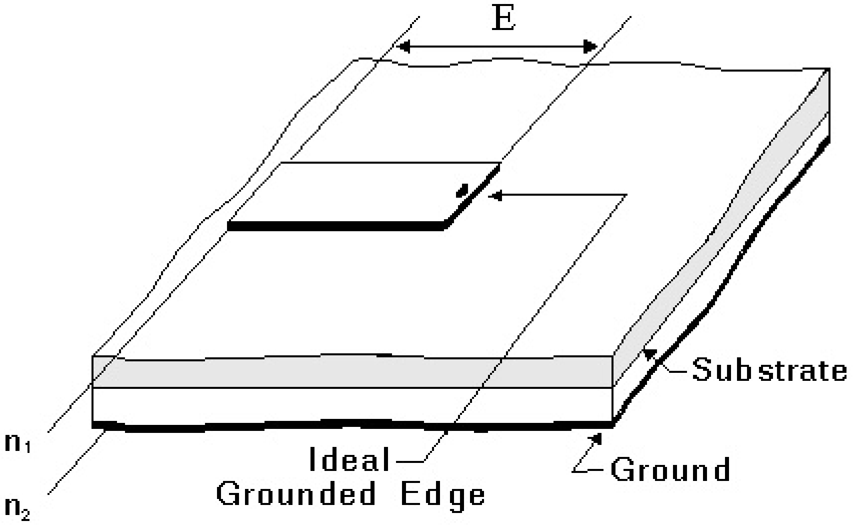
```
A23 Port1 0 W=.5e-003 P=0.001
+ COMPONENT=short_stub_physical SUBSTRATE=SS1
```

where SS1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SS1 SS (
+ Er=4.4 H=0.5e-3 HU=2.54e-003
+ MET1=1.7241379 T1=2.5400e-005
+ RGH=0 )
```

Shorted Stub, Electrical Length





Netlist Format

An instance of a suspended stripline shorted stub with electrical length has the following netlist syntax:

A*xxx n1* [*n2*] **W=***val* **E=***val* **F=***val* **COMPONENT=short_stub_electrical SUBSTRATE=***substrate_name*

n1 is node attached to the shorted stub. *n2* is the optional reference node. The entry **COMPONENT=short_stub_electrical** identifies the element.

The entry **SUBSTRATE=***substrate_name* identifies the suspended stripline substrate model name selected for the design (see "Selecting None for the Initial Substrate" on page 36-23). See the "Suspended Stripline (SS) Substrate Model" on page 36-26 for information on this substrate type.

Table 51: Suspended Stripline Shorted Stub with Electrical Length, Instance Parameters

Parameter	Description	Units	Default
W	Conductor width	Meter	1e-3
E	Electrical length	Degree	45
F	Reference frequency for E	Hz	1e9

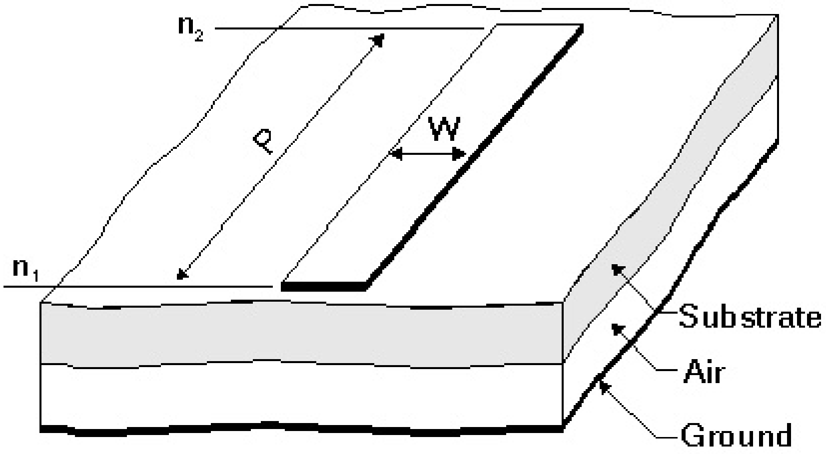
Netlist Example

```
A7 Port1 0 W=0.005 E=45 F=5000000000
+ COMPONENT=shorted_stub_electrical SUBSTRATE=SS1
```

where SS1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SS1 SS (
+ Er=4.4 H=0.5e-3 HU=2.54e-003
+ MET1=1.7241379 T1=2.5400e-005
+ RGH=0 )
```

Transmission Line, Physical Length



Netlist Format

An instance of a suspended stripline transmission line with physical length has the following netlist syntax:

```
Axxx n1 n2 [W=val] [P=val] COMPONENT=sstrl SUBSTRATE=substrate_name
```

n1 and *n2* are the names of the nodes attached to the transmission line. The entry **COMPONENT=sstrl** identifies the element as a suspended stripline transmission line with physical length.

The entry **SUBSTRATE=***substrate_name* identifies the suspended stripline substrate model name selected for the design (see "Selecting None for the Initial Substrate" on page 36-23). See the "Suspended Stripline (SS) Substrate Model" on page 36-26 for information on this substrate type.

Table 52: Suspended Stripline Transmission Line with Physical Length, Instance Parameters

Parameter	Description	Units	Default
P	Physical length	Meter	1e-3
W	Conductor width	Meter	1e-3

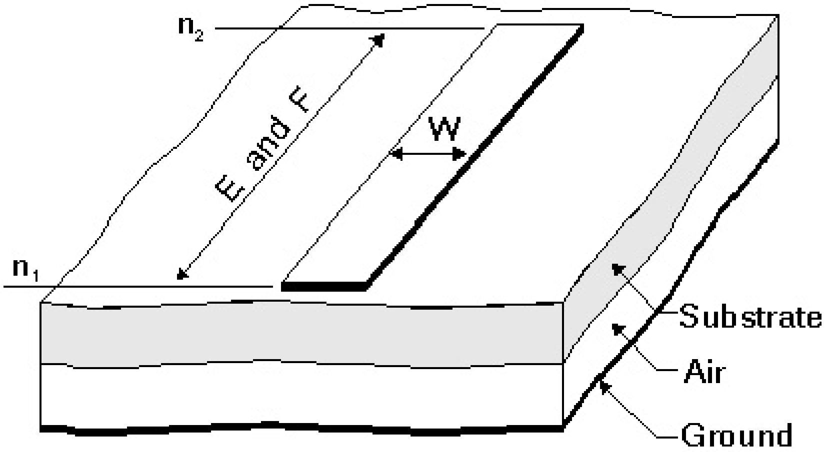
Netlist Example

```
A23 Port1 Port2 W=1.2700e-004 P=0.001
+ COMPONENT=SSTRL   SUBSTRATE=SS1
```

where SS1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SS1 SS (
+ Er=4.4 H=0.5e-3 HU=2.54e-003
+ MET1=1.7241379 T1=2.5400e-005
+ RGH=0 )
```

Transmission Line, Electrical Length



Netlist Format

An instance of a suspended stripline transmission line with electrical length has the following netlist syntax:

```
Axxx n1 n2 W=val E=val F=val COMPONENT=sstrle SUBSTRATE=substrate_
name
```

n1 and n2 are the names of the nodes attached to the transmission line. The entry **COMPONENT=sstrle** identifies the element as a transmission line with electrical length.

The entry **SUBSTRATE=***substrate_name* identifies the suspended stripline substrate model name selected for the design (see "Selecting None for the Initial Substrate" below). See the "Suspended Stripline (SS) Substrate Model" on page 36-26 for information on this substrate type.

Table 53: Transmission Line with Electrical Length, Instance Parameters

Parameter	Description	Units	Default
W	Conductor width	Meter	1e-3
E	Electrical length	Degree	45
F	Reference frequency for E	Hz	1e9

Netlist Example

```
A7 Port1 Port2 W=0.001 E=45 F=5000000000
+ COMPONENT=sstrle SUBSTRATE=SS1
```

where SS1, the selected layout technology or substrate type, has a definition such as:

```
.SUB SS1 SS (
+ Er=4.4 H=0.5e-3 HU=2.54e-003
+ MET1=1.7241379 T1=2.5400e-005
+ RGH=0 )
```

Selecting None for the Initial Substrate

For Nexxim designs that are created with the **Schematic Editor**, the initial selection of a global substrate type is made on the **Choose Layout Technology** window that appears when you select Insert Nexxim Circuit Design on the Project menu.

However, no suspended stripline substrates are available in the **Choose Layout Technology** window.

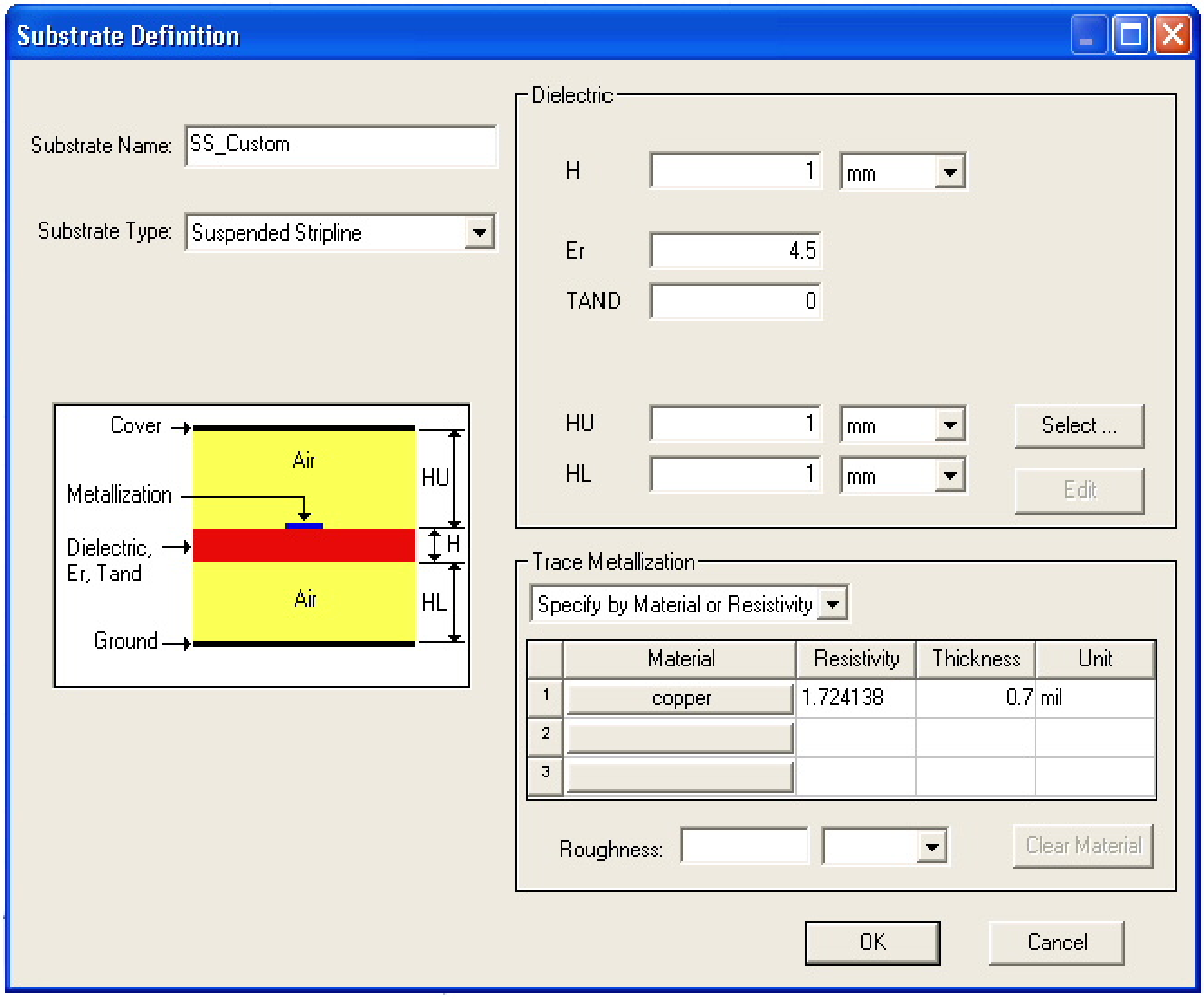
If you wish to use a suspended stripline substrate, you must create it as a custom substrate type.

In the **Choose Layout Technology** window, click **None**. The design opens, but no substrate type is applied to instances of distributed elements until you create a custom substrate type.

See "Creating a Custom Suspended Stripline Substrate" below for details.

Creating a Custom Suspended Stripline Substrate

To create a suspended stripline substrate definition, open the Nexxim design icon (e.g., “Nexxim1”, then right-click the **Add Reference Data** field and select **Add Substrate Definition** to open the **Substrate Definition** window. Specify the name of your new substrate (the following example uses the name “SS_Custom”):



Substrate Name: SS_Custom

Substrate Type: Suspended Stripline

Dielectric

H: 1 mm

Er: 4.5

TAND: 0

HU: 1 mm

HL: 1 mm

Trace Metallization

Specify by Material or Resistivity

	Material	Resistivity	Thickness	Unit
1	copper	1.724138	0.7	mil
2				
3				

Roughness:

Select **Suspended Stripline** as the Substrate Type. Complete the Dielectric and Metallization field information. Refer to the "Suspended Stripline (SS) Substrate Model" on the next page help topic for guidelines on defining suspended stripline substrates.

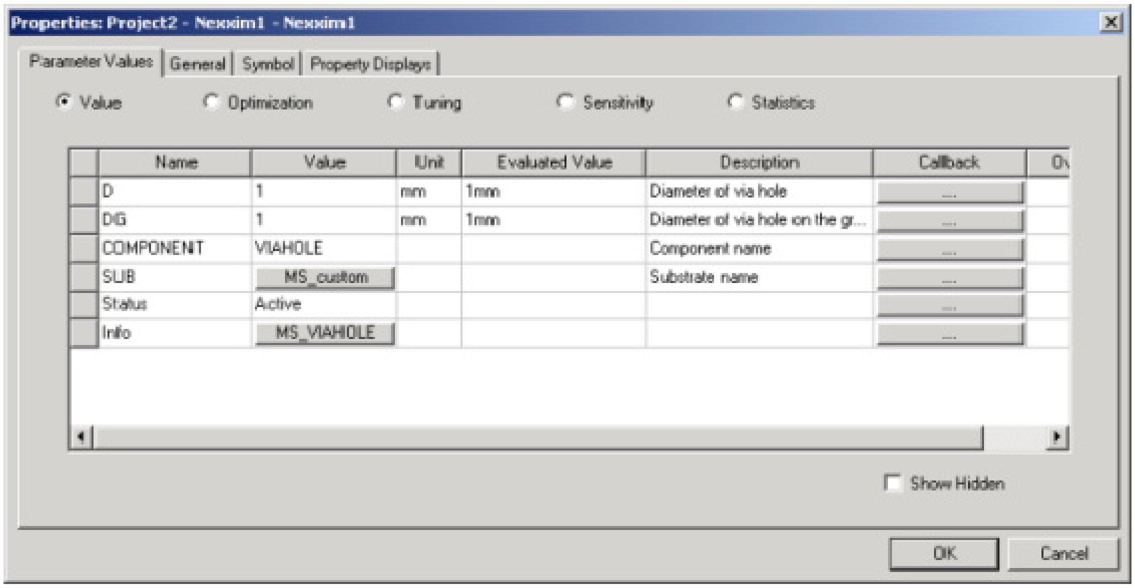
When the substrate definition is complete, click **OK**.

If you selected **None** for the global substrate type in the **Choose Layout Technology** window, the custom suspended stripline substrate becomes the global substrate type.

When an element is instantiated , it includes a **SUBSTRATE=***substrate_name* entry in its netlist syntax. **Electronics Desktop** automatically inserts the global *substrate_name* into the internal netlist entry for the instantiated element.

Selecting a Suspended Stripline Substrate at the Component Level

To specify a custom substrate type, or to change to a different predefined substrate type, you must make the assignment individually for each component. Double-click the distributed element to open the **Properties** window:



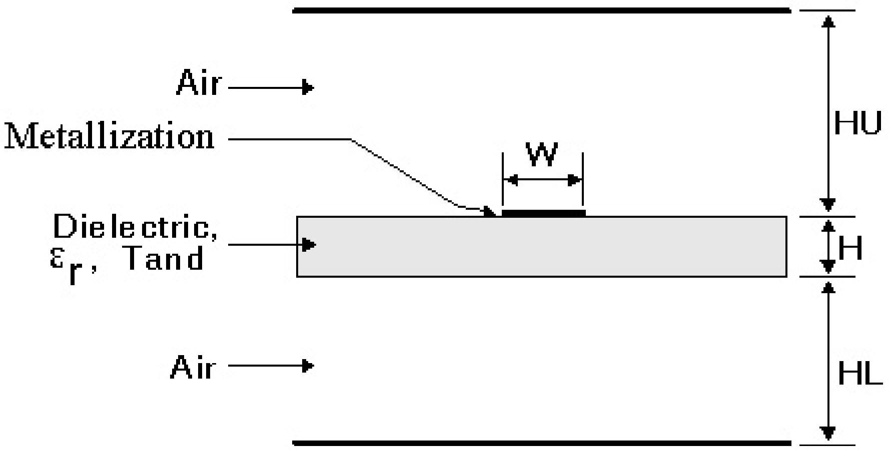
	Name	Value	Unit	Evaluated Value	Description	Callback	O\
	D	1	mm	1mm	Diameter of via hole	...	
	DIG	1	mm	1mm	Diameter of via hole on the gr...	...	
	COMPONENT	VIAHOLE			Component name	...	
	SUB	MS_custom			Substrate name	...	
	Status	Active				...	
	Info	MS_VIAHOLE				...	

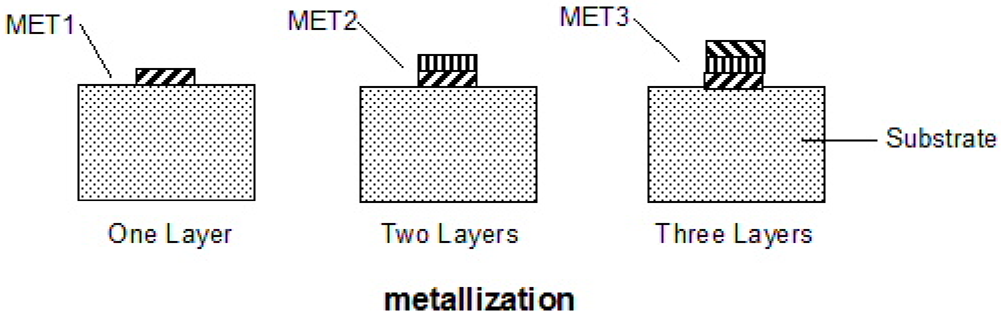
The **SUB** property identifies the substrate that is currently applied to the element. In the example above, a custom substrate type named “MS_custom” appears as the value of the **SUB** property.

To change to a different substrate type, click in the **SUB** Value field and select the appropriate substrate name as the value of the **SUB** property. Then click **OK**.

> **Note:** All distributed elements in a given design must use the same substrate type.

Suspended Stripline (SS) Substrate Model





Defining a Suspended Stripline Model

To add a suspended stripline substrate model to a new Nexxim design, you must add the definition to the set of substrate models.

To add a new substrate definition to an existing design, expand the **Project** icon, the **Design** icon. Right-click the **Data** icon and select **Add Substrate Definition** to open the **Substrate**

Definition window. Then add the substrate name and parameters as appropriate, and click **OK**. A substrate added in this manner requires you to specify the metallization parameters explicitly.

To edit the definition of a substrate, expand the **Project** icon, the **Design** icon, the **Data** icon. Click on the icon for the substrate you wish to edit to open the **Substrate Definition** window. Add or modify the substrate parameters as appropriate, then click **OK**.

Suspended Stripline Substrate Model Netlist Format

The Ssupended Stripline substrate model has the following netlist format:

```
.SUBsubstrate_name SS ( [ER=val] [TAND=val]
+ [H=val] [HU=val] [HL=val]
+ [MET1=val] [T1=val] [MET2=val] [T2=val] [MET3=val] [T3=val]
+ [RGH=val])
```

The *substrate_name* is the name for the substrate type used in distributed elements that refer to this substrate definition. The entry **SS** is required to identify the Suspended Stripline substrate type. The **SS** identifier must immediately follow the *substrate_name*.

Inside the parentheses, the labeled parameters may be entered in any order.

Table 54: Ssupended Stripline Substrate Parameters

Parameter	Description	Unit	Default
ER	Dielectric constant ≤ 128	None	4.5
H	Dielectric height	Meter	1e-3
HU	Height of upper air layer	Meter	1e-3
HL	Height of lower air layer	Meter	1e-3
MET1, **MET2**, **MET3**	Resistivity of metal layer 1, 2, 3	µOhm-cm	0.0
RGH	RMS surface roughness	Meter	0.0
T1, **T2**, **T3**	Thickness of metal layer 1, 2, 3	Meter	0.0
TAND	Dielectric loss tangent, [0,0.1]	None	0.0

Suspended Stripline Substrate Model Netlist Example

```
.SUB SS1 SS (
+Er=4.2 H=0.5e-3 HU=2.54e-003
+ MET1=1.7241 T1=2.54e-005
+ RGH=0)
```

37 - Switches

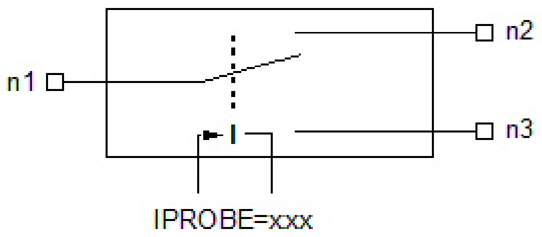
This topic describes the following controlled switches available in Nexxim.

"Current-Controlled Switch, ISPDT" below

"Voltage-Controlled Switch, VSPDT " on page 37-3

"Voltage-Controlled Switch, VSPST" on page 37-6

Current-Controlled Switch, ISPDT



Netlist Format

An instance of a current-controlled single-pole, double throw switch has the netlist syntax:

```
Gxxx (n1 n2 n3 ) ISPDT PROBE=name [ROFF=val] [RON=val]
[IOFF=val] [ION=val] [AREA=val]
```

n1 is the input node, *n2* and *n3* are the selectable output nodes. The control branch is specified with the name of a current probe or equivalent. The parentheses are required around the list of node names. The entry **ISPDT** identifies the element as a current-controlled SPDT switch.

Table 1: Current-Controlled Switch, ISPDT Instance Parameters

Parameter	Description	Units	Default
ROFF	Off resistance	Ohm	1e6
RON	On resistance	Ohm	1.0
IOFF	Control current for off state	Ampere	0.0
ION	Control current for on state	Ampere	1.0
AREA	Area scaling factor	None	1.0
PROBE	Name of the controlling current probe or voltage source	None	None

Netlist Example

```
v1 c1 0 SIN(0 10 1e6) // Control source

R1 c1 0 1

Vn1 n1 0 10

Rn2 n2 0 10

Rn3 n3 0 10

G1 (n1 n2 n3) ispdt probe=v1
```

Notes

1. In normal operation, **ION** is greater than **IOFF**. Output node *n2* is selected when control current **IC** is greater than or equal to **ION**, and output node *n3* is selected when **IC** is less than or equal to **IOFF**.
2. In inverted operation, **ION** is less than **IOFF**. Output node *n2* is selected when **IC** is less than or equal to **ION**, and output node *n3* is selected when **IC** is greater than or equal to **IOFF**.

ISPDT Model Equations

For the ISPDT, G1 is the conductance between input node n1 and output node n2. G2 is the conductance between input node n1 and output node n3. By default, on-resistance RON equals 1Ω, off-resistance ROFF equals 10^6Ω, and scale factor AREA equals 1. A conductance with value1 mho turns on the connection between the corresponding input and output nodes. A conductance of 10^{-6} mho blocks the connection between the corresponding input and output nodes.

If ((**ION** > **IOFF** && **IC** >= **ION**) || (**ION** < **IOFF** && **IC** <= **ION**)):

$$\mathrm{G1} = \frac{\mathrm{AREA}}{\mathrm{RON}}$$

[Output n2 is on]

$$\mathrm{G2} = \frac{\mathrm{AREA}}{\mathrm{ROFF}}$$

[Output n3 is off]

Else if ((**ION** > **IOFF** && **IC** <= **IOFF**) || (**ION** < **IOFF** && **IC** >= **IOFF**)):

$$\mathrm{G1} = \frac{\mathrm{AREA}}{\mathrm{ROFF}}$$

[Output n2 is off]

$$\mathrm{G2} = \frac{\mathrm{AREA}}{\mathrm{RON}}$$

[Output n3 is on]

Else:

$$\mathrm{G1} = \mathrm{AREA} * e^{\left(\mathrm{ag}+b*\mathrm{icm}-a*\mathrm{icm}^3\right)}$$

[From n1 to n2]

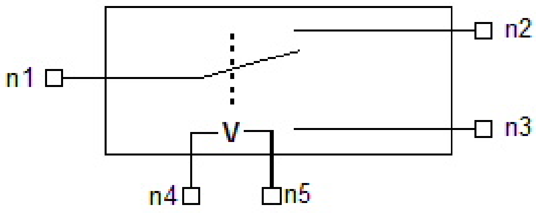
$$\mathrm{G2} = \mathrm{AREA} * e^{\left(\mathrm{ag}+\mathrm{b1}*\mathrm{icm}-\mathrm{a1}*\mathrm{icm}^3\right)}$$

[From n1 to n3]

where:

$$\mathrm{di} = \mathrm{ION} - \mathrm{IOFF}$$
$$\mathrm{dlg} = \log\left(\frac{\mathrm{ROFF}}{\mathrm{ROM}}\right)$$
$$\mathrm{dlg1} = \text{-}\mathrm{dlg}$$
$$a = \left(\frac{2*\mathrm{dlg}}{\mathrm{di}^3}\right)$$
$$b = \left(\frac{1.5*\mathrm{dlg}}{\mathrm{di}}\right)$$
$$\mathrm{a1} = \left(\frac{2*\mathrm{dlg1}}{\mathrm{di}^3}\right)$$
$$\mathrm{b1} = \left(\frac{1.5*\mathrm{dlg1}}{\mathrm{di}}\right)$$
$$\mathrm{ag} = \frac{\text{-}\log(\mathrm{RON}*\mathrm{ROFF})}{2}$$
$$\mathrm{icm} = \mathrm{IC} - (\mathrm{ION} + \mathrm{IOFF}) * 0.5$$

Voltage-Controlled Switch, VSPDT



Netlist Format

An instance of a voltage-controlled single-pole, double throw switch has the following netlist syntax:

`E``xxx` **`(`**`n1 n2 n3 n4 n5` **`)`** **`VSPDT`**`[`**`ROFF=`**`val] [`**`RON=`**`val] [`**`VOFF=`**`val]`
`[`**`VON=`**`val] [`**`AREA=`**`val]`

n1 is the input node, *n2* is the “OFF” output node, *n3* is the “ON” output node, *n4* and *n5* are the control nodes. The parentheses around the list of node names are required. The entry **VSPDT** identifies the element as a voltage-controlled SPDT switch.

Table 2: Voltage-Controlled Switch, SPDT Instance Parameters

Parameter	Description	Units	Default
ROFF	Off resistance	Ohm	1e6
RON	On resistance	Ohm	1.0
VOFF	Control voltage for off state	Volt	0.0
VON	Control voltage for on state	Volt	1.0
AREA	Area scaling factor	None	1.0

Netlist Example

```
v1 c1 0 SIN(0 10 1e6) // Control voltage

R1 c1 0 1

Vn1 n1 0 10

Rn2 n2 0 10

Rn3 n3 0 10


E1 (n1 n2 n3 c1 0) vspdt
```

Notes

1. In normal operation, **VON** is greater than or equal to **VOFF**. Output node *n3* is selected when control voltage **VC** is greater than or equal to **VON**, and output node *n2* is selected when **VC** is less than or equal to **VOFF**.
2. In inverted operation, **VON** is less than **VOFF**. Output node *n3* is selected when **VC** is less than or equal to **VON**, and output node *n2* is selected when **VC** is greater than or equal to **VOFF**.

VSPDT Model Equations

For the VSPDT, G1 is the conductance between input node n1 and output node n3. G2 is the conductance between input node n1 and output node n2. By default, on-resistance RON equals 1Ω, off-resistance ROFF equals 10^6Ω, and scale factor AREA equals 1. A conductance with value1 mho turns on the connection between the corresponding input and output nodes. A conductance of 10^{-6} mho blocks the connection between the corresponding input and output nodes.

If ((**VON** >= **VOFF** && **VC** >= **VON**) || (**VON** < **VOFF** && **VC** <= **VON**)):

$$\mathrm{G1} = \frac{\mathrm{AREA}}{\mathrm{RON}}$$

[Output n3 is on]

$$\mathrm{G2} = \frac{\mathrm{AREA}}{\mathrm{ROFF}}$$

[Output n2 is off]

Else if ((**VON** >= **VOFF** && **VC** <= **VOFF**) || (**VON** < **VOFF** && **VC** >= **VOFF**)):

$$\mathrm{G1} = \frac{\mathrm{AREA}}{\mathrm{ROFF}}$$

[Output n3 is off]

$$\mathrm{G2} = \frac{\mathrm{AREA}}{\mathrm{RON}}$$

[Output n2 is on]

Else:

$$\mathrm{G1} = \mathrm{AREA} * e^{\left(\mathrm{ag}+b*\mathrm{vcm}-a*\mathrm{vcm}^3\right)}$$

[From n1 to n3]

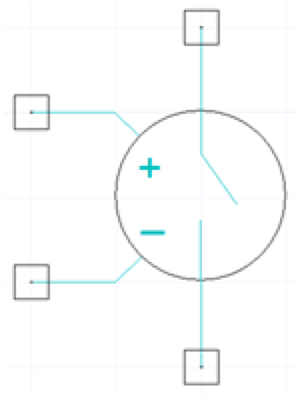
$$\mathrm{G2} = \mathrm{AREA} * e^{\left(\mathrm{ag}+\mathrm{b1}*\mathrm{vcm}-\mathrm{a1}*\mathrm{vcm}^3\right)}$$

[From n1 to n2]

where:

$$\mathrm{dv} = \mathrm{VON} - \mathrm{VOFF}$$
$$\mathrm{dlg} = \log\left(\frac{\mathrm{ROFF}}{\mathrm{ROM}}\right)$$
$$\mathrm{dlg1} = \text{-dlg}$$
$$a = \left(\frac{2^*\mathrm{dlg}}{\mathrm{dv}^3}\right)$$
$$b = \left(\frac{1.5^*\mathrm{dlg}}{\mathrm{dv}}\right)$$
$$\mathrm{a1} = \left(\frac{2^*\mathrm{dlg1}}{\mathrm{dv}^3}\right)$$
$$\mathrm{b1} = \left(\frac{1.5^*\mathrm{dlg1}}{\mathrm{dv}}\right)$$
$$\mathrm{ag} = \frac{\text{-log(RON*ROFF)}}{2}$$
$$\mathrm{vcm} = \mathrm{VC} - (\mathrm{VON} + \mathrm{VOFF}) * 0.5$$

Voltage-Controlled Switch, VSPST



Netlist Format

S*xxx* **(***n1 n2 n3 n4* **)** [*modelname*]

.MODEL *modelname* VSWITCH [**(**][*parameter=val*] ... [**)**]

N1 is the input node, *n2* is the output node, *n3* is the positive control node, and *n4* is the negative control node. **VSWITCH** (or alternatively **SW**) identifies the element as a voltage controlled SPST switch.

Table: Voltage-Controlled Switch, VSPST Instance Parameters

Parameter	Description	Default Value [Unit]
Von	Control voltage for ON state	1 [V]
Voff	Control voltage of OFF state	0 [V]
Ron	ON state resistance	1 [Ohm]
Roff	OFF state resistance	1e6 [Ohm]
Vh	Threshold voltage	0 [V]
Vt	Hysteresis voltage	0 [V]
Td	Time delay	0 [s]

When the parameter Vh is specified the switch with hysteresis is loaded (short-transition model in pspice).

Switch Equations

In the following equations:

- V_c = voltage across control nodes
- L_m = log-mean of resistor values = ln((Ron * Roff)$^{1/2}$)
- L_r = log-ratio of resistor values = ln(Ron/Roff)
- V_m = mean of control voltages = (Von+Voff)/2
- V_d = difference of control voltages = Von-Voff
- k = Boltzmann’s constant
- T = analysis temperature (°K)
- S_s = switch state
- R_s = switch resistance

Variable Resistance Equations for Switch Resistance

For Von > Voff:

- if V_c > Von, then R_s = Ron
- if V_c < Voff, then R_s = Roff
- if Voff < V_c < Von, then

$$R_s = exp\left(L_m + \frac{3L_r(V_c - V_m)}{2V_d} - \frac{2L_r(V_c - V_m)^3}{V_d^3}\right)$$

For Von < Voff

- if V_c < Von, then R_s = Ron
- if V_c > Voff, then R_s = Roff
- if Voff > V_c > Von, then

$$R_s \;=\; exp\left(L_m \;-\; \frac{3L_r(V_c - V_m)}{2V_d} + \frac{2L_r(V_c - V_m)^3}{V_d^3}\right)$$

Hysteresis Transition Equations for Switch Resistance

If S_s = off

- for V_c >= VT + VH
- then R_s = Ron and S_s = on

Else if S_s = on

- for V_c < Vt - Vh
- then R_s = Roff and S_s = off

Else use the current state (i.e., R_s = R_s and S_s = S_s)

38 - System

This topic describes the behavioral components available for Nexsys simulation. These components are available from **System** folder under the **Components** tab in the **Project** window when a Circuit design is active in the **Schematic Editor**.

The topics for this section include:

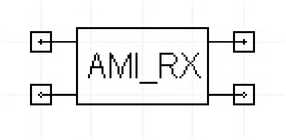
AMI Transceivers

This topic describes the following System components:

AMI Receiver (AMIRX)

"AMI Transmitter (AMITX)" on page 38-6

AMI Receiver (AMIRX)



Property	Description	Units	Default	Range/Type
LIBRARY	AMI receiver library file	None	None	File reference
PARAMETERS_ FILE	AMI receiver parameters file	None	None	File reference
NAME	Name of the associated AMI transmitter enclosed in quotes	None	None	String
BLOCK_SIZE	Block size	None	1000	[1, MAXINT]/Integer
UI	Unit interval	s	1e-9	(0, Inf]/Real
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT1	Output1 impedance	Ohm	0	[0, Inf)/Real
ROUT2	Output2 impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This is an IBIS AMI Receiver model. The user supplies the model equations and parameter values in files.

Netlist Form

```
AAMIRX:NAME in1 in2 out1 out2 Nexsys_component=amirx   LIBRARY='file_reference' PARAMETERS='file_reference'
NAME=”string” BLOCK_SIZE=val UI=val [Rin1=val] [Rin2=val]
[Rout1=val] [Rout2=val]
```

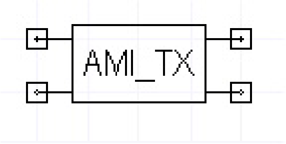
Netlist Example

```
AAMIRX:3 net11   net12   net34 net35 Nexsys_component=amirx
+ LIBRARY='AMI_receiver.txt'

+ PARAMETERS='AMI_receiver_params.txt'

+   NAME=”amitx1”
+ BLOCK_SIZE=1000 UI=1e-9
```

AMI Transmitter (AMITX)



Property	Description	Units	Default	Range/Type
LIBRARY	AMI transmitter library file	None	None	File reference
PARAMETERS_ FILE	AMI transmitter parameters file	None	None	File reference
NAME	Name of the AMI transmitter enclosed in quotes	None	None	String
BLOCK_SIZE	Block size	None	1000	[1, MAXINT]/Integer
UI	Unit interval	s	1e-9	(0, Inf]/Real
STEP_RESP_ NUM_UI	Number of unit intervals to run step response	None	10	[1, MAXINT]/Integer
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT1	Output1 impedance	Ohm	0	[0, Inf)/Real
ROUT2	Output2 impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This is an IBIS AMI Transmitter model. The user supplies the model equations and parameter values in files.

Netlist Form

```
AAMITX:NAME in1 in2 out1 out2 Nexsys_component=amitx  LIBRARY='file_reference' PARAMETERS='file_reference'
```

```
NAME=”string” BLOCK_SIZE=val UI=val STEP_RESP_NUM_UI=val
[Rin1=val] [Rin2=val] [Rout1=val] [Rout2=val]
```

Netlist Example

```
AAMITX:5 net5 net6 net31   net32   Nexsys_component=amitx
+ LIBRARY='AMI_transmitter.txt'

+ PARAMETERS='AMI_transmitter_params.txt'

+   NAME=”amitx1”
+ BLOCK_SIZE=1000 UI=1e-9
+ STEP_RESP_NUM_UI=20
```

CDMA/IS-95

This topic describes the following System components:

IS-95 Access Channel Block Deinterleaver (ACCBD95)

Property	**Description**	**Units**	**Default**	**Range/Type**
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This model implements an IS-95 block deinterleaver for the access channel (Reference 1).

Netlist Form

```
AACCBD95:Name n1  n2 nexsys_component=ACCBD95 [Rin=Val]
[Rout=Val]
```

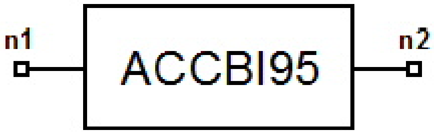
Netlist Example

```
AACCBD95:1 1  2 nexsys_component=ACCBD95
```

References

1. "Mobile-Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System” TIA/EIA/IS-95-A, May 1995.

IS-95 Access Channel Block Interleaver (ACCBI95)



Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Netlist Form

```
AACCBI95:Name n1  n2 nexsys_component=ACCBI95 [Rin=Val]
[Rout=Val]
```

Netlist Example

```
AACCBI95:1 1  2 nexsys_component=ACCBI95
```

Notes

1. This model implements an IS-95 block interleaver for the access channel. The first 576 symbols at a fixed rate 4800 Hz is interleaved according to IS-95 specifications (Reference 1)

References

1. Mobile-Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System” TIA/EIA/IS-95-A, May 1995.

IS-95 Add 8-Bit Tail Bits for Initializing Convolutional Coder (CCTAIL95)

Property	Description	Units	Default	Range/Type
FDR	Frame Data Rate	Hz	1200	[1200Hz, 9600]/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	output Impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This model adds the IS-95 tail bits to initialize the convolutional coder (Reference 1). Because eight tail bits have been added for 9600 Hz, 88 bits for 4800 Hz, 40 bits for 2400 Hz, 16 bits for 1200 Hz, the ratio of the output bit rate to input bit rate is 192/184, 96/88, 48/40, 24/16 for 9600Hz, 4800Hz, 2400Hz, and 1200Hz respectively.

Netlist Form

```
ACCTAIL95:Name n1  n2 nexsys_component=CCTAIL95 FDR=val
[Rin=Val] [Rout=Val]
```

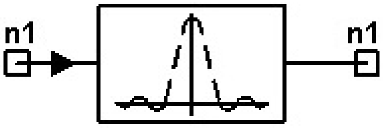
Netlist Example

```
ACCTAIL95:1 1  2 nexsys_component=CCTAIL95 FDR=9600Hz
```

References

1. "Mobile-Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System” TIA/EIA/IS-95-A, May 1995.

IS-95 Finite Impulse Response Filter (FIRIS95)



Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This model implements a 48-tap FIR filter based on the IS-95 specifications (Ref 1).
2. The input signal must have a sampling rate of 4.9152MHz.
3. The filter taps of the impulse response h[n] follow:

   h[0] = h[47] = -0.025288315
   h[1] = h[46] = -0.034167931
   h[2] = h[45] = -0.035752323
   h[3] = h[44] = -0.016733702
   h[4] = h[43] = 0.021602514
   h[5] = h[42] = 0.064938487
   h[6] = h[41] = 0.091002137
   h[7] = h[40] = 0.081894974
   h[8] = h[39] = 0.037071157
   h[9] = h[38] = -0.021998074
   h[10] = h[37] = -0.060716277
   h[11] = h[36] = -0.051178658
   h[12] = h[35] = 0.007874526
   h[13] = h[34] = 0.084368728
   h[14] = h[33] = 0.126869306
   h[15] = h[32] = 0.094528345
   h[16] = h[31] = -0.012839661
   h[17] = h[30] = -0.143477028

h[18] = h[29] = -0.211829088
h[19] = h[28] = -0.140513128
h[20] = h[27] = 0.094601918
h[21] = h[26] = 0.441387140
h[22] = h[25] = 0.785875640
h[23] = h[24] = 1.0

Netlist Form

```
AFIRIS95:Name n1  n2 nexsys_component=FIRIS95 [Rin=val]
[Rout=val]
```

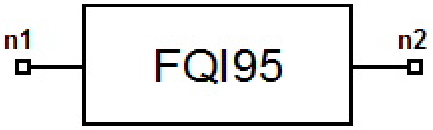
Netlist Example

```
AFIRIS95:1 1  2 nexsys_component=FIRIS95
```

References

1. "Mobile-Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System” TIA/EIA/IS-95-A, May 1995.

IS-95 Frame Quality Indicator (FQI95)



Property	Description	Units	Default	Range/Type
FDR	Frame Data Rate	Hz	4800	4800 or 9600
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. The ratio of output bit rate and input bit rate is 184/172 for 9600Hz, 88/80 for 4800Hz.
2. This model adds the IS-95 frame quality indicator bits to the input signal (reference 1).

Netlist Form

```
AFQI95:Name n1  n2  FDR=val nexsys_component=FQI95 [Rin=val]
[Rout=val]
```

Netlist Example

```
AFQI95:1 1  2 nexsys_component=FQI95 FDR=9600Hz
```

References

1. “Mobile-Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System” TIA/EIA/IS-95-A, May 1995.

IS-95 Forward Traffic Channel Block Deinterleaver (FTCBD95)

Property	Description	Units	Default	Range/Type
FDR	Frame Data Rate	Hz	9600	[1200 9600]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This model implements an IS-95 block deinterleaver that only supports the four traffic rates: 1200Hz, 2400Hz, 4800Hz, and 9600Hz. The data at each rate (384 symbols) is deinterleaved according to IS-95 specifications (Reference 1).

Netlist Form

```
AFTCBD95:Name n1  n2 nexsys_component=FTCBD95 FDR=val [Rin=val]
[Rout=val]
```

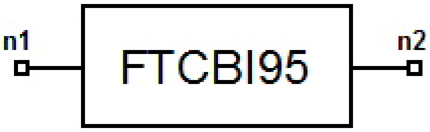
Netlist Example

```
AFTCBD95:1 1  2 nexsys_component=FTCBD95 FDR=9600Hz
```

References

1. "Mobile-Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System” TIA/EIA/IS-95-A, May 1995.

IS-95 Forward Traffic Channel Block Interleaver (FTCBI95)



Property	Description	Units	Default	Range/Type
FDR	Frame Data Rate	Hz	9600	[1200 9600]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output Impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This model implements an IS-95 block interleaver that only supports the four traffic rates: 1200Hz, 2400Hz, 4800Hz, and 9600Hz. The first 384 symbols at each rate are interleaved according to IS-95 specifications (Reference 1).

Netlist Form

```
AFTCBI95:Name n1  n2 nexsys_component=FTCBI95 FDR=val [Rin=val]
[Rout=val]
```

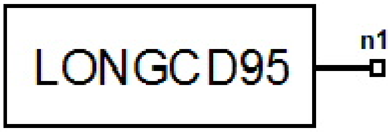
Netlist Example

```
AFTCBI95:1 1  2 nexsys_component=FTCBI95 FDR=9600Hz
```

References

1. "Mobile-Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System” TIA/EIA/IS-95-A, May 1995.

IS-95 Long Code Generator (LONGCD95)



Property	Description	Units	Default	Range/Type
NB	Number of bits	None	100	[0,INF)/Integer
BR	Output bit rate	MHz	1.2288	[0,INF)/Real
INITIAL_ CONTENT	Initial contents of the shift register in decimal	None	1	[0,INF)/Integer
File	Name of the external file with the tap connections of the shift register	None	Required	String
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Output	Output signal (real)			

Notes

1. The file name must have a .dsp extension, and must be in DSP format:

   ```
   xy

   fm1 sbn1

   ...

   fmN sbnN
   ```

   Where the first column is the frequency offset in Hz and the second column is the sideband noise in dB. For example:

   ```
   xy
   100 -80
   1000 -90
   ...
   ```

2. This model implements the IS-95 long code sequence generator.

Notes

```
ALONGCD95:Name n1 nexsys_component=LONGCD95 NB=val  BR=val
INITIAL_CONTENT=val [Rout=Val]
```

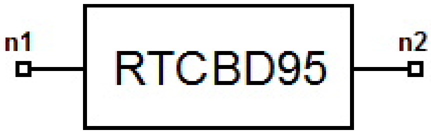
Netlist Example

```
ALONGCD95:1 1 nexsys_component=LONGCD95 NB=100  BR=1.2288MHz
INITIAL_CONTENT=97023
```

References

1. Mobile-Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System” TIA/EIA/IS-95-A, May 1995.

IS-95 Reverse Traffic Channel Block Deinterleaver (RTCBD95)



Property	**Description**	**Units**	**Default**	**Range/Type**
FDR	Frame Data Rate	Hz	9600	[1200, 9600]/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This model implements an IS-95 block de-interleaver that only supports the four traffic rates: 1200Hz, 2400Hz, 4800Hz, and 9600Hz. The data at each rate is de-interleaved according to IS-95 specifications (Reference 1).

Netlist Form

```
ARTCBD95:Name n1  n2 nexsys_component=RTCBD95 FDR=val [Rin=Val]
[Rout=Val]
```

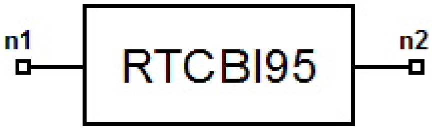
Netlist Example

```
ARTCBD95:1 1  2 nexsys_component=RTCBD95 FDR=9600Hz
```

References

1. "Mobile-Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System" TIA/EIA/IS-95-A, May 1995.

IS-95 Reverse Traffic Channel Block Interleaver (RTCBI95)



Property	Description	Units	Default	Range/Type
FDR	Frame Data Rate	Hz	9600	[1200, 9600]/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This model implement an IS-95 block interleaver that only supports the four traffic rates: 1200Hz, 2400Hz, 4800Hz, and 9600Hz. The first 576 symbols at each rate is interleaved according to IS-95 specifications (Reference 1).

Netlist Form

```
ARTCBI95:Name n1  n2 nexsys_component=RTCBI95 FDR=val [Rin=Val]
[Rout=Val]
```

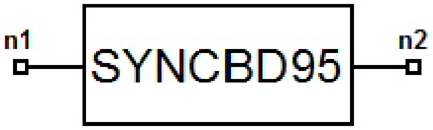
Netlist Example

```
ARTCBI95:1 1  2 nexsys_component=RTCBI95 FDR=9600Hz
```

References

1. "Mobile-Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System” TIA/EIA/IS-95-A, May 1995.

IS-95 Synchronization Channel Block Deinterleaver (SYNCBD95)



Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This model implements an IS-95 block deinterleaver for the IS-95 synchronization channel (Reference 1).

Netlist Form

```
ASYNCBD95:Name n1  n2 nexsys_component=SYNCBD95 [Rin=Val]
[Rout=Val]
```

Netlist Example

```
ASYNCBD95:1 1  2 nexsys_component=SYNCBD95
```

References

1. "Mobile-Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System” TIA/EIA/IS-95-A, May 1995.

IS-95 Synchronization Channel Block Interleaver (SYNCBI95)

Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This model implements an IS-95 block interleaver for the IS-95 synchronization channel. The first 128 symbols at a fixed rate 4800Hz are interleaved according to IS-95 specifications (Reference 1).

Netlist Form

```
ASYNCBI9:Name5  n1  n2 nexsys_component=SYNCBI95 [Rin=Val] [Rout=Val]
```

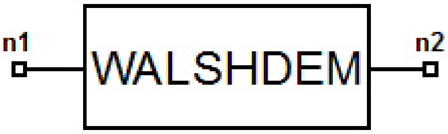
Netlist Example

```
ASYNCBI95:1 1  2 nexsys_component=SYNCBI95
```

References

1. "Mobile-Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System" TIA/EIA/IS-95-A, May 1995.

Walsh Function Demodulator (WALSHDEM)



Property	Description	Units	Default	Range/Type
N	Walsh Order	None	6	[0, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
WF_NUM	Walsh Function Number	None	0	[0,2^N-1)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

This model interprets the incoming signal as a binary signal. An input greater than 0.5V is interpreted as a 1; any other input level is interpreted as a 0. The Walsh function demodulator takes 2^N samples at a time, and correlates (XORs) them with the corresponding 2^N Walsh functions specified by **WF_NUM**. If the sum of the correlated samples is greater than $2N^2$, the output is 1; otherwise, the output is 0. The timestep of the output is 2^N times the size of the input step.

Netlist Form

```
AWALSHDEM:Name n1  n2 nexsys_component=WALSHDEM N=val
WF_NUM=val [Rin=val] [Rout=val]
```

Netlist Example

```
AWALSHDEM:1 1  2 nexsys_component=WALSHDEM N=6 WF_NUM=24
```

References

1. "Mobile-Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System” TIA/EIA/IS-95-A, May 1995.

Walsh Function Generator (WALSHGEN)

Property	Description	Units	Default	Range/Type
N	Number of bits per modulation symbol	None	6	[0, Inf)/Integer
WF_NUM	Number of the Walsh function	None	0	$[0,2^N-1)$/Real
NUM_SYMBOLS	Number of modulation symbols	None	100	[0, Inf)/Integer
BR	Bit rate at the output	MHz	1.2288	([0, Inf)/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Output	Output signal (real)			

Notes

1. This model generates **NUM_SYMBOL** modulation symbols. Each modulation symbol is composed of 2^N bits. The modulation symbol generated is based on the Walsh function (Reference 1) number **WF_NUM** which selects a modulation symbol out of 2^N modulation symbols.

Netlist Form

```
AWALSHGEN:Name n1 nexsys_component=WALSHGEN N=val  WF_NUM=val
NUM_SYMBOLS=val  BR=val [Rout=Val]
```

Netlist Example

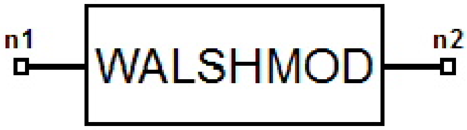
```
AWALSHGEN  1  nexsys_component=WALSHGEN N=6  WF_NUM=0
NUM_SYMBOLS=100  BR=1.2288MHZ
```

In this example, 20 samples are read on the input signal to **Output1** at n = 2 followed by 30 samples to **Output2** at n = 3 followed by 20 samples to **Output1** and so on until no more samples exist at the input port.

References

1. “Mobile-Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System” TIA/EIA/IS-95-A, May 1995.

Walsh Function Modulator (WALSHMOD)



Property	Description	Units	Default	Range/Type
N	Walsh Order	None	6	(0, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
WF_NUM	Walsh Function Number	None	0	[0,2^N-1)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

This model interprets the incoming signal as a binary signal. An input greater than 0.5V is interpreted as a 1; any other input level is interpreted as a 0. The Walsh Function Modulator divides the input sample into 2^N samples, each with the same amplitude as the input signal, but with a timestep that is reduced 2^N times. It then correlates (XORs) them with the corresponding 2^N Walsh functions specified by **WF_NUM** to produce the output.

Netlist Form

```
AWALSHMOD:Name n1  n2 nexsys_component=WALSHMOD N=val
WF_NUM=val [Rin=Val] [Rout=Val]
```

Netlist Example

```
AWALSHMOD:1 1  2 nexsys_component=WALSHMOD N=6 WF_NUM=0
```

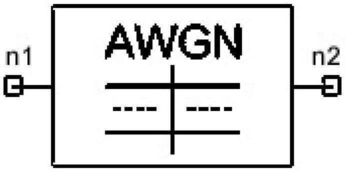
References

1. "Mobile-Station Compatibility Standard for Dual-Mode Wideband Spread Spectrum Cellular System" TIA/EIA/IS-95-A, May 1995.

Channels

This topic describes the following System components:

Additive White Gaussian Noise, Real (AWGN)



Property	Description	Units	Default	Range/Type
SNR	The average input power to average noise power ratio in dB	dB	10	[-200, 200]/Real
NSAMP	The number of samples used for signal power measurement	None	100	[1, Inf)/Integer
SEED	Random seed	None	0	[0, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This model can be used to perform a sample-by-sample addition of a real input signal and a zero mean White Gaussian noise.
2. Let the discrete input signal a $t = lT_s$ (l = 0, 1, 2, ...) be $x(l)$, where T_s is the sampling interval. And let the zero mean White Gaussian noise be n(l). The output signal can be expressed as

$$z(l) = x(l) + n(l) \tag{1}$$

3. The average power of the input signal is defined by

$$P_{in} = \frac{1}{N}\sum_{l=0}^{N-1}[x(l)]^2 \tag{2}$$

where *N* is the number of samples to calculate average power, i.e., the parameter *NSAMP* of this model. Thus, the average noise power can be given by

$$P_{noise} = \frac{P_{in}}{10^{\frac{SNR}{10}}} \qquad (3)$$

Therefore, a zero mean noise with variance P_{noise} is randomly generated and added to the input signal.

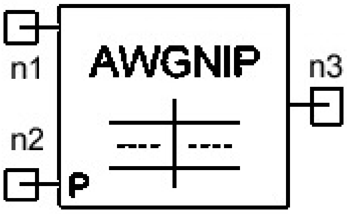
Netlist Form

```
AAWGN:NAME  n1 n2 nexsys_component=AWGN SNR=val  [NSAMP=val]
[SEED=val] [RIN=val] [ROUT=val]
```

Example

```
AAWGN:1 1 2 nexsys_component=AWGN SNR=10
```

Additive White Gaussian Noise with Average Input Power, Real (AWGNIP)



Property	Description	Units	Default	Range/Type
SNR	The average input power to average noise power ratio in dB	dB	10	[-200, 200)/Real
SEED	Random seed	None	0	[0, Inf)/Integer
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	0	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (real)			
Input2	Average input power (real)			
Output	Output signal (real)			

Notes

1. This model can be used to perform a sample-by-sample addition of a real input signal and a zero mean White Gaussian noise.
2. Let the discrete input signal at $t = lT_S$ $(l = 0,\ 1\ 2)$ be $x(l)$, where T_s is the sampling interval. And let the zero mean White Gaussian noise be $n(l)$. The output signal can be expressed as

$$z(l) = x(l) + n(l) \tag{1}$$

3. The average power of the input signal can be obtained at the second input. Define that T_p is the sample interval at this input. Assuming the current sample at the first input is x(l), use the *k*th sample at the second input port as the input power P_{in} if $kT_p \le l \cdot T_s \le (k+1) \cdot T_p$.

Thus, the average noise power can be given by

$$P_{noise} = \frac{P_{in}}{10^{\frac{SNR}{10}}} \qquad (2)$$

Therefore, a zero mean noise with variance T_{noise} is randomly generated and added to the input signal.

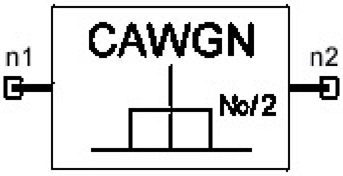
Netlist Form

```
AAWGNIP:NAME  n1 n2 n3 nexsys_component=AWGNIP SNR=val
[SEED=val] [RIN1=val] [RIN2=val]  [ROUT=val]
```

Netlist Example

```
AAWGNIP:1 1 2 3 nexsys_component=AWGNIP SNR=10
```

Additive White Gaussian Noise, Complex (CAWGN)



Property	Description	Units	Default	Range/Type
SNR	The average input power to average noise power ratio in dB	dB	10	[-200, 200]/Real
NSAMP	The number of samples used for signal power measurement	None	100	[1, Inf)/Integer
SEED	Random seed	None	0	[0, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal in complex envelope format (complex)			
Output	Output signal in complex envelope format (complex)			

Notes

1. This model can be used to perform a sample-by-sample addition of a complex input signal and a complex zero mean White Gaussian noise.
2. Let the discrete input signal at $t = lT_S$ $(l = 0, 1\ 2)$ be

   $$x(l) = x_r(l) + jx_i(l)$$

   (1)

   where T_S is the sampling interval. And let the complex zero mean White Gaussian noise be

   $$n(l) = n_r(l) + jn_i(l)$$

   (2)

   the output signal can be expressed as

$$z(l) = x(l) + n(l) = [x_r(l) + n_i(l)] + j[x_r(l) + n_i(l)] \quad (3)$$

3. The average power of the input signal is defined by

   $$P_{in} = \frac{1}{N}\sum_{l=0}^{N-1}\left\{[x_r(l)]^2 + [x_i(l)]^2\right\} \quad (4)$$

   where *N* is the number of samples to calculate average power, i.e., the parameter *NSAMP* of this model. Thus, the average noise power can be given by

   $$P_{noise} = \frac{P_{in}}{10^{\frac{SNR}{10}}} \quad (5)$$

   Therefore, a complex noise with zero mean and variance P_{noise} is randomly generated and added to the complex input signal.

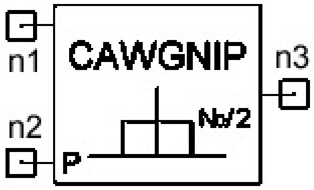
Netlist Form

```
ACAWGN:NAME  n1 n2 nexsys_component=CAWGN SNR=val  [NSAMP=val]
[SEED=val] [RIN=val] [ROUT=val]
```

Netlist Example

```
ACAWGN:1 1 2 nexsys_component=CAWGN SNR=10
```

Additive White Gaussian Noise with Average Input Power, Complex (CAWGNIP)



Property	Description	Units	Default	Range/Type
SNR	The average input power to average noise power ratio in dB	None	10	[-200, 200]/Real
SEED	Random seed	None	0	[0, Inf)/Integer
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input signal in complex envelope format (complex)			
Input2	Average input power (real)			
Output	Output signal in complex envelope format (complex)			

Notes

1. This model can be used to perform a sample-by-sample addition of a complex input signal and a complex zero mean White Gaussian noise.
2. Let the discrete input signal at

   $$t = lT_s \ (l = 0, 1, 2, \ldots)$$

   be

   $$x(l) = x_r(l) + jx_i(l)$$

   (1)

   where T_s is the sampling interval. And let the complex zero mean White Gaussian noise be

$$n(l) = n_r(l) + jn_i(l)$$

(2)

the output signal can be expressed as

$$z(l) = x(l) + n(l) = \left[x_r(l) + n_i(l)\right] + j\left[x_r(l) + n_i(l)\right]$$

(3)

3. The average power of the input signal can be obtained at the second input. Define T_s to be the sample interval at this input. Assume the current sample at the first input is x(l), use the *k*th sample at the second input port as the input power P_{in} if $kT_s \le lT_s \le (k+1)T_s$. Thus, the average power of the noise can be given by

   $$P_{noise} = \frac{P_{in}}{10^{\frac{SNR}{10}}}$$

   (4)

   Therefore, a complex noise with zero mean and variance P_{noise} is randomly generated and added to the input signal.

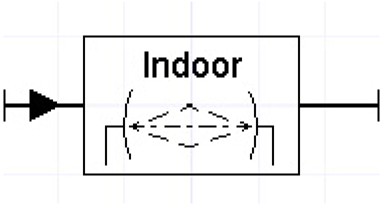
Netlist Form

```
ACAWGNIP:NAME  n1 n2 n3 nexsys_component=CAWGNIP SNR=val
[SEED=val] [RIN1=val] [RIN2=val]  [ROUT=val]
```

Netlist Example

```
ACAWGNIP:1 1 2 3 nexsys_component=CAWGNIP SNR=10
```

Indoor Channel (INDOORCH)



Property	Description	Units	Default	Range/Type
Delay_spread	Delay spread	Sec	0.0	[0, Inf]/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal in complex envelope format (complex)			
Output	Multipath nonfading signal in complex envelope format (complex)			

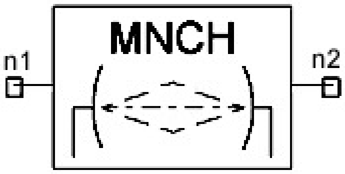
Netlist Form

```
AINDOORCH:NAME  n1 n2  Nexsys_component=indoorch
Delay_spread=val [RIN=val] [ROUT=val]
```

Netlist Example

```
AINDOORCH:2 net1 net2  Nexsys_component=indoorch
+ Delay_spread=1e-4
```

Multipath Channel, Constant Gains and Integer Delays (MNCH)



Property	Description	Units	Default	Range/Type
L	Number of paths	None	3	[1, 12]/Integer
D1	Delay of first path (samples)	None	0	[0, Inf)/Integer
Gain1	Magnitude of the compex gain factor for first path	None	1	[0, Inf)/Real
Phase1	Phase of the complex gain factor for the first path	Degree	0	[-180, 180]/Real
D2 ~ D12	Multipath delays of all other paths (samples)	None	0	[0, Inf)/Integer
Gain2 ~ Gain12	Magnitude of the complex gain factor of all other paths, in dB	None	0	[0, Inf)/Real
Phase2 ~ Phase12	Phase of the complex gain factor of all other paths	Degree	0	[-180, 180)/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal in complex envelope format (complex)			
Output	Multipath nonfading signal in complex envelope format (complex)			

Notes

1. This model can be used to simulate a Multipath Nonfading Channel with Integer Delays in samples.
2. Representing the RF channel as a time-variant channel and using a base-band complex envelope representation, the channel gain factor is specified by:

$$h(t) = \sum_{i=0}^{L-1} Gain_i e^{jPhase_i} \delta(t - \tau_i) \quad (1 \le L \le 12) \tag{1}$$

where *L* is the number of paths, $Gain_i$ and $Phase_i$ are magnitude and phase of the complex gain for the *i*th path, τ_i >= 0 is the channel delay which can be expressed by D_i samples.

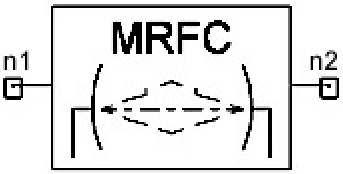
Netlist Form

```
AMNCH:NAME  n1 n2 nexsys_component=MNCH L=val D1=val  Gain1=val
Phase1=val [D2=val . . . Phase12=val] +[RIN=val] [ROUT=val]
```

Netlist Example

```
AMNCH:1 1 2 nexsys_component=MNCH L=2 D1=0  Gain1=1.0
Phase1=0DEG D2=2 Gain1=0.2 Phase1=30DEG
```

Multipath Rayleigh Fading Channel (MRFC)



Property	Description	Units	Default	Range/Type
FD	Doppler frequency	Hz	1	(0, Inf)/Real
SEED	Random seed	None	0	[0, Inf)/Integer
T1	Delay of first path in seconds	Sec	0	[0, Inf)/Real
RP1	Relative power of first path in dB	None	-1e+020	(-Inf, 0]/Real
T2, ..., T12	Delay of all other paths in seconds (optional)	Sec	0	[0, Inf)/Real
RP2, ..., RP12	Relative power of all other paths in dB	None	-1e+020	(-Inf, 0]/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Unfaded input signal (complex)			
Output	Faded output signal (complex)			

Notes

1. This model can be used to simulate a Multipath Rayleigh Fading Channel.
2. In general, let the input signal be given by

   $$V_{in}(t) = A(t)\cos\left(2\pi f_c t + \theta(t)\right)$$

   (1)

   Physically speaking, multipath fading implies that several delayed replicas or “images” of the above input (transmitted) signal is received with each image having a different level of attenuation.

   Mathematically, the output signal V_{out} is given by (assuming all 12 path delays and relative powers are specified)

$$V_{out}(t) = \sum_{i=1}^{N} \alpha_i(t)\, A(t - T_i) \cos\left(2\pi f_c (t - T_i) + \theta(t - T_i)\right) \qquad 1 \le N \le 12$$

(2)

where T_i is the delay along the *i*th path and $\alpha_i(t)$ is the attenuation (fading) along the *i*th path. The attenuation process $\alpha_i(t)$ *1 ≤ i ≤ 12* is a time varying random process and Rayleigh distributed. The average value of the power loss, i.e., $E\{\alpha^2_i(t)\}$ along the *i*th path is related to the relative power RP*i* along this path by the equation

$$\mathrm{RP}i = \frac{\mathrm{E}\left\{\alpha_i^2(t)\right\}}{\text{Reference Power Loss}}$$

(3)

If the reference power loss is assumed to be 0dB, then

$$\mathrm{RP}i = \mathrm{E}\left\{\alpha_i^2(t)\right\}$$

In addition, this model always ensures that the combined power loss (along all the specified fading paths) is normalized to unity, i.e.,

$$\sum_{i=1}^{N} \mathrm{RP}i = 1, \qquad 1 \le N \le 12$$

(4)

3. The remaining discussion focuses on how each of the random attenuation processes $a_i(t)$ is generated.

   Two correlated Gaussian noise processes are generated for each fading path (in-phase and quadrature) by filtering a White Guassian noise process through a filter which has the following frequency response:

   where *FD* is the Doppler frequency and is related to the receiver's speed V_r by the equation:
   $V_r = FD \times \lambda$, where λ is the wavelength of the carrier frequency (f_c), and is given by $\lambda = c/f_c$, where *c* is the speed of light (3 x 10^8 m/s).

   The frequency spectrum of the fading process is *S(f) = H(f) H*(f)*. This frequency response is generated in the FFT domain using *FFTL = 2048* points. Each FFT point (*0, j ≤ 1 ≤ FFTL - 1*) corresponds to a certain frequency (Freq) by means of the following equation:

$$f = j \cdot f_s$$

(6)

where $f_s$is the frequency sampling interval typically chosen to be on the order of *FD/10*. The above frequency response has an even real part and an odd imaginary part to guarantee that the filtering process yields a real in-phase and quadrature correlated Gaussian processes. Each two generated Gaussian processes are combined to yield a Rayleigh fading process. It is important to point out that each generated in-phase and quadrature process is correlated but the two processes are generated independently and therefore, uncorrelated.

Each generated Rayleigh fading process corresponds to a path with a user-specified delay and relative power ($T_i$and RP*i*, $1 \le i \le 12$). The expected output along the *i*th fading path should be the input signal delayed by T_i seconds and Rayleigh-faded in accordance (and on average) with the specified ith relative power, RP*i*. The total average power contribution from all paths is always normalized to unity. This is accomplished by setting the standard deviation of the *i*th generated in-phase and quadrature correlated Gaussian processes to

$$\sigma_i = \sqrt{(\mathrm{RP}\ i)}\ \sigma$$

, $1 \le \ i \le 12$ (7)

where

$$\sigma = 1 \Big/ \sqrt{2\left(\mathrm{RP1} + \mathrm{RP2} + \ldots.. + \mathrm{RP12}\right)}$$

The resolution of the generated fading process is further increased in the time domain to match the sampling rate of the input signal. This is accomplished by linearly interpolating the fading process (i.e., inserting fading points between each two originally generated fading points.).

$$H(f) = \begin{cases} \dfrac{1}{\sqrt[4]{1 - \left(\dfrac{f}{\mathrm{FD}}\right)^2}} & |f| < \mathrm{FD} \\ 0 & ? \end{cases}$$

Netlist Form

```
AMRFC:NAME  n1 n2 nexsys_component=MRFC FD=val  [SEED=val]
T1=val  RP1=val [T2=val . . . RP12=val] [RIN=val] [ROUT=val]
```

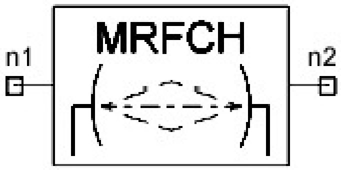
Netlist Example

```
AMRFC:1 1 2 nexsys_component=MRFC FD=50Hz  SEED=48568  T1=0S
RP1=0 T2=5US RP2=-2.0
```

References

1. W. C. Jakes, *Microwave Mobile Communications*, New York: Wiley, 1974.
2. T. S. Rappaport, *Wireless Communications: Principles and Practice*, Prentice-Hall, 1996.
3. W Raymond Steele, *Mobile Radio Communications*, Pentech Press, 1992.
4. J. I. Smith, "A computer generated multipath fading simulation for mobile radio," *IEEE Trans. Vehic Technol.*, vol. VT-24, no. 3, pp. 39-40, Aug. 1975.

Multipath Rayleigh Fading Channel, Integer Delays (MRFCH)



Property	Description	Units	Default	Range/Type
L	Number of Paths	None	3	[1, 12]/Integer
VM	Mobile velocity real in km/hour	None	12	(0, Inf)/Integer
SEED	Random seed	None	0	[0, Inf)/Integer
D1	Delay of first path (samples)	None	0	[0, Inf)/Integer
P1	Relative of first path in dB	None	-1e+020	(-Inf, 0]/Real
D2, ..., D12	Delays of all other paths (samples)	None	0	[0, Inf)/Integer
P2, ..., P12	Relative power of all other paths in dB	None	-1e +020	(-Inf, 0]/Real
RIN	Output impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal in complex envelope format (complex)			
Output	Multipath Rayleigh fading signal in complex envelope format (complex)			

Notes

1. This model can be used to simulate a Multipath Rayleigh Fading Channel with Integer Delays in samples.
2. The Doppler power spectrum for Multipath Rayleigh Fading Channel is given by [1][2]:

$$S_{E_z}(f) = \begin{cases} \frac{3b}{\omega_m}\left[1-\left(\frac{f-f_c}{f_m}\right)^2\right]^{-1/2} & |f-f_c|<f_m \\ 0 & \end{cases}$$

(1)

where *b* is the average received power, $f_m = \omega_m/2\pi$ is the maximum Doppler shift given by $V_m/2\lambda$ where V_m is mobile velocity and λ is the wavelength of the transmitted signal at frequency f_c.

3. Representing the RF channel as a time-variant channel and using a base-band complex envelope representation, the channel impulse response can be expressed as

$$h(t) = \sum_{i=0}^{L-1} \alpha_i(t) e^{j\varphi_i(t)} \delta(t-\tau_i) \quad (1 \le L \le 12)$$

(2)

where *L* is the number of paths, the amplitude $\alpha_i(t)$ for the *i*th path is a Rayleigh distributed random variable, the phase shift ϕ_i is uniformly distributed, τ_i > = 0 is the channel delay. Since the Rayleigh fading processes $\alpha_i(t) \exp[(j\phi_i(t)]$ is complex, the in-phase process and quadrature process for each path are implemented separately, as shown in Fig.1.

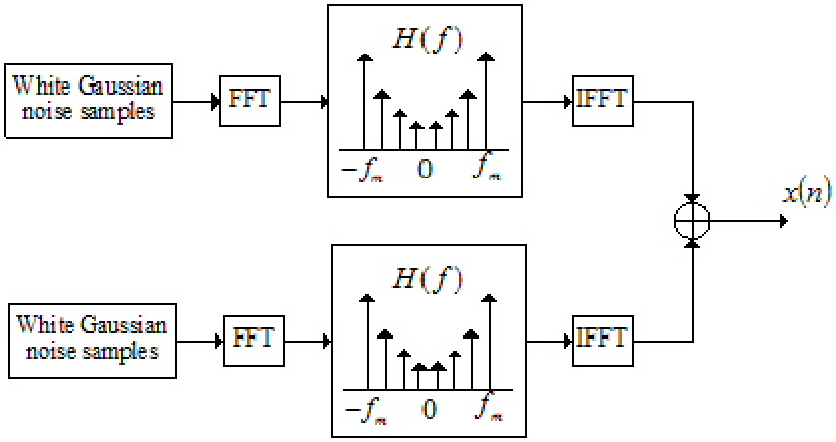


Fig. 1 Block diagram of Rayleigh fading simulator

Based on Eqn.(2), both the in-phase process and the quadrature process can be generated by passing a White Gaussian noise process through a baseband filter which has the following frequency response:

$$H(f) = \begin{cases} K\left[1-\left(\frac{f}{f_m}\right)^2\right]^{-1/4} & |f| < f_m \\ 0 & others \end{cases}$$

(3)

where *K*is constant to normalize the frequency response. The above frequency response is generated in the frequency domain using FFT with *length = 2048* points. Each point ($0 \le k \le length-1$) corresponds to a certain frequency (f_k) by means of the following equation:

$$f_k = k \times f_s$$

(4)

where f_s is the frequency sampling interval typically chosen to be on the order of $f_m/10$.

The above frequency response has an even real part and an odd imaginary part to guarantee that the filtering process generates a real in-phase and quadrature correlated Gaussian processes. Each two generated Gaussian processes are combined to generate a Rayleigh fading process. It is important to point out that whether in-phase process or quadrature process is correlated among different points but the two processes are generated independently and therefore, uncorrelated.

4. Assume that channel delay for each path can be expressed by D_i samples. Each generated Rayleigh fading process corresponds to a path with a user-specified delay D_i and relative
power P_i, ($0 \le i \le L-1$). The expected output along the *i*th fading path should be the input signal delayed by D_i samples and Rayleigh-faded with the specified *i*th relative power P_i. The total average power contribution from all paths is always normalized to unity. This is accomplished by setting the standard deviation of the *i*th generated in-phase and quadrature correlated Gaussian processes to

$$\sigma_i = \sqrt{\frac{P_i}{2\sum_{i=0}^{L-1} P_i}}$$

(5)

These time series of the generated fading process is further increased in the time domain to match the sampling rate of the input signal. This is accomplished by linearly interpolating the fading process (i.e., inserting fading points between each two originally generated fading points).

Netlist Form

```
AMRFCH:NAME  n1 n2 nexsys_component=MRFCH L=val VM=val
[SEED=val]  D1=val  P1=val  [D2=val . . . P12=val] [RIN=val]
[ROUT=val]
```

Netlist Example

```
AMRFCH:1 1 2 nexsys_component=MRFCH L=2 D1=0  P1=0 D2=2 P2=-2.0
```

References

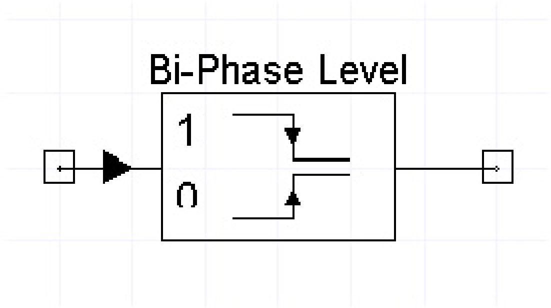
1. W. C. Jakes, *Microwave Mobile Communications*, New York: Wiley, 1974.
2. T. S. Rappaport, *Wireless Communications: Principles and Practice*, Prentice-Hall, 1996.

Coders/Decoders

This topic describes the following System components:

"Viterbi Decoder with Packet Transmission (VDECPT)" on page 38-103

Biphase Level Coding Model (BIPHL)



Property	Description	Units	Default	Range/Type
Level	Output signal amplitude	Volt	1.0	[0, INF]/Real
N	Oversampling factor	None	1	[1, INF]/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	(0, Inf]/Real
Ports				
Input	Input sequence (real)			
Output	Output sequence (real)			

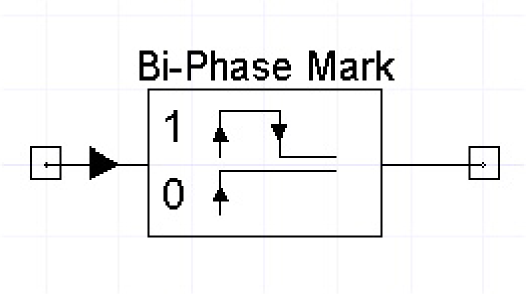
Netlist Form

```
ABI_PH_L:NAME  n1 n2  Nexsys_component=bi_ph_l Level=val N=val
[RIN=val] [ROUT=val]
```

Netlist Example

```
ABI_PH_L:1 1 2 Nexsys_component=bi_ph_l Level=2.2 N=2
```

Biphase Level Coding Model (BIPHM)



Property	Description	Units	Default	Range/Type
Level	Output signal amplitude	Volt	1.0	[0, INF]/Real
N	Oversampling factor	None	1	[1, INF]/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	(0, Inf]/Real
Ports				
Input	Input sequence (real)			
Output	Output sequence (real)			

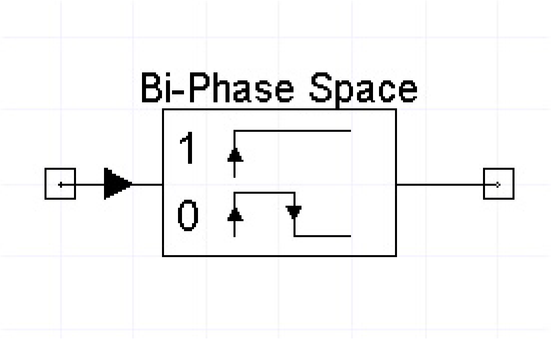
Netlist Form

```
ABI_PH_M:NAME  n1 n2  Nexsys_component=bi_ph_m Level=val N=val
[RIN=val] [ROUT=val]
```

Netlist Example

```
ABI_PH_M:1 1 2 Nexsys_component=bi_ph_m Level=2.2 N=2
```

Biphase Space Coding Model (BIPHS)



Property	Description	Units	Default	Range/Type
Level	Output signal amplitude	Volt	1.0	[0, INF]/Real
N	Oversampling factor	None	1	[1, INF]/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	(0, Inf]/Real
Ports				
Input	Input sequence (real)			
Output	Output sequence (real)			

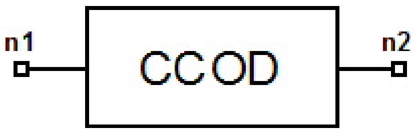
Netlist Form

```
ABI_PH_S:NAME  n1 n2  Nexsys_component=bi_ph_s Level=val N=val
[RIN=val] [ROUT=val]
```

Netlist Example

```
ABI_PH_S:1 1 2 Nexsys_component=bi_ph_s Level=2.2 N=2
```

Convolutional Coder (CCOD)



Property	Description	Units	Default	Range/Type
N	Number of bits to generate at the output for each K input bits	None	2	[1, 8]/Integer
K	Number of input bits to be shifted into shift register at each step.	None	1	[1, 8]/Integer
L	Constraint length of convolutional coder	None	5	[2, Inf)/Integer
T	True output value	None	1	(-Inf, Inf)/Real
F	False output value	None	0	(-Inf, Inf)/Real
G1, G2 , ..., G8	Generators of convolutional coder (specified in decimal)	None	0	[0, Inf)/Integer
RIN	Input impedance	Ohm	0	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Binary input sequence (integer)			
Output	Convolutionally coded binary sequence (real)			

Limits

$0 < K \times L \leq 32$

Notes

1. This model takes a binary input sequence and outputs a convolutionally encoded binary sequence according to the specified parameters of the model. In this model, every *K* input bits are encoded into *N* output bits. The length of the shift register in this convolutional

coder is
K x L, where *L* is the constraint length. Therefore, a convolutional coder is always denoted as *CCOD*(*N*, *K*, *L*). The rate of the convolutional coder is given by the ratio *K/N*.

2. The *N* ($N \leq 8$) output bits which are generated from each *K* input bits are determined by a set of binary generators $G_1, G_2, \ldots G_N$ (specified in a decimal value).
3. G_1 is used to generate the first bit of the *N* bits, G_2 is used to generate the second bit of the *N* bits and so on. The binary representation of each generator is the same length as the shift register, *K x L*.
4. For each *K* input bits, the contents of the *K x L* shift register are shifted by *K* bits to the right and new *N* bits are generated. The initial content of the shift register is always assumed to be *K x L* binary zeros
5. The ratio of the output bit rate to the input bit rate is given by *N/K*.

Netlist Form

```
ACCOD:NAME  n1 n2 nexsys_component=CCOD N=val K=val L=val
[T=val] [F=val] [G1...N=val] [RIN=val] [ROUT=val]
```

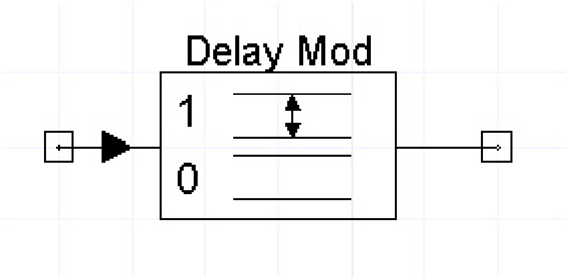
Netlist Example

```
ACCOD:1 1 2 nexsys_component=CCOD N=2  K=1  L=7  G1=91  G2=121
```

References

1. J. G. Proakis, Digital Communications, McGraw-Hill, 2001.

Delay Modulation (Miller Coding) Model (DLYMOD)



Property	Description	Units	Default	Range/Type
Level	Output signal amplitude	Volt	1.0	[0, INF]/Real
N	Oversampling factor	None	1	[1, INF]/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	(0, Inf]/Real
Ports				
Input	Input sequence (real)			
Output	Output sequence (real)			

Notes

For Delay modulation (Miller Coding), a high input value is represented by a transition at the midpoint of the bit interval. A low input value maintains the state value, unless two low input values occur in a row. When this happens, a transition occurs at the end of the bit interval.

In	**1**		**0**		**1**		**1**		**1**		**0**		**0**		**1**	
Out	**0**	**1**	**1**	**1**	**1**	**0**	**0**	**1**	**1**	**0**	**0**	**0**	**1**	**1**	**1**	**0**

Netlist Form

```
ADLYMOD:NAME  n1 n2  Nexsys_component=dly_mod Level=val N=val
[RIN=val] [ROUT=val]
```

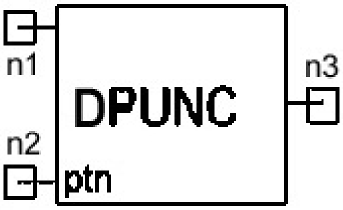
Netlist Example

```
ADLYMOD:1 1 2 Nexsys_component=dly_mod Level=2.2 N=2
```

Reference

[1] Bernard Sklar, *Digital Communications Fundamental and Applications*, Prentice-Hall 1988

Depuncturer (DPUNC)



Property	Description	Units	Default	Range/Type
N	Puncturing period	None	4	[1, Inf)/Integer
RIN1	Input impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	output Impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Received signal before depuncturing (real)			
Input2	Puncturing pattern (integer)			
Output	The signal after depuncturing (real)			

Notes

1. This model can be used to perform the inverse procedure of “Puncturing”. Depuncturing is done by inserting dummy bits into the locations that are punctured at the output of convolutional encoder. The value of dummy bits is set to “zero” in this model. Please refer to the Puncturer model for details.

Netlist Form

```
ADPUNC:NAME  n1 n2 n3 nexsys_component=DPUNC N=val [RIN1=val]
[RIN2=val] [ROUT=val]
```

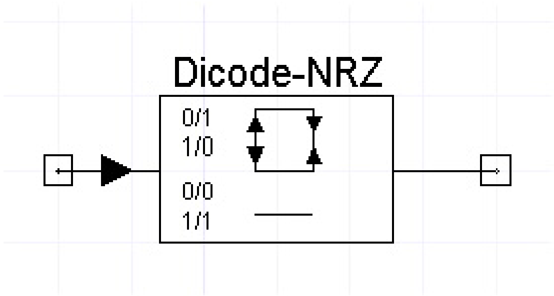
Netlist Example

```
ADPUNC:1 1 2 3 nexsys_component=DPUNC N=6
```

References

1. J. G. Proakis, *Digital Communications*, McGraw-Hill, 2001.

Dicode NRZ Formatting Model (DICNRZ)



Property	Description	Units	Default	Range/Type
Level	Output signal amplitude	Volt	1.0	[0, INF]/Real
N	Oversampling factor	None	1	[1, INF]/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	(0, Inf]/Real
Ports				
Input	Input sequence (real)			
Output	Output sequence (real)			

Notes

For Dicode NRZ, a change in input state (0->1 or 1->0) produces a bit wide pulse of opposite polarity on the prior pulse transmitted.

For no state change at the input (0->0 or 1->1), a bit wide zero voltage is transmitted. Initial reference pulse is equal (**-level**) with 0 previous input.

In	1	0	1	1	1	0	0	1	0	0	0	1	1	0	1	0
Out	+1	-1	+1	0	0	-1	0	+1	-1	0	0	+1	0	-1	+1	-1

Netlist Form

```
ADIC_NRZ:NAME  n1 n2  Nexsys_component=dic_nrz Level=val N=val
[RIN=val] [ROUT=val]
```

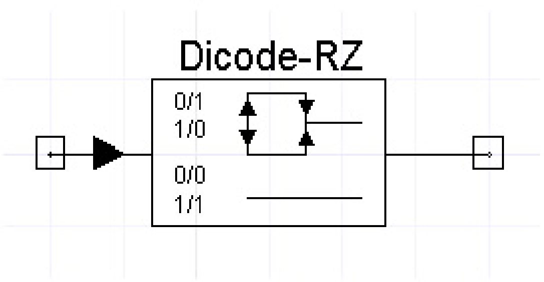
Netlist Example

```
ADIC_NRZ:1 1 2 Nexsys_component=dic_nrz Level=2.2 N=2
```

Reference

[1] Bernard Sklar, *Digital Communications Fundamental and Applications*, Prentice-Hall 1988

Dicode RZ Formatting Model (DICRZ)



Property	Description	Units	Default	Range/Type
Level	Output signal amplitude	Volt	1.0	[0, INF]/Real
N	Oversampling factor	None	1	[1, INF]/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	(0, Inf]/Real
Ports				
Input	Input sequence (real)			
Output	Output sequence (real)			

Notes

For Dicode RZ, a change in input state (0->1 or 1->0) produces a half bit wide pulse of opposite polarity on the prior pulse transmitted. A half bit wide zero is transmitted to fill the bit wide time interval.

For no state change at the input (0->0 or 1->1), a bit wide zero voltage is transmitted. Initial reference pulse is equal (**-level**) with 0 previous input.

In	**1**		**0**		**1**		**1**		**1**		**0**		**0**		**1**	
Out	**+1**	**0**	**-1**	**0**	**+1**	**0**	**0**	**0**	**0**	**0**	**-1**	**0**	**0**	**0**	**+1**	**0**

Netlist Form

```
ADIC_RZ:NAME  n1 n2  Nexsys_component=dic_rz Level=val N=val
[RIN=val] [ROUT=val]
```

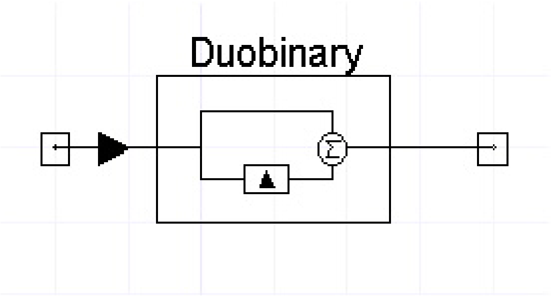
Netlist Example

```
ADIC_RZ:1 1 2 Nexsys_component=dic_rz Level=2.2 N=2
```

Reference

[1] Bernard Sklar, *Digital Communications Fundamental and Applications*, Prentice-Hall 1988

Duobinary Coding Model (DUOBIN)



Property	Description	Units	Default	Range/Type
Offset	Voltage shift of output level	Volt	0.0	[-INF, INF]/Real
Level	Output signal amplitude	Volt	1.0	[0, INF]/Real
N	Oversampling factor	None	1	[1, INF]/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	(0, Inf]/Real
Ports				
Input	Input sequence (real)			
Output	Output sequence (real)			

Notes

For **Duobinary Coding** (**partial response signaling, correlative coding**), the input passes through a digital filter comprised of a one sample delay. Each binary input is represented by –1 for a low input value and +1 for a high input value. The output is equal to the sum of the delayed symbol and the input symbol, which produces three possible values of –2, 0, and +2. The initial delayed input value is low (-1).

For decoding purposes, a change in states is represented by 0. Maintaining states produces –2 at the output for a low and +2 at the output for a high.

Input		**1**	**0**	**1**	**1**	**1**	**0**	**0**	**1**
Bipolar	**-1**	**+1**	**-1**	**+1**	**+1**	**+1**	**-1**	**-1**	**+1**

Output		**0**	**0**	**0**	**+2**	**+2**	**0**	**-2**	**0**

Netlist Form

```
ADUOBIN:NAME  n1 n2  Nexsys_component=duobin Offset=val
Level=val N=val [RIN=val] [ROUT=val]
```

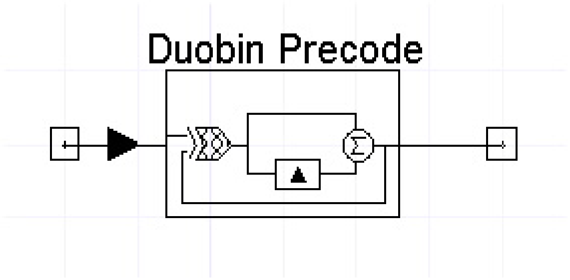
Netlist Example

```
ADUOBIN:1 1 2 Nexsys_component=duobin Offset=1.1 Level=2.2 N=2
```

Reference

[1] Bernard Sklar, *Digital Communications Fundamental and Applications*, Prentice-Hall 1988

Duobinary With Precode Coding Model (DUOBINP)



Property	Description	Units	Default	Range/Type
Offset	Voltage shift of output level	Volt	0.0	[-INF, INF]/Real
Level	Output signal amplitude	Volt	1.0	[0, INF]/Real
N	Oversampling factor	None	1	[1, INF]/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	(0, Inf]/Real
Ports				
Input	Input sequence (real)			
Output	Output sequence (real)			

Notes

For **Duobinary with Pre-coding**, the input is exclusive-ORed with a previous value of the the exclusive-OR output. This value passes through a digital filter comprised of a one sample delay. Each binary value is represented by –1 for a low input value and +1 for a high input value. The output is equal to the sum of the delayed exclusive-OR symbol and the input exclusive-OR symbol, which produces three possible values of –2, 0, and +2. The initial delayed input value is low.

For decoding purposes, no memory is needed. A 0 represents a high input value. Any non-zero value represents a low input value.

Input		1	0	1	1	1	0	0	1

Precode	**0**	**1**	**1**	**0**	**1**	**0**	**0**	**0**	**1**
Bipolar	**-1**	**+1**	**+1**	**-1**	**+1**	**-1**	**-1**	**-1**	**+1**
Output		**0**	**+2**	**0**	**0**	**0**	**-2**	**-2**	**0**

Netlist Form

```
ADUOBIN_P:NAME  n1 n2  Nexsys_component=duobin_p Offset=val
Level=val N=val [RIN=val] [ROUT=val]
```

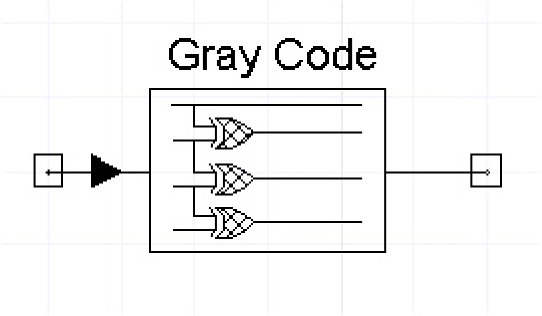
Netlist Example

```
ADUOBIN_P:1 1 2 Nexsys_component=duobin_p
+ Offset=1.1 Level=2.2 N=2
```

Reference

[1] Bernard Sklar, *Digital Communications Fundamental and Applications*, Prentice-Hall 1988

Gray Coder (GRAYCOD)



Property	Description	Units	Default	Range/Type
BITS	Bits per Gray code symbol	None	2	(2, INF]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	(0, Inf]/Real
Ports				
Input	Input sequence (real)			
Output	Output sequence (real)			

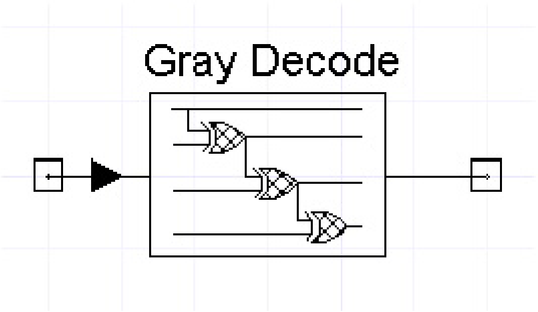
Netlist Form

```
AGRAYCOD:NAME  n1 n2  Nexsys_component=graycod Bits=val
[RIN=val] [ROUT=val]
```

Netlist Example

```
AGRAYCOD:1 1 2 Nexsys_component=graycod Bits=4
```

Gray Decoder (GRAYDEC)



Property	Description	Units	Default	Range/Type
BITS	Bits per Gray code symbol	None	2	(2, INF]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	(0, Inf]/Real
Ports				
Input	Input sequence (real)			
Output	Output sequence (real)			

Netlist Form

AGRAYDEC:NAME n1 n2 Nexsys_component=graydec Bits=*val*
[RIN=*val*] [ROUT=*val*]

Netlist Example

```
AGRAYDEC:1 1 2 Nexsys_component=graydec Bits=4
```

Interleaving Pattern Generator (INTLVPTN)

Property	Description	Units	Default	Range/Type
TYPE	Prime number interleaver {0} 3GPP FDD Turbo code interleaver {1}	None	0	[0, 1]/Integer
K	Interleaving period	None	65536	[2, Inf)/Integer
P	Prime number, only for TYPE= 0	None	257	[1, Inf)/Integer
SAMPLE_ RATE	Output sample rate in Hz	Hz	1000	[1, Inf)/Integer
ROUT	output Impedance	Ohm	0	(0, Inf)/Real
Ports				
Output	Prime number interleaving pattern sequence (integer)			

Notes

1. This model can be used to generate interleaving pattern sequence with the length of *K*.
2. Denote by *i* the index of the input sequence before interleaving and *f(i)* is the index of output sequence after interleaving, the interleaving pattern sequence is expressed as, *f (0)*, *f(1)*, *f(K-1)* .
3. The **prime number interleaver** is defined by the rule

$$f(i) = (P \times i) \bmod (K) \quad 0 \le i \le K - 1$$

   where *P* is a prime number, *K* is the interleaving period.
4. The **3GPP FDD Turbo code internal interleaver** The Turbo code internal interleaver consists of bits-input to a rectangular matrix with padding, intra-row and inter-row

permutations of the rectangular matrix, and bits-output on the rectangular matrix with pruning. The bits input to the Turbo code internal interleaver are denoted by $x_1, x_2, x_3, ..., x_K$ where *K* is the integer number of the bits and takes one value of $40 \leq K \leq 5114$. The relation between the bits input to the Turbo code internal interleaver and the bits input to the channel coding is defined by and $K = K_i$

Bits-input to rectangular matrix with padding

The bit sequence $x_1, x_2, x_3, ..., x_K$ input to the Turbo code internal interleaver is written into the rectangular matrix as follows.

[4.A.] Determine the number of rows of the rectangular matrix, *R*, such that:

$$R = \begin{cases} 5, \text{ if } (40 \leq K \leq 159) \\ 10, \text{ if } ((160 \leq K \leq 200) \text{ or } (481 \leq K \leq 530)) \\ 20, \text{ if } (K = \text{any other value}) \end{cases}$$

The rows of rectangular matrix are numbered 0, 1, …, *R* - 1 from top to bottom.

[4.B.] Determine the prime number to be used in the intra-permutation, *p*, and the number of columns of rectangular matrix, *C*, such that:

If $(481 \leq K \leq 530)$ then $p = 53$ and $C = p$.
else
Find minimum prime number *p* from Table 1 such that $K \leq R \times (p+1)$
and determine *C* such that:

$$C = \begin{cases} p-1 & \text{if } K \leq R \times (p-1) \\ p & \text{if } R \times (p-1) < K \leq R \times p \\ p+1 & \text{if } R \times p < K \end{cases}$$

The columns of rectangular matrix are numbered 0, 1, …, *C* - 1 from left to right.

Table 1: List of prime number *p* and associated primitive root*v*:

p	v	p	v	p	v	p	v	p	v
7	3	47	5	101	2	157	5	223	3
11	2	53	2	103	5	163	2	227	2

13	2	59	2	107	2	167	5	229	6
17	3	61	2	109	6	173	2	233	3
19	2	67	2	113	3	179	2	239	7
23	5	71	7	127	3	181	2	241	7
29	2	73	5	131	2	191	19	251	6
31	3	79	3	137	3	193	5	257	3
37	2	83	2	139	2	197	2		
41	6	89	3	149	2	199	3		
43	3	97	5	151	6	211	2		

[4.C.]Write the input bit sequence $x_1, x_2, x_3, ..., x_K$ into the *R* X *C* rectangular matrix row by row starting with bit y_1 in column 0 of row 0:

$$\begin{bmatrix} y_1 & y_2 & y_3 & \cdots\ y_C \\ y_{(C+1)} & y_{(C+2)} & y_{(C+3)} & \cdots\ y_{2C} \\ \vdots & \vdots & \vdots & \cdots\ \vdots \\ y_{((R-1)C+1)} & y_{((R-1)C+2)} & y_{((R-1)C+3)} & \cdots\ y_{R\times C} \end{bmatrix}$$

where $y_k = x_k$ for $k = 1, 2, \ldots, K$ and if $R X C > K$, the dummy bits are padded such that $y_k = 0$ *or 1*for $k = K + 1, K + 2, \ldots, R X C$. These dummy bits are pruned away on the output of the rectangular matrix after intra-row and inter-row permutations.

Intra-row and inter-row permutations

After the bits-input to the *R X C* rectangular matrix, the intra-row and inter-row permutations for the *R X C* rectangular matrix are performed stepwise by using the following algorithm with steps (1) – (6):

[1] Select a primitive root *v* from Table 1, which is indicated on the right side of the prime number *p*.

[2]Construct the base sequence $\langle s(j)\rangle_{j\varepsilon\{0, 1, ..., p-2\}}$ for intra-row permutation as:
$s(j) = (v \times s(j-1)) \bmod p$, $j = 1, 2, \ldots, (p - 2)$, and $s(0) = 1$.

[3] Assign $q_0 = 1$ to be the first prime integer in the sequence $\langle q_i\rangle_{i\varepsilon\{0, 1, ..., R-1\}}$, and determine the prime integer q_i in the sequence $\langle q_i\rangle_{\iota\varepsilon\{0, 1, ..., R-1\}}$ to be a least prime integer such that g.c.d $(q_i, p - 1) = 1, q_i > 6$, and $q_i > q_{(i - 1)}$ for each $i = 1, 2, \ldots, R – 1$. Here g.c.d. is greatest common

divisor.

[4] Permute the sequence $<q_i>_{i\varepsilon\{0, 1, \ldots, R-1}$ to make the sequence $<r_i>_{i\varepsilon\{0, 1, \ldots, R-1\}}$ such that $r_{T(i)} = q_i$, $i = 0, 1, \ldots, R - 1$, where $\langle T(i) \rangle_{i \in \{0, 1, \ldots, R-1\}}$ is the inter-row permutation pattern defined as the one of the four kind of patterns, which are shown in Table 2, depending on the number of input bits K.

Table 2: Inter-row permutation patterns for Turbo code internal interleaver

Number of input bits **K**	**Number of rows** **R**	**Inter-row permutation patterns** **<*T*(0), *T*(1), …, *T*(*R* - 1)>**
($40 \le K \le 159$)	5	<4, 3, 2, 1, 0>
($160 \le K \le 200$) or ($481 \le K \le 530$)	10	<9, 8, 7, 6, 5, 4, 3, 2, 1, 0>
($2281 \le K \le 2480$) or ($3161 \le K \le 3210$)	20	<19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 16, 13, 17, 15, 3, 1, 6, 11, 8, 10>
K = any other value	20	<19, 9, 14, 4, 0, 2, 5, 7, 12, 18, 10, 8, 13, 17, 3, 1, 16, 6, 15, 11>

[5] Complete the i-th ($i = 0, 1, \ldots, R - 1$) intra-row permutation as:

If ($C = p$) then
$U_i(j) = s((j \times r_i) \bmod (p-1))$, $j = 0, 1, \ldots, (p - 2)$, and $U_i(p - 1) = 0$,
where $U_i(j)$ is the original bit position of j-th permuted bit of i-th row.

if ($C = p + 1$) then
$U_i(j) = s((j \times r_i) \bmod (p-1))$, $j = 0, 1, \ldots, (p - 2)$. $U_i(p - 1) = 0$, and $U_i(p) = p$,
where $U_i(j)$ is the original bit position of j-th permuted bit of i-th row,
and if ($K = R \times C$) then exchange $U_{R-1}(p)$ with $U_{R-1}(0)$.

If ($C = p - 1$) then
$U_i(j) = s((j \times r_i) \bmod (p-1)) - 1$, $j = 0, 1, \ldots, (p - 2)$,
where $U_i(j)$ is the original bit position of j-th permuted bit of i-th row.

[6] Complete the inter-row permutation for the rectangular matrix based on the pattern $\langle T(i) \rangle_{i \in \{0,1,\ldots,R-1\}}$, where $T(i)$ is the original row position of the i-th permuted row.

Bits-output from rectangular matrix with pruning

After intra-row and inter-row permutations, the bits of the permuted rectangular matrix are denoted by y'_k:

$$\begin{bmatrix} y'_1 & y'_{(R+1)} & y'_{(2R+1)} & \cdots y'_{((C-1)R+1)} \\ y'_2 & y'_{(R+2)} & y'_{(2R+2)} & \cdots y'_{((C-1)R+2)} \\ \vdots & \vdots & \vdots & \cdots \quad \vdots \\ y'_R & y'_{2R} & y'_{3R} & \cdots \quad y'_{C \times R} \end{bmatrix}$$

The output of the Turbo code internal interleaver is the bit sequence read out column by column on the intra-row and inter-row permuted R X C rectangular matrix starting with bit y'_1 in row 0 of column 0 and ending with bit y'_{CR} in row R - 1 of column C - 1. The output is pruned by deleting dummy bits that are padded to the input of the rectangular matrix before intra-row and inter row permutations (i.e., bits) y'_k that corresponds to bits y_k with $k > K$ are removed on the output. The bits output from Turbo code internal interleaver are denoted by x'_1, x'_2, …, x'_K, where x'_1 corresponds to the bit y'_k with smallest index k after pruning, x'_2 to the bit y'_k with second smallest index k after pruning, and so on. The number of bits output from Turbo code internal interleaver is K and the total number of pruned bits is: R X $C – K$.

Netlist Form

```
AINTLVPTN:NAME  n1 nexsys_component=INTLVPTN [TYPE= val] K=val
[P=val] [SAMPLE_RATE=val] [ROUT=val]
```

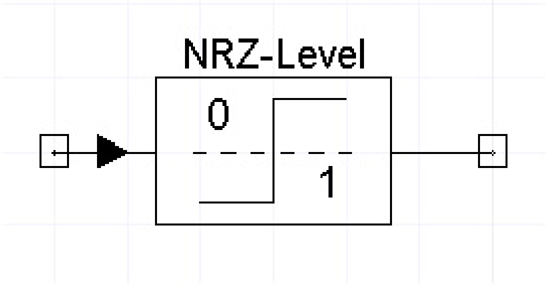
Netlist Example

```
AINTLVPTN:1 1 nexsys_component=INTLVPTN K = 636 P = 59
SAMPLE_RATE = 1khz
```

References

[1] 3GPP TS 25.212 “Multiplexing and channel coding (FDD)

NRZ Level Pulse Code Modulator (NRZL)



Property	Description	Units	Default	Range/Type
Level	Output signal amplitude	Volt	1.0	[0, INF]/Real
N	Oversampling factor	None	1	[1, INF]/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	(0, Inf]/Real
Ports				
Input	Input sequence (real)			
Output	Output sequence (real)			

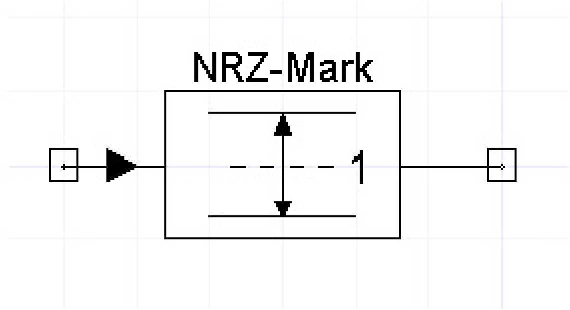
Netlist Form

```
ANRZ_L:NAME  n1 n2  Nexsys_component=nrz_l Level=val N=val
[RIN=val] [ROUT=val]
```

Netlist Example

```
ANRZ_L:1 1 2 Nexsys_component=nrz_l Level=2.2 N=2
```

NRZ Mark Pulse Code Modulator (NRZM)



Property	Description	Units	Default	Range/Type
Level	Output signal amplitude	Volt	1.0	[0, INF]/Real
N	Oversampling factor	None	1	[1, INF]/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	(0, Inf]/Real
Ports				
Input	Input sequence (real)			
Output	Output sequence (real)			

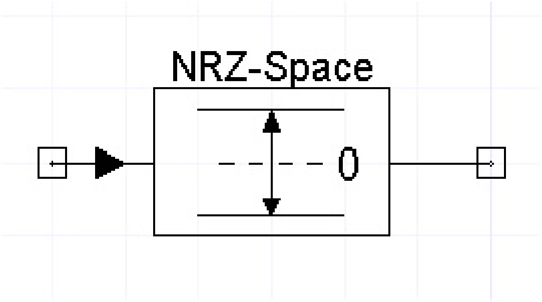
Netlist Form

```
ABNRZ_M:NAME  n1 n2  Nexsys_component=nrz_m Level=val N=val
[RIN=val] [ROUT=val]
```

Netlist Example

```
ANRZ_M:1 1 2 Nexsys_component=nrz_m Level=2.2 N=2
```

NRZ Space Pulse Code Modulator (NRZS)



Property	Description	Units	Default	Range/Type
Level	Output signal amplitude	Volt	1.0	[0, INF]/Real
N	Oversampling factor	None	1	[1, INF]/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	(0, Inf]/Real
Ports				
Input	Input sequence (real)			
Output	Output sequence (real)			

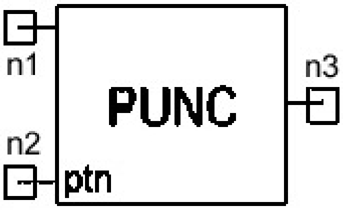
Netlist Form

```
ANRZ_S:NAME  n1 n2  Nexsys_component=nrz_s Level=val N=val
[RIN=val] [ROUT=val]
```

Netlist Example

```
ANRZ_S:1 1 2 Nexsys_component=nrz_s Level=2.2 N=2
```

Puncturer (PUNC)



Property	Description	Units	Default	Range/Type
N	Puncturing period	None	4	[1, Inf)/integer
RIN1	Input impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	output Impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Received signal before puncturing (real)			
Input2	Puncturing pattern (integer)			
Output	The signal after puncturing (real)			

Notes

1. This model can be used to increase coding rate by employing “puncturing”. Puncturing is a procedure for deleting some of the encoded bits at the output of a convolutional encoder.
2. Puncturing pattern is a *N*-bit sequence with taking the value 1 or 0. When the value is 1, the corresponding output of a convolutional encoder is transmitted. When the value is 0, the corresponding output of a convolutional encoder is deleted.

Netlist Form

```
APUNC:NAME  n1 n2 n3 nexsys_component=PUNC N=val [RIN1=val]
[RIN2=val] [ROUT=val]
```

Netlist Example

```
APUNC:1 1 2 3 nexsys_component=PUNC N=6
```

References

1. J. G. Proakis, *Digital Communications*, McGraw-Hill, 2001.

Reed-Solomon Coder (RSCOD)

Property	Description	Units	Default	Range/Type
N	Codeword length	None	204	[3, 65335]/Integer
K	Data length in each codeword	None	188	[1, 65335]/Integer
M	Size of the Galois Field	None	8	[2, 16]/Integer
B_0	First root of the generator polynomial	None	1	[0, 653345]/Integer
P_0, P_1, ..., P_m	Coefficients of the primitive polynomial	None	101110001	[0, 1]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	output Impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input symbol sequence (integer)			
Output	Reed Solomon coded output sequence (integer)			

Limits

$$3 \le N \le 2^M - 1$$

$$1 \le K \le N - 2$$

$$0 \le B_0 \le N - 1$$

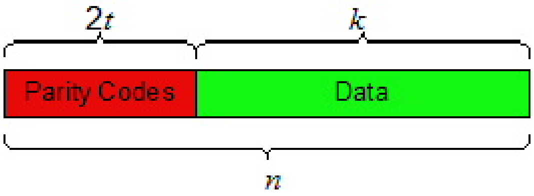
Notes

This model is used to perform Reed-Solomon (RS) encoding. RS codes are a non-binary subclass of the BCH block codes. The code format is *RS(n,k)* defined on Galois Field *(2^m).* The error correcting capability of the *RS(n,k)* code is defined by *t* = *(n-k)/2*, which means this code can correct up to $t = (n-k)/2$ errors.

The RS coder adds a sequence of $2t$ parity code symbols to each k input data symbols to form a codeword with $n = 2^m-1$ symbols. However, $RS(n,k)$ can be shorten into $RS(n-j, k-j)$ by forcing j leading input data symbols to be zeros, and then deleting these zero symbols from a systematic codeword.

For example, the digital satellite communications Reed-Solomon (RS) coder/decoder RS (204,188), is the shortened length of the RS(255,239) Reed-Solomon code. This shortened code is formed by 188 input data symbols, plus 51 additional zero-padded symbols, before encoding with the RS(255,239). The transmitted codeword doesn't contain the padding sequence which is rebuilt in RS decoder.

At the output of the RS coder, the data is left unchanged and the parity codes are appended as shown in Fig.1. In this model, the parity codes are transmitted first.
Fig.1: Codeword for systematic Reed-Solomon code



(1) Galois Field Arithmetic

Reed-Solomon codes are based on a specific area of mathematics known as Galois Field, which is set up according to the number of bits per symbol and the number of symbols per block (i.e., codeword). The elements of the Galois Field $GF(2^m)$ are generated on the mth degree irreducible **primitive polynomial** with the smallest number of terms. The primitive polynomial of degree m can be written in the form:

$$P(X) = P_0 + P_1X + P_2X^2 + \ldots + P_mX^m \qquad (1)$$

Table I. List of primitive polynomials
The elements if Galois Field GF(2^m) can have two representations: power representation and polynomial representations. Let α represent the root of the primitive polynomial P(X). Each power representation α_i, where

$$0 \le i \le 2^m - 2$$

,

for elements of Galois Field GF(2^m) can be expressed as

(2)

$$\alpha^i = a_{i0} + a_{i1}\alpha + a_{i2}\alpha^2 + \ldots + a_{i,m-1}\alpha^{m-1}$$

where the binary vector {a_{i0}, a_{1i}, ..., $a_{i,m-1}$} is the polynomial representation of α_i. The power representation is convenient for multiplication and the polynomial representation is convenient for addition.

m		m	
3	$1+X+X^3$	10	$1+X^3+X^{10}$
4	$1+X+X^4$	11	$1+X^2+X^{11}$
5	$1+X^2+X^5$	12	$1+X+X^4+X^6+X^{12}$
6	$1+X+X^6$	13	$1+X+X^3+X^4+X^{13}$
7	$1+X^3+X^7$	14	$1+X+X^6+X^{10}+X^{14}$
8	$1+X^2+X^3+X^4+X^8$	15	$1+X+X^{15}$
9	$1+X^4+X^9$	16	$1+X+X^3+X^{12}+X^{16}$

(2) Generator polynomial

The generator polynomial of Reed-Solomon code is generally defined as

$$g(X) = \left(X + \alpha^{b_0}\right)\left(X + \alpha^{b_0+1}\right)\ldots\left(X + \alpha^{b_0+2t-1}\right)$$

(3)

where *t* is the correctable error number. For the special case of $b_0 = 1$, the above equation is simplified into

$$g(X) = (X + \alpha)(X + \alpha^2)\ldots(X + \alpha^{2t})$$

(4)

The generator polynomial can also be expressed as a *2t* order of polynomial

$$g(X) = g_0 + g_1X + g_2X^2 + \ldots + g_{2t-1}X^{2t-1} + X^{2t}$$

(5)

(3) Encoding

2. In the Reed-Solomon code, all generated codewords are exactly divisible by the generator polynomial. Let

$$a(X) = a_0 + a_1X + a_2X^2 + \ldots + a_{k-1}X^{k-1}$$

(6)

be the input data to be encoded, where *k*= *n-2t*. The parity check codes are the coefficients of the remainder, b(X) = $b_0 + b_1X + \ldots + b_{2t-1}X^{2t-1}$ resulting from dividing the input data polynomial $X^{2t}a(X)$ by the generator polynomial *g(X)*. These parity codes are then joined to the data symbols to form the transmitted codeword. The RS encoding procedure can be accomplished by using a division circuit as shown in Fig.2

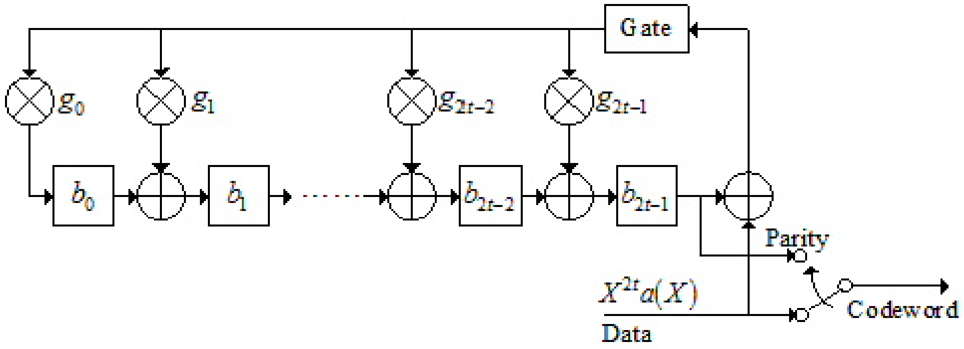


Fig.2 Encoding diagram for systematic Reed-Solomon code

Netlist Form

```
ARSCOD:NAME  n1 n2 nexsys_component=RSCOD N=val K=val M =val
[B0 =val] [P0=val . . . PM=val] [RIN=val] [ROUT=val]
```

Netlist Example

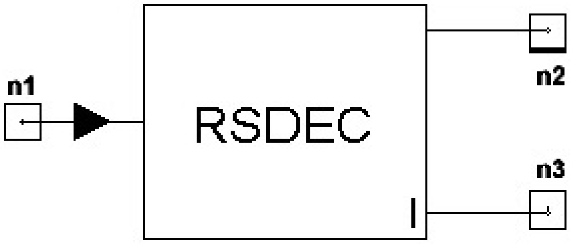
```
ARSCOD:1 1 2 nexsys_component=RSCOD N=204 K=188 M =8 B0 =1
{P0,…P8} = {1,0,1,1,1,0,0,0,1}
```

References

1. James J. Spilker, *Digital Communications by Satellite*, Prentice-Hall, 1977.
2. Shu Lin and D.J.Costello, *Error Control Coding: Fundamentals and Applications*, Prentice-Hall, 1983.
3. Y.Shayan, T.Le-Ngoc and V.Bhargava, “A versatile time-domain Reed-Solomon decoder,” *IEEE Journal on Selected Areas in Communications,* vol. 8, No.8, pp.1535-1542, Oct. 1990.

μv

Reed-Solomon Decoder (RSDEC)



Property	Description	Units	Default	Range/Type
N	Codeword length	None	204	[3, 65335]/Integer
K	Data length in each codeword	None	188	[1, 65335]/Integer
M	Size of the Galois Field	None	8	[2, 16]/Integer
B_0	First root of the generator polynomial	None	1	[0, 653345]/Integer
P_0, P_1, ..., P_m	Coefficients of the primitive polynomial	None	101110001	[0, 1]/Integer
RIN	Input impedance	Ohm	Inf	[0, Inf)/Real
ROUT1	Output impedance	Ohm	0	[0, Inf)/Real
ROUT2	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Received signal to be decoded (real)			
Output1	Reed-Solomon decoded sequence (integer)			
Output2	Error indicator (integer)			

Limits

$$2 \le M \le 16$$

$$3 \le N \le 2^M - 1$$

$$1 \le K \le N - 2$$

$0 \le B_0 \le N - 1$

Notes

This model is used to perform Reed-Solomon (RS) decoding. A systematic *RS(n,k)* code, which is defined on Galois Field (2^m), consists of *k* input data symbols and *(n-k)* parity code symbols. For details about RS coding, please refer to the **rscod** model. A general architecture for RS decoder is shown in Fig.1

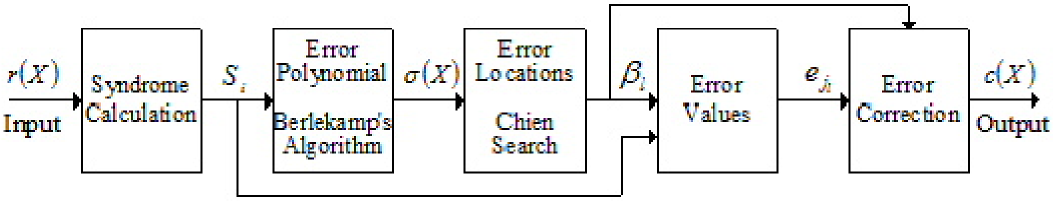


Fig.1: Codeword for systematic Reed-Solomon coder

r(x) Received codeword
β_l Error locations
S_i Syndromes
e_{ji} Error values
σ(X) Error location polynomial
c(x) Corrected codeword

A Reed-Solomon decoder attempts to identify the positions and values of up to
t = (n-k)/2 errors , then correct the errors. In case of shortened codes, the appropriate sequence of zero-padding is first rebuilt so the codeword is equal to 2^m-1.

Let *v(x)* be the transmitted code vector,

$$v(X) = v_0 + v_1X + v_2X^2 + \ldots + v_{n-1}X^{n-1} \qquad (1)$$

and *r(x)* be the corresponding received vector,

$$r(X) = r_0 + r_1X + r_2X^2 + \ldots + r_{n-1}X^{n-1} \qquad (2)$$

The error pattern, *e(X),*is added by the channel,

$$e(X) = r(X) - v(X) = e_0 + e_1 X + e_2 X^2 + \ldots + e_{n-1} X^{n-1}$$

(3)

where *e(X)* is an element from GF(2^m). Considering the number of elements, ν, in the error pattern, *e(X)*, at the location X^{j1},X^{j2} , …,X^{j}n with 0<= jν <= n-1, the result is

$$e(X) = e_{j_1} X^{j_1} + e_{j_2} X^{j_2} + \ldots + e_{j_\nu} X^{j_\nu}$$

(4)

Explanation of decoding process for RS codes:

(1) Syndrome Calculation

A Reed-Solomon codeword has *2t***syndromes**, which can be calculated by substituting the *2t* roots of the generator polynomial *g(X)* into *r(X)*, i.e., $S_i = r(a^{b0 + i - 1})$, where *i*= 1,2,...2t.

(2) Determination of the error-location polynomial

The syndromes are used to find the error-location polynomial. The error location polynomial is defined as

$$\sigma(X) = \sigma_0 + \sigma_1 X + \ldots + \sigma_\nu X^\nu$$

(5)

The error location polynomial has ν roots, the inverses of which indicate the error locations. σ(X) is an undetermined polynomial and its coefficients must be determined. The Berlekamp's iterative algoithm is used to construct this polynomial, which is the key to RS decoding.

Now consider the minimum degree polynomial determined at the μ-th step of iteration.

$$\sigma^{(\mu)}(X) = 1 + \sigma_1^{(\mu)} X + \sigma_2^{(\mu)} X^2 \ldots + \sigma_{l_\mu}^{(\mu)} X^{l_\mu}$$

(6)

where l^μ is the degree of $s^{(\mu)}(X)$ To determine $\sigma^{(\mu+1)}(X)$, compute the following quantity:

$$d_\mu = S_{\mu+1} + \sigma_1^{(\mu)} S_\mu + \sigma_2^{(\mu)} S_{\mu-1} \ldots + \sigma_{l_\mu}^{(\mu)} S_{\mu+1-l_\mu}$$

(7)

This quantity d_μ is called the μ-th discrepancy.
To carry out the iteration of finding σ(X), begin with Table I and proceed to fill out this table. Assuming all rows up to and including theX row are filled, fill out the μ+1-th row as follows:
(a) If d_μ= 0, then $\sigma^{(\mu+1)}(X) = \sigma^{(\mu)}(X)$ and $l_{\mu+1} = l_\mu$
(b) If d_μ is not equal to 0, find another row,ρ, prior to the μ-th row such that dρ does not equal

zero, and the number $\rho^{-l\rho}$ in the last column of the table has the largest value. Then, $\sigma^{(\mu+1)}(X)$ is given by the following two equations:

$$\sigma^{(\mu+1)}(X) = \sigma^{(\mu)}(X) + d_\mu d_\rho^{-1} X^{(\mu-\rho)} \sigma^{(\rho)}(X)$$

(8) and

$$l_{\mu+1} = \max(l_\mu, l_\rho + \mu - \rho)$$

(9)

And for both cases:

$$d_{\mu+1} = S_{\mu+2} + \sigma_1^{(\mu+1)} S_{\mu+1} + \ldots + \sigma_{l_{\mu+1}}^{(\mu+1)} S_{\mu+2-l_\mu}$$

(10)

Rows in this table after the first two are generated by iteratively applying the equations given above.

Table 1: Iterative Table for Berlekamp Algorithm (First Two Rows Filled In)

μ	$\sigma^{(\mu)}(X)$	d_μ	l_μ	$\mu - l_\mu$
-1	1	1	0	-1
0	1	S_1	0	0
...	...	...	...	..
...	...	...	...	..
...	...	...	...	..
...	...	...	...	..

If the order of the polynomial is greater than *t*, which means the received codeword has more than *t* errors, the errors cannot be corrected and the received vector *r(X)* is output as is, error indicator is set to -1. Otherwise, error indicator is the number of errors.

(3) Determination of the error-location numbers

The error location numbers β_l ($1 <= l <= \mu$) are the inverses of the roots of $\sigma(X)$. The roots of $\sigma(x)$ can be found by substituting $1, \alpha, \alpha^2, \ldots\alpha^{n-1}$ ($n = 2^m-1$) into $\sigma(X)$. Therefore, if α^l is a root of $\sigma(X)$, $\alpha^{(n-l)}$ is an error location number and the received r_{n-l} is an error symbol.

(4) Calculation of the error values and correcting the received codeword

The error value at location $\beta_l = \alpha^{jl}$ is calculated based on the following equation:

$$e_{j_l} = \beta_l^{(1-b_0)} \frac{Z\left(\beta_l^{-1}\right)}{\prod_{i=1, i\neq l}^{v}\left(1+\beta_i\beta_l^{-1}\right)} \qquad (11)$$

where

$$Z(X)=1+\left(S_1+\sigma_1\right)X+\left(S_2+\sigma_1 S_1+\sigma_2\right)X^2+\ldots+\left(S_v+\sigma_1 S_{v-1}+\sigma_2 S_{v-2}+\ldots+\sigma_v\right)X^v \qquad (12)$$

Finally, the decoding procedure is completed by the subtraction of the received vector *r(X)* and the error vector *e(X)*.

Netlist Form

```
ARSDEC:NAME  n1 n2 n3 nexsys_component=RSDEC N=val K=val M =val
[B0 =val] [P0=val . . . PM=val] +[RIN=val] [ROUT1=val]
[ROUT2=val]
```

Netlist Example

```
ARSDEC:1 1 2 3 nexsys_component=RSDEC N=204 K=188 M =8 B0 =1
{P0,…P8} = {1,0,1,1,1,0,0,0,1}
```

References

1. Shu Lin and D.J.Costello, *Error Control Coding: Fundamentals and applications*, Prentice-Hall, 1983.
2. Elwyn Berlekamp, *Algebraic Coding Theory*, McGraw-Hill, New York, 1968.
3. Y.Shayan, T.Le-Ngoc and V.Bhargava, “A versatile time-domain Reed-Solomon decoder,” *IEEE Journal on Selected Areas in Communications,* vol. 8, No.8, pp.1535-1542, Oct. 1990.

Reed-Solomon Addition (RSERRADD)

Property	Description	Units	Default	Range/Type
N	Codeword length	None	204	[3, 65535]/Integer
K	Data length in each codeword	None	188	[1, 65535]/Integer
M	Size of the Galois Field	None	8	[2, 16]/Integer
ERR_K	Number of errors to be set in data length	None	0	[0, 65533]/Integer
ERR_T	Number of errors to be set in parity code	None	0	[3, 65534]/Integer
Seed	Start value of the random number generator	None	0	[0, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf)/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input sequence (real)			
Output	Output sequence (real)			

Limits

$$2 \le M \le 16$$

$$3 \le N \le 2^M - 1$$

$$1 \le K \le N - 2$$

$$0 \le B_0 \le N - 1$$

$$0 \le ERR\_K \le K$$

$0 \le ERR\_T \le N - K$

Notes

1. This model is used to randomly set error locations and values in Reed-Solomon (RS) codeword.

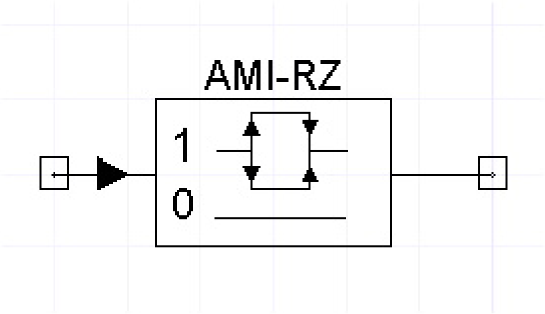
Netlist Form

```
ARSERRADD:NAME  n1 n2 nexsys_component=RSERRADD N=val K=val M
=val [ERR_K =val] [ERR_T =val] [SEED =val]+ [RIN=val]
[ROUT=val]
```

Netlist Example

```
ARSERRADD:1 1 2 nexsys_component=RSERRADD N=204 K=188 M =8
ERR_K =0 ERR_T =0
```

RZ Alternate Mark Inversion Pulse Code Modulator (RZAMI)



Property	Description	Units	Default	Range/Type
Level	Output signal amplitude	Volt	1.0	[0, INF]/Real
N	Oversampling factor	None	1	[1, INF]/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	(0, Inf]/Real
Ports				
Input	Input sequence (real)			
Output	Output sequence (real)			

Notes

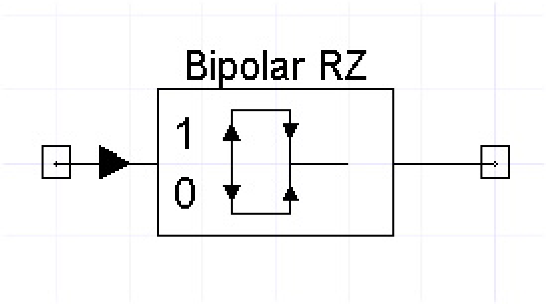
Netlist Form

```
ARZ_AMI:NAME  n1 n2  Nexsys_component=rz_ami Level=val N=val
[RIN=val] [ROUT=val]
```

Netlist Example

```
ARZ_AMI:1 1 2 Nexsys_component=rz_ami Level=2.2 N=2
```

RZ Bipolar Pulse Code Modulator (RZBI)



Property	Description	Units	Default	Range/Type
Level	Output signal amplitude	Volt	1.0	[0, INF]/Real
N	Oversampling factor	None	1	[1, INF]/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	(0, Inf]/Real
Ports				
Input	Input sequence (real)			
Output	Output sequence (real)			

Notes

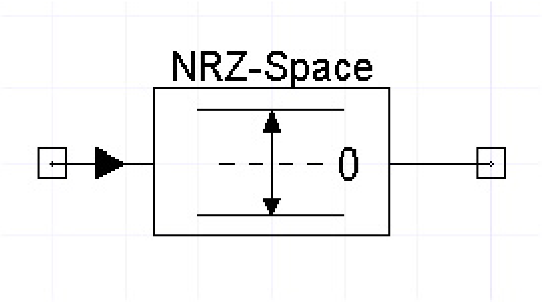
Netlist Form

```
ABI_RZ:NAME  n1 n2  Nexsys_component=bi_rz Level=val N=val
[RIN=val] [ROUT=val]
```

Netlist Example

```
ABI_RZ:1 1 2 Nexsys_component=bi_rz Level=2.2 N=2
```

RZ Unipolar Pulse Code Modulator (RZUNI)



Property	Description	Units	Default	Range/Type
Level	Output signal amplitude	Volt	1.0	[0, INF]/Real
N	Oversampling factor	None	1	[1, INF]/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	(0, Inf]/Real
Ports				
Input	Input sequence (real)			
Output	Output sequence (real)			

Notes

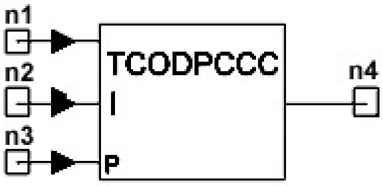
Netlist Form

```
AUNI_RZ:NAME  n1 n2  Nexsys_component=uni_rz Level=val N=val
[RIN=val] [ROUT=val]
```

Netlist Example

```
AUNI_RZ:1 1 2 Nexsys_component=uni_rz Level=2.2 N=2
```

Turbo Coder with PCCC (TCODPCCC)



Property	Description	Units	Default	Range/Type
K	Number of information bits in each code block	None	65536	[1, Inf)/integer
L1	Constraint length in the first RSC coder	None	5	[2, 32)/integer
L2	Constraint length in the second RSC coder	None	5	[2, 32)/integer
G1	Denominator of generator for the first RSC coder in decimal value	None	19	[1, 4294967295)/integer
G2	Numerator of generator for the first RSC coder in decimal value	None	25	[1, 4294967295)/integer
G3	Denominator of generator for the second RSC coder in decimal value	None	19	[1, 4294967295)/integer
G4	Numerator of generator for the second RSC coder in decimal value	None	25	[1, 4294967295)/integer
PUNCTURING	No {0} Puncturing period {>0}	None	0	[0, Inf)/Integer
TERMINATION	No {0} 1st RSC only {1} 2d RSC only{2} Both RSC {3}	None	0	[0, 3]/Integer
OUT_TYPE	Output value with 0 or 1 {0} Output value with -1 or 1 {1}	None	0	[0, 1]/Integer
RIN1	Input impedanc1e	Ohm	Inf	(0, Inf]/Real
RIN2	Input impedance2	Ohm	Inf	(0, Inf]/Real

RIN3	Input impedance3	Ohm	Inf	(0, Inf]/Real
ROUT	output Impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Binary input sequence (integer)			
Input2	Interleaving pattern (integer)			
Input3	Puncturing pattern (integer)			
Output	Turbo decoded binary sequence (real)			

Limits

$K \geq 1$

$L_1 \geq 2$

$L_2 \geq 2$

$G_1, G_2, \ldots G_4 \geq 0$

Notes

1. This model is used for Turbo Coder with Parallel Concatenated Convolutional Code (PCCC). Kis number of information bits in each code block
2. **Turbo Coder Structure**: Fig.1 shows the diagram of Turbo Coder with PCCC. The encoder consists of two recursive systematic convolutional (RSC) encoders with rate 1/2 which are separated by an K-bit interleaver, together with an optional puncturing procedure. Clearly, without the puncturer, the encoder is rate 1/3, mapping Kdata bits to 3K code bits. In the K-bit interleaver, denote by *i* the index of the input sequence before interleaving and *f(t)* is the index of output sequence after interleaving, the interleaving

pattern sequence is given by *f(0) f(1) ... f(K-1)* .

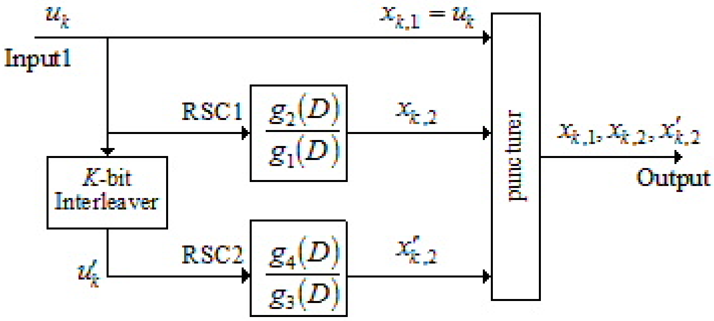


Fig.1 Turbo Coder with PCCC

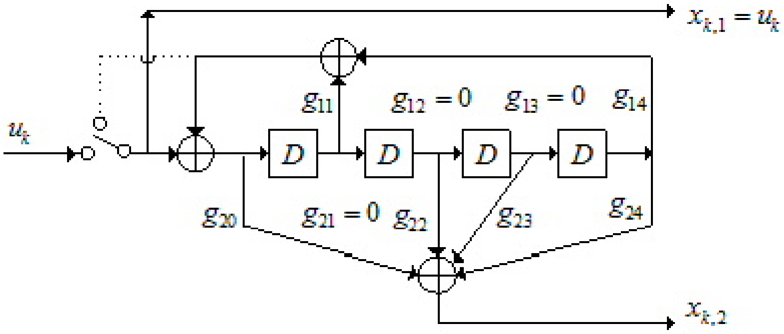


Fig.2 Recursive Systematic Convolutional (RSC) Encoder with $G_1 = 31 \quad G_2 = 27$,

3. **RSC Encoder**: The RSC code with rate 1/2 has the generator matrix

$$G(D) = \left[1 \quad \frac{g_2(D)}{g_1(D)}\right] \tag{1}$$

In the above equation, the polynomials $g_1(D)$ and g_2(D are given by

$$g_1(D) = \sum_{i=0}^{L-1} g_{1i} D^i \quad g_{1i} = \{0,1\} \tag{2}$$

$$g_2(D) = \sum_{i=0}^{L-1} g_{2i} D^i \quad g_{2i} = \{0,1\} \tag{3}$$

with L is the constraint length of the RSC code. In this model, $g_1(D)$ and $g_2(D)$ are expressed in octal form $G_1(D)$ and $G_2(D)$, respectively. For example, if $G_1(D) = 1 + D + D^4$ and $G_2(D) = 1 + D^2 + D^{3} + D^4$, the octal forms are $G_1 = 31$, $G_2 = 27$, as shown in Fig.2.

4. When *Puncturing* is set to 0, no puncturing is considered. Otherwise, some output bits are deleted according to a chosen puncturing pattern on the third input port. The number of bits in the puncturing pattern is called puncturing length. If the element of the pattern is 1, the corresponding output bit is transmitted. If the element of the pattern is 0, the corresponding output bit is omitted.
5. In this model, choose whether termination of each RSC encoder to the zero state or not. The termination method can be found in [2], as shown in Fig.2. For each RSC encoder, *L-1* bits are needed for termination, with *L* is the constraint length of the RSC code. Therefore, without the puncturer, set *Termination* to 3, the number of output bits is given by

   $$3K + 2(L_1 - 1) + 2(L_1 - 1) = 3K + 2L_1 + 2L_2 - 2 \tag{4}$$

   with L_1 and L_2 is the constraint length of the first RSC code and of the second RSC code, respectively.
6. If *Out_Type* is set to 0, the output of the true value and the false value are 1 and 0, respectively. If *Out_Type* is set to 1, the output of the true value and the false value are 1 and -1, respectively.

Netlist Form

```
ATCODPCCC:NAME  n1 n2 n3 n4 nexsys_component=TCODPCCC K=val
L1=val L2=val G1=val G2=val G3=val G4=val [PUNCTURING=val]

+ [TERMINATION =val] [OUT_TYPE =val] [RIN1=val] [RIN2=val]
[RIN3=val] [ROUT=val]
```

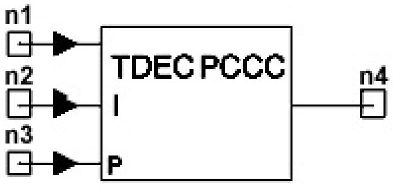
Netlist Example

```
ATCODPCCC:1 1 2 3 4 nexsys_component=TCODPCCC K=636 L1=5  L2=5
G1=19  G2=31 G3=19 G4=31 PUNCTURING=6 +TERMINATION=3 OUT_TYPE=1
```

References

1. C. Berrou and A. Glavieux, “Near optimum error correcting coding and decoding: Turbo-codes,” *IEEE Trans. Commun.*, vol. 44, no. 10, pp. 1261–1271, 1996.
2. D. Divsalar and F. Pollara, “Turbo codes for PCS applications,” *Proc. 1995 Int. Conf. Comm.*, pp54-59.

Turbo Decoder with PCCC (TDECPCCC)



Property	Description	Units	Default	Range/Type
ALGORITHM	BCJR-MAP {0} Max-Log-MAP {1} Log-MAP Eexact) {2} Log-MAP {3} SOVA {4}	None	3	[0, 4]/integer
K	Number of information bits in each code block	None	65536	[1, Inf)/integer
L1	Constraint length in the first RSC coder	None	5	[2, 32)/integer
L2	Constraint length in the second RSC coder	None	5	[2, 32)/integer
G1	Denominator of generator for the first RSC coder in decimal value	None	19	[1, 4294967295)/integer
G2	Numerator of generator for the first RSC coder in decimal value	None	25	[1, 4294967295)/integer
G3	Denominator of generator for the second RSC coder in decimal value	None	19	[1, 4294967295)/integer
G4	Numerator of generator for the second RSC coder in decimal value	None	25	[1, 4294967295)/integer
PUNCTURING	No {0} Puncturing period {>0}	None	0	[0, Inf)/Integer
TERMINATION	No {0} 1st RSC only {1} 2d RSC only{2}	None	3	[0, 3]/Integer

	Both RSC {3}			
ITERATION	Number of iterations	None	8	[1, Inf]/Integer
TRELLIS_ DEPTH	Trellis depth of SOVA algorithm	None	25	[1, Inf)/Integer
A	Fading amplitude (A = 1 for nonfading AWGN channel)	None	1	[0, Inf)/Real
EBNOR	Transmitted energy per information bit to noise spectral density ratio in dB	None	1	(-Inf, 100]/Real
FEEDBACK	Feedback factor for extrinsic information	None	.8	(0, 1]]/Real
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
RIN3	Input3 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	output Impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Received signal to be decoded (real)			
Input2	Interleaving pattern (integer)			
Input3	Puncturing pattern (integer)			
Output	Turbo decoded binary sequence (integer)			

Limits

$K \geq 1$

$L_1 \geq 2$

$L_2 \geq 2$

$G_1, G_2, \ldots G_4 \geq 0$

$Iteration \geq 1$

$0 \le Feedback \le 1$

Notes

1. This model is used for Turbo Decoder with Parallel Concatenated Convolutional Code (PCCC). *K* is number of information bits in each code block
2. Turbo Coder Structure: Fig.1 shows the diagram of Turbo Coder with PCCC. The encoder consists of two recursive systematic convolutional (RSC) encoders with rate 1/2 which are separated by an *K*-bit interleaver, together with an optional puncturing procedure. For details of the encoder, please refer to the model **Turbo Coder with PCCC**.

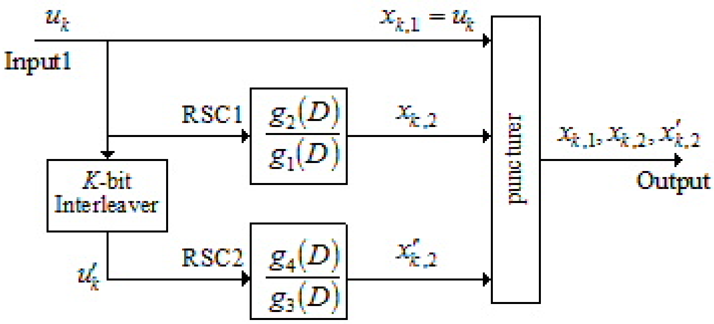


Fig.1 Turbo Coder with PCCC

3. **Iterative Turbo Decoder Structure**: The diagram of iterative Turbo Decoder with PCCC is shown in Fig.2. It should be noted that the turbo decoder must insert zeros in the soft channel output for these punctured bits. In addition, a Feedback Factor ($0 < Feedback \le 1$)

is used to multiply the extrinsic information for stability with a typical value 0.8.

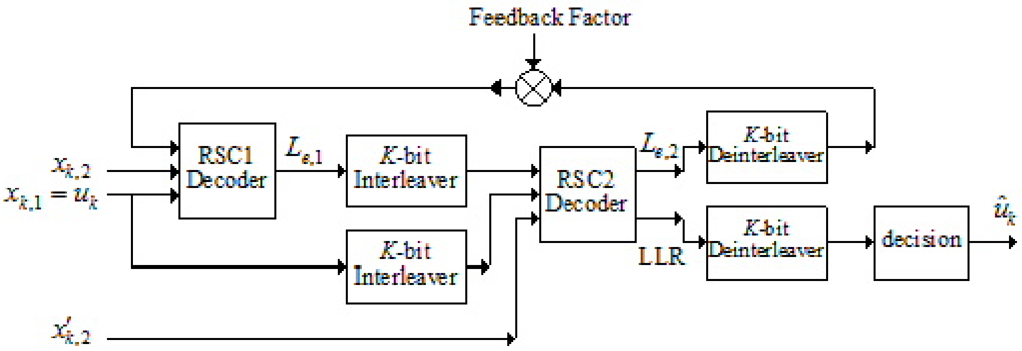


Fig.2 Iterative Turbo Decoder with PCCC

4. **RSC Decoder**: In this model, each of the five typical algorithms (**BCJR-MAP**, **Max-Log-MAP**, **Log-MAP (Exact)**, **Log-MAP** and **SOVA**) can be chosen used in RSC Decoder, which is the core of the iterative Turbo Decoder. The five algorithms are described in [3]. Please refer to [3] for details.

Netlist Form

```
ATDECPCCC:NAME  n1 n2 n3 n4 nexsys_component=TDECPCCC
[ALGORITHM=val] K=val L1=val L2=val G1=val G2=val G3=val G4=val

+ [PUNCTURING=val] [TERMINATION =val] [ITERATION=val] [TRELLIS_
DEPTH=val] [A =val]

+ [EBN0R=val] [FEEDBACK =val] [RIN1=val] [RIN2=val] [RIN3=val]
[ROUT=val]
```

Netlist Example

```
ATDECPCCC:1 1 2 3 4 nexsys_component=TDECPCCC ALGORITHM = 3
K=636 L1=5  L2=5  G1=19  G2=31 G3=19 G4=31

+ PUNCTURING=6  TERMINATION=3 ITERATION=6 TRELLIS_DEPTH =50
A=1.0

+ EbN0R=2 FEEDBACK=0.8
```

References

1. C. Berrou and A. Glavieux, “Near optimum error correcting coding and decoding: Turbo-codes,” *IEEE Trans. Commun.*, vol. 44, no. 10, pp. 1261–1271, 1996.

2. J. Hagenauer, E. Offer, and L. Papke, “Iterative decoding of binary block and convolutional codes,” *IEEE Trans. Inform. Theory*, pp. 429–445, Mar. 1996.
3. J. P. Woodard and L. Hanzo, “Comparative Study of Turbo Decoding Techniques: An Overview,” *IEEE Transactions on Vehicular Technology*, vol. 49, no. 6, pp. 2208-2233, Nov. 2000.
4. D. Divsalar and F. Pollara, “Turbo codes for PCS applications,” Proc. 1995 Int. Conf. Comm., pp54-59.
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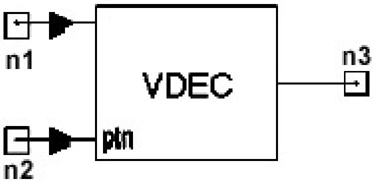
8. P. Robertson, E. Villebrun, and P. Hoeher, “A comparison of optimal and sub-optimal MAP decoding algorithms operating in the log domain,” in *Proc. Int. Conf. Communications*, June 1995, pp. 1009–1013.
9. J. Hagenauer and P. Hoeher, “A Viterbi algorithm with soft-decision outputs and its applications,” *IEEE Globecom*, pp. 1680–1686, 1989.
10. J. Hagenauer, “Source-controlled channel decoding,” *IEEE Trans. Commun.*, vol. 43, pp. 2449–2457, Sept. 1995.

Viterbi Decoder (VDEC)



Property	Description	Units	Default	Range/Type
N	Number of bits to generate at the output for each K input bits	None	2	[1, 8]/Integer
K	Number of input bits to be shifted into shift register at each step.	None	1	[1, 8]/Integer
L	Constraint length of convolutional coder	None	5	[2, Inf)/Integer
Decision	Hard decision {0} Soft decision {1}	None	0	[0, 1]/Integer
Puncturing	No {0} Puncturing period {>0}	None	0	[0, Inf)/Integer
Trellis_ Depth	Trellis depth of Viterbi decoder	None	25	(0, Inf)/Integer
T	True output value	None	1	(-Inf, Inf)/Real
F	False output value	None	0	(-Inf, Inf)/Real
G1, G2 , ..., G8	Generators of convolutional coder (specified in decimal) (optional)	None	0	[0, 4294967295]/Integer
RIN1	Input impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Received signal to be decoded (real)			
Input2	Puncturing pattern (integer)			
Output	The convolutionally decoded binary sequence (real)			

Limits

$0 < K \times L \leq 32$

Notes

1. This model is Viterbi decoder for a convolutional code. In order to provide the correct decoding process, the parameters which are shared by a **Convolutional Coder** and corresponding **Viterbi Decoder** must be identical except the two parameters: *T* and *F*. These identical parameters are *N*, *K*, *L*, $G_1, G_2, ... G_N$ with $N \leq 8$. Please refer to the list of parameters given for the **Convolutional Coder** model.
2. This model takes a received input sequence (which may contain errors when compared to the sequence originally transmitted by the **Convolutional Coder** model) and optimally decodes this sequence using the Viterbi Algorithm (**VA**) (Please refer to [1] for more details). This model can perform hard decision or soft decision, the corresponding metric may be either a Hamming metric or a Euclidean metric, respectively.
3. Puncturing is a procedure for omitting some of the encoded bits in the transmitter (thus reducing the number of transmitted bits and increasing the coding rate) and inserting a dummy “zero” into the convolutional decoder in the receiver in place of the omitted bits. If the parameter *Puncturing* is set to a positive integer, the corresponding puncturing pattern (the number of samples equals Puncturing period) is obtained on the second input port. For the values of the pattern sequence, please refer to the **Puncturer** model and **Depuncturer** model.
4. At the *Trellis_Depth* stage, this model starts to output the optimally decoded binary data only after receiving *N x Trellis_Depth* input bits. That means if the total number of bits present at the input port is less than *N x Trellis_Depth*, no bits are decoded and sent to the output port.
5. After receiving *N x Trellis_Depth* input bits, this model generates $2^{K(L-1)}$ possible decoded sequences. The model then chooses the decoded sequence that most likely corresponds to the originally transmitted sequence at the output of the **Convolutional Coder** model and outputs *K* optimally decoded bits at each stage in the decoding process. Note that the first optimally decoded *K* output bits appear at the output port only after *N x Trellis_Depth* input bits have been received. Then as each new *N* bits are received at the input port, the optimally decoded *K* bits (i.e., the bits that are received in *Trellis_Depth* stages) are sent to the output and so on. Finally, the model decodes the remaining (*N-1) x Trellis_Depth* input bits using Viterbi Algorithm (VA), chooses *(K-1) x Trellis_Depth* output bits that most likely corresponds to the originally transmitted sequence at the output ofthe **Convolutional Coder** model.
6. At the beginning of the decoding process, it is always assumed that this model starts in the all zero state (i.e., the content of the *K x L* shift register is binary zero).
7. The ratio of the output bit rate to the input bit rate is K/N.

Netlist Form

```
AVDEC:NAME  n1 n2 n3 nexsys_component=VDEC N=val K=val L=val
[DECISION=val] [PUNCTURING=val] TRELLIS_DEPTH =val + [T=val]
[F=val] [G1...N=val] [RIN1=val] [RIN2=val] [ROUT=val]
```

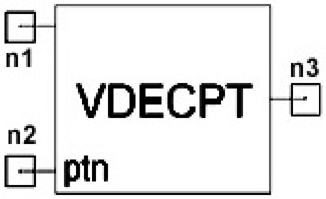
Netlist Example

```
AVDEC:1 1 2 3 nexsys_component=VDEC N=2  K=1  L=7  DECISION = 0
PUNCTURING = 6  TRELLIS_DEPTH = 35 G1=91  G2=121
```

References

1. J. G. Proakis, *Digital Communications*, McGraw-Hill, 2001.

Viterbi Decoder with Packet Transmission (VDECPT)



Property	Description	Units	Default	Range/Type
N	Number of bits to be generated at the output for each K input bits	None	2	[1, 8]/Integer
K	Number of input bits to be shifted into shift register at each step.	None	1	[1, 8]/Integer
L	Constraint length of convolutional coder	None	5	[2, Inf)]/Integer
Decision	Hard decision {0}, Soft decision {1}	None	0	[0, 1]/Integer
Puncturing	No {0} Puncturing period {>0}	None	0	[0, Inf)/Integer
Msg_ Length	Message length	None	100	[1, Inf)/Integer
Pkt_Length	Packet length	None	100	[1, Inf)/Integer
Trellis_ Depth	Trellis depth of Viterbi decoder	None	25	(0, Inf)/Integer
T	True output value	None	1	(-Inf, Inf)/Real
F	False output value	None	0	(-Inf, Inf)/Real
G1, G2, ..., G8	Generators of convolutional coder (specified in decimal) (optional)	None	0	[0, 4294967295]/Integer
RIN1	Input impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Received signal to be decoded (real)			

Input2	Puncturing pattern (integer)
Output	The convolutionally decoded binary sequence (real)

Limits

$$0 < K \times L \leq 32$$

$$Pkt\_Length \geq Trellis\_Depth$$

$$Pkt\_Length \geq Msg\_Length$$

Notes/Equations

1. This model is Viterbi decoder for a convolutional code with packet transmission. In order to provide the correct decoding process, the parameters which are shared by a **Convolutional Coder** and corresponding **Viterbi Decoderwith packet transmission** must be identical except the two parameters: *T* and *F* and . These identical parameters are $N, K, L, G_1, G_2, ...G_N$ with $N <= 8$. Please refer to the list of parameters given for the **Convolutional Coder** model.
2. This model takes a received input sequence (which may contain errors when compared to the sequence originally transmitted by the Convolutional Coder model) and optimally decodes this sequence using Viterbi Algorithm (**VA**) (Please refer to [1] for more details). This model can perform hard decision or soft decision, the corresponding metric may be either a Hamming metric or a Euclidean metric, respectively.
3. Puncturing is a procedure for omitting some of the encoded bits in the transmitter (thus reducing the number of transmitted bits and increasing the coding rate) and inserting a dummy “zero” into the convolutional decoder in the receiver in place of the omitted bits. If the parameter *Puncturing* is set to a positive integer, the corresponding puncturing pattern (the number of samples equals Puncturing period) is obtained on the second input port. For the values of the pattern sequence, please refer to the **Puncturer** model and **Depuncturer** model.
4. *Msg_Length* and *Pkt_Length* are the length of Message and Packet, respectively. It should be noted that each packet includes *K* x *Pkt_Length* bits at the input of the **Convolutional Coder** model and is formed by appending “zero” bits to each *K* x *Msg_Length* massage bits.
5. At the *Trellis_Depth* stage, this model starts to output the optimally decoded binary data only after receiving *N x Trellis_Depth* input bits. That means if the total number of bits

present at the input port is less than *N x Trellis_Depth*, no bits are decoded and sent to the output port.

6. After receiving *N x Trellis_Depth* input bits, this model generates $2^{K(L-1)}$ possible decoded sequences. The model then chooses the decoded sequence that most likely corresponds to the originally transmitted sequence at the output of the **Convolutional Coder** model and outputs *K* optimally decoded bits at each stage in the decoding process. Note that the first optimally decoded *K* output bits appear at the output port only after *N x Trellis_Depth* input bits have been received. Then as each new *N* bits are received at the input port, the optimally decoded *K* bits (i.e., the bits that are received in *Trellis_Depth* stages) are sent to the output and so on.

   Finally, the model decodes the remaining (*N-1) x Trellis_Depth* input bits using Viterbi Algorithm (**VA**), chooses (*K-1) x Trellis_Depth* output bits that most likely corresponds to the originally transmitted sequence at the output of the **Convolutional Coder** model.
7. At the beginning of the decoding process, it is always assumed that this model starts in the all zero state (i.e., the content of the *K x L* shift register is binary zero). The contents of this shift register can be reinitialized (i.e., set to binary zero) by properly specifying the parameter *Pkt_Length* (which must always be greater than or equal to *Trellis_Depth*). In other words, after receiving N x *Pkt_Length* bits, this model outputs *K xPkt_Length* optimally decoded bits, after which the contents of the shift register are reinitialized.
8. The ratio of the output bit rate to the input bit rate is K/N.

Netlist Form

```
AVDECPT:NAME  n1 n2 n3 nexsys_component=VDECPT N=val K=val
L=val [DECISION=val] [PUNCTURING=val] MSG_LENGTH =val
+ PKT_LENGTH =val TRELLIS_DEPTH =val [T=val] [F=val] [G1=val ...
GN=val]
+[RIN1=val] [RIN2=val] [ROUT=val]
```

Netlist Example

```
AVDECPT:1 1 2 3 nexsys_component=VDECPT N=2  K=1  L=7 DECISION=0
PUNCTURING=6 MSG_LENGTH=118
+PKT_LENGTH=120 TRELLIS_DEPTH=35 G1=91  G2=121
```

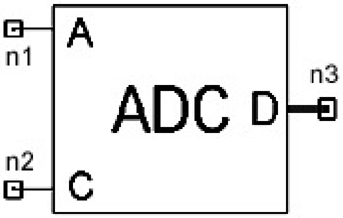
References

1. J. G. Proakis, *Digital Communications*, McGraw-Hill, 2001.

Data Converters

This topic describes the following System components:

Serial Analog to Digital Converter (ADC)

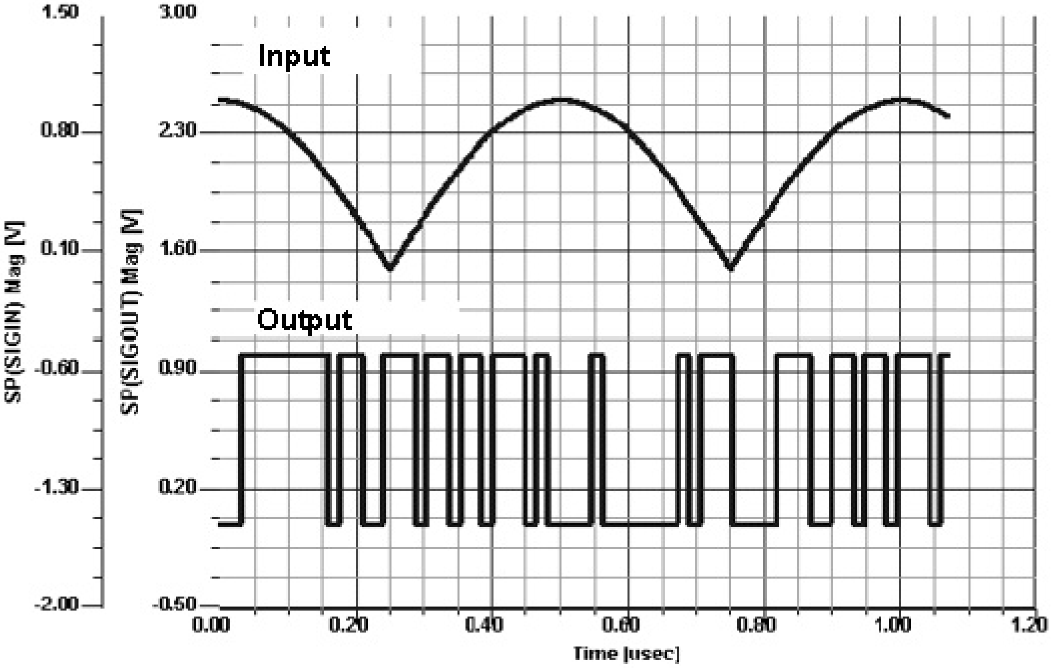


Property	Description	Units	Default	Range/Type
NBITS	Number of bits per sample	None	8	(0, Inf)/Real
VL	Minimum input voltage, in voltage units	Volt	-1.0	(-Inf, Inf)/Real
VH	Maximum input voltage (any number), in voltage units	Volt	1.0	(-Inf, Inf)/Real
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (real)			
Input2	Input2 clock signal (real)			
Output	Output signal (real)			

Notes

1. The output of this ADC is a serial bit stream representing the amplitude of the input signal at the sampling instances. The input voltage Range/Type from Vl to Vh is partitioned into 2^{nbits} values. Each interval is indexed by an integer value ranging between 0 and $2^{nbits-}1$. The intervals are labeled according to the offset binary format; that is, the interval corresponding to Vl is encoded at 00 … , 0; the next largest voltage interval is encoded as 00… ,01 etc.; and, the interval corresponding to Vh is encoded as 111 … , 11.
2. At every positive clock edge, the ADC samples the input signal, determines the interval in which the sample lies, and outputs the corresponding index of that interval. The output is a serial bit stream; each bit is placed on the output pin for one clock period—the LSB is output first and the MSB is output last. At the end of nbits clocks, all bits have been transmitted and the input voltage is sampled again.

3. In the following illustration, a signal is the input into the ADC element, which has as its parameter values Nbits=8, vl = -1V and Vh = 1V. The ADC is clocked at a rate of 0.015625 µs.



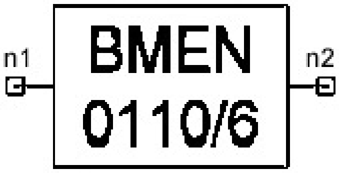
Netlist Form

```
AADC:Name n1  n2  n3 nexsys_component=ADC NBITS=val  Vl=val
Vh=val [Rin1=val] [Rin2=val][Rout=val]
```

Netlist Example

```
AADC:1 1  2  3   nexsys_component=ADC   Nbits=8  Vl=-1  Vh=1
```

Binary to M-ary Coder (BMEN)



Property	Description	Units	Default	Range/Type
NB	Number of bits to group into one symbol	None	1	[1, 31]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal of bits, starting with LSB (real)			
Output	Output signal of symbols (real)			

Notes

1. This model outputs integer symbols in the Range/Type of 0, ..., 2^{NB} – 1 from an integer input signal made up of 0's and 1's.
2. Each incoming NB bits are grouped and mapped to one of the corresponding above symbols (BMEN interprets the value of each bit as follows: V<0.5 : binary 0, V>=0.5 : binary 1).
3. The ratio of the output symbol rate to that of the input bit rate is 1/NB.

Netlist Form

```
ABMEN:Name n1  n2 nexsys_component=BMEN NB=val [Rin1=val]
[Rin2=val][Rout=val]
```

Netlist Example

```
ABMEN:1 1  2 nexsys_component=BMEN NB=2
```

Binary to NRZ Converter (BTONRZ)

Property	Description	Units	Default	Range/Type
TYPE	Type of mapping:{0} / {1}	None	0	[0, 1]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (complex)			
Output	Output Signal (real)			

Notes

1. This model converts binary bits to non-return zero signal. If TYPE is set to 0, a binary bit 0 is mapped to +1 and a binary bit 1 is mapped to -1. Otherwise, a binary bit 0 is mapped to -1 and a binary bit 1 is mapped to +1. The relation of the output z and the input x is given by

$$z = \begin{cases} -1 & x \geq 0.5 \\ 1 & x < 0.5 \end{cases} \quad \text{for} \quad TYPE = 0 \qquad (1)$$

$$z = \begin{cases} 1 & x \geq 0.5 \\ -1 & x < 0.5 \end{cases} \quad \text{for} \quad TYPE = 1 \qquad (2)$$

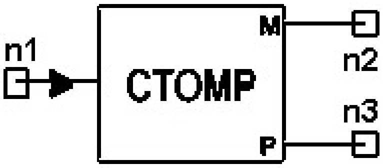
Netlist Form

```
ABTONRZ:NAME  n1 n2 nexsys_component=BTONRZ [TYPE=val]
[RIN=val] [ROUT=val]
```

Netlist Example

```
ABTONRZ:1 1 2 nexsys_component=BTONRZ
```

Complex to Magnitude & Phase Converter (CTOMP)



Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT1	Output1 impedance	Ohm	0	[0, Inf)/Real
ROUT2	Output2 impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (complex)			
Outpu1t	Output1 Signal (real)			
Output2	Outpu2t Signal (real)			

Notes

1. This model converts a complex signal to two real signals. The first output signal is the magnitude of the input signal and the other is the phase of the input signal, in radians.

Netlist Form

```
ACTOMP:NAME  n1 n2 n3 nexsys_component=CTOMP [RIN=val]
[ROUT1=val] [ROUT2=val]
```

Netlist Example

```
ACTOMP:1 1 2 3 nexsys_component=CTOMP
```

Complex to Real Converter (CTOR)

Property	**Description**	**Units**	**Default**	**Range/Type**
Phase	Phase for transforming input signal	Deg	0	[-180, 180]/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (complex)			
Output	Output Signal (real)			

Notes

This model converts the complex input signal Vin(t) into a real output signal Vout(t) accroding to the following equation:

Vout(t) = Re{Vin(t)} cos(PHASE) + Im{Vin(t)}sin(PHASE)

For PHASE = 0deg, the output equals the real part of the input signal, and for PHASE = 90 deg the output equals the imaginary part of the input signal .

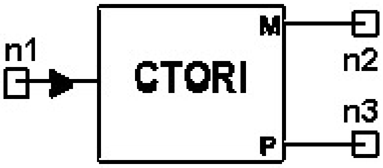
Netlist Form

```
ACTOR:Name n1  n2 nexsys_component=CTOR PHASE=val [Rin1=val]
[Rin2=val][Rout=val]
```

Netlist Example

```
ACTOR:1 1  2 nexsys_component=CTOR PHASE=90DEG
```

Complex to Real & Imaginary Converter (CTORI)



Property	Description	Units	Default	Range/Type
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
ROUT1	Output1 impedance	Ohm	0	[0, Inf)/Real
ROUT2	Output2 impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (complex)			
Output1	Output1 Signal (real)			
Output2	Output2 Signal (real)			

Notes

1. This model converts a complex signal to two real signals. The first output signal is the real part of the input signal and the other is the imaginary part.

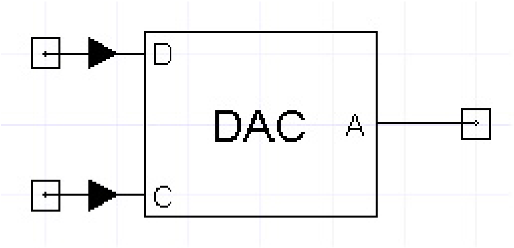
Netlist Form

```
ACTORI:NAME  n1 n2 n3 nexsys_component=CTORI[RIN=val]
[ROUT1=val] [ROUT2=val]
```

Netlist Example

```
ACTORI:1 1 2 3 nexsys_component=CTORI
```

Serial Digital to Analog Converter (DAC)

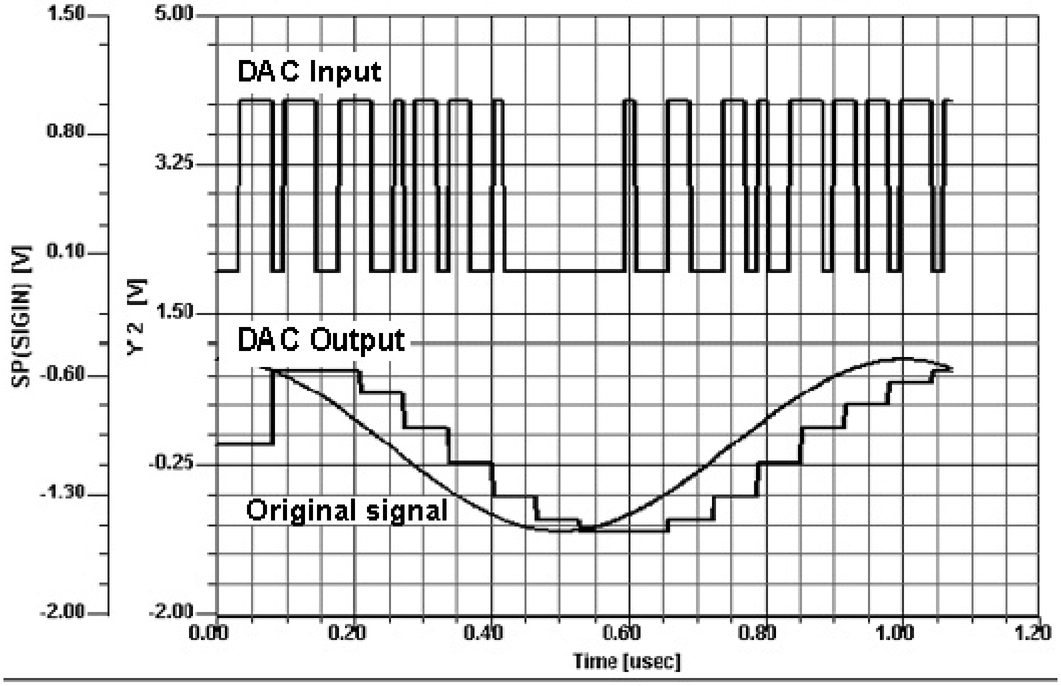


Property	Description	Units	Default	Range/Type
NBITS	Number of bits	None	8	(0, Inf)/Real
VH	Maximum output voltage, in voltage units	Volt	-1V	(-Inf, Inf)/Real
VL	Minimum output voltage, in voltage units	Volt	1V	(-Inf, Inf)/Real
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 bit stream (real)			
Input2	Input2 clock input (real)			
Output	Output signal (real)			

Notes

1. This DAC accepts a serial binary input and converts it into the appropriate analog voltage. At each positive clock edge (when the clock voltage becomes greater than 0.5V) the input signal is sampled and compared to 0.5V to determine if it is a logic 0
or 1. Once nbits bits are clocked into the DAC, the output voltage is calculated. It is assumed that the LSB is clocked in first and the MSB is clocked in last.
2. The following figure shows outputs for an ADC and A DAC with Nbit s= 4, VL = -1V and I = 1V. The clock has a rate of 0.015625 μs, thus, the DAC element outputs a new analog

sample every 0.125 µs.



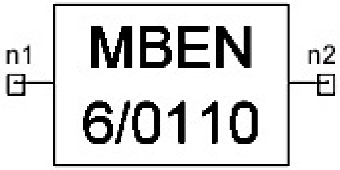
Netlist Form

```
ADAC:Name n1  n2  n3 nexsys_component=DAC NBITS=val  VL=val
VH=val [Rin1=val] [Rin2=val][Rout=val]
```

Netlist Example

```
ADAC:1 1  2  3 nexsys_component=DAC NBITS=4  VL=-1  VH=1
```

M-ary to Binary Decoder (MBEN)



Property	Description	Units	Default	Range/Type
NB	Number of bits to group into one symbol	None	2	[1, 32]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal of symbols (real)			
Output	Output signal of bits, LSB first (real)			

Notes

1. This model converts the M-ary input signal into a binary output signal of 0's and 1's.
2. The input signal is made of symbols (voltages) in the Range/Type of (0,...., 2^{NB} –1).
3. The ratio of the output bit rate to the input symbol rate is given by NB. For example, with NB=5, the MBEN expects an input voltage in the range [0,31]V. For an input of 0V, the 5-bit MBEN outputs 00000. For an input of 31V, the 5-bit MBEN outputs 11111.
4. For negative input voltages, the MBEN outputs NB bits of zeros.
5. For voltages above (2^{NB} –1), the MBEN outputs NB bits of ones (i.e., the maximum value).

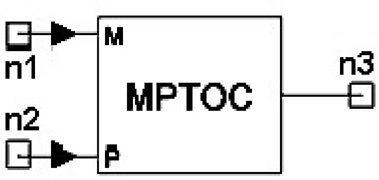
Netlist Form

```
AMBEN:Name n1  n2 nexsys_component=MBEN NB=val [Rin1=val]
[Rin2=val][Rout=val]
```

Netlist Example

```
AMBEN:1 1  2 nexsys_component=MBEN NB=4
```

Magnitude & Phase to Complex Converter (MPTOC)



Property	Description	Units	Default	Range/Type
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input signal (real)			
Input2	Input2 signal (real)			
Output	Output Signal (complex)			

Notes

1. This model converts two real signals to a complex signal. The first input signal is treated as the magnitude and the other as the phase of the output signal in radians.

Netlist Form

```
AMPTOC:NAME  n1 n2 n3 nexsys_component=MPTOC [RIN1=val] [RIN2=val]
[ROUT=val]
```

Netlist Example

```
AMPTOC:1 1 2 3 nexsys_component=MPTOC
```

NRZ to Binary Converter (NRZTOB)

Property	Description	Units	Default	Range/Type
TYPE	Type of mapping:{0} / {1}	None	0	[0, 1]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This model converts non-return zero signal to binary bits. The relation of the output z and the input x is given by

$$z=\begin{cases}0 & x\ge 0\\ 1 & x<0\end{cases}\qquad TYPE=0$$

for (1)

$$z=\begin{cases}1 & x\ge 0\\ 0 & x<0\end{cases}\qquad TYPE=1$$

for (2)

Netlist Form

```
ANRZTOB:NAME  n1 n2 nexsys_component=NRZTOB [TYPE=val]
[RIN=val] [ROUT=val]
```

Netlist Example

```
ANRZTOB:1 1 2 nexsys_component=NRZTOB
```

Parallel Analog to Digital Converter (PADC)

Property	Description	Units	Default	Range/Type
NBITS	Number of bits per sample	None	8	[1, 32]/Integer
VL	Minimum input voltage	Volt	-1	(-Inf, Inf)/Real
VH	Maximum input voltage	Volt	1	(-Inf, Inf)/Real
RIN1	Input impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input signal (real)			
Input2	Input clock signal (real) [Optional]			
Output	Output signal (real)			

Limits

1. VH> VL

Notes

1. The first input is supposed to be the analog signal to be sampled and quantized, while the second input is the clock signal. From the rising edge of the digital clock input to the parallel ADC, the input waveform is sampled and quantized. The number of quantization levels is equal to 2^nbits, with the range of input values being determined by **vl** and **vh**. Input signal values outside of this range outputs 0 on the low side and (2^nbits-1) on the high side.
2. If a clock signal is not supplied on *n2*, the output is clocked out for every incoming sample.

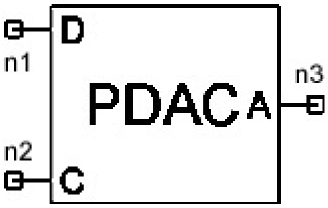
Netlist Form

```
APADC:NAME n1 n2 n3 nexsys_component=PADC nbits=val vl=val
vh=val [Rin1=val] [Rin2=val] [Rout=val]
```

Netlist Example

```
APADC:1 1 2 3 nexsys_component=PADC nbits=8 vl=0 vh=1
```

Parallel Digital to Analog Converter (PDAC)



Property	Description	Units	Default	Range/Type
NBITS	Number of bits per sample	None	8	[1, 32]/Integer
VL	Minimum output voltage	Volt	-1	(-Inf, Inf)/Real
VH	Maximum output voltage	Volt	1	(-Inf, Inf)/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (real)			
Input2	Input2 clocksignal (real) [Optional]			
Output	Output signal (real)			

Limits

1. VH > VL

Notes

1. From the rising edge of the digital clock input to the parallel DAC, the input digital signal is converted to analog. The number of quantization levels is equal to 2^nbits. The range of output values is determined by **vl** and **vh**. The output value is calculated like this:

$$v_{out}(n) = \frac{v_{in}(n)}{2^{nbits}} * (v_h - v_l) + v_l$$

2. The input signal is assumed to be in the range of [0, 2^nbits-1], if the input signal is out of this range, then it is regarded as 0 for those less than 0, and 2^nbits-1 for those greater than 2^nbits-1.
3. The clock signal is assumed to be thresholded at 0.5.
4. If a clock signal is not supplied on *n2*, the output is clocked out for every incoming sample.

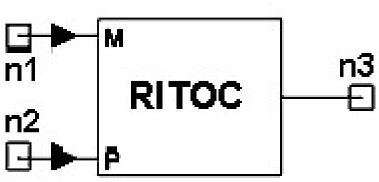
Netlist Form

```
APDAC:NAME n1 n2 n3 nexsys_component=PDAC nbits=val vl=val
vh=val [Rin1=val] [Rin2=val] [Rout=val]
```

Netlist Example

```
APDAC:1 1 2 3 nexsys_component=PDAC nbits = 8 vl = 0 vh = 1
```

Real & Imaginary to Complex Converter (RITOC)



Property	Description	Units	Default	Range/Type
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (real)			
Input2	Input2 signal (real)			
Output	Output Signal (complex)			

Notes

1. This model converts two real signals to a complex signal. The first input signal is treated as the real part and the other as the imaginary part.

Netlist Form

```
ARITOC:NAME  n1 n2 n3 nexsys_component=RITOC [RIN1=val]
[RIN2=val] [ROUT=val]
```

Netlist Example

```
ARITOC:1 1 2 3 nexsys_component=RITOC
```

Real Input to Complex Output (RTOC)

Property	**Description**	**Units**	**Default**	**Range/Type**
Phase	Phase for transforming input signal	Deg	0	[-180, 180]/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (complex)			

Notes

1. This model converts the real input signal Vin(t) into a complex output signal Vout(t) according to the following equations:
   Re{Vout(t)} = Vin(t) cos(PHASE)
   Im{Vout(t)} = Vin(t) sin(PHASE)
   For PHASE = 0deg, the output is real and equals the input signal (i.e., imaginary part is zero) and for PHASE = 90deg the output is pure imaginary and equals Vin(t) (i.e., real part is zero).

Netlist Form

```
ARTOC:Name n1  n2 nexsys_component=RTOC PHASE=val [Rin1=val]
[Rin2=val][Rout=val]
```

Netlist Example

```
ARTOC:1 1  2 nexsys_component=RTOC PHASE=90DEG
```

Demodulators

This topic describes the following System components:

Synchronous Amplitude Demodulator (AMDEM)

Property	Description	Units	Default	Range/Type
SEN	Demodulation sensitivity, in voltage units per volt	None	1V	[-1e6, 1e6)/Real
PHAS	Carrier phase offset	Deg	0	[-180, 180]/Real
TYPE	Type of Synchronous AM demodulator 1: In-phase AM demodulator 2: Quad-phase AM demodulator	None	1	[1, 2]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	The input AM modulated signal (complex)			
Output	The output of AM demodulator (complex)			

Notes

1. This model performs AM demodulation. The input to this model is assumed to be an AM modulated bandpass signal with in-phase and quad-phase envelopes $v_{in,i}(t)$ and $v_{in,q}(t)$. The output is a baseband signal.

   There are two different AM demodulators. The output quad-phase is always 0, and the in-phase signal is given as follows, respectively

   (1) TYPE = 1 for In-phase AM demodulator, $v_{out,i}(t) = SEN \bullet I(t)$
   (2) TYPE = 2 for Quad-phase AM demodulato, $v_{out,i}(t) = SEN \bullet Q(t)$

   where
   $I(t) = v_{in,i}(t) \bullet \cos(\Theta) + v_{in,q}(t) \bullet \sin(\Theta)$
   $Q(t) = -v_{in,i}(t) \bullet \sin(\Theta) + v_{in,q}(t) \bullet \cos(\Theta)$
   $\theta = PHAS \bullet \pi / 180$

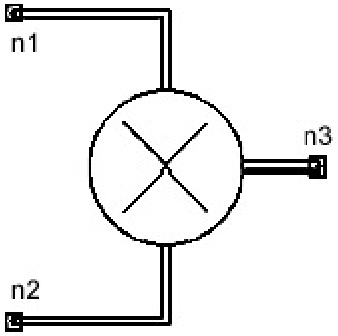
Netlist Form

`AAMDEM:Name` *`n1  n2`* `nexsys_component=AMDEM SEN=`*`val`* `[PHAS=`*`val`*`]` `[TYPE=`*`val`*`] [Rin=`*`Val`*`] [Rout=`*`Val`*`]`

Netlist Example

```
AAMDEM:1 1  2 nexsys_component=AMDEM SEN=1.2  PHAS=0DEG  TYPE=1
```

Complex Multiplier (CMULT)



Property	Description	Units	Default	Range/Type
TYPE	Type of multiplier: 1: High side multiplier 2: Low side multiplier	None	1	[1, 2]/Integer
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (complex)			
Input2	Input2 signal (complex)			
Output	Output signal (complex)			

Notes

1. This model performs complex multiplication. If both inputs to this model are baseband signals $v_{in,1}(t)$ and $v_{in,2}(t)$, the output is baseband signal. The output quad-phase is 0, and in-phase signal is given as follows
   $v_{out,i}(t) = v_{in,1,i}(t) \bullet v_{in,2,i}(t)$

   If both the inputs to this model are bandpass signals with the in-phase and quad-phase envelopes $v_{in,1,i}(t)$, $v_{in,1,q}(t)$ and $v_{in,2,i}(t)$, $v_{in,2,q}(t)$, the output is bandpass signal and has the different output carrier frequency. The output carrier frequency, in-phase and quad-phase envelopes are given as follows, respectively
2. TYPE = 1 for high side multiplier

$f_{out} = f_{in,1} + f_{in,2}$

$v_{out,i}(t) = v_{in,1,i}(t) \bullet v_{in,2,i}(t) - v_{in,1,q}(t) \bullet v_{in,2,q}(t)$

$v_{out,q}(t) = v_{in,1,i}(t) \bullet v_{in,2,q}(t) + v_{in,1,q}(t) \bullet v_{in,2,i}(t)$

3. TYPE = 2 for low side multiplier

   if $f_{in,1} > f_{in,2}$

   $f_{out} = f_{in,1} - f_{in,2}$

   $v_{out,i}(t) = v_{in,1,i}(t) \bullet v_{in,2,i}(t) + v_{in,1,q}(t) \bullet v_{in,2,q}(t)$

   $v_{out,q}(t) = -v_{in,1,i}(t) \bullet v_{in,2,q}(t) + v_{in,1,q}(t) \bullet v_{in,2,i}(t)$

   if $f_{in,1} = f_{in,2}$

   $f_{out} = 0$

   $v_{out,i}(t) = v_{in,1,i}(t) \bullet v_{in,2,i}(t) - v_{in,1,q}(t) \bullet v_{in,2,q}(t)$

   $v_{out,q}(t) = 0$

   if $f_{in,1} < f_{in,2}$

   $f_{out} = f_{in,2} - f_{in,1}$

   $v_{out,i}(t) = v_{in,1,i}(t) \bullet v_{in,2,i}(t) + v_{in,1,q}(t) \bullet v_{in,2,q}(t)$

   $v_{out,q}(t) = v_{in,1,i}(t) \bullet v_{in,2,q}(t) - v_{in,1,q}(t) \bullet v_{in,2,i}(t)$

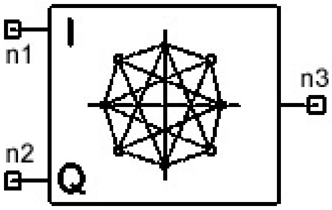
Netlist Form

```
ACMULT:Name n1  n2  n3 nexsys_component=CMULT [TYPE=val]
[Rin1=Val] [Rin2=Val] [Rout=Val]
```

Netlist Example

```
ACMULT:1 1  2  3 nexsys_component=CMULT TYPE=2
```

PI/4DQPSK Demodulator (DQPSKDEM)



Property	Description	Units	Default	Range/Type
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	in-phase input (real)			
Input2	Quadrature input (real)			
Output	Demodulated output symbols (real)			

Notes

1. This model performs PI/4DQPSK demodulation. The in-phase and quadrature inputs to this model (ri(n) and rq(n), n ≥ 0) are assumed to have been modulated by the model PI/4DQPSK.

   Since the input to the modulator PI/4DQPSK is assumed to be the symbol values A(n) = 0, 1, 2, 3, n ≥ 0, the recovered symbol values at the output of the demodulator B(n) are also 0, 1, 2, 3, for n ≥ 0.

   Let the received complex (in-phase + quadrature) symbols be r(n) = ri(n) + j rq(n), n ≥ 0. The demodulation process is performed as follows for n ≥ 0:

B(n) = 0, Re{r(n)r*(n-1)} > 0, Im{r(n)r*(n-1)} > 0

B(n) = 1, Re{r(n)r*(n-1)} < 0, Im{r(n)r*(n-1)} > 0

B(n) = 2, Re{r(n)r*(n-1)} > 0, Im{r(n)r*(n-1)} < 0

B(n) = 3, Re{r(n)r*(n-1)} < 0, Im{r(n)r*(n-1)} < 0 where r*(n-1) is the complex conjugate of r(n-1), and Re{.} and Im{.} denote the real and imaginary operators respectively. The following initial condition is always assumed:

r(-1) = cos(PI/4) + j sin(PI/4)

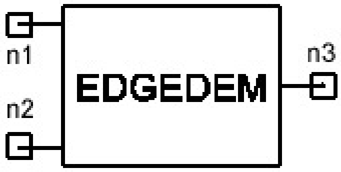
Netlist Form

```
ADQPSKDEM:Name n1 n2 n3 nexsys_component=DQPSKDEM [Rin1=Val]
[Rin2=Val] [Rout=Val]
```

Netlist Example

```
ADQPSKDEM:1 1 2 3 nexsys_component=DQPSKDEM
```

Edge Demodulator (EDGEDEM)



Property	Description	Units	Default	Range/Type
DECISION	Hard{0}/soft{1} output selection	None	0	[0, 1]/Integer
RIN1	Input impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	The FM modulated I-input signal (complex)			
Input2	The FM modulated Q-input signal (complex)			
Output	The output of FM demodulator (complex)			

Notes

1. This element converts received I/Q signal stream into bit stream based on the EDGE 8PSK modulation. Each three output bits correspond to a pair of in-phase and quadrature input signals. Depending upon *DECISION*=0 or *DECISION*=1, the output can be either hard (e.g., 0,1,1,0,0,1,…) or soft (e.g., -0.21, 1.13, 0.82, -1.33, -0.78, 1.41, …). Performance can be maximized when the soft output in conjunction with channel coding are employed.
2. Let <Θ_n> be the estimated signal phase with removal of the additional phase shift $\Theta_{n.,\ offset}$, corresponding to the time index *n*. The hard-output decision rule (i.e., the mapping of <Θ_n> onto output bits) follows:

$$-\frac{\pi}{8} < \hat{\theta}_n \le \frac{\pi}{8} \rightarrow 111 \quad , \quad \frac{\pi}{8} < \hat{\theta}_n \le \frac{3\pi}{8} \rightarrow 011 \quad ,$$

$$\frac{3\pi}{8} < \hat{\theta}_n \le \frac{5\pi}{8} \rightarrow 010$$, $$\frac{5\pi}{8} < \hat{\theta}_n \le \frac{7\pi}{8} \rightarrow 000$$,

$$\frac{7\pi}{8} < \hat{\theta}_n \le \frac{9\pi}{8} \rightarrow 001$$, $$\frac{9\pi}{8} < \hat{\theta}_n \le \frac{11\pi}{8} \rightarrow 101$$,

$$\frac{11\pi}{8} < \hat{\theta}_n \le \frac{13\pi}{8} \rightarrow 100$$, $$\frac{13\pi}{8} < \hat{\theta}_n \le \frac{15\pi}{8} \rightarrow 110$$.

In contrast with the hard-output demodulation, the soft-output demodulation uses a bit-by-bit decision rule called maximum a posteriori (MAP). For any given time index, let $X = x_I + j \bullet x_Q$, $|X| = 1$, be a signal taken on the normal 8PSK signal set S, represent the binary bit triplet mapping onto a 8PSK signal, and $Y = y_I + j \bullet y_Q$, be received baseband signal with removal of the additional phase shift. The soft-output value <b$_k$> (corresponding to b_k), k = 1,2,3..., is
given by

$$\tilde{b}_k = \ln\left[\sum_{X \in S, b_k = 1} \Pr(X \mid Y)\right] - \ln\left[\sum_{X \in S, b_k = 0} \Pr(X \mid Y)\right], \quad k = 1,2,3$$

If the channel noise is AWGN, it can be proved that probability Pr(X|Y) in above equation can be expressed as

$$\Pr(X \mid Y) = C \cdot \exp\left[(x_I \cdot y_I + x_Q \cdot y_Q) \cdot \alpha / \sigma^2\right]$$,

where Cis a constant, α is received signal amplitude and σ^2 denotes the noise power. For simplification, factor α/σ^2 is not taken into account inside this demodulator, and ,b$_k$> is actually computed by using equation

$$\tilde{b}_k = \ln\left[\sum_{X\in S,b_k=1}\exp(x_I\cdot y_I + x_Q\cdot y_Q)\right] - \ln\left[\sum_{X\in S,b_k=0}\exp(x_I\cdot y_I + x_Q\cdot y_Q)\right], \quad k=1,2,3$$

which implies that, in the case that the channel is fading, the input signal should be weighted by instantaneous amplitude α to achieve better performance. Note that this modification in calculating the soft-output values do not degrade BER performance when a Viterbi decoder following the demodulator is used at the receiver.

Additional details about the EDGE 8PSK modulation can be found in [1]. For soft-output processing, refer to [2]-[4].

Netlist Form

```
AEDGEDEM:Name n1 n2 n3 nexsys_component=EDGEDEM DECISION=val
[Rin1=val], [Rin2=val], [Rout=val]
```

Netlist Example

```
AEDGEDEM:1 1 2 3 nexsys_component=EDGEDEM DECISION=0
```

References

1. GSM 05.04 (i.e., ETSI EN 300 959): “Digital cellular telecommunications system (Phase 2+); Modulation”
2. R. Herzog, A. Schmidbauer and J. Hagenauer, “Iterative decoding and dispreading improves CDMA-system using M-ary orthogonal modulation and FEC.”
3. L. R. Bahl, J. Cocke, F. Jelinek and J. Ravivo, “Optimal decoding of linear codes for minimizing symbol error rate,” IEEE Trans. Inform. Theory, vol. IT-20, pp. 284-287, Mar. 1974.
4. H. H. Zeng, Y. Li and J. H. Winters, “Improved spatial-temporal equalization for EDGE: a fast selective-direction MMSE timing recory algorithm and two-stage soft-output equalizer,” IEEE Trans. Commun., vol. 49, pp. 2124-2134, Dec. 2001.

Envelope Detector (ENVELOPE)

Property	Description	Units	Default	Range/Type
SEN	Demodulation sensitivity, in voltage units per volt	None	1V	[-1e6, 1e6]/Real
PHAS	Carrier phase offset	Deg	0	[-180, 180]/Real
TYPE	Detection type option (optional): 1: Full rectified envelope 2: In-phase rectified envelope 3:Quadrature-phase rectified envelope	None	1	[1, 3]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	The input AM modulated signal (complex)			
Output	The output of envelope detector (complex)			

Notes

1. This model performs envelope detection. The input to this model is assumed to be an AM modulated bandpass signal with in-phase and quad-phase envelopes $v_{in,i}(t)$ and $v_{in,q}(t)$. The output is a baseband signal.

   There are three different envelope detectors. The output quad-phase is always 0, and the in-phase signal is given as follows, respectively

   TYPE = 1 for full rectified envelope $v_{out,i}(t) = SEN \bullet SQRT(I(t)^2 + Q(t)^2)$
   TYPE = 2 for in-phase rectified envelope $v_{out,i}(t) = SEN \bullet SQRT(I(t)^2)$
   TYPE = 3 for quadrature-phase rectified envelope $v_{out,i}(t) = SEN \bullet SQRT(Q(t)^2)$, where
   $I(t) = v_{in,i}(t) \bullet \cos(\Theta) + v_{in,q}(t) \bullet \sin(\Theta)$
   $Q(t) = -v_{in,i}(t) \bullet \sin(\Theta) + v_{in,q}(t) \bullet \cos(\Theta)$
   $\Theta = PHAS \bullet \pi / 180$

Netlist Form

```
AENVELOPE:Name n1  n2 nexsys_component=ENVELOPE SEN=val
[PHAS=val]  [TYPE=val] [Rin=val] [Rout=Val]
```

Netlist Example

```
AENVELOPE:1 1  2 nexsys_component=ENVELOPE SEN=1.2  PHAS=0DEG
TYPE=1
```

Frequency Demodulator (FMDEM)

Property	Description	Units	Default	Range/Type
SEN	Frequency demodulation sensitivity, in voltage units per Hz	None	0	[-1e6 1e6]/Real
PHAS	Carrier phase offset	Deg	0	[-180, 180]/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	The input FM modulated signal (complex)			
Output	The output of FM demodulator (complex)			

Notes

1. This model performs FM demodulation. The input to this model is assumed to be an FM modulated bandpass signal with in-phase and quad-phase envelopes $v_{in,i}(t)$ and $v_{in,q}(t)$. The output is a baseband signal. The output quad-phase is 0, and the in-phase signal is given as follows

   $v_{out,i}(t) = SEN \cdot (I(t) \cdot d[Q(t)]/dt - Q(t) \cdot d[I(t)]/dt) / (2\pi \cdot (I(t)^2 + Q(t)^2))$ where
   $I(t) = v_{in,i}(t) \cdot \cos(\Theta) + v_{in,q}(t) \cdot \sin(\Theta)$
   $Q(t) = -v_{in,i}(t) \cdot \sin(\Theta) + v_{in,q}(t) \cdot \cos(\Theta)$
   $\Theta = PHAS \cdot \pi / 180$

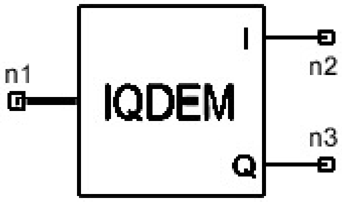
Netlist Form

```
AFMDEM:Name n1  n2 nexsys_component=FMDEM SEN=val  [PHAS=val]
[Rin=Val] [Rout=Val]
```

Netlist Example

```
AFMDEM:1 1  2 nexsys_component=FMDEM SEN=1.2  PHAS=90DEG
```

I-Q Demodulator (IQDEM)



Property	Description	Units	Default	Range/Type
S	Sensitivity	None	1	[-1e6, 1e6]/Real
P	Phase reference	Deg	0	[-180, 180]/Real
PHIQ	I-Q phase imbalance	Deg	0	[180, 180]/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT1	Output1 impedance	Ohm	0	[0, Inf)/Real
ROUT2	Output2 impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (complex)			
Output1	in-phase output signal (real)			
Output2	Quadrature output signal (real)			

Notes

1. For a given input signal

$$V_{in}(t) = A(t)\cos(2\pi f_c t + \theta(t))$$

the baseband in-phase output signal is computed as:

$$V_{Iout}(t) = S\{A(t)\cos(\theta(t))\cos(P) - A(t)\sin(\theta(t))\sin(P + PHIQ)\}$$

and the baseband quadrature output signal is computed as:

$$V_{Qout}(t) = S\left\{A(t)\cos(\theta(t))\sin(P) + A(t)\sin(\theta(t)\cos(P + PHIQ))\right\}$$

The output signal is always assumed to be baseband (i.e., fc=0) regardless of the input carrier frequency.

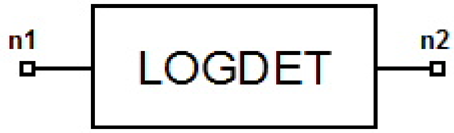
Netlist Form

```
AIQDEM:Name n1  n2  n3 nexsys_component=IQDEM S=val  P=val
PHIQ=val [Rin=val] [Rout=val]
```

Netlist Example

```
AIQDEM:1 1  2  3 nexsys_component=IQDEM S=1 P=0DEG PHIQ=0DEG
```

Logarithmic Detector (LOGDET)



Property	Description	Units	Default	Range/Type
SEN	Log sensitivity, in voltage units per dB	None	0	[0, Inf)/Real
PL	Low input power	Watt	0W	[1e-23, 1e7]/Real
E	Peak log error, in dB	dB	0	[0, 200]/Real
EC	Log error cycle, in dB	dB	1	[0, 200]/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	The input signal (complex)			
Output	The output signal (complex)			

Notes

1. This model performs logarithmic detection. The input to this model is assumed to be a bandpass signal with in-phase and quad-phase envelopes $v_{in,i}(t)$ and $v_{in,q}(t)$. The output is a baseband signal. The output quad-phase is 0, and the in-phase signal is given as follows
   $v_{out,i}(t) = M2(t)$ where
   $A1(t) = SQRT(v_{in,i}(t)^2 + v_{in,q}(t)^2)$
   $M2(t) = 20 \bullet SEN \bullet LOG10(A1(t)/VL) + SEN \bullet E \bullet \sin(\Theta)$ for $A1(t) > VL$
   $M2(t) = 0$ for $A1(t) \le VL$
   $VL = SQRT(2 \bullet 50 \bullet PL)$
   $\Theta = 2 \bullet \pi \bullet (PA - 10 \bullet LOG10(PL))/EC$
   $PA = 10 \bullet LOG10(A1(t)^2/(2 \bullet 50))$

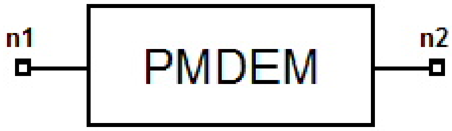
Netlist Form

```
ALOGDET:Name n1  n2 nexsys_component=LOGDET SEN=val  PL=val
E=val  EC=val [Rin=val] [Rout=val]
```

Netlist Example

```
ALOGDET:1 1  2 nexsys_component=LOGDET SEN=1.2  PL=10W
E=0.75dB  EC=10dB
```

Phase Demodulator (PMDEM)



Property	Description	Units	Default	Range/Type
SEN	Phase demodulation sensitivity, in voltage units per degree	None	1	[-1e6, 1e6]/Real
PHAS	Carrier phase offset	Deg	0	[-180, 180]/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	The input PM modulated signal (complex)			
Output	The output of PM demodulator (complex)			

Notes

1. This model performs PM demodulation. The input to this model is assumed to be a PM modulated bandpass signal with in-phase and quad-phase envelopes $v_{in,i}(t)$ and $v_{in,q}(t)$. The output is a baseband signal. The demodulated quad-phase is 0, and the in-phase signal is given as follows:

   $v_{out,i}(t) = SEN \bullet ATAN2[Q(t), I(t)] \bullet 180 / \pi$, where
   $I(t) = v_{in,i}(t) \bullet \cos(\Theta) + v_{in,q}(t) \bullet \sin(\Theta)$
   $Q(t) = -v_{in,i}(t) \bullet \sin(\Theta) + v_{in,q}(t) \bullet \cos(\Theta)$
   $\Theta = PHAS \bullet \pi / 180$

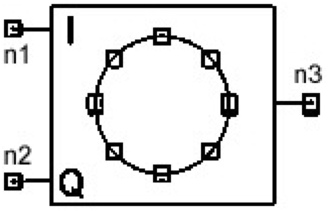
Netlist Form

```
APMDEM:Name n1  n2 nexsys_component=PMDEM SEN=val  [PHAS=val]
[Rin=Val] [Rout=Val]
```

Netlist Example

```
APMDEM:1 1  2 nexsys_component=PMDEM SEN=1.2  PHAS=0DEG
```

Phase Shift Keying Demodulator (PSKDEM)



Property	Description	Units	Default	Range/Type
M	The order of the signal space. M = 2: BPSK, M = 4: QPSK, etc.	None	2	[2, 128]/Integer
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Real part of the complex input signal (real)			
Input2	Imaginary part of the complex input signal (real)			
Output	Output signal of symbols in the Range/Type 0,....., M -1 (real)			

Notes

1. This model maps each pair of samples (one from each input signal) into one symbol k, where k is in the Range/Type 0,...., M - 1. This model is normally used in conjunction with the model "Phase Shift Keying Modulator (PSKMOD)" on page 38-439. The symbol which corresponds to the minimum Euclidean distance on the received complex symbol is written to the output.

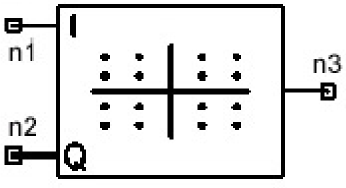
Netlist Form

```
APSKDEM:Name n1 n2 n3 nexsys_component=PSKDEM M=val [Rin1=val]
[Rin2=val] [Rout=val]
```

Netlist Example

```
APSKDEM:1 1 2 3 nexsys_component=PSKDEM M=4
```

QAM Demodulator (QAMDEM)



Property	Description	Units	Default	Range/Type
M	Order of constellation space	None	4	(0, Inf)/Integer
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (real)			
Input2	Input2 signal (real)			
Output	Output signal (real)			

Notes

1. This model outputs N bits for each incoming in-phase and quadrature input samples, where
   $N = Log_2(M)$, and
   M is the order of the constellation space (i.e., M=4 for 4-QAM and M=16 for 16-QAM …)

   For a given M, this model determines the constellation point (in the I — Q signal space) with the minimum metric distance to a given complex (in-phase and quadrature) input sample.

   Once the constellation point is determined, its N-bit binary representation is then transmitted. If this model is immediately preceded by the QAMMOD model, then its output should be identical to the input of the QAMMOD model. The output bit rate is equal to N times the input (I and Q) symbol rate.

Netlist Form

```
AQAMDEM:Name n1  n2  n3 nexsys_component=QAMDEM M=val [Rin1=Val] [Ri2
n=Val] [Rout=val]
```

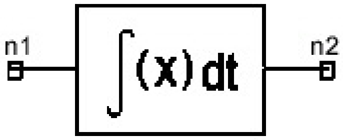
Netlist Example

```
AQAMDEM:1 1  2  3 nexsys_component=QAMDEM M=4
```

Digital Filters

This topic describes the following System components:

Complex Integrator (CINTG)



Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (complex)			
Output	Output signal (complex)			

Notes

1. For a given input signal, $V_{in}(t) = X(t) \cos(2\pi f_c t + \Theta_x(t))$ the output signal is given by $V_{out}(t) = Y(t) \cos(2\pi f_c t + \Theta_y(t))$, where

   The above continuous time integration is actually computed in discrete fashion based on the timestep of the complex input envelope, $X(t) \cdot \exp[j \Theta_x(t)]$

$$Y(t)e^{j\theta_y(t)} = \int_0^t X(\tau)e^{j\theta_x(\tau)}d\tau$$

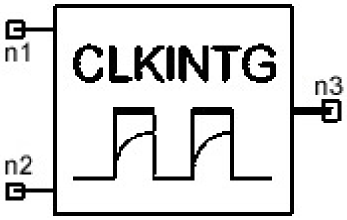
Netlist Form

```
ACINTG:Name n1 n1 nexsys_component=CINTG
NUM_OF_SAMPLES=val [Rin=val] [Rout=val]
```

Netlist Example

```
ACINTG:1 1 2 nexsys_component=CINTG NUM_OF_SAMPLES=100
```

Integrator with Clock (CLKINTG)

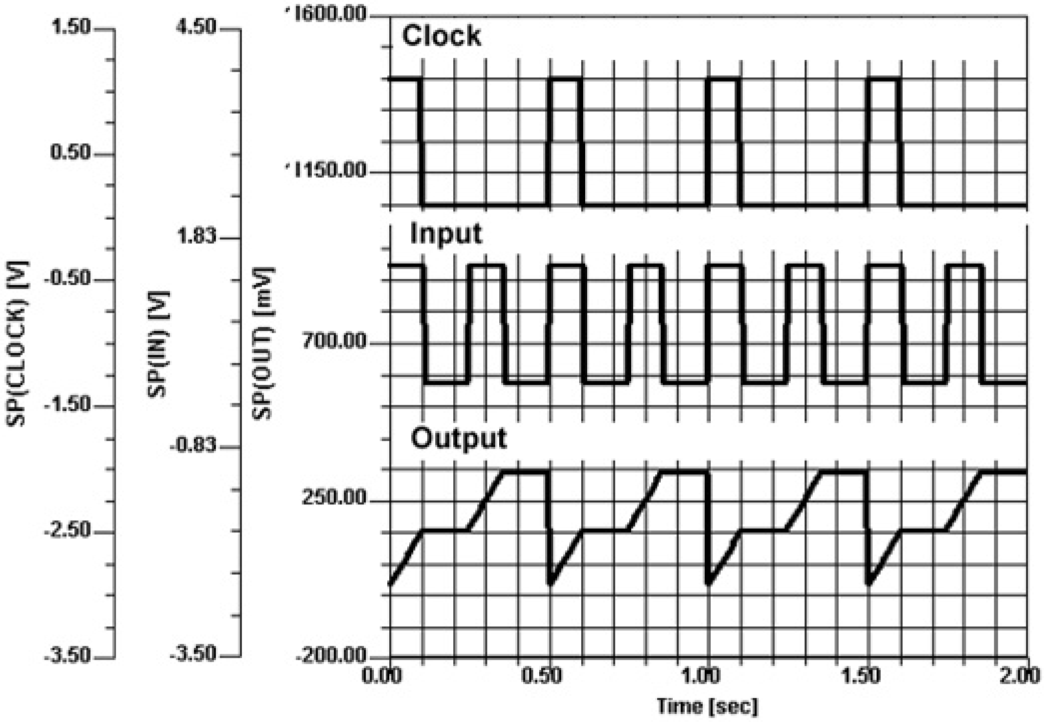


Property	Description	Units	Default	Range/Type
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This element performs an integration on the input signal during the time interval determined by the clock signal. Let T_0, T_1, T_2, … be the time instances with the positive edges of the input clock, $V_2(t)$, occur (a positive edge occurs at the instant when the clock voltage, $V_2(t)$, crosses a threshold of 0.5V). The output signal $V_3(t)$ is then determined by the following equations in terms of input signal $V_1(t)$.
   The integration is performed using the trapezoidal rule. The input signal, clock signal, and output signal voltages of the CLKINTG element are shown in the figure.

$$V_3(t) = \int_{T_k}^{t} \mathrm{V}_1(\mathrm{t})\mathrm{dt} \quad \mathrm{T}_k < \mathrm{t} \leq \mathrm{T}_{k+1}$$



Netlist Form

```
ACLKINTG:Name n1  n2  n3 nexsys_component=CLKINTG [Rin1=val]
[Rin2=val][Rout=val]
```

Netlist Example

```
ACLKINTG:1 1  2  3 nexsys_component=CLKINTG
```

Finite Impulse Response Filter (FIR)

Property	Description	Units	Default	Range/Type
FILE	External filename	None	<Project>	String
TRAN	0 = Discard transient samples, 1 = Retain samples	None	0	[0, 1]/Integer
RIN1	Input 1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input 2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (real)			
Input2	Input2 clock signal (real, optional)			
Output	The output signal (real)			

Notes

1. This model implements FIR filter. The transfer function is of the form

$$H(Z) = \sum_{k=0}^{M} b_k Z^{-k}$$

2. The filter tap coefficients are provided in the data block in two-column XY DSP format. Each (X,Y) entry indicates the tap index and the corresponding tap coefficient (k, b_k).
3. The second input is optional. If it is connected, this model operates as an edge triggered device, with the trigger level 0.5V.

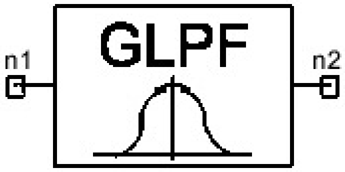
Netlist Form

```
AFIR:NAME n1 n2 n3 nexsys_component=FIR FILE=”filename.dsp”
[Rin1=val] [Rin2=val]
+ [Rout=val] [TRAN=val]
```

Netlist Example

```
AFIR:1 1 2 3 nexsys_component=FIR FILE="firdata.dsp"
```

Gaussian Low Pass Filter (GLPF)



Property	Description	Units	Default	Range/Type
FB	Effective Bandwidth Frequency	Hz	50000	(0, Inf)/Real
FILT_LENGTH	Number of filter coefficients	None	16	[8, Inf)/Integer
TRAN	0 = Discard transient samples, 1 = Retain samples	None	0	[0, 1]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Filtered output signal (real)			

Notes

1. This is a lowpass filter model which has the following transfer function
   H(f) = sqrt (2) exp [-ln (2) * ($f^{2/FB}$)] for - Inf < f < Inf
   where FB is the effective 3dB bandwidth of the filter.
2. The impulse response of the filter is obtained by implementing the above function in the FFT domain (taking the input sampling frequency (FS) into consideration) , then using an inverse FFT of length FFTL which must be a power of 2. This FFTL is given by:

   FFTL = Minimum power of 2 larger than 2 x FILT_LENGTH.
3. Note that the above frequency response must be truncated in the frequency domain since it has an infinite duration. This means that there is always aliasing regardless of the FFT length chosen. Upon finding the impulse response, the filter is made causal by delaying the impulse response.

   For a more accurate impulse response, the user must ensure

FILT_LENGTH ≥ 5.0(FS/FB)

4. The program does not issue a warning message if this condition is not met.

Netlist Form

```
AGLPF:Name n1 n2  nexsys_component=GLPF
FB=val  FILT_LENGTH=val [Rin=val] [Rout=val]
[TRAN=val]
```

Example

```
AGLPF:1 1  2  nexsys_component=GLPF FB=100KHZ  FILT_LENGTH=32
```

Infinite Impulse Response Filter (IIR)

Property	Description	Units	Default	Range/Type
FILE	File name	None	<Project>	String
RIN1	Input 1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input 2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input 1 signal (real)			
Input2	Input 2 clock signal (real, optional)			
Output	Output signal (real)			

Notes

1. This model implements IIR filter. I can be either clocked or non-clocked. If non-clocked, the second input port should be left open. The transfer function is of the form

$$H(Z)=\frac{\sum_{k=0}^{M} b_k Z^{-k}}{\sum_{k=0}^{N} a_k Z^{-k}} \qquad (1)$$

2. The filter tap coefficients are provided in the data block in two-column XY DSP format. Each (X,Y) entry indicates the coefficients (a_k, b_k).

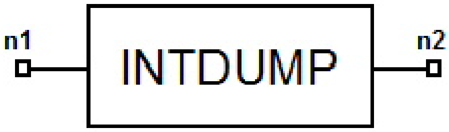
Netlist Form

```
AIIR:NAME n1 n2 n3 nexsys_component=IIR FILE=”filename.dsp”
[RIN1=val] [RIN2=val]
+ [ROUT=val]
```

Netlist Example

```
AIIR:1 1 2 3 nexsys_component=IIR FILE="iirdata.dsp"
```

Integrate and Dump (INTDUMP)



Property	Description	Units	Default	Range/Type
Num_of_ Samples	Number of samples to integrate over each invocation	None	1	[1, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	The input signal (real)			
Output	The output signal (real)			

Notes

1. This model implements an integrate and dump filter. Each output sample y(n) is computed as:

$$y(n) = \frac{1}{NumOfSamples} \sum_{m=0}^{NumOfSamples-1} x(NumOfSamples(n+1)-m)$$

where *x*(n) is the input sequence

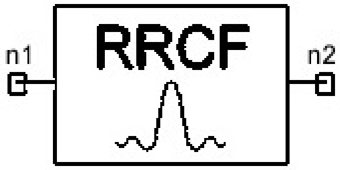
Netlist Form

```
AINTDUMP:name n1  n2  nexsys_component=AINTDUMP
NUM_OF_SAMPLES=val [Rin=val] [Rout=val]
```

Example

```
AINTDUMP  1  2  nexsys_component=AINTDUMP NUM_OF_SAMPLES=100
```

Root Raised Cosine Filter (RRCF)



Property	Description	Units	Default	Range/Type
FC	3 dB Cutoff_Frequency	Hz	50	(0, Inf)/Real
BETA	Rolloff factor	None	0.5	[0, 1]/Real
FILT_LENGTH	Number of filter coefficients	None	16	[9, Inf]/Integer
TRAN	0 = Discard transient samples, 1 = Retain samples	None	0	[0, 1]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This is a lowpass filter model which has the following transfer function:

H(f) = 1, for 0 ≤ |f| ≤ (1 - BETA)* FC

H(f) =sqrt (0.5 * (1 - sin (pi * (|f| - FC)/(2 * FC * BETA))))
for (1 - BETA) * FC ≤ |f| ≤ (1 + BETA) * FC

H(f) = 0, for |f| ≥ (1 + BETA) * FC
where **FC** is the 3 dB cutoff frequency and **BETA** is the rolloff factor.

2. The impulse response of the filter is obtained by implementing the above function in the FFT domain (taking the input sampling frequency (FS) into consideration) , then using an inverse FFT of length FFTL. This length is given by

   FFTL = Minimum power of 2 larger than 2 x FILT_LENGTH.

   Upon finding the impulse response, the filter is made causal by delaying the impulse

response. For a more accurate impulse response, the user must ensure
FILT_LENGTH ≥ 5.0(FS/(1+BETA)FC
and avoid aliasing, the user must ensure that
FS ≥ 2 x(1+ BETA) FC

3. The model does not issue warning messages if these conditions are not met.

Netlist Form

ARRCF:Name 1 2 nexsys_component=RRCF FC=*val* BETA=*val* FILT_LENGTH=*val* [Rin=*val*] [Rout=*val*] [TRAN=*val*]

Netlist Example

ARRCF:1 1 2 nexsys_component=RRCF FC=100KHZ BETA=.75 FILT_LENGTH=32

References

1. J. G. Proakis, *Digital Communications*, McGraw-Hill, 1989.

Sinc Filter (SINC)

Property	Description	Units	Default	Range/Type
M	Filter order	None	35	[1, Inf)/Integer
K	Number of stages	None	1	[1, Inf)/Integer
RIN1	Input 1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input 2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input 1 signal (real)			
Input2	Input 2 clock signal (real, optional)			
Output	Output signal (real)			

Notes

1. This model implements Sinc^k Filter. I can be either clocked or non-clocked. If non-clocked, the second input port should be left open. The transfer function is of the form

$$H(Z)=\left[\frac{1}{M}\left(\frac{1-Z^{-M}}{1-Z^{-1}}\right)\right]^{K}$$

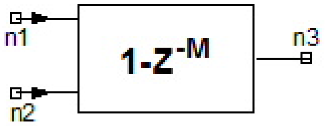
Netlist Form

```
ASINC:NAME n1 n2 n3 nexsys_component=SINC M=val [K=val] [RIN1=val]
[RIN2=val]

+ [ROUT=val]
```

Netlist Example

```
ASINC:1 1 2 3 nexsys_component=SINC M=10 K=2
```

Z-Domain Differentiator with Order M (ZDIFF)



Property	Description	Units	Default	Range/Type
M	Filter order	None	35	[1, Inf]/integer
RIN1	Input 1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input 2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input 1 signal (real)			
Input2	Input 2 clock signal (real, optional)			
Output	Output signal (real)			

Notes

1. This model implements Z-Domain Differentiator with order *M*. I can be either clocked or non-clocked. If non-clocked, the second input port should be left open. The transfer function is of the form

$$H(Z)=1-Z^{-M}$$

(1)

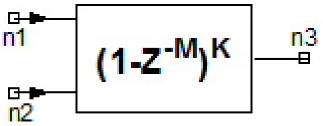
Netlist Form

```
AZDIFF:NAME n1 n2 n3 nexsys_component=ZDIFF M=val [RIN1=val]
[RIN2=val] [ROUT=val]
```

Netlist Example

```
AZDIFF:1 1 2 3 nexsys_component=ZDIFF M=10
```

Z-Domain Differentiator with Order M, K Stages (ZDIFFK)



Property	Description	Units	Default	Range/Type
M	Filter order	None	35	[1, Inf)/Integer
K	Number of stages	None	1	[1, Inf)/Integer
RIN1	Input 1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input 2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input 1 signal (real)			
Input2	Input 2 clock signal (real, optional)			
Output	Output signal (real)			

Notes

1. This model implements Z-Domain Differentiator with order *M* and *K* stages. I can be either clocked or non-clocked. If non-clocked, the second input port should be left open. The transfer function is of the form

$$H(Z)=\left(1-Z^{-M}\right)^{K}$$

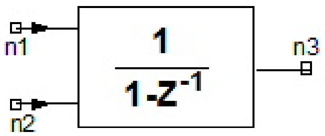
Netlist Form

```
AZDIFFK:NAME n1 n2 n3 nexsys_component=ZDIFFK M=val [K=val]
[RIN1=val] [RIN2=val]

+ [ROUT=val]
```

Netlist Example

```
AZDIFFK:1 1 2 3 nexsys_component=ZDIFFK M=10 K=2
```

Z-Domain Integrator (ZINTEG)



Property	Description	Units	Default	Range/Type
RIN1	Input 1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input 2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input 1 signal (real)			
Input2	Input 2 clock signal (real, optional)			
Output	Output signal (real)			

Notes

1. This model implements Z-Domain Integrator. I can be either clocked or non-clocked. If non-clocked, the second input port should be left open. The transfer function is of the form

$$H(Z) = \frac{1}{1 - Z^{-1}}$$

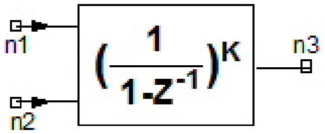
Netlist Form

```
AZINTEG:NAME n1 n2 n3 nexsys_component=ZINTEG [RIN1=val] [RIN2=val]
[ROUT=val]
```

Netlist Example

```
AZINTEG:1 1 2 3 nexsys_component=ZINTEG
```

Z-Domain Integrator, K Stages (ZINTEGK)



Property	Description	Units	Default	Range/Type
K	Number of stages	None	1	[1, Inf)/Integer
RIN1	Input 1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input 2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input 1 signal (real)			
Input2	Input 2 clock signal (real, optional)			
Output	Output signal (real)			

Notes

1. This model implements Z-Domain Integrator with *K* stages. I can be either clocked or non-clocked. If non-clocked, the second input port should be left open. The transfer function is of the form

$$H(Z)=\left(\frac{1}{1-Z^{-1}}\right)^{K}$$

Netlist Form

```
AZINTEGK:NAME n1 n2 n3 nexsys_component=ZINTEGK [K=val]
[RIN1=val] [RIN2=val] [ROUT=val]
```

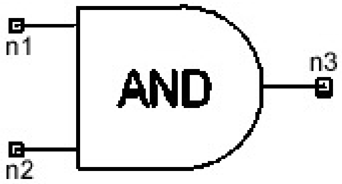
Netlist Example

```
AZINTEGK:1 1 2 3 VK K=2
```

Digital Logic

This topic describes the following System components:

AND Gate (AND)



Property	Description	Units	Default	Range/Type
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (real)			
Input2	Input2 signal (real)			
Output	Output signal (real)			

Notes

$$V_3(t) = \begin{cases} 1 & \text{when } V_1(t) \geq 0.5 \text{ and } V_2(t) \geq 0.5 \\ 0 & \text{otherwise} \end{cases}$$

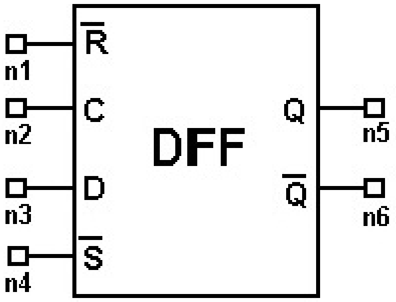
Netlist Form

```
AAND:Name n1  n2  n3 nexsys_component=DAND [Rin1=val]   [Rin2=val]
[Rout=val]
```

Netlist Example

```
AAND:1 1  2  3 nexsys_component=DAND
```

D Flip-Flop--Edge Triggered (DFF)



Property	Description	Units	Default	Range/Type
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
RIN3	Input3 impedance	Ohm	Inf	(0, Inf]/Real
RIN4	Input4 impedance	Ohm	Inf	(0, Inf]/Real
ROUT1	Output1 impedance	Ohm	0	[0, Inf)/Real
ROUT2	Output2 impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	The reset/clear signal (real, inverted)			
Input2	The clock signal (real)			
Input3	The D input signal (real)			
Input4	The Preset signal (real, inverted)			
Output1	The non-inverted output signal (real)			
Output2	The inverted output signal (real)			

Notes

Function Table					
Input				**Output**	
R (n1)	**C (n2)**	**D (n3)**	**S (n4)**	**Q (n5)**	**NQ (n6)**
H	x	x	L	H	L

L	x	x	H	L	H
L	x	x	L	H	H
H	UP	H	H	H	L
H	UP	L	H	L	H
H	Not UP	x	H	Q0	NQ0

S = input preset, active with low level

R = input clear, active with logic low level

C = input clock, active with low to high transition

D = input digital signal

x = don’t care state

L = logic low level. Input: < 0.5; Output: 0.0

H = logic high level. Input: > 0.5; Output 1.0

UP = low-to-high transition

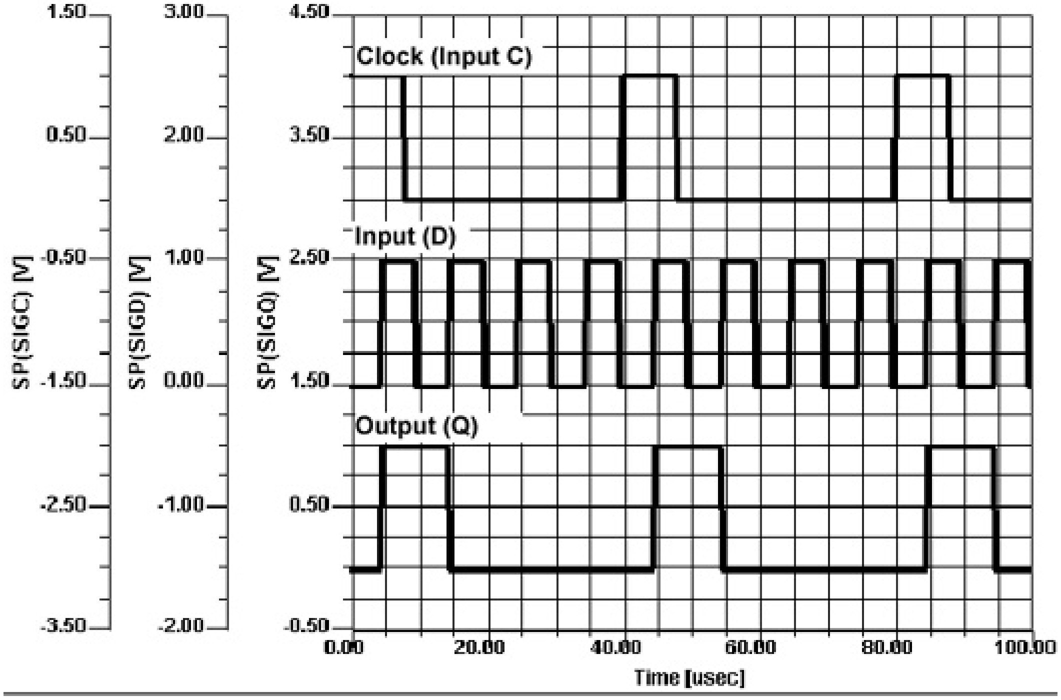
Not UP = not an UP edge

Q0 = previous state

NQ inverted Q state

NQ0 = previous inverted Q state

The input, output and clock signal voltages of the DFF element, with S (n4) and R (n1) both tied to a high logic level (1.0 V), are shown in the following figure.



Netlist Form

```
ADFF:Name n1  n2  n3  n4  n5  n6 nexsys_component=DFF [Rin1=val]
[Rin2=val] [Rin3=val] [Rin4=val] [Rout1=val] [Rou2t=val]
```

Netlist Example

```
ADFF:1 1  2  3  4  5  6 nexsys_component=DFF
```

Divide by N Counter (DIVN)

Property	Description	Units	Default	Range/Type
N	Divide by factor	None	1	(0, Inf)/Integer
N0	Initial counter value	None	1	(0, **N** -1)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This element is a model of a positive edge-triggered, modulo N down counter. The input to the element is a clock signal and the output is a signal that is high or low, depending on whether the current counter value is greater or less than floor (N/2). Note that the counter value itself is not available as an output.

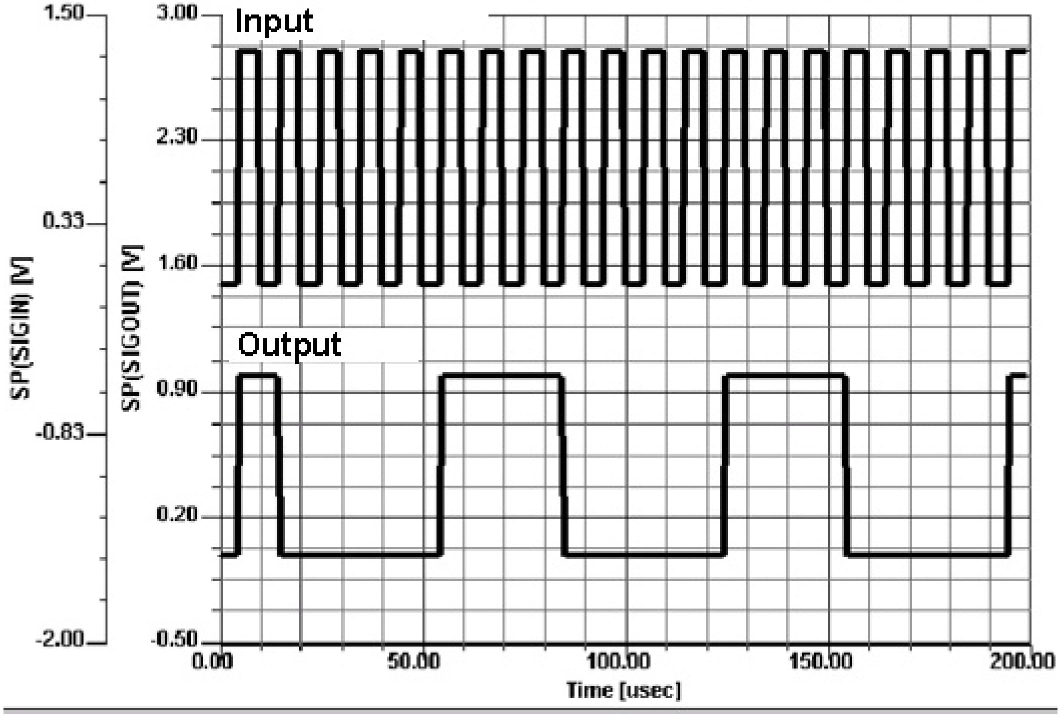
   Let M(k) denote the counter value after the kth positive clock edge. Then

   M(0) = N0

   M(k) = (M(k-1) -1) modulo N, k ≥ 1

$$V_2(t) = \begin{cases} 0 \text{ if } M(k) \geq \text{floor}\left(\frac{N}{2}\right) \\ 1 \text{ if } M(k) < \text{floor}\left(\frac{N}{2}\right) \end{cases}$$

2. The initial counter value N0 is limited to the range [0, N-1] where N is the divide-by factor.
3. The input and output signal voltages of the DIVN element, with parameters N=7 and N0=1, are shown. Output is low until the first positive clock edge occurs at time 10 msec. Output jumps to high level at 10 msec, since initial counter N_0=1 (< floor (7/2)).
4. Note that the period of the input signal is 10µsec and the period of the output period is 70µsec, which yields the signal frequency divided by 7 after the element.



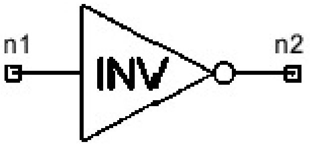
Netlist Form

```
ADIVN:Name n1  n2 nexsys_component=DIVN [Rin1=Val]   [Rout=Val]
```

Netlist Example

```
ADIVN:1 1  2 nexsys_component=DIVN
```

Inverter (INV)



Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal			
Output	Output signal			

Notes

$$V_2(t) = \begin{cases} 0 & \text{when } V_1(t) \geq 0.5 \\ 1 & \text{when } V_1(t) < 0.5 \end{cases}$$

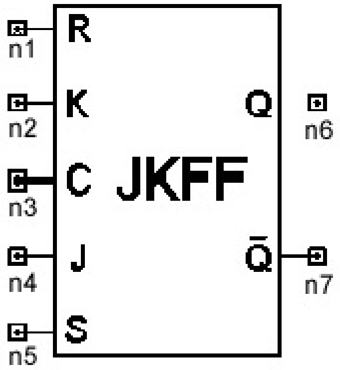
Netlist Form

```
AINV:Name n1  n2 nexsys_component=INV [Rin1=val]   [Rin2=val]
[Rout=val]
```

Netlist Example

```
AINV:1 1  2 nexsys_component=INV
```

J-K Flip-Flop (JKFF)



Property	Description	Units	Default	Range/Type
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
RIN3	Input3 impedance	Ohm	Inf	(0, Inf]/Real
RIN4	Input4 impedance	Ohm	Inf	(0, Inf]/Real
ROUT1	Output1 impedance	Ohm	0	[0, Inf)/Real
ROUT2	Output2 impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	The reset/clear signal (real)			
Input2	The K input signal (real)			
Input3	The Clock signal (real)			
Input4	The J input (real)			
Input5	The preset signal (real)			
Output1	Output1 signal (real)			
Output2	The inverted output signal (real)			

Notes

Functional Table

Input					**Output**	
R (n1)	**K (n2)**	**C (n3)**	**J (n4)**	**S (n5)**	**Q (n6)**	**NQ (n7)**
L	x	x	x	L	H	H
H	x	x	x	L	H	L
L	x	x	x	H	L	H
H	L	UP	L	H	Q0	NQ0
H	L	UP	H	H	H	L
H	H	UP	L	H	L	H
H	H	UP	H	H	Toggle	

CLK = input clock, active with low to high transition

S = input preset, active with logic low level

R = input clear, active with logic low level

x = don’t care state

L = logic low level; Inputs: <0.5; Outputs: 0.0

H = logic high level; Inputs: ≥0.5; Outputs : 1.0

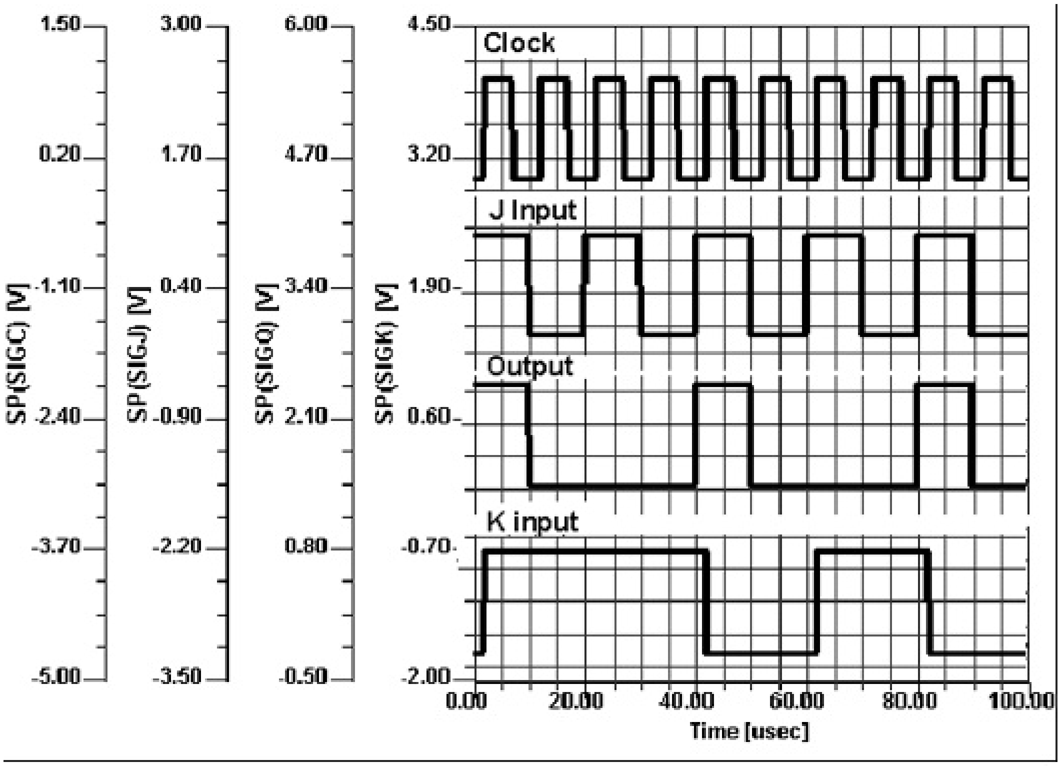
UP = low-to-high transition

Q0 = previous Q state

NQ = inverted Q state

1. Initially, at time equal to 0 time units, the outputs Q and NQ are equal to L and H, respectively.
2. The input (C, K, J) and output (Q) signal voltages of the JKFF element, with S and R both

tied to a high logic level (1.0V), are shown.



Netlist Form

AJKFF:Name *n1* *n2* *n3* *n4* *n5* *n6* *n7* nexsys_component=JKFF [Rin1=*val*] [Rin2=*val*] [Rin1=*val*] [Rin3=*val*] [Rin4=*val*] [Rin5=*val*] [Rout1=*val*] [Rout2=*val*]

Netlist Example

```
AJKFF:1 1  2  3  4  5  6  7 nexsys_component=JKFF
```

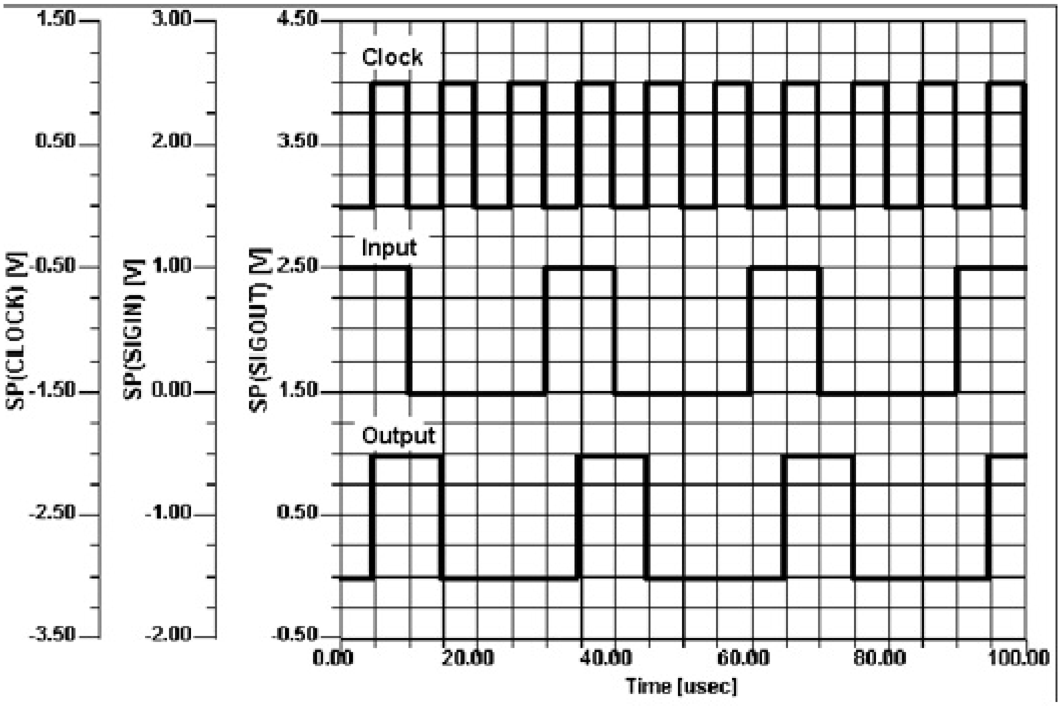
Latch (LATCH)

Property	Description	Units	Default	Range/Type
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (real)			
Input2	The clock signal (real)			
Output	Output signal (real)			

Notes

Function Table		
Input (n1)	**Clock (n2)**	**Output (n3)**
L	H	L
H	H	H
x	L	Q0
x = don’t care state L = logic low level; Inputs: < 0.5; Outputs: 0.0 H = logic high level; Inputs: ≥ 0.5; Outputs : 1.0 Q0 = previous Q state		

1. Initially, at time equal to 0 time units, the output Q is equal to L.
2. This element is clock level sensitive. If the user prefers a clock edge-triggered latch, the DFF element can be used with S=R=H.
3. The input, clock, and output signal voltages of the LATCH elements are shown.



Netlist Form

```
ALATCH:Name n1  n2  n3 nexsys_component=LATCH [Rin1=val] [Rin2=val]
[Rout=val]
```

Netlist Example

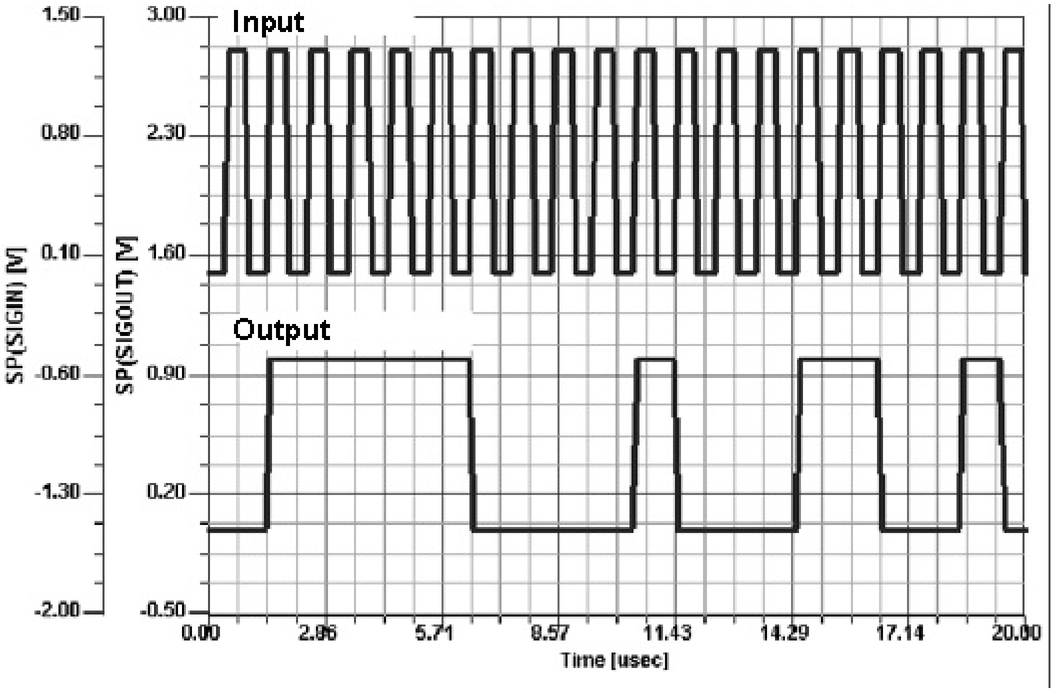
```
ALATCH:1 1  2  3 nexsys_component=LATCH
```

Linear Feedback Shift Register (LFSR)

Property	Description	Units	Default	Range/Type
SR_LENGTH	Length of Shift Register	None	5	[0,32)/Integer
TAP_ CONNECTIONS	Tap connections of the shift register	None	1	[0,Inf)/Integer
INITIAL_CONTENT	Initial contents of the shift register in decimal	None	1	[0,Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. The linear feedback shift register element can be used to generate PN sequences with user-defined recurrence relations. The input to the LFSR is a clock signal; with each positive clock edge the next output bit is calculated according to user provided initial value and tap connection value.
2. The initial output on the LFSR is zero until the first rising clock edge.
3. The following figure shows the input and output signals. The LFSR used in the example has register length of 5, initial value 31, and tap_connection of 24.



4. The element uses decimal values to represent initial values and tap connections to the shift register. For a certain SR_LENGTH value, only the least significant SR_LENGTH bits of INITIAL_CONTENT and TAP_CONNECTIONS is used to perform the calculation. In the above example, a register with 5 stages, initially loaded with 5 bits of information 11111 (31 = 16 + 8 + 4 + 2 + 1) and non-zero feedback coefficient C_5 = 1 and C_4 = 1 (since 24 = 16 + 8). Note that the MSB is first shifted out once a positive edge is detected.

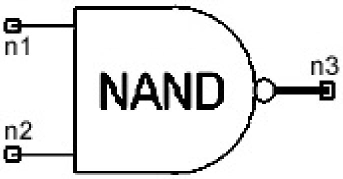
Netlist Form

```
ALFSR:Name n1 n2 nexsys_component=LFSR SR_LENGTH=val
TAP_CONNECTIONS=val  INITIAL_CONTENT=val [Rin=val] [Rout=val]
```

Netlist Example

```
ALFSR: 1  2 nexsys_component=LFSR SR_LENGTH=10
TAP_CONNECTIONS=340  INITIAL_CONTENT=457
```

NAND Gate (NAND)



Property	Description	Units	Default	Range/Type
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	The first input signal (real)			
Input2	The second input signal (real)			
Output	Output signal (real)			

Notes

$$V_3(t) = \begin{cases} 0 & \text{when } V_1(t) \geq 0.5 \text{ and } V_2(t) \geq 0.5 \\ 1 & \text{otherwise} \end{cases}$$

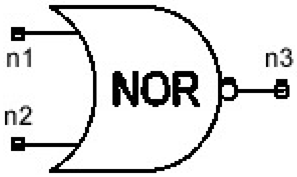
Netlist Form

```
ANAND:Name n1  n2  n3 nexsys_component=NAND [Rin1=val] [Rin2=val ]
[Rout=val]
```

Netlist Example

```
ANAND:1 1  2  3 nexsys_component=NAND
```

NOR Gate (NOR)



Property	Description	Units	Default	Range/Type
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (real)			
Input2	Input2 signal (real)			
Output	Output signal (real)			

Notes

$$V_3(t) = \begin{cases} 1 & \text{when } V_1(t) < 0.5 \text{ and } V_2(t) < 0.5 \\ 0 & \text{otherwise} \end{cases}$$

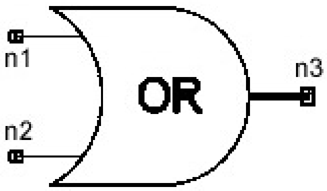
Netlist Form

```
ANOR:Name n1  n2  n3 nexsys_component=NOR [Rin1=val] [Rin2=val]
[Rout=val]
```

Netlist Example

```
ANOR:1 1  2  3 nexsys_component=NOR
```

OR Gate (OR)



Property	Description	Units	Default	Range/Type
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (real)			
Input2	Input2 signal (real)			
Output	Output signal (real)			

Notes

$$V_3(t) = \begin{cases} 0 & \text{when } V_1(t) < 0.5 \text{ and } V_2(t) < 0.5 \\ 1 & \text{otherwise} \end{cases}$$

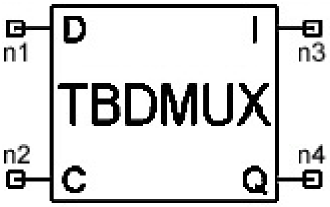
Netlist Form

```
AOR:Name n1  n2  n3 nexsys_component=DOR [Rin1=val] [Rin2=val]
[Rout=val]
```

Netlist Example

```
AOR:1 1  2  3 nexsys_component=DOR
```

Two-Bit Demultiplexer (TBDMUX)



Property	Description	Units	Default	Range/Type
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT1	Output1 impedance	Ohm	0	[0, Inf)/Real
ROUT2	Output2 impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (real)			
Input2	Input2 clock signal (real)			
Output1	The output I signal (real)			
Output2	The output Q signal (real)			

Notes

Functional Table			
D **(n1)**	**C** **(n2)**	**I** **(n3)**	**Q** **(n4)**
L	L	L	H
H	L	H	H
L	H	H	L
H	H	H	H
L = logic low level input: < 0.5; output: 0.0 H = logic high level input: > 0.5; output: 1.0			

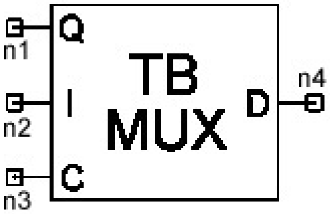
Netlist Form

```
ATBDMUX:Name n1  n2  n3  n4 nexsys_component=TBDMUX [Rin1=val]
[Rin2=val ][Rout1=val] [Rout2=val]
```

Netlist Example

```
ATBDMUX:1 1  2  3  4 nexsys_component=TBDMUX
```

Two-Bit Multiplexer (TBMUX)



Property	Description	Units	Default	Range/Type
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
RIN3	Input3 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal, Q (real)			
Input2	Input2 signal, I (real)			
Input3	Clock signal, C (real)			
Output	Output signal (real)			

Notes

Functional table			
Q (n1)	**I (n2)**	**C (n3)**	**D (n4)**
L	L	L	L
L	L	H	L
L	H	L	L
L	H	H	H
H	L	L	H
H	L	H	L
H	H	L	H
H	H	H	H
L = logic low level input: < 0.5; output: 0.0			

H = logic high level input: > 0.5; output: 1.0

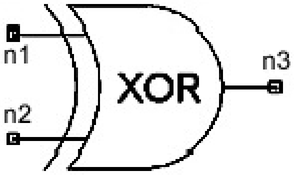
Netlist Form

```
ATBMUX:Name n1  n2  n3  n4 nexsys_component=TBMUX [Rin1=val]
[Rin2=val][Rin3=val] [Rout=Val]
```

Netlist Example

```
ATBMUX:1 1  2  3  4 nexsys_component=TBMUX
```

Exclusive OR Gate (XOR)



Property	Description	Units	Default	Range/Type
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (real)			
Input2	Input2 signal (real)			
Output	Output signal (real)			

Notes

$$V_3(t) = \begin{cases} 1 & \text{when } V_1(t) \geq 0.5 \text{ and } V_2(t) < 0.5 \text{ or when } V_1(t) < 0.5 \text{ and } V_2(t) \geq 0.5 \\ 0 & \text{otherwise} \end{cases}$$

Netlist Form

```
AXOR:Name n1  n2  n3 nexsys_component=DXOR [Rin1=val]   [Rin2=val
][Rout=val]
```

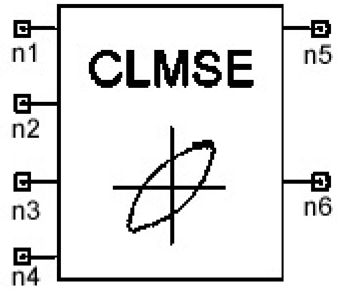
Netlist Example

```
AXOR:1 1  2  3 nexsys_component=DXOR
```

Equalizers

This topic describes the following System components:

Least Mean Square Equalizer, Complex (CLMSE)



Property	Description	Units	Default	Range/Type
NTAPS	The number of filter coefficients	None	4	(-Inf, Inf)/Integer
DELTA	The LMS algorithm step size	None	1	(-Inf, Inf)/Real
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
RIN3	Input3 impedance	Ohm	Inf	(0, Inf]/Real
RIN4	Input4 impedance	Ohm	Inf	(0, In]f
ROUT1	Output1 impedance	Ohm	0	[0, Inf)/Real
ROUT2	Output2 impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Real part of the complex input signal (real)			
Input2	Imaginary part of the complex input signal (real)			
Input3	Real part of the error signal (real)			
Input4	Imaginary part of the error signal (real)			
Output1	Real part of the complex output signal (real)			
Output2	Imaginary part of the complex output signal (real)			

Notes

1. This model updates the filter coefficients of the equalizer based on the input signal and the error signal (i.e., the difference between the output of the equalizer and the actual appropriate output). The update is based on minimizing the mean square error.

2. Let X(n) and h(n) denote the complex input signal vector and the vector of the complex filter coefficients respectively at time instant n. Each vector is assumed to be of length NTAPS (i.e., number of filter taps). The update of the filter coefficients is done according to

   h(n+1) = h(n) + DELTA * e(n) * conj(X(n))

   where: conj(X(n)) is the complex conjugate of the vector X(n) and e(n) = d(n) - y(n), where d(n) is the appropriate output and y(n) is the equalizer output at time instant n.
3. The complex output of the equalizer at instant n + 1 is given by
   y(n+1) = transpose(X(n+1)) * h(n+1)
4. The following initial conditions are always assumed:
   h(-1) = 0, X(-1) = $\underline{0}$

Netlist Form

```
ACLMSE:NAME n1 n2 n3 n4 n5 n6 nexsys_component=CLMSE NTAPS=val
DELTA=val [RIN1=val] [RIN2=val] [RIN3=val] [RIN4=val]
[ROUT1=val] [ROUT2=val]
```

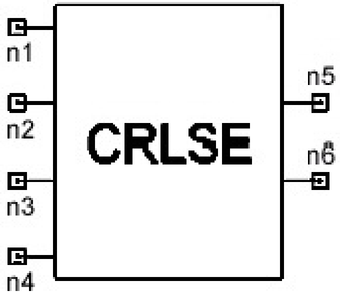
Netlist Example

```
ACLMSE:1 1 2 3 4 5 6 nexsys_component=CLMSE NTAPS=6 DELTA=.005
```

References

1. G. Proakis, *Digital Communications*, McGraw-Hill, 1989.
2. G. Proakis and D. G. Manolakis, *Digital Signal Processing*, Macmillan, 1988.

Recursive Least Square Equalizer, Complex (CRLSE)



Property	Description	Units	Default	Range/Type
NTAPS	The number of filter coefficients	None	4	(-Inf, Inf)/Integer
DELTA	Inverse correlation matrix initialization factor	None	0.0005	(-Inf, Inf)/Real
LAMBDA	Forgetting factor of the RLS algorithm	None	1	[0, 1]/Real
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
RIN3	Input3 impedance	Ohm	Inf	(0, Inf]/Real
RIN4	Input4 impedance	Ohm	Inf	(0, Inf]/Real
ROUT1	Output1 impedance	Ohm	0	[0, Inf)/Real
ROUT2	Output2 impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Real part of the complex input signal (real)			
Input2	Imaginary part of the complex input signal (real)			
Input3	Real part of the error signal (real)			
Input4	Imaginary part of the error signal (real)			
Output1	Real part of the complex output signal (real)			
Output2	Imaginary part of the complex output signal (real)			

Notes

This model updates the filter coefficients of the equalizer based on the complex input and error signals (i.e., the difference between the output of the equalizer and the actual appropriate output). The update is based on the recursive least square algorithm [1], [2].

Let X(n) and h(n) denote the input signal vector and the vector of the complex filter coefficients respectively at time instant n. Each vector is assumed to be of length NTAPS (i.e., number of filter taps). In addition, let K(n) denote the NTAPS x 1 complex Kalman gain vector and let the NTAPS x NTAPS inverse of the complex correlation matrix of the input signal be denoted by P (n).

The recursive least square algorithm is given by the following 5 steps:

1. Compute the filter output:

   y(n) = trans(X(n)) * h(n-1)

2. Compute the error:

   e(n) = d(n) - y(n), where d(n) is the appropriate output

3. Compute the NTAPS x 1 Kalaman gain vector:

   K(n) = [P(n-1) * conj(X(n))] / [LAMBDA + trans(X(n)) * P(n-1) * conj(X(n))]

4. Update the inverse of the complex correlation matrix:

   P(n) = (1/LAMBDA) [P(n-1) - K(n) * trans(X(n)) * P(n-1)]

5. Update the coefficients of the complex filter:

   h(n) = h(n-1) + K(n) * e(n)

The following initial conditions are always assumed:

P(-1) = (1/DELTA) * I, where DELTA is a small positive number and I is the NTAPS x NTAPS identity matrix. e(-1) = 0, and h(-1) = 0.

Netlist Form

```
ACRLSE:NAME n1 n2 n3 n4 n5 n6 nexsys_component=CRLSE NTAPS=val
DELTA=val LAMBDA=val [RIN1=val] [RIN2=val] [RIN3=val]
[RIN4=val] [ROUT1=val] [ROUT2=val]
```

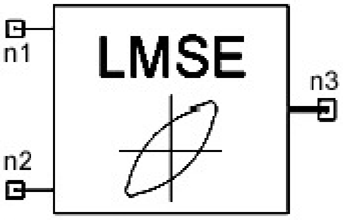
Netlist Example

```
ACRLSE:1 1 2 3 4 5 6 nexsys_component=CRLSE NTAPS=6 DELTA=.005
LAMBDA=.999
```

References

1. J. G. Proakis, *Digital Communications*, McGraw-Hill, 1989.
2. J. G. Proakis and D. G. Manolakis, *Digital Signal Processing*, Macmillan, 1988.

Least Mean Square Equalizer (LMSE)



Property	Description	Units	Default	Range/Type
NTAPS	The number of filter coefficients	None	16	(-Inf, Inf)/Integer
DELTA	The LMS algorithm step size	None	0.01	(-Inf, Inf)/Real
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (real)			
Input2	Input2 Error signal (real)			
Output	Output of the equalizer (real)			

Notes

This model updates the filter coefficients of the equalizer based on the input signal and the error signal (i.e., the difference between the output of the equalizer and the actual appropriate output). The update is based on minimizing the mean square error (i.e., minimizing the absolute value of the error signal).

Let X(n) and h(n) denote the input signal vector and the vector of filter coefficients respectively at time instant n. Each vector is assumed to be of length **NTAPS** (i.e., number of filter taps). The update of the filter coefficients is done according to

h(n+1) = h(n) + DELTA * e(n) * X(n)

where e(n) = d(n) - y(n), where d(n) is the appropriate output and y(n) is equalizer output. The output of the equalizer at instant n + 1 is given by

y(n+1) = trans(X(n+1)) * h(n+1)

Where trans(.) denotes the transpose operator. The following initial conditions are always assumed:

h(-1) = 0, X(-1) = 0

Netlist Form

```
ALMSE:NAME n1  n2  n3 nexsys_component=LMSE NTAPS=val
DELTA=val [RIN1=val] [RIN2=val]
```

Netlist Example

```
ALMSE:1 1  2  3 nexsys_component=LMSE NTAPS=8  DELTA=.005
```

References

1. J. G. Proakis, *Digital Communications*, McGraw-Hill, 1989.
2. J. G. Proakis and D. G. Manolakis, *Digital Signal Processing*, Macmillan, 1988.

Recursive Least Square Equalizer (RLSE)

Property	Description	Units	Default	Range/Type
NTAPS	The number of filter coefficients	None	4	(-Inf, Inf)/Integer
DELTA	Inverse correlation matrix initialization factor	None	0.0005	(-Inf, Inf)/Real
LAMBDA	Forgetting factor of the RLS algorithm	None	1	[0, 1]/Real
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	The first input signal (real)			
Input2	The second input signal (real)			
Output	The output signal (real)			

Notes

This model updates the filter coefficients of the equalizer based on the input signal and the error signal (i.e., the difference between the output of the equalizer and the actual appropriate output). The update is based on the recursive least square algorithm [1], [2].

Let X(n) and h(n) denote the input signal vector and the vector of the real filter coefficients respectively at time instant n. Each vector is assumed to be of length NTAPS (i.e., number of filter taps). In addition, let K(n) denote the NTAPS x 1 Kalman gain vector and let the NTAPS x NTAPS inverse of the correlation matrix of the input signal be denoted by P(n).

The recursive least square algorithm is given by the following 5 steps:

1. Compute the filter output:

   y(n) = tran(X(n)) * h(n-1

2. Compute the error:

   e(n) = d(n) - y(n), where d(n) is the appropriate output

3. Compute the NTAPS x 1 Kalman gain vector:

   K(n) = [P(n-1) * X(n)]/[LAMBDA + tran(X(n)) * P(n-1) * X(n)]

4. Update the inverse of the correlation matrix:

   P(n) = (1/LAMBDA) [P(n-1) - K(n) * tran(X(n)) * P(n-1)]

5. Update the coefficients of the filter:

   h(n) = h(n-1) + K(n) * e(n)

The following initial conditions are always assumed:

P(-1) = (1/DELTA) * I, where DELTA is a small positive number and I is the NTAPS x NTAPS identity matrix, e(-1) = 0, and h(-1) = 0.

Netlist Form

```
ARLSE:NAME n1  n2  n3 nexsys_component=RLSE NTAPS=val
DELTA=val  LAMBDA=val [RIN1=val] [RIN2=val] [ROUT=val]
```

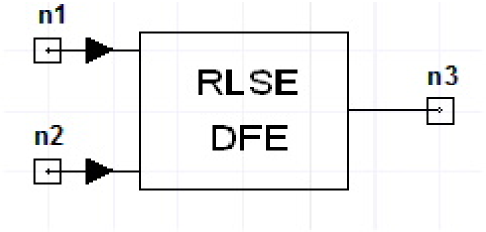
Netlist Example

```
ARLSE:1 1  2  3 nexsys_component=RLSE NTAPS=8  DELTA=.005
LAMBDA=0.999
```

References

1. J. G. Proakis, *Digital Communications*, McGraw-Hill, 1989.
2. J. G. Proakis and D. G. Manolakis, *Digital Signal Processing*, Macmillan, 1988

RLSE DFE Equalizer



RLSE DFE Netlist Format

The RLSE DFE is inserted across a differential line pair to tell transient analysis to generate an eye diagram for the equalized signal at the associated signal probe. Equalization uses the recursive least squares (RLS) algorithm (see Notes).

```
ARLSE_DFE: xxxx n1 n2 n3
+ Nexsys_component=rlse_dfe
 + UI=val OVERSAMPLE=1   FF_TAPS=val FB_TAPS=val LAMBDA=val
+ DECISION_HIGH=val DECISION_LOW=val DECISION_THRESHOLD=val
+ TRAINING_DATA='file_reference'
+ RIN1=val RIN2=val ROUT=val
```

n1 is the positive node and *n2* is the negative node of the differential line pair. The entry **COMPONENT=rlse_dfe** identifies the component.

DFE/FFE Probe Parameters

Parameter	Description	Unit	Default
UI	Unit interval (symbol duration)	Second	125e-12
OVERSAMPLE	Number of samples per UI (symbol interval). **NOTE: OVERSAMPLE must be left at the default of 1 in the current implementation.**	None	1
FF_TAPS	Number of feed-forward taps (filter coefficients)	None	4
FB_TAPS	Number of feed-backward taps (filter coefficients)	None	2
LAMBDA	Forgetting factor for the RLS algorithm (0 <= LAMBDA <= 1)	None	0.9
DECISION_ HIGH	High signal value corresponds to associated source high	Volt	1
DECISION_ LOW	Low signal value corresponds to associated source low	Volt	-1
DECISION_	Threshold value for decision between high and low	Volt	Midpoint

Parameter	Description	Unit	Default
THRESHOLD	value		output of source
TRAINING_ DATA	Name of file containing training data (1s and 0s separated by spaces)	None	None
RIN1	Input 1 impedance	Ohm	1meg
RIN2	Input 2 impedance	Ohm	1meg
ROUT	Output impedance	Ohm	0.0

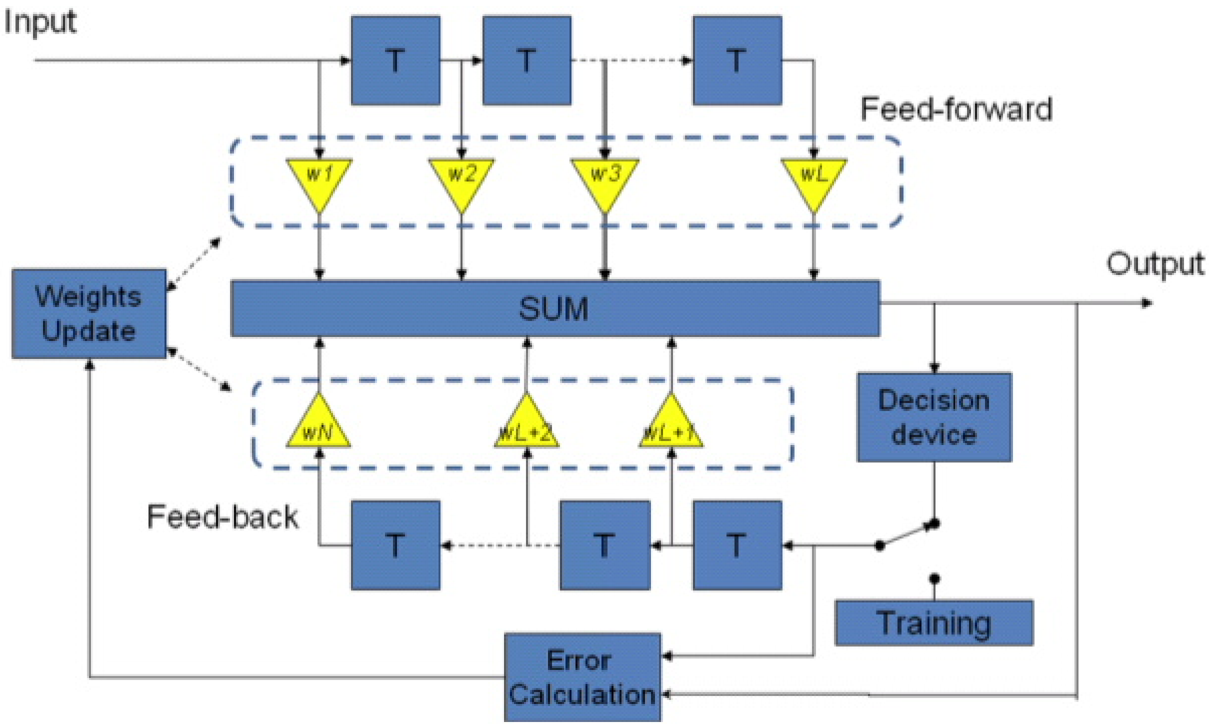
DFE Equalizer Netlist Example

```
ARLSE_DFE:2 net_1 net_2 net_3
+ Nexsys_component=rlse_dfe
+ UI=125e-12 OVERSAMPLE=1 FF_TAPS=4 FB_TAPS=2 LAMBDA=0.9
+ DECISION_HIGH=1 DECISION_low=-1 DECISION_THRESHOLD=0
+ TRAINING_DATA='TrainingData.txt'
+ RIN1=1e9 RIN2=1e9 ROUT=0
```

Notes

A decision-feedback equalizer (DFE) is a non-linear equalizer containing a feed-forward filter and a feed-back filter. For a feed-forward equalizer, the feed-back portion is eliminated. A training signal must be provided to allow the equalizer to calculate the initial tap weights.

Here is the architecture of a DFE with N weights, where the symbol period is T.



Recursive Least Squares Algorithm

This model updates the filter coefficients of the equalizer based on the input signal and the error signal (i.e., the difference between the output of the equalizer and the actual appropriate output). The update is based on the recursive least square algorithm [1], [2].

Let X(n) and h(n) denote the input signal vector and the vector of the real filter coefficients respectively at time instant n. Each vector is assumed to be of length NTAPS, the combined number of feed-forward and feed-back filter taps (NTAPS = FF_TAPS + FB_TAPS). In addition, let K(n) denote the NTAPS x 1 Kalman gain vector and let P(n) denote the NTAPS x NTAPS inverse of the correlation matrix of the input signal.

The recursive least square algorithm is given by the following five steps:

1. Compute the filter output:

```
y(n) = tran(X(n)) * h(n-1)
```

2. Compute the error:

```
e(n) = d(n) - y(n), where d(n) is the appropriate output
```

3. Compute the NTAPS x 1 Kalman gain vector:

```
K(n) = [P(n-1) * X(n)]/[LAMBDA + tran(X(n)) * P(n-1) * X(n)]
```

4. Update the inverse of the correlation matrix:

```
P(n) = (1/LAMBDA) [P(n-1) - K(n) * tran(X(n)) * P(n-1)]
```

5. Update the coefficients of the filter:

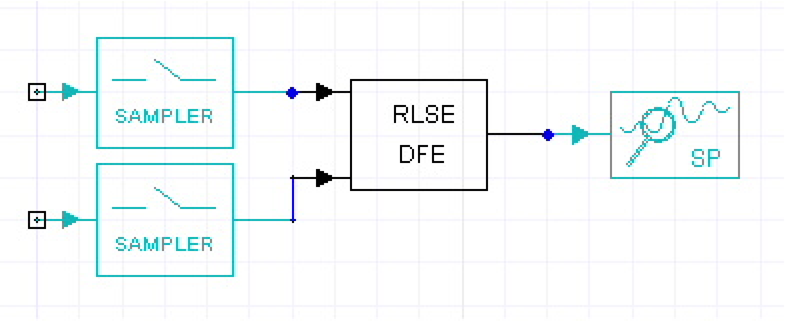
```
h(n) = h(n-1) + K(n) * e(n)
```

The following initial conditions are always assumed:

1. P(-1) = (1/DELTA) * I, where DELTA is a small positive number and I is the NTAPS x NTAPS identity matrix,
2. e(-1) = 0
3. h(-1) = 0.

Schematic Configuration for Transient Analysis

For Transient analysis, the schematic includes the RLS equalizer, samplers to convert the real signals to symbols, and a system probe to generate the eye diagram:

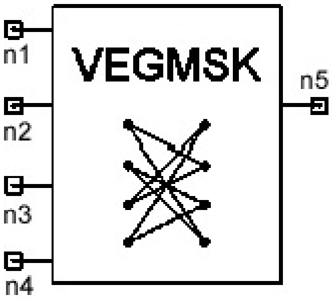


The **SAMPLE_RATE** for both samplers is (**1** / **UI**).

References

1. J. G. Proakis, *Digital Communications*, McGraw-Hill, 1989.
2. J. G. Proakis and D. G. Manolakis, *Digital Signal Processing*, Macmillan, 1988.

GMSK Viterbi Equalizer (VEGMSK)



Property	Description	Units	Default	Range/Type
NB	Number of bits per symbol (integer)	None	1	(0, 8])/Integer
V	The number of VEGMSK equalizer states in symbols (integer)	None	4	(-Inf, Inf)/Integer
M	MODULATION_INDEX = M/P ((see GMSK modulator) (integers)	None	M = 2, P = 4	(1, Inf)/Integer
P	MODULATION_INDEX = M/P ((see GMSK modulator) (integers)	None	M = 2, P = 4	(1, Inf)/Integer
NUM_ SAMPLES	Number of samples per symbol (integer)	None	2	[10e-7, 10e7]/Integer
NORMALIZED_ BW	Normalized bandwidth of Gaussian filter (real)	None	0.3	(-Inf, Inf).Real
RESPONSE_ LENGTH	Length of Gaussian filter impulse response in symbols (integer)	None	4	(0, Inf)/Integer
VE_DEPTH	Number of symbols to receive prior to resetting memory (integer)	None	100	(-Inf, Inf)/Integer
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
RIN3	Input3 impedance	Ohm	Inf	(0, Inf]/Real
RIN4	Input4 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				

Input1	Received in-phase samples (real)
Input2	Received quadrature samples (real)
Input3	Received in-phase channel information (i.e., in-phase impulse response) (real)
Input4	Received quadrature channel information (i.e., quadrature impulse response) (real)
Output	Equalized output symbols in the range 0, 1, ..., M -1 (real)

Notes

This model equalizes (or demodulates) the received **GMSK** -modulated in-phase and quadrature input signals using the in-phase and quadrature channel information. The equalization algorithm used is based on Maximum Likelihood Sequence Estimation (**MLSE**) and the Viterbi Algorithm (**VA**) [1], [2].

The received input signals are assumed to have been modulated by a **GMSK** modulator prior to transmission. the parameters shared by the **GMSK** modulator used in the transmitter and its corresponding Viterbi Equalizer at the receiver, namely, **NB**, **NUM_SAMPLES**, **NORMALIZED_ BW**, **RESPONSE_LENGTH**, and the **MODULATION_INDEX** = M/P must be identical. This must be the case since the **VEGMSK** model uses these parameters to locally generate all possible received data sequences (using the channel information) and determine the most probable transmitted sequence.

The number of states for equalization in the **VEGMSK** is determined by the integer **V**. In addition, the number of the internally generated states depends on the integers **M** and **P**, where **M** and **P** are relative prime numbers. If **M** is even, the **VEGMSK** have $P * 2^{V-1}$ states, and if **M** is odd, the **VE** $2 * P * 2^{V-1}$ states instead.

In other words, if **M** is even, the number of phase states in the **VEGMSK** model is **P**, otherwise, the number of phase states is 2 * **P**.

It's important to keep in mind that for a given **MODULATION_INDEX** at the **GMSK** transmitting modulator, the **M** and **P** that must be properly specified by the user if proper equalization is to be performed. For example, a **MODULATION_INDEX** of 0.5 at the **GMSK** modulator implies that the number of phase states in the modulator is 4 (0, PI/2, PI, 3*PI/2). This implies that the corresponding number of phase states in the **VEGMSK** model at the receiver must be 4 and the modulation index must be 0.5. These two conditions can be simultaneously satisfied if **M** = 1 and **P** = 2, or **M** = 2, and **P** = 4.

V is the number of equalization states in symbols and is always assumed to be equal to the sum of the **GMSK** modulator's impulse response length (i.e., **RESPONSE_LENGTH**) and the length of the channel's impulse response (in symbols too). In other words

V = RESPONSE_LENGTH + Lc,

where **Lc** is the length of the channel's impulse response in symbols. For example, if **RESPONSE_LENGTH** = 3 symbols, and **V** was chosen to equal 5 symbol states, this implies the **VEGMSK** model assumes the channel information is contained in an impulse response of length 2 symbols. The **VEGMSK** model always assumes that the length of the corresponding impulse response in samples is given by **RESPONSE_LENGTH** * **NUM_SAMPLES** and **Lc** * **NUM_SAMPLES** + 1 for the **GMSK** modulator and the channel, respectively.

For example, if **V** = 5, **RESPONSE_LENGTH** = 3, and **NUM_SAMPLES** = 2, the **VEGMSK** model assumes that the transmitting **GMSK** modulator's impulse response (in samples) is (please refer to the **GMSK** model):

q[0], q[1], q[2], q[3], q[4], q[5]

and the channel's impulse response in samples is:

h[0], h[1], h[2], h[3], h[4]

If **V** is equal to or greater than the sum of actual lengths of the two impulse responses (i.e., the impulse response of the **GMSK** modulator used at the transmitter and the actual impulse response of the channel), then full equalization is possible, otherwise, the equalization process is hindered. The **VEGMSK** model uses q[i], 0 ≤ i ≤**RESPONSE_LENGTH** * **NUM_SAMPLES** – 1 and h[i], 0 ≤ i ≤ Lc * **NUM_SAMPLES** to generate all possible received sequences , then decides in favor of the most probable transmitted sequence using **MLSE** and the VA ([1], [2]).

Since the input to the transmitting **GMSK** modulator (please refer to **GMSK** model) is assumed to be the symbols Ai, where Ai = 0, 1, ..., M -1, and M = 2^{NB}, the symbols recovered at the output of the **VEGMSK** model are also in the range 0, 1, ..., M - 1. If **NB** = 1, the **VEGMSK** model performs equalization on binary symbols (i.e., each symbol conveys a one-bit information), other wise equalization is performed on M-ary data (where each symbol conveys the information of NB-bits, NB > 1).

The maximum number of equalization states that can be accommodated by this model is V = 32/NB. For example, for a 16-ary data (NB = 4), the maximum number of allowable states is V = 8 symbol states (with each symbol conveying the information of 4 bits). Keep in mind that each symbol may be represented by an arbitrary **NUM_SAMPLES**.

Observe that an increase in **V**, **NB**, or **NUM_SAMPLES** increases the processing time inside the **VEGMSK** model.

The **VEGMSK** model also assumes that it begins in the zero internal state and one of the P or 2 * P possible phase states. This means that the first received in-phase and quadrature input samples that go into the **VEGMSK** model are assumed to have been preceded by V - 1 0 symbol values at the **GMSK** modulator. This is done to reduce the equalization's probability of making errors which is the case, assuming all possible internal states for the beginning state.

Upon receiving **VE_DEPTH** symbols (i.e., **VE_DEPTH** * **NUM_SAMPLES** samples), the **VEGMSK** model outputs **VE_DEPTH** equalized symbols (in the range 0, 1, ..., M -1) then resets its memory to the zero state. This means the next stream of received input symbols is also assumed to have been preceded by V - 1 0 symbols at the **GMSK** modulator and so on.

Netlist Form

```
AVEGMSK:NAME n1  n2  n3  n4  n5 nexsys_component=VEGMSK NB=val  M=val
 P=val

+ NUM_SAMPLES=val  RESPONSE_LENGTH=val

+ NORMALIZED_BW=val  V=val VE_DEPTH=val [RIN1=val] [RIN2=val]
[RIN3=val] [RIN4=val] [ROUT=val]
```

Netlist Example

```
AVEGMSK:1  1  2  3  4  5 nexsys_component=VEGMSK NB=1  M=1  P=2  NUM_
SAMPLES=2

+ RESPONSE_LENGTH=3  NORMALIZED_BW=0.3  V=6  VE_DEPTH=100
```

This equalizer corresponds to the first example used in the **GMSK** modulator model (The GSM example). Note that the equalizer may use M = 2 and P = 4 as well and still yield the same performance. This example assumes that the channel's information (i.e., impulse response) is entirely contained in (V - **RESPONSE_LENGTH**) * **NUM_SAMPLES** + 1 samples = 7 samples. As mentioned above, it is always assumed that the first input symbol (i.e., **NUM_SAMPLES** samples) to the **VEGMSK** model has been preceded by V - 1 = 5 zero symbol values at the transmitting **GMSK** modulator. This means that the input to the **GMSK** modulator should have been 0, 0, 0, 0, 0, followed by arbitrary symbols which are be fed into the **VEGMSK** model at the receiver. This implies that the first received (V - 1) * **NUM_SAMPLES** samples = 10 samples must be discarded, and the next samples (10, 11, ...) are fed to the **VEGMSK** model (i.e., the 10th sample (counting from 0) is actually the first input sample that should be applied to the input of **VEGMSK** model).

References

1. J. G. Proakis, *Digital Communications*, McGraw-Hill, 1989.
2. Raymond Steele, *Mobile Radio Communications*, Pentech Press, 1992.

Fixed-Point

This topic describes the following System components:

Complex to Fixed-Point Converter (CTOFXT)

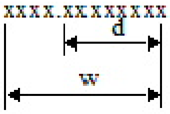
Property	Description	Units	Default	Range/type
outW	Word length of the output fixed point number	None	32	[1, 32]/Integer
outD	Precision of the output fixed point number	None	0	[0, 32]/Integer
ovf	Overflow characteristic: 0 for wrapped, 1 for saturate, 2 for zero saturate	None	0	[0, 2]/Integer
IorQ	In-phase or quadrature component: 0 for in-phase, 1 for quadrature	None	0	[0, 1]/Integer
quant	Quantization characteristic: 0 for truncated, 1 for rounded, 2 for truncated 0	None	0	[0, 2]/Integer
ArithType	Arithmetic type: 0 for signed, 1 for unsigned	None	0	[0 ,1]/Integer
Rin	Input impedance	Ohm	Inf	(0, Inf]/Real
Rout	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (floating point complex number)			
Output	Output signal (fixed point real number)			

Limits

outW > outD for signed arithmetic

Notes

This model converts the complex floating point signal to a real fixed-point signal. If **IorQ** is set to 0, the output is on the real part of the input signal (in-phase component); else, if **IorQ** is equal to 1, the output is on the imaginary part of the input signal (quadrature component). The format of the output signal is set by the parameters: **outW**, **outD**, **ovf**, **quant**, **arithtype**, where **ovf** defines the overflow characteristics, **quant** defines the quantization characteristics and **arithtype** defines the arithmetic type. The following plot shows the relationship between the word length and the precision.



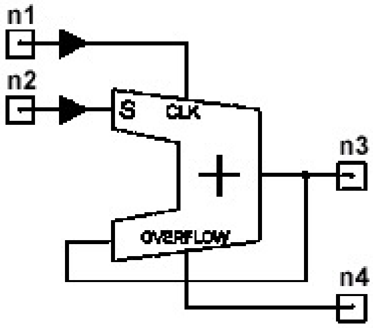
Netlist Form

```
ACTOFXT:NAME n1 n2 nexsys_component=CTOFXT [outW=val]
[outD=val] [ovf=val] [quant=val] [IorQ=val] [arithtype=val]
[Rin=val] [Rout=val]
```

Netlist Example

```
ACTOFXT:1 1 2 nexsys_component=CTOFXT outW=16 outD=4 ovf=1
quant=1 IorQ=1
```

Fixed-Point Accumulator (FXTACCUM)



Property	Description	Units	Default	Range/type
useInAsOut	Use the input precision as the output precision: 1: Use 0: Do not use	None	1	[0, 1]/Integer
outW	Word length of the output fixed point number	None	32	[1, 32]/Integer
outD	**Precision of the output fixed point number**	None	0	[0, 32]/Integer
ovf	Overflow characteristic: 0 for wrapped, 1 for saturate, 2 for zero saturate	None	0	[0, 2]/Integer
quant	Quantization characteristic: 0 for truncated, 1 for rounded, 2 for truncated 0	None	0	[0, 2]/Integer
Arithtype	Arithmetic type: 0 for signed , 1 for unsigned	None	0	[0, 1]/Integer
Rin1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
Rin2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
Rout1	Output1 impedance	Ohm	0	[0, Inf)/Real
Rout2	Output2 impedance	Ohm	0	[0, Inf)/Real

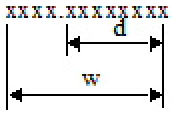
Ports	
Input1	Input1 clock signal (floating point real number, optional)
Input2	Input2 signal (fixed point real number)
Output1	Output1 signal (fixed point real number)
Output2	Output2 signal (floating point real number)

Limits

outW > outD for signed arithmetic

Notes

1. This model is a fixed point accumulator. It can be either clocked or non-clocked. If non-clocked, leave the clock signal port (the first input) open. When clocked, it is a rising edge triggered device. The trigger level is set to be 0.5 inside this model; therefore, care must be taken to ensure the input signal level is in accordance, a scaler may be needed to scale the incoming signal down in some cases.
2. The parameters **outW**, **outD**, **ovf**, **quant**, and **arithtype** are used to define the output format of the fixed point number. Note that when the parameter **useInAsOut** is activated, the previously mentioned parameters are ignored; instead, the format of the output signal are the same as the format of the input signal. To use an output format different on the input format, set **useInAsOut** to 0, and set the corresponding format.
3. The first output is the accumulated output signal, while the second output is the overflow output. When an overflow occurs during one accumulation step, a logic signal “1” is written to the second output to indicate an overflow.
4. The following plot shows the relationship between word length and precision.



Netlist Form

```
AFXTACCUM:NAME n1 n2 n3 n4 nexsys_component=FXTACCUM
[useInAsOut=val] [outW=val] [outD=val] [ovf=val] [quant=val]
[arithtype=val] [Rin1=val] [Rin2=val] [Rout1=val] [Rout2=val]
```

Netlist Example

```
AFXTACCUM:1 1 2 3 4 nexsys_component=FXTACCUM outW=10 outD=10 ovf=0
quant=1 arithtype=1
```

Fixed-Point Finite Impulse Response Filter (FXTFIR)

Property	Description	Units	Default	Range/type
useInAsOut	Use the input precision as the output precision: 1 for used, 0 for not used	None	1	[0, 1]/Integer
coefW	Word length of fixed point coefficient	None	32	[1, 32]/Integer
coefD	**Precision of the fixed point coefficient**	None	0	[0, 32]/Integer
outW	Word length of the output fixed point number	None	32	[1, 32]/Integer
outD	Precision of the output fixed point number	None	0	[0, 32]/Integer
ovf	Overflow characteristic: 0 for wrapped, 1 for saturate, 2 for zero saturate	None	0	[0, 2]/Integer
quant	Quantization characteristic: 0 for truncated, 1 for rounded, 2 for truncated	None	0	[0, 2]/Integer
file	Name of the external file (required)	None	Required	String
ArithType	Arithmetic type: 0 for signed, 1 for unsigned	None	0	[0, 1]/Integer
Rin	Input impedance	Ohm	32	(0,Inf]/Real

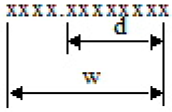
Rout	Output impedance	Ohm	32	[0, Inf)/Real
Ports				
Input	Input signal (fixed point real number)			
Output	Output signal (floating point real number)			

Limits

1. outW > outD, coefW > coefD for signed arithmetic

Notes

1. This model implements an FIR filter based on filter tap coefficients provided by the two-column XY format data block in the external file. Each (X,Y) entry indicates the tap number and the corresponding tap coefficient. The coefficients are floating point numbers. They are converted to fixed-point number according to the parameters: **coefW**, **coefD**, **ovf**, **quant, arithtype**. The format of the output signal is specified by the parameters: **outW**, **outD**, **ovf**, **quant, arithtype**. Note that if **useInAsOut** is set to 1, the format of the fixed output number is set to be the format of the input fixed point number, ignoring the parameters **outW**, **outD**, **ovf**, **quant, arithtype**.
2. The following plot shows the relationship between word length and precision.



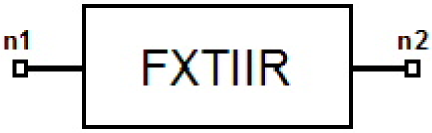
Netlist Form

```
AFXTFIR:NAME n1 n2 nexsys_component=FXTFIR [useInAsOut=val]
[coefW=val] [coefD=val] [outW=val] [outD=val] [ovf=val]
[quant=val] [file=val]  [arithtype=val] [Rin=val] [Rout=val]
```

Example

```
AFXTFIR:1 1 2 nexsys_component=FXTFIR useInAsOut=0 coefW=16
coefD=4 outW=24 outD=8 ovf=1 quant=1 file=”filename”
```

Fixed-Point IIR Filter (FXTIIR)



Property	Description	Units	Default	Range/type
useInAsOut	Use the input precision as the output precision: 1 for used, 0 for not used	None	1	[0, 1]/Integer
coefW	Word length of fixed point coefficient	None	32	[1, 32]/Integer
coefD	Precision of the fixed-point coefficient	None	0	[0, 32]/Integer
outW	Word length of the output fixed-point number	None	32	[0, 32]/Integer
outD	Precision of the output fixed-point number	None	0	[0, 32]/Integer
ovf	Overflow characteristic: 0 for wrapped, 1 for saturate, 2 for zero saturate	None	0	[0, 2]/Integer
quant	Quantization characteristic: 0 for truncated, 1 for rounded, 2 for truncated 0	None	0	[0, 2]/Integer
file	Name of the external file	None	Required	String
ArithType	Arithmetic type: 0 for signed, 1 for unsigned	None	0	[0, 1]/Integer
Rin	Input impedance	Ohm	Inf	(0, Inf]/Real

Rout	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (fixed point real number)			
Output	Output signal (fixed point real number)			

Limits

1. outW > outD, coefW > coefD for signed arithmetic

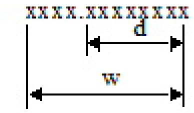
Notes

1. This model implements IIR filter based on the following system function:
   or equivalently, the difference equation:
   The system parameters (a_k) and (b_k) and are provided by a two-column XY format data block in an external file. The first column is the (a_k) value. The second column is the (b_k) value. The coefficients are floating point numbers. They are converted to fixed point number according to the parameters: **coefW**, **coefD**, **ovf**, **quant, arithtype**. The format of the output is specified by the parameters: **outW**, **outD**, **ovf**, **quant, arithtype**. Note that if useInAsOut is set to 1, the format of the fixed output number is set to be the format of the input fixed point number. That is to say, the values **outW**, **outD**, **ovf**, **quant, arithtype** are ignored in this case.

$$H(z) = \frac{\sum_{k=0}^{M} b_k z^{-k}}{1 + \sum^{N} a_k z^{-k}}$$

$$y(n) = -\sum_{k=1}^{N} a_k y(n-k) + \sum_{k=0}^{M} b_k x(n-k)$$

2. The following plot shows the relationship between word length and precision.



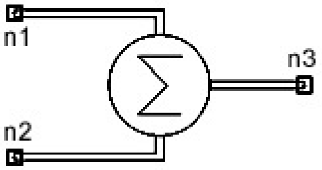
Netlist Form

```
AFXTIIR:NAME n1 n2 nexsys_component=FXTIIR [useInAsOut=val]
[coefW=val] [coefD=val] [outW=val] [outD=val] [ovf=val]
[quant=val] [file=val] [arithtype=val] [Rin=val] [Rout=val]
```

Netlist Example

```
AFXTIIR:1 1 2 nexsys_component=FXTIIR useInAsOut=0 coefW=16
coefD=4 outW=24 outD=8 ovf=1 quant=1 file=”filename”
```

Fixed-Point Real Adder (FXTRADD)



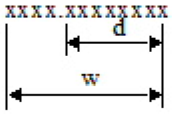
Property	Description	Units	Default	Range/type
useInAsOut	Use the input precision as the output precision: 1 for use, 0 for not use	None	1	[0, 1]/Integer
outW	Word length of the output fixed point number	None	32	[1, 32]/Integer
outD	**Precision of the output fixed point number**	None	0	[0, 32]/Integer
ovf	Overflow characteristic: 0 for wrapped, 1 for saturate, 2 for zero saturate	None	0	[0, 2]/Integer
quant	Quantization characteristic: 0 for truncated, 1 for rounded, 2 for truncated 0	None	0	[0, 2]/Integer
ArithType	Arithmetic type: 0 for signed, 1 for unsigned	None	0	[0, 1]/Integer
Rin1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
Rin2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
Rout	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (fixed point real number)			
Input2	Input2 signal (fixed point real number)			
Output	Output signal (floating point real number)			

Limits

1. outW > outD for signed arithmetic

Notes

1. This model produces the result of the sum of two input fixed point real signals. It is assumed that the user assigns the same format for the two inputs. The fixed point output signal format is the same as the input signal format when the parameter **useInAsOut** is set to be 0, in which case parameters **outW**, **outD**, **ovf**, **quant** and **arithtype** is ignored; otherwise, the format is set by **outW**, **outD**, **ovf**, **quant** and **arithtype**.
2. The following plot shows the relationship between word length and precision.



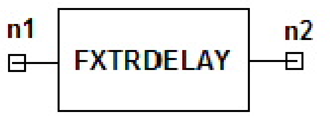
Netlist Form

```
AFXTRADD:NAME n1 n2 n3 nexsys_component=FXTRADD
[useInAsOut=val] [outW=val] [outD=val] [ovf=val] [quant=val]
[arithtype=val] [Rin1=val] [Rin2=val] [Rout=val]
```

Example

```
AFXTRADD:1 1 2 3 nexsys_component=FXTRADD useInAsOut=0,
outW=16, outD=4, ovf=1, quant=1
```

Fixed-Point Real Delay Element (FXTRDELAY)



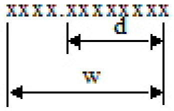
Property	Description	Units	Default	Range/type
changeIn_ Prec	Change the incoming precision of the signal: 0 for no change, 1 for change	None	0	[0, 1]/Integer
outW	Word length of the output fixed point number	None	32	[0, 1]/Integer
outD	**Precision of the output fixed point number**	None	0	[1, 32]/Integer
ovf	Overflow characteristic: 0 for wrapped, 1 for saturate, 2 for zero saturate	None	0	[0, 2]/Integer
quant	Quantization characteristic: 0 for truncated, 1 for rounded, 2 for truncated 0	None	0	[0, 2]/Integer
D	Number of delay	None	1	[1, Inf)/Integer
ArithType	Arithmetic type: 0 for signed, 1 for unsigned	None	0	[0, 1]/Integer
Rin	Input impedance	Ohm	Inf	(0, Inf]/Real
Rout	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (fixed point real number)			
Output	Output signal (fixed point real number)			

Limits

1. outW > outD for signed arithmetic

Notes

1. This model delays a fixed-point real signal by a specified number of samples set by the parameter **D**. It effectively places **D** zeros at the beginning of the output signal. The output signal follows the same format as the input signal if **changeInPrec** is set to 0, or the output fixed-point format is set by the user through the parameters **outW**, **outD**, **ovf**, **quant, arithtype**.
2. The following plot shows the relationship between worldlength and precision.



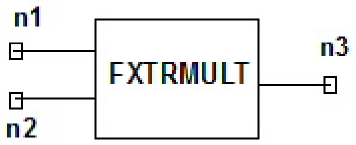
Netlist Form

```
AFXTRDELAY:NAME n1 n2 nexsys_component=FXTRDELAY
[changeInPrec=val] [outW=val] [outD=val] [ovf=val] [quant=val]
[D=val] [arithtype=val]   [Rin=val] [Rout=val]
```

Example

```
AFXTRDELAY:1 n1 n2 nexsys_component=FXTRDELAY changeInPrec=1 outW=16
outD=4 ovf=1 quant=1 D=2
```

Fixed-Point Real Multiplier (FXTRMULT)



Property	**Description**	Units	Default	Range/type
useInAsOut	Use the input precision as the output precision: 1 for use, 0 for not use 1	None	1	[0, 1]/Integer
outW	Word length of the output fixed point number 32	None	32	[1, 32]/Integer
outD	Precision of the output fixed point number	None	0	[0, 32]/Integer
ovf	Overflow characteristic: 0 for wrapped, 1 for saturate, 2 for zero saturate	None	0	[0, 2]/Integer
quant	Quantization characteristic: 0 for truncated, 1 for rounded, 2 for truncated 0	None	0	[0, 2]/Integer
ArithType	Arithmetic type: 0 for signed, 1 for unsigned	None	0	[0, 1]/Integer
Rin1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
Rin2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
Rout	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (fixed point number)			
Input2	Input2 signal (fixed point number)			

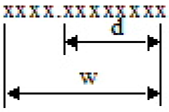
Output	Output signal (fixed point number)

Limits

outW > outD for signed arithmetic

Notes

1. This model produces the result of the multiplication of two input fixed point signals. It is assumed that the user assigns the same format for the two inputs. The fixed point output signal format is the same as the input signal format when the parameter **useInAsOut** is set to be 0, in which case **outW**, **outD**, **ovf**, **quant** and **arithtype** ignored; otherwise, the format is set by **outW**, **outD**, **ovf** and **quant, arithtype**.
2. The following plot shows the relationship between word length and precision.



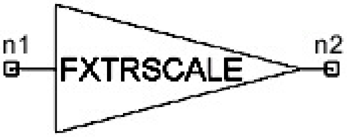
Netlist Form

```
AFXTRMULT:NAME n1 n2 n3 nexsys_component=FXTRMULT
[useInAsOut=val] [outW=val] [outD=val] [ovf=val] [quant=val]
[arithtype=val] [Rin1=val] [Rin2=val] [Rout=val]
```

Netlist Example

```
AFXTRMULT:1 1 2 3 nexsys_component=FXTRMULT useInAsOut=0
outW=16 outD=4 ovf=1 quant=1
```

Fixed-Point Real Scaler (FXTRSCALE)



Property	**Description**	**Units**	**Default**	**Range/type**
useInAsOut	Use the input precision as the output precision: 1 for use, 0 for not use	None	1	[0, 1]/Integer
coefW	Word length of fixed point coefficient	None	32	[1, 32]/Integer
coefD	Precision of the fixed point coefficient	None	0	[0, 32]/Integer
outW	Word length of the output fixed point number	None	32	[1, 32]/Integer
outD	Precision of the output fixed point number	None	0	[0, 32]/Integer
ovf	Overflow characteristic: 0 for wrapped, 1 for saturate, 2 for zero saturate	None	0	[0, 2]/Integer
quant	Quantization characteristic: 0 for truncated, 1 for rounded, 2 for truncated 0	None	0	[0, 2]/Integer
gain	Gain of the scaler	None	1	(Inf, -Inf)/Real
ArithType	Arithmetic type: 0 for signed, 1 for unsigned	None	0	[0, 1]/Integer
Rin	Input impedance	Ohm	Inf	(0, Inf]/Real
Rout	Output impedance	Ohm	0	[0, Inf)/Real

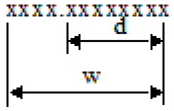
Ports	
Input	Input signal (fixed point real number)
Output	Output signal (floating point real number)

Limits

outW > outD, coefW > coefD for signed arithmetic

Notes

1. This model produces the result of the multiplication of the input signal with the coefficient. The coefficient is a fixed-point number converted on the parameter value “gain” according to the user-defined format **coefW**, **coefD**, **ovf**, **quant, arithtype**. The fixed point output signal format is the same as the input signal format when the parameter **useInAsOut** is set to be 0, in which case **outW**, **outD**, **ovf**, **quant** and **arithtype** ignored. Otherwise, the output format is set by **outW**, **outD**, **ovf**, **quant** and **arithtype**.
2. The following plot shows the relationship between word length and precision.



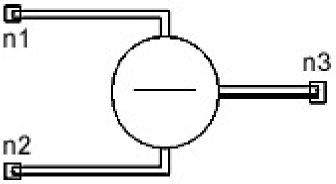
Netlist Form

```
AFXTRSCALE:NAME n1 n2 nexsys_component=FXTRSCALE
[useInAsOut=val] [coefW=val] [coefD=val] [outW=val] [outD=val]
[ovf=val] [quant=val] gain=val [arithtype=val] [Rin=val]
[Rout=val]
```

Netlist Example

```
AFXTRSCALE:1 1 2 nexsys_component=FXTRSCALE useInAsOut=0
coefW=16 coefD=4 outW=24 outD=8 ovf=1 quant=1 gain=2.34
```

Fixed-Point Real Subtractor (FXTRSUB)



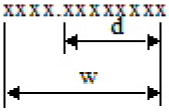
Property	Description	Units	Default	Range/type
useInAsOut	Use the input precision as the output precision: 1 for use, 0 for not use	None	1	[0, 1]/Integer
outW	Word length of the output fixed point number	None	32	[1, 32]/Integer
outD	**Precision of the output fixed point number**	None	0	[0, 32]/Integer
ovf	Overflow characteristic: 0 for wrapped, 1 for saturate, 2 for zero saturate	None	0	[0, 2]/Integer
quant	Quantization characteristic: 0 for truncated, 1 for rounded, 2 for truncated 0	None	0	[0, 2]/Integer
ArithType	Arithmetic type: 0 signed, 1 for unsigned	None	0	[0, 1]/Integer
Rin1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
Rin2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
Rout	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (fixed point real number)			
Input2	Input2 signal (fixed point real number)			
Output	Output signal (floating point real number)			

Limits

1. outW > outD for signed arithmetic

Notes

1. This model produces the result of the subtraction of two input fixed point real signals. It is assumed that the user assigns the same format for the two inputs. The fixed point output signal format is the same as the input signal format when the parameter **useInAsOut** is set to be 0, in which case parameters **outW**, **outD**, **ovf**, **quant** and **arithtype** are ignored; otherwise, the format is set by **outW**, **outD**, **ovf**, **quant** and **arithtype**.
2. The following plot shows the relationship between word length and precision.



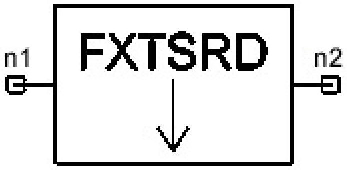
Netlist Form

```
AFXTRSUB:NAME n1 n2 n3 nexsys_component=FXTRSUB
[useInAsOut=val] [outW=val] [outD=val] [ovf=val] [quant=val]
[arithtype=val] [Rin1=val] [Rin2=val] [Rout=val]
```

Example

```
AFXTRSUB:1 1 2 3 nexsys_component=FXTRSUB useInAsOut=0 outW=16
outD=4 ovf=1 quant=1
```

Sampling Rate Decimator for Fixed-Point Real Signal (FXTSRD)



Property	Description	Units	Default	Range/type
DF	The factor by which the input signal is decimated	None	1	[1, Inf)/Integer
Rin	Input impedance	Ohm	Inf	(0, Inf]/Real
Rout	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (fixed point real number)			
Output	Output signal (floating point real number)			

Notes

This model decimates a fixed point input signal. Beginning with the first input sample, only each **DF** th sample is written to the output port. The format of the output signal remains the same as the format of the input signal.

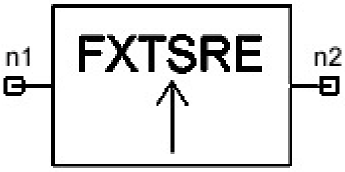
Netlist Form

```
AFXTSRD:NAME n1 n2 nexsys_component=FXTSRD DF=val [Rin=val]
[Rout=val]
```

Netlist Example

```
AFXTSRD:1 1 2 nexsys_component=FXTSRD DF=2
```

Sampling Rate Expander for Fixed-Point Real Signal (FXTSRE)



Property	Description	Units	Default	Range/type
EF	The factor by which the input signal is expanded	None	1	[1, Inf)/Integer
Rin	Input impedance	Ohm	Inf	(0, Inf]/Real
Rout	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (fixed point real number)			
Output	Output signal (floating point real number)			

Notes

This model expands a fixed point input signal. Beginning with the first input sample, each input sample followed by EF – 1 zeros are written to the output port. The format of the output signal remains the same as the format of the input signal.

Netlist Form

```
AFXTSRE:NAME n1 n2 nexsys_component=FXTSRE EF=val [Rin=val]
[Rout=val]
```

Netlist Example

```
AFXTSRE:1 1 2 nexsys_component=FXTSRE EF=2
```

Fixed-Point to Complex Converter (FXTTOC)

Property	Description	Units	Default	Range/type
IorQ	In-phase quadrature component: 0 for in-phase, 1 for quadrature	None	0	[0, 1]/Integer
Rin	Input impedance	Ohm	Inf	(0, Inf]/Real
Rout	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (fixed point real number)			
Output	Output signal (floating point complex number)			

Notes

This model converts the real fixed point signal to a complex floating point signal. The fixed-point input signal is transformed to the real part if IorQ is 1; otherwise, it is transformed to the imaginary part.

Netlist Form

```
AFXTTOC:NAME n1 n2 nexsys_component=FXTTOC [IorQ=val] [Rin=val]
[Rout=val]
```

Netlist Example

```
AFXTTOC:1 1 2 nexsys_component=FXTTOC IorQ=1
```

Fixed-Point to Fixed-Point Converter (FXTTOFXT)

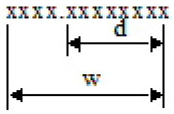
Properties	Description	Units	Default	Range/type
outW	Word length of the output fixed point number	None	32	[1, 32]/Integer
outD	Precision of the output fixed point number	None	0	[0, 32]/Integer
ovf	Overflow characteristic: 0 for wrapped, 1 for saturate, 2 for zero saturate	None	0	[0, 2]/Integer
quant	Quantization characteristic: 0 for truncated, 1 for rounded, 2 for truncated 0	None	0	[0, 2]/Integer
ArithType	Arithmetic type: 0 for signed, 1 for unsigned	None	0	[0, 1]/Integer
Rin	Input impedance	Ohm	Inf	(0, Inf]/Real
Rout	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal : (fixed point real number)			
Output	Output signal (fixed point real number)			

Limits

1. outW > outD for signed arithmetic

Notes

This model converts the real fixed point input signal to a real fixed-point signal of a different format. The output format is set by the user specified parameters: **outW**, **outD**, **ovf** , **quant** and **arithtype**, where **ovf** defines the overflow characteristics, **quant** defines the quantization characteristics and **arithtype** defines the arithmetic type. The following plot shows the relationship between the word length and the precision.



Netlist Form

```
AFXTTOFXT:NAME n1 n2 nexsys_component=FXTTOFXT [outW=val]
[outD=val] [ovf=val] [quant=val] [arithtype=val]   [Rin=val]
[Rout=val]
```

Netlist Example

```
AFXTTOFXT:1 1 2 nexsys_component=FXTTOFXT outW=24 outD=4 ovf=1
quant=1
```

Fixed-Point to Real Converter (FXTTOR)

Property	**Description**	**Units**	**Default**	**Range/type**
Rin	Input impedance	Ohm	Inf	(0, Inf]/Real
Rout	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (fixed point real number)			
Output	Output signal (floating point real number)			

Notes

This model converts the real fixed point input signal to a real floating-point signal.

Netlist Form

```
AFXTTOR:NAME n1 n2  nexsys_component=FXTTOR [Rin=val] [Rout=val]
```

Netlist Example

```
AFXTTOR:1 1 2 nexsys_component=FXTTOR
```

Real to Fixed-Point Converter (RTOFXT)

Property	**Description**	**Units**	**Default**	**Range/type**
outW	Word length of the output fixed-point number	None	32	[1, 32]/Integer
outD	Precision of the output fixed-point number	None	0	[1, 32]/Integer
ovf	Overflow characteristic: 0 for wrapped, 1 for saturate, 2 for zero saturate	None	0	[0, 2]/Integer
quant	Quantization characteristic: 0 for truncated, 1 for rounded, 2 for truncated 0	None	0	[0, 2]/Integer
ArithType	Arithmetic type: 0 for signed, 1 for unsigned	None	0	[0, 1]/Integer
Rin	Input impedance	Ohm	Inf	(0, Inf]/Real
Rout	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (floating point real number)			
Output	Output signal (fixed point real number)			

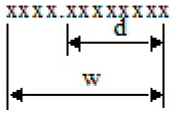
Limits

1. outW > outD for signed arithmetic

Notes

This model converts the real floating point input signal to real fixed-point signal. The output format is set by the user specified parameters: **outW**, **outD**, **ovf**, **quant** and **arithtype**, where **ovf** defines the overflow characteristics, **quant** defines the quantization characteristics and

arithtype defines the arithmetic type. The following plot shows the relationship between the word length and the precision.



Netlist Form

ARTOFXT:NAME n1 n2 nexsys_component=RTOFXT [outW=*val*] [outD=*val*] [ovf=*val*] [quant=*val*] [arithtype=*val*] [Rin=*val*] [Rout=*val*]

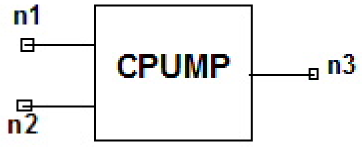
Example

```
ARTOFXT:1 1 2 nexsys_component=RTOFXT outW=16 outD=4
```

Frequency Synthesizers

This topic describes the following System components:

Charge Pump (CPUMP)



Property	Description	Units	Default	Range/Type
I_UP	Up current	uA	160	[0, Inf)/Real
UP_NFLOOR	Up current noise floor in A^2/Hz	None	1e-25	[0, Inf)/Real
UP_FC	Up current flicker corner frequency	Hz	10000	(0, Inf)/Real
UP_NOISE	Up current noise: 1 for On, 0 for Off	None	1	[0, 1]/Integer
I_DOWN	Down current	uA	160	[0, Inf)/Real
DOWN_NFLOOR	Down current noise floor in A^2/Hz	A^2/Hz	1e-25	[0, Inf)/Real
DOWN_FC	Down current flicker corner frequency	Hz	10000	(0, Inf)/Real
DOWN_NOISE	Down noise: 1 for On, 0 for Off	None	1	[0, 1]/Integer
STARTTIME	Start time for pumping total output current	Sec	0	[0, Inf)/Real
STOPTIME	Stop time for pumping total output current	Sec	Inf	[0, Inf)/Real
I_TRICKLE	Trickle current	Current	40uA	(0, Inf)/Real
TRICKLE_NFLOOR	Trickle current noise floor in A^2/Hz	A^2/Hz	1e-25	(0, Inf)/Real
TRICKLE_FC	Trickle current flicker corner frequency	Hz	10000	(0, Inf)/Real
TRICKLE_NOISE	Trickle current noise: 1 for On, 0 for Off	None	1	[0, 1]/Integer
SEED	Random seed	None	0	[0, Inf)/Integer
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				

Input1	Input1 signal (real)
Input2	Input2 signal (real)
Output	Output signal (real)

Notes

1. This element models the behavior of the charge pump device.
2. Let the first input signal be $V_{up}(t)$, the second input signal be $V_{down}(t)$, and the output signal be $V_{out}(t)$, the output signal is calculated like this:

$$V_{out}(t) = (I_{up}V_{up}(t) - I_{down}V_{down}(t) + I_{trickle} + I_{noise}) \bullet Rout$$

3. In the above equation, the term I_{noise} is formed by two parts: one part is the noise on the trickle current, the other part is the noise either on the up current or on the down current depending on which one is active at that time instance. The user has the option to deactivate the noise for the three noise sources, if any of the noise sources is deactivated, no noise is generated for that source. Note that noise simulation is expensive, turning off the noise option speeds up the simulation.
4. In general, for typical PLL applications, the two input impedances should be set to default (INF), and the output impedance should be set to a large value, normally 1e10 is good enough.

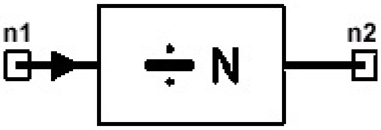
Netlist Form

```
ACPUMP:Name n1 n2 n3 nexsys_component=CPUMP [I_UP=val]
[UP_NFLOOR=val] [UP_FC=val] +[UP_NOISE=val][I_DOWN=val]
[DOWN_NFLOOR=val] [DOWN_FC=val] +[DOWN_NOISE=val]
[STARTTIME=val] [STOPTIME=val] +[I_TRICKLE=val]
[TRICKLE_NFLOOR=val] [TRICKLE_FC=val] +[TRICKLE_NOISE=val]
[SEED=val] [RIN1=val] [RIN2=val] +[ROUT=val]
```

Netlist Example

```
ACPUMP:1 1 2 3 nexsys_component=CPUMP IUP=160uA IDOWN=160uA
ITRICKLE=40uA FC=1000Hz
```

Frequency Divider (FREQDIV)



Property	Description	Units	Default	Range/Type
N	Frequency Division Factor	None	1	(0, Inf)/Integer
SEED	Random seed	None	0	[0, Inf)/Integer
FLOOR	Noise floor in dB	None	-500	(-Inf, Inf)/Real
FLICKER	Divider flicker corner frequency	Hz	10000	(0, Inf)/Real
NOISEON	Noise: 1 for ON, 0 for OFF	None	1	[0, 1]/Integer
WAVETYPE	Incoming signal waveform type: 0 for sinusoid, 1 for sawtooth	None	0	[0, 1]/Integer
VPIN	Incoming signal peak voltage value (valid for sawtooth option)	Volt	1	(0, Inf)/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (complex)			
Output	Output signal (complex)			

Notes

1. This component models the frequency divider device. The division ratio is determined by the parameter N.
2. The input signal can be either of base-band sawtooth waveforms or envelope signals. When it is a sawtooth input signal, the user has to specify the corresponding peak voltage value “VPIN” of the incoming signal to make the model behave properly.
3. The parameters “FLOOR” and “FLICKER” are used to specify the noise characteristic of the divider device. When not needed, the noise simulation should be deactivated by

setting “NOISEON” to 0, this normally speeds up the simulation since it is expensive to simulate noise statistically.

4. In typical PLL applications, this model is used together with the reference oscillator to divide down the reference frequency (called R divider). Note, however, that using this component as a reference divider requires the use of base-band sawtooth waveforms.

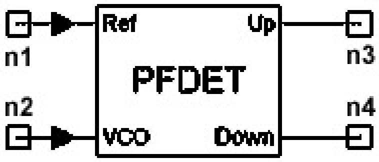
Netlist Form

```
AFREQDIV:Name n1  n2  N=val nexsys_component=FREQDIV [SEED=val]
+ [FLOOR=val] [FLICKER=val] [NOISEON=val] [WAVETYPE=val] [VPIN=val]
[RIN=val]
+ [ROUT=val]
```

Netlist Example

```
AFREQDIV:1 1  2 nexsys_component=FREQDIV N=10 FLOOR=-160dB
FLICKER=15000Hz WAVETYPE=1
```

Tri-State Phase Frequency Detector (PFDET)



Property	Description	Units	Default	Range/Type
VLin	Input low voltage level	Volt	0	(-Inf, Inf)/Real
VHin	Input high voltage level	Volt	1	(-Inf, Inf)/Real
VLout	Output low voltage level	Volt	0	(-Inf, Inf)/Real
VHout	Output high voltage level	Volt	1	(-Inf, Inf)/Real
AMMOD	Amplitude modulation: 0: Without modulation 1: With modulation	None	0	[0, 1]/Integer
NC	Noise constant in dB	dB	-500	(-Inf, Inf)/Real
Fr	Reference frequency	Hz	1	(0, Inf)/Real
Seed	Random seed	None	0	[0, Inf)/Integer
NoiseOn	Noise: 1 for On, 0 for Off	None	1	[0, 1]/Integer
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT1	Output1 impedance	Ohm	0	[0, Inf)/Real
ROUT2	Output2 impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (real)			
Input2	Input2 signal (real)			
Output1	Output1 signal (real)			
Output2	Output2 signal (real)			

Notes

1. This element models the digital behavior of common D flip-flop type tri-state phase-frequency detectors often used in phase-locked loops.
2. The parameters VLin and VHin define the voltage level of the input signal. If an input signal is below VLin, it is limited to VLin. If the signal is higher than VHin, it is assumed to be VHin. The output level is set by VLout and VHout in a similar fashion.
3. The threshold at which the phase detector is triggered is determined by (VLin + VHin)/2.
4. This model can handle any type of input signals. The two inputs are usually from a reference oscillator and a divided VCO signal for phase-locked-loop applications.
5. In order to avoid large amount of time jitter and phase noise that is normally be introduced by not using a high enough sampling rate (higher sampling rate means slower simulation), the two output signals can be chosen to be amplitude modulated by setting AMMOD to 1. The so-called amplitude modulation works as follows: if based on the threshold-crossing line, the pulse width should be 1ms but the simulation timestep is 100ms, the output amplitude or that timestep is 1% of the VHout value. In detecting the pulse width, linear interpolation is used. Therefore, sawtooth waveforms are recommended.
6. The power spectrum of the noise contribution follows the equation $L = Nc + 10\log(F_r)$ [1], where F_r is the reference frequency in PLL applications and *Nc* is a constant that is equivalent to the phase frequency detector noise with F_r = 1Hz.
7. When the parameter **NoiseOn** is set to 1, noise is simulated. Otherwise, noise is not incorporated.

Netlist Form

```
APFDET:Name n1 n2 n3 n4 nexsys_component=PFDET VLin=val
VHin=val VLout=val VHout=val

+ [AMMOD=Val] [Nc=Val] [Fr=Val] [Seed=Val] [RIN1=Val]
+ [RIN2=Val] [ROUT1=Val] [ROUT2=Val]
```

Netlist Example

APFDET:1 1 2 3 4 nexsys_component=PFDET VLin=-1 VHin=1 VLout=0 VHout=1

References

1. Ulrich L. Rohde, David P. Newkirk, “RF/Microwave Circuit Design for Wireless Applications.”

Voltage Controlled Oscillator (VCO)

Property	Description	Units	Default	Range/Type
FLO	Center frequency	MHz	800	(0, Inf)/Real
FC	Flicker frequency of the semiconductor	Hz	1000	(0, Inf)/Real
QLOAD	Loaded Q of the tuned circuit	None	200	(0, Inf)/Real
F	Noise factor	None	10	(0, Inf)/Real
NOISEON	Noise: 1 for On, 0 for Off	None	1	[0, 1]/Integer
DivNoiseOn	Divider noise: 1 for On, 0 for Off	None	1	[0,1]/Integer
VcoNoiseOn	Vco noise: 1 for On, 0 for Off	None	1	[0, 1]/Integer
FM1...n	Frequency offset	Hz	100	(0,Inf)/Real
SBN1...n	Sideband noise in dB at frequency offset	dB	-80	(-Inf,0)/Real
FILE	Filename for FM, SBN data	None	<Project>	String
PSAV	Average available power	dBm	0	[0, Inf)/Real
R	Equivalent noise resistance of tuning diode	Ohm	5000	(0, Inf)/Real
K	Oscillator voltage gain	Hz/V	1000	(0, Inf)/Real
T	Temperature	Cel	27	(0, Inf)/Real
FDEV	Maximum phase noise frequency offset from carrier	Hz	100	(0, Inf)/Real
Seed	Random seed	None	0	[0, Inf)/Integer
Wavetype	Output wave type 0: Sinusoid 1: Sawtooth	None	0	[0, 1]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	50	[0, Inf)/Real
Ports				
Input	Input signal (complex)			

Output	Output signal (complex)

Notes

1. This is a Voltage Controlled Oscillator model. It can either output sinusoidal signal or sawtooth signal depending on how the parameter “WAVETYPE” is set.
2. Suppose the output waveform is sinusoid, the relationship between the input and the output is then given by

$$V_{out}(t) = A\cos(2\pi f_0 t + \theta(t))$$

where $A = \sqrt{4R_{out}P_{sav}}$ for evenlope analysis, or $A = \sqrt{8R_{out}P_{sav}}$ for instantaneous analysis, and $\theta(t) = \theta_n(t) + 2\pi K\int_0^t V_{in}(t)d\tau$, $\theta_n(t)$ is the random phase component at time *t*.

3. If the user sets the output waveform option to be sawtooth, then sawtooth signal is sent to the output with the peak value “A” and the same phase information as the sinusoidal option.
4. The indexed parameters “FM” and “SBN” allow the user to specify measured noise data. When measured noise data is provided, the model ignores the parameters QLOAD, F, R, FC.
5. The “FILE” parameter identifies a data file for the phase noise parameters FM and SBN. The file name must have a .dsp extension, and must be in DSP format:

```
xy

fm1 sbn1

...

fmN sbnN
```

Where the first column is the frequency offset in Hz and the second column is the sideband noise in dB. For example:

```
xy
100 -80
1000 -90
...
```

If a valid “FILE” parameter is present, the data on the file is used and the corresponding “FM” and “SBN” parameters in the netlist is ignored. Any “FM” and “SBN” parameters in the netlist that are not also defined in the data file is used.

6. When the parameter “VcoNoiseOn” is set to 1, VCO noise is simulated. Otherwise, VCO noise is not incorporated in the simulation. The same happens to the divider noise. Note that noise simulation is expensive, so when it is not needed, the two parameters should be activated.
7. The power spectral density for this random phase noise process is given by [1]

$$L(F_m) = 10\log\left\{\left[1+\frac{f_b^2}{(2f_m q_{load})^2}\right]\left(1+\frac{f_c}{f_m}\right)\frac{FkT}{2p_{sav}}+\frac{2kTRK^2}{f_m^2}\right\}$$

A random phase noise process $\theta_n(t)$ is generated by filtering a white Gaussian random sequence through a filter with a frequency response $H(f_m)$, where $H(f_m) = \sqrt{L(f_m)}$ with $1 \le f_m \le FDEV$

If required, linear interpolation is applied in the time domain on the generated phase noise process $\theta_n(t)$ to ensure it has the same sampling rate as that of the input signal. In general, the random phase noise process $\theta_n(t)$ is a slowly time-varying process.

8. To avoid aliasing the VCO output signal, the simulation sample rate should be set to twice the maximum swing of the VCO. This swing is based on the Oscillator Voltage Gain parameter [K] and the maximum allowed tuning voltage of the design.

$$SampleRate = 2 \times V_{\max} \times K$$

The VCO output must be a complex envelope signal so you have to also have to ensure your sample rate is less than twice your VCO center frequency [FLO]. In general, your sample rate should be in the range of:

$$10 \times FREF < SampleRate < \min\left\{2 \times FLO, 2 \times V_{\max} \times K\right\}$$

If you are limited by the FLO parameter, you are not able to simulate the high-end of your tuning voltage range.

Netlist Form

```
AVCO:Name n1  n2 nexsys_component=VCO FLO=val  [FC=val]
[QLOAD=val] [F=val]

+ [PSAV=val] [R=val] K=val  T=val  [FDEV=val]   [Seed=val]

+[DivNoiseOn=val] [VcoNoiseOn=val] [FM1..n=val] [SBN1..n=val]
[FILE='filename']

+ [Wavetype=val] [Rin=Val] [Rout=Val]
```

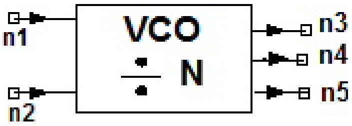
Netlist Example

```
AVCO:1 1 2 nexsys_component=VCO FLO=800MHZ  FC=1KHZ  QLOAD=200 F=10
PSAV=0dBm
+ R=5000OH  K=1000  T=300DEG  FDEV=100KHZ
```

References

1. Ulrich L. Rohde, J. Whitaker, and T.T.N. Bucher, *Communications Receivers*. McGraw-Hill, 1996.

Voltage Controlled Oscillator with Frequency Divider (VCODIVBYN)



Property	Description	Units	Default	Range/Type
FLO	Center frequency	MHz	800	(0,Inf) /Real
FC	Flicker frequency of the semiconductor	Hz	1000	(0,Inf) /Real
QLOAD	Loaded Q of the tuned circuit	None	200	(0,Inf) /Real
F	Noise factor	None	10	(0,Inf) /Real
PSAV	Average available power	dBm	0	[0,Inf) /Real
R	Noise resistance of tuning diode	Ohm	5000	(0,Inf) /Real
K	Nominal oscillator voltage gain	None	1000	(0,Inf)/Real
T	Temperature	Cel	27	(0,Inf) /Real
SEED	Random seed	None	0	[0,Inf)/Integer
N	Frequency division factor	None	1	(0,Inf)/Integer
DivNoiseOn	Divider noise: 1 for On, 0 for Off	None	1	[0,1]/Integer
VcoNoiseOn	Vco noise: 1 for On, 0 for Off	None	1	[0, 1]/Integer
WAVETYPE	Output waveform type 0: sinusoid 1: sawtooth	None	0	[0, 1]/Integer
DIV_FLOOR	Divider noise floor in dB	None	-500	(-Inf, Inf)/Real
DIV_FC	Divider flicker corner frequency	Hz	10000	(0, Inf)/Real
FM1...n	Frequency offset	Hz	100	(0,Inf)/Real
SBN1...n	Sideband noise in dB at frequency offset	dB	-80	(-Inf,0)/Real
FILE	Filename for FM, SBN data	None	<Project>	String
TSTART	Time instance to start measuring phase noise	Sec	0	[0,Inf)/Real
FRACTION	Division fraction of fractional-N synthesizer (for phase noise measurement use)	None	0	[0,1)/Real
FREF	Reference frequency (for phase noise	Hz	1000	(0, Inf)/Real

	measurement use)			
V_1...n	Voltage data point	Volt	0	(0, Inf)/Real
K_1...n	Oscillator voltage gain at voltage data point	None	0	(0, Inf)/Real
Rin1	Input1 impedance	Ohm	Inf	(0,Inf]/Real
Rin2	Input2 impedance	Ohm	Inf	(0,Inf]/Real
Rout1	Output1 impedance	Ohm	50	[0, Inf)/Real
Rout2	Output2 impedance	Ohm	0	[0, Inf)/Real
Rout3	Output3 impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (complex)			
Input2	Input2 signal (real, optional)			
Output1	Output1 signal (complex)			
Output2	Output2 signal (complex, optional)			
Output3	Output3 signal (real, optional)			

Notes

1. This model combines the voltage controlled oscillator with the frequency divider.
2. The pin assignment is as follows: the first input is the tuning voltage signal; the second input (optional, can be left open) is the instant division factor variation *dN*; the first output is the divided VCO output; the second output (optional, can be left open) is the undivided VCO output; the third output is the phase noise output, it is optional also.
3. The sawtooth waveform type option is valid for baseband output signal only. If the option is set to be sawtooth when the actual signal is a bandpass signal, no action is taken.
4. The parameter “DIV_FLOOR” allows the user to specify noise floor due to the frequency divider.
5. The indexed parameters “FM” and “SBN” allow the user to specify measured noise data. When measured noise data is provided, the model ignores the parameters QLOAD, F, R, FC.
6. The “FILE” parameter identifies a data file for the phase noise parameters FM and SBN. The file name must have a .dsp extension, and must be in DSP format:

```
xy

fm1 sbn1

...

fmN sbnN
```

Where the first column is the frequency offset in Hz and the second column is the sideband noise in dB. For example:

```
xy
100 -80
1000 -90
...
```

If a valid “FILE” parameter is present, the data on the file is used and the corresponding “FM” and “SBN” parameters in the netlist is ignored. Any “FM” and “SBN” parameters in the netlist that are not also defined in the data file is used.

7. When the parameter “VcoNoiseOn” is set to 1, VCO noise is simulated. Otherwise, VCO noise is not incorporated in the simulation. The same happens to the divider noise. Note that noise simulation is expensive, so when it is not needed, the two parameters should be activated.
8. Parameters "TSTART", "FRACTION", and "FREF" are used to directly output phase noise data on the third output port. TSTART should be set to a value after the PLL has locked on; this ensures that only steady-state phase noise samples are sent to the phase noise probe. FRACTION is the fractional portion of the steady-state divide- ratio, and should be set to 0 for integer-N PLL designs. Finally, FREF should be set to the reference or comparison frequency that feeds the phase detector. If choose to use this model without the divider, you must set N equal to 1 and set FREF equal to FLO (Free-running VCO frequency).
9. Assume the output waveform type is set to be sinusoid. Let the signal on the first input be $V_{in}(t)$, and the signal on the second input be $dN(t)$. The relationship between the inputs and the outputs is given by

$$V_{out1}(t) = A(t)\cos\left(2\pi\frac{f_c}{N+dN(t)}t + \frac{\theta(t)}{N+dN(t)}\right)$$

$$V_{out2}(t) = A(t)\cos(2\pi f_{lo}t + \theta(t))$$

Here, $A = \sqrt{4R_{out1}P_{sav}}$ for envelope analysis

or $A = \sqrt{8R_{out1}P_{sav}}$ for instantaneous analysis, and

$\theta(t) = \theta_n(t) + 2\pi K\int_0^t V_{in}(\tau)d\tau$, $\theta_n(t)$ is the random phase noise process, with the power spectral density [1}:

$$L(F_m) = 10\log\left\{\left[1 + \frac{f_b^2}{(2f_m q_{load})^2}\right]\left(1 + \frac{f_c}{f_m}\right)\frac{FkT}{2p_{sav}} + \frac{2kTRK^2}{f_m^2}\right\}$$

A random phase noise process $\theta_n(t)$ is generated by filtering a white Gaussian random sequence

through a filter with a frequency response $H(f_m)$, where $H(f_m) = \sqrt{L(f_m)}$

In general, the random phase noise process $\theta_n(t)$ is a slowly time-varying process.

9. If the user sets the output waveform option to be sawtooth, then sawtooth signal is sent to the output with the peak value “A” and the same phase information as the sinusoidal option.

10. If the user supplies the measured V-K data pair, that is the voltage and oscillator voltage gain pair, the tuning sensitivity is based on the dataset instead of the nominal oscillator voltage gain. At the same time, the K value in the noise spectrum calculation is the average of the supplied measured K values instead of the nominal value. Note that when supplying the V-K pairs, V should be in ascending order. Also, if the actual tuning voltage is smaller than V_1, then K_1 is used; if the actual tuning voltage is larger than V_n, then K_n is used.

11. An example using the VCODIVBYN in a fractional-N synthesizer design is provided with **Electronics Desktop**. Use the **File** menu to open *InstallDirectory*/**Examples/System/Motorola_Fractional_Synthesizer.adsn**. *InstallDirectory* is the directory where **Electronics Desktop** is installed. See the References under this topic for a paper describing this design and how it was simulated in **Electronics Desktop**.

12. To avoid aliasing the VCO output signal, the simulation sample rate should be set to twice the maximum swing of the VCO. This swing is based on the Oscillator Voltage Gain parameter [K] and the maximum allowed tuning voltage of the design.

$$SampleRate = 2 \times V_{\max} \times K$$

The VCO output must be a complex envelope signal so you have to also have to ensure your sample rate is less than twice your VCO center frequency [FLO]. In general, your sample rate should be in the range of:

$$10 \times FREF < SampleRate < \min\left\{2 \times FLO, 2 \times V_{\max} \times K\right\}$$

If you are limited by the FLO parameter, you are not able to simulate the high-end of your tuning voltage range.

Netlist Form

```
AVCODIVBYN:Name n1  n2  n3 n4 n5 nexsys_component=VCODIVBYN
FLO=val  [FC=val] [QLOAD=val]
+[F=val][PSAV=val] [R=val] K=val  T=val  [SEED=val] [N=val]
+[DivNoiseOn=val] [VcoNoiseOn=val] [WAVETYPE=val]
+[DIV_FLOOR=val] [FM1..n=val] [SBN1..n=val] [FILE='filename']
+[TSTART=val] [FRACTION=val] [FREF=val]
+ [RIN1=val] [RIN2=val] [ROUT1=val] [ROUT2=val] [ROUT3=val]
```

Netlist Example

```
AVCODIVBYN:1 1 2 3 4 5 nexsys_component=VCODIVBYN FLO=800MHZ
FC=1KHZ  QLOAD=200  F=10
```

```
+ PSAV=0dbm R=5000OH  K=1e6 T=290Kel
```

References

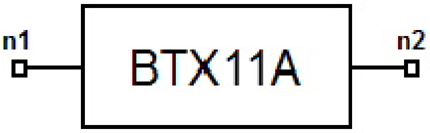
[1] Wael Al-Qaq, JianHua Gu, William J. Martin, and Jeffrey L. Cutcher, “Fast and Accurate Fractional-N Synthesizer Simulation Using Ansoft Designer™”, Motorola, Inc., Copyright 2004.

[2] Ulrich L. Rohde, J. Whitaker, and T.T.N. Bucher, *Communications Receivers*, McGraw-Hill, 1996.

IEEE802dot11a

This topic describes the following System components:

Baseband Transmitter (BTX11A)



Property	Description	Units	Default	Range/Type
MODULATION	Modulation type	None	2	[0, 3]/Integer
CODING	Coding Rate	None	2	[0, 2]/Integer
LENGTH	Length of PSDU (number of octets)	None	100	[1, 4095]/Integer
S0	Initial state for scrambling in decimal value	None	93	[0, 127]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	PSDU bit stream (integer)			
Output	PSDU frame (complex)			

Limits

$$Modulation = \begin{cases} 0 & \text{BPSK} \\ 1 & \text{QPSK} \\ 2 & \text{16 - QAM} \\ 3 & \text{64 - QAM} \end{cases}$$

$$Coding = \begin{cases} 0 & \text{Coding Rate} = 1/2 \\ 1 & \text{Coding Rate} = 2/3 \\ 2 & \text{Coding Rate} = 3/4 \end{cases}$$

Notes

1. This model is a high level component of the IEEE 802.11a baseband transmitter. The block diagram of this model is shown in Fig. 1, which does not include PSDU Generator. For some details, please refer to the related models.

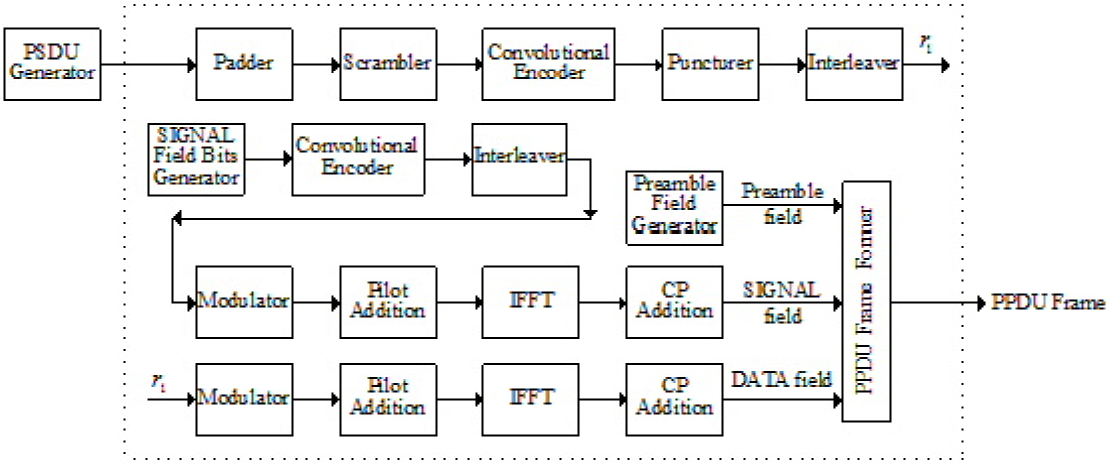


Fig.1 Block diagram of the IEEE 802.11a baseband transmitter

Notes

```
APAD11A:5_a n1 inet_0 nexsys_component=PAD11A MODULATION=2
CODING=2 LENGTH=val RIN=val

ASCRM11A:5_b inet_0 inet_1 nexsys_component=SCRM11A
MODULATION=2 CODING=2 LENGTH=val S0=val

ACOD11A:5_c inet_1 inet_2 nexsys_component=COD11A PURPOSE=1
MODULATION=2 CODING=2 LENGTH=val

APUNC11A:5_d inet_2 inet_3 nexsys_component=PUNC11A CODING=2

AINTLV11A:5_e inet_3 inet_4 nexsys_component=INTLV11A
MODULATION=2

AMOD11A:5_f inet_4 inet_5 nexsys_component=MOD11A MODULATION=2

APLTADD11A:5_g inet_5 inet_6 nexsys_component=PLTADD11A
PURPOSE=1 MODULATION=2 CODING=2 LENGTH=val

AIFFT11A:5_h inet_6 inet_7 nexsys_component=IFFT11A
```

```
ACPADD11A:5_i inet_7 inet_8 nexsys_component=CPADD11A PURPOSE=1
MODULATION=2 CODING=2 LENGTH=val

ASIG11A:5_j inet_9 nexsys_component=SIG11A MODULATION=2
CODING=2 LENGTH=val

ACOD11B:5_k inet_9 inet_10 nexsys_component=COD11A PURPOSE=0
MODULATION=0 CODING=0

AINTLV11A:5_l inet_10 inet_11 nexsys_component=INTLV11A
MODULATION=0

AMOD11A:5_m inet_11 inet_12 nexsys_component=MOD11A
MODULATION=0

APLTADD11A:5_n inet_12 inet_13 nexsys_component=PLTADD11A
PURPOSE=0 MODULATION=0 CODING=0 LENGTH=val

AIFFT11A:5_o inet_13 inet_14 nexsys_component=IFFT11A

ACPADD11A:5_p inet_14 inet_15 nexsys_component=CPADD11A
PURPOSE=0 MODULATION=0 CODING=0 LENGTH=100

APREAM11A:5_q inet_16 nexsys_component=PREAM11A

APFORM11A:5_r inet_16 inet_15 inet_8 n2
nexsys_component=PFORM11A MODULATION=2 CODING=2 LENGTH=val
ROUT=val
```

Netlist Example

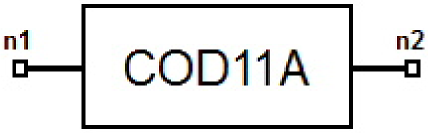
```
APAD11A:5_a Port1 inet_0 nexsys_component=PAD11A MODULATION=2
CODING=2 LENGTH=100 RIN=1000000000

ASCRM11A:5_b inet_0 inet_1 nexsys_component=SCRM11A
MODULATION=2 CODING=2 LENGTH=100

ACOD11A:5_c inet_1 inet_2 nexsys_component=COD11A PURPOSE=1
MODULATION=2 CODING=2 LENGTH=100

APUNC11A:5_d inet_2 inet_3 nexsys_component=PUNC11A CODING=2

AINTLV11A:5_e inet_3 inet_4 nexsys_component=INTLV11A
MODULATION=2

AMOD11A:5_f inet_4 inet_5 nexsys_component=MOD11A MODULATION=2

APLTADD11A:5_g inet_5 inet_6 nexsys_component=PLTADD11A
PURPOSE=1 MODULATION=2 CODING=2 LENGTH=100

AIFFT11A:5_h inet_6 inet_7 nexsys_component=IFFT11A
```

```
ACPADD11A:5_i inet_7 inet_8 nexsys_component=CPADD11A PURPOSE=1
MODULATION=2 CODING=2 LENGTH=100

ASIG11A:5_j inet_9 nexsys_component=SIG11A MODULATION=2
CODING=2 LENGTH=100

ACOD11B:5_k inet_9 inet_10 nexsys_component=COD11A PURPOSE=0
MODULATION=0 CODING=0

AINTLV11A:5_l inet_10 inet_11 nexsys_component=INTLV11A
MODULATION=0

AMOD11A:5_m inet_11 inet_12 nexsys_component=MOD11A
MODULATION=0

APLTADD11A:5_n inet_12 inet_13 nexsys_component=PLTADD11A
PURPOSE=0 MODULATION=0 CODING=0 LENGTH=100

AIFFT11A:5_o inet_13 inet_14 nexsys_component=IFFT11A

ACPADD11A:5_p inet_14 inet_15 nexsys_component=CPADD11A
PURPOSE=0 MODULATION=0 CODING=0 LENGTH=100

APREAM11A:5_q inet_16 nexsys_component=PREAM11A

APFORM11A:5_r inet_16 inet_15 inet_8 Port2
nexsys_component=PFORM11A MODULATION=2 CODING=2 LENGTH=100
ROUT=1e-009
```

References

1. IEEE Std 802.11a, Part 11: “Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band,” ISO/IEC 8802-11:1999/Amd 1:2000(E).

Convolutional Encoder, 802.11a (COD11A)



Property	Description	Units	Default	Range/Type
PURPOSE	Signal field {0}, DATA field {1}	None	1	[0,1]/Integer
MODULATION	Modulation Type	None	0	[0, 3]/Integer
CODING	Coding Rate type	None	0	[0, 2]/Integer
LENGTH	Length of PSDU (number of octets)	None	100	[1, 4095]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Bits before encoding (integer)			
Output	Bits after encoding (integer)			

Limits

$$Modulation = \begin{cases} 0 & \text{BPSK} \\ 1 & \text{QPSK} \\ 2 & \text{16-QAM} \\ 3 & \text{64-QAM} \end{cases}$$

$$Coding = \begin{cases} 0 & \text{Coding Rate} = 1/2 \\ 1 & \text{Coding Rate} = 2/3 \\ 2 & \text{Coding Rate} = 3/4 \end{cases}$$

Notes

1. This model can be used to encode the DATA field and SIGNAL field according to IEEE 802.11a standard.
2. The convolutional encoder uses the industry-standard generator polynomials,g_d = 133 and g_l = 171 , of rate R = 1/2, as shown in Fig.1. The bit denoted as "*A*" is output on the encoder before the bit denoted as "*B.*"
3. The initial state of convolutional encoder is set to "all zero." When the next DATA field arrives, the initial state of convolutional encoder is reset to "all zero". The number of bits of DATA field, N_{Data}, can be determined by the three parameters, Modulation, Coding, and Length. For the calculation of N_{Data}, please refer to the PAD11A model.

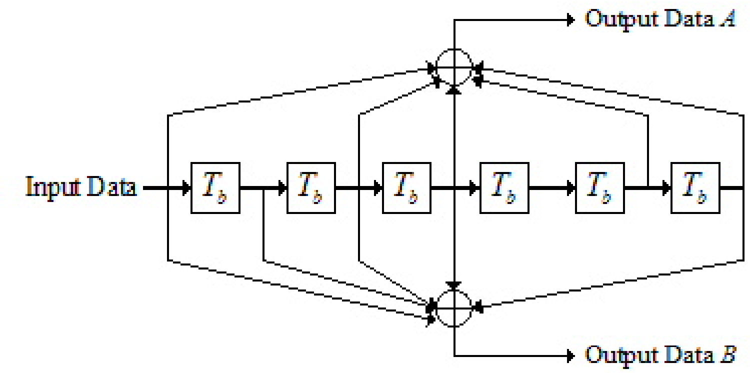


Fig.1 Convolutional encoder

Netlist Form

```
ACOD11A:NAME  n1 n2  nexsys_component=COD11A [PURPOSE =val]
[MODULATION =val]
+ [CODING =val] [LENGTH =val] [RIN=val] [ROUT=val]
```

Netlist Example

```
ACOD11A:1 1 2 nexsys_component=COD11A MODULATION = 2 CODING= 2
LENGTH = 100
```

References

1. IEEE Std 802.11a, Part 11: "Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band," ISO/IEC 8802-11:1999/Amd 1:2000(E).
2. J. Terry and J. Heiskala, Proakis, *OFDM Wireless LANs: A Theoretical and Practical Guide*, Sams Publishing, 2002.
3. J. G. Proakis, *Digital Communications*, McGraw-Hill, 2001.

CP Addition, 802.11a (CPADD11A)

Property	Description	Units	Default	Range/Type
PURPOSE	SIGNAL field {0} DATA field {1}	None	1	[0, 1]/Integer
MODULATION	Modulation Type	None	0	[0, 3]/Integer
CODING	Coding Rate Type	None	0	[0, 2]/Integer
LENGTH	Length of PSDU (number of octets)	None	100	[1, 4095]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Signal before cyclic prefix addition (complex)			
Output	Signal after cyclic prefix addition (complex)			

Limits

$$Modulation = \begin{cases} 0 & \text{BPSK} \\ 1 & \text{QPSK} \\ 2 & 16\text{-QAM} \\ 3 & 64\text{-QAM} \end{cases}$$

$$Coding = \begin{cases} 0 & \text{Coding Rate} = 1/2 \\ 1 & \text{Coding Rate} = 2/3 \\ 2 & \text{Coding Rate} = 3/4 \end{cases}$$

Notes

1. This model can be used to add cyclic prefix (CP) into the outputs of 64-point IFFT, according to *IEEE* 802.11a standard.
2. The input time domain signal $x_{0,...,63}$ are extended using cyclic prefix (CP) as follows:

$$y_k = \begin{cases} x_{k+48} & 0 \le k \le 15 \\ x_{k-16} & 16 \le k \le 79 \\ x_0 & k = 80 \end{cases} \qquad (1)$$

, then multiplied with the window function

$$W(k) = \begin{cases} 0.5 & k = 0 \\ 1 & 1 \le k \le 79 \\ 0.5 & k = 80 \end{cases} \qquad (2)$$

3. The time domain samples of SIGNAL field are appended with one sample overlap to the preamble. The time domain samples of the first DATA symbol are appended with one sample overlap to the SIGNAL field symbol. The symbols of DATA field are appended after the other with one sample overlap.

Netlist Form

```
ACPADD11A:NAME  n1 n2 nexsys_component=CPADD11A [PURPOSE =val]
[MODULATION =val]
+ [CODING =val] [LENGTH =val] [RIN=val] [ROUT=val]
```

Netlist Example

```
ACPADD11A:1 1 2 nexsys_component=CPADD11A MODULATION = 2
CODING= 2 LENGTH = 100
```

References

1. IEEE Std 802.11a, Part 11: “Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band,” ISO/IEC 8802-11:1999/Amd 1:2000(E).
2. J. Terry and J. Heiskala, Proakis, *OFDM Wireless LANs: A Theoretical and Practical Guide*, Sams Publishing, 2002.

CP Removal, 802.11a (CPRM11A)

Property	Description	Units	Default	Range/Type
PURPOSE	SIGNAL field {0} DATA field {1}	None	1	[0, 1]/Integer
SOURCE	Signal field/Data field {0} PPDU Frame {1}	None	0	[0, 1]/Integer
MODULATION	Modulation Type	None	0	[0, 3]/Integer
CODING	Coding Rate Type	None	0	[0, 2]/Integer
LENGTH	Length of PSDU (number of octets)	None	100	[1, 4095]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Signal before cyclic prefix removed (complex)			
Output	Signal after cyclic prefix removed (complex)			

Limits

$$Modulation = \begin{cases} 0 & \text{BPSK} \\ 1 & \text{QPSK} \\ 2 & \text{16 - QAM} \\ 3 & \text{64 - QAM} \end{cases}$$

$$Coding = \begin{cases} 0 & \text{Coding Rate} = 1/2 \\ 1 & \text{Coding Rate} = 2/3 \\ 2 & \text{Coding Rate} = 3/4 \end{cases}$$

Notes

1. This model can be used to remove the symbol cyclic prefix (CP) that the cpadd11a model added to the outputs of 64-point IFFT, according to *IEEE* 802.11a standard. For details, please refer to the cpadd11a model.
2. It should be noted that if the parameter Source is set to SIGNAL field/DATA field {0}, the input of the model is connected to the output of the **cpadd11a** model. If Source is set to PPDU Frame {1}, the input of the model should be connected to the output of the **pform11a** model. the **cprm11a** model extracts SIGNAL field or DATA field on the PPDU frame, which depends on the parameter Purpose.
3. Fig.1 shows a block diagram of the IEEE 802.11a baseband receiver (basic components).

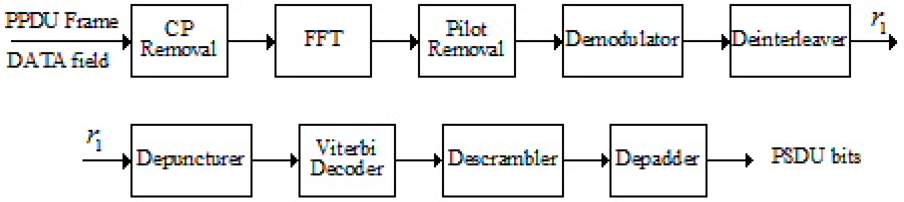


Fig. 1 Block diagram of the IEEE 802.11a baseband receiver (basic components)

Netlist Form

```
ACPRM11A:NAME  n1 n2 nexsys_component=CPRM11A [PURPOSE =val]
[SOURCE =val]
+ [MODULATION =val] [CODING =val]
+ [LENGTH =val] [RIN=val]
+ [ROUT=val]
```

Netlist Example

```
ACPRM11A:1 1 2 nexsys_component=CPRM11A MODULATION = 2 CODING=
2 LENGTH = 100
```

References

1. IEEE Std 802.11a, Part 11: “Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band,” ISO/IEC 8802-11:1999/Amd 1:2000(E).
2. J. Terry and J. Heiskala, Proakis, *OFDM Wireless LANs: A Theoretical and Practical Guide*, Sams Publishing, 2002.

Deinterleaver, 802.11a (DEILV11A)

Property	Description	Units	Default	Range/Type
MODULATION	Modulation type	None	0	[0,3]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Bits before deinterleaving (integer)			
Output	Bits after deinterleaving (integer)			

Limits

$$Modulation = \begin{cases} 0 & \text{BPSK} \\ 1 & \text{QPSK} \\ 2 & 16\text{-QAM} \\ 3 & 64\text{-QAM} \end{cases}$$

Notes

1. This model can be used for data deinterleaving, according to *IEEE* 802.11a standard.
2. All demodulated data bits is deinterleaved by a block deinterleaver with a block size corresponding to the number of bits in a single OFDM symbol, N_{CBPS}. The deinterleaver, which performs the inverse relation of the interleaver, is also defined by a two-step permutation.
3. Denote by *J* the index of the original received bit before the first permutation; *i* is the index after the first and before the second permutation, and *k* is the index after the second permutation, just prior to delivering the coded bits to the convolutional (Viterbi) decoder. The first permutation is defined by the rule

$$i = s \times \text{floor}(j/s) + (j + \text{floor}(16 \times j/N_{CBPS})) \bmod s \quad j = 0,1,\ldots N_{CBPS} - 1 \qquad (1)$$

where the function floor (.) denotes the largest integer not exceeding the parameter, and

$$s = \max\left(N_{BPSC}/2, 1\right)$$

(2)

This permutation is the inverse of permutation described in Eqn.(2) of the model **intlv11a**. The second permutation is defined by the rule

$$k = 16 \times i - \left(N_{CBPS} - 1\right)\mathrm{floor}\left(16 \times i/N_{CBPS}\right)\ i = 0, 1, \ldots N_{CBPS} - 1$$

(3)

This permutation is the inverse of permutation described in Eqn.(1) of the model **intlv11a**. In the above equations,N_{CBPS} and N_{BPSC} depend on the base modulation mode, as shown in Table I.

Table I *IEEE* 802.11a Rate-dependent parameter

Data rate (Mbits/s)	**Modulation**	**Coding rate (R)**	**Coding bits per subcarrier (N_{BPSC})**	**Coding bits per OFDM symbol (N_{CBPS})**	**Data bits per OFDM symbol (N_{DBPS})**
6	BPSK	1/2	1	48	24
9	BPSK	3/4	1	48	36
12	QPSK	1/2	2	96	48
18	QPSK	3/4	2	96	72
24	16-QAM	1/2	4	192	96
36	16-QAM	3/4	4	192	144
48	64-QAM	2/3	6	288	192
54	64-QAM	3/4	6	288	216

Netlist Form

```
ADEILV11A:NAME  n1 n2 nexsys_component=DEILV11A [MODULATION
=val] [RIN=val] [ROUT=val]
```

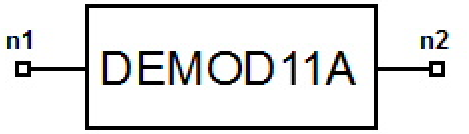
Netlist Example

```
ADEILV11A:1 1 2 nexsys_component=DEILV11A MODULATION = 2
```

References

1. IEEE Std 802.11a, Part 11: “Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band,” ISO/IEC 8802-11:1999/Amd 1:2000(E).
2. J. Terry and J. Heiskala, Proakis, *OFDM Wireless LANs: A Theoretical and Practical Guide*, Sams Publishing, 2002.

Demodulator, 802.11a (DEMOD11A)



Property	Description	Units	Default	Range/Type
MODULATION	Modulation Type	None	0	[0, 3]/Integer
DECISION	Hard decision {0}/ Soft decision {1}	None	0	[0, 1]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Signal before demodulation (complex)			
Output	Signal after demodulation (real)			

Limits

$$Modulation = \begin{cases} 0 & \text{BPSK} \\ 1 & \text{QPSK} \\ 2 & 16\text{-QAM} \\ 3 & 64\text{-QAM} \end{cases}$$

Notes

1. This model can be used for demodulation according to Gray-coded constellation mappings[1]. For details, please refer to the **MOD11a** model.
2. Hard decision demodulator makes a definite determination of whether a zero or one bit was transmitted, thus the outputs of the demodulator are zeros and ones. Soft decision demodulator outputs information of the reliability of the decision along with a zero or one bit. The sign of the soft decision indicators a zero or one bit, and the absolute value of each soft decision is the distance to the decision boundary[2].

Netlist Form

```
ADEMOD11A:NAME  n1 n2 nexsys_component=DEMOD11A [MODULATION
=val] [DECISION = val]
+ [RIN=val] [ROUT=val]
```

Netlist Example

```
ADEMOD11A:1 1 2 nexsys_component=DEMOD11A MODULATION = 2
```

References

1. [1] IEEE Std 802.11a, Part 11: “Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band,” ISO/IEC 8802-11:1999/Amd 1:2000(E).
2. [2]J. Terry and J. Heiskala, Proakis, *OFDM Wireless LANs: A Theoretical and Practical Guide*, Sams Publishing, 2002.

Depadder, 802.11a (DPAD11A)

Property	Description	Units	Default	Range/Type
MODULATION	Modulation Type	None	0	[0, 3]/Integer
CODING	Coding Rate	None	0	[0, 2]/Integer
LENGTH	Length PSDU (number of octets)	None	100	[1, 4095]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Bits before depadding (integer)			
Output	Bits after depadding (integer)			

Limits

$$Modulation = \begin{cases} 0 & \text{BPSK} \\ 1 & \text{QPSK} \\ 2 & 16\text{-QAM} \\ 3 & 64\text{-QAM} \end{cases}$$

$$Coding = \begin{cases} 0 & \text{Coding Rate} = 1/2 \\ 1 & \text{Coding Rate} = 2/3 \\ 2 & \text{Coding Rate} = 3/4 \end{cases}$$

Notes

1. This model can be used to extract the PSDU bits on the DATA field bits by removing the SERVICE field, tail bits and pad bits, according to IEEE 802.11a standard. For details, please refer to the PAD11A model.

Netlist Form

```
ADPAD11A:NAME  n1 n2 nexsys_component=DPAD11A [MODULATION =val]
[CODING =val]
+ [LENGTH =val] [RIN=val] [ROUT=val]
```

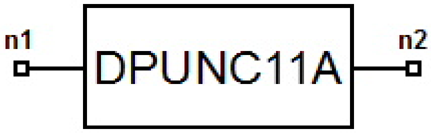
Netlist Example

```
ADPAD11A:1 1 2 nexsys_component=DPAD11A MODULATION = 2 CODING=
2 LENGTH = 100
```

References

1. IEEE Std 802.11a, Part 11: “Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band,” ISO/IEC 8802-11:1999/Amd 1:2000(E).

Depuncturer, 802.11a (DPUNC11A)



Property	Description	Units	Default	Range/Type
CODING	Coding Rate Type	None	0	[0, 2]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Signal before depuncturing (real)			
Output	Signal after depuncturing (real)			

Limits

$$Coding = \begin{cases} 0 & \text{Coding Rate} = 1/2 \\ 1 & \text{Coding Rate} = 2/3 \\ 2 & \text{Coding Rate} = 3/4 \end{cases}$$

Notes

1. This model can be used to perform “depuncturing”, according to *IEEE* 802.11a standard.
2. The DATA field, composed of SERVICE, PSDU, tail, and pad parts, is coded with a convolutional encoder of coding rate R = 1/2, 2/3, or 3/4, corresponding to the appropriate data rate. The convolutional encoder uses the industry-standard generator polynomials, $g_0 = 133_z$ and $g_I = 133_z$, of rate R =1/2, please refer to the **COD11A** model. Higher rates are derived from it by employing “puncturing.” Puncturing is a procedure for omitting some of the encoded bits in the transmitter (thus reducing the number of transmitted bits and increasing the coding rate) and inserting a dummy “zero” metric into the convolutional decoder in the receiver in place of the omitted bits. The “puncturing” and “depuncturing”

procedure are illustrated in Fig.1a and Fig 1b.

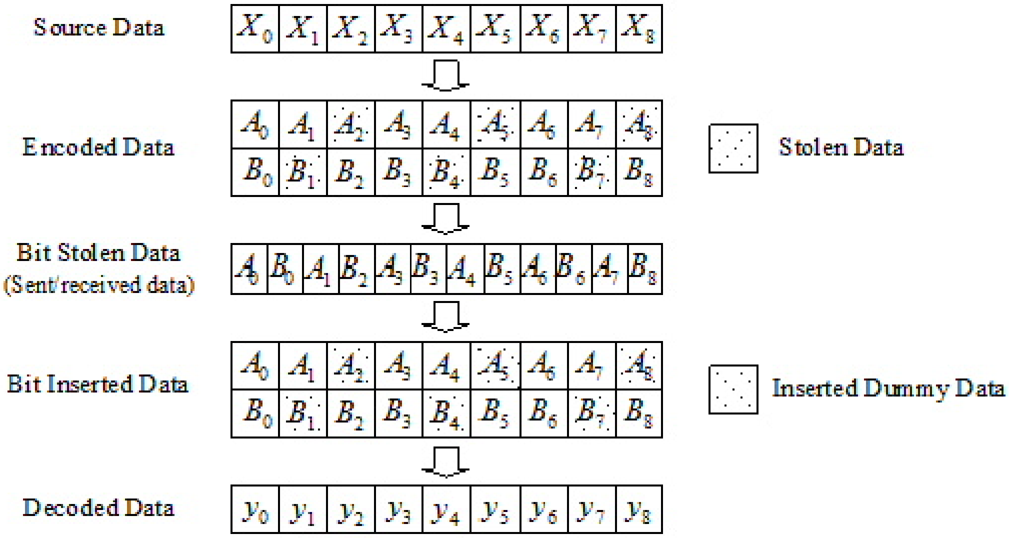


Fig.1A The “puncturing” and “depuncturing” procedure for coding rate R = 3/4.

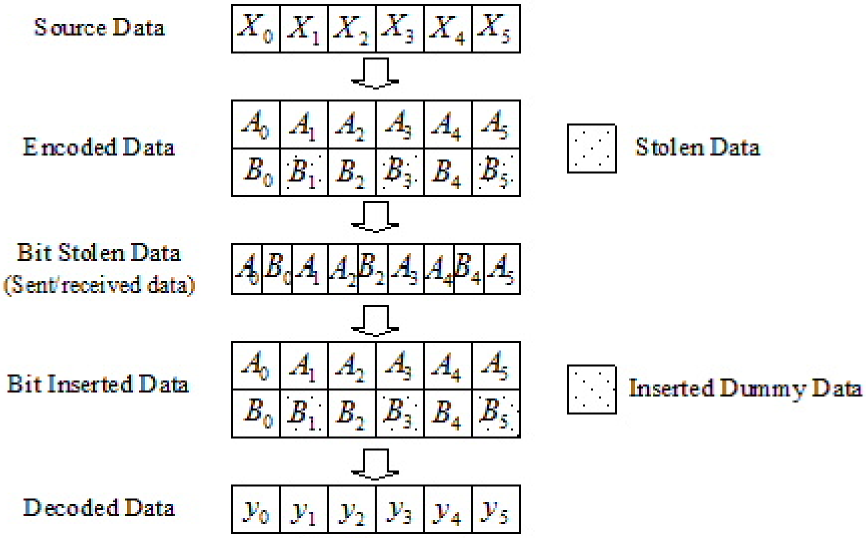


Fig.1B The “puncturing” and “depuncturing” procedure for coding rate R = 2/3

Netlist Form

```
ADPUNC11A:NAME  n1 n2 nexsys_component=DPUNC11A [CODING=val]
[RIN=val] [ROUT=val]
```

Netlist Example

```
ADPUNC11A:1 1 2 nexsys_component=DPUNC11A CODING = 2
```

References

1. [1] IEEE Std 802.11a, Part 11: “Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band,” ISO/IEC 8802-11:1999/Amd 1:2000(E).
2. [2]J. Terry and J. Heiskala, Proakis, *OFDM Wireless LANs: A Theoretical and Practical Guide*, Sams Publishing, 2002.

Descrambler, 802.11a (DSCRM11A)

Property	Description	Units	Default	Range/Type
MODULATION	Modulation Type	None	0	[0, 3]/Integer
CODING	Coding Rate Type	None	0	[0, 2]/Integer
LENGTH	Length of PSDU (number of octets)	None	100	[1, 4095]/Integer
S0	Initial state of the scrambler in decimal	None	93	[0, 127]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Bits before descrambling (integer)			
Output	Bits after descrambling (integer)			

Limits

$$Modulation = \begin{cases} 0 & \text{BPSK} \\ 1 & \text{QPSK} \\ 2 & \text{16-QAM} \\ 3 & \text{64-QAM} \end{cases}$$

$$Coding = \begin{cases} 0 & \text{Coding Rate} = 1/2 \\ 1 & \text{Coding Rate} = 2/3 \\ 2 & \text{Coding Rate} = 3/4 \end{cases}$$

Notes

1. This model can be used to descramble the DATA field, according to IEEE 802.11a standard. The structure is the same as scrambler, as shown in Fig.1. For details, please refer to the model SCRM11a.

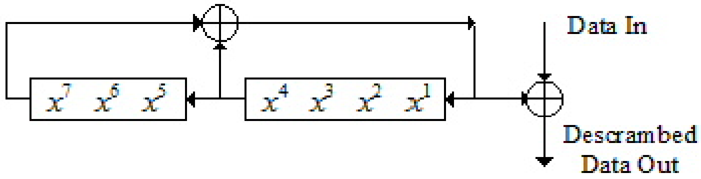


Fig.1 Data descrambler

Netlist Form

```
ADSCRM11A:NAME  n1 n2 nexsys_component=DSCRM11A [MODULATION
=val] [CODING =val]
+ [LENGTH =val] [S0=val] [RIN=val] [ROUT=val]
```

Netlist Example

```
ADSCRM11A:1 1 2 nexsys_component=DSCRM11A MODULATION = 2
CODING= 2 LENGTH = 100 S0 = 93
```

References

1. IEEE Std 802.11a, Part 11: “Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band,” ISO/IEC 8802-11:1999/Amd 1:2000(E).

FFT, 802.11a (FFT11A)

Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Signal before FFT, time domain representation (complex)			
Output	Signal after FFT, time domain representation (complex)			

Notes

1. This model can be used to implement 64-point Fast Fourier Transform (IFFT) according to *IEEE* 802.11a standard.
2. In this model, a 64-point FFT is used. It should be noted that the coefficients of subcarriers at the output are arranged from -32 to 31 rather than from 0 to 63. Therefore, the FFT

mapping is illustrated in Fig.1.

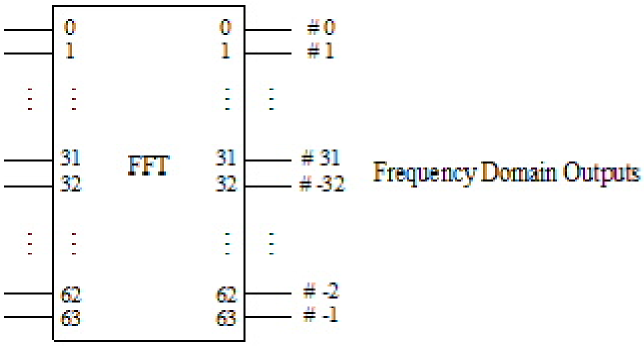


Fig.1 Inputs and outputs of FFT

Netlist Form

```
AFFT11A:NAME  n1 n2 nexsys_component=FFT11A [RIN=val]
[ROUT=val]
```

Netlist Example

```
AFFT11A:1 1 2 nexsys_component=FFT11A
```

References

1. IEEE Std 802.11a, Part 11: “Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band,” ISO/IEC 8802-11:1999/Amd 1:2000(E).
2. J. Terry and J. Heiskala, Proakis, *OFDM Wireless LANs: A Theoretical and Practical Guide*, Sams Publishing, 2002.

IFFT, 802.11a (IFFT11A)

Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (complex)			
Output	Output signal (complex)			

Notes

1. This model can be used to implement 64-point inverse Fast Fourier Transform (IFFT) according to IEEE 802.11a standard.
2. In this model, a 64-point IFFT is used. It should be noted that the coefficients of subcarriers at the input are arranged from -32 to 31 rather than from 0 to 63. Therefore, the IFFT mapping is illustrated in Fig.1.

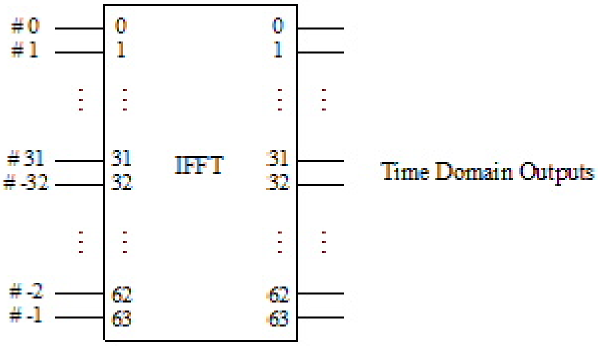


Fig.1 Inputs and outputs of IFFT

Netlist Form

```
AIFFT11A:NAME  n1 n2 nexsys_component=IFFT11A [RIN=val] [ROUT=val]
```

Netlist Example

```
AIFFT11A:1 1 2 nexsys_component=IFFT11A
```

References

1. IEEE Std 802.11a, Part 11: “Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band,” ISO/IEC 8802-11:1999/Amd 1:2000(E).
2. J. Terry and J. Heiskala, Proakis, *OFDM Wireless LANs: A Theoretical and Practical Guide*, Sams Publishing, 2002.

Interleaver, 802.11a (INTLV11A)

Property	Description	Units	Default	Range/Type
MODULATION	Modulation type	None	0	[0, 3]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Bits before interleaving (integer)			
Output	Bits after interleaving (integer)			

Limits

$$Modulation = \begin{cases} 0 & \text{BPSK} \\ 1 & \text{QPSK} \\ 2 & 16\text{-QAM} \\ 3 & 64\text{-QAM} \end{cases}$$

Notes

1. This model can be used for encoded data interleaving, according to *IEEE* 802.11a standard.
2. All encoded data bits is interleaved by a block interleaver with a block size corresponding to the number of bits in a single OFDM symbol, N_{CBPS}. The interleaver is defined by a two-step permutation. The first permutation ensures that adjacent coded bits are mapped onto nonadjacent subcarriers. The second ensures that adjacent coded bits are mapped alternately onto less and more significant bits of the constellation and, thereby, long runs of low reliability (LSB) bits are avoided.
3. Denote by k the index of the coded bit before the first permutation; i, is the index after the first and before the second permutation, and J is the index after the second permutation, just prior to modulation mapping. The first permutation is defined by the rule

$$i = (N_{CBPS}/16)(k \bmod 16) + \text{floor}(k/16) \quad k = 0,1,\ldots N_{CBPS} - 1$$

(1)

where the function floor (.) denotes the largest integer not exceeding the parameter. The second permutation is defined by the rule

$$j = s \times \text{floor}(i/s) + \left(i + N_{CBPS} - \text{floor}(16 \times i/N_{CBPS})\right) \bmod s \quad i = 0,1,\ldots N_{CBPS} - 1$$

(2)

where the value of s is determined by the number of coded bits per subcarrier, N_{BPSC} , according to

$$s = \max(N_{BPSC}/2, 1)$$

(3)

In the above equations, N_{CBPS} and N_{BPSC} depend on the base modulation mode, as shown in the following Table (IEEE 802.11a Rate-dependent parameter).

Data rate (Mbits/s)	**Modulation**	**Coding rate (R)**	**Coding bits per subcarrier (N_{BPSC})**	**Coding bits per OFDM symbol (N_{CBPS})**	**Data bits per OFDM symbol (N_{DBPS})**
6	BPSK	1/2	1	48	24
9	BPSK	3/4	1	48	36
12	QPSK	1/2	2	96	48
18	QPSK	3/4	2	96	72
24	16-QAM	1/2	4	192	96
36	16-QAM	3/4	4	192	144
48	64-QAM	2/3	6	288	192
54	64-QAM	3/4	6	288	216

Netlist Form

```
AINTLV11A:NAME  n1 n2 nexsys_component=INTLV11A [MODULATION
=val] [RIN=val] [ROUT=val]
```

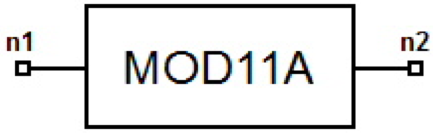
Netlist Example

```
AINTLV11A:1 1 2 nexsys_component=INTLV11A MODULATION = 2
```

References

1. [1] IEEE Std 802.11a, Part 11: “Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band,” ISO/IEC 8802-11:1999/Amd 1:2000(E).
2. [2]J. Terry and J. Heiskala, Proakis, *OFDM Wireless LANs: A Theoretical and Practical Guide*, Sams Publishing, 2002.

Modulator, 802.11a (MOD11A)



Property	Description	Units	Default	Range/Type
MODULATION	Modulation Type	None	0	[0, 3]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Bits before modulation (integer)			
Output	Modulated signal (complex)			

Limits

$$Modulation=\begin{cases}0 & \text{BPSK}\\ 1 & \text{QPSK}\\ 2 & 16\text{-QAM}\\ 3 & 64\text{-QAM}\end{cases}$$

Notes

1. This model can be used for modulation according to Gray-coded constellation mappings [1].
2. The OFDM subcarriers can be modulated by using BPSK, QPSK, 16-QAM, or 64-QAM modulation, depending on the RATE requested. The encoded and interleaved binary serial input data is divided into groups of N_{BPSC} (1, 2, 4, or 6) bits and converted into complex numbers representing BPSK, QPSK, 16-QAM, or 64-QAM constellation points. The conversion is performed according to Gray-coded constellation mappings[1]. The output values, d, are formed by multiplying the resulting I + jQ value by a normalization factor K_{MOD}, as described in Eqn.(1).

$$d=(I+jQ)\times K_{MOD}$$

(1)

The normalization factor,K_{MOD}, depends on the base modulation mode, as prescribed in Table I. Note that the modulation type can be different on the start to the end of the transmission, as the signal changes from SIGNAL to DATA, as shown in Fig.1. The purpose of the normalization factor is to achieve the same average power for all mappings. In practical implementations, an approximate value of the normalization factor can be used, as long as the device conforms with the modulation accuracy requirements described in [1].

For BPSK, b_0 determines the *I* value, as illustrated in Table II. For QPSK, b_0 determines the *I* value and b1 determines the *Q* value, as illustrated in Table III. For 16-QAM, b_0b_1 determines the *I* value and b_2b_3 determines the *Q* value, as illustrated in Table IV. For 64-QAM, $b_0b_1b_2$ determines the *I* value and $b_2b_3b_4$ determines the *Q* value, as illustrated in Table V. The input bit, b_0, is the earliest in the stream.

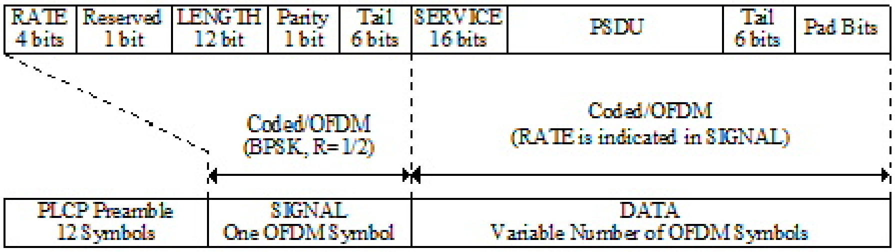


Fig.1 PPDU frame format

Table I *IEEE* 802.11a Modulation-dependent normalization factor K_{MOD}

Modulation	(K_{MOD})
BPSK	1
QPSK	$1/\sqrt{2}$
16-QAM	$1/\sqrt{10}$

64-QAM	$1/\sqrt{42}$

Table II *IEEE* 802.11a BPSK encoding table

Input bit (b_0)	*I*-out	*Q*-out
0	-1	0
1	1	0

Table III *IEEE* 802.11a QPSK encoding table

Input bit (b_0)	*I*-out		Input bit (b_1)	*Q*-out
0	-1		0	-1
1	1		1	1

Table IV *IEEE* 802.11a 16-QAM encoding table

Input bits (b_0b_1)	*I*-out		Input bits (b_2b_3)	*Q*-out
00	-3		00	-3
01	-1		01	-1
11	1		11	1
10	3		10	3

Table V *IEEE* 802.11a 64-QAM encoding table

Input bits ($b_0b_1b_2$)	*I*-out		Input bits ($b_3b_4b_5$)	*Q*-out
000	-7		000	-7
001	-5		001	-5
011	-3		011	-3
010	-1		010	-1
110	1		110	1
111	3		111	3
101	5		101	5
100	7		100	7

Notes

```
AMOD11A:NAME  n1 n2 nexsys_component=MOD11A [MODULATION =val]
[RIN=val] [ROUT=val]
```

Netlist Example

```
AMOD11A:1 1 2 nexsys_component=MOD11A MODULATION = 2
```

References

1. IEEE Std 802.11a, Part 11: “Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band,” ISO/IEC 8802-11:1999/Amd 1:2000(E).
2. J. Terry and J. Heiskala, Proakis, OFDM Wireless LANs: A Theoretical and Practical Guide, Sams Publishing, 2002.

Padder, 802.11a (PAD11A)

Property	Description	Units	Default	Range/Type
MODULATION	Modulation Type	None	0	[0, 3]/Integer
CODING	Coding Rate Type	None	0	[0, 2]/Integer
LENGTH	Length of PSDU (number of octets)	None	100	[1, 4095]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Bits before padding (integer)			
Output	Bits after padding (integer)			

Limits

$$Modulation=\begin{cases}0 & \text{BPSK}\\ 1 & \text{QPSK}\\ 2 & \text{16-QAM}\\ 3 & \text{64-QAM}\end{cases}$$

$$Coding=\begin{cases}0 & \text{Coding Rate}=1/2\\ 1 & \text{Coding Rate}=2/3\\ 2 & \text{Coding Rate}=3/4\end{cases}$$

Notes

1. This model can be used to form DATA field bits by prepending the SERVICE field, add tail bits and pad bits, according to IEEE 802.11a standard.

2. Fig.1 shows the format for the PPDU including the OFDM PLCP preamble, OFDM PLCP header, PSDU, tail bits, and pad bits. The PLCP header contains the following fields: LENGTH, RATE, a reserved bit, an even parity bit, and the SERVICE field. In terms of modulation, the LENGTH, RATE, reserved bit, and parity bit (with 6 “zero” tail bits appended) constitute a separate single OFDM symbol, denoted SIGNAL, which is transmitted with the most robust combination of BPSK modulation and a coding rate of R=1/2. The SERVICE field of the PLCP header and the PSDU (with 6 “zero” tail bits and pad bits appended), denoted as DATA, are transmitted at the data rate described in the RATE field and may constitute multiple OFDM symbols. The tail bits in the SIGNAL symbol enable decoding of the RATE and LENGTH fields immediately after the reception of the tail bits. The RATE and LENGTH are required for decoding the DATA part of the packet. The DATA field is described in the following sections

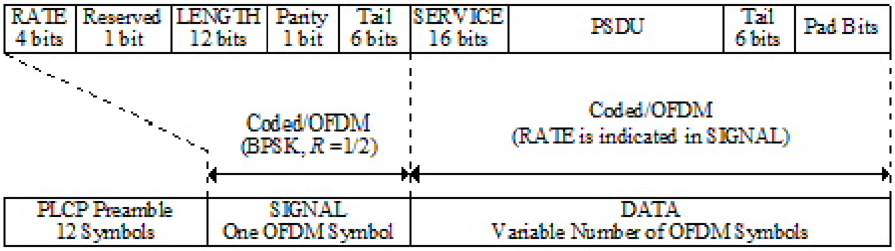


Fig.1 PPDU frame format

3. Service field (SERVICE)
The IEEE 802.11 SERVICE field has 16 bits, which is denoted as bits 0~15, as shown in Fig.2. The bit 0 is transmitted first in time. The bits from 0~6 of the SERVICE field, which are transmitted first, are set to zeros and are used to synchronize the descrambler in the receiver. The remaining 9 bits (7~15) of the SERVICE field is reserved for future use. All reserved bits is set to zero.

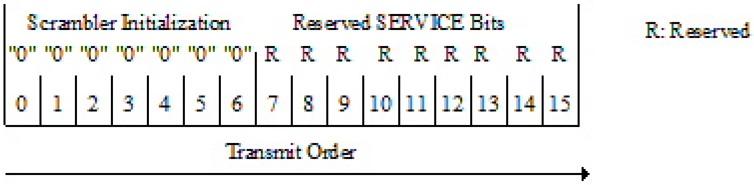


Fig.2 SERVICE field bit assignment

4. Tail bits field (TAIL)
   The PPDU tail bits field is six bits of “0”, which are required to return the convolutional encoder to the “zero state”. This procedure improves the error probability of the convolutional decoder, which relies on future bits when decoding and which may be not be available past the end of the message. The PLCP tail bit field is produced by replacing six scrambled “zero” bits following the message end with six nonscrambled “zero” bits.
5. Pad bits (PAD)
   The number of bits in the DATA field is a multiple of N_{CBPS}, the number of coded bits in an OFDM symbol (48, 96, 192, or 288 bits), as shown in Table I. To achieve that, the length of the message is extended so it becomes a multiple of N_{DBPS}, the number of data bits per OFDM symbol. N_{CBPS} and N_{DBPS} can be determined by the two parameters, Modulation and Coding as shown in Table I. At least 6 bits are appended to the message, in order to accommodate the TAIL bits. The number of OFDM symbols N_{SYM} the number of bits in the DATA field N_{DATA} and the number of pad bits N_{PAD} are computed on the length of the PSDU (Length) as follows:

   $$N_{SYM} = \text{Ceiling}\ \left((16 + 8 \times \text{Length} + 6)/N_{DBPS}\right) \quad (1)$$

   $$N_{DATA} = N_{SYM} \times N_{DBPS} \quad (2)$$

   $$N_{PAD} = N_{DATA} - (16 + 8 \times \text{Length} + 6) \quad (3)$$

   The function ceiling (.) is a function that returns the smallest integer value greater than or equal to its argument value. The appended bits (“pad bits”) are set to “zeros” and are subsequently scrambled with the rest of the bits in the DATA field.

Table I *IEEE* 802.11a Rate-dependent parameter

Data rate (Mbits/s)	**Modulation**	**Coding rate (R)**	**Coding bits per subcarrier (N_{BPSC})**	**Coding bits per OFDM symbol (N_{CBPS})**	**Data bits per OFDM symbol (N_{DBPS})**
6	BPSK	1/2	1	48	24
9	BPSK	3/4	1	48	36
12	QPSK	1/2	2	96	48

18	QPSK	3/4	2	96	72
24	16-QAM	1/2	4	192	96
36	16-QAM	3/4	4	192	144
48	64-QAM	2/3	6	288	192
54	64-QAM	3/4	6	288	216

Netlist Form

```
APAD11A:NAME  n1 n2 nexsys_component=PAD11A [MODULATION =val] [CODING
=val]
+ [LENGTH =val] [RIN=val] [ROUT=val]
```

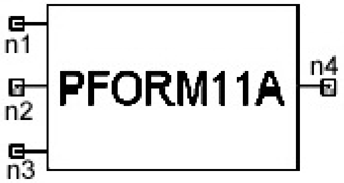
Netlist Example

```
APAD11A:1 1 2 nexsys_component=PAD11A MODULATION = 2 CODING= 2
LENGTH = 100
```

References

1. IEEE Std 802.11a, Part 11: “Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band,” ISO/IEC 8802-11:1999/Amd 1:2000(E).

PPDU Frame Former, 802.11a (PFORM11A)



Property	Description	Units	Default	Range/Type
MODULATION	Modulation Type	None	0	[0, 1]/Integer
CODING	Coding Rate	None	0	[0, 2]/Integer
LENGTH	Length of PSDU	None	100	[1, 4095]/Integer
RIN1	Input impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input impedance	Ohm	Inf	(0, Inf]/Real
RIN3	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Preamble field (complex)			
Input2	Signal field (complex)			
Input3	Data field (complex)			
Output	PPDU Frame (complex)			

Limits

$$Modulation = \begin{cases} 0 & \text{BPSK} \\ 1 & \text{QPSK} \\ 2 & \text{16-QAM} \\ 3 & \text{64-QAM} \end{cases}$$

$$Coding = \begin{cases} 0 & \text{Coding Rate} = 1/2 \\ 1 & \text{Coding Rate} = 2/3 \\ 2 & \text{Coding Rate} = 3/4 \end{cases}$$

Notes

1. This model can be used to form PPDU frame, according to IEEE 802.11a standard.
2. Fig.1 shows a block diagram of the IEEE 802.11a baseband transmitter. One sample overlap occurs between preamble and SIGNAL field and between SIGNAL field and DATA field. The number of OFDM symbols during DATA field is determined by the three parameters, Modulation, Coding, and Length.. For some details, please refer to the PAD11A model.

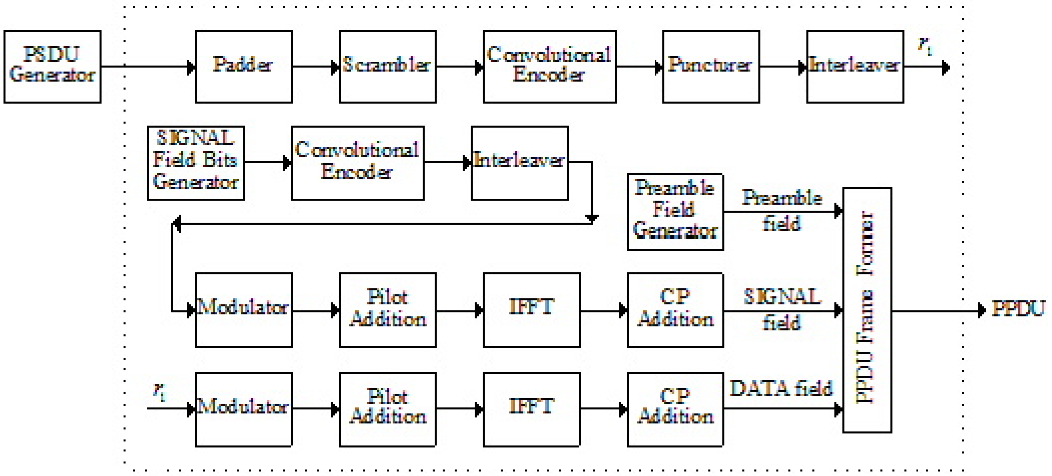


Fig.1 Block diagram of the IEEE 802.11a baseband transmitter

Netlist Form

```
APFORM11A:NAME  n1 n2 n3 n4 nexsys_component=PFORM11A
[MODULATION =val] [CODING =val]
+ [LENGTH =val] [RIN=val] [RIN1=val] [RIN2=val] [RIN3=val]
+ [ROUT=val]
```

Netlist Example

```
APFORM11A:1 1 2 3 4 nexsys_component=PFORM11A MODULATION = 2
CODING= 2 LENGTH = 100
```

References

1. IEEE Std 802.11a, Part 11: “Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band,” ISO/IEC 8802-11:1999/Amd 1:2000(E).

Pilot Addition, 802.11a (PLTADD11A)

Property	Description	Units	Default	Range/Type
PURPOSE	Signal field {0} Data field {1}	None	1	[0, 1]/Integer
MODULATION	Modulation Type	None	0	[0, 3]/Integer
CODING	Coding rate type	None	0	[0, 2]/Integer
LENGTH	Length of PSDU (number of octets)	None	100	[1, 4095]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Signal before pilot addition (complex)			
Output	Signal after pilot addition) (complex)			

Limits

$$Modulation = \begin{cases} 0 & \text{BPSK} \\ 1 & \text{QPSK} \\ 2 & \text{16-QAM} \\ 3 & \text{64-QAM} \end{cases}$$

$$Coding = \begin{cases} 0 & \text{Coding Rate} = 1/2 \\ 1 & \text{Coding Rate} = 2/3 \\ 2 & \text{Coding Rate} = 3/4 \end{cases}$$

Notes

1. This model can be used for pilot addition according to IEEE 802.11a standard.
2. In each OFDM symbol, four of the subcarriers are dedicated to pilot signals in order to make the coherent detection robust against frequency offsets and phase noise. These pilot signals is put in subcarriers –21, –7, 7 and 21. The pilots is BPSK modulated by a pseudo binary sequence to prevent the generation of spectral lines. The contribution of the pilot subcarriers to each OFDM symbol is described in the following sections.
3. The stream of complex numbers at the output of modulation is divided into groups of N_{SD} = 48 complex numbers. Denote this by writing the complex number $d_{k,n}$ which corresponds to subcarrier k of OFDM symbol n, as follows:

   $$d_{k,n} = d_{k+N_{SD}\times n} \; k = 0,1,\ldots N_{SD} - 1 \; n = 0,1,\ldots N_{SYM} - 1 \tag{1}$$

   The number of OFDM symbols, N_{SYM}, depends on the three parameters, Modulation, Coding, and Length. For details, please refer to the"Padder, 802.11a (PAD11A)" on page 38-286 model.
4. The contribution of the pilot subcarriers for the nth OFDM symbol is produced by Fourier transform of sequence P, given by

   $$\begin{aligned} P_{-26,26} = \{&0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, \\ &0, 0, 0, 0, 0, 0, 1, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, 0, -1, 0, 0, 0, 0, 0\} \end{aligned} \tag{2}$$

   The polarity of the pilot subcarriers is controlled by the sequence, P_n, which is a cyclic extension of the 127 elements sequence and is given by the following equation

   $$\begin{aligned} P_{0\_126v} = \{&1,1,1,1, \; -1,-1,-1,1, \; -1,-1,-1,-1, \; 1,1,-1,1, \; -1,-1,1,1, \; -1,1,1,-1, \; 1,1,1,1, \; 1,1,-1,1, \\ &1,1,-1,1, \; 1,-1,-1,1, \; 1,1,-1,1, \; -1,-1,-1,1, \; -1,1,-1,-1, \; 1,-1,-1,1, \; 1,1,1,1, \; -1,-1,1,1, \\ &-1,-1,1,-1, \; 1,-1,1,1, \; -1,-1,-1,1, \; 1,-1,-1,-1, \; -1,1,-1,-1, \; 1,-1,1,1, \; 1,1,-1,1, \; -1,1,-1,1, \\ &-1,-1,-1,-1, \; -1,1,-1,1, \; 1,-1,1,-1, \; 1,1,1,-1, \; -1,1,-1,-1, \; -1,1,1,1, \; -1,-1,-1,-1, \; -1,-1,-1\} \end{aligned}$$

   (3)

   Each sequence element is used for one OFDM symbol. The first element, P_0, multiplies the pilot subcarriers of the SIGNAL symbol, while the elements from P_1 on are used for the DATA symbols.

The subcarrier frequency allocation is shown in Fig.1. To avoid difficulties in D/A and A/D converter offsets and carrier feedthrough in the RF system, the subcarrier falling at DC (0th subcarrier) is not used. Fig.1 Subcarrier frequency allocation

5. To meet 64-point requirement, 11 “zero” is put in subcarriers –32~-27 and 27~31.

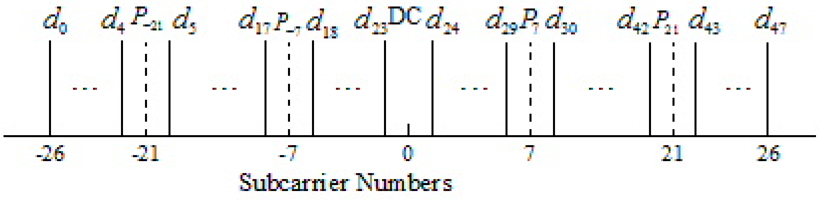


Fig.1 Subcarrier frequency allocation

Netlist Form

```
APLTADD11A:NAME  n1 n2 nexsys_component=PLTADD11A [PURPOSE=val]
[MODULATION=val]
+ [CODING =val] [LENGTH =val] [RIN=val] [ROUT=val]
```

Netlist Example

```
APLTADD11A:1 1 2 nexsys_component=PLTADD11A MODULATION=2 CODING=2
LENGTH=100
```

References

1. IEEE Std 802.11a, Part 11: “Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band,” ISO/IEC 8802-11:1999/Amd 1:2000(E).
2. J. Terry and J. Heiskala, Proakis, *OFDM Wireless LANs: A Theoretical and Practical Guide*, Sams Publishing, 2002.

Pilot Removal, 802.11a (PLTRM11A)

Property	**Description**	**Units**	**Default**	**Range/Type**
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Signal before pilot removal (complex)			
Output	Signal after pilot removal (complex)			

Notes

1. This model can be used for remove the pilot signal that the **pltadd11a** model added to the outputs of modulator, according to IEEE 802.11a standard. For details, please refer to the "Pilot Addition, 802.11a (PLTADD11A)" on page 38-292 model.

Netlist Form

```
APLTRM11A:NAME  n1 n2 nexsys_component=PLTRM11A [RIN=val] [ROUT=val]
```

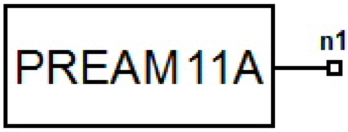
Netlist Example

```
APLTRM11A:1 1 2 nexsys_component=PLTRM11A
```

References

1. IEEE Std 802.11a, Part 11: “Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band,” ISO/IEC 8802-11:1999/Amd 1:2000(E).
2. J. Terry and J. Heiskala, Proakis, *OFDM Wireless LANs: A Theoretical and Practical Guide*, Sams Publishing, 2002.

Preamble Generator, 802.11a (PREAM11A)



Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Output	Preamble field (integer)			

Notes

1. This model can be used to generate PLCP Preamble according to IEEE 802.11a standard.
2. The PLCP preamble field is used for synchronization. It consists of 10 short symbols and two long symbols shown in Fig.1.

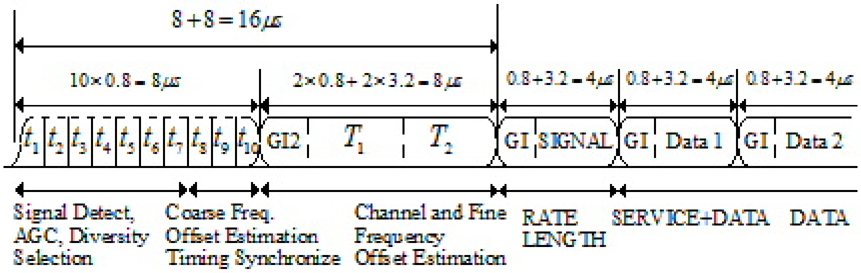


Fig.1 OFDM training structure

3. Fig.1 shows the OFDM training structure (PLCP preamble), where f_I and f_{ID} to denote short training symbols and T_I and T_1 denote long training symbols. The PLCP preamble is followed by the SIGNAL field and DATA field. The total training length is 16μs. The dashed boundaries in the figure denote repetitions due to the periodicity of the inverse Fourier

transform.

4. A short OFDM training symbol consists of 12 subcarriers, which are modulated by the elements of the sequence S, given by
   The multiplication by a factor of $(13/6)^{1/2}$ is in order to normalize the average power of the resulting OFDM symbol, which utilizes 12 out of 52 subcarriers. To meet 64-point IFFT requirement, 11 “zero” is put in subcarriers –32~-27 and 27~31, respectively. These samples are transformed using IFFT, extended periodically for 161 samples (about 8 ms), then multiplied by the window function:

$$W(k) = \begin{cases} 0.5 & k = 0 \\ 1 & 1 \le k \le 159 \\ 0.5 & k = 160 \end{cases}$$

(2)

$$S_{-26,26} = \sqrt{13/6} \times \{0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 0, \\ 0, 0, 0, -1-j, 0, 0, 0, -1-j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0, 0, 1+j, 0, 0\}$$

5. A long OFDM training symbol consists of 53 subcarriers (including a zero value at dc), which are modulated by the elements of the sequence, L, , given by

$$L_{-26,26} = \{1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 1, 1, -1, -1, 1, 1, -1, 1, -1, 1, 1, 1, 1, 0, \\ 1, -1, -1, 1, 1, -1, 1, -1, 1, -1, -1, -1, -1, -1, 1, 1, -1, -1, 1, -1, 1, -1, 1, 1, 1, 1\}$$

(3)

   To meet 64-point IFFT requirement, 11 “zero” is put in subcarriers –32~-27 and 27~31. The time domain samples are produced by performing IFFT, cyclically extending the results to get cyclic prefix, then multiplied by the window function:

$$W(k) = \begin{cases} 0.5 & k = 0 \\ 1 & 1 \le k \le 159 \\ 0.5 & k = 160 \end{cases}$$

(4)

   The resulting 161 samples are appended with one sample overlap to the SIGNAL field symbol.

Netlist Form

```
APREAM11A:NAME  n1 nexsys_component=PREAM11A [RIN=val] [ROUT=val]
```

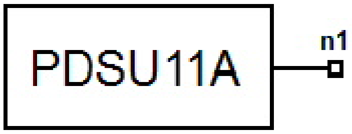
Netlist Example

```
APREAM11A:1 1 nexsys_component=PREAM11A
```

References

1. IEEE Std 802.11a, Part 11: “Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band,” ISO/IEC 8802-11:1999/Amd 1:2000(E).
2. J. Terry and J. Heiskala, Proakis, *OFDM Wireless LANs: A Theoretical and Practical Guide*, Sams Publishing, 2002.

PSDU Generator, 802.11a (PSDU11A)



Property	Description	Units	Default	Range/Type
MODULATION	Modulation Type	None	0	[0, 3]/Integer
CODING	Coding Rate Type	None	0	[0, 2]/Integer
NUM_OCTETS	Number of octets	None	100	[1, Inf]/Integer
SEED	Random seed	None	0	[0, Inf)/Integer
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	PSDU bit stream (integer)			

Limits

$$Modulation=\begin{cases}0 & \text{BPSK}\\1 & \text{QPSK}\\2 & 16\text{-QAM}\\3 & 64\text{-QAM}\end{cases}$$

$$Coding=\begin{cases}0 & \text{Coding Rate}=1/2\\1 & \text{Coding Rate}=2/3\\2 & \text{Coding Rate}=3/4\end{cases}$$

Notes

1. This model can be used to generate IEEE 802.11a PSDU bit stream.
2. The PSDU Generator generates random binary sequence, taking the value 1 or 0 with equal probability. The number of bits equals Num_Octets x 8.
3. The output bit rate is determined by the first two parameters, Modulation and Coding, as shown in Table I.

Table I IEEE 802.11a Rate-dependent parameter

Data rate (Mbits/s)	**Modulation**	**Coding rate (*R*)**	**Coding bits per subcarrier (N_{BPSC})**	**Coding bits per OFDM symbol (N_{CBPS})**	**Data bits per OFDM symbol (N_{DBPS})**
6	BPSK	1/2	1	48	24
9	BPSK	3/4	1	48	36
12	QPSK	1/2	2	96	48
18	QPSK	3/4	2	96	72
24	16-QAM	1/2	4	192	96
36	16-QAM	3/4	4	192	144
48	64-QAM	2/3	6	288	192
54	64-QAM	3/4	6	288	216

Netlist Form

```
APSDU11A:NAME  n1 n2 nexsys_component=PSDU11A [MODULATION =val]
[CODING =val]
+ [NUM_OCTETS =val] [SEED =val] [ROUT=val]
```

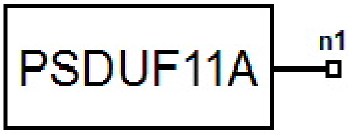
Netlist Example

```
APSDU11A:1 1 2 nexsys_component=PSDU11A MODULATION = 2 CODING=
2 NUM_OCTETS = 200 SEED=17427
```

References

1. IEEE Std 802.11a, Part 11: “Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band,” ISO/IEC 8802-11:1999/Amd 1:2000(E).

PSDU Generator with External File, 802.11a (PSDUF11A)



Property	Description	Units	Default	Range/Type
MODULATION	Modulation Type	None	0	[0, 3]/Integer
CODING	Coding Rate Type	None	0	[0, 2]/Integer
NUM_OCTETS	Number of octets to read from external file	None	100	[1, Inf)/Integer
FILE	Name of the external data file	None	Required	N/A
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	PSDU bit stream (integer)			

Limits

$$Modulation = \begin{cases} 0 & \text{BPSK} \\ 1 & \text{QPSK} \\ 2 & \text{16 - QAM} \\ 3 & \text{64 - QAM} \end{cases}$$

$$Coding = \begin{cases} 0 & \text{Coding Rate} = 1/2 \\ 1 & \text{Coding Rate} = 2/3 \\ 2 & \text{Coding Rate} = 3/4 \end{cases}$$

File name must have a “.mat” extension.

> **Note:**
> 1. This model generates IEEE 802.11a PSDU bit stream using an external file.
> 2. The PSDU Generator reads hexadecimal integer type data from a MATLAB file (extension .mat) and converts it into a binary signal with the least significant bit (LSB) being outputted first. The file should contain the ASCII data to be read out. If the file contains less data than Num_Octets, the data in the file is read periodically until Num_Octets data is read out.
> 3. The output bit rate is determined by the first two parameters, Modulation and Coding, as shown in Table I.

Table I IEEE 802.11a Rate-dependent parameter

Data rate (Mbits/s)	**Modulation**	**Coding rate (*R*)**	**Coding bits per subcarrier (N_{BPSC})**	**Coding bits per OFDM symbol (N_{CBPS})**	**Data bits per OFDM symbol (N_{DBPS})**
6	BPSK	1/2	1	48	24
9	BPSK	3/4	1	48	36
12	QPSK	1/2	2	96	48
18	QPSK	3/4	2	96	72
24	16-QAM	1/2	4	192	96
36	16-QAM	3/4	4	192	144
48	64-QAM	2/3	6	288	192
54	64-QAM	3/4	6	288	216

Netlist Form

```
APSDUF11A:NAME  n1 n2 nexsys_component=PSDUF11A [MODULATION=val]
[CODING=val]
+ [NUM_OCTETS=val] [RIN=val] [ROUT=val] FILE = "filename"
```

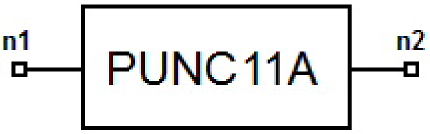
Netlist Example

```
APSDUF11A:1 1 2 nexsys_component=PSDUF11A MODULATION = 2
CODING= 2 NUM_OCTETS = 200
+ FILE = "octets11a.mat"
```

References

1. IEEE Std 802.11a, Part 11: “Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band,” ISO/IEC 8802-11:1999/Amd 1:2000(E).

Puncturer, 802.11a (PUNC11A)



Property	Description	Units	Default	Range/Type
CODING	Coding Rate Type	None	0	[0, 2]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Bits before puncturing (integer)			
Output	Output signal (complex)			

Limits

$$Coding = \begin{cases} 0 & \text{Coding Rate} = 1/2 \\ 1 & \text{Coding Rate} = 2/3 \\ 2 & \text{Coding Rate} = 3/4 \end{cases}$$

Notes

1. This model can be used to increase coding rate by employing “puncturing”, according to IEEE 802.11a standard.
2. The DATA field, composed of SERVICE, PSDU, tail, and pad parts, is coded with a convolutional encoder of coding rate R = 1/2, 2/3, or 3/4, corresponding to the appropriate data rate. The convolutional encoder uses the industry-standard generator polynomials, g_0 = 133 and g_l = 171 and , of rate R = 1/2, please refer to the COD11A model. Higher rates are derived from it by employing “puncturing”. Puncturing is a procedure for omitting some of the encoded bits in the transmitter (thus reducing the number of transmitted bits and increasing the coding rate) and inserting a dummy “zero” metric into the convolutional decoder in the receiver in place of the omitted bits. The puncturing patterns are illustrated

in Fig.1.

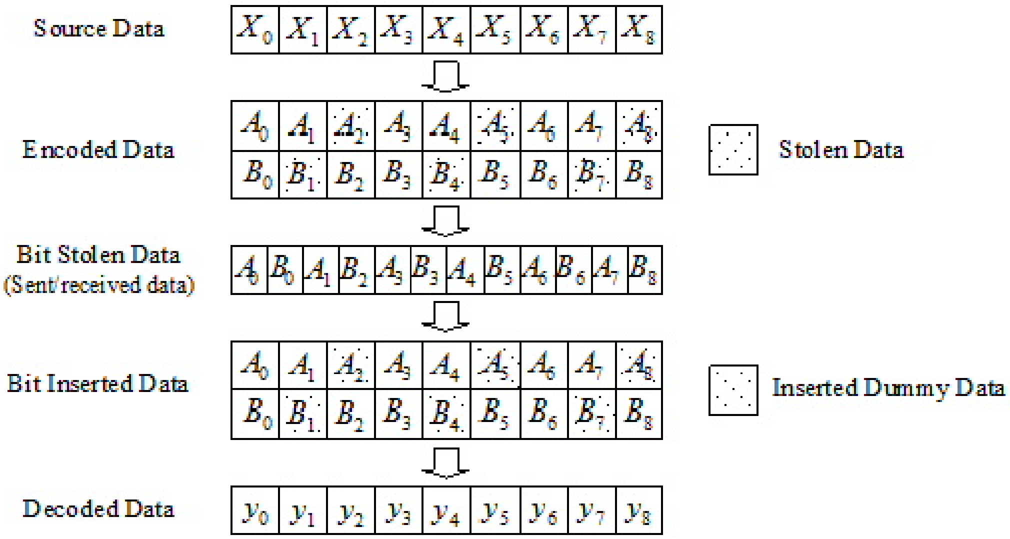


Fig.1A The “puncturing” and “depuncturing” procedure for coding rate R = 3/4

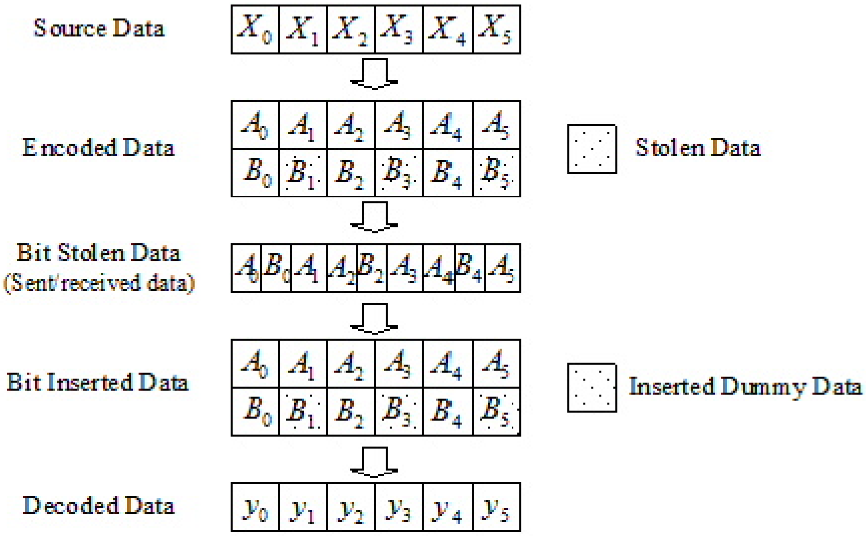


Fig. 1b, The “puncturing” and “depuncturing” procedure for coding rate R = 2/3.

Netlist Form

```
APUNC11A:NAME  n1 n2 nexsys_component=PUNC11A [CODING =val] [RIN=val]
[ROUT=val]
```

Netlist Example

```
APUNC11A:1 1 2 nexsys_component=PUNC11A CODING=2
```

References

1. IEEE Std 802.11a, Part 11: “Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band,” ISO/IEC 8802-11:1999/Amd 1:2000(E).
2. J. Terry and J. Heiskala, Proakis, *OFDM Wireless LANs: A Theoretical and Practical Guide*, Sams Publishing, 2002.

Scrambler, 802.11a (SCRM11A)

Property	Description	Units	Default	Range/Type
MODULATION	Modulation Type	None	0	[0,3]/Integer
CODING	Coding Rate Type	None	0	[0,2]/Integer
LENGTH	Length of PSDU (number of octets)	None	100	[1, 4095]/Integer
S0	Initial state of the scrambler in decimal	None	93	[0, 12]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Bits before scrambling (integer)			
Output	Bits after scrambling (integer)			

Limits

$$Modulation = \begin{cases} 0 & \text{BPSK} \\ 1 & \text{QPSK} \\ 2 & \text{16 - QAM} \\ 3 & \text{64 - QAM} \end{cases}$$

$$Coding = \begin{cases} 0 & \text{Coding Rate} = 1/2 \\ 1 & \text{Coding Rate} = 2/3 \\ 2 & \text{Coding Rate} = 3/4 \end{cases}$$

$$1 \le Length \le 4095 \quad 0 \le S_0 \le 2^7 - 1$$

Notes

1. This model can be used to scramble the DATA field , then let the tail bits be zero, according to *IEEE* 802.11a standard.
2. The DATA field, composed of SERVICE, PSDU, tail, and pad parts, is scrambled with a length-127 frame-synchronous scrambler. The frame synchronous scrambler uses the generator polynomia S(x)l as follows, and is illustrated in Fig.1.

   $$S(x) = x^7 + x^4 + 1 \quad (1)$$

   The 127-bit sequence generated repeatedly by the scrambler is (leftmost used first), 00001110 11110010 11001001 00000010 00100110 00101110 10110110 00001100 11010100 11100111 10110100 00101010 11111010 01010001 10111000 1111111, when the “all ones” initial state is used. The same scrambler is used to scramble transmit data and descramble receive data. When transmitting, the initial state of the scrambler is set to a pseudo random non-zero state S_d. The seven LSBs of the SERVICE field is set to all zeros prior to scrambling to enable estimation of the initial state of the scrambler in the receiver.
3. The 6 tail bits should be reset to “zero”. The position of the tail bits can be determined by the three parameters, Modulation, Coding, and Length. The position of the first tail bit is determined by:

   $$p_0 = (16 + 8 \times \text{Length}) \bmod N_{DATA} \quad (2)$$

   For the calculation of N_{Data}, please refer to the **pad11a** model.

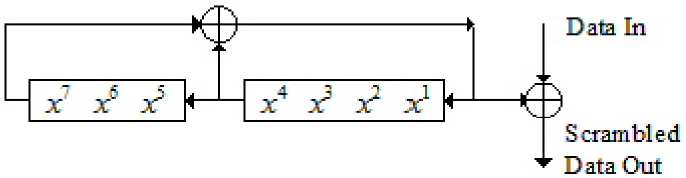


Fig.1 Data scrambler

Netlist Form

```
ASCRM11A:NAME  n1 n2 nexsys_component=SCRM11A [MODULATION =val]
[CODING =val]
+ [LENGTH =val] [S0=val] [RIN=val] [ROUT=val]
```

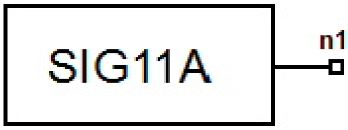
Netlist Example

```
ASCRM11A:1 1 2 nexsys_component=SCRM11A MODULATION = 2 CODING=
2 LENGTH = 100 S0 = 93
```

References

1. IEEE Std 802.11a, Part 11: “Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band,” ISO/IEC 8802-11:1999/Amd 1:2000(E).

Signal Field Bits Generator, 802.11a (SIG11A)



Property	Description	Units	Default	Range/Type
MODULATION	Modulation Type	None	0	[0, 3]/Integer
CODING	Coding Rate Length	None	0	[0, 2]/Integer
LENGTH	Length of PSDU (number of octets)	None	100	[1, 4095]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Output	Output signal (integer)			

Limits

$$Modulation = \begin{cases} 0 & \mathrm{BPSK} \\ 1 & \mathrm{QPSK} \\ 2 & 16\text{-}\mathrm{QAM} \\ 3 & 64\text{-}\mathrm{QAM} \end{cases}$$

$$Coding = \begin{cases} 0 & \mathrm{Coding\ Rate} = 1/2 \\ 1 & \mathrm{Coding\ Rate} = 2/3 \\ 2 & \mathrm{Coding\ Rate} = 3/4 \end{cases}$$

Notes

1. This model can be used to generate the contents of the SIGNAL field according to the *IEEE 802.11a* standard.
2. The SIGNAL field contains the RATE and the LENGTH fields. The RATE field conveys information about the type of modulation and the coding rate as used in the rest of the packet. The encoding of the SIGNAL single OFDM symbol is performed with **BPSK** modulation of the subcarriers and using convolutional coding at R = 1/2.

The contents of the SIGNAL field are not scrambled. The SIGNAL field is composed of 24 bits, as illustrated in Fig.1. The four bits 0 to 3 encodes the RATE. Bit 4 is reserved for future use. Bits 5~16 encodes the LENGTH field, with the least significant bit (LSB) being transmitted first.

3. Data rate (RATE): The bits R1~R4 is set, dependent on RATE, according to the values in Table I. The data rate is determined by the two parameters, Modulation and Coding, as shown in Table II.
4. PLCP length field (LENGTH): The PLCP length field is an unsigned 12-bit integer that indicates the number of octets in the PSDU that the MAC is currently requesting the PHY to transmit. This value is used to determine the number of octet transfers that occurs between the MAC and the PHY after receiving a request to start transmission. The LSB is transmitted first in time.
5. Parity (P), Reserved (R), and SIGNAL tail (SIGNAL TAIL): The Bit 4 is reserved for future use. Bit 17 ror a positive parity (even parity) bit for bits 0~16. The bits 18–23 constitute the SIGNAL TAIL field, and all 6 bits is set to zero.

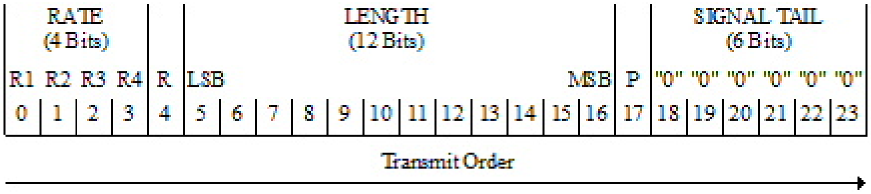


Fig.1 SIGNAL field bit assignment

Table I Contents of *IEEE* 802.11a SIGNAL field

Rate (Mbits/s)	R1~R4
6	1101
9	1111
12	0101
18	0111
24	1001
36	1011
48	0001
54	0011

Table II *IEEE 802.11a* Rate-dependent parameter

Data rate (Mbits/s)	**Modulation**	**Coding rate (R)**	**Coding bits per subcarrier (N_{BPSC})**	**Coding bits per OFDM symbol (N_{CBPS})**	**Data bits per OFDM symbol (N_{DBPS})**
6	BPSK	1/2	1	48	24
9	BPSK	3/4	1	48	36
12	QPSK	1/2	2	96	48
18	QPSK	3/4	2	96	72
24	16-QAM	1/2	4	192	96
36	16-QAM	3/4	4	192	144
48	64-QAM	2/3	6	288	192
54	64-QAM	3/4	6	288	216

Netlist Form

```
ASIG11A:NAME  n1 n2 nexsys_component=SIG11A [MODULATION =val] [CODING
=val]
+ [LENGTH =val] [RIN=val] [ROUT=val]
```

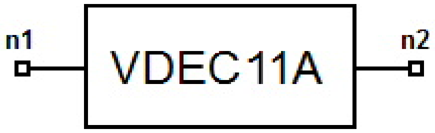
Netlist Example

```
ASIG11A:1 1 2 nexsys_component=SIG11A MODULATION = 2 CODING= 2
LENGTH = 100
```

References

1. IEEE Std 802.11a, Part 11: “Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band,” ISO/IEC 8802-11:1999/Amd 1:2000(E).

Viterbi Decoder, 802.11a (VDEC11A)



Property	Description	Units	Default	Range/Type
PURPOSE	Signal field {0} DATA field {1}	None	0	[0, 1]/Integer
MODULATION	Modulation Type	None	0	[0, 3]/Integer
CODING	Coding Rate type	None	0	[0, 2]/Integer
LENGTH	Length of PSDU (number of octets)	None	100	[1, 4095]/Integer
DECISION	Hard decision {0}/ Soft decision {1}	None	0	[0, 1]/Integer
DEPTH	Trellis depth of Viterbi decoder	None	100	[0, 1]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Signal before encoding (real)			
Output	Bits after decoding (integer)			

Limits

$$Modulation = \begin{cases} 0 & \text{BPSK} \\ 1 & \text{QPSK} \\ 2 & \text{16 - QAM} \\ 3 & \text{64 - QAM} \end{cases}$$

$$Coding = \begin{cases} 0 & \text{Coding Rate} = 1/2 \\ 1 & \text{Coding Rate} = 2/3 \\ 2 & \text{Coding Rate} = 3/4 \end{cases}$$

Notes

1. This model can be used to decode the DATA field and SIGNAL field by using Viterbi algorithm, according to *IEEE* 802.11a standard. For details, please refer to the COD11A model.

Netlist Form

```
AVDEC11A:NAME  n1 n2 nexsys_component=VDEC11A [PURPOSE =val]
[MODULATION =val]
+ [CODING =val] [LENGTH =val] [DEPTH =val] [RIN=val] [ROUT=val]
```

Netlist Example

```
AVDEC11A:1 1 2 nexsys_component=VDEC11A MODULATION = 2 CODING=
2 LENGTH = 100 DEPTH = 200
```

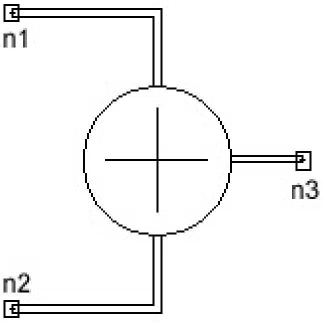
References

1. IEEE Std 802.11a, Part 11: “Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) specifications: High-speed Physical Layer in the 5 GHz Band,” ISO/IEC 8802-11:1999/Amd 1:2000(E).
2. J. Terry and J. Heiskala, Proakis, *OFDM Wireless LANs: A Theoretical and Practical Guide*, Sams Publishing, 2002.
3. J. G. Proakis, *Digital Communications*, McGraw-Hill, 2001.

Math, Complex

This topic describes the following System components:

Add Two Complex Signals (CADD)



Property	Description	Units	Default	Range/Type
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (complex)			
Input2	Input2 signal (complex)			
Output	Output signal (complex)			

Notes

1. This model adds the two complex input signals (sample by sample) and writes the result to the output port.

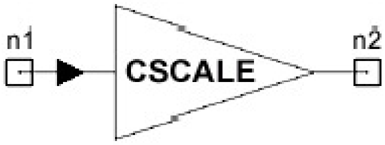
Netlist Form

```
ACADD:NAME n1 n2 n3 nexsys_component=CADD [Rin1=val] [Rin2=val]
[Rout=val]
```

Netlist Example

```
ACADD:1 1  2  3 nexsys_component=CADD
```

Scale a Complex Signal (CSCALE)



Property	Description	Units	Default	Range/Type
GAIN	Magnitude of complex gain	None	1	[0, Inf)/Real
PHASE	Phase of voltage gain	Deg	0	[-180, 180)/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (complex)			
Output	Output signal (complex)			

Notes

This model takes a complex input signal and scales each input sample by the complex gain *GAIN •exp (j •PHASE)*If the input signal is *x(n)*, the output signal *y(n)* is given by

y(n) = GAIN •exp (j •PHASE)•x(n)

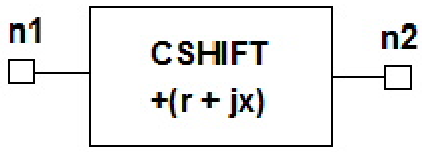
Netlist Form

```
ACSCALE:Name n1  n2 nexsys_component=CSCALE GAIN=val PHASE=val
[Rin=val][Rout=val]
```

Netlist Example

```
ACSCALE:1 1  2 nexsys_component=CSCALE GAIN=1.2  PHASE=10DEG
```

Shift a Complex Signal (CSHIFT)



Property	Description	Units	Default	Range/Type
REAL_SHIFT	Real shift value	None	0	(-Inf, Inf)/Real
IMAG_SHIFT	Imaginary shift value	None	0	(-Inf, Inf)/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

This model takes a complex input signal, then shifts the real part of each input waveform by REAL_SHIFT and the imaginary part by IMAG_SHIFT.

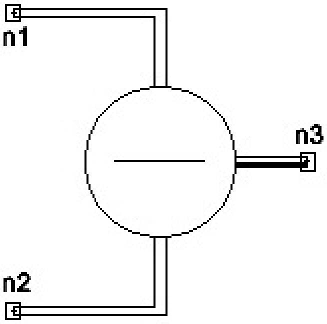
Netlist Form

```
ACSHIFT:Name n1 n2 nexsys_component=CSHIFT REAL_SHIFT=val
IMAG_SHIFT=val [Rin=val][Rout=val]
```

Netlist Example

```
ACSHIFT:1 1 2 nexsys_component=CSHIFT REAL_SHIFT=0.1
IMAG_SHIFT=-0.1
```

Subtract Two Complex Signals (CSUB)



Property	Description	Units	Default	Range/Type
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (complex)			
Input2	Input2 signal (complex)			
Output	Output signal (complex)			

Notes

1. This model subtracts the two complex input signals (sample by sample) and writes the result to the output port

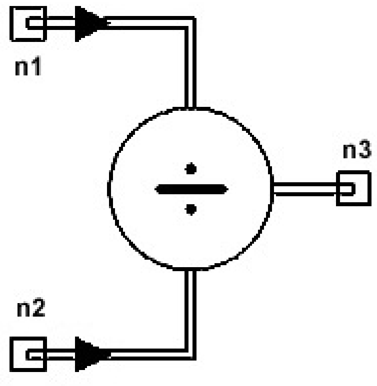
Netlist Form

```
ACSUB:NAME n1  n2  n3 nexsys_component=CSUB [Rin1=val]
[Rin2=val] [Rout=val]
```

Netlist Example

```
ACSUB:1 1  2  3 nexsys_component=CSUB
```

Divide Two Signals (DIV)



Property	Description	Units	Default	Range/Type
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal, numerator (complex)			
Input2	Input2 signal, denominator (complex)			
Output	Output signal (complex)			

Notes

1. This model performs a sample by sample division of two complex (or real) baseband signal.

Netlist Form

```
ADIV:NAME  n1 n2 n3 nexsys_component=DIV [RIN1=val] [RIN2=val]
[ROUT=val]
```

Netlist Example

```
ADIV:1 1 2 3 nexsys_component=DIV
```

Angle (FANGLE)

Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (complex)			
Output	Output signal (real)			

Notes

1. This is a math function. The output is the phase angle of the input complex signal.

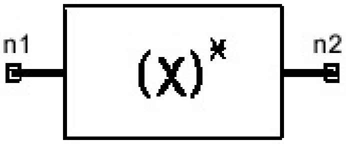
Netlist Form

```
AFANGLE:NAME n1  n2 nexsys_component=FANGLE [Rin=val]
[Rout=val]
```

Netlist Example

```
AFANGLE:1 1 2 nexsys_component=FANGLE
```

Complex Conjugate (FCONJ)



Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (complex)			
Output	Output signal (complex)			

Notes

1. This is a math function. The output is the complex conjugate value of the input complex signal.

Netlist Form

```
AFCONJ:NAME n1  n2 nexsys_component=FCONJ [Rin=val] [Rout=val]
```

Netlist Example

```
AFCONJ:1 1 2 nexsys_component=FCONJ
```

Complex Magnitude (FMAG)

Property	**Description**	**Units**	**Default**	**Range/Type**
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (complex)			
Output	Output signal (real)			

Notes

1. This is a math function. The output is the magnitude of the complex input signal.

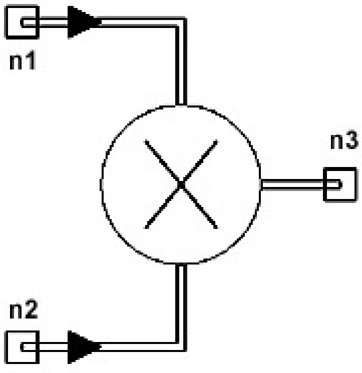
Netlist Form

```
AFMAG:NAME n1  n2 nexsys_component=FMAG [Rin=val] [Rout=val]
```

Netlist Example

```
AFMAG:1 1 2 nexsys_component=FMAG
```

Multiply Two Signals (MULT)



Property	Description	Units	Default	Range/Type
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (complex)			
Input2	Input2 signal (complex)			
Output	Output signal (complex)			

Notes

1. This model performs a sample by sample multiplication of two complex (or real) baseband signal.

Netlist Form

```
AMULT:NAME  n1 n2 n3 nexsys_component=MULT [RIN1=val]
[RIN2=val] [ROUT=val]
```

Netlist Example

```
AMULT:1 1 2 3 nexsys_component=MULT
```

Math, Exponential

This topic describes the following System components:

Exponential Base e (FEXP)

Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This is a math function. The output is the exponential (base e = 2.7182818) of the input signal.

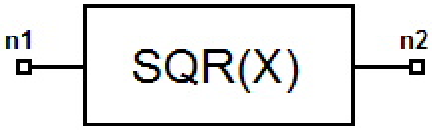
Netlist Form

```
AFEXP:NAME n1  n2 nexsys_component=FEXP [Rin=val] [Rout=val]
```

Netlist Example

```
AFEXP:1 1 2 nexsys_component=FEXP
```

Square (FSQR)



Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This is a math function. The output is the square of the input signal.

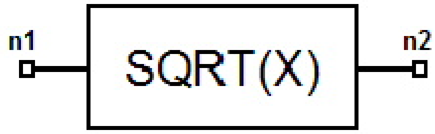
Netlist Form

```
AFSQR:NAME n1  n2 nexsys_component=FSQR [Rin=val] [Rout=val]
```

Netlist Example

```
AFSQR:1 1 2 nexsys_component=FSQR
```

Square Root (FSQRT)



Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This is a math function. The output is the square root of the input signal.

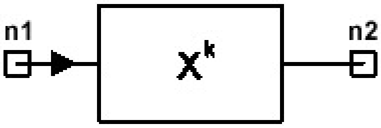
Netlist Form

```
AFSQRT:NAME n1  n2 nexsys_component=FSQRT [Rin=val] [Rout=val]
```

Netlist Example

```
AFSQRT:1 1 2 nexsys_component=FSQRT
```

Power (POW)



Property	Description	Units	Default	Range/Type
K	Exponent	None	2	(-Inf, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This is a math function. The output is the power of the input signal. The relation of the output *Z* and the input *X*i s given by

$$z = x^k$$

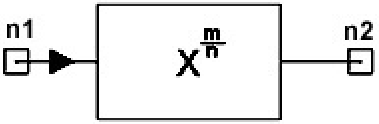
Netlist Form

```
APOW:NAME  n1 n2 nexsys_component=POW [K=val] [RIN=val] [ROUT=val]
```

Netlist Example

```
APOW:1 1 2 nexsys_component=POW K=2
```

Power with Exponential Format (POW2)



Property	Description	Units	Default	Range/Type
M	Numerator of exponent	None	1	(-Inf, Inf)/Integer
N	Denominator of exponent	None	2	[2, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This is a math function. The output is the power of the input signal. The relation of the output *Z* and the input *X* is given by

$$z = x^{\frac{m}{n}}$$

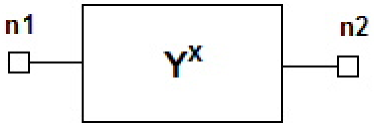
Netlist Form

```
APOW2:NAME  n1 n2 nexsys_component=POW2 [M=val]  [N=val] [RIN=val]
[ROUT=val]
```

Netlist Example

```
APOW2:1 1 2 nexsys_component=POW2 M=1 N=2
```

Exponential Base Y (POW3)



Property	Description	Units	Default	Range/Type
Y	Exponential base	None	1	(-Inf, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This is a math function. The output is the parameter Y raised to the power given by the input signal. The relation of the output *Z* and the input *X* s given by

$$Z = Y^X$$

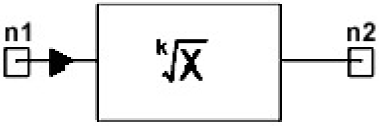
Netlist Form

```
APOW3:NAME  n1 n2 Y=val [RIN=val] [ROUT=val] nexsys_component=pow3
```

Netlist Example

```
APOW3:1 1 2 Y=3 nexsys_component=pow3
```

Root (ROOT)



Property	Description	Units	Default	Range/Type
K	Root	None	2	[2, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This is a math function. The output is the root of the input signal. The relation of the output z and the input x is given by

   $$z = \sqrt[k]{x}$$

Netlist Form

```
AROOT:NAME  n1 n2 nexsys_component=ROOT [K=val] [RIN=val]
[ROUT=val]
```

Netlist Example:

```
AROOT:1 1 2 nexsys_component=ROOT K=2
```

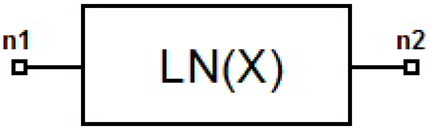
Math, Logarithm

This topic describes the following System components:

"Natural Logarithm (FLN)" on the next page

"Logarithm Base 10 (FLOG)" on page 38-335

Natural Logarithm (FLN)



Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This is a math function. The output is the natural logarithm of the input signal.

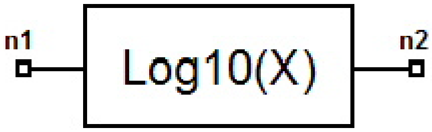
Netlist Form

```
AFLN:NAME n1  n2 nexsys_component=FLN [Rin=val] [Rout=val]
```

Netlist Example

```
AFLN:1 1 2 nexsys_component=FLN
```

Logarithm Base 10 (FLOG)



Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This is a math function. The output is the logarithm (base 10) of the input signal.

Netlist Form

```
AFLOG:NAME n1  n2 nexsys_component=FLOG [Rin=val] [Rout=val]
```

Netlist Example

```
AFLOG:1 1 2 nexsys_component=FLOG
```

Math, Precision

This topic describes the following System components:

"Ceiling (CEIL)" on the facing page

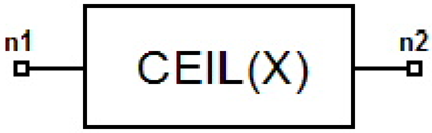
"Floor (FLOOR)" on page 38-338

"Fraction (FRACTION)" on page 38-339

"Round (ROUND) " on page 38-340

"Truncation (TRUNC) " on page 38-341

Ceiling (CEIL)



Property	Description	Units	Default	Range/Type
RIN	Inpu1 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This model rounds the input values to the nearest integers toward infinity.

Netlist Form

```
ACEIL:NAME  n1 n2 nexsys_component=CEIL [RIN=val] [ROUT=val]
```

Netlist Example

```
ACEIL:1 1 2 nexsys_component=CEIL
```

Floor (FLOOR)

Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This model rounds the input values to the nearest integers toward minus infinity.

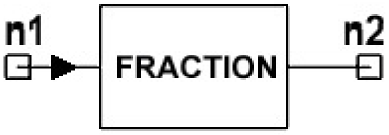
Netlist Form

`AFFLOOR:NAME  n1 n2 nexsys_component=FFLOOR [RIN=`*`val`*`] [ROUT=`*`val`*`]`

Netlist Example

```
AFFLOOR:1 1 2 nexsys_component=FFLOOR
```

Fraction (FRACTION)



Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This model is used to output the fractional part of the input values.

Netlist Form

```
AFRACTION:NAME  n1 n2 nexsys_component=FRACTION [RIN=val]
[ROUT=val]
```

Netlist Example

```
AFRACTION:1 1 2 nexsys_component=FRACTION
```

Round (ROUND)

Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This model rounds the input values to the nearest integers.

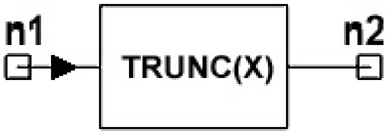
Netlist Form

`AROUND:NAME  n1 n2 nexsys_component=ROUND [RIN=val] [ROUT=val]`

Netlist Example

`AROUND:1 1 2 nexsys_component=ROUND`

Truncation (TRUNC)



Property	**Description**	**Units**	**Default**	**Range/Type**
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This model rounds the input values to the nearest integers toward zero.

Netlist Form

```
ATRUNC:NAME  n1 n2 nexsys_component=TRUNC [RIN=val] [ROUT=val]
```

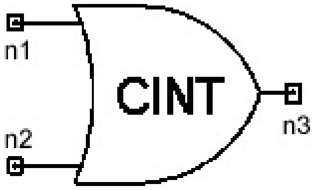
Netlist Example

```
ATRUNC:1 1 2 nexsys_component=TRUNC
```

Math, Real

This topic describes the following System components:

Compare Two Real Input Signals (CINT)



Property	Description	Units	Default	Range/Type
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (real)			
Input2	Input2 signal (real)			
Output	Output signal (real)			

Notes

1. This model compares two input signals. If the nth sample of both signals is different, the model outputs a 1, otherwise, it outputs a 0. This model could be used as an error counter.

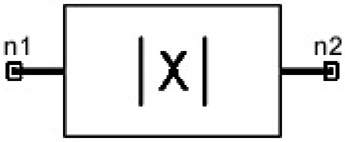
Netlist Form

```
ACINT:NAME n1  n2  n3 nexsys_component=CINT [Rin1=val]
[Rin2=val] [Rout=val]
```

Netlist Example

```
ACINT:1 1 2 3 nexsys_component=CINT
```

Absolute Value (FABS)



Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

>Model Notes

1. This is a math function. The output is the absolute value of the input signal.

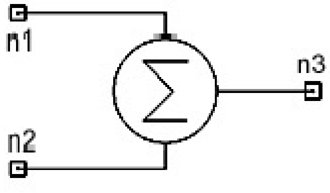
Netlist Form

`FABS:NAME n1  n2 [Rin1=val] [Rout=val]`

Netlist Example

`FABS:1 1 2`

Add Two Real Input Signals (RADD)



Property	Description	Units	Default	Range/Type
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (real)			
Input2	Input2 signal (real)			
Output	Output signal (real)			

Notes

1. This model performs a sample by sample addition of two real input signals.

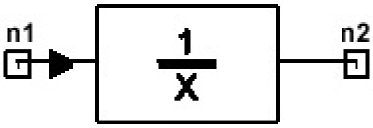
Netlist Form

```
ARADD:NAME n1  n2  n3 nexsys_component=RADD [Rin1=val]
[Rin2=val] [Rout=val]
```

Netlist Example

```
ARADD:1 1 2 3 nexsys_component=RADD
```

Reciprocator (RECIP)



Property	**Description**	**Units**	**Default**	**Range/Type**
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This is a math function. The output is the reciprocal of the input signal. The relation of the output *Z* and the input *X* is given by

$$z = \frac{1}{x}$$

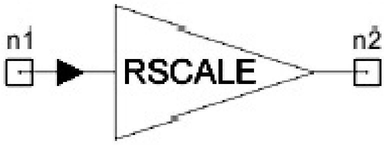
Netlist Form

```
ARECIP:NAME  n1 n2 nexsys_component=RECIP [RIN=val] [ROUT=val]
```

Netlist Example

```
ARECIP:1 1 2 nexsys_component=RECIP
```

Scale a Real Signal (RSCALE)



Property	**Description**	**Units**	**Default**	**Range/Type**
GAIN	Gain factor	None	1	(-Inf, Inf)/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

This model takes a real input signal and scales each input sample by GAIN. If the input signal is *x(n)*, the output signal *y(n)* is given by: *y(n) = GAIN •x(n)*, where n ≥ 0.

Netlist Form

ARSCALE:Name *n1 n2* nexsys_component=RSCALE GAIN=*val* [Rin=*val*][Rout=*val*]

Netlist Example

ARSCALE:1 1 2 nexsys_component=RSCALE GAIN=0.01

Shift a Real Signal (RSHIFT)

Property	**Description**	**Units**	**Default**	**Range/Type**
SHIFT	Shift offset value	None	0	(-Inf, Inf)/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

This model takes a real input signal and shifts each input sample by SHIFT.

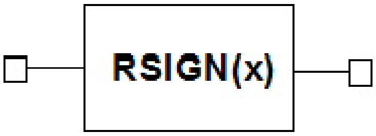
Netlist Form

ARSHIFT:Name *n1 n2* nexsys_component=RSHIFT SHIFT=*val* [Rin=*val*][Rout=*val*]

Netlist Example

ARSHIFT:1 1 2 nexsys_component=RSHIFT SHIFT=0.1

Sign (RSIGN)



Property	**Description**	**Units**	**Default**	**Range/Type**
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This is a math function. The output is the sign of the input signal. The relation of the output *Z* and the input X is:

Z = -1 when X < 0

Z = 0 when X = 0

Z = +1 when X >1

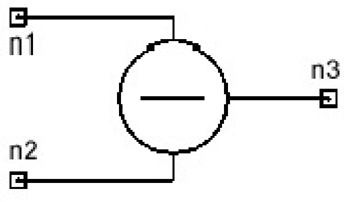
Netlist Form

`ARSIGN:NAME  n1 n2 [RIN=`*`val`*`] [ROUT=`*`val`*`] nexsys_component=rsign`

Netlist Example

```
ARSIGN:1 1 2 nexsys_component=rsign
```

Subtract Two Real Input Signals (RSUB)



Property	**Description**	**Units**	**Default**	**Range/Type**
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (real)1			
Input2	Input2 signal (real)			
Output	Output signal (real)			

Notes

1. This model performs a sample by sample subtraction of two real input signals. Input2 which corresponds to node n2 is subtracted from Input1 which corresponds to node n1.

Netlist Form

```
ARSUB:NAME n1  n2  n3 nexsys_component=RSUB [Rin1=val]
[Rin2=val] [Rout=val]
```

Netlist Example

```
ARSUB:1 1 2 3 nexsys_component=RSUB
```

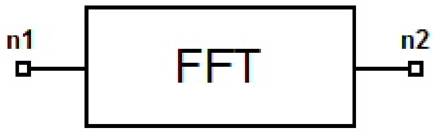
Math, Transforms

This topic describes the following System components:

"Fast Fourier Transform (FFT)" on the next page

"Inverse Fast Fourier Transform (IFFT)" on page 38-353

Fast Fourier Transform (FFT)



Property	Description	Units	Default	Range/Type
FFTL	FFT length	None	1024	[1, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (complex)			
Output	Output signal (complex)			

Notes

1. This model performs FFT on the incoming signal. If “FFTL” is not a power of 2, it is set to the integer next power of 2 value greater than FFTL.

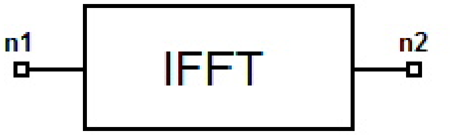
Netlist Form

```
 AFFT:NAME n1 n2 nexsys_component=FFT fftl=val [Rin=val]
[Rout=val]
```

Netlist Example

```
AFFT:1 1 2 nexsys_component=FFT fftl=2048
```

Inverse Fast Fourier Transform (IFFT)



Property	Description	Units	Default	Range/Type
FFTL	FFT length	None	1024	[1, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This model performs inverse FFT on the incoming signal. If “FFTL” is not a power of 2, it is set to the integer next power of 2 value greater than FFTL.

Netlist Form

```
AIFFT:NAME n1 n2 nexsys_component=IFFT fftl=val [Rin=val] [Rout=val]
```

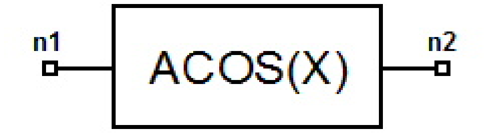
Netlist Example

```
AIFFT:1 1 2 nexsys_component=IFFT fftl  = 2048
```

Math, Trigonometry

This topic describes the following System components:

Arc Cosine (FACOS)



Property	**Description**	**Units**	**Default**	**Range/Type**
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This is a math function. The output is the arc cosine of the input signal.

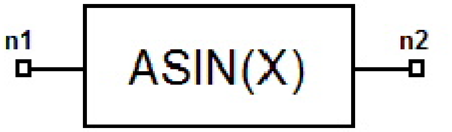
Netlist Form

```
AFACOS:NAME n1  n2 nexsys_component=FACOS [Rin=val] [Rout=val]
```

Netlist Example

```
AFACOS:1 2 nexsys_component=FACOS
```

Arc Sine (FASIN)



Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This is a math function. The output is the arc sine of the input signal.

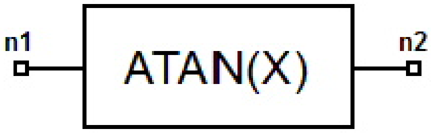
Netlist Form

```
AFASIN:NAME n1  n2 nexsys_component=FASIN [Rin=val] [Rout=val]
```

Netlist Example

```
AFASIN:1 1 2 nexsys_component=FASIN
```

Arc Tangent (FATAN)



Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This is a math function. The output is the arc tangent of the input signal.

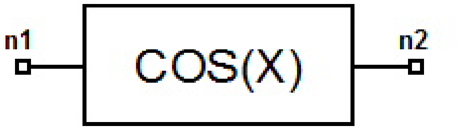
Netlist Form

```
AFATAN:NAME n1  n2 nexsys_component=FATAN [Rin=val] [Rout=val]
```

Netlist Example

```
AFATAN:1 1 2 nexsys_component=FATAN
```

Cosine (FCOS)



Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This is a math function. The output is the cosine of the input signal.

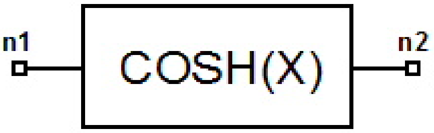
Netlist Form

AFCOS:NAME *n1* *n2* nexsys_component=FCOS [Rin=val] [Rout=val]

Netlist Example

```
AFCOS:1 1 2 nexsys_component=FCOS
```

Hyperbolic Cosine (FCOSH)



Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This is a math function. The output is the hyperbolic cosine of the input signal.

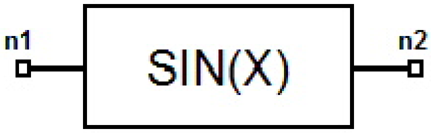
Netlist Form

```
AFCOSH:NAME n1  n2 nexsys_component=FCOSH [Rin=val] [Rout=val]
```

Netlist Example

```
AFCOSH:1 1 2 nexsys_component=FCOSH
```

Sine (FSIN)



Property	**Description**	**Units**	**Default**	**Range/Type**
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This is a math function. The output is the sine of the input signal.

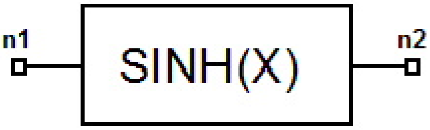
Netlist Form

```
AFSIN:NAME n1  n2 nexsys_component=FSIN [Rin=val] [Rout=val]
```

Netlist Example

```
AFSIN:1 1 2 nexsys_component=FSIN
```

Hyperbolic Sine (FSINH)



Property	**Description**	**Units**	**Default**	**Range/Type**
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This is a math function. The output is the hyperbolic sine of the input signal.

Netlist Form

```
AFSINH:NAME n1  n2 nexsys_component=FSINH [Rin=val] [Rout=val]
```

Netlist Example

```
AFSINH:1 1 2 nexsys_component=FSINH
```

Tangent (FTAN)

Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This is a math function. The output is the tangent of the input signal.

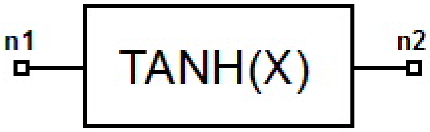
Netlist Form

```
AFTAN:NAME n1  n2 nexsys_component=FTAN [Rin=val] [Rout=val]
```

Netlist Example

```
AFTAN:1 1 2 nexsys_component=FTAN
```

Hyperbolic Tangent (FTANH)



Property	**Description**	**Units**	**Default**	**Range/Type**
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This is a math function. The output is the hyperbolic tangent of the input signal.

Netlist Form

```
AFTANH:NAME n1  n2 nexsys_component=FTANH [Rin=val] [Rout=val]
```

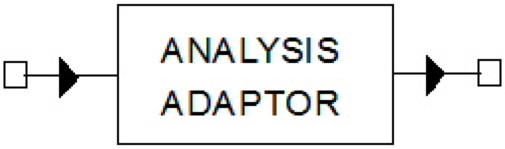
Netlist Example

```
AFTANH:1 1 2 nexsys_component=FTANH
```

Miscellaneous

This topic describes the following System components:

Analysis Adaptor (AADAPTOR)



Property	Description	Units	Default	Range/Type
Type	0 = transient, 1 = convolution	None	0	[0, 1)/Integer
Length	Impulse response length for convolution	None	1024	[0, MAX_INT]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (complex)			
Output	Output signal (complex)			

Notes

This model selects transient analysis (the default) or convolution to solve the associated Nexxim (physical) subcircuit.

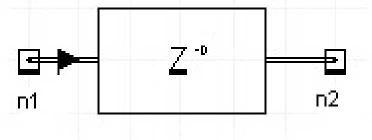
Netlist Form

```
Aanalysisadaptor:Name n1 n2 Nexsys_component=analysisadaptor
Type=val Length=val [Rin=val] [Rout=val]
```

Netlist Example

```
Aanalysisadaptor:1 1 2 Nexsys_component=analysisadaptor
+ Type=1 Length=2048
```

Delay, Complex Signal (CDELAY)



Property	Description	Units	Default	Range/Type
D	The number of samples by which the input signal is delayed.	None	1	[0, Inf)/Integer
REAL_V	Real part of the value of the first D output samples	Volt	0	(-Inf, Inf)/Real
IMAG_V	Imaginary part of the value of the first D output samples	Volt	0	(-Inf, Inf)/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (complex)			
Output	Output signal (complex)			

Notes

This model delays a complex signal by a specified number of samples given by the parameter **D**. This delay is effectively place **D** number of samples at the beginning of the output signal with the value $RealV + jImagV$.

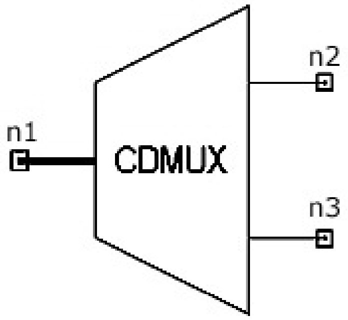
Netlist Form

```
ACDELAY:Name n1 n2 nexsys_component=CDELAY D=val [REAL_V=val]
[IMAG_V=val] [Rin=val] [Rout=val]
```

Netlist Example

```
ACDELAY:1 1 2 nexsys_component=CDELAY D=8 REAL_V=1
```

Demultiplexer, Complex (CDMUX)



Property	Description	Units	Default	Range/Type
Type	Output sample rate changed: 0 for No, 1 for Yes	None	0	[0, 1]/Integer
NS1	Number of samples to write to output1	None	1	[1, Inf)/Integer
NS2	Number of samples to write to output2	None	1	[1, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT1	Output1 impedance	Ohm	0	[0, Inf)/Real
ROUT2	Output2 impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (complex)			
Output1	Output1 signal (complex)			
Output2	Output2 signal (complex)			

Notes

This model demultiplexes one complex input signal into two complex output signals. It works as follows: the first output reads NS1 samples on the input signal, the second output reads NS2 samples on the incoming signal, the first output reads again, repeating the pattern until there are no more data to be read. Based on whether the parameter “type” is set or not, the sampling rate of the two output signals can change or remain the same. Suppose the sampling rate of the input signal is $f_s(in)$, if TYPE is set to be 1, the sampling rate for the two outputs is $f_s(out1) = f_s(in) \times \frac{NS1}{NS1 + NS2}$ and $f_s(out2) = f_s(in) \times \frac{NS2}{NS1 + NS2}$ respectively.

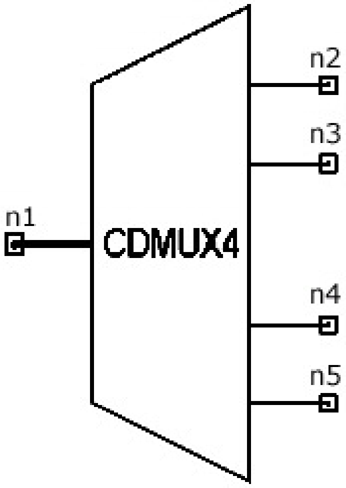
Netlist Form

```
ACDMUX:Name n1  n2  n3 nexsys_component=CDMUX [TYPE=val]
NS1=val  NS2=val [Rin=val] [Rout1=val] [Rout2=val]
```

Netlist Example

```
ACDMUX:Name 1  2  3 nexsys_component=CDMUX NS1=20  NS2=30
```

Demultiplexer with Four Outputs, Complex (CDMUX4)



Property	Description	Units	Default	Range/Type
TYPE	Output sample rate changed: 0 for No, 1 for Yes	None	0	[0, 1]/Integer
N	Number of output ports used for demultiplexing	None	4	[1, 4]/Integer
NS1	Number of samples to write to output1	None	1	[1, Inf)/Integer
NS2	Number of samples to write to output2	None	1	[0, Inf)/Integer
NS3	Number of samples to write to output3	None	1	[0, Inf)/Integer
NS4	Number of samples to write to output4	None	1	[0, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT1	Output1 impedance	Ohm	Inf	[0, Inf)/Real
ROUT2	Output2 impedance	Ohm	Inf	[0, Inf)/Real
ROUT3	Output3 impedance	Ohm	Inf	[0, Inf)/Real
ROUT4	Output4 impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (complex)			
Output1	Output1 signal (complex)			
Output2	Output2 signal (complex)			
Output3	Output3 signal (complex)			

Output4	Output4 signal (complex)

Notes

This model is used to demultiplex one complex input signal into **N** (1≤**N** ≤ 4) complex output signals. Note that only **N** ports are used to do the demultiplexing, the remaining output ports receive no data. If TYPE is set to 0, the sampling rate of the output signals are not changed. Otherwise, the sampling rate of the *i*th output port can be calculated as

$$f_s(outi) = f_s(in) \times \frac{NSi}{NS1 + NS2 + \ldots + NS_4}$$

Netlist Form

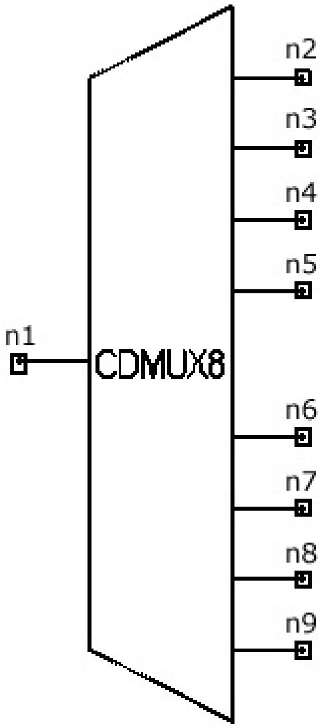
```
ACDMUX4:Name n1  n2  n3  n4  n5 nexsys_component=CDMUX4
[TYPE= val] N= val  [NS1= val] [NS2= val] [NS3= val] [NS4=
val] [Rin=val][Rout1=val] [Rout2=val] [Rout3=val] Rout4=val]
```

Netlist Example

```
ACDMUX4:1 1 2 3 4 5 nexsys_component=CDMUX4 N=3 TYPE=0 NS1=1
NS2=1  NS3=1  NS4=0
```

In this example, one sample is read on the input signal to **Output1** followed by one sample to **Output2**, followed by one sample to**Output3** and followed by one sample to **Output1** and so on until no sample exists at the input port. Each output sample rate equals one third the input sample rate.

Demultiplexer with Eight Outputs, Complex (CDMUX8)



Property	Description	Units	Default	Range/Type
TYPE	Output sample rate changed: 0 for No, 1 for Yes	None	0	[0, 1]/Integer
N	Number of output ports used for demultiplexing	None	8	[1, 8]/Integer
NS1	Number of samples to write to output1	None	1	[1, Inf)/Integer
NS2	Number of samples to write to output2	None	1	[0, Inf)/Integer
NS3	Number of samples to write to output3	None	1	[0, Inf)/Integer
NS4	Number of samples to write to output4	None	1	[0, Inf)/Integer
NS5	Number of samples to write to output5	None	1	[0, Inf)/Integer
NS6	Number of samples to write to output6	None	1	[0, Inf)/Integer
NS7	Number of samples to write to output7	None	1	[0, Inf)/Integer
NS8	Number of samples to write to output8	None	1	[0, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real

ROUT1	Output1 impedance	Ohm	0	[0, Inf)/Real
ROUT2	Output2 impedance	Ohm	0	[0, Inf)/Real
ROUT3	Output3 impedance	Ohm	0	[0, Inf)/Real
ROUT4	Output4 impedance	Ohm	0	[0, Inf)/Real
ROUT5	Output5 impedance	Ohm	0	[0, Inf)/Real
ROUT6	Output6 impedance	Ohm	0	[0, Inf)/Real
ROUT7	Output7 impedance	Ohm	0	[0, Inf)/Real
ROUT8	Output8 impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (complex)			
Output1	Output1 signal (complex)			
Output2	Output2 signal (complex)			
Output3	Output3 signal (complex)			
Output4	Output4 signal (complex)			
Output5	Output5 signal (complex)			
Output6	Output6 signal (complex)			
Output7	Output7 signal (complex)			
Output8	Output8 signal (complex)			

Notes

This model is used to demultiplex one complex input signal into **N** (1≤ **N** ≤ 8) complex output signals. Note that only **N** ports are used to do the demultiplexing, the remaining output ports receive no data. If TYPE is set to 0, the sampling rate of the output signals are not changed. Otherwise, the sampling rate of the *i*th output port can be calculated as

$$f_s(outi) = f_s(in) \times \frac{NSi}{NS1 + NS2 + \ldots + NS8}$$

Netlist Form

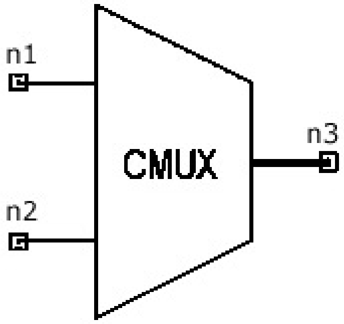
```
ACDMUX8:Name n1  n2  n3  n4  n5  n6  n7  n8  n9
nexsys_component=CDMUX8 [TYPE=val] N=val  [NS1=val] [NS2=val]
[NS3=val] [NS4=val] [NS5=val] [NS6=val] [NS7=val] [NS8=val]
[Rin=val][Rout1=val] [Rout2=val] [Rout3=val] [Rout4=val]
[Rout5=val] [Rout6=val] [Rout7=val] [Rout8=val]
```

Netlist Example

```
ACDMUX8:1 1 2 3 4 5 6 7 8 9 nexsys_component=CDMUX8 TYPE=0 N=5
NS1=1 NS2=1  NS3=1  NS4=0 NS5=1 NS6=0 NS7=0 NS8=0
```

In this example, 1 sample is read on the input signal to **Output1** followed by 1 sample to **Output2**, … followed by 1 sample to **Output5** and followed by 1 sample to **Output1** and so on until no sample exists at the input port. Each output sample rate equals one fifth the input sample rate.

Multiplexer, Complex (CMUX)



Property	Description	Units	Default	Range/Type
Type	Output sample rate changed: 0 for No, 1 for Yes	None	0	[0, 1]/Integer
NS1	Number of samples to read from input1	None	1	[1, Inf)/Integer
NS2	Number of samples to read from input2	None	1	[1, Inf)/Integer
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (complex)			
Input2	Input2 signal (complex)			
Output	Multiplexed output signal (complex)			

Notes

This model multiplexes two complex input signals with the same sampling rate into a single complex output signal. The output signal takes NS1 samples on the first input, then NS2 samples from the second input, then NS1 samples on the first input again, continuing until no data remains for processing. If **TYPE** is set to 0, then the sampling rate of the output signals are not changed. Otherwise, the sampling rate of the *i*th output port can be calculated as

$$f_s(out) = f_s(in) \times \frac{NS1 + NS2}{NS1}$$

If the incoming signal is real, the simulator automatically inserts a real-to-complex converter internally.

Netlist Form

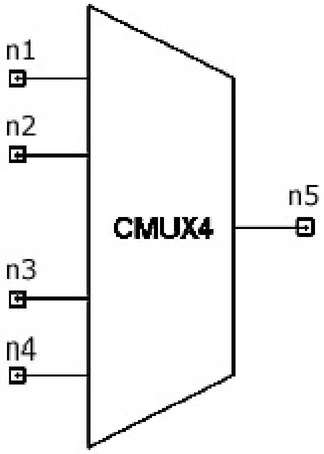
ACMUX:Name *n1 n2 n3* nexsys_component=CMUX [TYPE=*val*] [NS1=*val*] [NS2=*val*] [Rin1=*val*] [Rin2=*val*] [Rout=*val*]

Netlist Example

```
ACMUX:1 1  2  3 nexsys_component=CMUX INPUT1=45 INPUT2=100
```

In this example, the multiplexed complex output signal consists of 45 samples from **Input1** followed by 100 samples from **Input2** followed by 45 samples from **Input1**, continuing until no more input samples remain at one or both input nodes.

Multiplexer with Four Inputs, Complex (CMUX4)



Property	Description	Units	Default	Range/Type
TYPE	Output sample rate changed: 0 for No, 1 for Yes	None	0	[0, 1]/Integer
N	Number of input ports used for multiplexing	None	4	[1, 4]/Integer
NS1	Number of samples to read from input1	None	1	[1, Inf)/Integer
NS2	Number of samples to read from input2	None	1	[0, Inf)/Integer
NS3	Number of samples to read from input3	None	1	[0, Inf)/Integer
NS4	Number of samples to read from input4	None	1	[0, Inf)/Integer
RIN1	Input1 Impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 Impedance	Ohm	Inf	(0, Inf]/Real
RIN3	Input3 Impedance	Ohm	Inf	(0, Inf]/Real
RIN4	Input4 Impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (complex)			
Input2	Input2 signal (complex)			
Input3	Input3 signal (complex)			
Input4	Input4 signal (complex)			
Output	Output signal (complex)			

Notes

This model is used to multiplex **N** (1 ≤ **N** ≤ 4) complex input signals with the same sampling rate into a single complex output signal. Note that if only **N** input ports are used to do the multiplexing, the remaining ports are not used. If **TYPE** is set to 0, the sampling rate of the output signals are not changed. Otherwise,

the sampling rate of the output port can be calculated as $f_s(out) = f_s \times \frac{NS1 + NS2 + \ldots NS4}{NS1}$

If the incoming signal is real, the simulator automatically inserts a real-to-complex converter internally.

Netlist Form

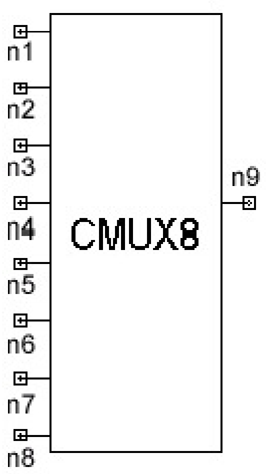
```
ACMUX4:Name n1  n2  n3  n4  n5 nexsys_component=CMUX4
[TYPE=val] [N=val] [NS1=val] [NS2=val] [NS3=val]
[NS4=val] [Rin1=val][Rin2=val] [Rin3=val] [Rin4=val]
[Rout=val]
```

Netlist Example

```
ACMUX4:1 1 2 3 4 5 nexsys_component=CMUX4 N=3 TYPE=0 NS1=1 NS2=1
NS3=1
```

In this example, the multiplexed complex output signal consists of one sample from **Input1** followed by 1 sample from **Input2**, …, followed by one sample from input3 and followed by one sample from **Input1** and so on until no input sample exists at the input ports being processed. The output sample rate equals three times the first input sample rate.

Multiplexer with Eight Inputs, Complex (CMUX8)



Property	Description	Units	Default	Range/Type
TYPE	Output sample rate changed: 0 for No, 1 for Yes	None	0	[0, 1]/Integer
N	Number of input ports used for multiplexing	None	8	[1, 8]/Integer
NS1	Number of samples to read from input1	None	1	[1, Inf)/Integer
NS2	Number of samples to read from input2	None	1	[0, Inf)/Integer
NS3	Number of samples to read from input3	None	1	[0, Inf)/Integer
NS4	Number of samples to read from input4	None	1	[0, Inf)/Integer
NS5	Number of samples to read from input5	None	1	[0, Inf)/Integer
NS6	Number of samples to read from input6	None	1	[0, Inf)/Integer
NS7	Number of samples to read from input7	None	1	[0, Inf)/Integer
NS8	Number of samples to read from input8	None	1	[0, Inf)/Integer
RIN1	Input1 Impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 Impedance	Ohm	Inf	(0, Inf]/Real
RIN3	Input3 Impedance	Ohm	Inf	(0, Inf]/Real
RIN4	Input4 Impedance	Ohm	Inf	(0, Inf]/Real
RIN5	Input 5 Impedance	Ohm	Inf	(0, Inf]/Real
RIN6	Input6 Impedance	Ohm	Inf	(0, Inf]/Real

RIN7	Input7 Impedance	Ohm	Inf	(0, Inf]/Real
RIN8	Input8 Impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (complex)			
Input2	Input2 signal (complex)			
Input3	Input3 signal (complex)			
Input4	Input4 signal (complex)			
Input5	Input5 signal (complex)			
Input6	Input6 signal (complex)			
Input7	Input7 signal (complex)			
Input8	Input8 signal (complex)			
Output	Output signal (complex)			

Notes

This model is used to multiplex **N** (1≤ **N** ≤ 8) complex input signals with same sampling rate into a single complex output signal. Note that if only **N** input ports are used to do the multiplexing, the remaining ports are not used. If **TYPE** is set to 0, the sampling rate of the output signals are not changed. Otherwise,

the sampling rate of the output port can be calculated as $f_s(out) = f_s \times \frac{NS1 + NS2 + \ldots NS8}{NS1}$

If the incoming signal is real, the simulator automatically inserts a real-to-complex converter internally.

Netlist Form

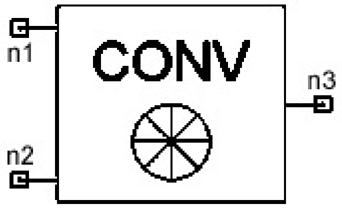
```
ACMUX8:Name n1  n2  n3  n4  n5  n6  n7  n8  n9
nexsys_component=CMUX8 [TYPE=val] [N=val] [NS1=val] [NS2=val]
[NS3=val] [NS4=val] [NS5=val] [NS6=val] [NS7=val] [NS8=val]
[Rin1=val][Rin2=val] [Rin3=val] [Rin4=val] [Rin5=val]
[Rin6=val] [Rin7=val] [Rin8=val] [Rout=val]
```

Netlist Example

```
ACMUX8:1 1 2 3 4 5 6 7 8 9 nexsys_component=CMUX8 TYPE=0 N=5
NS1=1 NS2=1  NS3=1  NS4=0 NS5=1 NS6=0 NS7=0 NS8=0
```

In this example, the multiplexed complex output signal consists of one sample from **input1** followed by 1 sample from **Input2**, followed by one sample from **Input5** and followed by one sample from **Input1** and so on until no input sample exists at the input node which is being processed. The output sample rate equals five times the first input sample rate.

Convolution of Two Real Input Signals (CONV)



Property	Description	Units	Default	Range/Type
NS1	Number of samples on the first input per invocation	None	1	[1, Inf)/Integer
NS2	Number of samples on the second input per invocation	None	1	[1, Inf)/Integer
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (real)			
Input2	Input2 signal (real)			
Output	Output signal (real)			

Notes

This model convolves two real input signals. The convolution is performed in the frequency domain according to the overlap-save technique [1].

If the number of samples is **INPUT1_NSAMP** at the first input port and **INPUT2_NSAMP** at the second input port, then the total number of samples at the output port (per invocation) is **INPUT1_NSAMP** + **INPUT2_NSAMP** – 1. Keep in mind that the convolution process is commutative, which implies that switching the input ports around should not alter the outcome at the output port.

Netlist Form

```
ACONV:Name n1 n2 n3 nexsys_component=CONV [NS1=val]   [NS2=val]
[Rin1=val][Rin2=val] [Rout=val]
```

Netlist Example

```
ACONV:1 1 2 3 nexsys_component=CONV NS1=300 NS2=400
```

References

1. J. G. Proakis and D. G. Manolakis, *Digital Signal Processing*, Macmillan, 1988.

Real Signal Correlator (CRLTR)

Property	Description	Units	Default	Range/Type
COR_LEN	Correlation length	None	1	[1, Inf)/Integer
RIN1	Input impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (real)			
Input2	Input2 signal (real)			
Output	Output signal (real)			

Notes

This model accepts COR_LEN samples each on the two inputs per invocation and generates 2*COR_LEN-1 samples to the output. For a given two input sequences, $x_1(n)$ and $x_2(n)$, the output signal y(n) is calculated as:

$$y(n) = \sum_{m=0}^{CorLen-1} x_1(m)x_2(n-m)$$

with n in the range of [0, 2*CorLen-1]. Note $x_1(n)$ and $x_2(n)$ are zero when n is out of the range of [0, CorLen-1] in the above equation.

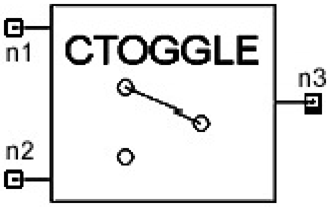
Netlist Form

```
ACRLTR:Name n1  n2  n3 nexsys_component=CRLTR COR_LEN=val
[Rin1=val] [Rin2=val] [Rout=val]
```

Netlist Example

```
ACRLTR:1 1 2 3 nexsys_component=CRLTR COR_LEN=100
```

Toggle Complex Input Signals (CTOGGLE)



Property	Description	Units	Default	Range/Type
NS	The number of samples to output from Input1 before switching to Input2.	None	0	[0, Inf)/Integer
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (complex)			
Input2	Input2 signal (complex)			
Output	Output signal (complex)			

Notes

This model switches from **Input1** to **Input2** after a specified number of samples given by the parameter **NS**. The output is a replica of **Input1** for the duration of the first **NS** samples after which it consists of samples on the second input signal.

Netlist Form

```
ACTOGGLE:Name n1 n2 n3 nexsys_component=CTOGGLE NS=val
[Rin1=val] [Rin2=val] [Rout=val]
```

Netlist Example

```
ACTOGGLE:1 1 2 3 nexsys_component=CTOGGLE NS=8
```

Deinterleaver (DEILV)

Property	Description	Units	Default	Range/Type
BLOCK_SIZE	Number of input samples to window per invocation	None	64	[1, Inf)/Integer
RANDOM_ SEED	Random seed	None	0	[-1, Inf)
FILE	Data file used to generate interleaving function	None	Optional	String
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Deinterleaved input signal (real)			

Notes

1. This model deinterleaves a real signal using given interleave functions, which may be provided by an external data file or created from computer by pseudo-random generator. During each invocation, this model deinterleaves **BLOCK_SIZE** input samples
2. The interleave function is just a sequence of **BLOCK_SIZE** integers:
   f(i) = a_i (i= 1, … ,**BLOCK_SIZE**)
   The output signal values related to input signal values for every **BLOCK_SIZE** samples are: Output(f(i)) = input (i) (i= 1, … ,**BLOCK_SIZE**)
3. The parameters **RANDOM_SEED** and **FILE** are optional. If neither is provided, the program uses the default value of **RANDOM_SEED**, which is 0.
4. For any non-negative values of **RANDOM_SEED**, the program sets up a random seed from its internal random generator = **RANDOM_SEED** and generates the interleaving function randomly.

5. An external file is used to generate interleaving function for either of the following cases: **RANDOM_SEED** = -1, or **FILENAME** has been provided.

   Data format for the external file is text file. The contents of the file are just **BLOCK_SIZE** integers, which are used as interleave function.
6. This element recovers the interleaved signal if the **RANDOM_SEED** are the same (or use same external file) for **INTLV** and **DEILV**.

Netlist Form

ADEILV:Name *n1 n2* nexsys_component=DEILV BLOCK_SIZE=*val* [RANDOM_SEED=*val*] FILE=”filename” [Rin=*val*] [Rout=*val*]

Netlist Example

1. Random deinterleaver:

```
ADEILV:1 1 2 nexsys_component=DEILV BLOCK_SIZE=256
RANDOM_SEED=40435
```

2. Interleave function provided by external file:

```
ADEILV:1 3 2 nexsys_component=DEILV BLOCK_SIZE=960
RANDOM_SEED=-1 FILE=”filename”
```

```
END
```

Interleaver (INTLV)

Property	Description	Units	Default	Range/Type
BLOCK_SIZE	Number of input samples to window per invocation	None	64	[1, Inf)/Integer
RANDOM_ SEED	Random seed	None	0	[-1, Inf)/Integer
FILE	Data file used to generate interleaving function	None	Optional	String
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Interleaved input signal (real)			

Notes

1. This model interleaves a real signal using given interleave functions, which may be provided by an external data file or created from computer by pseudo-random generator. During each invocation, this model deinterleaves **BLOCK_SIZE** input samples
2. The interleave function is just a sequence of **BLOCK_SIZE** integers:
   $f(i) = a_i$ (i= 1, … ,**BLOCK_SIZE**)
   The output signal values related to input signal values for every **BLOCK_SIZE** samples are: Output(f(i)) = input (i) (i= 1, … ,**BLOCK_SIZE**)
3. The parameters **RANDOM_SEED** and **FILE** are optional. If neither is provided, the program uses the default value of **RANDOM_SEED**, which is 0.
4. For any non-negative values of **RANDOM_SEED**, the program sets up a random seed from its internal random generator = **RANDOM_SEED** and generates the interleaving function randomly.

5. An external file is used to generate interleaving function for either of the following cases: **RANDOM_SEED** = -1, or **FILENAME** has been provided.

   Data format for the external file is text file. The contents of the file are just **BLOCK_SIZE** integers, which are used as interleave function.
6. This element recovers the interleaved signal if the **RANDOM_SEED** are the same (or use same external file) for **INTLV** and **DEILV**.

Netlist Form

```
AINTLV:Name n1 n2 nexsys_component=INTLV BLOCK_SIZE=val
[RANDOM_SEED=val] FILE=”filename” [Rin=val] [Rout=val]
```

Netlist Examples

1. Random interleaver:

```
AINTLV:1 1 2 nexsys_component=INTLV BLOCK_SIZE=256
RANDOM_SEED=40435
```

2. Interleave function provided by external file:

```
AINTLV:1 3 2 nexsys_component=INTLV BLOCK_SIZE=960 FILE="myfile"
RANDOM_SEED=-1
```

Limiter (LIMITER)

Property	Description	Units	Default	Range/Type
VN	Negative output saturation voltage	Volt	-1	(-Inf, 0]/Real
VP	Positive output saturation voltage	Volt	1	[0, Inf)/Real
GAIN	Small signal voltage gain	None	10^9	(-Inf, Inf)/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (complex)			
Output	Output signal (complex)			

Notes

1. This model performs amplitude limitation. If the input to this model is a baseband signal $v_{in}(t)$, the output is a baseband signal. The output quadrature-phase is 0, and in-phase signal is given as follows
   $V_{out,i}(t) = GAIN \bullet V_{in}(t)$, for $VN \le GAIN \bullet V_{in,i}(t) \le VP$
   $V_{out,i}(t) = VN$, for $GAIN \bullet V_{in,i}(t) < VN$
   $V_{out,i}(t) = VP$, for $GAIN \bullet V_{in,i}(t) > VP$
   $V_{out,q}(t) = 0$

   If the input to this model is a bandpass signal with the in-phase and quad-phase envelopes $V_{in,i}(t)$ and $V_{in,q}(t)$, the output is bandpass signal and has the same carrier frequency as the input. The output in-phase and quad-phase envelopes are given as follows, respectively

   $V_{out,i}(t) = GAIN \bullet V_{in,i}(t)$ and $V_{out,q}(t) = GAIN \bullet V_{in,q}(t)$ for $GAIN \bullet V(t) < VP$

   $V_{out,i}(t) = [VP/V(t)] \bullet V_{in,i}(t)$ and $V_{out,q}(t) = [VP/V(t)] \bullet V_{in,q}(t)$ for $GAIN \bullet V(t) \ge VP$

   where $V(t) = SQRT(V_{in,i}(t)^2 + V_{in,q}(t)^2)$

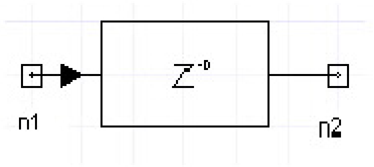
Netlist Form

```
ALIMITER:Name n1  n2 nexsys_component=LIMITER VN=val  VP=val
[GAIN=val] [Rin=val] [Rout=val]
```

Netlist Example

ALIMITER:1 1 2 nexsys_component=LIMITER VN=-2V VP=2V GAIN=3

Delay, Real Signal (RDELAY)



Property	Description	Units	Default	Range/Type
D	The number of samples by which the input signal is delayed	None	1	[0, Inf)/Integer
V	The value of the first D samples at the output	Volt	0.0	(-Inf, Inf)/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Delayed input signal (real)			

Notes

This model delays a real signal by a specified number of samples given by the parameter **D**. This delay effectively places **D** samples of **V** at the beginning of the output signal.

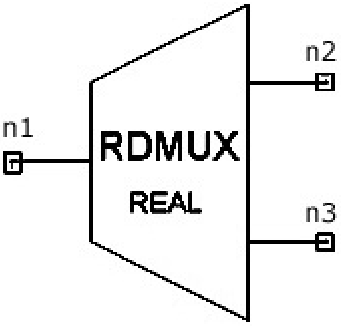
Netlist Form

```
ARDELAY:Name n1 n2 nexsys_component=RDELAY D=val [Rin=val]
[Rout=val]
```

Netlist Example

```
ARDELAY:1 1 2 D=8 nexsys_component=RDELAY
```

Demultiplexer, Real (RDMUX)



Property	Description	Units	Default	Range/Type
TYPE	Output sample rate changed: 1 for Yes, 0 for No	None	0	[0, 1]/Integer
NS1	Number of samples to write to output1 per cycle	None	1	[1, Inf)/Integer
NS2	Number of samples to write to output2 per cycle	None	1	[1, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT1	Output1 impedance	Ohm	0	[0, Inf)/Real
ROUT2	Output2 impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output1	The first demultiplexed output signal (real)			
Output2	The second demultiplexed output signal (real)			

Notes

This model demultiplexes one real input signal into two real output signals. It works as follows: the first output reads NS1 samples on the input signal, the second output reads NS2 samples on the incoming signal, the first output reads again, and so on until there are no more data to be read. Based on whether the parameter “type” is set or not, the sampling rate of the two output signals can change or remain the same. Suppose the sampling rate of the input signal is $f_s(in)$, if TYPE is set to be 1, the sampling rate for the two outputs are $f_s(out1) = f_s(in) \times \frac{NS1}{NS1 + NS2}$ and $f_s(out2) = f_s(in) \times \frac{NS2}{NS1 + NS2}$ respectively.

Netlist Form

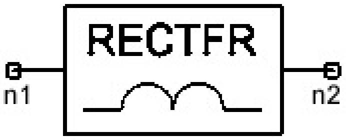
```
ARDMUX:Name n1 n2 n3 nexsys_component=RDMUX NS1=val NS2=val
[TYPE=val] [Rin=val] [Rout1=val][Rout2=val]
```

Netlist Example

```
ARDMUX:1 1  2  3 nexsys_component=RDMUX NS1=20 NS2=30
```

In this example, 20 samples are read on the input signal to **Output1** at n = 2 followed by 30 samples to **Output2** at n = 3 followed by 20 samples to **Output1** and so on until no more samples exist at the input port.

Rectifier (RECTFR)



Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	The input signal (complex)			
Output	The output signal (real)			

Notes

The output of this rectifier is: $V_2(t) = |V_1(t)|$

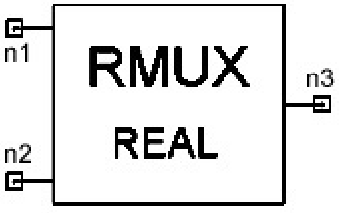
Netlist Form

```
ARECTFR:Name n1 n2 nexsys_component=RECTFR [Rin=val] [Rout=val]
```

Netlist Example

```
ARECTFR:1 1  2 nexsys_component=RECTFR
```

Multiplexer, Real (RMUX)



Property	Description	Units	Default	Range/Type
TYPE	Output sampling rate changed: 1 for Yes, 0 for No	None	0	[0, 1]/Integer
NS1	Number of samples to read from input1 per cycle	None	1	[1, Inf)/Integer
NS2	Number of samples to read from input2 per cycle	None	1	[1, Inf)/Integer
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (real)			
Input2	Input2 signal (real)			
Output	Multiplexed output signal (real)			

Notes

This model multiplexes two real input signals with the same sampling rate into a single real output signal. The output signal takes NS1 samples on the first input, then NS2 samples on the second input, then NS1 samples on the first input again, and so on until no data is available for processing. If **TYPE** is set to 0, the sampling rate of the output signals do not change. Otherwise, the sampling rate of the *i*th output port can be calculated as $f_s(out) = f_s(in) \times \frac{NS1 + NS2}{NS1}$

Netlist Form

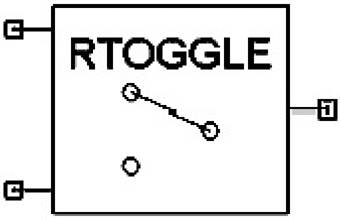
```
ARMUX:Name n1  n2  n3 nexsys_component=RMUX NS1=val NS2=val
[TYPE=val] [Rin1=val] [Rin2=val][Rout=val]
```

Netlist Example

```
ARMUX:1 1  2  3 nexsys_component=RMUX NS1=45 NS2=100
```

In this example, the multiplexed real output signal consists of 45 samples from Input1 followed by 100 samples from Input2 followed by 45 samples from Input1 and so on until no more input samples exist at one or both input nodes

Toggle Real Input Signals (RTOGGLE)



Property	Description	Units	Default	Range/Type
NS	The number of samples to output from Input1 before switching to Input2.	None	0	[0, Inf)/Integer
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	The first input signal (real)			
Input2	The second input signal (real)			
Output	Output signal (real)			

Notes

This model switches from **Input1** to **Input2** after a specified number of samples given by the parameter **NS**. In other words, the output is a replica of **Input1** for the duration of the first **NS** samples after which it outputs samples on the second input signal.

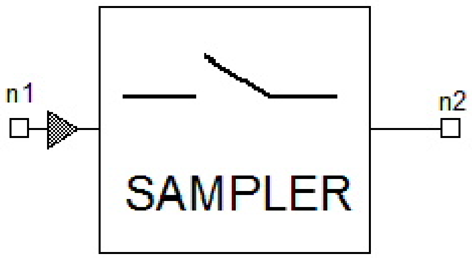
Netlist Form

```
ARTOGGLE:Name n1 n2 n3 nexsys_component=RTOGGLE NS=val
[Rin=val][Rout=val]
```

Netlist Example

```
ARTOGGLE:1 1 2 3 nexsys_component=RTOGGLE NS=8
```

Sampler



Property	Description	Units	Default	Range/Type
SAMPLE_RATE	Sampling rate	Hz	1000	[1, Inf)/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (Real)			
Output	Output signal (Real)			

Notes

This model samples an incoming continuous signal to generate the corresponding discrete signal.
In a Nexxim-System circuit with a continuous source, a sampler is required at the interface of the source and the system component.

Netlist Form

```
ASAMPLER:Name n1 n2 nexsys_component=sampler sample_rate=val
[Rin=val][Rout=val]
```

Netlist Example

```
ASAMPLER:1 1 2 nexsys_component=sampler sample_rate=1e6
```

Symbol Repeater (SAMPREP)

Property	Description	Units	Default	Range/Type
NOR	Number of repetitions per input symbol	None	1	[1, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (Real)			
Output	Output signal (Real)			

Notes

This model repeats every input symbol NOR times. The sampling rate of the output is NOR times the sampling rate of the input.

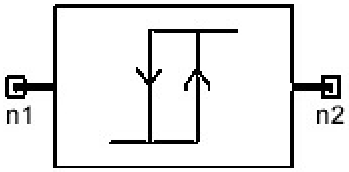
Netlist Form

```
ASAMPREP:Name n1 n2 nexsys_component=SAMPREP NOR=val
[Rin=val][Rout=val]
```

Netlist Example

```
ASAMPREP:1 1 2 nexsys_component=SAMPREP NOR=6
```

Schmitt Trigger Nonlinear (SCHMIT)



Property	Description	Units	Default	Range/Type
VIL	Lower input trigger voltage	Volt	0	(-Inf, Inf)/Real
VIH	Higher input trigger voltage	Volt	0	(-Inf, Inf)/Real
VOL	Lower output voltage	Volt	0	(-Inf, Inf)/Real
VOH	Higher output voltage	Volt	0	(-Inf, Inf)/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Limits

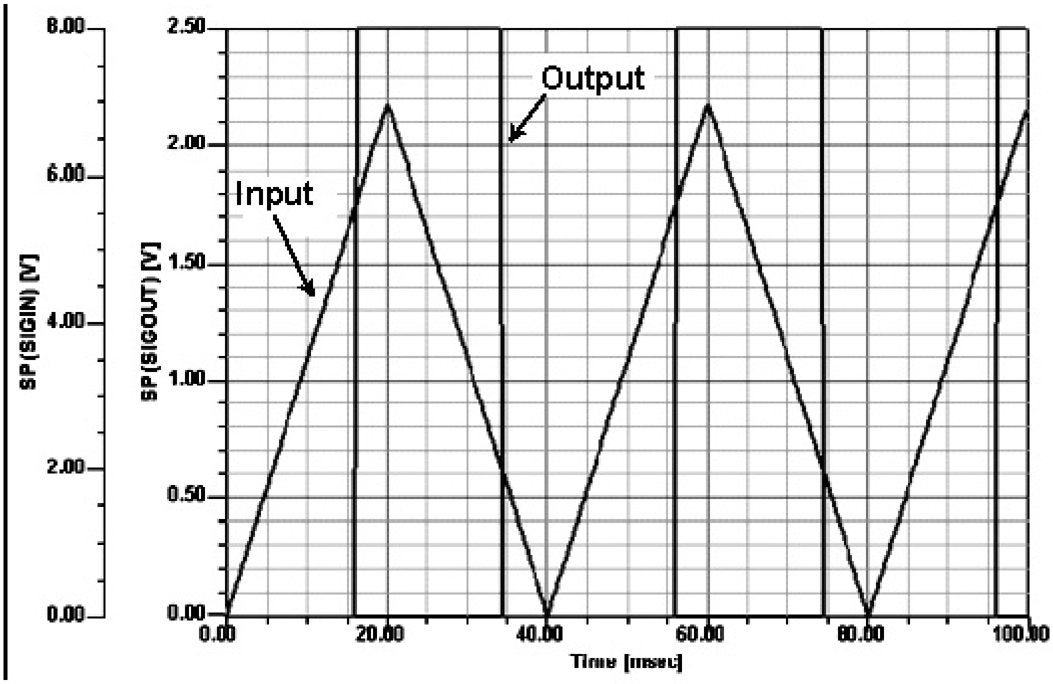
VIL ≤ VIH

VOL ≤ VOH

Notes

1. This element is a Schmitt trigger with programmable levels. The output of this element is always a baseband signal.
2. The input voltage must actually cross the threshold before the output voltage changes. For example, a trigger VIL=0 and VIH=2, whose output is currently the ‘low’ value, does not change its output on the input sequence, 1.7V, 1.8V, 1.9V, 2.0V, 1.9V, etc.
3. The initial value of the output is VOH if the initial input is greater than VIH. The initial value of the output is VOL otherwise.
4. Example: Input and output waveforms are shown for a Schmitt trigger with the following

parameters: VIL = 2, VIH = 5.6, VOL = 0, and VOH = 2.5.



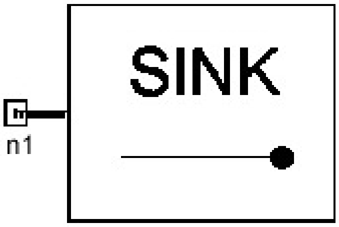
Netlist Form

```
ASCHMIT:Name n1  n2 nexsys_component=SCHMIT VIL=val  VIH=val
VOL=val  VOH=val [Rin=val][Rout=val]
```

Netlist Example

```
ASCHMIT:1 1  2 nexsys_component=SCHMIT VIL=13.5mv  VIH=15mv
VOL=0  VOH=1
```

Signal Sink (SINK)



Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
Ports				
Input	Input signal (Real, Complex)			

Notes

1. This model is used to terminate any output signal (i.e., no further processing takes place after this component). This model is normally used to terminate all open nodes in a DSP system.

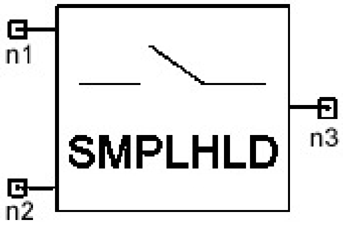
Netlist Form

```
ASINK:Name n1 nexsys_component=SINK [Rin=val]
```

Netlist Example

```
ASINK:1 1 nexsys_component=SINK
```

Sample and Hold (SMPLHLD)

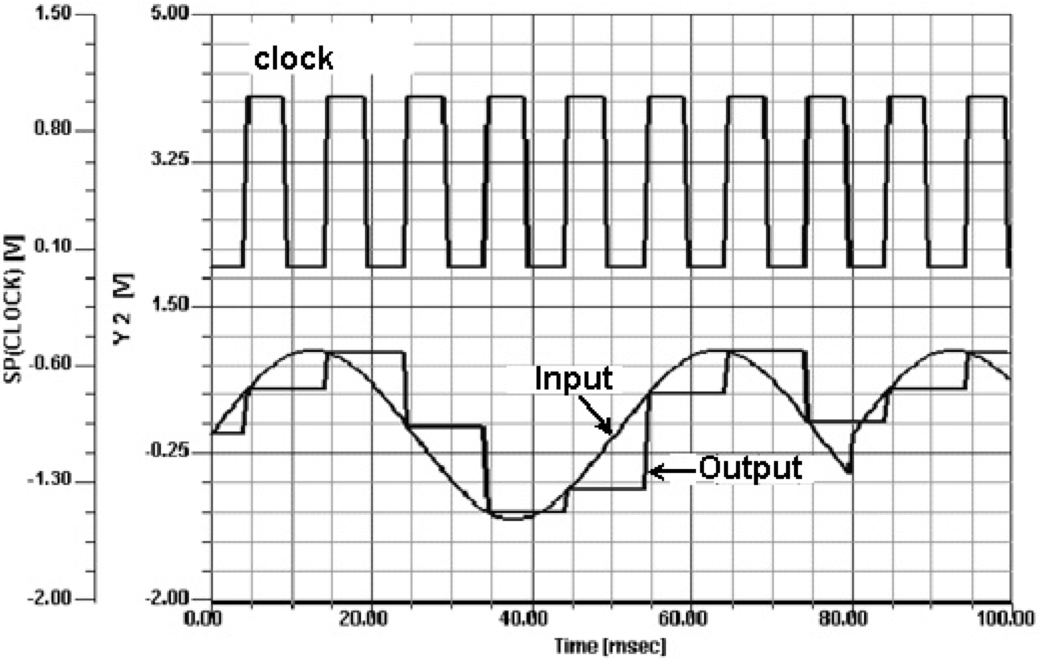


Property	Description	Units	Default	Range/Type
DECAY_RATE	Output voltage decay rate, in 1/second unit	V/Sec	0	[0, Inf)/Real
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (real)			
Input2	Input2 clock signal (real)			
Output	Output signal (real)			

Notes

1. The input signal is sampled at each rising edge of the clock signal (the input is sampled at the instant when the clock signal crosses a threshold of 0.5V). In the hold state of the sample and hold the output voltage decays at a constant rate determined by the parameter **DECAY_RATE**.
2. The output signal is always a baseband signal.
3. The input signal and output signal voltages of the SMPLHLD element, with its CLK pin tied to a clock source with period 10 msec and **DECAY_RATE** = 0, are shown in the following

figure.



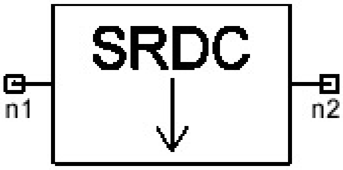
Netlist Form

```
ASMPLHLD:Name n1  n2  n3 nexsys_component=SMPLHLD
DECAY_RATE=val [Rin1=val] [Rin2=val] [Rout=val]
```

Netlist Example

```
ASMPLHLD:1 1  2  3 nexsys_component=SMPLHLD DECAY_RATE=0
```

Sampling Rate Downsampler for Complex Signal (SRDC)



Property	**Description**	**Units**	**Default**	**Range/Type**
DF	Factor by which the input signal is downsampled	None	8	[1, Inf)/Integer
OFFSET	Initial samples to remove	None	0	[0, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	The input signal (complex)			
Output	The output signal (complex)			

Notes

This model downsamples a complex input signal. After removing **OFFSET** samples on the beginning of the data, the downsampler outputs the first sample in each block of **DF** input samples. This model can be used for ideal sampling.

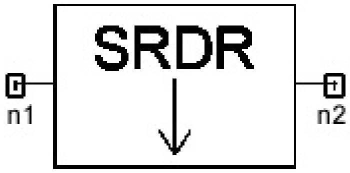
Netlist Form

```
ASRDC:Name n1  n2 nexsys_component=SRDC DF=val [OFFSET=val]
[Rin=val][Rout=val]
```

Netlist Example

```
ASRDC:1 1  2 nexsys_component=SRDC DF=16
```

Sampling Rate Downsampler for Real Signal (SRDR)



Property	Description	Units	Default	Range/Type
DF	The factor by which the input signal is downsampled	None	8	[1, Inf)/Integer
OFFSET	Initial samples to remove	None	0	[0, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

This model downsamples a real input signal. After removing **OFFSET** samples on the beginning of the data, the downsampler outputs the first sample in each block of **DF** input samples.This model can be used for ideal sampling.

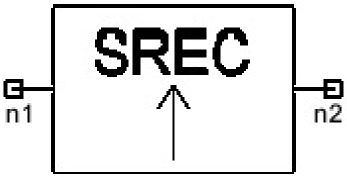
Netlist Form

```
ASRDR:Name n1 n2 nexsys_component=SRDR DF=val [OFFSET=val]
[Rin=val][Rout=val]
```

Netlist Example

ASRDR:1 1 2 nexsys_component=SRDR DF=16

Sampling Rate Upsampler for Complex Signal (SREC)



Property	Description	Units	Default	Range/Type
EF	Factor by which the input signal is upsampled	None	8	[1, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (complex)			
Output	Output signal (complex)			

Notes

1. This model expands the sampling rate of the complex input signal. Beginning with the first input sample, each input sample followed by EF - 1 zeros are written to the output port.

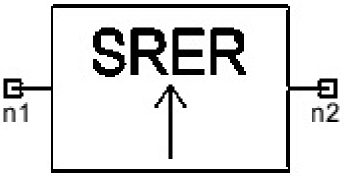
Netlist Form

```
ASREC:Name n1  n2 nexsys_component=SREC EF=val
Rin=val][Rout=val]
```

Netlist Example

```
ASREC:1 1  2 nexsys_component=SREC EF=16
```

Sampling Rate Upsampler for Real Signal (SRER)



Property	Description	Units	Default	Range/Type
EF	The factor by which the input signal is upsampled	None	1	[1, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

This model expands the sampling rate of the real input signal. Beginning with the first input sample, each input sample followed by **EF** – 1 zeros are written to the output port.

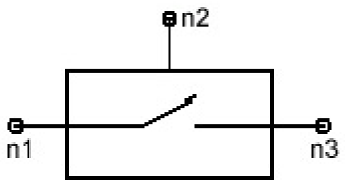
Netlist Form

```
ASRER:Name n1 n2 nexsys_component=SRER EF=val [Rin=val]
[Rout=val]
```

Netlist Example

```
ASRER:1 1 2 nexsys_component=SRER EF=16
```

Voltage Controlled Switch: Type 1 (SWITCH1)



Property	Description	Units	Default	Range/Type
VTHRESHOLD	Control voltage threshold	Volt	0.5	(-1e+020, 1e20)/Real
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input1 signal (complex)			
Input2	Input2 signal (complex)			
Output	Output signal (complex)			

Notes

1. This model performs voltage-controlled switching. The control voltage is the voltage at the second input port represented by _V2:

   $\_V2 = V_{2I} \cdot \cos(2\pi f_{2c}\, t) - V_{2Q} \cdot \sin(2\pi f_{2c}\, t)$,

   where, $V_{2I} + jV_{2Q}$ is the voltage complex envelope at the second input port, and f_{2c} is its carrier frequency. The output carrier frequency equals to the carrier frequency of the first input signal. The voltage complex envelope ($V_{3I} + jV_{3Q}$) at the output port is determined by

   $V_{3I} + jV_{3Q} = V_{1I} + jV_{1Q}$ for V2 > VTHRESHOLD, and
   $V_{3I} + jV_{3Q} = 0$ elsewhere,

   where $V_{1I} + jV_{1Q}$ is the voltage complex envelope at the first input port.

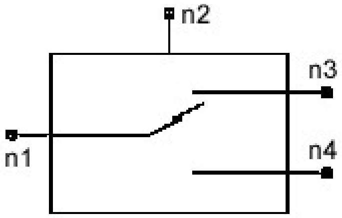
Netlist Form

```
ASWITCH1:Name n1  n2  n3 nexsys_component=SWITCH1
[VTHRESHOLD=val] [Rin1=val][Rin2=val] [Rout=Val]
```

Netlist Example

```
ASWITCH1:1 1  2  3 nexsys_component=SWITCH1 VTHRESHOLD=1V
```

Voltage Controlled Switch: Type 2 (SWITCH2)



Property	Description	Units	Default	Range/Type
VTHRESHOLD	Control voltage threshold	Volt	0.5	(-1e+020, 1e20)/Real
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT1	Output1 impedance	Ohm	0	[0, Inf)/Real
ROUT2	Output2 impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	First input signal (complex)			
Input2	Second input signal, control signal (complex)			
Output1	First output signal (complex)			
Output2	Second output signal (complex)			

Notes

This model performs voltage-controlled switching. The control voltage is represented by _V2:

$\_V2 = V_{2I} \cdot \cos(2\pi f_{2c} t) - V_{2Q} \cdot \sin(2\pi f_{2c} t)$

where , $V_{2I} + jV_{2Q}$ is the voltage complex envelope at the second input port, and f_{2c} is its carrier frequency. The carrier frequency at output ports equals to the carrier of the first input port. The voltage complex envelopes ($V_{3I} + jV_{3Q}$) and ($V_{4I} + jV_{4Q}$) at the first and second output ports are determined by

$V_{3I} + jV_{3Q} = V_{1I} + jV_{1Q}$ and $V_{4I} + jV_{4Q} = 0$ for V2 > VTHRESHOLD,

$V_{4I} + jV_{4Q} = V_{1I} + jV_{1Q}$ and $V_{3I} + jV_{3Q} = 0$ elsewhere,

where $V_{1I} + jV_{1Q}$ is the voltage complex envelope at the first input port.

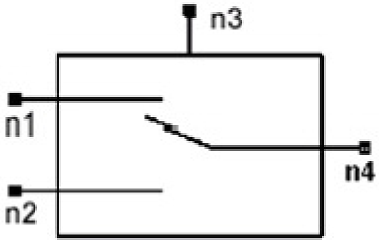
Netlist Form

```
ASWITCH2 n1 n2  n3  n4 nexsys_component=SWITCH2
[VTHRESHOLD=val] [Rin1=val] [Rin2=val] [Rout1=val] [Rout2=val]
```

Netlist Example

```
ASWITCH2:1 1  2  3   4 nexsys_component=SWITCH2 VTHRESHOLD = 1V
```

Voltage Controlled Switch: Type 3 (SWITCH3)



Property	Description	Units	Default	Range/Type
VTHRESHOLD	Control voltage threshold	Volt	0.5	(-1e+020, 1e20)/Real
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
RIN3	Input3 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	First input signal (complex)			
Input2	Second input signal (complex)			
Input3	Third input signal, control signal (complex)			
Output	Output signal (complex)			

Notes

1. This model performs voltage-controlled switching. The control voltage is represented by *V3:*

   _$V3 = V_{3I} \bullet \cos(2\pi f_{3c} t) - V_{3Q} \cdot \sin(2\pi f_{3c} t)$

   Where, $V_{3I} + jV_{3Q}$ is the voltage complex envelope at the third input port, and f_{3c} is its carrier frequency. The carrier frequency f_{4c} and voltage complex envelope $(V_{4I} + jV_{4Q})$ at output port are determined by

   $f_{4c} = f_{1c},$ and $(V_{4I} + jV_{4Q}) = (V_{1I} + jV_{1Q})$ for the condition V3 > VTHRESHOLD, and

   $f_{4c} = f_{2c},$ and $(V_{4I} + jV_{4Q}) = (V_{2I} + jV_{2Q})$ elsewhere

   where, f_{1c}, $V_{1I} + jV_{1Q}$ are the carrier frequency and voltage complex envelope at the first input port, and f_{2c}, V_{2I}+ jV_{2Q} are the carrier frequency and voltage complex envelope at the second input port.

Netlist Form

```
ASWITCH3:Name n1 n2  n3  n4 nexsys_component=SWITCH3
[VTHRESHOLD=val] [Rin1=val][Rin2=val] [Rin3=val] [Rout=val]
```

Netlist Example

```
ASWITCH3:1 1  2  3  4 nexsys_component=SWITCH3 VTHRESHOLD=1V
```

Window (WINDOW)

Property	Description	Units	Default	Range/Type
NSAMP	Number of input samples to window per invocation	None	64	[1, Inf)/Integer
WINDOW_ LENGTH	Length of window in samples	None	16	[1, Inf)/Integer
WINDOW_SHIFT	Initial shift of window in samples	None	1	[0, Inf)/Integer
WINDOW_TYPE	0: Bartlett 1: Hanning 2: Rectangular 3: Hamming 4: Blackman 5: Blackman-Harris (3 term) 6: Blackman-Harris (4 term) 7: Gaussian (alpha=3) 8: De la Valle-Poussin.	None	0	[0, 8]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal (real)			
Output	Output signal (real)			

Notes

1. This model windows a real signal using various window functions. During each invocation, this model processes **NSAMP** input samples. The number of samples windowed is determined by **WINDOW_LENGTH**. The position of the window’s left edge is determined by **WINDOW_SHIFT**.

Netlist Form

```
AWINDOW:Name n1 n2  nexsys_component=WINDOW NSAMP=val
WINDOW_LENGTH=val WINDOW_SHIFT=val WINDOW_TYPE=val
[Rin=val][Rout=val]
```

Netlist Example

```
AWINDOW:1 1 2 nexsys_component=WINDOW NSAMP=256
WINDOW_LENGTH=40 WINDOW_SHIFT=10 WINDOW_TYPE=2
```

Envelope Adaptor

Property	Description	Units	Default	Range/Type
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal in complex format (complex)			
Output	Output signal in complex format (complex)			

Notes

Nexsys only. This model is used at the interface between System behavioral models and Nexxim physical models if the signal at the interface is modulated.

Netlist Form

```
Aenvelopeadaptor:Name n1 n2
nexsys_component=envelopeadaptor  [RIN=val][ROUT=val]
```

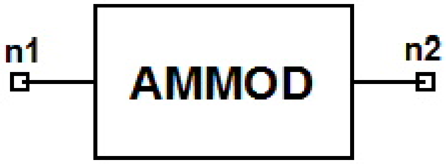
Netlist Example

```
Aenvelopeadaptor:1 1 2
+ nexsys_component=envelopeadaptor RIN=50 ROUT=50
```

Modulators

This topic describes the following System components:

Amplitude Modulator (AMMOD)



Property	Description	Units	Default	Range
FC	Carrier frequency	Hz	1000000	[0, Inf)/Real
P	Carrier power	Watt	0	[0, Inf)/Real
REF	Input signal voltage level for 100 percent AM	Volt	1	[-1e6, 1e6]/Real
TYPE	Type of AM modulator (optional): 1: Conventional AM modulator 2: Suppressed carrier	None	1	[1, 2]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]
ROUT	Output impedance	Ohm	0	[0, Inf)
Ports				
Input	Input signal (complex)			
Output	Output of amplitude modulator (complex)			

Notes

1. This model performs amplitude modulation (AM). The input to this model is assumed to be a baseband signal $v_{in}(t)$. The output is an amplitude modulated bandpass signal with a carrier frequency FC and a carrier power P.

   There are two different types of amplitude modulation. The output in-phase and quad-phase envelopes are given as follows, respectively

   1.TYPE = 1 for conventional AM modulation
   $v_{out,i}(t) = A \cdot (1 + v_{in}(t)/REF)$
   $v_{out,q}(t) = 0$

   2.TYPE = 2 for suppressed carrier
   $v_{out,i}(t) = A \cdot v_{in}(t)/REF$
   $v_{out,q}(t) = 0$

A = SQRT(8 • ROUT • P) for FC < input sampling rate/2 (i.e., sampled carrier output)

or

A = SQRT(4 • ROUT • P) for FC > input sampling rate/2 (i.e., complex envelope output)

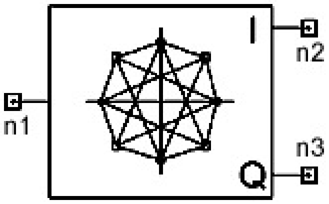
Netlist Form

```
AAMMOD:Name n1  n2 nexsys_component=AMMOD FC=val  P=val
REF=val  [TYPE=val][Rin=Val] [Rout=Val]
```

Netlist Example

```
AAMMOD:1 1  2  FC=1MHz  P=0.002W  RFE=1mV  TYPE=1
nexsys_component=AMMOD
```

PI/4 DQPSK Modulator (DQPSKMOD)



Property	Description	Units	Default	Range
RIN1	Input impedance	Ohm	Inf	(0, Inf]
ROUT1	Output1 impedance	Ohm	0	[0, Inf)
ROUT2	Output2 impedance	Ohm	0	[0, Inf)
Ports				
Input	Integer symbol values A(n) (real)			
Output1	in-phase output of modulator (real)			
Output2	Quadrature output of modulator (real}			

Notes

1. This model performs PI/4DQPSK modulation. The input to this model is assumed to be the symbol values A(n) = 0, 1, 2, 3 for n ≥ 0. The modulation information is stored differentially in the phase. Specifically, the in-phase and quadrature outputs of the modulator are given by cos(theta(n)) and sin(theta(n)) respectively, where
   theta(-1) = PI/4, and
   theta(n) = theta(n-1) + delta_theta(n), n ≥ 0
   PI/4 if A(n) = 0
   3 * PI/4 if A(n) = 1
   delta_theta(n) =
   7 * PI/4 if A(n) = 2
   5 * PI/4 if A(n) = 3

Netlist Form

`ADQPSKMOD:Name` *`n1 n2 n3`* `nexsys_component=DPSQMOD [Rin=`*`Val`*`] [Rout=`*`Val`*`]`

Netlist Example

```
ADQPSKMOD:1 1 2 3 nexsys_component=DPSQMOD
```

Edge Modulator (EDGEMOD)

Property	Description	Units	Default	Range
RIN	Input impedance	Ohm	Inf	(0, Inf]
ROUT1	Output impedance	Ohm	0	[0, Inf)
ROUT2	Output impedance	Ohm	0	[0, Inf)
Ports				
Input	Input signal (complex)			
Output1	Output of AM modulator (complex)			
Output2	Output of AM modulator (complex)			

Notes

1. This model converts each three input bits into a pair of in-phase and quadrature output signals based on the EDGE 8PSK modulation. The in-phase and quadrature output values at time index *n* are calculated using equations

   $$V_I(n) = \cos\left(\theta_n + \theta_{n,offset}\right)$$

   and

   $$V_Q(n) = \sin\left(\theta_n + \theta_{n,offset}\right)$$

   respectively; where *n* is the total number of received symbols. The EDGE 8PSK modulation uses the following mapping of input-bit triplets onto each phase Θ_n:

$$000 \rightarrow \frac{3\pi}{4},\ 001 \rightarrow \pi,\ 010 \rightarrow \frac{\pi}{2},\ 011 \rightarrow \frac{\pi}{4},\ 100 \rightarrow -\frac{\pi}{2},\ 101 \rightarrow -\frac{3\pi}{4},\ 110 \rightarrow -\frac{\pi}{4},\ 111 \rightarrow 0.$$

Where $\Theta_{n,\ offset}$ is the additional phase shift at the time index *n*, equal to n x 3π/8.

Form

```
 AEDGEMOD:Name n1 n2 n3 nexsys_component=EDGEMOD [Rin=val],
[Rout1=val], [Rout2=val]
```

Example

```
AEDGEMOD:1 1 2 3 nexsys_component=EDGEMOD
```

References

1. GSM 05.04 (i.e., ETSI EN 300 959): “Digital cellular telecommunications system (Phase 2+); Modulation”

Frequency Modulator (FMMOD)

Property	Description	Units	Default	Range
FC	Carrier frequency	Hz	0	[0, Inf)/Real
P	Carrier power	Watt	0	[0, Inf)/Real
SEN	Frequency deviation sensitivity, in Hz/Volt	Hz/V	0	[-1e6, 1e6]/Real
PHASE	Output phase shift	Deg	0	(-Inf, Inf)/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]
ROUT	Output impedance	Ohm	50	[0, Inf)
Ports				
Input	Input signal (complex)			
Output	Output of frequency modulator (complex)			

Notes

1. This model performs frequency modulation (FM). The input to this model is assumed to be a baseband signal $v_{in}(t)$. The output is an FM modulated bandpass signal with carrier frequency FC and carrier power P. The output in-phase and quad-phase envelopes are given as follows, respectively

   $v_{out,i}(t) = A \cdot \cos(\Theta(t)+phase)$
   $v_{out,q}(t) = A \cdot \sin(\Theta(t)+phase)$
   where

$\Theta(t) = \int (2\pi SEN \cdot v_{in}(t))\, dt$

and

A = SQRT(8 • ROUT • P) for FC < input sampling rate/2 (i.e., sampled carrier output)

or

A = SQRT(4 • ROUT • P) for FC > input sampling rate/2 (i.e., complex envelope output)

Netlist Form

```
AFMMOD:Name n1  n2 nexsys_component=FMMOD FC=val  P=val
SEN=val [PHASE=Val] [Rin=Val] [Rout=Val]
```

Netlist Example

```
AFMMOD:1 1  2 nexsys_component=FMMOD FC=1MHz  P=0.002W  SEN=1.2
PHASE=45deg
```

Gaussian Minimum Shift Keying Modulator (GMSK)

Property	Description	Units	Default	Range
NB	Number of bits per symbol	None	1	(0, 8]/Integer
MOD_INDEX	Modulation index of GMSK modulator	None	0.5	(0, 1]/Integer
NUM_ SAMPLES	Number of samples per symbol	None	8	(0, Inf]/Integer
RESPONSE_ LENGTH	Length of Gaussian filter impulse response in symbols	None	4	(0, Inf]/Real
NORMALIZED_ BW	Normalized bandwidth of Gaussian filter	Hz	0.3	(0, 1]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]
ROUT1	Output impedance	Ohm	0	[0, Inf)
ROUT2	Output impedance	Ohm	0	[0, Inf)
Ports				
Input	Input symbols in the range 0, 1, ..., M - 1, where M = 2^{NB} (real)			
Output1	in-phase output of GMSK modulator (real)			
Output2	Quadrature output of GMSK modulator (real)			

Notes

1. This model modulates a sequence of input symbols that have values in the range 0 to M – 1 , where M = 2^{NB}.

   The input to this model must be the symbol values Ai, where 0 ≤ Ai ≤ M 1, and M = 2^{NB}. Each Ai input symbol value is then internally converted to the symbol value Ki, where

Ki = 2 * (Ai + 1) – M. This implies that the values Ki may assume are
– (M – 1), ..., –5, –3, –1, +1, +3, +5, ..., +(M – 1).

For example, when NB = 1 (i.e., each symbol is represented by one bit as in the binary case), the values Ki might assume are -1 and +1 only.

Each Ki symbol value (representing NB bits) is then upsampled by **NUM_SAMPLES** by adding **NUM_SAMPLES** - 1 zeros after each Ki symbol value. In other words, **NUM_SAMPLES** represents the number of samples per symbol inside the GMSK modulator. Upsampling is performed because this model involves a Gaussian filtering process to frequency modulate the carrier.

The n-th sample of the in-phase and quadrature outputs of the GMSK modulator is given by cos(theta(n)) and sin(theta(n)) respectively, where

theta(n) = 2 * PI * **MODULATION_INDEX** * SUM_1(Ki * q[n - i]) +
PI * **MODULATION_INDEX** * SUM_2(Ki)
where the limits of **SUM_1** are from i = n - **RESPONSE_LENGTH** + 1 to n, and
the limits of **SUM_2** are from i = 0 to n - **RESPONSE_LENGTH**.

The filter coefficients q[i], 0 ≤ i ≤ **RESPONSE_LENGTH** * **NUM_SAMPLES** - 1, are determined from integrating a Gaussian filter's impulse response [1]. The duration of this impulse response (in samples) is **RESPONSE_LENGTH** * **NUM_SAMPLES**.

The frequency response of the Gaussian filter is determined by the normalized bandwidth (**NORMALIZED_BW**) which is given by B * T, where B is the 3dB-bandwidth of the Gaussian filter and T is the symbol duration. For example, the bit rate in the GSM system (NB = 1) is 3.69 μS, therefore, a normalized bandwidth of **NORMALIZED_BW** = 0.3 (used by the GSM system) should correspond to a Gaussian filter's 3dB-bandwidth of 81.25 KHz.

Netlist Form

```
AGMSK:Name n1  n2  n3 nexsys_component=GMSK NB=val
MODULATION_INDEX=val  NUM_SAMPLES=val + RESPONSE_LENGTH=val
NORMALIZED_BW=val [Rin=Val] [Rout=Val]
```

Netlist Examples

1. Example 1:

```
AGMSK:1 1  2  3 nexsys_component=GMSK NB=1
MODULATION_INDEX=0.5  NUM_SAMPLES=2

+ RESPONSE_LENGTH=3  NORMALIZED_BW=0.3
```

The parameters in this example correspond to those used by the GSM system. A typical input sequence and the corresponding output sequence are shown in the following table:

Input to GMSK	Modified unsampled Input	in-phase Output	Quadrature Output
1	+1.000	1.000	0.009
	0.000	0.994	0.111
0	-1.000	0.884	0.468
	0.000	0.563	0.826
0	-1.000	0.571	0.821
	0.000	0.930	0.368
.	.	.	.
	.	.	.
.	.	.	.
	.	.	.

2. Example 2:

```
AGMSK 1 2 3 nexsys_component=GMSK NB=2 MODULATION_INDEX=0.5
NUM_SAMPLES=3 + RESPONSE_LENGTH=4 NORMALIZED_BW= 0.25
```

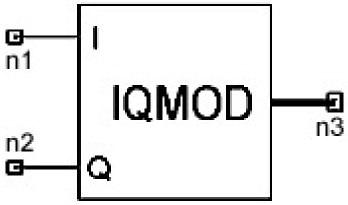
Input to GMSK	Modified unsampled Input	in-phase Output	Quadrature Output
2	+1.000	1.000	0.001
	0.000	1.000	0.008
	0.000	0.999	0.039
1	-1.000	0.992	0.126
	0.000	0.952	0.305
	0.000	0.839	0.544
1	-1.000	0.676	0.737
	0.000	0.600	0.800
	0.000	0.703	0.711
2	+1.000	0.901	0.434
	0.000	1.000	0.000

	0.000	0.901	-0.434
2	+1.000	0.703	-0.711
	0.000	0.606	-0.796
	0.000	0.703	-0.711
3	+3.000	0.903	-0.438
	0.000	0.999	0.034
	0.000	0.823	0.568
3	+3.000	0.260	0.966
	0.000	-0.610	0.793
	0.000	-0.966	-0.259
0	-3.000	0.074	-0.997
	0.000	1.000	-0.029
	0.000	0.222	0.975
.	.	.	.
	.	.	.
	.	.	.
.	.	.	.

References

1. Raymond Steele, *Mobile Radio Communications*, Pentech Press, 1992.

I-Q Modulator (IQMOD)



Property	Description	Units	Default	Range
FC	Carrier frequency	Hz	0	[0, Inf)/Real
CP	Carrier power	Watt	0.01	[0, Inf)/Real
VREF	Input signal voltage level	Volt	1	[-10e-6, 10e6]/Real
PHIQ	I-Q phase imbalance	Deg	0	[-180, 180]/Real
RIN1	Input impedance	Ohm	Inf	(0, Inf]
RIN2	Input impedance	Ohm	Inf	(0, Inf]
ROUT	Output impedance	Ohm	0	[0, Inf)
Ports				
Input1	First input signal (real)			
Input2	First second signal (real)			
Output	Output signal (complex)			

Notes

1. For a given in-phase and quadrature baseband signals $V_{Iin}(t)$ and $V_{Qin}(t)$, the output voltage is computed according to:

   $$V_{out}(t) = \mathrm{Re}\{U(t)e^{j2\pi Fct}\}$$

   where

   $$\mathrm{Re}\{U(t)\} = (A/VREF)\left[V_{Iin}(t) - V_{Qin}(t)\sin(PHIQ)\right]$$

   , and

$$I_m\{U(t)\} = (A/VREF)\left[V_{Qin}(t)\cos(PHIQ)\right]$$

With

$$A = \sqrt{2 \bullet 50 \bullet CP}$$

(CP in Watts)

Netlist Form

```
AIQMOD:Name n1  n2  n3 nexsys_component=IQMOD FC=val  CP=val
VREF=val  PHIQ=val [Rin=val] [Rout=val]
```

Netlist Example

```
AIQMOD:1 1  2  3 nexsys_component=IQMOD FC=0HZ  CP=.01W  VREF=1V
PHIQ=0DEG
```

Logarithmic Amplifier (LOGAMP)

Property	Description	Units	Default	Range
SEN	Log sensitivity, in voltage units per dB	V/dB	0	[0, Inf)/Real
PL	Low input power	Watt	0	[1e-23, 1e17]/Real
E	Peak log error, in dB	dB	0	[0, 200]/Real
EC	Log error cycle, in dB	dB	1	[0, 200]/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]
ROUT	Output impedance	Ohm	0	[0, Inf)
Ports				
Input	Input signal (complex)			
Output	Output signal (complex)			

Notes

1. This model performs logarithmic amplification. The input to this model is assumed to be a bandpass signal with in-phase and quad-phase envelopes $v_{in,i}(t)$ and $v_{in,q}(t)$. The output is a bandpass signal and has same carrier frequency as the input. The output in-phase and quad-phase envelopes are logarithmically amplified as follows
   $v_{out,i}(t) = M2(t) \cdot v_{in,i}(t)/A1(t)$
   $v_{out,q}(t) = M2(t) \cdot v_{in,q}(t)/A1(t)$
   where
   $A1(t) = SQRT(v_{in,i}(t)^2 + v_{in,q}(t)^2)$
   $M2(t) = 20 \cdot SEN \cdot LOG10(A1(t)/VL) + SEN \cdot E \cdot \sin(\Theta)$ for $A1(t) > VL$
   $M2(t) = 0$ for $A1(t) \leq VL$
   $VL = SQRT(2 \cdot 50 \cdot PL)$
   $\Theta = 2 \cdot \pi \cdot (PA - 10 \cdot LOG10(PL))/EC$
   $PA = 10 \cdot LOG10(A1(t)^2/(2 \cdot 50))$

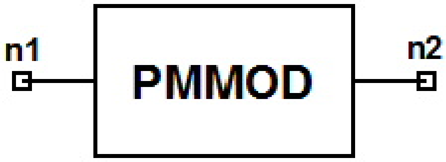
Netlist Form

```
ALOGAMP:Name n1  n2 nexsys_component=LOGAMP SEN=val  PL=val
E=val  EC=val [Rin=val] [Rout=val]
```

Netlist Example

```
ALOGAMP:1 1   2 nexsys_component=LOGAMP SEN=1.2  PL=10W
E=0.75dB  EC=10dB
```

Phase Modulator (PMMOD)



Property	Description	Units	Default	Range
FC	Carrier frequency	Hz	100000	[0, Inf)/Real
P	Carrier power	Watt	0	[0, Inf)/Real
SEN	Phase deviation sensitivity, in rad per second per volt	Radian/Sec/Volt	1	[-1e6, 1e6]/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]
ROUT	Output impedance	Ohm	0	[0, Inf)
Ports				
Input	Input signal (complex)			
Output	Output of phase modulator (complex)			

Notes

1. This model performs phase modulation. The input to this model is assumed to be a baseband signal $v_{in}(t)$. The output is a phase modulated bandpass signal with carrier frequency FC and carrier power P. The output in-phase and quad-phase envelopes are given as follows, respectively
   $v_{out,i}(t) = A \cdot \cos(\Theta(t))$
   $v_{out,q}(t) = A \cdot \sin(\Theta(t))$
   where
   $\theta(t) = SEN \cdot v_{in}(t)$

and

A = SQRT(8 • ROUT • P) for FC < input sampling rate/2 (i.e., sampled carrier output)

or

A = SQRT(4 • ROUT • P) for FC > input sampling rate/2 (i.e., complex envelope output)

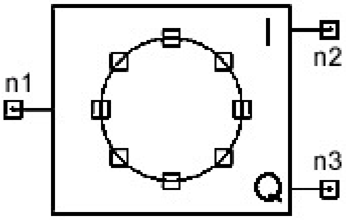
Netlist Form

```
APMMOD:Name n1  n2 nexsys_component=PMMOD FC=val  P=val
SEN=val [Rin=Val] [Rout=Val]
```

Netlist Example

```
APMMOD:1 1  2 nexsys_component=PMMOD FC=1MHz  P=0.002W  SEN=1.2
```

Phase Shift Keying Modulator (PSKMOD)



Property	Description	Units	Default	Range
M	The order of the signal space. M = 2: BPSK M = 4: QPSK, etc.	None	2	[2, 128]/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]
ROUT1	Output impedance	Ohm	0	[0, Inf)
ROUT2	Output impedance	Ohm	0	[0, Inf)
Ports				
Input	Input signal of symbols in the range 0,....., M -1 (integer)			
Output1	The real part of the complex output signal (real)			
Output2	The imaginary part of the complex output signal (real)			

Notes

1. This model maps the integer input symbols, each in the range 0,...., M -1, into a complex (real and imaginary) output value. The complex value of the output is given by
   exp(j* 2*PI*k/M) M = 2
   exp(j* 2*PI*(k+1/2)/M), M = 4, 6, 8, ..

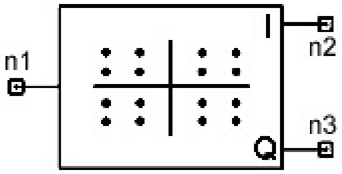
Netlist Form

```
APSKMOD n1 n2 n3 nexsys_component=PSKMOD M=val [Rin=val]
[Rout=val]
```

Netlist Example

```
APSKMOD:1 1 2 3 nexsys_component=PSKMOD M=4
```

Quadrature Amplitude Modulator (QAMMOD)



Property	Description	Units	Default	Range
M	Order of QAM constellation	None	4	(0, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]
ROUT1	Output impedance	Ohm	0	[0, Inf)
ROUT2	Output impedance	Ohm	0	[0, Inf)
Ports				
Input	Input signal (real)			
Output1	in-phase output (real)			
Output2	Quadrature output (real)			

Notes

1. For a given stream of input bits, this model combines every incoming N bits, where
   $N = Log_2(M)$

   and M is the order of the constellation space (i.e., M=4 for 4-QAM, M=16 for 16-QAM, and M=64 for 64-QAM).

   Each incoming N bits are split into half, N/2 bits are used to compute the in-phase output sample and the other N/2 bits are used to compute the corresponding quadrature output sample.
   For each N/2 input bits (per I and Q), the corresponding in-phase and quadrature output samples are computed according to

   $I = 2M_I + 1 - \sqrt{M}$

$$Q = 2M_Q + 1 - \sqrt{M}$$

Where, M_I and M_Q are the corresponding decimal values of the N/2 in-phase and quadrature binary bits. The output (I and Q) symbol rate is equal to 1/N times the input bit rate.

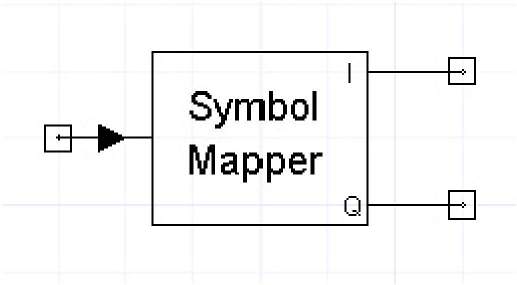
Netlist Form

```
AQAMMOD:Name n1  n2  n3 nexsys_component=QAMMOD M=val [Rin=Val]
[Rout=Val]
```

Netlist Example

```
AQAMMOD:1 1  2  3 nexsys_component=QAMMOD M=4
```

Symbol Mapper (SYMMAP)



Property	Description	Units	Default	Range
Bits	Bits per output symbol	None	2	[1,Inf]/Integer
File	Symbol mapping file with IQ data	None	None	String
RIN	Input impedance	Ohm	Inf	(0, Inf]
ROUT1	Output impedance	Ohm	0	[0, Inf)
ROUT2	Output impedance	Ohm	0	[0, Inf)
Ports				
Input	Input signal (real)			
Output1	in-phase output (real)			
Output2	Quadrature output (real)			

Notes

Netlist Form

```
ASYMMAP:Name n1  n2  n3 Nexsys_component=symmap bits=val
file=file_reference [Rin=Val] [Rout=Val]
```

Netlist Example

```
ASYMMAP:24 net11  net42  net3 Nexsys_component=symmap
+ bits=4 file=”bitfile.txt”
```

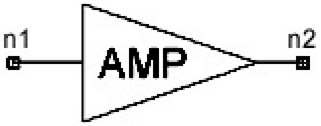
Nonlinear RF

This topic describes the following System components:

"Amplifier (AMP)" on the next page

"Mixer (MIXER)" on page 38-448

Amplifier (AMP)



Property	Description	Units	Default	Range/Type
FILE	File name that holds the data	None	Optional	String
MS11	Magnitude of S11 in dB	dB	-1e+020	(-Inf, 200]/Real
PS11	Phase of S11	Deg	0	[-180, 180]/Real
MS12	Magnitude of S12 in dB	dB	-1e+020	(-Inf, 200]/Real
PS12	Phase of S12	Deg	0	[-180, 180]/Real
MS21	Magnitude of S21 in dB	dB	0	(-Inf, 200]/Real
PS21	Phase of S21	Deg	0	[-180, 180]/Real
MS22	Magnitude of S22 in dB	dB	-1e+020	(-Inf, 200]/Real
PS22	Phase of S22	Deg	0	[-180, 180]/Real
OIP3	Output power at third order intercept point	dBm	0	[0, Inf)/Real
P1dB	Output power at 1 dB compression point	dBm	0	[0, Inf)/Real
Psat	Output power at saturation	dBm	0	[0, Inf)/Real
TEMP	Local temperature	Cel	25	(0, Inf)/Real
NF	Noise figure in dB	dB	0	[0, 200]/Real
FMIN	Minimum noise figure in dB	dB	0	[0, 200]/Real
MGO	Magnitude of optimum noise figure reflection coefficient	None	0	[0, Inf)/Real
PGO	Phase of optimum noise figure reflection	Deg	0	(-Inf, Inf)/Real

Property	Description	Units	Default	Range/Type
	coefficient			
RN	Real equivalent normalized noise resistance	Ohm	0	[0, Inf)/Real
MINF	Harmonics below MINF ignored	Hz	0	[0, Inf)/Real
MAXF	Harmonics above MAXF ignored	GHz	100	[0, Inf)/Real

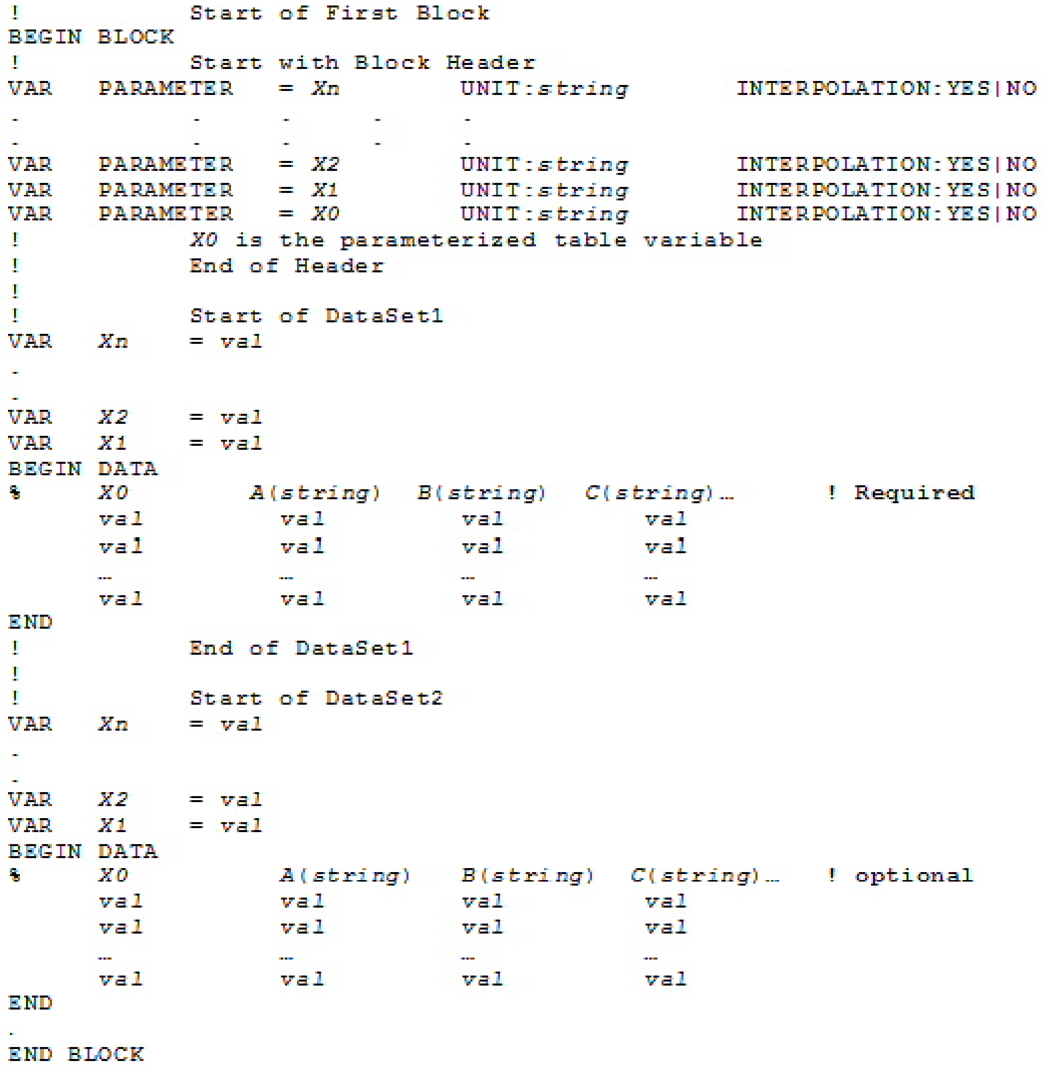
Notes

1. OIP3(dBm) = P1dB(dBm) + 10.64 dB.
2. Either OIP3 or P1dB can be specified, but not both.
3. If noise figure (NF) and the noise parameters (FMIN, MGO, PGO, and RN) are both specified, the noise parameters are used for noise calculations.
4. For more accurate calculations, measured or circuit simulation data can be supplied using Extended NMF (Neutral Model Format). Extended NMF files should have a ".nmf" extension (e.g., AmpData.nmf).

   > **Note:** NMF, or Neutral Model Format, is designed to be a common file format that allows data transfer among microwave simulators. **Electronics Desktop** supports the linear table-based data subset of the NMF specification. The full MDE Neutral Model Format Specification must be obtained on the MAFET consortium.

5. Amplifier measured data can be one of or a combination of the following:
   - AM-AM and AM-PM compression data
   - S-parameters
   - NF
   - Noise parameters: FMIN, GOPT, RN
   - IP3
6. Measured data overrides model parameters. For example, if the MS21 parameter is specified and at the same time measured S-parameter data is referenced in an external data file, the calculations is based on the measured S-parameter data.
7. Measured data can be a function of several independent variables such as input frequency (Tone1 or Freq), input power (P1), and temperature (TEMP).

8. The format for specifying data in extended NMF is:



```
!          Start of First Block
BEGIN BLOCK
!          Start with Block Header
VAR   PARAMETER   = Xn        UNIT:string       INTERPOLATION:YES|NO
.          .      .     .     .
.          .      .     .     .
VAR   PARAMETER   = X2        UNIT:string       INTERPOLATION:YES|NO
VAR   PARAMETER   = X1        UNIT:string       INTERPOLATION:YES|NO
VAR   PARAMETER   = X0        UNIT:string       INTERPOLATION:YES|NO
!          X0 is the parameterized table variable
!          End of Header
!
!          Start of DataSet1
VAR   Xn     = val
.
.
VAR   X2     = val
VAR   X1     = val
BEGIN DATA
%     X0        A(string)  B(string)  C(string)...      ! Required
      val         val        val          val
      val         val        val          val
      ...         ...        ...          ...
      val         val        val          val
END
!          End of DataSet1
!
!          Start of DataSet2
VAR   Xn     = val
.
.
VAR   X2     = val
VAR   X1     = val
BEGIN DATA
%     X0          A(string)   B(string)  C(string)...   ! optional
      val         val         val          val
      val         val         val          val
      ...         ...         ...          ...
      val         val         val          val
END
.
END BLOCK
```

Note that for the extended NMF data shown above:

a. *A*(*string*) in a dataset is used to define the name of the column and describe the unit/format of each data column.

   A is the name

   string = *string1* UNIT:*string2*

   string1 is optional and represents the format information. The format can assume one of the following values:

REAL (default).

RI (expects a 2-column data with no header required for the second imaginary column).

MA (expects a 2-column data with no header required for the second angle column).

dB (expects a 2-column data with no header required for the second angle column).

UNIT:*string2* is optional and represents the unit information e.g., pF, dB, dBm.

b. A data block must always start with BEGIN BLOCK and end with END BLOCK unless a data file has a single data block, in which case these two statements are not required.
c. A dataset within a data block always starts with BEGIN DATA and ends with END.
d. Datasets within a given data block must be of the same type and have the same number of columns. The header of a dataset is only required for the first data set and assumed optional for the remaining datasets. If a header is used with each dataset, the same header must be used for all data sets within a given data block.
e. Multiple data blocks supporting multiple data formats are allowed to be present in a single NMF data file with each data block identified by its corresponding BEGIN BLOCK and END BLOCK statements.
f. Multiple data blocks supporting the same data format are not allowed.

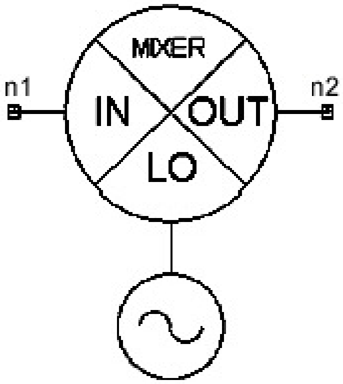
Netlist Form

```
AAMP:Name n1 n2 nexsys_component=AMP [MS11=val] [MS12=val] ...
[T=val]
```

Netlist Example

```
AAMP:1 12 15 nexsys_component=AMP MS21=-5dB NF=2.5 OIP3=17dBm
```

Mixer (MIXER)



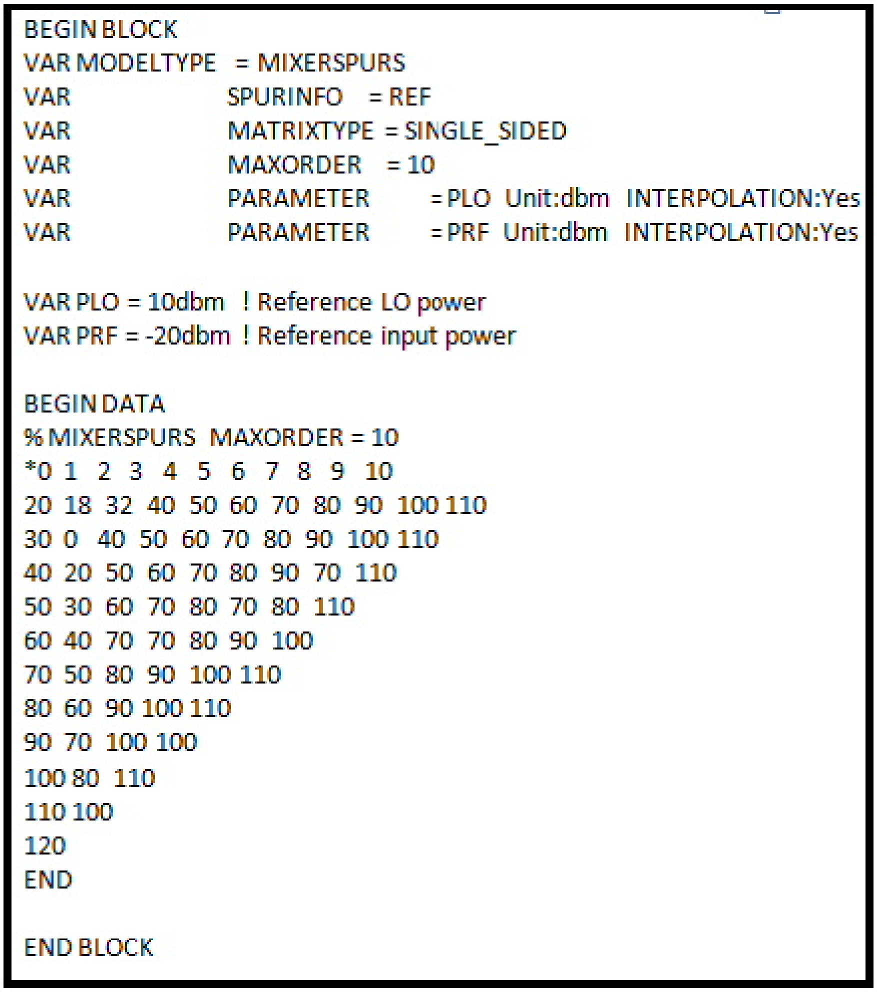
Property	Description	Units	Default	Range/Type
FILE	File name that holds the data	None	Optional	String
MS11	Magnitude of S11 in dB	dB	-1e+020	(-Inf, 200]/Real
PS11	Phase of S11	Deg	0	[-180, 180]/Real
MS22	Magnitude of S22 in dB	dB	-1e+020	(-Inf, 200]/Real
PS22	Phase of S22	Deg	0	[-180, 180]/Real
CONVGAINMAG	RF (IN) to IF (OUT) gain in dB	dB	0	(-Inf, 200]/Real
CONVGAINPHASE	RF (IN) to IF (OUT) phase shift	Deg	0	[-180,180]/Real
LOTOIFISOLATION	LO to IF (OUT) isolation in dB	dB	200	[0, 200]/Real
RFTOIFISOLATION	RF (IN) to IF (OUT) isolation in dB	dB	200	[0, 200]/Real
IFTORFISOLATION	IF (OUT) to RF (IN) isolation in dB	dB	200	[0, 200]/Real
OIP3	Output power at third order intercept point	dBm	0	[0, Inf)/Real
P1dB	Output power at 1dB compression point	dBm	0	[0, Inf)/Real
Psat	Output power at saturation	dBm	0	[0, Inf)/Real

Property	Description	Units	Default	Range/Type
TEMP	Local temperature	Cel	298	(0, Inf)/REAL
NF	Noise figure in dB	dB	0	[0, 200]/Real
FMIN	Minimum noise figure in dB	dB	0	[0, 200]/Real
MGO	Magnitude of optimum noise figure reflection coefficient	None	0	(0, Inf)/Real
PGO	Phase of optimum noise figure reflection coefficient	Deg	0	(-Inf, Inf)/Real
RN	Real equivalent normalized noise resistance	Ohm	0	[0, Inf)/Real
NRF	RF (IN) frequency multiplier	None	1	(-Inf, Inf)/Integer
NLO	LO frequency multiplier	None	-1	(-Inf, Inf)/Integer
MAXO	Maximum order for spurs	None	10	(0, Inf)/Real
MINF	Spurs below MINF ignored	Hz	0	(0, Inf)/Real
MAXF	Spurs above MAXF ignored	GHz	100	(0, Inf)/Real
MINP	Spurs below MINP ignored	Watt	0	(0, Inf)/Real
FLO	LO Frequency	Hz	1	(0, Inf)/Real
PLO	LO Power	Watt	1	(-Inf, Inf)/Real
F1	First frequency offset from FLO	Hz	0	(10, Inf)/Real
F2	Second frequency offset from FLO	Hz	0	(F1, Inf)/Real
M2	Phase noise magnitude at F2	Deg	-180	[-180,0]/Real
TYPE	0 for low Q 1 for High Q	None	0	0 , 1
SEED	Random seed (Nexsys only)	None	0	(0, Inf)/Real

Notes

1. Mixer S-parameters and noise parameters are treated as if they are measured on a two-port black box. The fact that the input and output frequencies are different is ignored during analysis. The input frequency is always used for interpreting any measurement data associated with this element.

2. The nonlinear figures of merit (OIP2, OIP3, P1dB, and PSAT) are specified based on the reference LO power (PLO).
3. OIP3(dBm) = P1dB(dBm) + 10.64 dB.
4. Either OIP3 or P1dB can be specified, but not both.
5. This model accepts all the linear and nonlinear two-port measurement data used by the amplifier (AMP) model. (see examples of measured data for the AMP model.
6. The oscillator noise frequency offset parameters **F1** and **F2** must be consistent with the **TYPE**. For a low qload (**TYPE** =0), **F1** and **F2** correspond to F_C and F_{LO}/2qload respectively. For a high qload (**TYPE** =1), **F1** and **F2** correspond to F_{LO}/2qload and F_C, respectively. (See the one port oscillator element (OSC) in the *Sources* topic for more details.
7. This model accepts MIXERSPURS data tables.



```
BEGIN BLOCK
VAR MODELTYPE  = MIXERSPURS
VAR            SPURINFO   = REF
VAR            MATRIXTYPE = SINGLE_SIDED
VAR            MAXORDER   = 10
VAR            PARAMETER      = PLO  Unit:dbm  INTERPOLATION:Yes
VAR            PARAMETER      = PRF  Unit:dbm  INTERPOLATION:Yes

VAR PLO = 10dbm  ! Reference LO power
VAR PRF = -20dbm ! Reference input power

BEGIN DATA
% MIXERSPURS  MAXORDER = 10
*0 1  2  3  4  5  6  7  8  9  10
20 18 32 40 50 60 70 80 90 100 110
30 0  40 50 60 70 80 90 100 110
40 20 50 60 70 80 90 70 110
50 30 60 70 80 70 80 110
60 40 70 70 80 90 100
70 50 80 90 100 110
80 60 90 100 110
90 70 100 100
100 80 110
110 100
120
END

END BLOCK
```

8. For any MIXERSPURS data table:

N $_{RF}$ = The row number = harmonic number for the input carrier frequency (F_{RF})

N $_{LO}$ = The column number = harmonic number for the LO frequency (F_{LO})

P $_{RFREF}$ = The reference input power level, in dBm

P $_{LOREF}$ = The reference LO power level, in dBm

SPUR(N $_{RF}$ x F $_{RF}$ + N $_{LO}$ x F $_{LO}$) = The power level of the N_{RF} x N_{LO} IM product, in dB, relative to the fundamental output power level.

In the MIXERSPURS data table above, N_{RF} = 0, 1, 2, …, 10 and N_{LO} = 0, 1, 2, …, 10 with N_{RF} + N_{LO} <= MAXO (default = 10).

For example, the table entry SPUR(3 x F_{RF} + 2 x F_{LO}) = 60dB implies that the power level of the 3 x F_{RF} + 2 x F_{LO} intermodulation product is 60 dB below the power level of the fundamental output frequency. The power level in dBm of the 3 x F_{RF} + 2 x F_{LO} IM product is given by:

$$P_{\text{NrfNlo}} = P_{RFREF} + S21(dB) - SPUR(3 \times F_{RF} + 2 \times F_{LO})$$

In general, if the input and LO power levels are identical to the reference power levels specified in the MIXERSPURS data table, the power level in dBm of each generated IM product (in association with the MIXERSPURS data table) is given by:

$$P_{\text{NrfNlo}} = P_{RFREF} + S21(dB) - SPUR(N_{RF} \times F_{RF} + N_{LO} \times F_{LO})$$

This formula is accurate for P_{RF}= P_{RFREF} and P_{LO}=P_{LOREF}.

If the actual input RF power P_{RF} is not equal to the specified reference PRF power P_{RFREF} and/or the actual LO input power P_{LO} is not equal to the specified reference LO power P_{LOREF}, the output IM product formula is adjusted:

$$P_{\text{NrfNlo}} = P_{RFREF} + S21(dB) - SPUR(N_{RF} \times F_{RF} + N_{LO} \times F_{LO}) + ADJ$$

$$ADJ = (|N_{LO}|)(P_{LO} - P_{LOREF}) + (|N_{RF}| - 1)(P_{RF} - P_{RFREF})$$

The adjustment is typically reasonable for P_{LO} levels not exceeding the reference power P_{LOREF} by 3dBm and for P_{RF} levels not exceeding the reference power P_{RFREF} by 7dBm.

Netlist Form

AMIXER:Name *n1 n2* nexsys_component=MIXER [T=*val*] [MS11=*val*] . . .

Netlist Example

```
AMIXER:A 12  15 nexsys_component=MIXER CONVGAINMAG =-5dB
OIP3=17dBm
```

Probes

This topic describes the following System components:

Adjacent Channel Power Ratio Probe (ACPRP)

Property	**Description**	**Units**	**Default**	**Range/Type**
Name	Probe name	None	Required	String
NSAMP	Number of input samples used for acpr calculations per invocation	None	1024	(0, Inf)/Integer
IN_BAND _OFFSET	Maximum frequency offset of inband spectrum	Hz	1000	(0, ≤ MAX_ OFFSET]/Real
OUT_ BAND _OFFSET	Minimum frequency offset of outband spectrum	Hz	1000	(0, ≤ MAX_ OFFSET]/Real
MAX_ OFFSET	Maximum frequency offset from center frequency	Hz	100000	(0, Inf)/Real
INITSAMP	Number of initial samples removed from waveform	None	0	[0, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
Ports				
Input	Input signal (complex)			

Notes

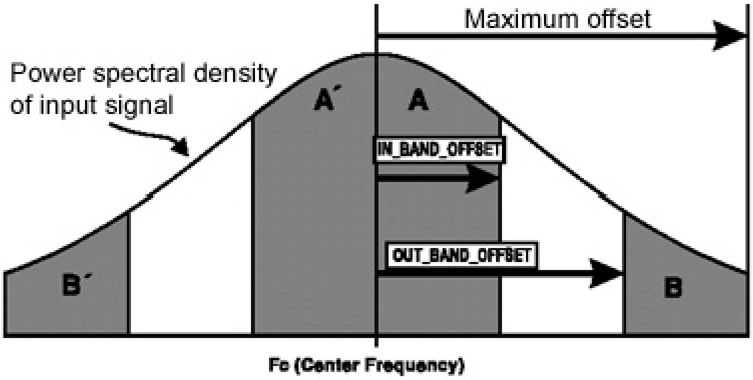
1. For a given random input signal

$$V_{in}(t) = A(t)\cos(2\pi f_c t + \theta(t))$$

this model computes the average power in the main band (i.e., appropriate band) and the average power in the adjacent band (i.e., undesired band), then computes the ACPR as

ACPR = Power in adjacent bands/ Power in main bands = Area(B+B') / Area(A+A')

The calculated ACPR quantity is more accurate for longer input sequences. During each invocation of this model, a block of NSAMP input samples is used to compute the power spectrum of the input. This power spectrum is then used in the fashion described above to compute the ACPR. As more input blocks become available at the input, the ACPR calculations is adjusted accordingly and tend to become more accurate.



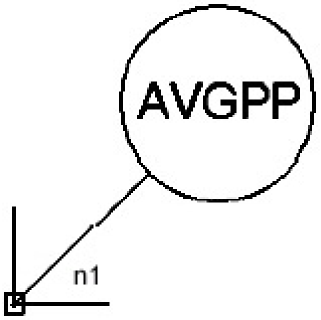
Netlist Form

```
AACPRP:Name n1 nexsys_component=ACPRP NSAMP=val
IN_BAND_OFFSET=val  OUT_BAND_OFFSET=val

+ MAX_OFFSET=val  [INITSAMP=val] [Rin=val]
```

Netlist Example

```
AACPRP:My_Acprp nexsys_component=ACPRP NSAMP=256
IN_BAND_OFFSET=10KHZ  OUT_BAND_OFFSET=10KHZ MAX_OFFSET=15KHZ
```

Average Power Probe (AVGPP)



Property	Description	Units	Default	Range/Type
Name	Probe name	None	Required	String
INITSAMP	Number of initial samples removed from waveform	None	0	[0, Inf)/Integer
RIN	Input impedance	Ohm	50	(0, Inf]/Real
Ports				
Input	Input signal (complex)			

Notes

1. The results of this probe may only be viewed in the SWEEP/Network Function domain. They may not be viewed in the time or spectral domain. For a given input signal

$$V_{in}(t) = A(t)\cos(2\pi f_c t + \theta(t))$$

This average power probe takes the samples of the incoming input complex envelope signal $A(t)e^{j\theta(t)}$ and computes the average power by

$$avgp = \frac{1}{R_{in}}\sum_{k=0}^{N-1}\frac{\left|A(k\Delta t)e^{j\theta(k\Delta t)}\right|^2}{N}$$

Where Δt is the time sampling step, N is the total number of samples available at the input, and Rin is the load impedance looking into the input port of the probe.

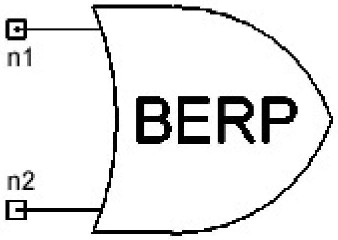
Netlist Form

`AAVGPP:Name n1 nexsys_component=AAVGPP [Initsamp=val] [Rin=val]`

Netlist Example

```
AAVGPP:My_Avgpp 1 nexsys_component=AAVGPP
```

Bit Error Rate Probe (BERP)



Property	Description	Units	Default	Range/Type
Name	Probe name	None	Required	String
INITSAMP1	Number of initial samples removed from input1 waveform	None	0	[0, Inf)/Integer
INITSAMP2	Number of initial samples removed from input2 waveform	None	0	
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
Ports				
Input1	Input1 signal (real)			
Input2	Input2 signal (real)			

Notes

1. This model is used to calculate the **BER** in a digital communications systems by comparing a transmitted stream of binary bits (**Input1**) with the corresponding received data stream (**Input2**). The total error count (ErrorCount) is incremented by 1 each time a mismatch is detected between the two input streams. The final **BER** value is computed as:

$$BER = \frac{ErrorCount}{TotalCount}$$

Systems with low **BER** s require an increased number of bits to be transmitted through the system to obtain an accurate measure of **BER**

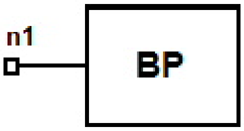
Netlist Form

`ABERP:Name n1 n2 nexsys_component=ABERP [Initsamp1=val] [Initsamp2=val] [Rin1=val] [Rin2=val]`

Netlist Example

```
ABERP:My_Berp 1 2 nexsys_component=ABERP
```

Bandwidth Power Probe (BP)



Property	Description	Units	Default	Range
NAME	Probe name	None	Required	String
NSAMP	Number of samples used for calculation per invocation	None	1024	[0, Inf)/Integer
MINF	Minimum frequency of the band to be measured	Hz	0	[0, Inf)/Real
MAXF	Maximum frequency of the band to be measured	Hz	1000	(MINF, Inf)/Real
RIN	Input impedance	Ohm	50	(0, Inf)/Real
Ports				
Input	Input signal (complex)			

Notes

This probe calculates the power of the signal (across the input impedance RIN) in the frequency band starting from MINF to MAXF.

Netlist Form

```
ABP:NAME n1 nexsys_component=BP NSAMP=val][MINF=val][MAXF=val]
[RIN=val]
```

Netlist Example

```
ABP:1 1 nexsys_component=BP NSAMP=1024 MINF=100Hz MAXF=1MHz
```

Complementary Cumulative Distribution Function Probe (CCDFP)

Property	Description	Units	Default	Range
Name	Probe name	None	Required	String
nbin	Number of histogram bins	None	64	[1, Inf)/Integer
nsamp	Number of samples used for histogram	None	1024	[1, Inf)/Integer
Initsamp	Number of initial samples removed from waveform	None	0	[0, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
Ports				
Input	Input signal (real)			

Notes

1. The Complementary Cumulative Distribution Function (CCDF) probe is equal to 1 minus the value of CDFP. (See the notes of CDFP to see how CDF is calculated.

Netlist Form

```
ACCDFP:NAME n1 nexsys_component=CCDFP nbin=val nsamp=val
[Initsamp=val] [Rin=val]
```

Netlist Example

```
ACCDFP:1 1 nexsys_component=CCDFP nbin=64 nsamp=65536
```

Cumulative Distribution Function Probe (CDFP)

Property	Description	Units	Default	Range
Name	Probe name	None	Required	String
nbin	Number of histogram bins	None	64	[1, Inf)/Integer
nsamp	Number of samples used for histogram	None	1024	[1, Inf)/Integer
Initsamp	Number of initial samples removed from waveform	None	0	[0, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
Ports				
Input	Input signal (real)			

Notes

1. The Cumulative Distribution Function (CDF) probe is similar to the Histogram probe. After determining the histogram function, it is normalized by the total number of samples. After the normalization is performed, a running sum is created to build the CDF.
2. The maximum and minimum values for the input signal waveform are determined for histogram bin calculations. The histogram bins exist at intervals of **dx = (Max_Input - Min_Input) / nbin**. The bin centers are located at **x[n] = (n + 0.5)*dx + Min_Input.**
3. The total number of input samples per bin are determined and displayed versus the x-axis. If the user specifies a nsamp value larger than the total number received on the source, the actual number of samples received is used for the histogram calculation.

Netlist Form

```
ACDFP:NAME n1 nexsys_component=CDFP nbin=val nsamp=val
[Initsamp=val] [Rin=val]
```

Netlist Example

```
ACDFP:1 1 nexsys_component=CDFP nbin=64 nsamp=65536
```

Crest Factor Probe (CFP)

Property	Description	Units	Default	Range
Name	Probe name	None	Required	String
Initsamp	Number of initial samples removed from waveform	None	0	[0, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
Ports				
Input	Input signal (real)			

Notes

1. This probe calculates the crest factor (the ratio of the peak value to RMS value of a waveform) of an incoming signal. Suppose the input signal is $v(n), n = 1, 2, ...N$. The crest factor is calculated as follows:

$$CrestFactor = \frac{max(|v(n)|)}{sqrt\left(\frac{1}{N}\sum^{N}|v(n)|^2\right)}$$

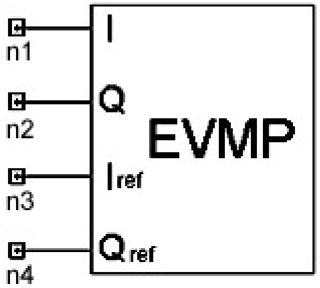
Netlist Form

```
ACFP:NAME n1 nexsys_component=CFP [Initsamp=val] [Rin=val]
```

Netlist Example

```
ACFP:1 2 nexsys_component=CFP
```

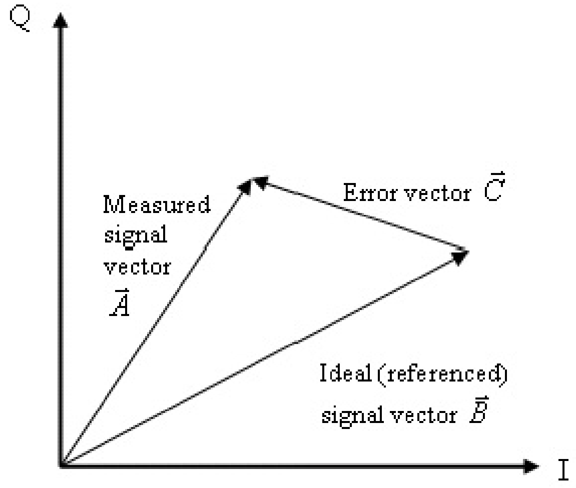
Error Vector Magnitude Probe (EVMP)



Property	Description	Units	Default	Range/Type
Name	Probe name	None	Required	String
Initsamp1	Number of samples removed from input1 waveform	None	0	[0, Inf)/Integer
Initsamp2	Number of samples removed from input2 waveform	None	0	[0, Inf)/Integer
Initsamp3	Number of samples removed from input3 waveform	None	0	[0, Inf)/Integer
Initsamp4	Number of samples removed from input4 waveform	None	0	[0, Inf)/Integer
RIN1	Input1 impedance	Ohm	Inf	[0, Inf)/Real
RIN2	Input2 impedance	Ohm	Inf	[0, Inf)/Real
RIN3	Input3 impedance	Ohm	Inf	[0, Inf)/Real
RIN4	Input4 impedance	Ohm	Inf	[0, Inf)/Real
Ports				
Input1	Received in-phase signal (real)			
Input2	Received quadrature signal (real)			
Input3	Reference in-phase signal (real)			
Input4	Reference quadrature signal (real)			

Notes

1. This probe calculates the error vector magnitude of a measured signal vector and an ideal (reference) signal vector (see the figure).



Expressed using vector representation, the error vector magnitude (EVM) is shown in the following figure.

$$|\vec{C}| = |\vec{A} - \vec{B}|$$

The assumption here is that there is no constant offset between the measured and ideal signals. That is, both vectors have a common origin. In here, the measured and referenced signals invariably have different peak levels due to attenuation, distortion, etc. Consequently, the magnitudes for *A* and *B* need to be normalized, in our case, to the peak reference magnitude. For N input samples, the EVM reported by this probe is given by:

$$EVM = \sqrt{\frac{\sum_{n=1}^{N} \frac{1}{N}\|\vec{C}(n)\|^2}{MAX\{\|\vec{B}(n)\|^2\}}} \times 100\%$$

Netlist Form

```
AEVMP:NAME n1 n2 n3 n4 nexsys_component=EVMP [Initsamp1=val]
[Initsamp2=val] [Initsamp3=val] [Initsamp4=val] [Rin1=val]
Rin2=val] Rin3=val] Rin4=val]
```

Netlist Example

```
AEVMP:1 1 2 3 4 nexsys_component=EVMP
```

Frequency Trajectory Probe (FTRAJP)

Properties	Description	Units	Default	Range/Type
Name	Probe name	None	Required	String
INITSAMP	Number of initial samples removed from waveform	None	0	[0,Inf)/Integer
RIN	Probe Name	Ohm	inf	(0, Inf]/Real
Ports				
Input	Input signal (complex)			

Notes

1. Given an input signal to this probe of the form:

$$V_{in}(t) = A(t)\cos(2\pi f_c t + \theta(t))$$

the measurement obtained by means of this probe is the frequency trajectory (i.e., variations) *freq(t)* of the input signal with respect to time:

$$freq(t) = f_c + \frac{d\theta(t)}{2\pi dt}$$

The derivative in the above expression is computed using a fine timestep which is equal to the inverse of the sampling frequency of the envelope of the input signal.

Netlist Form

```
AFTRAJP:Name n1 nexsys_component=FTRAJP [Initsamp=val] [Rin=val]
```

Netlist Example

```
AFTRAJP:My_Ftrajp 1 nexsys_component=FTRAJP
```

Histogram Probe (HISTP)

Properties	Description	Units	Default	Range/Type
Name	Probe name	None	Required	String
nbin	Number of histogram bins	None	64	[1, Inf)/Integer
nsamp	Number of samples used for histogram	None	1024	[1, Inf)/Integer
Initsamp	Number of initial samples removed from waveform	None	0	[0, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
Ports				
Input	Input signal (real)			

Notes

1. The maximum and minimum values for the input signal waveform are determined for histogram bin calculations. The histogram bins exist at intervals of **dx = (Max_Input - Min_Input) / nbin**. The bin centers are located at **x[n] = (n + 0.5)*dx + Min_Input.**

   The total number of input samples per bin are determined and displayed versus the x-axis, represented by the bin locations. If the user specifies a nsamp value larger than the total number received on the source, the actual number of samples received are used for the histogram calculation.

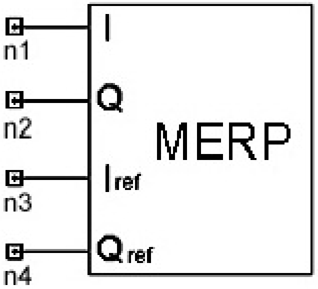
Form

```
AHISTP:NAME n1 nexsys_component=HISTP nbin=val nsamp=val
[Initsamp=val] [Rin=val]
```

Example

```
AHISTP:1 1 nexsys_component=HISTP nbin=64 nsamp=65536
```

Modulation Error Ratio Probe (MERP)



Property	Description	Units	Default	Range/Type
Name	Probe name	None	Required	String
Initsamp1	Number of samples removed from input1 waveform	None	0	[0, Inf)/Integer
Initsamp2	Number of samples removed from input2 waveform	None	0	[0, Inf)/Integer
Initsamp3	Number of samples removed from input3 waveform	None	0	[0, Inf)/Integer
Initsamp4	Number of samples removed from input4 waveform	None	0	[0, Inf)/Integer
RIN1	Input1 impedance	Ohm	Inf	[0, Inf)/Real
RIN2	Input2 impedance	Ohm	Inf	[0, Inf)/Real
RIN3	Input3 impedance	Ohm	Inf	[0, Inf)/Real
RIN4	Input4 impedance	Ohm	Inf	[0, Inf)/Real
Ports				
Input1	Received in-phase signal (real)			
Input2	Received quadrature signal (real)			
Input3	Reference in-phase signal (real)			
Input4	Reference quadrature signal (real)			

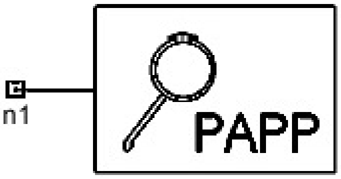
Netlist Form

```
AMERP:Name n1 n2 n3 n4 Nexsys_component=merp [Initsamp1=val]
[Initsamp2=val] [Initsamp3=val] [Initsamp4=val] [Rin1=val]
Rin2=val] Rin3=val] [Rin4=val]
```

Netlist Example

```
AMERP:21 net1 net2 net3 net4 Nexsys_component=merp
+ Initsamp1=1024 Initsamp2=512 Initsamp3=1024 Initsamp4=2048
```

Peak-to-Average Power Probe (PAPP)



Properties	Description	Units	Default	Range/Type
Name	Probe name	None	Required	String
Initsamp	Number of initial samples removed from waveform	None	0	[0, Inf)/Integer
Rin	Input impedance	Ohm	Inf	(0, Inf]/Real
Ports				
Input	Input signal (real)			

Notes

1. This probe calculates the peak to average power ratio of an incoming signal.
   If the input signal is $v(n)$, $n \in [1, N]$, the peak-to-average power ratio is calculated as follows:

$$PAP = \frac{max(|v(n)|^2)}{\frac{1}{N}\sum_{n=1}^{N} |v(n)|^2}$$

Netlist Form

```
APAPP:Name n1 nexsys_component=PAPP [Initsamp=val] [Rin=val]
```

Netlist Example

```
APAPP:my_papp 2 nexsys_component=PAPP
```

Probability Density Function Probe (PDFP)

Properties	Description	Units	Default	Range/Type
Name	Probe name	None	Required	String
nbin	Number of histogram bins	None	64	[1, Inf)/Integer
nsamp	Number of samples used for histogram	None	1024	[1, Inf)/Integer
Initsamp	Number of initial samples removed from waveform	None	0	[0, Inf)/Integer
Rin	Input impedance	Ohm	Inf	(0, Inf]/Real
Ports				
Input	Input signal (real)			

Notes

1. The Probability Density Function (PDF) probe is similar to the Histogram probe. After determining the histogram function, it is normalized by the total number of samples. The total number of input samples per bin are determined and displayed versus the x-axis, represented by the bin locations. If the user specifies a **nsamp** value larger than the total number received on the source, the actual number of samples received is used for the calculation.

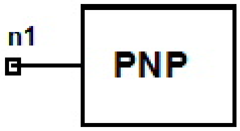
Netlist Form

```
APDFP:NAME n1 nexsys_component=PDFP nbin=val nsamp=val [Initsamp=val]
[Rin=val]
```

Netlist Example

```
APDFP:my_pdfp 1 nexsys_component=PDFP nbin=64 nsamp=65536
```

Phase Noise Probe (PNP)



Properties	Description	Units	Default	Range
NAME	Probe name	None	Required	String
FMIN	Minimum measurement frequency	Frequency	100	[100, 1e6]/Real
WINDOW_ TYPE	0 for Bartlett, 1 for Hanning, 2 for Rectangular, 3 for Hamming, 4 for Blackman, 5 for Blackman-Harris (3 term), 6 for Blackman-Harris (4 term) 7 for Gaussian (alpha=3), 8 for de la Valle-Poussin.	None	1	[0,8] /Integer
INITSAMP	Number of initial samples removed from waveform	None	0	[0, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
Ports				
Input	Input signal (real)			

Notes

1. In general, this phase noise probe (PNP) takes the noise signal on the PN pin of the VCODIVBYN (combined VCO and Frequency Divider component) and outputs the single side band noise spectrum. If you plot the data with the dB operation, the units are dBc/Hz.

2. Due to the statistical nature of the noise simulation, the number of samples need to be simulated should be at least 10*fs/FMIN, where fs is the sampling rate. The more samples are simulated, the more accurate the spectrum is. If not enough samples are sent, this model may not generate any plot, and the simulator gives a warning message saying not enough samples after the simulation is completed.
3. Normally, RIN should be set to 1ohm when measuring phase noise.
4. This probe always assumes the input signal is the base-band phase noise signal. If you want to measure the phase noise for a carrier signal, you need to extract the phase noise (i.e., using a complex multiplier) first, then feed this extracted noise signal to the probe. Also note you have to remove the unwanted samples in a PLL simulation during the locking period

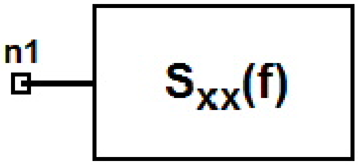
Netlist Form

```
APNP:NAME n1 nexsys_component=PNP [FMIN=val] [WINDOW_TYPE=val]
[INISTSAMP=val] [RIN=val]
```

Netlist Example

```
APNP:1 1 nexsys_component=PNP FMIN=100Hz WINDOW_TYPE=1 RIN=1ohm
```

Power Spectral Density Probe (PSDP)



Properties	Description	Units	Default	Range/Type
Name	Probe name	None	Required	String
FFTL	Number of input samples used for spectral estimation per invocation	None	256	[8, Inf)/Integer (must be a power of 2)
TYPE	0 for nonperiodic signals and 1 for periodic	None	0	[0, 1]/Integer
WINDOW _TYPE	0 for Bartlett, 1 for Hanning, 2 for rectangular, 3 for Hamming, 4 for Blackman, 5 for Blackman-Harris (3 term), 6 for Blackman-Harris (4 term) 7 for Gaussian (alpha=3), 8 for de la Valle-Poussin.	None	1	[0, 8]/Integer
INITSAMP	Number of initial samples removed from waveform	None	0	[0, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
RL	Impedance used for Power Spectral Density (PSD) calculation	Ohm	50	(0, Inf]/Real
Ports				
Input	Input signal (complex)			

Notes

1. For a given random input signal

$$V_{in}(t) = A(t)\cos(2\pi f_c t + \theta(t))$$

this model takes blocks of the incoming input samples (each block of length FFTL samples), and computes the resulting power spectrum density S(ω) for each block according to

$$S(\omega) = \frac{|V_{in}(\omega)|^2}{R_L}$$

where $V_{in}(\omega)$ is the frequency spectrum of the input complex envelope ($A(t)e^{j\Theta(t)}$) computed using an FFT of length FFTL, and R_L is the impedance used to calculate the PSD.

2. The resulting power spectrum is then averaged out over the total number of available input blocks (each of length FFTL samples). The averaging process is done according to the Welch Method [1] for spectral estimation. The averaging process becomes more accurate as more input samples are used in the estimation process. The averaging process then yields an estimate of the power spectral density of the random input signal.
3. The user should set the TYPE parameter to 0 if the expected spectral estimate is continuous. Non-periodic signals always yield continuous power spectral densities. If, on the other hand, the spectral estimate is expected to be discrete (i.e., input is periodic), the user should set the TYPE parameter to 1.
4. It is important to note that from a software point of view, a periodic signal (e.g., a sinusoid) does not yield a discrete spectrum unless the frequency of the periodic signal, the simulation timestep, and the number of samples representing the signal all meet a certain criterion.

Netlist Form

```
APSDP:Name n1 nexsys_component=PDSP FFTL=val [TYPE=val] [WINDOW_
TYPE=val][INITSAMP=val]
+ [RIN=val] [RL=val]
```

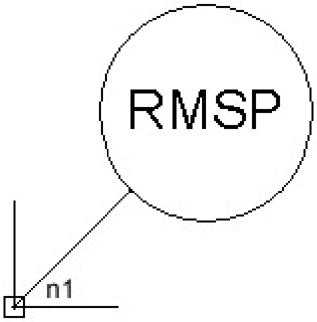
Netlist Example

```
APSDP:My_Psdp 1 nexsys_component=PDSP FFTL=256 Window_type=2
TYPE=0
```

References

1. J. G. Proakis and D. G. Manolakis, *Introduction to Digital Signal Processing*, Macmillan

Root Mean Square Probe (RMSP)



Properties	**Description**	**Units**	**Default**	**Range/Type**
Name	Probe name	None	Required	String
INITSAMP	Number of initial samples removed from waveform	None	0	[0, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
Ports				
Input	Input1 signal (complex)			

Notes

1. The results of this probe may be viewed only in the SWEEP/Network Function domain. They may not be viewed in the time or spectral domain. Assuming the following input signal

$$V_{in}(t) = A(t)\cos(2\pi f_c t + \theta(t))$$

the RMS probe takes the samples of the incoming input complex envelop signal A(*t*)$e^{j\Theta(t)}$ and computes the root mean square by

$$V_{rms} = \sqrt{\sum_{k=0}^{N-1} \frac{\left|A(k\Delta t)e^{j\theta(k\Delta t)}\right|^2}{N}}$$

Where Δt is the time sampling step and N is the total number of samples available to the input port.

2. Using this element to probe an electrical node loads that node by R_{in}.

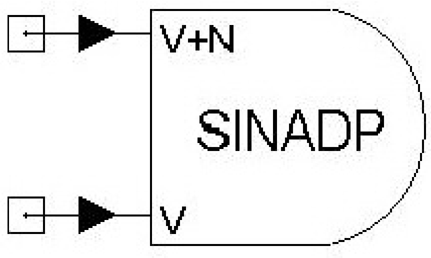
Netlist Form

`ARMSP:Name` *`n1`* `nexsys_component=RMSP [Initsamp=`*`val`*`] [Rin=`*`val`*`]`

Netlist Example

```
ARMSP:My_rmsp 1 nexsys_component=RMSP
```

Signal to Noise & Distortion Probe (SINADP)



Properties	Description	Units	Default	Range/Type
Name	Probe name	None	Required	String
INITSAMP1	Number of initial samples removed from input1 waveform	None	0	[0,Inf)/Integer
INITSAMP2	Number of initial samples removed from input2 waveform	None	0	[0,Inf)/Integer
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real

Notes

1. This model is used to calculate the signal to noise and distortion ratio (SINAD) in a digital communications system by computing the average power $E(V_{v+n}(t))^2$ for the received input stream with noise and distortion (Signal+Noise+Distortion) and the average $E(V_v(t))^2$ of the corresponding input stream without noise (Signal). The average noise power is computed as:

$$E\{(V_{v+n}(t)-V_v(t))^2\}$$

The final SINAD value is computed as:

$$\frac{E\left((V_v(t))^2\right)}{E\left(N(t)^2\right)}$$

Systems with a high SINAD ratio require a large number of samples be transmitted through the system to obtain an accurate measure of SINAD.

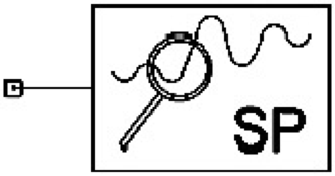
Netlist Form

ASINADP:NAME n1 n2 nexsys_component=SINADP [Initsamp1=*val*] [Initsamp2=*val*] [Rin1=*val*] [Rin2=*val*]

Netlist Example

```
ASINADP:my_sinadp 1 2 nexsys_component=SINADP
```

Signal Probe (SP)



Properties	Description	Units	Default	Range/Type
Name	Probe name	None	Required	String
INITSAMP	Number of initial samples removed from waveform	None	0	[0, Inf)/Integer
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
Ports				
Input	Input signal (real, complex)			

Notes

1. This probe yields the voltage of the input signal $V_{in}(t)$. This voltage signal may be viewed in the time or spectral domain.
2. For baseband signals (i.e., zero carrier frequency), this probe yields the input voltage signal in the time domain and its spectrum in the frequency domain.

   The baseband frequency domain response *Vin(f)* is computed at a set of discrete frequency points according to:

$$V\left[\left(k-\frac{N}{2}\right)df\right] = \frac{1}{N}\sum_{n=0}^{N-1} V_{in}(nt_s)\exp(-j2\pi nt_s kdf)$$

where:

k = 0, 1, 2, . . . N-1

t_s = Input signal timestep

N = The next power of 2 larger than the total number of samples available at the input port, and

$$df = \frac{1}{Nt_s}$$

3. For passband input signals of the form $V_{in}(t) = A(t)\cos(2\pi f_c t + \theta(t))$, this probe yields the complex input voltage $\{A(t)e^{j\theta(t)}\}$ in the time domain and its spectrum in the frequency domain.
4. The passband frequency domain response $V_{in}(f)$ is computed at a set of discrete frequency points according to:

$$V\left[f_c + \left(k - \frac{N}{2}\right)df\right] = \frac{1}{N}\sum_{n=0}^{N-1} A(nt_s)\exp\{j\theta(nt_s)\}\exp\{-j2\pi nt_s kdf\}$$

where:

k = 0, 1, 2, . . . N-1

t_s = Input complex envelope timestep

N = The next power of 2 larger than the total number of samples available at the input port.

$df = 1/Nt_s$

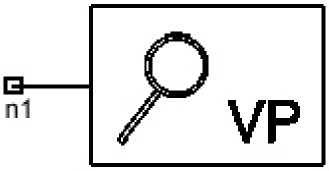
Notes

```
ASP:Name n1 nexsys_component=SP [Initsamp=val] [Rin=val]
```

Netlist Example

```
ASP:My_sp 1 nexsys_component=SP
```

Voltage Probe (VP)



Properties	Description	Units	Default	Range/Type
Name	Probe name	None	Required	String

Notes

This voltage probe is only for Nexsys Frequency Domain analysis. It is inactive for all other analyses.

Netlist Form

`VP:Name n1 nexsys_component=VP`

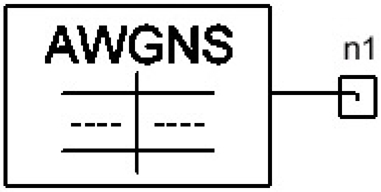
Netlist Example

`VP:mixer_out net5 nexsys_component=VP`

Sources

This topic describes the following System components:

Additive White Gaussian Noise Source, Real (AWGNS)



Property	Description	Units	Default	Range/Type
NSAMP	Number of samples	None	100	[1, Inf)/Integer
Seed	Random Seed	None	0	[0, Inf)/Integer
Noise_Power	Noise power	Watt	1	[0, Inf)/Real
Sample_Rate	Output bit rate in Hz	Hz	1000	(0, Inf)/Integer
FC	Carrier frequency in Hz	Hz	0	[0, Inf)/Real
ROUT	Output impedance	Ohm	50	[0, Inf)/Real
Ports				
Output	Output signal (real)			

Notes

This model generates a real additive white Gaussian noise signal. The output voltage is given by

$$V_{out}(t) = A(t)\cos(2\pi f_c t)$$

Where A(t) is a random white Gaussian processes with a standard deviation given by

$$\sigma = \sqrt{4 \times Rout \times NoisePower}$$

for envelope analysis

or

$$\sigma = \sqrt{8 \times Rout \times NoisePower}$$

for instantaneous analysis

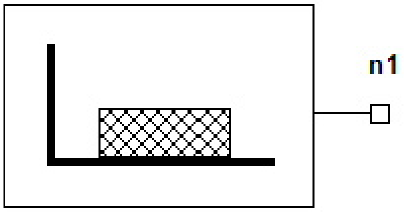
Netlist Form

```
AAWGNS:Name n1 nexsys_component=AWGNS NSAMP=val [SEED=val]
Noise_Power=val
+ Sample_Rate=val [FC=val] [ROUT=val]
```

Netlist Example

```
AAWGNS:1 1 nexsys_component=AWGNS nsamp=1024 seed=10 Noise_
Power=10dbm
+ Sample_Rate=200KHz
```

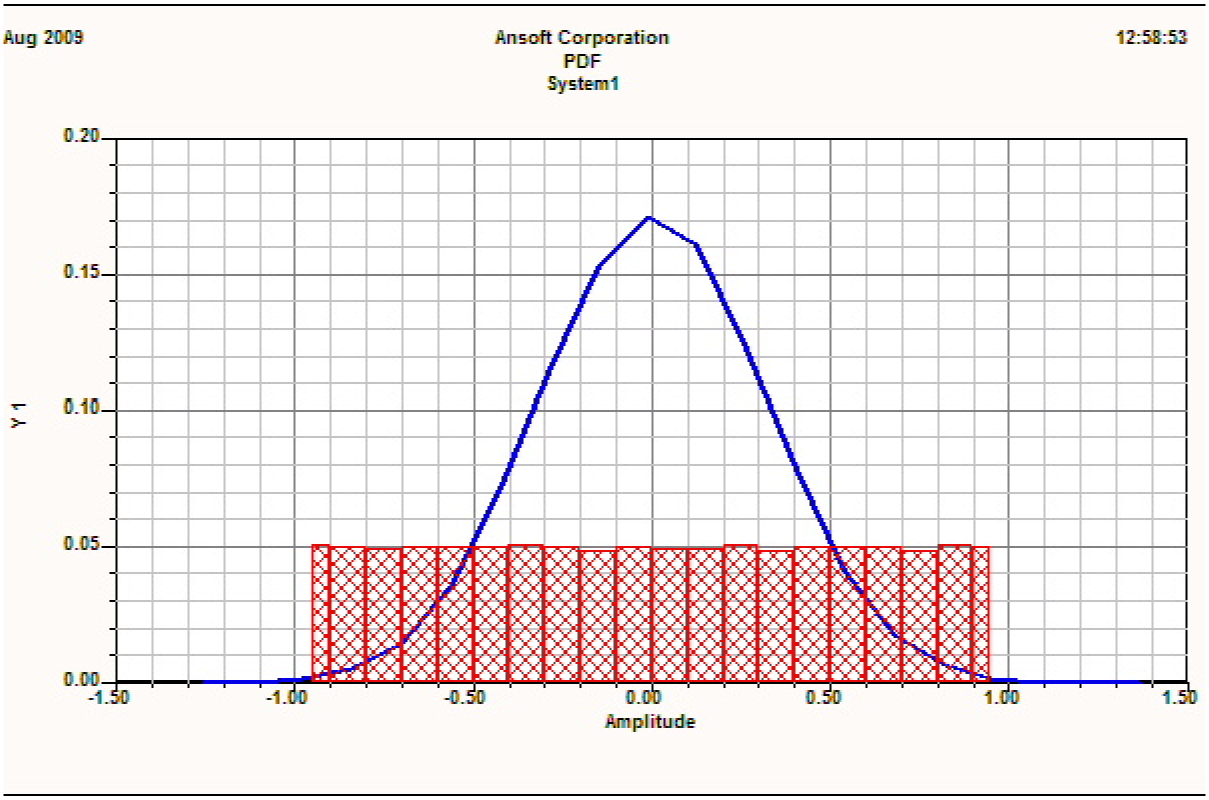
Uniform Noise Source, Real (UNS)



Property	Description	Units	Default	Range/Type
Nsamp	Number of samples	None	100	[1, Inf)/Integer
Sample_Rate	Output bit rate in Hz	Hz	1000	(0, Inf)/Integer
Offset	Offset of noise	None	0	[0, Inf)/Real
Deviation	Maximum deviation from offset	None	1	[0, Inf)/Real
Seed	Random Seed	None	0	[0, Inf)/Integer
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Output	Output signal (real)			

> **Note:** This model generates a real uniform noise signal.

For an offset of -1 and a deviation of 2, the output values vary randomly between -1.0 (offset) and +1.0 (offset + deviation). The following figure compares this distribution (red) with that of a Gaussian noise source (blue)



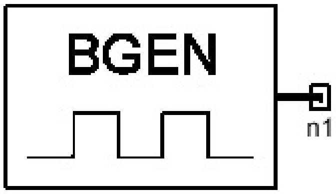
Netlist Form

```
AUNS:Name n1 Nsamp=val Sample_Rate=val [Offset=val]
+ [Deviation=val]   [SEED=val]
+ [ROUT=val] Nexsys_component=uns
```

Netlist Example

```
AUNS:1 net_5 Nexsys_component=uns Nsamp=1024 Offset=-1
+ Deviation=2 Sample_Rate=200KHz seed=10
```

Periodic Binary Bit Generator (BGEN)



Property	Description	Units	Default	Range/Type
BIT_ PATTERN	Pattern of bits to generate during each period in binary format	None	0101	String
PERIOD	Period of the generated binary sequence	None	1	(0, Inf)/Integer
NB	Total number of binary bits to generate	None	100	(0, Inf)/Real
BR	Bit rate of the generated binary sequence	Hz	1000	(0, Inf)/Real
T	True output value	Volt	1	(-Inf, Inf)/Real
F	False output value	Volt	0	(-Inf, Inf)/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Output	Output signal consisting of a periodic binary sequence (real)			

Notes

This model generates a periodic binary sequence of T's and F's with a BR bit rate . The period of this bit sequence is given by PERIOD and the bits generated during each period are specified by BIT_PATTERN in binary format. For example, if BIT_PATTERN is set to 1010 and PERIOD is set to 4, then output sequence is FTFTFTFT..... Note that the pattern always starts with the least significant bit of BIT_PATTERN. It is common that the parameters T and F are set to the default values of 1 and 0 respectively. In this case, this model outputs a binary sequence.

Netlist Form

```
ABGEN:Name n1  nexsys_component=BGEN NB=val  BIT_PATTERN=val
+ PERIOD=val  BR=val
+ Rout=Val]
```

Netlist Example

```
ABGEN:1 1 nexsys_component=BGEN NB=200 BIT_PATTERN=10 PERIOD=4
BR=2KHZ
```

Pseudo Random Binary Source (BSRC)

Property	Description	Units	Default	Range/Type
NB	Total number of binary bits to generate	None	100	(0, Inf)/Real
BR	Bit rate of the generated binary sequence	Hz	1000	(0, Inf)/Real
SEED	Random seed	None	0	[0, Inf)/Integer
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Output	Output signal (integer)			

Notes

This model generates NB random binary bits (0's and 1's) with equal probability. The output bit rate is specified by BR.

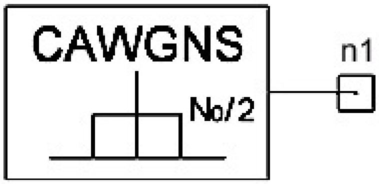
Netlist Form

```
ABSRC:Name n1 nexsys_component=BSRC   NB=val  BR=val  SEED=val
[Rout=Val]
```

Netlist Example

```
ABSRC:1 1  nexsys_component=BSRC NB=200  BR=100KHZ  SEED=57824
```

Additive White Gaussian Noise Source, Complex (CAWGNS)



Property	Description	Units	Default	Range/Type
NSAMP	Number of samples	None	100	[1, Inf)/Integer
Seed	Random Seed	None	0	[0, Inf)/Integer
Noise_Power	Noise power	Watt	1	[0, Inf)/Real
Sample_Rate	Output bit rate in Hz	Hz	1000	(0, Inf)/Integer
FC	Carrier frequency in Hz	Hz	0	[0, Inf)/Real
ROUT	Output impedance	Ohm	50	[0, Inf)/Real
Ports				
Output	Output signal (complex)			

Notes

This model generates a complex additive white Gaussian noise signal. The output voltage is given by

$$V_{out}(t) = A(t)\cos(2\pi f_c t) - B(t)\sin(2\pi f_c t)$$

Where A(t) and B(t) are independent random white Gaussian processes each with a standard deviation given by

$$\sigma = \sqrt{2 \times Rout \times NoisePower}$$

for envelope analysis

or

$$\sigma = \sqrt{4 \times Rout \times NoisePower}$$

for instantaneous analysis

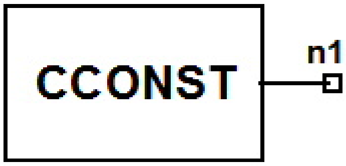
Netlist Form

```
ACAWGNS:Name n1 nexsys_component=CAWGNS NSAMP=val [SEED=val]
Noise_Power=val
+ Sample_Rate=val [FC=val] [ROUT=val]
```

Netlist Example

```
ACAWGNS:1 1 nexsys_component=CAWGNS nsamp=1024 seed=10
Noise_Power=10dbm
+ Sample_Rate=200KHz
```

Constant Source Complex (CCONST)



Property	Description	Units	Default	Range/Type
REAL_CONST	Real part	Volt	1	(-Inf, Inf)/Real
IMAG_CONST	Imaginary part	Volt	1	(-Inf, Inf)/Real
NSAMP	Number of samples to output	None	100	(0, Inf)/Integer
SAMPLE_RATE	Output sample rate	Hz	1000	(0, Inf)/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Output	Output signal (complex)			

Notes

1. This model outputs a stream of complex samples, each of value REAL_CONST + jIMAG_CONST
   for a total of NSAMP samples The sampling rate of the output signal is SAMPLE_RATE Hz.

Netlist Form

```
ACCONST:Name n1  nexsys_component=CCONST REAL_CONST=val
IMAG_CONST=val  NSAMP=val

+ SAMPLE_RATE=val [Rout=Val]
```

Netlist Example

```
ACCONST:1 1  nexsys_component=CCONST REAL_CONST=1V
IMAG_CONST=1V  NSAMP=100

+ SAMPLE_RATE=1KHZ
```

Data File Source, Complex (CFILESRC)

Property	Description	Units	Default	Range/Type
NSAMP	Number of samples to read from external file	None	100	(0, Inf)/Integer
SAMPLE_ RATE	Rate at which samples output from source file	Hz	1000	(0, Inf)/Real
FILE	Name of the external file	None	<Filename>	String
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Output	The output signal (complex)			

Notes

This model reads complex type data from an external file and outputs it at a rate equals to SAMP_RATE. The file should contain the ascii data to be read out. The data should be stored on a sample by sample basis the sample’s real value followed by its imaginary value. If the file contains fewer than NSAMP data points, the data in the file is read in a periodic fashion until NSAMP samples are output.

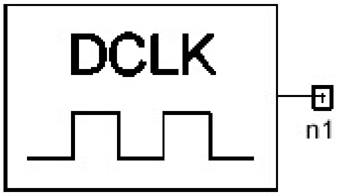
Netlist Form

```
ACFILESRC:Name n1  nexsys_component=CFILESRC NSAMP=val
SAMPLE_RATE=val File= val +[Rout=Val]
```

Netlist Example

```
ACFILESRC:1 1 nexsys_component=CFILESRC NSAMP=1000
SAMPLE_RATE=3.5MHZ
```

Digital Clock (DCLK)



Property	**Description**	**Units**	**Default**	**Range/Type**
Period	Clock time period, in time units	Sec	1	(0, Inf)/Real
Delay	Clock delay from time zero, in time units	Sec	0	[0, Inf)/Real
Duty	Clock duty cycle	None	0.5	[0, 1]/Real
NSAMP	Number of samples	None	100	(0, Inf)/Integer
Sample_Rate	Sample rate	Hz	0	(0, Inf)/Real
Phase	Output phase shift	Deg	0	(-Inf, Inf)/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Output	The output clock signal (real)			

Notes

1. The output amplitude of the clock signal is either 0V or 1V. In the time interval 0 ≤ t < Delay, the output is 0V and at time t=Delay, the clock is at 1V. For time t ≥ Delay, the output oscillates with the specified period and duty values.

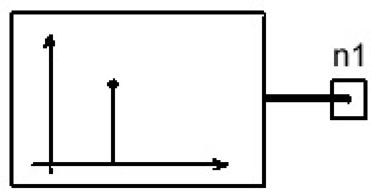
Netlist Form

```
ADCLK:Name n1  nexsys_component=DCLK PERIOD=val  DELAY=val
DUTY=val  NSAMP=val

+ SAMPLE_RATE=val [Phase=val]   [Rout=Val]
```

Netlist Example

```
ADCLK:1 5  nexsys_component=DCLK PERIOD=1us  DELAY=3us
DUTY=0.5  NSAMP=200
+ SAMPLE_RATE=2KHZ Phase=45
```

Impulse Waveform Generator (IMPULSE)



Property	Description	Unit	Default	Range/Type
NSAMP	Number of samples of the output waveform	None	100	[1,INF) /Integer
SAMPLE_ RATE	Output sample rate	Hz	1000	(0,INF)/Real
A	Amplitude of impulse waveform	Volt	1	(-INF,INF) /Real
D	Number of delay samples	None	20	[0,INF) /Integer
Rout	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Output	Output signal (real)			

Notes

This model generates an impulse signal with amplitude A and delay D.

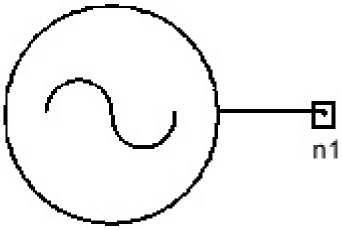
Netlist Form

```
AIMPULSE:Name n1 nexsys_component=IMPULSE NSAMP=val Sample_Rate=val
A=val D=val
+ [ROUT=val]
```

Netlist Example

```
AIMPULSE:1 1 nexsys_component=IMPULSE nsamp=1024
Sample_Rate=200KHz A=1 D=20
```

One Port Oscillator (OSC)



Property	Description	Units	Default	Range/Type
NSAMP	Number of samples	None	1024	(0, Inf)/Integer
SAMPLE_ RATE	Output sample rate	MHz	102.4	(0, Inf)/Real
PLO	Average Power at oscillator output	Watt	0.01	[0, Inf)/Real
FLO	Center frequency	MHz	1	[0, Inf)/Real
NOISEON	Noise: 1 for On, 0 for Off	None	1	[0, 1]/Integer
DivNoiseOn	Divider noise: 1 for On, 0 for Off	None	1	[0,1]/Integer
VcoNoiseOn	Vco noise: 1 for On, 0 for Off	None	1	[0, 1]/Integer
F1	Frequency offset from **FLO**, region 1	Hz	0	(0, Inf)/Real
F2	Frequency offset from **FLO**, region 2	Hz	0	(0, Inf)/Real
M2	Phase noise magnitude at **F2** (i.e., phase noise floor) in dB	dB	-180	(-Inf, 0]/Real
TYPE	0: Low loaded Q 1: High loaded Q	None	0	[0, 1]/Integer
FM1...n	Frequency offset	Hz	100	(0,Inf)/Real
SBN1...n	Sideband noise in dB at frequency offset	dB	-80	(-Inf,0)/Real
FILE	Filename for FM, SBN data	None	<Project>	String
PHASE	Output Phase Shift	Deg	0	(-Inf, Inf)/Real
SEED	Random seed used for phase noise generation	None	0	[0, Inf)/Integer
Wavetype	Output waveform type	None	0	[0, 1]/Integer

	0: Sinusoid 1: Sawtooth			
ROUT	Output impedance	Ohm	50	[0, Inf)/Real
Ports				
Output	Output signal (complex)			

Note:

1. All phase noise data must be provided if output is to include phase noise effects
2. In general, the output voltage of this model is given by:

$$V_{out}(t) = A\cos(2\pi f_c t + PHASE + \theta_n(t))$$

where

$$A = \sqrt{4R_{out}P_{LO}}$$

for envelope analysis

or

$$A = \sqrt{8R_{out}P_{LO}}$$

for instantaneous analysis

and $\Theta_n(t)$ is the random phase noise component at time *t*. This phase noise component is only nonzero if the NOISEON parameter is set to 1, otherwise, the oscillator is assumed noiseless.

The power spectral density of the random phase noise processes is given by the Leeson’s model [1]

$$L(f_m) = 10\log\left\{\left[1 + \frac{f_{lo}^2}{(2f_m q_{load})^2}\right]\left(1 + \frac{f_c}{f_m}\right) \bullet \frac{FkT}{2p_{lo}}\right\}(dB)$$

where f_c is the flicker noise frequency and q_{load} is the loaded Q. The noise floor M2 is shown in the following figure.

$$M2 = \frac{FkT}{2p_{lo}}$$

3. The frequency offsets **F1** and **F2** must be consistent with the specified oscillator **TYPE** as shown in the phase noise plots that follow. For a low qload, **F1** and **F2** correspond to fc and flo/2qload respectively while for a high qload, **F1** and **F2** correspond to flo/2qload and f_c respectively.
4. The indexed parameters “FM” and “SBN” allow the user to specify measured noise data. When measured noise data is provided, the model ignores the parameters QLOAD, F, R, FC.
5. The “FILE” parameter identifies a data file for the phase noise parameters FM and SBN. The file name must have a .dsp extension, and must be in DSP format:

```
xy

fm1 sbn1


...


fmN sbnN
```

Where the first column is the frequency offset in Hz and the second column is the sideband noise in dB. For example:

```
xy
100 -80
1000 -90
...
```

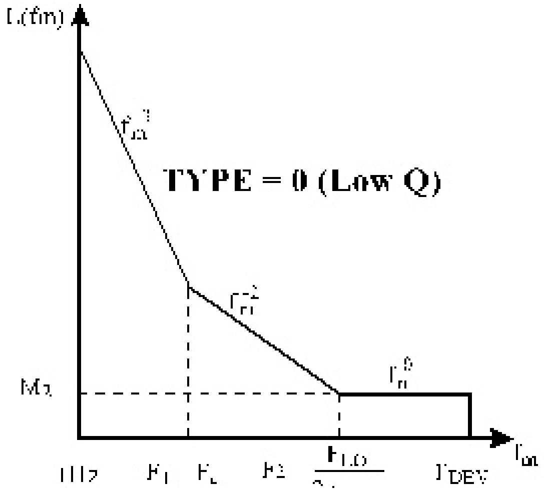
If a valid “FILE” parameter is present, the data on the file is used and the corresponding “FM” and “SBN” parameters in the netlist is ignored. Any “FM” and “SBN” parameters in the netlist that are not also defined in the data file is used.

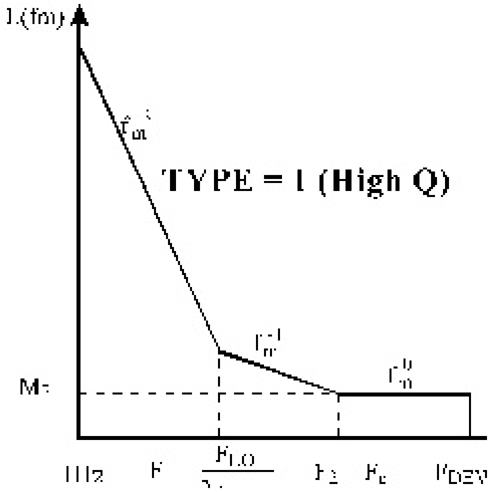
6. When the parameter “VcoNoiseOn” is set to 1, VCO noise is simulated. Otherwise, VCO noise is not incorporated in the simulation. The same happens to the divider noise. Note that noise simulation is expensive, so when it is not needed, the two parameters should be activated.
7. A random phase noise process is generated by filtering a white Gaussian

> random sequence through a filter with a frequency response $H(f_m)$, where
>
> $$H(f_m) = \sqrt{L(f_m)}$$

This frequency response is decomposed into three regions: near-carrier region (fm ≤ F1), far-carrier region (F1 < fm < F2) and the White noise region (fm ≥ F2). Regions one and two are represented in the frequency domain using 8192 frequency points each. Region one typically uses a much smaller frequency resolution than region 2. Region 3 is modeled as an additive white Gaussian process. The total random phase noise process is the sum of the contributions from each region.

Since in general the sampling frequency of the generated phase noise process is less than the actual output sampling frequency F_S, linear interpolation is applied in the time domain on the generated phase noise process $\Theta_n(t)$ to ensure it has the same sampling rate as that of the output signal.





Netlist Form

```
AOSC:Name n1 nexsys_component=OSC  FLO=val  PLO=val  NSAMP=val
SAMPLE_RATE=val

+ [PHASE=val]   [F1=val] [F2=val] [FDEV=val] [M2=val] [TYPE=val]

+[DivNoiseOn=val] [VcoNoiseOn=val] [FM1..n=val] [SBN1..n=val]
[FILE='filename']
```

```
+ [SEED=val] [Wavetype=val] [Rout=val]
```

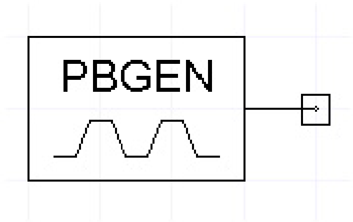
Netlist Example

```
AOSC:1 1 nexsys_component=OSC FLO=800MHZ PLO=10dbm NSAMP=1000
SAMPLE_RATE=1MHZ

+ PHASE=90  F1=150Hz  F2=10KHz  FDEV=100KHz M2=-180dB TYPE=0
```

References

1. Ulrich L. Rohde, J. Whitaker, and T.T.N. Bucher, *Communications Receivers*, McGraw-Hill, 1996.

Periodic Binary Bits Generator, Waveform Output (PBGEN)



Property	Description	Unit	Default	Range/Type
Bit_Pattern	Pattern of bits to generate during each period in binary format	None	0101	String
Period	Period of the generated binary sequence	None	1	(0, Inf)/Integer
NB	Total number of binary bits to generate	None	100	(0, Inf)/Integer
BR	Bit rate of the generated binary sequence	Hz	1000	(0, Inf)/Real
T	True output value	Volt	1	(-Inf,Inf)/Real
F	False output value	Volt	0	(-Inf,Inf)/Real
V0	Initial value	Volt	0	(-Inf,Inf)/Real
TS	Sampling time	Sec	1e-6	(0,Inf)/Real
TR	Rise time	Sec	0	[0,Inf)/Real
TF	Fall time	Sec	0	[0,Inf)/Real
DCD	Duty cycle distortion, fraction of UI	None	0	[0,1)/Real
TXRJ	Gaussian random transmit jitter	None	0	
TXPJ	Periodic random transmit jitter	None		
TXUJ	Uniform random transmit jitter	None		
RANDOM_ SEED	Seed for random jitter	None	None	[0,MAXINT)/Integer
Rout	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Output	Output signal (real)			

Notes

This model outputs a periodic waveform defined by the user specified parameters.

This generated output waveform is a periodic binary waveform of T's and F's with a BR bit rate and a TS sampling period. The period of this bit sequence, in bits, is given by PERIOD and the bits generated during each period are specified by BIT_PATTERN in binary format. For example, if BIT_PATTERN = 1010, PERIOD = 4 bits, BR = 10 bits/sec, TS = 50 ms, then output sequence is (in samples) FFTTFFTTFFTT ... . Note that the resulting number of samples per bit in this case is 2 = 1/(TS*BR). Also note that the pattern always starts with the least significant bit of BIT_PATTERN. It is common that the parameters T and F are set to the default values of 1 and 0 respectively. In this case, the model outputs a binary sequence.

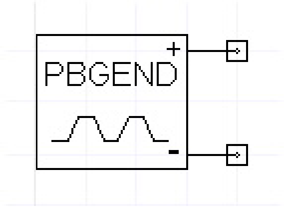
Netlist Form

```
APBGEN:NAME n1 nexsys_component=PBGEN Bit_Pattern=val Period=val
[NB=val] [BR=val] [T=val] [F=val]
+ [V0=val] [TS=val] [TR=val] [TF=val]
+ [DCD=val][TXRJ=val][[TXPJ=val][TXUJ=val][RANDOM_SEED=val]
+ [Rout=val]
```

Netlist Example

```
APBGEN:1 net12  nexsys_component=PBGEN Bit_Pattern=10110010101100
Period=6 NB=1024
```

Periodic Binary Bits Generator, Differential Waveform Outputs (PBGEND)



Property	Description	Unit	Default	Range/Type
Bit_Pattern	Pattern of bits to generate during each period in binary format	None	0101	String
Period	Period of the generaged binary sequence in bits	None	1	(0, Inf)/Integer
NB	Total number of binary bits to generate	None	100	(0, Inf)/Integer
BR	Bit rate of the generated binary sequence	Hz	1000	(0, Inf)/Real
T	True output value	Volt	1	(-Inf,Inf)/Real
F	False output value	Volt	0	(-Inf,Inf)/Real
V0	Initial value	Volt	0	(-Inf,Inf)/Real
TS	Sampling time	Sec	1e-6	(0,Inf)/Real
TR	Rise time	Sec	0	[0,Inf)/Real
TF	Fall time	Sec	0	[0,Inf)/Real
DCD	Duty cycle distortion, fraction of UI	None	0	[0,1)/Real
TXRJ	Gaussian random transmit jitter	None	0	
TXPJ	Periodic random transmit jitter	None		
TXUJ	Uniform random transmit jitter	None		
RANDOM_ SEED	Seed for random jitter	None	None	[0,MAXINT)/Integer
Rout1	Output1 impedance	Ohm	0	[0,Inf)/Real
Rout2	Output2 impedance	Ohm	0	[0,Inf)/Real
Ports				
Output1	Output1 signal (real)			

Output2	Output2 signal (real)

Note:

This model outputs a periodic waveform to the first output defined by the user specified parameters. The second output is the negative of the first output.

This generated “positive” output waveform is a periodic waveform of T's and F's with a BR bit rate and a TS sampling period. The period of this bit sequence, in bits, is given by PERIOD and the bits generated during each period are specified by BIT_PATTERN in binary format. For example, if BIT_PATTERN = 1010, PERIOD = 4 bits, BR = 10 bits/sec, TS = 50 ms, then output sequence is (in samples) F/2F/2T/2T/2F/2F/2T/2T/2F/2F ... . Note that the resulting number of samples per bit in this case is 2 = 1/(TS*BR). Also note that the pattern always starts with the least significant bit of BIT_PATTERN. It is common that the parameters T and F are set to the default values of 1 and 0 respectively.

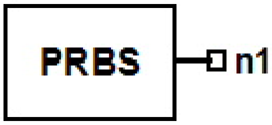
Netlist Form

```
APBGEND:NAME n1 n2 nexsys_component=PBGEND Bit_Pattern=val
Period=val [NB=val] [BR=val] [T=val] [F=val]
+ [V0=val] [TS=val] [TR=val] [TF=val]
+ [DCD=val][TXRJ=val][[TXPJ=val][TXUJ=val][RANDOM_SEED=val]
+ [Rout1=val] [Rout2=val]
```

Netlist Example

```
APBGEND:1 1 2 nexsys_component=PBGEND Bit_Pattern=10 Period=6
NB=1024
```

Pseudo Random Binary Source (PRBS)



Property	Description	Units	Default	Range/Type
NB	Total number of binary bits to generate	Sec	100	[1, Inf)/Integer
BR	Bit rate of the generated binary sequence in bits per second	Bits/sec	1000	(0, Inf)/Real
T	True output value	Volt	1	(-Inf, Inf)/Real
F	False output value	Volt	0	(-Inf, Inf)/Real
V0	Initial value	Volt	0	(-Inf, Inf)/Real
TS	Sampling time	Sec	1e-006	(0, Inf)/Real
TR	Rise time	Sec	0	[0, Inf)/Real
TF	Fall time	Sec	0	[0, Inf)/Real
SEED	Random seed	None	0	[0, Inf)/Integer
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Output	Output signal (real)			

Notes

This model generates the Pseudo Random Binary signal, and output it as a waveform according to the specified parameters.

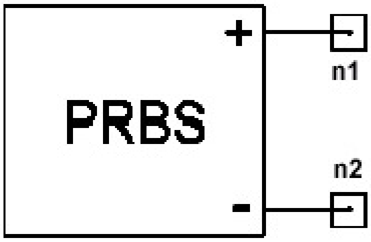
Netlist Form

```
APRBS:Name n1  nexsys_component=PRBS NB=val  BR=val TS=val
[T=val] [F=val] [V0=val] [TR=val] [TF=val] [SEED=val]
[Rout=val]
```

Netlist Example

```
APRBS:1 1  nexsys_component=PRBS NB=100  BR=1000 TS=1e-6
```

Pseudo Random Binary Source:Differential Waveform Outputs (PRBSD)



Property	Description	Units	Default	Range/Type
NB	Total number of binary bits to generate	Sec	100	[1, Inf)/Integer
BR	Bit rate of the generated binary sequence in Hz	Hz	1000	(0, Inf)/Real
T	True output value	Volt	1	(-Inf, Inf)/Real
F	False output value	Volt	0	(-Inf, Inf)/Real
V0	Initial value	Volt	0	(-Inf, Inf)/Real
TS	Sampling time	Sec	1e-006s	(0, Inf)/Real
TR	Rise time	Sec	0	[0, Inf)/Real
TF	Fall time	Sec	0	[0, Inf)/Real
SEED	Random seed	None	0	[0, Inf)/Integer
ROUT1	Output1 impedance	Ohm	0	[0, Inf)/Real
ROUT2	Output2 impedance	Ohm	0	[0, Inf)/Real
Ports				
Output1	Output1 signal (real)			
Output2	Output2 signal (real)			

Note:

This model generates the Pseudo Random Binary signal, and output it as a waveform according to the specified parameters to the first output. The signal at the second output is the negative of the first output.

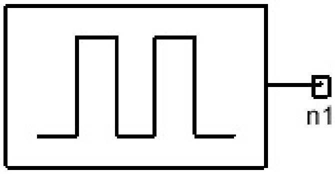
Netlist Form

```
APRBSD:Name n1 nexsys_component=PRBSD NB=val  BR=val TS=val
[T=val] [F=val] [V0=val] [TR=val] [TF=val] [SEED=val]
[Rout1=val] [Rout2=val]
```

Netlist Example

```
APRBSD:1 1 nexsys_component=PRBSD NB=100  BR=1000 TS=1e-6
```

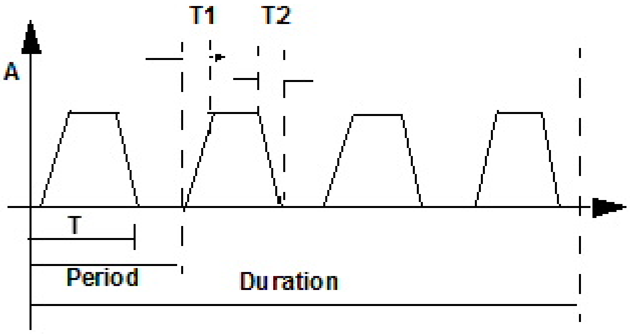
Periodic Pulse Waveform Generator (PULSE)



Property	Description	Units	Default	Range/Type
NSAMP	Number of samples of the output waveform	None	100	(0, Inf)/Integer
SAMPLE_RATE	Output sample rate	Hz	1000	(0, Inf)/Real
PERIOD	Time period of pulse	Sec	0.01s	(0, Inf)/Real
A	Amplitude of pulse	Volt	1	(-Inf, Inf)/Real
DUTY	Duty cycle	None	0.5	[0, 1]/Real
T1	Pulse rise time	Sec	0	[0, Inf)/Real
T2	Pulse fall time	Sec	0	[0, Inf)/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Output	Output signal (real)			

Notes

This model generates a periodic pulse voltage waveform, as follows:



$$DURATION = \frac{NSAMP}{SampleRate}$$

$$T = PERIOD \bullet DUTY$$

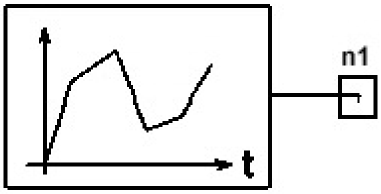
Netlist Form

```
APULSE:Name n1  nexsys_component=PULSE NSAMP=val
SAMPLE_RATE=val  PERIOD=val  A=val  DUTY=val [T1=val] [T2=val]
[Rout=val]
```

Netlist Example

```
APULSE  1  nexsys_component=PULSE NSAMP=1000 SAMPLE_RATE=100KHZ

+  PERIOD=10mS  A=1V DUTY=0.3
```

Piecewise Linear Source (PWL)



Property	Description	Units	Default	Range/Type
T1....Tn	Time instance	Sec	0	[0, Inf)/Real
V1....Vn	Voltage at corresponding time instance	Volt	0	[0, Inf)/Real
File	File name	None	Optional	String
NSAMP	Number of samples of the output waveform	None	100	(0, Inf)/Real
SAMPLE_RATE	Output sample rate	Hz	1000	(0, Inf)/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Output	Output signal (real)			

Notes

1. This model outputs a piece wise linear waveform. The waveform is defined by either the parameters T and V, or by the external file. The external file should be a text file with two columns of data: the first column being time points and the second column being voltage points. Note that the external file is predominant over the parameters T and V when both are specified.
2. Linefeeds are optional in external files, which means that:

```
# s v
0 0
1 0
2 1
3 1
4 1 5 1 6 2 7 2 8 0 9 0 10 1
```

is parsed the same as:

0 0
1 0
2 1
3 1
4 1
5 1
6 2
7 2
8 0
9 0
10 1

Netlist Form

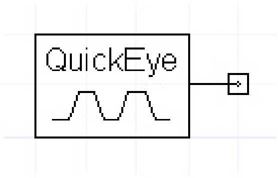
```
APWL:Name n1  nexsys_component=PWL [T1...Tn=val] [V1...Vn=val]
[File=val] NSAMP=val  SAMPLE_RATE=val [Rout=val]
```

Netlist Example

```
APWL:1 1  nexsys_component=PWL NSAMP=1000  SAMPLE_RATE=100KHZ
T1=1s T2=2s T3=4s V1=1v V2=5.2v V3=1.3v
```

```
APWL:1 1  nexsys_component=PWL NSAMP=1000  SAMPLE_RATE=100KHZ
FILE=”pwl.txt”
```

QuickEye Source (QE_Source)



Property	Description	Unit	Default	Range/Type
Bit_Pattern	Pattern of bits to generate during each period in binary format	None	0101	String
Period	Period of the generated binary sequence	None	1	(0, Inf)/Integer
NB	Total number of binary bits to generate	None	100	(0, Inf)/Integer
UI	Unit interval	Second	1e-9	(0, Inf)/Real
STEP_RESP_ NUM_UI	Number of unit intervals to run step response	None	10	(0, MAX_ INT]/Integer
TRISE	Rise time	Sec	0	[0,Inf)/Real
TFALL	Fall time	Sec	0	[0,Inf)/Real
DCD	Duty cycle distortion, fraction of UI	None	0	[0,1)/Real
TXRJ	Gaussian random transmit jitter	None	0	
TXPJ	Periodic random transmit jitter	None		
TXUJ	Uniform random transmit jitter	None		
RANDOM_ SEED	Seed for random jitter	None	None	[0,MAXINT)/Integer
Rout	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Output	Output signal (real)			

Notes

This model outputs a periodic waveform defined by the user specified parameters for Quick Eye analysis.

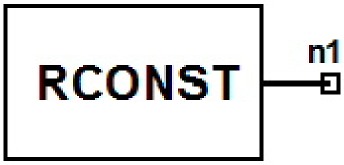
Netlist Form

```
AQESRC:NAME n1 nexsys_component=quickeye_source
+ Bit_Pattern=val Period=val [NB=val] [UI=val] [STEP_RESP_NUM_UI=val]
+ [TRISE=val] [TFALL=val]
+ [DCD=val][TXRJ=val] [TXPJ=val] [TXUJ=val] [RANDOM_SEED=val]
+ [Rout1=val] [Rout2=val]
```

Netlist Example

```
AQESRC:1 1  nexsys_component=quickeye_source
+ Bit_Pattern=1110010101100101 Period=6 NB=1024 UI=1e-9
+ TRISE=2e-10 TFALL=2e-10
+ TXRJ=0.2 RANDOM_SEED=201
```

Constant Source, Real (RCONST)



Property	Description	Units	Default	Range/Type
CONSTANT	Constant value	Volt	1	(-Inf, Inf)/Real
NSAMP	Number of Samples	None	100	(0, Inf)/Integer
SAMPLE_RATE	Output sample rate	Hz	1000	(0, Inf)/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Output	Output signal (real)			

Notes

This model outputs a stream of real samples, each of value CONSTANT (for a total of NSAMP samples). The sampling rate of the output signal is SAMPLE_RATE Hz.

Netlist Form

```
ARCONST:Name n1  nexsys_component=RCONST Constant=val
NSAMP=val  Sample_Rate=val [Rout=Val]
```

Netlist Example

```
ARCONST:1 1  nexsys_component=RCONST Constant=1V  NSAMP=100
Sample_Rate=1KHZ
```

Data File Source, Real (RFILESRC)

Property	Description	Units	Default	Range/Type
NSAMP	Number of samples to read from external file	None	100	(0, Inf)/Integer
SAMPLE_ RATE	Rate at which samples output from source file	Hz	1000	(0, Inf)/Real
File	Name of the external data file	None	<Filename>	String
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Output	The output signal (real)			

Notes

This model reads real type data from an external file and outputs it at a rate equals to SAMPLE_ RATE. The file should have no header information, it should contain the ascii data to be read out. If the file contains fewer than NSAMP data points, the data in the file is read in a periodic fashion until NSAMP samples are output.

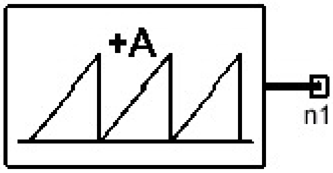
Netlist Form

```
ARFILESRC:Name n1  nexsys_component=RFILESRC NSAMP=val
SAMPLE_RATE=val FILE=val +[Rout=val]
```

Netlist Example

```
ARFILESRC:1 1  nexsys_component=RFILESRC NSAMP=1000
SAMPLE_RATE=3.5MHZ FILE=”data.txt”
```

Periodic Sawtooth Waveform Generator (SAWTOOTH)



Property	Description	Units	Default	Range/Type
NSAMP	Number of samples of the output waveform	None	100	(0, Inf)/Integer
SAMPLE_ RATE	Output sample rate	Hz	1000	(0, Inf)/Real
PERIOD	Time period of sawtooth	Sec	0.01	[0, Inf)/Real
A	Amplitude of sawtooth	Volt	1	(0,Inf)/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Output	Output of voltage waveform generator (real)			

Notes

This model generates a periodic sawtooth voltage waveform with a total duration calculated by:

$$Duration = \frac{NSAMP}{SampleRate}$$

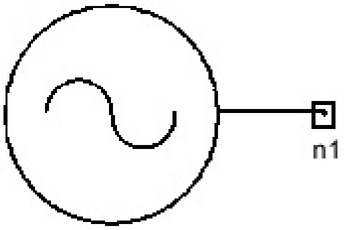
Netlist Form

```
ASAWTOOTH:Name n1  nexsys_component=SAWTOOTH NSAMP=val
SAMPLE_RATE=val  PERIOD=val  A=val [Rout=Val]
```

Netlist Example

```
ASAWTOOTH:1 1  nexsys_component=SAWTOOTH NSAMP=1000
SAMPLE_RATE=100KHZ  PERIOD=10mS  A=1V
```

Sine Wave (SIN)



Property	Description	Units	Default	Range/Type
NSAMP	Number of samples	None	1024	(0, Inf)/Integer
SAMPLE_RATE	Output sample rate	MHz	102.4	(0, Inf)/Real
F	Output frequency	MHz	1	[0, Inf)/Real
AMPLITUDE	Amplitude	Volt	1	(-Inf, Inf)/Real
OFFSET	Voltage offset	Volt	0	(-Inf, Inf)/Real
PHASE	Output Phase Shift	Deg	0	(-Inf, Inf)/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Output	Output signal (real)			

Notes

The output voltage of this model is given by:

$$V_{out}(t) = ASin(2\pi ft + PHASE) + OFFSET$$

where *A* is the amplitude. Note that the sampling rate must be at least twice larger than the frequency of the sinusoid.

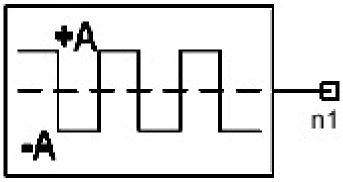
Netlist Form

```
ASIN:Name n1 nexsys_component=SIN [NSAMP=val]
[SAMPLE_RATE=val][F=val] [AMPLITUDE=val] [OFFSET=val]
[PHASE=val] [Rout=val]
```

Netlist Example

```
ASIN:1 n1 nexsys_component=SIN NSAMP=2048 SAMPLE_RATE=10MHz
F=1MHz AMPLITUDE=2v OFFSET=0.5v PHASE=45
```

Periodic Square Waveform Generator (SQRSRC)



Property	Description	Units	Default	Range/Type
NSAMP	Number of samples of the output waveform	None	100	(0, Inf)/Integer
SAMPLE_ RATE	Output sample rate	Hz	1000	(0, Inf)/Real
PERIOD	Time period of square	Sec	0.01	[0, Inf)/Real
A	Amplitude of square	Volt	1V	(0,Inf)/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Output	Output of voltage waveform generator (real)			

Notes

1. This model generates a periodic square voltage waveform with a total duration calculated by:

$$DURATION = \frac{NSAMP}{SampleRate}$$

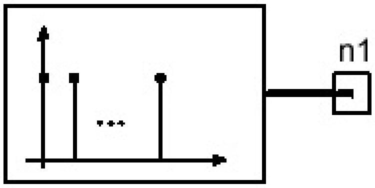
Netlist Form

```
ASQRSRC:Name n1  nexsys_component=SQRSRC NSAMP=val
SAMPLE_RATE=val  PERIOD=val  A=val [Rout=Val]
```

Netlist Example

```
ASQRSRC:1 1  nexsys_component=SQRSRC NSAMP=1000
SAMPLE_RATE=100KHZ  PERIOD=10mS  A=1V
```

Step Waveform Generator (STEPGEN)



Property	Description	Unit	Default	Range/Type
NSAMP	Number of samples of the output waveform	None	100	[1,INF) /Integer
SAMPLE_ RATE	Output sample rate	Hz	1000	(0,INF)/Real
A	Amplitude of step waveform	Volt	1	(-INF,INF) /Real
NSAMP_A	Number of samples with amplitude A	None	20	[0,INF) /Integer
Rout	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Output	Output signal (real)			

Notes

This model generates a step signal. The first NSAMP_A samples are of amplitude A, while the rest of the samples are of 0 value.

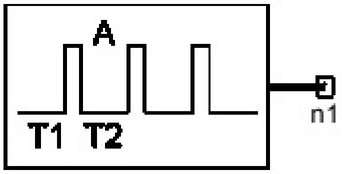
Netlist Form

```
ASTEPGEN:Name n1 nexsys_component=STEPGEN NSAMP=val
Sample_Rate=val A=val NSMAP_A=val [ROUT=val]
```

Netlist Example

```
ASTEPGEN:1 1 nexsys_component=STEPGEN nsamp=1024
Sample_Rate=200KHz A=1 NSAMP_A=20
```

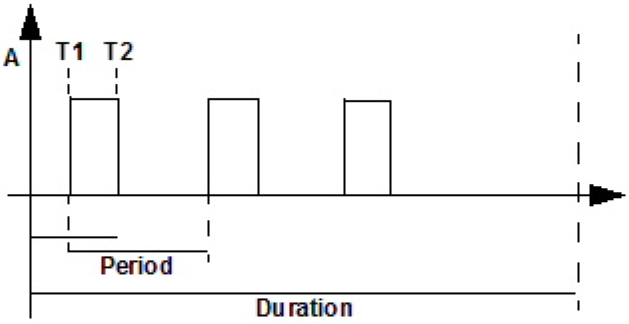
Periodic Step Waveform Generator (STEPSRC)



Property	**Description**	**Units**	**Default**	**Range/Type**
NSAMP	Number of samples of the output waveform	None	100	(0, Inf)/Integer
SAMPLE_ RATE	Output sample rate	Hz	1000	(0, Inf)/Real
PERIOD	Time period of step	Sec	0.01	[0, Inf)/Real
A	Amplitude of step	Volt	1v	(0,Inf)/Real
T1	Start time of step	Sec	0s	[0, Inf)/Real
T2	Stop time of step	Sec	1s	[0, Inf)/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Output	Output of voltage waveform generator (real)			

Notes

1. This model generates a periodic step voltage waveform, as follows:



$$DURATION = \frac{NSAMP}{SampleRate}$$

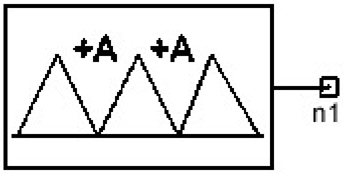
Netlist Form

```
ASTEPSRC:Name n1 nexsys_component=STEPSRC NSAMP=val
SAMPLE_RATE=val PERIOD=val A=val

+ T1=val T2=val [Rout=Val]
```

Netlist Example

```
ASTEPSRC:1 nexsys_component=STEPSRC NSAMP=1000
SAMPLE_RATE=100KHZ PERIOD=10mS A=1V T1=5mS

+ T2=8mS
```

Periodic Triangle Waveform Generator (TRIANGLE)



Property	Description	Units	Default	Range/Type
NSAMP	Number of samples of the output waveform	None	100	(0, Inf)/Integer
SAMPLE_ RATE	Output sample rate	Hz	1000	(0, Inf)/Real
PERIOD	Time period of triangle	Sec	0.01	[0, Inf)/Real
A	Amplitude of triangle	Volt	1	(0,Inf)/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Output	Output of voltage waveform generator (real)			

Notes

This model generates a periodic triangle voltage waveform, with a total duration calculated by:

Duration = NSAMP / Sample_Rate

Netlist Form

```
ATRIANGLE:Name n1  nexsys_component=TRIANGLE NSAMP=val
+ SAMPLE_RATE=val  PERIOD=val  A=val
[Rout=Val]
```

Netlist Example

```
ATRIANGLE:1 1  nexsys_component=TRIANGLE NSAMP=1000
SAMPLE_RATE=100KHZ PERIOD=10mS  A=1V
```

WCDMA Multi-Antenna

This topic describes the following System components:

"Multipath Nonfading Channel for Linear Antenna Array (MNCHLAA) " on the facing page

"Multipath Rayleigh Fading Channel for Linear Antenna Array (MRFCHLAA) " on page 38-534

Multipath Nonfading Channel for Linear Antenna Array (MNCHLAA)

Property	Description	Units	Default	Range/Type
L	Number of paths	None	3	[1, 12]/Integer
J	Number of antennas	None	2	[1, 16]/Integer
C	Antenna array spacing	Meter	0.1	(0, Inf)/Real
D1	Delay of first path (samples)	None	0	[0, Inf)/Integer
GAIN1	Magnitude of the complex gain factor for first path	None	1	[0, Inf)/Real
PHASE1	Phase of the complex gain factor for first path	Deg	0	[-180, 180)/Real
A1	DOA of first path	Deg	0	[-180, 180)/Real
D2~D12	Delay of nth path (samples)	None	0	[0, Inf)/Integer
GAIN2 ~GAIN12	Magnitude of the complex gain factor of all other paths	None	0	[0, Inf)/Real
PHASE2 ~PHASE12	Phase of the complex gain factor for all other paths	Deg	0	[-180, 180)/Real
A2~A12	DOA of all other paths	Deg	0	[-180, 180)/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal in complex envelope format (complex)			
Output	Multipath nonfading signal, in complex envelope format, for all antennas			

	(complex)

Notes

1. This model can be used to simulate a Multipath Nonfading Channel , then generate the signal at each antenna when Linear Antenna Array is used in the receiver.
2. Representing the RF channel as a time-variant channel and using a base-band complex envelope representation, the channel gain factor is specified by:

$$h(t)=\sum_{i=0}^{L-1} Gain_i e^{jPhase}\delta(t-\tau_i) \quad (1\le L\le 12) \qquad (1)$$

   where *L* is the number of paths, *Gain* and *Phase* are magnitude and phase of the complex gain for the *i*th path, τ_i => 0 is the channel delay which can be expressed by D_i samples.
3. The above does not consider linear antenna array. A uniformly spaced linear antenna array with *J* elements[1][2] is considered, as shown in Fig.1.

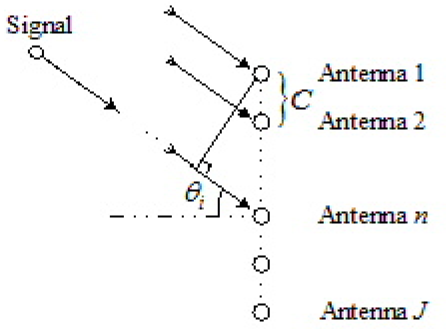


   Fig. 1 Block diagram of Linear Antenna Array

   Assuming a signal with wavelength λ arrives at the linear antenna array from a direction, which is called direction of arrival (DOA) Θ_i, and taking the first element in the array as phase reference, the relative phase shift of the received signal at the nth element can be expressed as

$$\psi_{i,n}=\frac{2\pi C(n-1)}{\lambda}\sin\theta_i \qquad (2)$$

   where *C* is the array spacing. The vector channel impulse response for the *J* elements can be expressed as

$$\vec{h}(t)=\sum_{i=0}^{L-1} Gain_i e^{jPhase_i}\vec{\beta}(\theta_i)\delta(t-\tau_i) \quad (1 \le L \le 12) \tag{3}$$

where $\beta(\Theta_i)$s the array response vector, which is given by

$$\vec{\beta}(\theta_i)=\begin{bmatrix} e^{j\psi_{i,1}} & e^{j\psi_{i,2}} & \dots & e^{j\psi_{i,J}} \end{bmatrix}^T \tag{4}$$

where $[\,]^T$ denotes the matrix transpose.

4. Note that *J* samples are outputted successively for each input sample.

Netlist Form

```
AMNCHLAA:NAME  n1 n2 nexsys_component=MNCHLAA L=val J=val C=val
D1=val  Gain1=val  Phase1=val  A1=val
+ [D2=val . . . A12=val] [RIN=val] [ROUT=val]
```

Netlist Example

```
AMNCHLAA:1 1 2 nexsys_component=MNCHLAA L=2 J =2 C = 0.17 D1 = 0
Gain1 = 1.0 Phase1 = 0DEG  A1 = 0DEG
+ D2 = 150 Gain2 = 0.1 Phase2 = 0DEG A2 = 10DEG
```

References

1. S. C. Swales, M. A. Beach, et al, “The performance enhancement of multibeam adaptive base-station antennas for cellular land mobile radio systems,” *IEEE Trans. Veh. Technol.*, vol. 39, pp. 56–67, Feb. 1990.
2. S. Tanaka, A. Harada, et al, “Experiments on coherent adaptive antenna array diversity for wideband DS-CDMA mobile radio,” *IEEE Journal on Selected Areas in Communications,* vol. 18, No.8, pp.1495-1504, Aug. 2000.

Multipath Rayleigh Fading Channel for Linear Antenna Array (MRFCHLAA)

Property	Description	Units	Default	Range/Type
L	Number of paths	None	3	[1, 12]/Integer
J	Number of antennas	None	2	[1, 16]/Integer
VM	Mobile velocity in km/h	None	12	[0, Inf)/Real
C	Antenna array spacing	Meter	0.15	(0, Inf)/Real
SEED	Random seed	None	0	(0, Inf)/Real
D1	Delay of first path (samples)	None	0	[0, Inf)/Integer
P1	Relative power of first path in dB	dB	-1e+020	(-Inf, 0]/Real
A1	DOA of first path	Deg	0	[-180, 180)/Real
D2~D12	Delay of nth path (samples)	None	0	[0, Inf)/Integer
P2~P12	Relative power of all other paths in dB	dB	-1e+020	(-Inf, 0]/Real
A2~A12	DOA of all other paths	Deg	0	[-180, 180)/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Input signal in complex envelope format (complex)			
Output	Multipath Rayleigh fading signal, in complex envelope format, for all antennas (complex)			

Notes

1. This model can be used to simulate a Multipath Rayleigh Fading Channel , then generate the signal at each antenna when Linear Antenna Array is used in the receiver.
2. The Doppler power spectrum for Multipath Rayleigh Fading Channel is given by [1][2]:

$$S_{E_z}(f) = \begin{cases} \dfrac{3b}{\omega_m}\left[1-\left(\dfrac{f-f_c}{f_m}\right)^2\right]^{-1/2} & |f-f_c| < f_m \\ 0 & \end{cases}$$

(1)

where b is the average received power, $f_m = \omega_m/2\pi$ is the maximum Doppler shift given by V_m/λ where V_m is mobile velocity and λ is the wavelength of the transmitted signal at frequency f_c.

3. Representing the RF channel as a time-variant channel and using a base-band complex envelope representation, the channel impulse response can be expressed as

$$h(t) = \sum_{i=0}^{L-1} \alpha_i(t) e^{j\varphi_i(t)} \delta(t-\tau_i) \quad (1 \le L \le 12)$$

(2)

where L is the number of paths, the amplitude $\alpha_i(t)$ for the ith path is Rayleigh distributed random variable, the phase shift $\phi(t)$ is uniformly distributed, $\tau_i \geq 0$ is the channel delay.

Since the Rayleigh fading process $\alpha_i(t)e^{j\phi_i(t)}$ is complex, the in-phase process and quadrature process for each path are implemented separately, as shown in Fig.1.

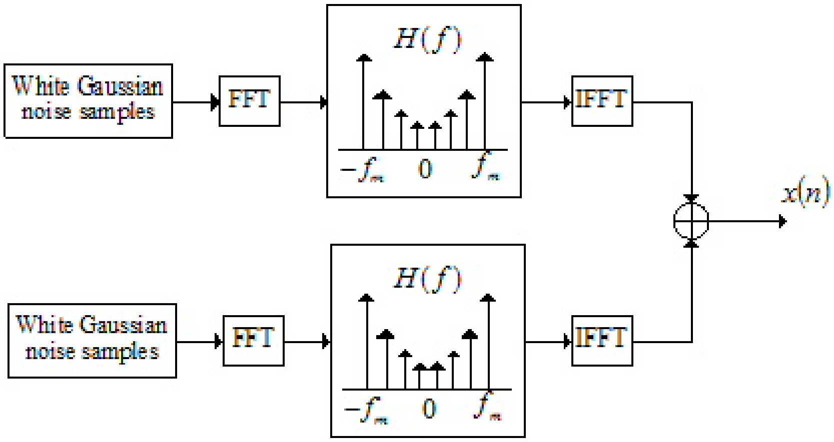


Fig. 1 Block diagram of Rayleigh fading simulator

Based on Eqn.(2), both the in-phase process and the quadrature process can be generated by passing a White Gaussian noise process through a baseband filter which has the following frequency response:

$$H(f) = \begin{cases} K\left[1-\left(\frac{f}{f_m}\right)^2\right]^{-1/4} & |f| < f_m \\ 0 & others \end{cases}$$

(3)

where *K* is constant to normalize the frequency response. The above frequency response is generated in the frequency domain using FFT with *length = 2048* points. Each point (*0* <= *K* <= *length -1*) corresponds to a certain frequency (f_k) by means of the following equation:

$f_k = k \times f_s$ (4)

where f_s is the frequency sampling interval typically chosen to be on the order of $f_m/10$. The above frequency response has an even real part and an odd imaginary part to guarantee that the filtering process generates a real in-phase and quadrature correlated Gaussian processes. Each two generated Gaussian processes are combined to generate a Rayleigh fading process. It is important to point out that whether in-phase process or quadrature process is correlated among different points but the two processes are generated independently and therefore, uncorrelated.

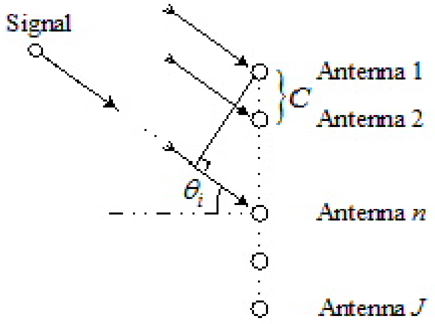
Assume that channel delay for each path can be expressed by D_i samples. Each generated Rayleigh fading process corresponds to a path with a user-specified delay D_i and relative power P_i, 0 <= i <= L-1. The expected output along the ith fading path should be the input signal delayed by D_i samples and Rayleigh-faded with the specified ith relative power P_i. The total average power contribution from all paths is always normalized to unity. This is accomplished by setting the standard deviation of the ith generated in-phase and quadrature correlated Gaussian processes to

$$\sigma_i = \sqrt{\frac{P_i}{2\sum_{i=0}^{L-1} P_i}}$$

(5)

These time series of the generated fading process is further increased in the time domain to match the sampling rate of the input signal. This is accomplished by linearly interpolating the fading process (i.e., inserting fading points between each two originally generated fading points).

4. The above does not consider linear antenna array. A uniformly spaced linear antenna array with *J* elements[3][4] is considered, as shown in Fig.2.



5. Fig. 2 Block diagram of Linear Antenna Array

   Assuming a signal with wavelength λ arrives at the linear antenna array from a direction, which is called direction of arrival (DOA) Θ_i, and taking the first element in the array as phase reference, the relative phase shift of the received signal at the nth element can be expressed as

   $$\psi_{i,n} = \frac{2\pi C(n-1)}{\lambda}\sin\theta_i$$

   (6)

   where *C* is the array spacing. The vector channel impulse response for the *J* elements can be expressed as

   $$\vec{h}(t) = \sum_{i=0}^{L-1}\alpha_i(t)e^{j\varphi_i(t)}\vec{\beta}(\theta_i)\delta(t-\tau_i) \quad (1 \le L \le 12)$$

   (7)

   where $\beta(\Theta_i)$ is the array response vector, which is given by

   $$\vec{\beta}(\theta_i) = \left[e^{j\psi_{i,1}} \quad e^{j\psi_{i,2}} \quad \ldots \quad e^{j\psi_{i,J}}\right]^T$$

   (8)

   where $[\,]^T$ denotes the matrix transpose.
5. Note that *J* samples are outputted successively for each input sample.

Netlist Form

```
AMRFCHLAA:NAME  n1 n2 nexsys_component=MRFCHLAAA L=val J=val
VM=val C=val [SEED=val] D1=val P1=val  A1=val

+ [D2=val . . . A12=val] [RIN=val] [ROUT=val]
```

Netlist Example

```
AMRFCHLAA:1 1 2 nexsys_component=MRFCHLAAA L=2 J =2 VM = 12.0 C
= 0.17 SEED = 7359749  D1 = 0  P1 = 0 A1 = 0DEG
+D2 = 150 P2 = 0 A2 = 10DEG
```

References

1. W. C. Jakes, *Microwave Mobile Communications*, New York: Wiley, 1974.
2. T. S. Rappaport, Wireless Communications: Principles and Practice, Prentice-Hall, 1996.
3. S. C. Swales, M. A. Beach, et al, “The performance enhancement of multibeam adaptive base-station antennas for cellular land mobile radio systems,” *IEEE Trans. Veh. Technol.*, vol. 39, pp. 56–67, Feb. 1990.
4. S. Tanaka, A. Harada, et al, “Experiments on coherent adaptive antenna array diversity for wideband DS-CDMA mobile radio,” *IEEE Journal on Selected Areas in Communications,* vol. 18, No.8, pp.1495-1504, Aug. 2000.

WCDMA Rake Receiver

This topic describes the following System components:

Despreader (DESPREADER)

Property	Description	Units	Default	Range/Type
L	Number of paths	None	2	[1, 16]/Integer
G	Spreading factor	None	32	[2, Inf]/Integer
S	Number of samples per chip	None	4	[1, 128]/Integer
DMAX	Maximum multipath delay for multi-path (samples)	None	31	[0, Inf)/Integer
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
RIN3	Input3 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Received signal in complex envelope format (complex)			
Input2	Multipath delays, in terms of samples (integer)			
Input3	Spreading code (complex)			
Output	Symbols after despreading on each path (complex)			

Limits

$$0 \le D_{\max} \le \left(N_p + N_d\right) \times G \times S - 1$$

Notes

1. The despreader model can be used to resolve the received multi-path signal and despread symbols on each path in DS/CDMA systems. For detailed algorithm, please refer to the **matched filter** model.
2. Note that *L* samples are outputted successively for each symbol.

Netlist Form

```
ADESPREADER:NAME  n1 n2 n3 n4 nexsys_component=DESPREADER L=val
G=val [S=val] [DMAX=val] +[RIN1=val] [RIN2=val] [RIN3=val]
[ROUT=val]
```

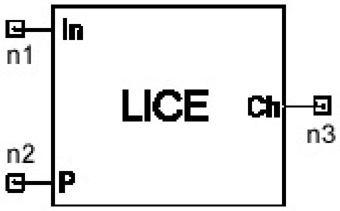
Netlist Example

```
ADESPREADER:1 1 2 3 4 nexsys_component=DESPREADER L =2 G = 32 S
= 4 DMAX = 20
```

References

1. J. G. Proakis, Digital Communications, McGraw-Hill, 2001.
2. A. J. Viterbi, CDMA: Principles of Spread Spectrum Communication, Wesley Publishing Company, 1995.
3. K. Higuchi, H. Andoh, et al, “Experimental evaluation of combined effect of coherent RAKE combining and SIR-based fast transmit power control for reverse link of DS-CDMA mobile radio,” *IEEE Journal on Selected Areas in Communications*, vol. 18, No.8, pp.1526-1535, Aug. 2000.

Channel Estimation (LICE)



Property	Description	Units	Default	Range/Type
PURPOSE	Data demodulation {0} Power control {1}	None	0	[0, 1]/Integer
L	Number of paths	None	2	[1, 16]/Integer
NP	Number of pilot symbols	None	4	[0, INF)/Integer
ND	Number of data symbols	None	36	[0, INF)/Integer
N0	Number of the first pilot symbol	None	0	[0, INF)/Integer
PHASE	Additional phase of pilot symbols	Deg	0	[-180, 180)/Real
Rin1	Input1 Impedance	Ohm	Inf	(0,INF]/Real
Rin2	Input2 Impedance	Ohm	Inf	(0,INF]/Real
Rout	Output impedance	Ohm	0	[0,INF)/Real

Limits

$0 \le N_0 \le N_d - 1$

Notes

1. The Linear interpolation channel estimation model can be used to estimate channel characteristics for all paths using pilot symbols.
2. Algorithm description: Let $r_i(n,k)$ be the nth received symbol at the output of the matched filter in the kth slot for the ith resolved path, and p(n,k) be the nth local standard pilot symbol in the kth slot. The instantaneous channel estimation of the ith resolved path is performed using the pilot symbols belonging to the kth slot as follows

$$\hat{\eta}_l(k) = \frac{1}{N_p}\sum_{n=0}^{N_p-1}\frac{r_l(n+N_0,k)}{p(n+N_0,k)}$$

(1)

where N_p is the number of pilot symbols per slot, N_0 is the number of the first pilot symbol.

The instantaneous channel estimation is used for Power control. Extend the observation interval to more than one slot to add coherently several consecutive channel estimates for Data demodulation. The channel estimation is performed by a first order interpolation filter, and the following equation (2) is used for channel estimation of the first slot:
The following equation (3) is used for channel estimation of the other slots:
where $N_s = N_p + N_d$ is number of symbols per slot. Finally, *L* samples are outputted successively for each symbol.

$$\tilde{\eta}_l(n,k) = \begin{cases} \hat{\eta}_l(k) & 0 \le n < N_0 + N_p \\ \left(1 - \frac{n - N_0 - (N_p - 1)/2}{N_s}\right)\hat{\eta}_l(k) + \frac{n - N_0 - (N_p - 1)/2}{N_s}\hat{\eta}_l(k+1) & N_0 + N_p \le n < N_s \end{cases}$$

$$\tilde{\eta}_l(n,k) = \begin{cases} \frac{N_0 + (N_p - 1)/2 - n}{N_s}\hat{\eta}_l(k+1) + \left(1 - \frac{N_0 + (N_p - 1)/2 - n}{N_s}\right)\hat{\eta}_l(k) & 0 \le n < N_0 \\ \hat{\eta}_l(k) & N_0 \le n < N_0 + N_p \\ \left(1 - \frac{n - N_0 - (N_p - 1)/2}{N_s}\right)\hat{\eta}_l(k) + \frac{n - N_0 - (N_p - 1)/2}{N_s}\hat{\eta}_l(k+1) & N_0 + N_p \le n < N_s \end{cases}$$

3. In order to understand this model better, a block diagram of Rake receiver used in time-multiplexed pilot channel is given, as shown in Fig.1

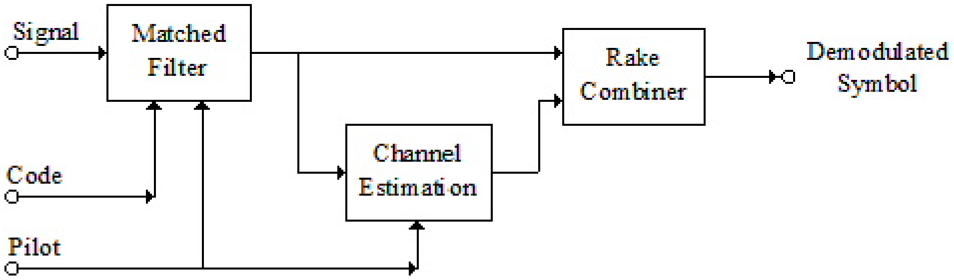


Fig. 1 Block diagram of Rake receiver

Netlist Form

```
ALICE:NAME  n1 n2 n3 nexsys_component=LICE [PURPOSE=val] L=val
NP=val ND=val [N0=val] [PHASE=val] + [RIN1=val]  [RIN2=val]
[ROUT=val]
```

Netlist Example

```
ALICE:1 1 2 3 nexsys_component=LICE PURPOSE = 0 L =2 NP = 4 ND =
16 PHASE = 0DEG
```

References

1. F. Adachi, K. Ohno, et al, “Coherent multicode DS-CDMA mobile radio access,” *IEICE Trans. Commun.*, vol. E79-B, pp. 1316–1325, Sept. 1996.
2. S. Sampei and T. Sunaga, “Rayleigh fading compensation for QAM in land mobile radio communications,” *IEEE Trans. Veh. Tech.*, vol. 42, no. 2, pp. 137–147, May 1993.

Matched Filter (MATCHFILTER)

Property	Description	Units	Default	Range/Type
METHOD	Pilot Assisted {0} / Perfect {1}	None	0	[0, 1]/Integer
L	Number of paths	None	2	[1, 16]/Integer
G	Spreading factor	None	32	[2, Inf)/Integer
S	Number of samples per chip	None	4	[1, 128]/Integer
K	Number of slots for block-average power delay estimation	None	1	[1, Inf)/Integer
NP	Number of pilot symbols	None	4	[1, Inf)/Integer
ND	Number of data symbols	None	36	[0, Inf)/Integer
N0	Number of the first pilot symbol	None	0	[0, Inf)/Integer
DMAX	Maximum multipath delay (samples)	None	31	[0, Inf)/Integer
D0~D15	Multipath delays (samples)	None	0	[0, Inf)/Integer
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
RIN3	Input3 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				

Input1	Received signal in complex envelope format (complex)
Input2	Spreading code (complex)
Input3	Pilot symbols (complex)
Output	Despread symbols of the current slot (complex)

Limits

$0 \le N_0 \le N_d - 1$

Notes

1. The matched filter model can be used to resolve the received multi-path signal and despread symbols on each path in DS/CDMA systems. The block diagram of the matched filter is shown in Fig.1. If Method is set to Pilot Assisted {0}, the received signal is despread using the estimated multi-path delays (i.e., the output of the Multi-Path Search). If Method is set to Perfect {1}, the received signal is despread using the given parameter values $D_0 \sim D_{L-1}$.

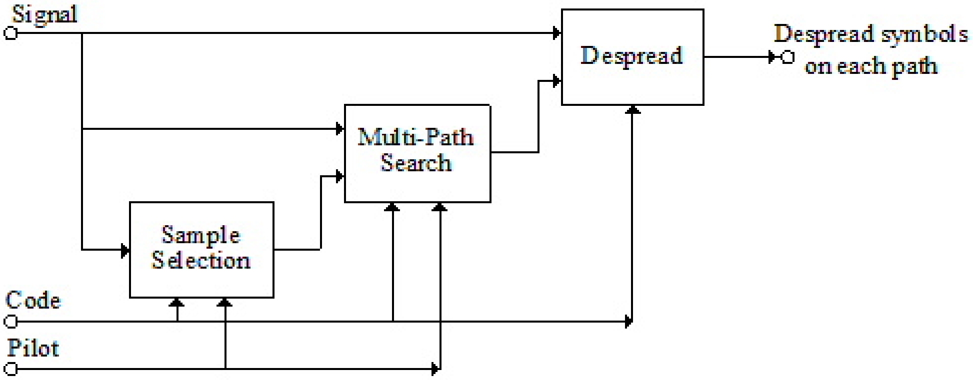


Fig. 1 Block diagram of matched filter

2. Slot Structure
   The slot structure is shown in Fig.2. Each slot comprises N_p pilot symbols and N_d data symbols. N_0 is the number of the first pilot symbol, i.e, the $N_0 \sim (N_0 + N_p - 1)$ symbols are

pilots.

Fig.2 Slot structure

3. Sample Selection: Because of channel delay and shaping filter, the optimum sample position should be found to maximize the output power and minimize inter-symbol interference. The input signal is a discrete one sampled at the rate of $1/T_s$ in simulation. To determine the optimum sample position is to select an optimum sample on the *S* samples during a chip. The optimum sample position can be determined by comparing correlation values between the received signal starting at each sample point and the corresponding spreading code.

   Assume complex vector *x [ ]* stores the received signal sampled at the rate of $1/T_s$. Thus the correlation value between the received signal and the spreading code is given by

   $$R_1(j)=\frac{1}{2G}\sum_{i=0}^{G-1}\sum_{k=0}^{S-1}x[i\times S+k+j]\times c^*[i]$$

   (1)

4. where *G* is the spreading factor and *S* is the number of samples per chip and the vector *c* [ ] stores the corresponding spreading code. The factor 1/2 is used to remove changes of symbol power caused by spreading and despreading. When the *j*th sample point of input signal hits the first chip of that symbol (which is spread by the spreading code c [ ]), the magnitude of the correlation value is the greatest among these samples.

   In this model, there are (D_{max}+1) correlation values, where D_{max} is the possible maximum path delay in terms of samples. Once the ($D_{max}+1$) correlation values are calculated, the sample position where the magnitude of the correlation value is the greatest is selected. If this sample is the *j*th sample, then *j mod S* becomes the optimum sample position (S_{OPT}..

   Because all N_F pilot symbols in a slot are known for the matched filter in the receiver, their correlation values are added to increase processing gain. However, pilot symbols are not the same in a slot, these correlation values must be divided by the corresponding pilot symbol values before the addition. So ($D_{max}+1$) values are produced. If the *j*th one has the greatest magnitude, the (*J mod S*) sample position for each chip is selected as the optimum sample position for the current slot.

In a practical situation, it is very difficult to search, slot by slot. This model allows us to use the block-average power delay profile (*K>1*) [3]. First, the instantaneous power delay profile is measured by using pilot symbols belonging to each slot and, then, average them over multiple slots.

5. Multi-Path Search: The transmitted signal arrives at the receiver via different paths and delays. To use more signal power, multi-path delays of the received signal of the appropriate user are determined and signals on each resolved paths are combined. Because it is difficult to determine the relative multi-path delays at the precision of T_S, multi-path delays are determined at the precision of T_c, where $D_c = T_c x S$ is chip duration. Let D_c be the maximum delay in terms of chips, i.e., D_c equals the largest integer which is not larger than D_c/S, can be expressed as

$$D_c = \lfloor D_s / S \rfloor \qquad (2)$$

6. After the optimum sample position D_{OPT} has been determined by Sample Selection, the correlation values between the received signal at each possible delay, in terms of chips, are calculated as follows:

$$R_2(j) = \frac{1}{2G}\sum_{i=0}^{G-1}\sum_{k=0}^{S-1} x\left[(i+j)\times S + k + S_{opt}\right]\times c^*[i] \qquad (3)$$

7. As in Sample Selection, the correlation values of different pilot symbols on the same path are divided by the corresponding pilot symbol values and added. $D_c + 1$ results of additions are obtained. In these results, *L* with the greatest magnitude are selected, the corresponding paths that belong to *L* results are determined as *L* valid paths. The Multi-Path Search process can also use the block-average power delay profile (*K>1*) [3].
8. Despread: After multi-path delays are obtained by the Multi-Path Search, symbols on each path in current slot are despread. If *Method* is set to Perfect {1}, symbols on each path in current slot are despread using the given parameter values D_0~D_{L-1}, rather than the multi-path delays are obtained by the Multi-Path Search. The despreading process is the same as the process of calculating correlation value. Finally, *L* samples are outputted successively for each symbol.

Netlist Form

```
AMATCHFILTER:NAME  n1 n2 n3 n4 nexsys_component=MATCHFILTER
[METHOD=val] L=val G=val [S=val] [K=val]  NP=val ND=val
```

```
[N0=val] [DMAX=val] [D0=val,…, D15=val] [RIN1=val] [RIN2=val]
[RIN3=val] [ROUT=val]
```

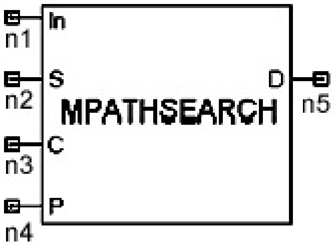
Netlist Example

```
AMATCHFILTER:1 1 2 3 4 nexsys_component=MATCHFILTER METHOD = 0
L =2 G = 32 S = 4 DMAX = 20 NP = 4 ND = 16 D0 = 1 D1 = 9
```

References

1. J. G. Proakis, *Digital Communications*, McGraw-Hill, 2001.
2. A. J. Viterbi, *CDMA: Principles of Spread Spectrum Communication*, Wesley Publishing Company, 1995.
3. K. Higuchi, H. Andoh, et al, “Experimental evaluation of combined effect of coherent RAKE combining and SIR-based fast transmit power control for reverse link of DS-CDMA mobile radio,” *IEEE Journal on Selected Areas in Communications,* vol. 18, No.8, pp.1526-1535, Aug. 2000.

Multipath Search (MPATHSEARCH)



Property	Description	Units	Default	Range/Type
METHOD	Pilot Assisted {0} / Perfect {1}	None	0	[0, 1]/Integer
L	Number of paths	None	2	[1, 16]/Integer
G	Spreading factor	None	32	[2, Inf)/Integer
S	Number of samples per chip	None	4	[1, 128]/Integer
K	Number of slots for block-average power delay estimation	None	1	[1, Inf)/Integer
NP	Number of pilot symbols	None	4	[1, Inf)/Integer
ND	Number of data symbols	None	36	[0, Inf)/Integer
N0	Number of the first pilot symbol	None	0	[0, Inf)/Integer
DMAX	Maximum multipath delay (samples)	None	31	[0, Inf)/Integer
D0~D15	Multipath delays (samples)	None	0	[0, Inf)/Integer
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
RIN3	Input3 impedance	Ohm	Inf	(0, Inf]/Real
RIN4	Input4 impedance	Ohm	Inf	(0, Inf]/Real

ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Received signal in complex envelope format (complex)			
Input2	Optimum sample position (integer)			
Input3	Spreading code (complex)			
Input4	Pilot symbols (complex)			
Output	Multipath delays, in terms of samples (integer)			

Limits

$$0 \le D_{\max} \le (N_p + N_d) \times G \times S - 1 \quad 0 \le D_0, \ldots, D_{15} \le D_{\max}$$

,

Notes

1. The multi-path search model can be used to search multi-path and estimate multi-path delays under the condition that the optimum sample position is known. If *Method* is set to Pilot Assisted {0}, the multi-path delays are estimated using the corresponding spreading code and pilot symbols. For detailed algorithm, please refer to the matched filter model. If *Method* is set to Perfect {1}, the multi-path delays are set to $D_0 \sim D_{L-1}$.
2. Note that *L* delay values are outputted successively for each symbol.

Netlist Form

```
AMPATHSEARCH:NAME  n1 n2 n3 n4 n5 nexsys_component=MPATHSEARCH
[METHOD=val] L=val G=val [S=val] [K=val]  NP=val ND=val

+ [N0=val] [DMAX=val] [D0=val,…, D15=val] [RIN1=val] [RIN2=val]
[RIN3=val] [RIN4=val]  [ROUT=val]
```

Netlist Example

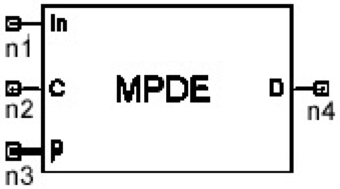
```
AMPATHSEARCH:1 1 2 3 4 5 nexsys_component=MPATHSEARCH METHOD =
0 L =2 G = 32 S = 4 DMAX = 20 NP = 4 ND = 16 D0 = 1 D1 = 9
```

References

1. J. G. Proakis, *Digital Communications*, McGraw-Hill, 2001.
2. A. J. Viterbi, *CDMA: Principles of Spread Spectrum Communication*, Wesley Publishing Company, 1995.

3. K. Higuchi, H. Andoh, et al, “Experimental evaluation of combined effect of coherent RAKE combining and SIR-based fast transmit power control for reverse link of DS-CDMA mobile radio,” *IEEE Journal on Selected Areas in Communications*, vol. 18, No.8, pp.1526-1535, Aug. 2000.

Multipath Delay Estimation (MPDE)



Property	Description	Units	Default	Range/Type
METHOD	Pilot Assisted {0} / Perfect {1}	None	0	[0, 1]/Integer
L	Number of paths	None	2	[1, 16]/Integer
G	Spreading factor	None	32	[2, Inf)/Integer
S	Number of samples per chip	None	4	[1, 128]/Integer
K	Number of slots for block-average power delay estimation	None	1	[1, Inf)/Integer
NP	Number of pilot symbols	None	4	[1, Inf)/Integer
ND	Number of data symbols	None	36	[0, Inf)/Integer
N0	Number of the first pilot symbol	None	0	[0, Inf)/Integer
DMAX	Maximum multipath delay (samples)	None	31	[0, Inf)/Integer
D0~D15	Multipath delays (samples)	None	0	[0, Inf)/Integer
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
RIN3	Input3 impedance	Ohm	Inf	(0, Inf]/Real
RIN4	Input4 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real

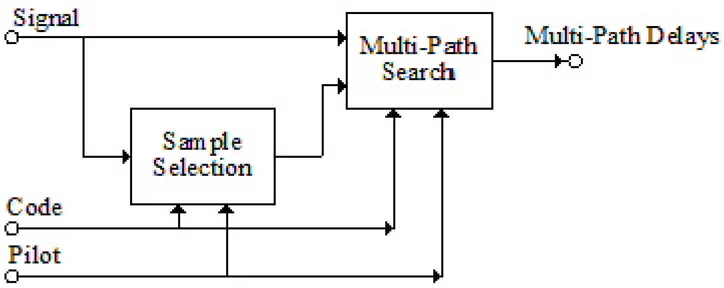
Ports	
Input1	Received signal in complex envelope format (complex)
Input2	Optimum sample position (integer)
Input3	Spreading code (complex)
Input4	Pilot symbols (complex)
Output	Multipath delays, in terms of samples (integer)

Limits

$0 \le N_0 \le N_d - 1$, $0 \le D_{\max} \le (N_p + N_d) \times G \times S - 1$, $0 \le D_0, \ldots, D_{15} \le D_{\max}$

Notes

1. The multi-path delay estimation model can be used to search multi-path and estimate multi-path delays. If *Method* is set to Pilot Assisted {0}, the multi-path delays are estimated using the corresponding spreading code and pilot symbols. This component consists of the sample selection and multi-path search, as shown in Fig.1. For detailed algorithm, please refer to the **matched filter** model. If Method is set to Perfect {1}, the multi-path delays are set to D_0~D_{L-}
2. Note that *L* delay values are outputted successively for each symbol.
   Fig. 1 Block diagram of multipath delay estimation



Netlist Form

```
AMPDE:NAME  n1 n2 n3 n4 nexsys_component=MPDE [METHOD=val]
L=val G=val [S=val] [K=val]  NP=val ND=val  [N0=val]
[DMAX=val] [D0=val,…, D15=val] [RIN1=val] [RIN2=val]
[RIN3=val] [ROUT=val]
```

Netlist Example

```
AMPDE:1 1 2 3 4 nexsys_component=MPDE METHOD=0 L=2 G=32 S=4 DMAX=20
NP=4 ND=16 D0=1 D1=9
```

References

1. J. G. Proakis, *Digital Communications*, McGraw-Hill, 2001.
2. A. J. Viterbi, *CDMA: Principles of Spread Spectrum Communication*, Wesley Publishing Company, 1995.
3. K. Higuchi, H. Andoh, et al, “Experimental evaluation of combined effect of coherent RAKE combining and SIR-based fast transmit power control for reverse link of DS-CDMA mobile radio,” *IEEE Journal on Selected Areas in Communications*, vol. 18, No.8, pp.1526-1535, Aug. 2000.

MPSK Symbol Decision (MPSKSD)

Property	Description	Units	Default	Range/Type
M	Order of the signal space (default: 4, i.e., QPSK)	None	4	[2, 1024]/Integer
PHASE	Additional phase of symbols	Deg	0	[-180, 180)/Real
RIN	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input	Symbol before decision (complex)			
Output	Symbol after decision (complex)			

Notes

1. The MPSK Symbol Decision model can be used to make the symbol decision for MPSK signals.

Netlist Form

```
AMPSKSD:NAME  n1 n2 nexsys_component=MPSKSD M=val [PHASE=val]
[RIN=val]  [ROUT=val]
```

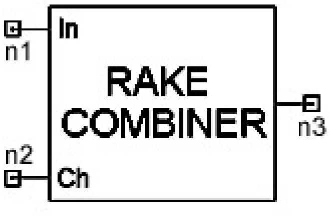
Netlist Example

```
AMPSKSD:1 1 2 nexsys_component=MPSKSD M =4 PHASE = 0DEG
```

References

1. J. G. Proakis, *Digital Communications*, McGraw-Hill, 2001.

Rake Combiner (RAKECOMBINER)



Property	Description	Units	Default	Range/Type
L	Number of paths	None	2	[1, 16]/Integer
RIN1	Input impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Received signal in complex envelope format (complex)			
Input2	Channel estimates (complex)			
Output	Rake-combined signal (complex)			

Notes

1. The Rake Combiner model can be used to generate a Rake-combined signal.
2. Rake-combining is performed based on maximum ratio criteria. Maximal ratio criteria is a weighted signal combining method in which the weighting factor for each signal to be combined is the strength of the signal if the phase factor is not considered. Let $r_l(n,k)$ be the nth received symbol at the output of the matched filter in the kth slot for the lth resolved path, and $n_l(n,k)$ be corresponding channel estimate. The output of the Rake Combiner for the nth symbol of the kth slot is represented by

$$\tilde{r}_d(n,k) = \sum_{l=0}^{L-1} \tilde{r}_l(n,k)\tilde{\eta}_l^*(n,k) \tag{1}$$

where L is the number of resolved paths, * denotes the complex conjugate. In order to understand this model better, a block diagram of Rake receiver used in time-multiplexed pilot channel is given, as shown in Fig. 1.

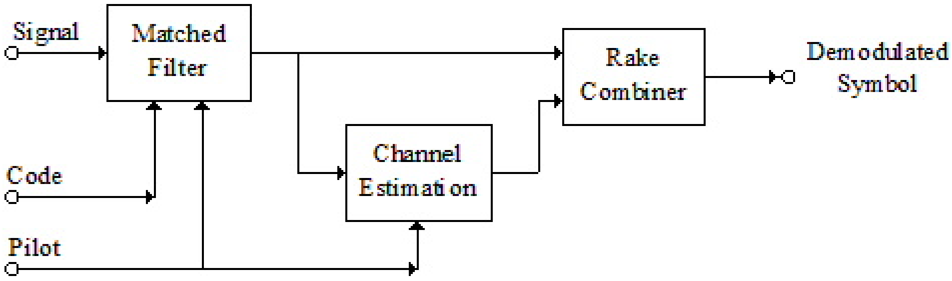


Fig. 1 Block Diagram of Rake Receiver

Netlist Form

```
ARAKECOMBINER: NAME  n1 n2 n3 nexsys_component=RAKECOMBINER
L=val [RIN1=val] [RIN2=val] [ROUT=val]
```

Netlist Example

```
ARAKECOMBINER:1 1 2 3 nexsys_component=RAKECOMBINER L =2
```

References

1. K. Higuchi, H. Andoh, et. al., "Experimental evaluation of combined effect of coherent RAKE combining and SIR-based fast transmit power control for reverse link of DS-CDMA mobile radio", *IEEE Journal on Selected Areas in Communications,* vol. 18, No.8, pp.1526-1535, Aug. 2000.
2. T. Dohi, Y. Okumura, et. al., “Further results on field experiments of coherent wideband DS-CDMA mobile radio,” *IEICE Trans. Commun*., vol. E81-B, pp. 1239–1247, June 1998.

Sample Selection (SAMPSELECT)

Property	Description	Units	Default	Range/Type
METHOD	Pilot Assisted {0} Perfect {1}	None	0	[0, 1]/Integer
G	Spreading factor	None	32	[2, Inf)/Integer
S	Number of samples per chip	None	4	[1, 128]/Integer
K	Number of slots for block-average power delay estimation integer	None	1	[1, Inf)/Integer
NP	Number of pilot symbols	None	4	[1, Inf)/Integer
ND	Number of data symbols	None	6	[0, Inf)/Integer
N0	Number of the first pilot symbol	None	0	[0, Inf)/Integer
DMAX	Maximum delay for multi-path (samples)	None	16	[0, Inf)/Integer
S0	Perfect sample position	None	0	[0, 127]/Integer
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
RIN3	Input3 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Received signal on complex envelope format (complex)			
Input2	Spreading code (complex)			
Input3	Pilot symbols (complex)			
Output	Optimum sample position (integer)			

Limits

$0 \le N_0 \le N_d - 1 \quad 0 \le D_{\max} \le (N_p + N_d) \times G \times S - 1 \quad 0 \le S_0 < S$

Notes

1. The sample selection model can be used to determine the optimum sample position for each slot in DS/CDMA systems. If *Method* is set to Pilot Assisted {0}, the optimum sample position is estimated using the corresponding spreading code and pilot symbols. For detailed algorithm, please refer to the matched filter model. If *Method* is set to Perfect {1}, the optimum sample position is the value of the parameter S_0.

Netlist Form

```
ASAMPSELECT:NAME  n1 n2 n3 n4 nexsys_component=SAMPSELECT
[METHOD=val] G=val [S=val] [K=val]  NP=val ND=val  [N0=val]+
[DMAX=val] [S0=val]  [RIN1=val] [RIN2=val] [RIN3=val]
[ROUT=val]
```

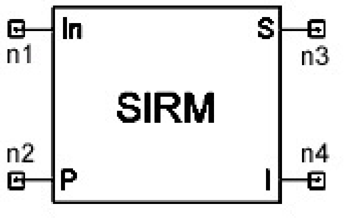
Netlist Example

```
ASAMPSELECT:1 1 2 3 4 nexsys_component=SAMPSELECT METHOD = 0 G =
32 S = 4 DMAX = 20 NP = 4 ND = 16 S0 = 1
```

References

1. J. G. Proakis, *Digital Communications*, McGraw-Hill, 2001.
2. A. J. Viterbi, *CDMA: Principles of Spread Spectrum Communication*, Wesley Publishing Company, 1995.
3. K. Higuchi, H. Andoh, et al, “Experimental evaluation of combined effect of coherent RAKE combining and SIR-based fast transmit power control for reverse link of DS-CDMA mobile radio", *IEEE Journal on Selected Areas in Communications,* vol. 18, No.8, pp.1526-1535, Aug. 2000.

SIR Measurement (SIRM)



Property	Description	Units	Default	Range/Type
NP	Number of pilot symbols	None	4	[1, Inf)/Integer
ND	Number of data symbols	None	36	[1, Inf)/Integer
N0	Number of the first pilot symbol	None	0	[0, Inf)/Integer
N1	The first symbol used for signal power measurement	None	0	[0, Inf)/Integer
N2	The last symbol used for signal power measurement	None	39	[0, Inf)/Integer
RIN1	Input impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT1	Output impedance	Ohm	0	[0, Inf)/Real
ROUT2	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Received signal in complex envelope format (complex)			
Input2	Pilot symbols (complex)			
Output1	Signal power (real)			
Output2	Interference power (real)			

Limits

$0 \le N_0 \le N_d - 1$ $0 \le N_1 < N_2 \le N_p + N_d - 1$

,

Notes

1. The SIR Measurement model can be used for signal power and interference power measurement.
2. Signal power measurement: Define signal power as the average of squared value of magnitude of symbols after Rake-Combining. Assuming *r(n,k)* is the nth received symbol at the output of the matched filter in the kth slot, then average signal power starting from symbol N_1 and ending on symbol N_2, which can be expressed as

   $$S(k) = \frac{1}{N_2 - N_1 + 1} \sum_{n=N_1}^{N_2} \left| r_i(n,k) \right|^2 \tag{1}$$

3. Interference power measurement: Interference power, assisted by pilot symbols, is calculated as the average of squared magnitude of differences between the received and estimated pilot symbols. The average signal power of pilot symbols after Rake-Combining is calculated as follows

   $$P_{pilot}(k) = \frac{2}{N_p} \left| \sum_{n=0}^{N_p - 1} \frac{r(n + N_0, k)}{p(n + N_0, k)} \right|^2 \tag{2}$$

   where N_p is number of pilot symbols per slot, N_0 is the number of the first pilot symbol, p (n,k) is the nth local standard pilot symbol in the kth slot. Interference power is calculated as follows

   $$I(k) = \frac{1}{N_p} \sum_{n=0}^{N_p - 1} \left| r(n,k) - \sqrt{\frac{P_{pilot}(k)}{2}}\, p(n,k) \right|^2 \tag{3}$$

4. If the SIR Measurement model is used for Fast Transmission Power Control, large time delay caused by Channel estimation is not allowed. Therefore, separate the Rake combining process for SINR Measurement from that for data demodulation. In order to understand the idea better, a block diagram of SIR Measurement model with Rake

receiver used in time-multiplexed pilot channel is given, as shown in Fig.1

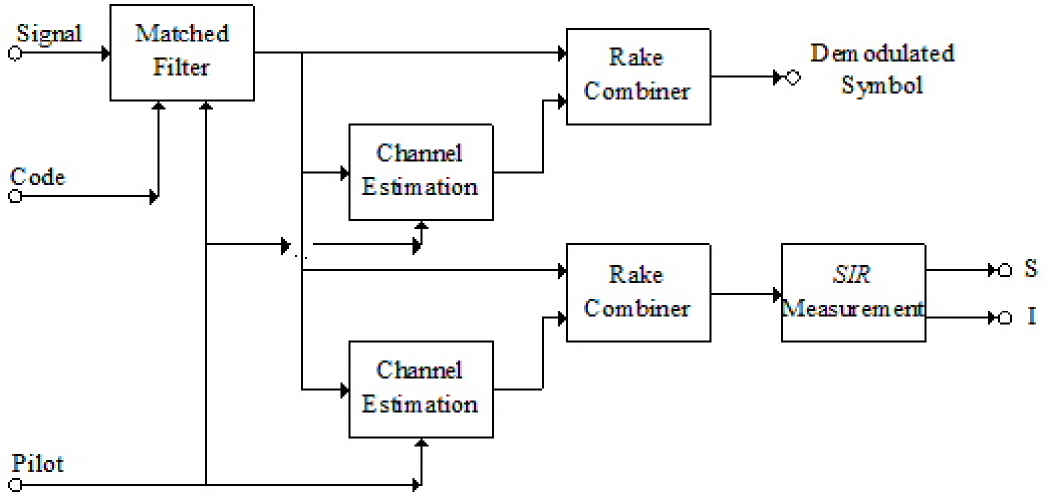


Fig. 1 Block diagram of Rake receiver

Netlist Form

```
ASIRM:NAME  n1 n2 n3 n4 nexsys_component=SIRM NP=val ND=val
[N0=val]  [N1=val]  [N2=val]
+ [RIN1=val] [RIN2=val]
[ROUT1=val] [ROUT2=val]
```

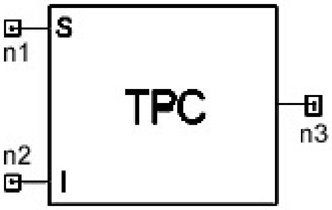
Netlist Example

```
ASIRM:1 1 2 3 4 nexsys_component=SIRM PURPOSE=0 L=2 NP=4 ND=16 N0=0
N1=0 N2=19
```

References

1. A. J. Viterbi, *CDMA: Principles of Spread Spectrum Communication*, Wesley Publishing Company, 1995.
2. H. Andoh, M. Sawahashi, and F. Adachi, “Channel estimation filter using time-multiplexed pilot channel for coherent Rake combining in DS-CDMA mobile radio", *IEICE Trans. Commun.*, vol. E81-B, no. 7, pp. 1517–1526, July 1998.
3. K. Higuchi, H. Andoh, et al, “Experimental evaluation of combined effect of coherent RAKE combining and SIR-based fast transmit power control for reverse link of DS-CDMA mobile radio", *IEEE Journal on Selected Areas in Communications,* vol. 18, No.8, pp.1526-1535, Aug. 2000.

Transmission Power Control (TPC)



Property	Description	Units	Default	Range/Type
SIR	Target (dB)	None	0	(-Inf, 200]/Real
FORGETTOR	Forgetting factor	None	0.1	[0.0, 1.0]/Real
INIT_SLOT	Number of initial invalid slots	None	10	[0, Inf)/Integer
RIN1	Input impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Signal power (real)			
Input2	Interference power (real)			
Output	Transmission power control command: +1/ -1 (Integer)			

Notes

1. The Transmission Power Control model can be used generate transmission power control commands (+/- 1) with an interval of one slot. +1 indicates increasing transmission power, and -1 indicates reducing transmission power.
2. Let *I(k)* be the interference power at the kth slot. Before being used to calculate SINR, the input interference power is pre-averaged using a first-order filter with forgetting factor as follows

   $$\bar{I}(k) = (1-\mu)\bar{I}(k-1) + \mu I(k)$$

   (1), where µis the forgetting factor.
3. The measured SIR λ*(k)* the kth slot is defined as

   $$\lambda(k) = 10\log\left(S(k)/\bar{I}(k)\right)$$

   (2)

This value λ*(k)* is compared to a pre-determined Target SIR (dB), if greater, transmission power control command -1 is output, otherwise, +1 is output.

Netlist Form

```
ATPC:NAME  n1 n2 n3 nexsys_component=TPC SIR=val [FORGETTOR
=val] [INIT_SLOT =val] [RIN1=val] [RIN2=val] [ROUT=val]
```

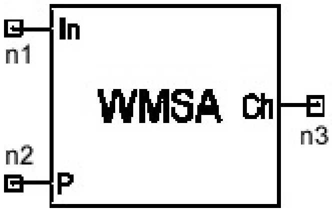
Netlist Example

```
ATPC:1 1 2 3 nexsys_component=TPC SIR = 0 FORGETTOR=1.0
INIT_SLOT =1
```

References

1. A. J. Viterbi, *CDMA: Principles of Spread Spectrum Communication*, Wesley Publishing Company, 1995.
2. H. Andoh, M. Sawahashi, and F. Adachi, “Channel estimation filter using time-multiplexed pilot channel for coherent Rake combining in DS-CDMA mobile radio,” *IEICE Trans. Commun.*, vol. E81-B, no. 7, pp. 1517–1526, July 1998.

Channel Estimation (WMSA)



Property	Description	Units	Default	Range/Type
PURPOSE	Data demodulation {0} Power control {1}	None	0	[0, 1]/Integer
L	Number of paths	None	2	[1,16]/Integer
K	Number of taps in each side	None	1	[1, 16]/Integer
NP	Number of pilot symbols	None	4	[1, Inf)/Integer
ND	Number of data symbols	None	36	[0, Inf)/Integer
N0	Number of the first pilot symbol	None	0	[0, Inf)/Integer
PHASE	Additional phase of pilot symbols	Deg	0	[180, -180]/Integer
A0~A15	Weighting factor	None	0	[0, Inf)/Integer
RIN1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
RIN2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Received signal in complex envelope format (complex)			
Input2	Pilot symbols (complex)			
Output	Channel estimates (complex)			

Limits

$0 \le N_0 \le N_d - 1$

Notes

1. The weighted multi-slot averaging (WMSA) channel estimation model can be used to estimate channel characteristics for all paths using pilot symbols. The WMSA channel

estimation is shown in Fig.1.

2. Algorithm description: Let $r_l(n,k)$ be the nth received symbol at the output of the matched filter in the kth slot for the lth resolved path, and $p(n,k)$ is the nth local standard pilot symbol in the kth slot. The instantaneous channel estimation of the lth resolved path is performed using the pilot symbols belonging to the kth slot as follows

$$\hat{\eta}_l(k) = \frac{1}{N_p}\sum_{n=0}^{N_p-1}\frac{r_l(n+N_0,k)}{p(n+N_0,k)} \tag{1}$$

where N_f is the number of pilot symbols per slot, N_0 is the number of the first pilot symbol. In the case of slow fading, since the channel gain remains almost the same over a period of several slots, extend the observation interval to more than one slot to add coherently several consecutive channel estimates. Apply a linear filter with 2K taps. The filter output is expressed as

$$\tilde{\eta}_l(k) = \sum_{i=0}^{K-1}\alpha_{-i}\hat{\eta}_l(k-i) + \sum_{i=0}^{K-1}\alpha_i\hat{\eta}_l(k+i+1) \tag{2}$$

where α_i is the real-valued weighting factor (or tap coefficient). Since the magnitude of the autocorrelation function of the time-varying complex-valued channel gain is an even function with respect to the time difference, the contribution on the past and future channel gains to the channel estimate should be the same. Therefore, set the filter coefficients, α_i and α_{-i}, equal to each other. Term $n_l(k)$ is used as the channel estimate at all symbol positions in thee kth slot, so the channel estimate is represented as

$$\tilde{\eta}_l(n,k) = \tilde{\eta}_l(k) \quad \text{for} \quad n = 0,1,\ldots,N_p+N_d-1 \tag{3}$$

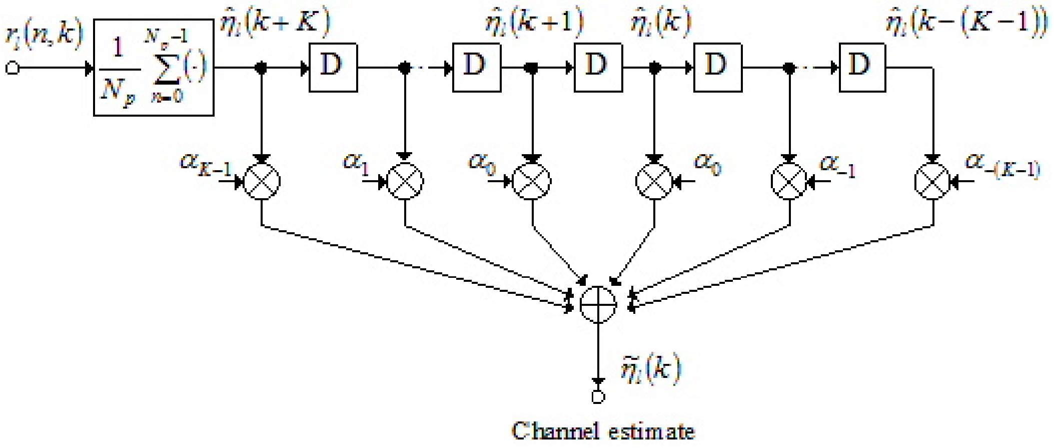


Fig. 1 Block diagram of WMSA channel estimation

3. In order to understand this model better, a block diagram of Rake receiver used in time-multiplexed pilot channel is given, as shown in Fig.2.

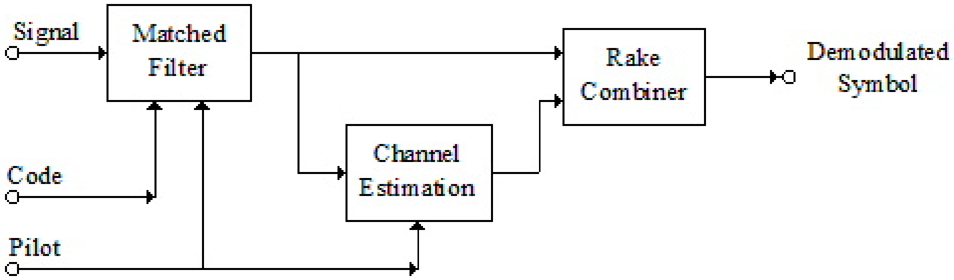


Fig. 2 Block diagram of Rake receiver

Netlist Form

```
AWMSA:NAME  n1 n2 n3 nexsys_component=WMSA L=val [K=val]
[NP=val] [ND=val] [N0=val] [PHASE=val] A0=val
[A1=val...A15=val] [RIN1=val] [RIN2=val] [ROUT=val]
```

Netlist Example

```
AWMSA:1 1 2 3 nexsys_component=WMSA
```

References

1. [1]K. Higuchi, H. Andoh, et al, “Experimental evaluation of combined effect of coherent RAKE combining and SIR-based fast transmit power control for reverse link of DS-CDMA mobile radio,” *IEEE Journal on Selected Areas in Communications,* vol. 18, No.8, pp.1526-1535, Aug. 2000.
2. [2]H. Andoh, M. Sawahashi, and F. Adachi, “Channel estimation filter using time-multiplexed pilot channel for coherent Rake combining in DS-CDMA mobile radio,” *IEICE Trans. Commun.*, vol. E81-B, no. 7, pp. 1517–1526, July 1998.

WCDMA Transmitter

This topic describes the following System components:

"Gold Sequence Generator (GOLD)" below

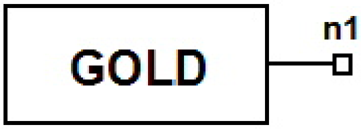
"M-Sequence Generator (MSEQ)" on page 38-573

"Power Amplifier (POWAMP)" on page 38-577

"Random Sequence Generator (RANDSEQ) " on page 38-578

"Spreader (SPREADER) " on page 38-579

Gold Sequence Generator (GOLD)



Property	Description	Units	Default	Range/Type/Type
L	Length of shift register	None	5	[2, 63]/Integer
N	Period of the m-sequence	None	31	[1, Inf)/Integer
PL1	The first primitive polynomial (low 32 bits) in decimal	None	37	[1, Inf)/Integer
PH1	The first primitive polynomial (high 32 bits) in decimal	None	0	[0, Inf)/Integer
PL2	The second primitive polynomial (low 32 bits) in decimal	None	37	[1, Inf)/Integer
PH2	The second primitive polynomial (high 32 bits) in decimal	None	0	[0, Inf)/Integer
SL1	Initial state of the first shift register (low 32 bits) in decimal	None	1	[0, Inf)/Integer
SH1	Initial state of the first shift register (high 32	None	0	[0, Inf)/Integer

	bits) in decimal			
SL2	Initial state of the second shift register (low 32 bits) in decimal	None	1	[0, Inf)/Integer
SH2	Initial state of the second shift register (high 32 bits) in decimal	None	0	[0, Inf)/Integer
NC	Number of chips	None	Required	[0, Inf)/Integer
RC	Chip rate of the m-sequence	Hz	1000	(0, Inf)/Real
T	True output value	None	-1	(-Inf, Inf)/Real
F	False output value	None	1	(-Inf, Inf)/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Output	Truncated Gold sequence (real)			

Notes

1. The Gold Sequence Generator model is used to generate Gold sequence.
2. The Gold sequence can be generated by taking modulo-2 sum of two m-sequences with different offset in Galois field. Not all pairs of m-sequences do generate Gold sequence and those which generate Gold sequence are called *preferred pairs*. A typical LFSR structure used to be generate a family of Gold sequences is illustrated in Fig.1. For detailed description of LFSR, please refer to the **m-sequence Generator** model.
3. As in the **m-sequence Generator** model, that the primitive polynomial in binary is

$g_o g_1 ... g_L$ and the initial state of the shift register in binary is $S_{L-1}S_{L-2}...S_0$.

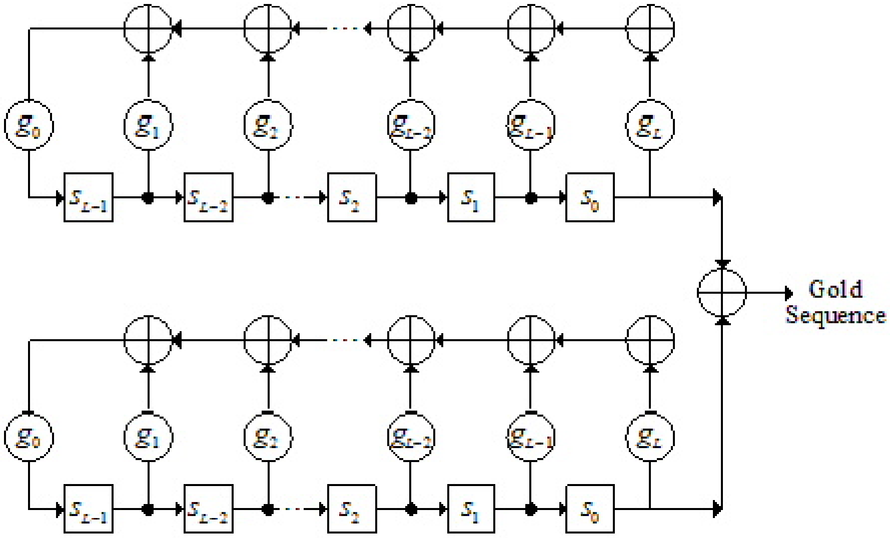


Fig. 1 Block diagram of Gold Sequence Generator

Netlist Form

AGOLD:NAME n1 nexsys_component=GOLD L=*val* [N =*val*] [PL1=*val*] [PH1 =*val*] [PL2=*val*] [PH2 =*val*] [SL1=*val*] [SH1 =*val*] + [SL2=*val*] [SH2 =*val*] NC=*val* [RC=*val*] [T=*val*] [F =*val*] [ROUT=*val*]

Netlist Example

```
AGOLD:1 1 nexsys_component=GOLD L = 5  N=31 PL1 = 41 PH1 = 0 PL2
= 41 PH2 = 0 SL1 = 31 SH1 = 0  SL2 = 1 SH2 = 0 NC = 124 + RC =
1khz T= 1 F= 0
```

References

1. J. G. Proakis, *Digital Communications*, McGraw-Hill, 2001.
2. R. L. Peterson, R. E. Ziemer, and D. E. Borth, *Introduction to Spread Spectrum Communications*. Prentice Hall International Editions, 1995.

M-Sequence Generator (MSEQ)

Property	Description	Units	Default	Range/Type
L	Length of shift register	None	5	[2, 63]/Integer
N	Period of the m-sequence	None	31	[1, Inf)/Integer
PL	Primitive polynomial (low 32 bits) in decimal	None	37	[1, Inf)/Integer
PH	Primitive polynomial (high 32 bits) in decimal	None	0	[0, Inf)/Integer
SL	Initial state of the shift register (low 32 bits) in decimal	None	1	[0, Inf)/Integer
SH	Initial state of the shift register (high 32 bits) in decimal	None	0	[0, Inf)/Integer
NC	Number of chips	None	0	[0, Inf)/Integer
RC	Chip rate of the m-sequence	Hz	1000	(0, Inf)/Real
T	True output value	None	-1	(-Inf, Inf)/Integer
F	False output value	None	1	(-Inf, Inf)/Integer
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Output	Truncated m-sequence (real)			

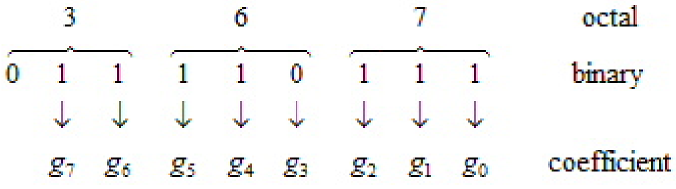
Notes

1. The m-sequence Generator model can be used to generate m-sequence.
2. The m-sequence can be generated using Linear Feedback Shift Register (LFSR) with a primitive polynomial[2]. For a given primitive polynomial, there are two methods[2] of implementing LFSR, i.e, Galois feedback generator and Fibonacci feedback generator.

Since *m-sequence* has the maximum possible period for a L-stage LFSR, it is also called *maximal length sequence*. The maximum period of a L-stage LFSR can be proven to be 2^L-1. The structure of Linear Feedback Shift Register with Fibonacci feedback generator is shown in Fig.1. The primitive polynomials g(D) is given by

$$g(D)=g_0+g_1D+g_2D^2+\ldots+g_LD^L \tag{1}$$

3. Table I shows a list of primitive polynomials for Linear Feedback Shift Register[2]. In the table, all polynomials are specified by an octal number that defines the coefficients of g (D). The octal number gives the coefficients of g(D) beginning with g_o on the right and proceeding to g_L in the last nonzero position on the left. For example, a L-tage LFSR uses the entry [367]. Expand the octal entry 367 into binary form to obtain



$$g(D)=1+D+D^2+D^4+D^5+D^6+D^7$$

Therefore,

In Table I, each entry in brackets represents one primitive polynomial as a series of octal numbers, explained in the above example. The entries following by an asterisk correspond to circuit implementation with only two feedback connections, which are very useful for high-speed applications. No reciprocal polynomial is listed in Table I. Since the reciprocal polynomial of a primitive polynomial is also primitive, each entry in this table can be used to generate two distinct m-sequences.

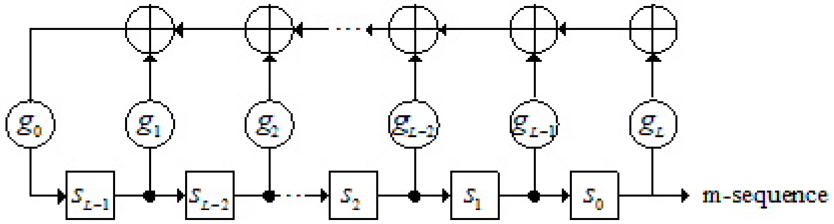


Fig. 1 Block diagram of m-sequence Generator (Fibonacci feedback generator)

4. Note that the primitive polynomial in binary is $g_0g_1...g_L$ and the initial state of the shift register in binary is $S_{L-1}S_{L-2}...S_0$.
5. A list of primitive polynomials is tabulated in the following table:

Degree	**Octal Representation of primitive polynomial (g_0 on left to g_L on right)**
2	[7]*
3	[13]*
4	[23]*
5	[45]*, [75], [67]
6	[103]*, [147], [155]
7	[211]*, [217], [235], [367], [277], [325], [203]*, [313], [345]
8	[435], [551], [747], [453], [545], [537], [703], [543]
9	[1021]*, [1131], [1461], [1423], [1055], [1167], [1541], [1333], [1605], [1751], [1743], [1617], [1553], [1157]
10	[2011]*, [2415], [3771], [2157], [3515], [2773], [2033], [2443], [2461], [3023], [3543], [2745], [2431], [3177]
11	[4055]*, [4445], [4215], [4055], [6015], [7413], [4143], [4563], [4053], [5023], [5623], [4577], [6233], [6673]
12	[10123], [15647], [16533], [16047], [11015], [14127], [17673], [13565], [15341], [15053], [15621], [15321], [11417], [13505]
13	[20033], [23261], [24623], [23517], [30741], [21643], [30171], [21277], [27777], [35051], [34723], [34047],

	[32535], [31425]
14	[42103], [43333], [51761], [40503], [77141], [62677], [44103], [45145], [76303], [64457], [57231], [64167], [60153], [55753]
15	[100003]*, [102043], [110013], [102067], [104307], [100317], [177775], [103451], [110075], [102061], [114725], [103251], [100021]*, [100201]*
16	[210013], [234313], [233303], [307107], [307527], [306357], [201735], [272201], [242413], [270155], [302157], [210205], [305667], [236107]
17	[400011]*, [400017], [400431], [525251], [410117], [400731], [411335], [444257], [600013], [403555], [525327], [411077], [400041]*, [400101]*
18	[1000201]*, [1000247], [1002241], [1002441], [1100045], [1000407], [1003011], [1020121], [1101005], [1000077], [1001361], [1001567], [1001727], [1002777]
19	[2000047], [2000641], [2001441], [2000107], [2000077], [2000157], [2000175], [2000257], [2000677], [2000737], [2001557], [2001637], [2005775], [2006677]
20	[4000011]*, [4001051], [4004515], [6006031], [4442235]
21	[10000005]*, [10040205], [10020045], [10040315], [10000635], [10103075], [10050335], [10002135], [17000075]

Netlist Form

```
AMSEQ:NAME  n1 nexsys_component=MSEQ L=val [N =val] [PL=val]
[PH =val] [SL=val] [SH =val] NC=val [RC=val] + [T=val] [F =val]
[ROUT=val]
```

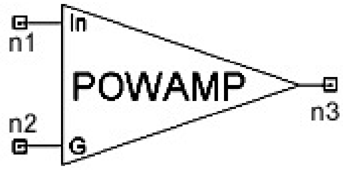
Netlist Example

```
AMSEQ:1 1 nexsys_component=MSEQ L = 5  N=31 PL = 41 PH = 0 SL =
31 SH = 0  NC = 124  RC = 1khz T= 1 F= 0
```

References

1. J. G. Proakis, *Digital Communications*, McGraw-Hill, 2001.
2. R. L. Peterson, R. E. Ziemer, and D. E. Borth, *Introduction to Spread Spectrum Communications*. Prentice Hall International Editions, 1995.

Power Amplifier (POWAMP)



Property	Description	Units	Default	Range/Type
METHOD	Constant gain {0} Input gain {1} TPC command {2}	None	0	[0, 2]/Integer
GAIN	Initial power gain in dB	None	0	(-Inf, 200]/Real
STEP	Step size of power adjustment in dB	None	1	[0, 200]/Real
N	Number of samples in a slot	None	200	[1, Inf)/Integer
INIT_SLOT	Number of initial invalid slots	None	10	[0, Inf)/Integer
RIN	Input impedance	Ohm	Inf	[0, Inf]/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Input1	Input signal in complex envelope format (complex)			
Input2	Gain or transmission power control command (integer)			
Output	Output signal in complex envelope format (complex)			

Notes

1. The Power Amplifier model can be used to amplify the input signal.
2. If *Method* is set to Constant gain {0}, the input signal at Input1 is amplified by *Gain* (dB).
3. If *Method* is set to Input gain {1}, Input2 must be connected and each sample corresponds *N* samples (i.e., one slot) at Input1. The input signal at Input1 during the first *InitSlot* slots

is amplified by *Gain* (dB) , the input signal of each slot at Input1 is amplified by the value (dB) of the corresponding sample at Input2.

4. If *Method* is set to TPC command {2}, Input2 also must be connected and each sample corresponds *N* samples at Input1, i.e., one slot. The input signal at Input1 during the first *InitSlot* slots is amplified by *Gain* (dB), and the input signal of each slot at Input1 is further amplified by *Step* (dB) if the value of the corresponding sample at Input2 (i.e., TPC command) is 1, by -*Step* (dB) for TPC command is -1, or kept the power of the previous slot if TPC command is 0, as shon in Fig.1.

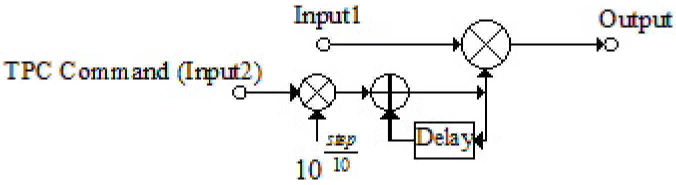


Fig. 1 Block diagram of Power Amplifier with Method = 2.

Netlist Form

```
APOWAMP:NAME  n1 n2 n3 nexsys_component=POWAMP [METHOD =val]
GAIN =val [STEP =val] [N =val] [INIT_SLOT =val] +[RIN1=val]
[RIN2=val] [ROUT=val]
```

Netlist Example

```
APOWAMP:1 1 2 3 nexsys_component=POWAMP METHOD=2 GAIN=0 STEP=1 N=20
INIT_SLOT=1
```

References

1. S. Seo, T. Dohi, and F. Adachi, “SIR-based transmit power control of reverse link for coherent DS-CDMA mobile radio,” *IEICE Trans. Commun*., vol. E81-B, no. 7, pp. 1508–1516, July 1998.

Random Sequence Generator (RANDSEQ)

Property	Description	Units	Default	Range/Type
NB	Number of random binary bits to be generated	None	100	[1, Inf)/Integer
BR	Bit rate at the output	Hz	1000Hz	(0, Inf)/Real
SEED	Random Seed	None	0	[0, Inf)/Integer
T	True output value	None	-1	(-Inf, Inf)/Real
F	False output value	None	1	(-Inf, Inf)/Real
ROUT	Output impedance	Ohm	0	[0, Inf)/Real
Ports				
Output	Random sequence, taking the value T or F, equal probability (real)			

Notes

1. The Random Sequence Generator model can be used to generate random sequence, taking the value *T* or *F* or with equal probability.

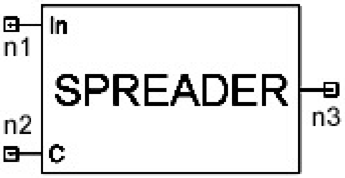
Netlist Form

```
ARANDSEQ:NAME  n1 nexsys_component=RANDSEQ NB =val BR=val
[SEED=val]  [T=val] [F =val] [ROUT=val]
```

Netlist Example

```
ARANDSEQ:1 1 nexsys_component=RANDSEQ NB=100 BR=1khz SEED=14727 T=1
F=0
```

Spreader (SPREADER)



Property	Description	Units	Default	Range/Type
G	Spreading Factor	None	16	[1, Inf)/Integer
S	Number of samples per chip	None	4	[1, 128]/Integer

FC	Carrier frequency in Hz	Hz	0	[0, Inf)/Real
Rin1	Input1 impedance	Ohm	Inf	(0, Inf]/Real
Rin2	Input2 impedance	Ohm	Inf	(0, Inf]/Real
Rout	Output impedance	Ohm	0	[0, Inf]/Real
Ports				
Input1	Input signal in complex envelope format (complex)			
Input2	Spreading code (complex)			
Output	Symbols after spreading (complex)			

Notes

1. The Spreader model can be used to perform spreading (i.e., each sample at Input1 multiplies *G* samples at Input2 and thus *G* products are obtained) , then repeat the outcome *S* times.

Netlist Form

```
ASPREADER:NAME  n1 n2 n3 nexsys_component=SPREADER G =val S=val
+ [FC=val] [RIN1=val] [RIN2=val] [ROUT=val]
```

Netlist Example

```
ASPREADER:1 1 2 3 nexsys_component=SPREADER G = 31 S = 4
```

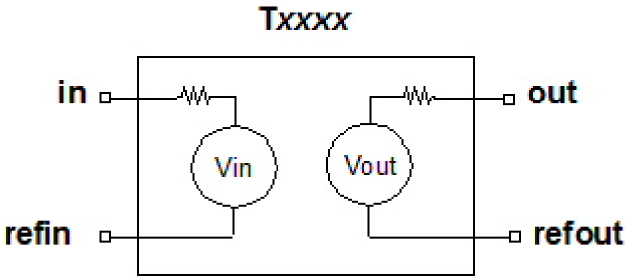
References

1. J. G. Proakis, *Digital Communications*, McGraw-Hill, 2001.
2. R. L. Peterson, R. E. Ziemer, and D. E. Borth, *Introduction to Spread Spectrum Communications*. Prentice Hall International Editions, 1995.

39 - Transmission Lines

This topic describes the following transmission lines:

T-Element Lossless Transmission Line



T-Element Instance Netlist Syntax

The netlist syntax for a lossless transmission line instance has two possible forms:

```
Txxxx in invref out outvref Z0=imped TD=delay
```

or

```
Txxxx in invref out outvref Z0=imped F=freq NL=normlen
```

In both forms, node *in* is the input signal node and node *refin* is the input reference node. Nodes *out* and *refout* are the corresponding output signal node and output reference node. When **TD** is specified, **F** and **NL** parameters are ignored if present. When **TD** is not specified, you must specify the **F** parameter and set the **NL** parameter.

Table 3: Lossless Transmission Line Instance Parameters

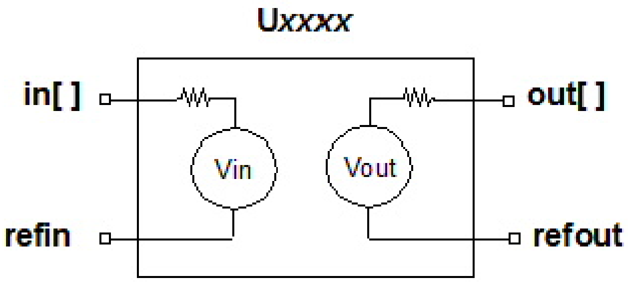
Instance Parameter	Description	Unit	Default
F	Frequency (required when TD not specified; ignored when TD is specified)	Hertz	None
NL	Normalized length with respect to wavelength (ignored when TD is specified)	None	0.25 (quarter-wavelength)
TD	Time delay	Second	Calculated as NL/F
Z0	Characteristic impedance	Ohm	50

T-Element Instance Netlist Example

```
T1 10 0 12 0 Z0=50 TD=0.7e-8
```

```
T2 11 0 13 0 Z0=50 FREQ=5e+9 NL=0.5
```

U-Element Lossy Transmission Line



U-Element Instance Netlist Syntax

The netlist syntax for a lossy transmission line instance is:

```
Uxxxx in1 [...inNL] refin out1 [...outNL]]refout
[modelname] L=length [LUMPS=num_sections]
```

Nodes *in1* through *inNL* are the input signal voltages. *refin* is the common reference voltage for all inputs. *out1* through *outNL* are the output signal voltages corresponding to the inputs. *refout* is the common reference voltage for all outputs.

The *modelname* is the name of a .MODEL statement for a type **U** lossy transmission line; see U Model Lossy Transmission Line for details.. The number of signal lines specified by the **NL** parameter on the model must be the same as the number of signal lines on the instance.

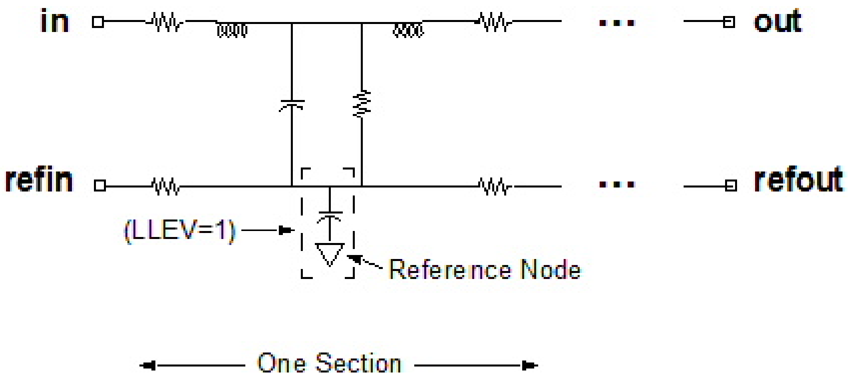
Table 4: U-Element Instance Parameters

Model Parameter	Description	Unit	Default
L	Line length	Meter	Required
LUMPS	Number of lumped-parameter sections	None	20

U-Element Instance Netlist Example

```
U21 1 2 3 0 4 5 6 0 umodel1 L=5e-3 LUMPS=20
```

U-Model Lossy Transmission Line



U Model Netlist Syntax

The netlist format for a lossy transmission line model is:

```
.MODELmodelname U [parameter=val] ...
```

Table 5: U-Model Selector/Flag Parameters

Model Parameter	Description	Unit	Default
DLEV	Dielectric model selector 0 = Microstrip, sea of dielectric	None	1

	1 = Microstrip 2 = Stripline 3 =Dielectric with overlay dielectric		
ELEV	Electrical model selector 1 = geometric 2 = precomputed 3 = electrical	None	1
LLEV	Capacitance CREF from signal reference nodes to system reference node 0 = Omit capacitance 1 = Include capacitance	None	0
PLEV	Physical model selector 1 = planar 2 = coaxial (not supported) 3 = twin-lead (not supported)	None	1

Table 6: U-Model Basic Parameters

Model Parameter	**Description**	**Unit**	**Default**
C	Capacitance per unit length (ELEV=2)	Farad/Meter	0.0
CEXT	External capacitance per unit length between reference plane and ground (LLEV=1)	Farad/Meter	Calculated
CMULT	Dielectric constant of material between reference plane and ground (LLEV=1) [Used when CEXT is not specified]	None	1.0
CORKD	Correction multiplier for KD	None	1.0
G	Conductance per unit length (ELEV=2)	Mho/Meter	0.0
HGP	Height of reference plane above simulator ground, for calculating capacitance from reference plane to simulator ground (LLEV=1) [Used when CEXT is not specified]	Meter	1.5 × HT
HT (**HT1**)	Height of all conductors	Meter	1.0e-3

KD (**KD1**)	Relative dielectric constant of dielectric	None	3.5
KD2	Relative dielectric constant for overlay dielectric (DLEV=3)	None	3.5
L	Inductance per unit length (ELEV=2)	Henry/Meter	0.0
MAXL	Maximum number of lumps per element	None	20
NL	Number of conductors (1 to 20)	None	Calculated from instance
NLAY	Number of layers for conductor resistance calculation 1 = DC/core resistance 2 = Core and skin resistance at skin effect frequency	None	1
R	Resistance per unit length (ELEV=2)	Ohm/Meter	0.0
RHO	Conductor resistivity	Ohm-Meter	17.0e-9
RHOB	Reference plane resistivity	Ohm-Meter	RHO
SIG (**SIG1**)	Dielectric conductivity	Mho/Meter	0.0
SP (**SP12**)	Spacing between conductors (NL > 1)	Meter	1.0e-3
TH (**TH1**)	Thickness of all conductors	Meter	17.0e-6
THB	Thickness of reference plane	Meter	TH
THK1	Dielectric thickness for DLEV=3	Meter	HT
THK2	Overlay dielectric thickness for DLEV=3	Meter	0.0
TS	Distance between reference planes for stripline (DLEV=2)	Meter	(2 × HT) + TH
WD (**WD1**)	Width of each conductor	Meter	1.0e-3
WLUMP	Number of lumps per wavelength	None	20
XW	Difference between drawn width and physical width	Meter	0.0

U Model Netlist Example

```
.MODEL tranu1 U DLEV=1
```

W-Element Transmission Line

W-Element Instance Netlist Syntax

The netlist syntax for a W-element transmission line instance is:

```
Wxxxx in1 [... inN]] refin out1 [... outN]]refout
N=num_signals L=length RLGCMODEL=modelname
```

or

```
Wxxxx in1 [...inN] refin out1 [...outN]] refout
N=num_signals L=length RLGCFILE='filename'
```

or

```
Wxxxx in1 [...inN] refin out1 [...outN]] refout
N=num_signals L=length TABLEMODEL=modelname
```

or

```
Wxxxx in1 [...inN] refin out1 [...outN]] refout
N=num_signals L=length FSMODEL=modelname
```

or

```
Wxxxx in1 [...inN] refin out1 [...outN]] refout
N=num_signals L=length SMODEL=modelname
```

Nodes *in1* through *inN* are the input signal voltages. *refin* is the common reference voltage for all inputs. *out1* through *outN* are the output signal voltages corresponding to the inputs. *refout* is the common reference voltage for all outputs. Parameter **N** specifies the number of signal lines, not counting the reference. Parameter **L** is the length of the transmission line in meters.

RLGCMODEL is the name of a W model of type **RLGC** described in a .MODEL statement.

RLGCFILE is the path to a file in RLGC file syntax. The file path must be enclosed in quote marks.

TABLEMODEL is the name of a W model of type **TABLE** described in a .MODEL statement.

FSMODEL is the name of a W model of type **FIELDSOLVER** described in a .MODEL statement.

SMODEL is the name of an "S Frequency Dependent Data Model" on page 33-13 described in a .MODEL statement. With **SMODEL**, the W-element is described by S-parameter data from a Touchstone file. The **XLINELENGTH** parameter on the S-Model specifies a unit length. Nexxim computes the equivalent RLGC or TABLE model for that unit length on the S-parameter data. The parameter **L** on the W-Element specifies the actual length of transmission line to simulate using the calculated model.

One of the types of model—**RLGCMODEL**, **RLGCFILE**, **TABLEMODEL**, **FSMODEL**, or **SMODEL** – must be specified.

Table 7: W Element Instance Parameters

Model Parameter	Description	Unit	Default
L	Line length	Unit of model	Required
N	Number of signal conductors, not counting the common signal references	None	Required

W-Element Instance Netlist Examples

```
W1 1 2 0
+ 4 5 0
+ N=2 L=1 RLGCMODEL=test2d_w

W1
+ 1 2 3
+ 4 5 6
+ N=2 L=1 TABLEMODEL=test2d_tabw
```

W-Model Transmission Line, FIELDSOLVER

W Fieldsolver Model Netlist Syntax

The netlist format for a W-model transmission line with **FIELDSOLVER** model type is:

```
.MODELmodelname W MODELTYPE=FIELDSOLVER
RLGCFILE=filename
ACCURACY=low|medium|high
FDIE=freq
LAYERSTACK=stackname
CONDUCTOR=(


SHAPE=shapename
[MATERIAL=materialname]
[ORIGIN=(x,y)]
[TYPE=SIGNAL|REFERENCE]
```

```
)

[CONDUCTOR=(

SHAPE=shapename
[MATERIAL=materialname]
[ORIGIN=(x,y)]
[TYPE=SIGNAL|REFERENCE]
)]...
```

Table 8: W FIELDSOLVER Model Parameters

Model Parameter	Description	Unit	Default
LAYERSTACK	Name of layer stack defined in **.LAYERSTACK** statement	None	Required
CONDUCTOR	Subfields specify the parameters of a conductor. The **.MODEL** statement can include one or more **CONDUCTOR** definitions. **CONDUCTOR** entries must be the last entries in the .MODEL statement	None	One **CONDUCTOR** definition is required
SHAPE	Name of shape defined in **.SHAPE** statement	None	Required
MATERIAL	Name of material defined in **.MATERIAL** statement	None	See description of **.MATERIAL** statement for default
ORIGIN	In Cartesian coordinates, the (X,Y) location of the origin of the conductor The X coordinate can be positive, negative, or zero. The Y coordinate must be positive or zero.	Meter	0.0, 0.0
TYPE	Conductor type **SIGNAL** = signal node **REFERENCE** = use as reference node in W element	None	**SIGNAL**
RLGCFILE	Name of the file of RLGC values saved for a particular setup. If the file exists, new values are appended.	None	None

ACCURACY	Discretization level for the geometry: low, medium, or high	None	**medium**
FDIE	Frequency at which dielectric data are measured or specified	Hz	1e9

Example FIELDSOLVER Model Statement

```
.MODEL fs_test W MODELTYPE=FIELDSOLVER
+ LAYERSTACK=stack_2
+ RLGCFILE=example4.rlgc
+ ACCURACY=low
+ CONDUCTOR=(SHAPE=rect1, ORIGIN=(-0.6mm, 0.8mm),
MATERIAL=copper)
+ CONDUCTOR=(SHAPE=poly_1, ORIGIN=(-0.5mm, 0.2mm),
MATERIAL=copper)
+ CONDUCTOR=(SHAPE=strip_1, ORIGIN=(0.1mm, 0.2mm),
MATERIAL=copper)
+ CONDUCTOR=(SHAPE=circ_1, ORIGIN=(0.2mm, 0.7mm),
MATERIAL=copper)
```

FIELDSOLVER Model Notes

1. FIELDSOLVER models in externally-generated netlists may contain FSOPTIONS, RLGCFILE, COORD, or OUTPUTFORMAT parameters. These parameters are ignored by this version of Nexxim.
2. The Nexxim fieldsolver uses Cartesian coordinates only. Polar coordinates are not supported.
3. The Nexxim fieldsolver supports conductors of type SIGNAL and REFERENCE. The presence of any conductors of type FLOATING in an externally-generated netlist causes a simulation to fail.

.MATERIAL Statement

The **.MATERIAL** statement defines the parameters for a single material type. The syntax is:

```
.MATERIALmaterialname METAL|DIELECTRIC


[ER=val]

[CONDUCTIVITY=val]

[LOSSTANGENT=val]
```

The material must be defined to be either **METAL** or **DIELECTRIC**.

Table 9: MATERIAL Statement Entries

Entry	Description	Unit	Default
ER	Dielectric constant (relative permittivity)	None	METAL: 1 DIELECTRIC: 1
CONDUCTIVITY	Static field conductivity	Siemens/Meter	METAL: -1 DIELECTRIC: 0
LOSSTANGENT	AC field loss tangent of dielectric	None	DIELECTRIC: 0

Example .MATERIAL Statements

```
.MATERIAL copper METAL CONDUCTIVITY=57.6meg
.MATERIAL diel_1 DIELECTRIC ER=9.64 LOSSTANGENT=0.00064
.MATERIAL diel_2 DIELECTRIC ER=4.95 LOSSTANGENT=0.00086
.MATERIAL diel_3 DIELECTRIC ER=7.80 LOSSTANGENT=0.00024
```

MATERIAL Statement Notes

1. **PEC** is a system-defined METAL material with the default values for METAL materials.
2. **AIR** is a system-defined DIELECTRIC material with the default values for DIELECTRIC materials.
3. The parameter values for these system-defined material names cannot be changed.

.LAYERSTACK Statement

The **.LAYERSTACK** statement specifies the sequence of dielectric and metal layers in the object to be analyzed. The syntax is:

```
.LAYERSTACKstackname

[LAYER=(materialname,thickness)

[, LAYER=(materialname,thickness)]...]
```

Table 10: LAYERSTACK Statement Entries

Entry	Description	Unit	Default
LAYER	*materialname* = material name defined in **.MATERIAL** statement. *thickness* = thickness of layer.	Thickness: Meter	If no LAYER entry is present, stackup represents a free space without a ground plane. If a LAYER entry is present, the

	Layers are specified starting with the lowest layer. The bottom of the layer stack is at Y=0.0. METAL materials can be the bottom layer, the top layer, or both. Inner layers must be DIELECTRIC.		*materialname* and *thickness* are both required.

> **Note:**
>
> Nexxim automatically supplies a layer of AIR above the topmost layer specified in the .LAYERSTACK statement. BACKGROUND entries in externally-generated netlists are ignored by Nexxim.

Example .LAYERSTACK Statement

```
.LAYERSTACK stack_1
+ LAYER=(copper, 0.0) // Lowest layer
+ LAYER=(diel_1, 0.2mm)
+ LAYER=(diel_2, 0.5mm)
+ LAYER=(diel_3, 0.3mm)
+ LAYER=(copper, 0.0) // Topmost layer
```

.SHAPE Statement

The **.SHAPE** statement specifies the cross-sectional shape of a conductor. Rectangle, circle, polygon, and strip shapes are supported in Nexxim.

> **Note:**
>
> Externally-generated netlists may include the NH and NW parameters. These parameters are ignored by the Nexxim fieldsolver. The equivalent controls are generated and adjusted internally and do not require user input.

`.SHAPEshapename RECTANGLE WIDTH=val HEIGHT=val`

The origin for a rectangular conductor is at the lower left corner.

Table 11: Rectangular SHAPE Statement Entries

Entry	Description	Unit	Default

WIDTH	Width of conductor cross-section	Meter	Required
HEIGHT	Height of conductor cross-section	Meter	Required

`.SHAPEshapename CIRCLE RADIUS=val`

The origin for a circular conductor is the center of the circle.

Table 12: Circular SHAPE Statement Entries

Entry	**Description**	**Unit**	**Default**
RADIUS	Radius of conductor cross-section	Meter	Required

`.SHAPEshapename POLYGON VERTEX=[x1, y1, x2, y2, ...]`

The origin for a polygonal conductor can be any vertex; x1, y1 is recommended.

Table 13: Polygon SHAPE Statement Entries

Entry	**Description**	**Unit**	**Default**
VERTEX	x and y coordinates of all vertices of the polygon. The vertices may be specified in clockwise or in counterclockwise sequence	Meter	Required

`.SHAPEshapename STRIP WIDTH=val`

The origin for a 2D strip conductor is the left edge.

Table 14: Strip SHAPE Statement Entries

Entry	**Description**	**Unit**	**Default**
Width	Width of conductor	Meter	Required

Example SHAPE Statements

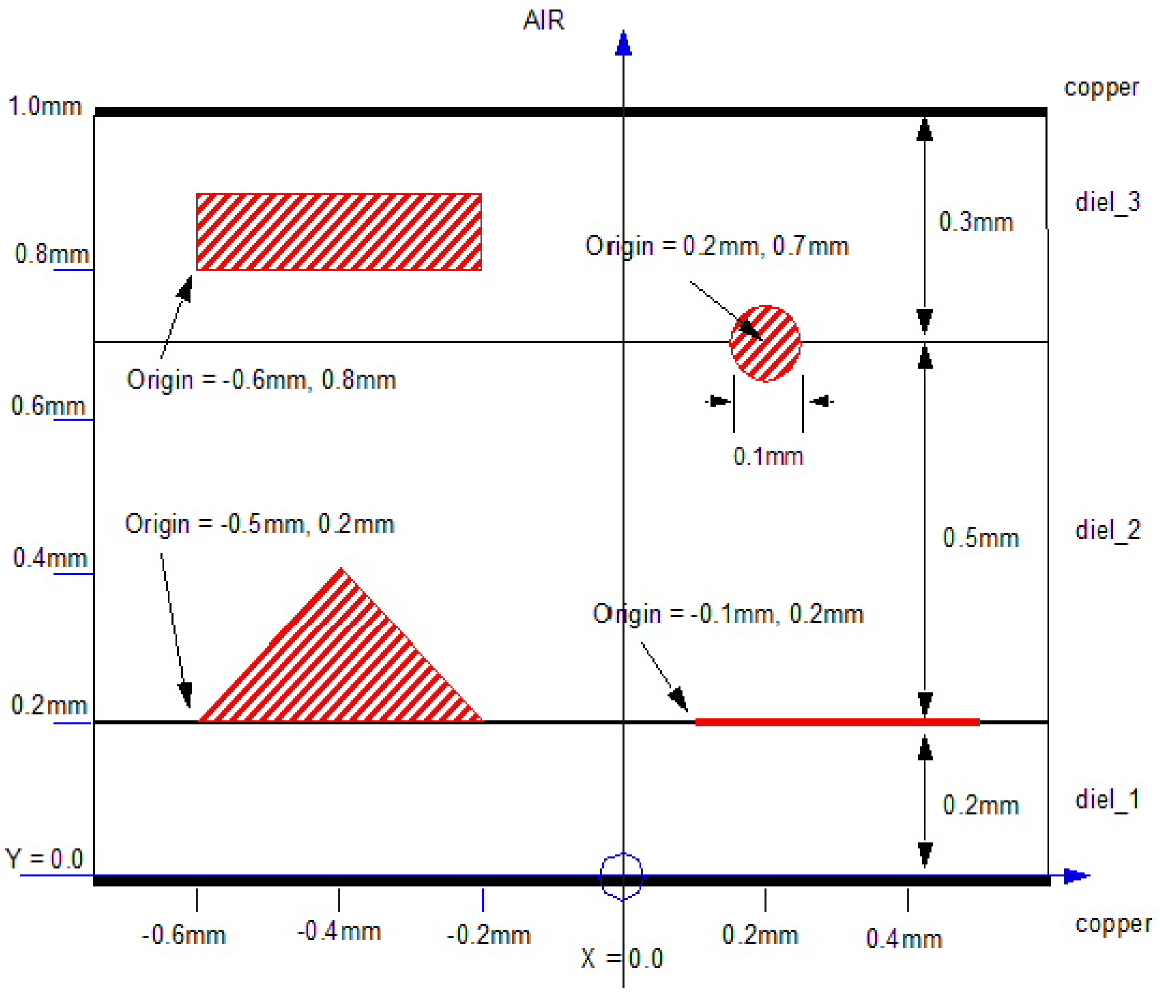
```
.SHAPE rect_1 RECTANGLE HEIGHT=0.01mm WIDTH=0.4mm
.SHAPE circ_1 CIRCLE RADIUS=0.1mm
.SHAPE poly_1 POLYGON VERTEX=[-0.5,0.2,-0.3,0.4,-0.1,0.2]
.SHAPE strip_1 STRIP WIDTH=0.4mm
```

Netlist Example of W FIELDSOLVER Transmission Line

of a W FIELDSOLVER transmission line that includes all the statement types described in this topic.

```
* W FIELDSOLVER TRANSMISSION LINE EXAMPLE

W1 Port1 Port2 0 Port3 Port4 0 N=2 L=10e-3 FSMODEL=fs_test

.MATERIAL copper METAL CONDUCTIVITY=57.6meg
.MATERIAL diel_1 DIELECTRIC ER=9.64 LOSSTANGENT=0.00064
.MATERIAL diel_2 DIELECTRIC ER=4.95 LOSSTANGENT=0.00086
.MATERIAL diel_3 DIELECTRIC ER=7.80 LOSSTANGENT=0.00024

.SHAPE rect_1 RECTANGLE HEIGHT=0.1mm WIDTH=0.4mm
.SHAPE circ_1 CIRCLE RADIUS=0.1mm
.SHAPE poly_1 POLYGON VERTEX=[-0.5,0.2,-0.3,0.4,-0.1,0.2]
.SHAPE strip_1 STRIP WIDTH=0.4mm

.LAYERSTACK stack_1
+ LAYER=(copper, 0.0) // Lowest layer
+ LAYER=(diel_1, 0.2mm)
+ LAYER=(diel_2, 0.5mm)
+ LAYER=(diel_3, 0.3mm)
+ LAYER=(copper, 0.0) // Topmost layer

.MODEL fs_test W MODELTYPE=FIELDSOLVER
+ LAYERSTACK=stack_1
+ RLGCFILE=example4.rlgc
+ ACCURACY=low
+ CONDUCTOR=(SHAPE=rect_1, ORIGIN=(-0.6mm, 0.8mm),
MATERIAL=copper)
+ CONDUCTOR=(SHAPE=poly_1, ORIGIN=(-0.5mm, 0.2mm),
MATERIAL=copper)
+ CONDUCTOR=(SHAPE=strip_1, ORIGIN=(0.1mm, 0.2mm),
MATERIAL=copper)
+ CONDUCTOR=(SHAPE=circ_1, ORIGIN=(0.2mm, 0.7mm),
MATERIAL=copper)
```

The transmission line described by this netlist can be illustrated as:



W-Model Transmission Line, RLCG

W-RLGC Model Netlist Syntax

The netlist format for a W-model transmission line with RLGC model type is:

```
.MODELmodelname W MODELTYPE=RLGC N=val
FDIE=frequency
Lo=matrix_entries
Co=matrix_entries
[Ro=matrix_entries]
[Go=matrix_entries]
```

```
[Rs=matrix_entries]
[Gd=matrix_entries]
```

All of the input matrices are symmetrical, so the *matrix_entries* specify only the lower triangular matrix elements. The diagonal elements are the resistance, inductance, conductance, and capacitance (RLGC) values for each of the signal lines. For the **Lo** and **Co** matrices, diagonal elements are positive (non-zero). For the **Ro**, **Rs**, **Go**, and **Gd** matrices, diagonal elements can be positive or zero. The off-diagonal elements are mutual effect values. For the **Lo** and **Ro** matrices, off-diagonal elements can be positive or zero. For the **Co**, **Go**, and **Gd** matrices, off - diagonal elements can be negative or zero.

RLGC models with large matrix sizes are typically written in separate files and included into the netlist with an .INCLUDE or .LIB statement.

The unit of length can be any unit as long as the L in the instance is in the same unit.

Table 15: RLGC W-Model Parameters

Model Parameter	Description	Unit	Default
N	Number of signal lines	None	Required
Lo	Matrix of high-frequency limits of inductance per unit length. The Lo matrix is required for simulation to proceed.	Henry	Required
Co	Matrix of capacitance per unit length at FDIE. The Co matrix is required for simulation to proceed.	Farad	Required
Ro	Matrix of DC resistance per unit length	Ohm	0 in every matrix element
Go	Matrix of DC conductance per unit length	Siemens	0 in every matrix element
Rs	Matrix of frequency-dependent skin effect resistance per unit length	Ohm/Hertz^{½}	0 in every matrix element
Gd	Matrix of frequency-dependent dielectric loss conductance per unit length	Siemens/Hertz ½	0 in every matrix element
FDIE	Frequency at which capacitance (dielectric) data is measured or specified	Hz	1e9

> **Note:**
>
> If Ro, Go, Rs, and Gd are not specified, they default to zero values, and the W-element reduces to a lossless line.

W-RLGC Model Netlist Example

```
.model test2d_w W modeltype=RLGC N=2
+ FDIE=1e9
+ Lo=
+   3.964542432094597e-007
+   1.027885379257179e-007
+   3.949500843672859e-007
+ Co=
+   1.346852474191454e-010
+  -3.521195569886902e-011
+   1.353506631279533e-010
+ Ro=
+   0.001027851458885933
+   0.0001657824933686929
+   0.00102785145888604
+ Rs=
+   1.357902308438043e-013
+   1.867284066122683e-014
+   1.369158440674621e-013
+ Gd=
+   1.683520634126077e-011
+  -4.218325637497574e-012
+   1.690051828177642e-011
```

W-Model Transmission Line, TABLE

W Table Model Netlist Syntax

The netlist format for a W-model transmission line of model type **TABLE** is:

```
.MODELmodelname W MODELTYPE=TABLE N=val
LMODEL=modelname
CMODEL=modelname
[RMODEL=modelname]
[GMODEL=modelname]
```

TABLE models with large matrix sizes are typically written in separate files and included into the netlist with an .INCLUDE or .LIB statement.

Table 16: TABLE W-Model Parameters

Model Parameter	Description	Unit	Default
N	Number of signal lines	None	Required
LMODEL	SP model for frequency-dependent inductance matrix defined in a separate .MODEL statement	None	None
CMODEL	SP model for frequency-dependent capacitance matrix defined in a separate .MODEL statement	None	None
RMODEL	SP model for frequency-dependent resistance matrix defined in a separate .MODEL statement	None	None
GMODEL	SP model for frequency-dependent conductance matrix defined in a separate .MODEL statement	None	None

See the help on the SP Frequency-Dependent Data Model for details.

W Table Model Netlist Example

```
.MODEL test2d_tabw W MODELTYPE=table N=2

+ RMODEL=rtest2d_tabw

+ LMODEL=ltest2d_tabw

+ GMODEL=gtest2d_tabw

+ CMODEL=ctest2d_tabw
```

W-Element Options

These options apply to W-element transmission lines.

Table 17: Nexxim W-Element Options

Option	Default Value	Description
w_element.auto_enforce_passivity	1	**This option is supported only for legacy designs.** Use the Global Analysis option **auto_enforce_passivity=1** to enable automatic passivity enforcement for both S-elements and W-elements. When the Global option is unavailable (set to 0), the **auto_enforce_passivity** option set in a W-element or S-element is ignored. 1=If transient fails with a passivity violation, and passivity enforcement is not enabled, automatically restart transient with passivity enforcement enabled (**w_element.enforce_passivity=7**). 0=No restart after transient fails **auto_enforce_passivity** is valid only in a transient simulation and is ignored in a frequency-domain analysis (HB or LNA).
w_element.dc_only	0	0=unavailable, 1=enabled. When **dc_only** is enabled, Nexxim computes the steady-state behavior of the lines without any transient behavior such as reflections. When this option is enabled, passivity enforcement requests are ignored. When **w_element.dc_only** is enabled and the **time_domain_w_model** option is also set, requests for time domain modeling are also ignored.
w_element.enforce_causality	2	0=No causality enforcement 1=Ensure the input data is causal (satisfies the Kramer-Kronig or Hilbert-transform relations). 2=Try fitting with no enforcement. If the fit fails to achieve sufficient accuracy, refit with causality enforcement enabled. Valid only for TABLE models.
w_element.enforce_passivity	0	0=No passivity enforcement 1=Enforce the passivity of the state-space model during transient analysis of S-parameter element 2= Use a point-by-point method for enforcing passivity. Use this

Option	Default Value	Description
		option in cases with large numbers of ports (more than about 30). 6=Use a passivity by perturbation algorithm 7=Use Iterated Fitting of Passivity Violations (IFPV) algorithm 8=Use Iterated Fitting of Passivity Violations Low Frequency (IFPVLF) algorithm Setting **enforce_passivity=2** automatically sets **mor=3**, since this passivity enforcement algorithm requires this model-order reduction strategy. Setting **enforce_passivity=8** builds upon the existing IFPV while ensuring a better fit to “Z” at DC and low frequencies.
w_element.ensure_accurate_long_time_response	1	1=Use enhanced W-element methodology to ensure that the long-time response of the transmission line is the same as a resistor with the equivalent impedance. 0=Use legacy methodology.
w_element.fdie	1e9	Frequency at which the capacitance matrix is specified, for Hilbert causality correction
w_element.g_to_gnd	1e-12	Conductance between all terminal nodes of all W-elements and ground
w_element.hspice_skin	0	1=Turn on HSPICE skin effect model
w_element.ignore_losses	0	1=Generate lossless model (ignoring R and G)
w_element.min_freq_count	0	Minimum number of frequencies required in TABLE model. If fewer frequencies are present, the table is interpolated up to the specified minimum.
w_element.mor	0	0=No model order reduction (MOR) 1=MOR of entire matrix at once 2=MOR of rows of matrix individually, then final MOR for the combination 3=MOR of rows of matrix individually, no final MOR

Option	Default Value	Description
		4=MOR of columns of matrix individually, then final MOR for the combination 5=MOR of columns of matrix individually, no final MOR
w_element.reltol	1e-3	Tolerance for state-space fit.

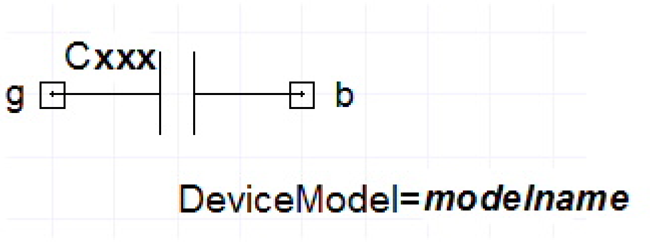
40 - Varactors

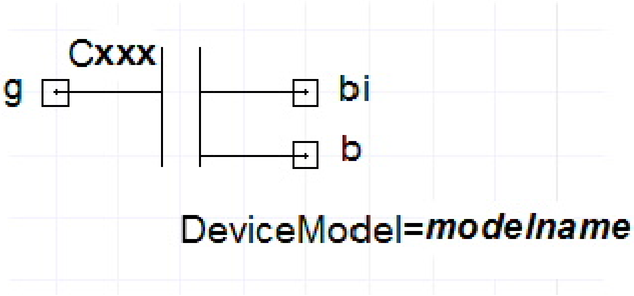
This topic describes the following varactors:

"CMC MOS Varactor Instance" below

"CMC MOS Varactor Model" on the next page

CMC MOS Varactor Instance





Varactor Instance Netlist Syntax

The syntax for a CMC MOS varactor instance is:

C*xxxx g* [*bi*] *b modelname* **L=** val **W=** val [**M=** val] [**M_SEG=** val] [**NGCON=***val*] [**DTA=***val*]

For the two-pin instance, *g* and *b* are the nodes of the varactor. The three-pin instance adds node *bi*.The *modelname* is the name of a .MODEL statement for the varactor model associated with the instance. In the syntax above, the *modelname* must be supplied.

Table 1: Varactor Instance Parameters

Instance Parameter	Description	Unit	Default

L	Capacitor length	Meter	1e-6
W	Capacitor width	Meter	1e-6
M	Multiplier to simulate parallel varactors	None	1
M_SEG	Number of gate segments	None	1
NGCON	Number of gate contacts	None	1
DTA	Local temperature offset with respect to ambient circuit temperature	°C	0.0

Varactor Instance Netlist Example

```
C1 3 4 mosvar1 L=0.5e-6 W=0.5e-6 DTA=5.0
```

CMC MOS Varactor Model

The .MODEL statement for the CMC MOS Varactor specifies values for one or more model parameters.

`.MODEL modelname C LEVEL=7 [modelparameter=val] ...`

Table 2: CMC MOS Varactor Model Parameters

Model Parameter	Description	Unit	Default
Version	Model version	None	1
TMIN	Minimum ambient temperature	°C	-100.0
TMAX	Maximum ambient temperature	°C	500.0
LEVEL	Model level (Level=7 is required for the CMC MOS Varactor model)	None	7
CFRL	Fringing capacitance in length direction	Farad/Meter	0
CFRW	Fringing capacitance in width direction	Farad/Meter	0
DLQ	Length delta for capacitor size	Meter	0
DNSUBO	Doping profile slope parameter	None	0
DWQ	Width delta for capacitor size	Meter	0
DWR	Width delta for substrate resistance calculation	Meter	0
FETA	Effective field parameter	None	1.0

LMAX	Maximum allowed drawn length	Meter	9.9e9
LMIN	Minimum allowed drawn length	Meter	1e-8
MNSUBO	Maximum change in absolute doping, limited to 1 order of magnitude up	None	1
NSLPO	Doping profile smoothing parameter	None	0.1
NSUBO	Substrate doping level	$1/\text{Meter}^3$	3e23
REND	End resistance (extrinsic well resistance plus vertical contact resistance to well) per width	Ohm*Meter	1e-4
RPV	Vertical resistance down through gate	Ohm*Meter^2	0
RSHG	Gate sheet resistance	Ohm/sq	1
RSHS	Substrate sheet resistance	Ohm/sq	1000
STREND	Temperature dependence of REND	None	0
STRPV	Temperature dependence of RPV	None	0
STRSHG	Temperature dependence of RSHG	None	0
STRSHS	Temperature dependence of RSHS	None	0
STUAC	Temperature dependence of UAC	None	0
STVFB	Temperature dependence of VFB	V/°K	0
TOXO	Oxide thickness	Meter	2e-9
TR	Nominal (reference) temperature	°C	21
UAC	Accumulation layer zero-bias mobility	$\text{Meter}^2/\text{Volt/Sec}$	5e-2
UACRED	Accumulation layer mobility degradation factor	1/Volt	0
VFBO	Flat-band voltage	Volt	-1
VNSUBO	Doling profile corner voltage parameter	None	0
WMAX	Maximum allowed drawn width	Meter	9.9e9
WMIN	Minimum allowed drawn width	Meter	1e-8
SWRES	Switch to control series resistance (0=exclude, 1=include)	None	1
NPO	Polysilicon doping level	$1/\text{Meter}^3$	1e27
QMC	Quantum mechanical correction factor	None	1
SWIGATE	Flag for gate current (0=deactivate, 1=activate	None	0
TAU	Time constant for inversion charge recombination/generation	Second	0.1

TYPE	Substrate doping type (-1=n-type, +1=p-type)	None	-1
TYPEP	Polysilicon doping type (-1=n-type, +1=p-type)	None	-1
CHIBO	Tunneling barrier height for electrons	Volt	3.1
CHIBPO	Tunneling barrier height for holes	Volt	4.5
GC2HVO	HVB gate current slope factor	None	0.375
GC2O	ECB gate current slope factor	None	0.375
GC3HVO	HVB gate current curvature factor	None	0.063
GC3O	ECB gate current curvature factor	None	0.063
GCOHVO	HVB gate tunneling energy adjustment	None	0
GCOO	ECB gate tunneling energy adjustment	None	0
IGCHVLW	HVB gate channel prefactor for 1µm^2 channel area.	Ampere	0
IGINVLW	ECB gate channel prefactor for 1µm^2 channel area.	Ampere	0
IGMAX	Maximum gate current	Ampere	1e-5
IGOVHVW	HVB gate overlap current prefactor for 1µm wide gate overlap region	Ampere	0
IGOVW	ECB gate overlap current prefactor for 1µm wide gate overlap region	Ampere	0
LOV	Overlap length	Meter	0
NOVO	Effective doping level of overlap regions	1/Meter^3	5e25
VMAX	Maximum voltage across *g* and *b*	Volt	1000
STIG	Common temperature coefficient for gate currents	None	2

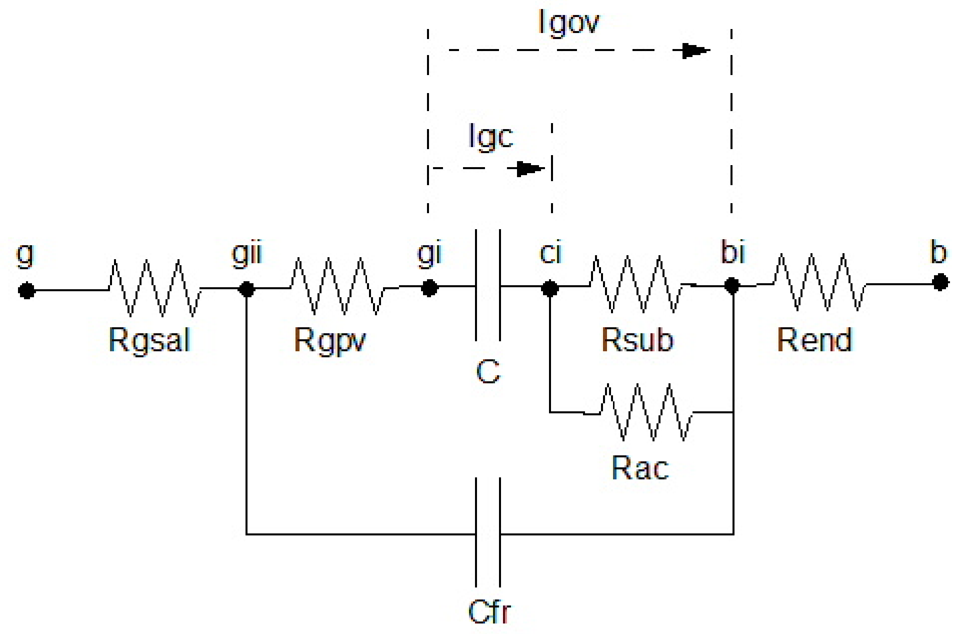
Capacitor Model Netlist Example

```
.MODEL mosvar1 C VERSION=1.1 TMIN=-100 TMAX=500 LEVEL=7

+ CFRL=0 CFRW=0 DLQ=0 DNSUBO=0 DWQ=0 DWR=0 FETA=1

+ LMAX=9.9e009 LMIN=1e-008 MNSUBO=0 NSLPO=0.1 NSUBO=3e+023

+ REND=0.0001 RPV=0 RSHG=1 RSHS=1000

+ STREND=0 STRPV=0 STRSHG=0 STRSHS=0 STUAC=0 STVFB=0

+ TOXO=2e-009 TR=21

+ UAC=0.05 UACRED=0 VFBO=-1 VNSUBO=0 WMAX=9.9e009 WMIN=1e-008

+ SWRES=0 NPO=1e+027 QMC=1 SWIGATE=0 TAU=0.1 TYPE=-1 TYPEP=-1
```

```
+ CHIBO=3.1 CHIBPO=4.5 GC2HVO=0.375 GC2O=0.375
+ GC3HVO=0.063 GC3O=0.063 GCOHVO=0 GCOO=0
+ IGCHVLW=0 IGINVLW=0 IGMAX=1e-005 IGOVHVW=0
+ IGOVW=0 LOV=0 NOVO=5e+025 VMAX=1000 STIG=2
```

Note

1. The following figure gives the equivalent circuit.



Index