



Twin Builder Components: Sensors



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1 - Sensors Library

The Twin Builder sensors library consists of two principal types of components:

- Sensor building blocks. These can be used to develop a behavioral model for a specific sensor type.
- Sensor models that can be parameterized. These are behavioral models of specific sensor types.

All sensor models and sensor building blocks have an ideal version (Level 1) and a non-ideal version (Level 2).

The sensor library consists of four main parts:

1. *Level 1 Sensor Model Building Blocks*: The components in this library can be used to construct ideal sensor models. The blocks have parameters that can typically be derived from manufacturer datasheet parameters.
2. *Level 2 Sensor Model Building Blocks*: The components in this library can be used to construct non-ideal sensor models. The blocks have parameters that can typically be derived from manufacturer datasheet parameters.
3. *Level 1 Sensor Models*: The components in this library are ideal sensor models that can be parameterized using common manufacturer datasheet parameters.
4. *Level 2 Sensor Models*: The components in this library are non-ideal sensor models that can be parameterized using common manufacturer datasheet parameters.

Level 1 Sensor Model Building Blocks

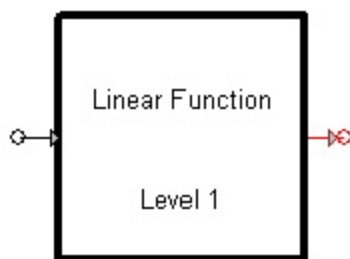
The Level 1 Sensor Model Building Blocks library consists of components that can be used to build ideal sensor models that can be parameterized using common manufacturer datasheet parameters. There are three types of models available in the library: Green measuring blocks, Black processing blocks, and Red output signal blocks. One of each is needed to build a typical sensor model.

- **Measuring Blocks:** These blocks measure a physical quantity in one of the Twin Builder physical domains via conservative pins in that physical domain. This measured value is then passed out of the block by a nonconservative output pin. The block shown here is used to measure angular acceleration in the Twin Builder Displacement-Force rotational domain.



The block's green pin is a conservative pin with a displacement-force rotational nature and must be connected to a node in a displacement-force rotational network. The block then takes the second time derivative of the rotational position at the node to determine the angular acceleration at the node. This value can then be passed to any of the processing blocks by the black pin, which is a nonconservative pin.

- **Processing Blocks:** These blocks take a real value that is passed from one of the measuring blocks as its independent variable. The block then calculates its dependent variable via a function that is determined by user-input parameters and outputs the value of the dependent variable via a nonconservative pin. The processing block shown here is for a linear function:

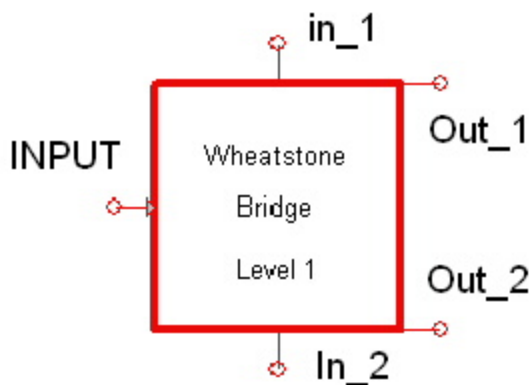


The block's black pin is a nonconservative input pin, which should be connected to the black output pin of a measuring block. The block then calculates the value of its output according to a linear function with the parameters **INPUT**, **SENS** and **OFFSET**.

The parameter **INPUT** is the function's independent variable, which is typically obtained from connecting the block's input pin to the output pin of a measuring block. The parameters **SENS** and **OFFSET** are the linear function's slope and intercept and can be input by the user.

When the value of the block's dependent variable is calculated, it is passed out of the block by the red nonconservative output pin.

- **Output Signal Blocks:** These blocks take a real value from the output of a processing block. This value is used to control the behavior of a circuit element or a combination of circuit elements that is connected to a Twin Builder electric circuit network via one or more conservative pins via an electrical nature. Some output signal blocks also allow the user to input one or more parameters. The block shown here is for a Wheatstone resistor bridge.



The red nonconservative input pin **INPUT** takes the value of the output from a processing block. The four conservative electrical-nature pins, **in_1**, **In_2**, **Out_1**, and **Out_2**, are, respectively, the positive and negative input pins and positive and negative output pins of the Wheatstone bridge. The four conservative pins are used to connect the block into a Twin Builder electrical circuit network.

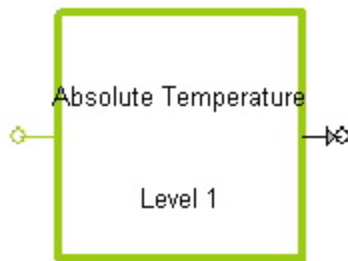
The Wheatstone bridge block has four parameters: **INPUT**, **max_pct_change**, **max_input_magnitude**, and **equivalent_resistance**.

The parameter **INPUT** is the value that controls the Wheatstone bridge's resistors and is usually taken from the output pin of a processing block. The parameters **max_pct_change**, **max_input_magnitude**, and **equivalent_resistance** are parameters for the maximum percent change in the bridge resistors' values, the maximum input that the block will receive from a processing block, and the equivalent resistance of the Wheatstone bridge. These parameters are input by the user.

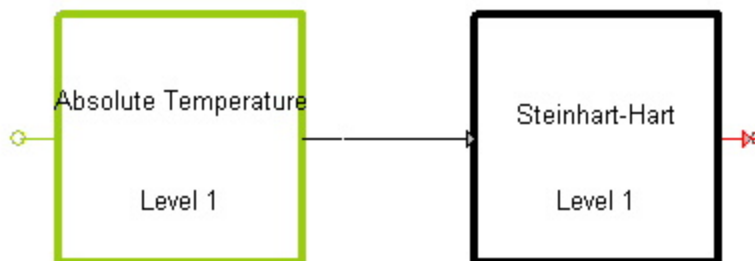
Example:

The following example shows how to build a Level 1 model for a 100-ohm negative temperature coefficient thermistor using elements from the Level 1 Sensor Building Blocks library.

1. Since a thermistor responds to absolute temperature, the first step is to drop an Absolute Temperature measuring block on a Twin Builder schematic sheet.

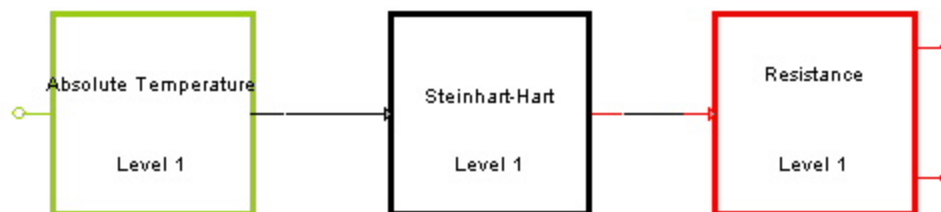


2. The second step is to connect the black output pin of the measuring block to the input pin of a processing block. Since the sensor to be modeled is an NTC thermistor, the Steinhart-Hart Function block should be connected to the measuring block.



3. The third step is to add the parameters to the processing block. The Steinhart-Hart parameters a , b , and c for a typical 100-ohm thermistor are $a=1.94295E-3$, $b=2.989769E-4$, and $c=3.504383E-7$. These parameters can be entered via the dialog box for the Steinhart-Hart processing block.

4. Since the output signal of a thermistor is a variable resistance, the fourth step is to connect the nonconservative input pin of a Resistance output signal block to the output of the previous processing block.



5. Finally, the conservative thermal nature pin of the initial measuring block can be connected to a node in a thermal network, and the conservative electrical nature pins of the final output block can be connected to an electrical network.

Level 1 Measuring Blocks

The Level 1 Measuring Blocks are the first blocks used to build sensor models. They are used to measure physical quantities in the Twin Builder physical domains.

The Level 1 Measuring Blocks measure the following physical quantities:

- Absolute temperature
[Absolute Temperature Sensing \(ABS_TEMP\)](#)
- Angular acceleration
[Rotational Acceleration Sensing \(Displacement-Force\) \(ANG_ACC\)](#)
[Rotational Acceleration Sensing \(Velocity-Force\) \(ANG_ACC_V\)](#)
- Angular displacement
[Rotational Displacement Sensing \(Displacement-Force\) \(ANG_DIFF_SENS\)](#)
[Rotational Displacement Sensing \(Velocity-Force\) \(ANG_DISP_SENS_V\)](#)
- Angular velocity
[Angular Velocity Sensing \(Displacement-Force\) \(ANG_VELOCITY_DF\)](#)
[Angular Velocity Sensing \(Velocity-Force\) \(ANG_VELOCITY_VF\)](#)
- Magnetic field
[Magnetic Field Sensing \(B_SENS\)](#)
- Differential temperature
[Differential Temperature Sensing \(DIFF_TEMP\)](#)
- Linear displacement
[Translational \(Linear\) Displacement Sensing \(Displacement-Force\) \(DISP_SENS\)](#)
[Translational \(Linear\) Displacement Sensing \(Velocity-Force\) \(DISP_SENS_V\)](#)
- Flow
[Flow Sensing \(FLOW_SENS\)](#)
- Jerk
[Jerk Sensing \(Displacement-Force\) \(JERK_DF\)](#)
[Jerk Sensing \(Velocity-Force\) \(JERK_VF\)](#)
- Differential pressure
[Differential Pressure Sensing \(PM_DIFF\)](#)
- Gage pressure
[Gage Pressure Sensing \(PM_GAGE\)](#)
- Absolute pressure
[Absolute Pressure Sensing \(PMabs\)](#)
- Torque
[Torque Sensing \(Displacement-Force\) \(TORQUE_DF\)](#)
[Torque Sensing \(Velocity-Force\) \(TORQUE_VF\)](#)
- Linear acceleration
[Translational \(Linear\) Acceleration Sensing \(Displacement-Force\) \(TRANS_ACC\)](#)
[Translational \(Linear\) Acceleration Sensing \(Velocity-Force\) \(TRANS_ACC_V\)](#)

The measuring blocks are connected to physical domain networks via conservative pins. The internal components of the blocks then measure some specific physical quantity, such as displacement, pressure, or temperature. Finally, the value of the measured physical quantity is passed from the block by a nonconservative output pin, which can be connected to a processing block.

Level 1 Absolute Temperature Sensing

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

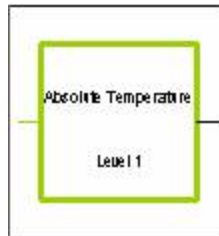


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Description

The Level 1 Absolute Temperature Sensing building block is used to measure absolute temperature, the temperature at a single node in a thermal network, and pass the value of the absolute temperature as a real value. The input to the block is via a conservative thermal nature pin. The output from the block is a nonconservative output pin.

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Assumptions and Limitations

This is an ideal component, hence no measure losses or delays are considered.

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Mathematical Description

[Top](#)

Netlist Syntax

```
MODEL ABS_TEMP ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) TEMP:= %0 ( )  
SRC: DB(Lib:=@ModelLibraryName);
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
TEMP	Absolute temperature input	Thermal

[Top](#)

Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
MEAS	Measured absolute temperature as a real number	Output	real

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Example

In this example, a sinusoidal Heat Flow Source H1 is applied to two Thermal Resistances – RTH1 and RTH2 in series. The Absolute Temperature Sensing block measures the temperature of RTH2. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

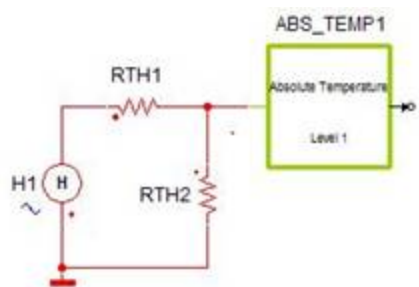


Figure 2. Application example of the Absolute Pressure Sensing block

Table 3

Component	Parameter	Value [Unit]
Thermal Resistor RTH1	K	2 [k/W]
Thermal Resistor RTH2	K	1 [k/W]
Heat Source H1	AMPL	0.5 [W]
	FREQ	50 [Hz]
	PHASE	0 [degree]
	OFF	5 [W]
	TDELAY	0 [s]

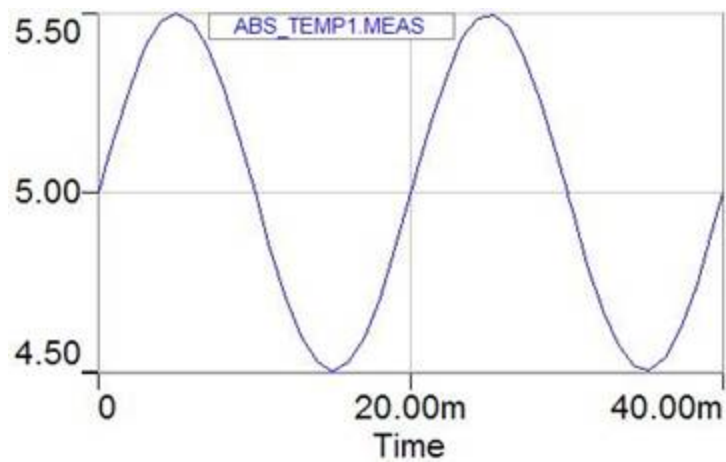


Figure 3. Simulation result

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References

Level 1 Rotational (Angular) Acceleration (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2



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Description

The Level 1 Rotational Acceleration (Displacement-Force) building block is used to measure angular acceleration, the second time derivative of the angle at a node in a rotational network, and pass the value of the angular acceleration as a real value. The input to the block is via a conservative rotational nature pin. The output from the block is a nonconservative output pin.

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Assumptions and Limitations

This is an ideal component, hence no measure losses or delays are considered.

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Mathematical Description

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Netlist Syntax

```
MODEL ANG_ACC ?InstanceName(@InstanceName):(@Refbase@ID)) ANGLE:= %0 ( )  
SRC: DB(Lib:=@ModelLibraryName);
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
ANGLE	Connection to rotational network	Rotational

[Top](#)

Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
MEAS	Angular acceleration as a real number	Output	real

[Top](#)

Example

In this example, a constant Torque Source F_ROT1 is applied to a Mass block MASS_ROT1. The Rotational (Angular) Acceleration (Displacement-Force) measuring block ANG_ACC1 measures the angular displacement of MASS_ROT1 as a result of the applied force. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

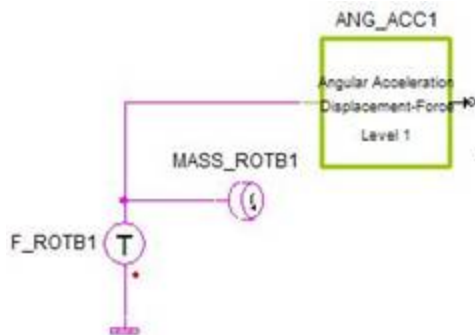


Figure 2. Application example of the Rotational (Angular) Displacement (Displacement-Force) measuring block

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROT B1	VALUE	1 [Nm]
MASS MASS_ROT B1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]

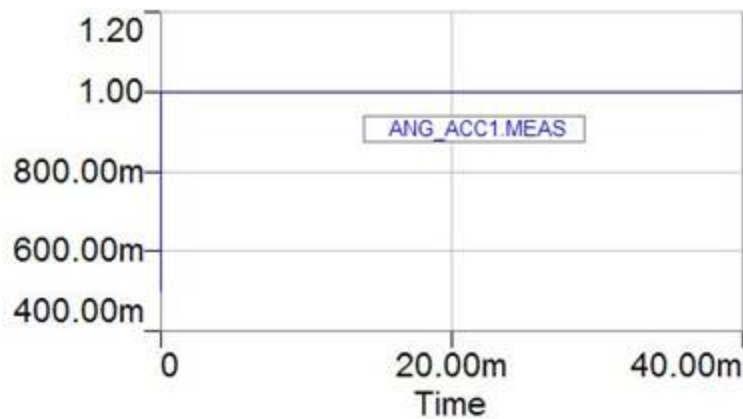


Figure 3. Simulation result

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References

Level 1 Rotational (Angular) Acceleration (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2



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Description

The Level 1 Rotational Acceleration (Velocity-Force) building block is used to measure angular acceleration, the first time derivative of the angular velocity at a node in a rotational_v network, and pass the value of the angular acceleration as a real value. The input to the block is via a conservative rotational_v nature pin. The output from the block is a nonconservative output pin.

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Assumptions and Limitations

This is an ideal component, hence no measure losses or delays are considered.

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Mathematical Description

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Netlist Syntax

MODEL ANG_ACC_V ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) OMEGA:= %0 ()
SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
OMEGA	Connection to rotational_v network	Rotational

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
MEAS	Angular acceleration as a real number	Output	real

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Example

In this example, a constant Torque Source F_ROT1 is applied to a Mass block MASS_ROT1. The Rotational (Angular) Acceleration (Velocity-Force) measuring block ANG_ACC_V1 measures the angular displacement of MASS_ROT1 as a result of the applied force. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

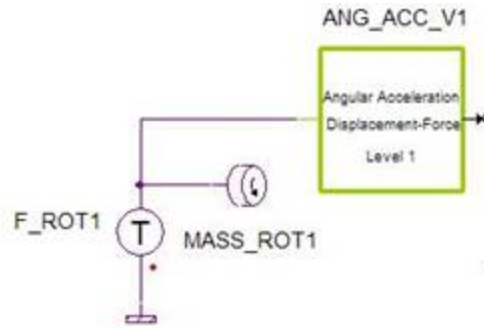


Figure 2. Application example of the Rotational (Angular) Displacement (Velocity-Force) measuring block

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROT1	VALUE	1 [Nm]
MASS MASS_ROT1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]

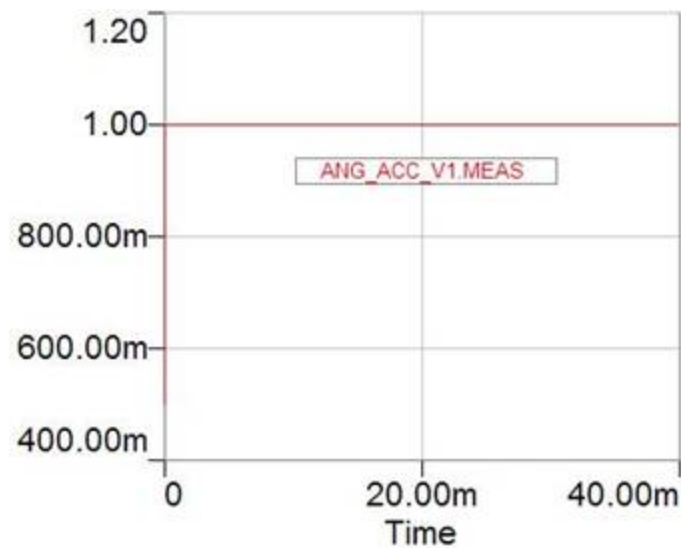


Figure 3. Simulation result

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References

Level 1 Rotational (Angular) Displacement (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

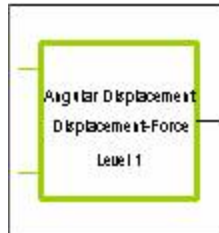


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Description

The Level 1 Rotational Displacement (Displacement-Force) building block is used to measure rotational displacement, the position difference between two nodes in a rotational network, and pass the value of the rotational displacement as a real value. The inputs to the block are via conservative rotational nature pins. The output from the block is a nonconservative output pin.

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Assumptions and Limitations

This is an ideal component, hence no measure losses or delays are considered.

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Mathematical Description

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Netlist Syntax

MODEL ANG_DIFF_SENS ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) REF:= %0,
POSITION:= %1 () SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
REF	Reference angle	Rotational
POSITION	Measured angle	Rotational

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
MEAS	Rotational displacement as a real number	Output	real

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Example

In this example, a constant Torque Source F_ROT1 is applied to a Mass block MASS_ROT1. The Rotational (Angular) Displacement (Displacement-Force) measuring block ANG_DIFF_SENS1 measures the angular displacement of MASS_ROT1 as a result of the applied force. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

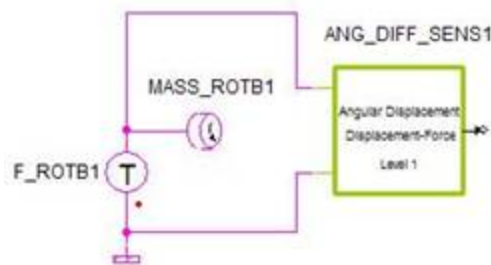


Figure 2. Application example of the Rotational (Angular) Displacement (Displacement-Force) measuring block

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROT B1	VALUE	1 [Nm]
MASS MASS_ROT B1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]

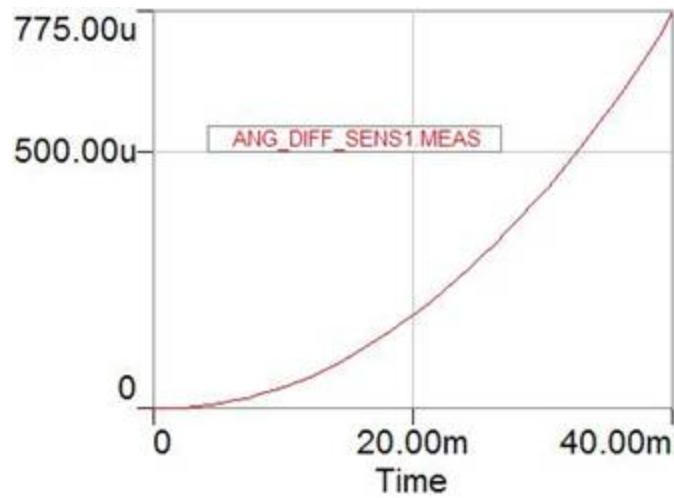


Figure 3. Simulation result

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References

Level 1 Rotational (Angular) Displacement (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

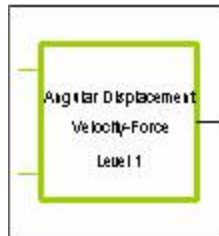


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Description

The Level 1 Rotational Displacement (Velocity-Force) building block is used to measure rotational displacement, the position difference between two nodes in a rotational_v network, and pass the value of the rotational displacement as a real value. The inputs to the block are via conservative rotational_v nature pins. The output from the block is a nonconservative output pin.

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Assumptions and Limitations

This is an ideal component, hence no measure losses or delays are considered.

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Mathematical Description

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Netlist Syntax

MODEL ANG_DISP_SENS_V ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) REF:= %0, POSITION:= %1 (phi_init:= @phi_init) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
REF	Reference angle	Rotational
POSITION	Measured angle	Rotational

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Parameters

Table 2

Name	Description	Data Type	Default Value[Unit]
phi_init	Initial angle of the sensor	real	0

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
MEAS	Rotational displacement as a real number (output to processing block)	Output	real

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Example

In this example, a constant Torque Source F_ROT1 is applied to a Mass block MASS_ROT1. The Rotational (Angular) Displacement (Velocity-Force) measuring block ANG_DIFF_SENS_V1 measures the angular displacement of MASS_ROT1 as a result of the applied force. The

schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

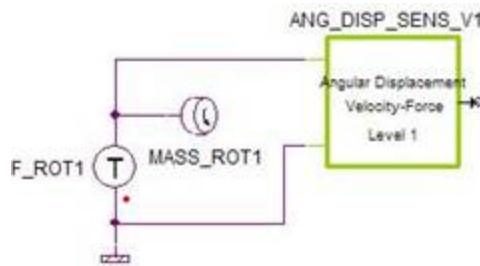


Figure 2. Application example of the Rotational (Angular) Displacement (Displacement-Force) measuring block

Table 4

Component	Parameter	Value [Unit]
Torque Source F_ROT1	VALUE	1 [Nm]
MASS MASS_ROT1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Rotational (Angular) Displacement (Velocity-Force) measuring block ANG_DISP_SENS_V1	phi_init	0

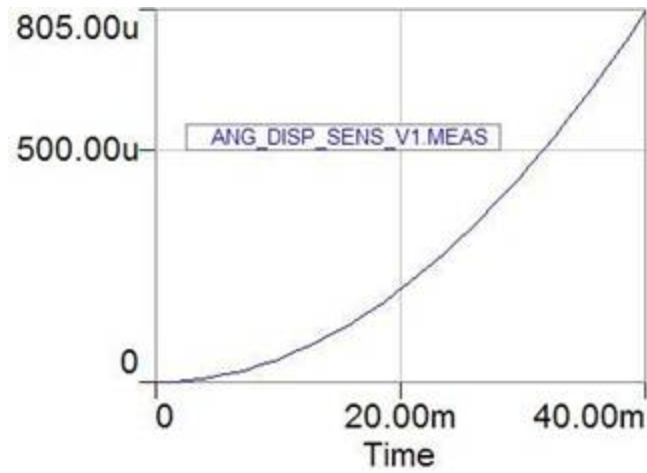


Figure 3. Simulation result

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References

Level 1 Angular Velocity (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2



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Description

The Level 1 Angular Velocity (Displacement-Force) building block is used to measure angular velocity in a rotational network and pass the value of the angular velocity as a real value. The input to the block is via a conservative rotational nature pin. The output from the block is a non-conservative output pin.

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Assumptions and Limitations

This is an ideal component, hence no measure losses or delays are considered.

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Mathematical Description

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Netlist Syntax

```
MODEL ANG_VELOCITY_DF ?InstanceName(@InstanceName):(@ (Refbase)@(ID))
OMEGA:= %0 ( ) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
OMEGA	Angular velocity input	real

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
MEAS	Measured angular velocity as a real number	Output	real

[Top](#)

Example

In this example, a constant Torque Source F_ROTB1 is applied to a Mass (rotational) block MASS_ROTB1. The Angular Velocity (Displacement-Force) measurement block ANG_VELOCITY_DF1 measures the angular velocity of MASS_ROTB1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

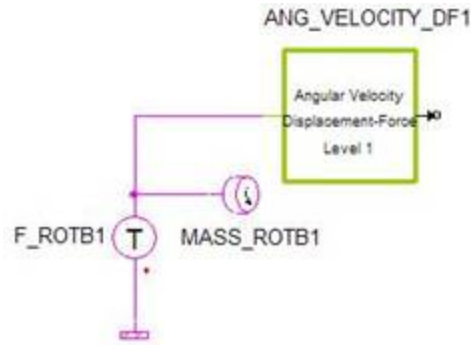


Figure 2. Application example of the Angular Velocity (Displacement-Force) measurement block

Table 3

Component	Parameter	Value [Unit]
Mass MASS_ROT B1	J	1 [kg m ²]
	OMEGA0	0 [rad/s]
	PHI0	0 [rad]
Torque Source F_ROT B1	VALUE	100 [Nm]



Figure 3. Simulation result

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References

Level 1 Angular Velocity (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2



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Description

The Level 1 Angular Velocity (Velocity-Force) building block is used to measure angular velocity in a rotational network and pass the value of the angular velocity as a real value. The input to the block is via a conservative rotational_v nature pin. The output from the block is a non-conservative output pin.

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Assumptions and Limitations

This is an ideal component, hence no measure losses or delays are considered.

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Mathematical Description

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Netlist Syntax

```
MODEL ANG_VELOCITY_VF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
OMEGA:= %0 ( ) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
OMEGA	Angular velocity input	real

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
MEAS	Measured angular velocity as a real number	Output	real

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Example

In this example, a constant Torque Source F_ROT1 is applied to a Mass block MASS_ROT1. The Angular Velocity (Velocity-Force) measurement block ANG_VELOCITY_VF1 measures the angular velocity of MASS_ROT1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

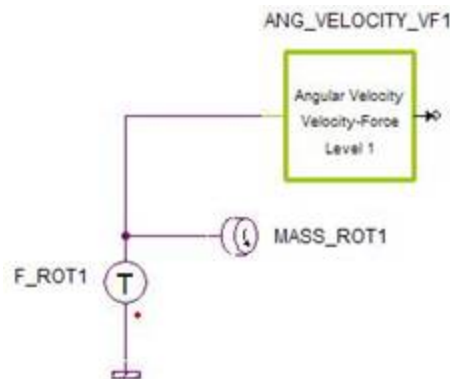


Figure 2. Application example of the Angular Velocity (Displacement-Force) measurement block

Table 3

Component	Parameter	Value [Unit]
Mass MASS_ROT1	J	1 [kg m²]
	OMEGA0	0 [rad/s]
	PHI0	0 [rad]
Torque Source F_ROT1	VALUE	100 [Nm]

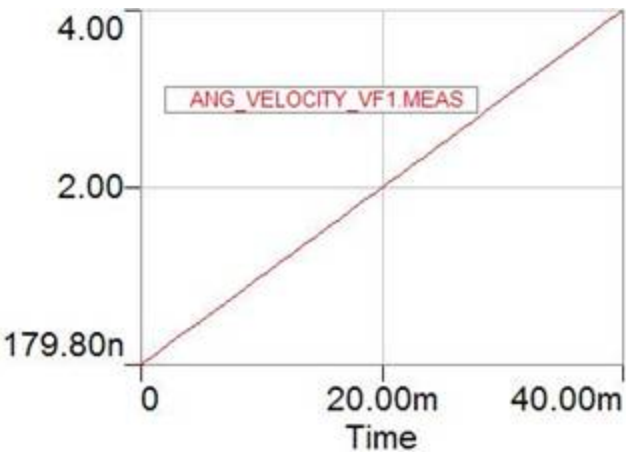


Figure 3. Simulation result

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References

Level 1 Magnetic Field Sensing

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

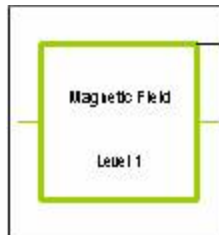


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Description

The Level 1 Magnetic Field Sensing building block is used to measure the magnetic field, which is the flux via an element in a magnetic network divided by its area, and pass the value of the magnetic field as a real value. Magnetic flux passes in and out of the block via conservative magnetic nature pins. The output from the block is a nonconservative output pin.

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Assumptions and Limitations

This is an ideal component, hence no measure losses or delays are considered.

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Mathematical Description

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Netlist Syntax

MODEL B_SENS ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) FLUX_IN:= %0,
FLUX_OUT:= %1 (AREA:= @AREA) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
FLUX_IN	Magnetic flux entrance	Magnetic
FLUX_OUT	Magnetic flux exit	Magnetic

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
AREA	Area of flux-sensitive region	real	10n

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Input/Output Quantities

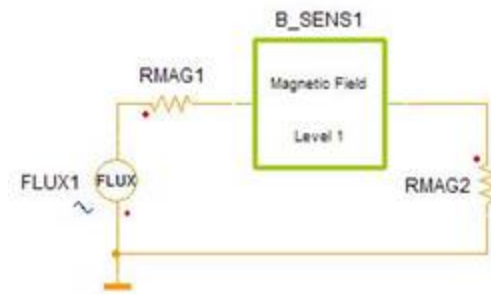
Table 3

Name	Description [Unit]	Direction	Data Type
MEAS	Magnetic field as a real number	Output	real

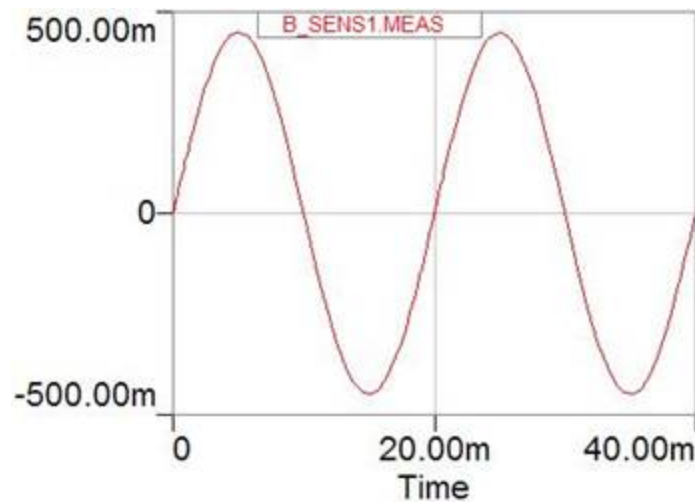
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Example

In this example, a sinusoidal Flux Source FLUX1 is applied to two Magnetoresistor- RMAG1 and RMAG2 in series. The Magnetic Field Sensing block B_SENS1 measures the flux that flows through the loop. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

**Figure 2. Application example of the Magnetic Field Sensing block****Table 4**

Component	Parameter	Value [Unit]
Flux Source FLUX1	AMPL	4.5m [web]
	FREQ	50 [Hz]
	PHASE	0 [degree]
	OFF	0 [web]
	TDELAY	0 [s]
Magnetoresistor RMAG1/ RMAG2	K	1e9 [A/web]

**Figure 3. Simulation result**[Top](#)

References

Level 1 Differential Temperature Sensing

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2



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Description

The Level 1 Differential Temperature Sensing building block is used to measure differential temperature, the temperature difference between two nodes in a thermal network, and pass the value of the differential Temperature as a real value. The inputs to the block are conservative thermal nature pins. The output from the block is a nonconservative output pin.

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Assumptions and Limitations

This is an ideal component, hence no measure losses or delays are considered.

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Mathematical Description

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Netlist Syntax

```
MODEL DIFF_TEMP ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) REF:= %0,  
TEMP:= %1 ( ) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
REF	Reference temperature	Thermal
TEMP	Measured temperature	Thermal

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
MEAS	Differential temperature as a real number	Output	real

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Example

In this example, a sinusoidal Heat Flow Source H1 is applied to two Thermal Resistances – RTH1 and RTH2 in series. The Differential Temperature Sensing block DIFF_TEMP1 measures the temperature of RTH1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

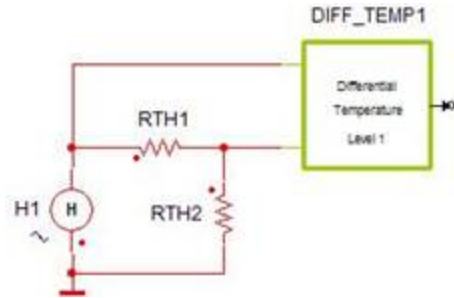


Figure 2. Application example of the Differential Pressure Sensing block

Table 3

Component	Parameter	Value [Unit]
Thermal Resistor RTH1	K	2 [k/W]
Thermal Resistor RTH2	K	1 [k/W]
Heat Source H1	AMPL	0.5 [W]
	FREQ	50 [Hz]
	PHASE	0 [degree]
	OFF	5 [W]
	TDELAY	0 [s]

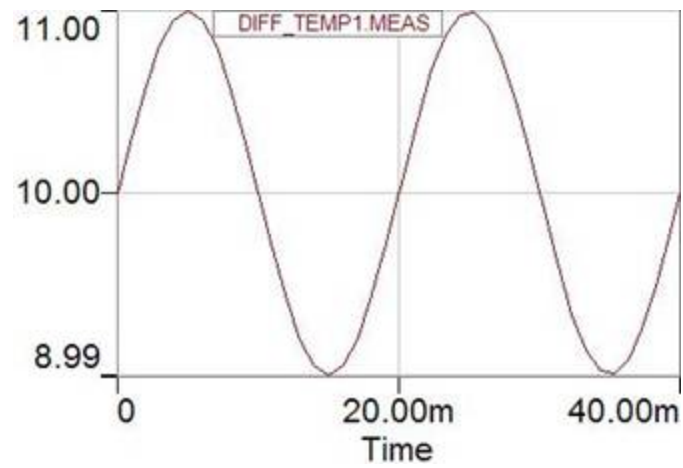


Figure 3. Simulation result

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References

Level 1 Translational (Linear) Displacement (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

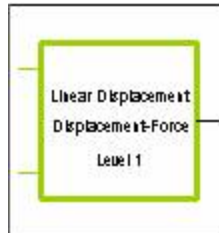


Figure 1. Component symbol

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Description

The Level 1 Linear Translational Displacement (Displacement-Force) building block is used to measure linear displacement, the position difference between two nodes in a translational network, and pass the value of the linear displacement as a real value. The inputs to the block are via conservative Translational nature pins. The output from the block is a nonconservative output pin.

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Assumptions and Limitations

This is an ideal component, hence no measure losses or delays are considered.

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Mathematical Description

[Top](#)

Netlist Syntax

MODEL DISP_SENS ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) REF:= %0,
POSITION:= %1 () SRC: DB(Lib:=@ModelLibraryName);

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
REF	Reference position	Translational
POSITION	Measured position	Translational

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
MEAS	Linear displacement as a real number	Output	real

[Top](#)

Example

In this example, a constant Force Source F_TRB1 is applied to a Mass block MASS_TRB1. The Translational (Linear) Displacement (Displacement-Force) sensing block DISP_SENS1 measures the displacement of MASS_TRB1 as a result of the applied force. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

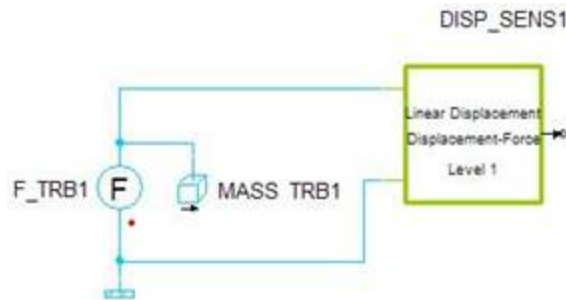


Figure 2. Application example of the Translational (Linear) Displacement (Displacement-Force) sensing block

Table 3

Component	Parameter	Value [Unit]
Force Source F_TRB1	VALUE	10 [N]
MASS MASS_TRB1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]

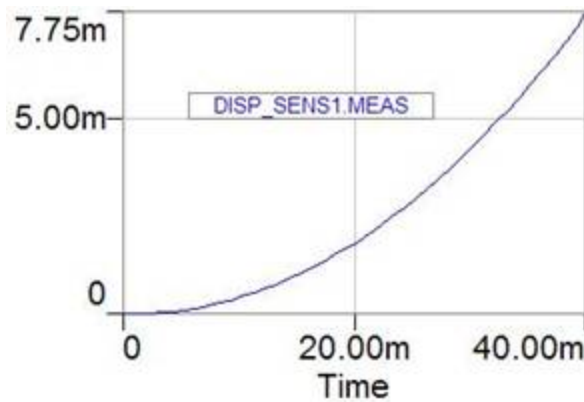


Figure 3. Simulation result

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References

Level 1 Translational (Linear) Displacement (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

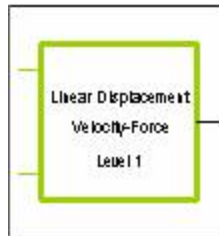


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Description

The Level 1 Translational Displacement (Velocity-Force) building block is used to measure Translational displacement, the position difference between two nodes in a Translational_V network, and pass the value of the Translational displacement as a real value. The inputs to the block are via conservative Translational_V nature pins. The output from the block is a non-conservative output pin.

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Assumptions and Limitations

This is an ideal component, hence no measure losses or delays are considered.

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Mathematical Description

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Netlist Syntax

```
MODEL DISP_SENS_V ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) REF:= %0,  
POSITION:= %1 ( s_init:= @s_init) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
REF	Reference position	Translational
POSITION	Measured position	Translational

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Parameters

Table 2

Name	Description	Data Type	Default Value[Unit]
s_init	Initial position of sensor	real	0

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
MEAS	Translational displacement as a real number	Output	real

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Example

In this example, a constant Force Source F_TR1 is applied to a Mass block MASS_TR1. The Translational (Linear) Displacement (Velocity-Force) sensing block DISP_SENS_V1 measures the displacement of MASS_TR1 as a result of the applied force. The schematic of the system is

shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

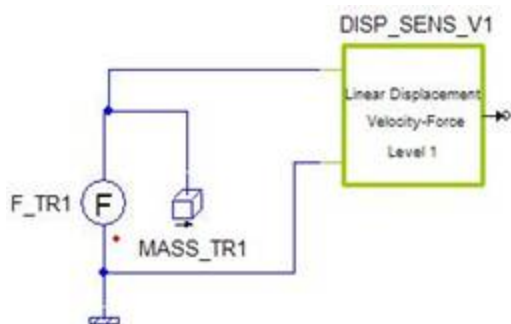


Figure 2. Application example of the Translational (Linear) Displacement (Displacement-Force) sensing block

Table 4

Component	Parameter	Value [Unit]
Force Source F_TR1	VALUE	1 [N]
MASS MASS_TR1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Translational (Linear) Displacement (Velocity-Force) DISP_SENS_V1	s_init	0

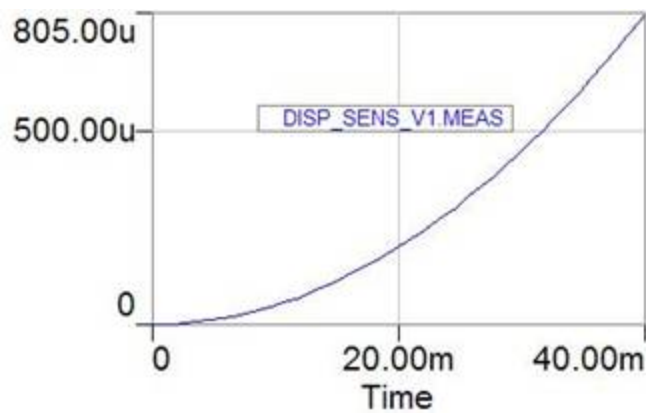


Figure 3. Simulation result

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References

Level 1 Flow Sensing

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

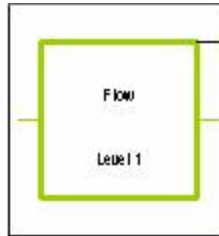


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Description

The Level 1 Flow Sensing building block is used to measure flow through a branch of a fluidic network and pass the value of the flow as a real value. Fluid flow passes in and out of the block via conservative fluidic nature pins. The output from the block is a nonconservative output pin.

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Assumptions and Limitations

This is an ideal component, hence no measure losses or delays are considered.

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Mathematical Description

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Netlist Syntax

```
MODEL FLOW_SENS ?InstanceName(@InstanceName):(@Refbase)@(ID)) FLOW_P:= %0,  
FLOW_M:= %1 ( ) SRC: DB(Lib:=@ModelLibraryName) ;
```


[Top](#)**Conservative Pins****Table 1**

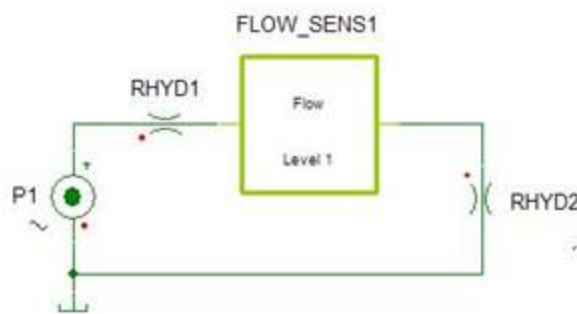
Name	Port/Terminal Description	Nature/Data type
FLUX_P	Flow entry	Rotational
FLUX_M	Flow exit	Rotational

[Top](#)**Input/Output Quantities****Table 2**

Name	Description [Unit]	Direction	Data Type
MEAS	Flow as a real number	Output	real

[Top](#)**Example**

In this example, a sinusoidal Pressure Source P1 is applied to two Linear Orifices - RHYD1 and RHYD2 in series. The Flow Sensing block FLOW_SENS1 measures the flow rate of P1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

**Figure 2. Application example of the Magnetic Field Sensing block****Table 3**

Component	Parameter	Value [Unit]

Pressure Source P1	AMPL	100k [Pa]
	FREQ	50 [Hz]
	PHASE	0 [degree]
	OFF	900k [Pa]
	TDELAY	0 [s]
Linear Orifice RHYD1/ RHYD2	K	1n [m ³ /(Pa s)]

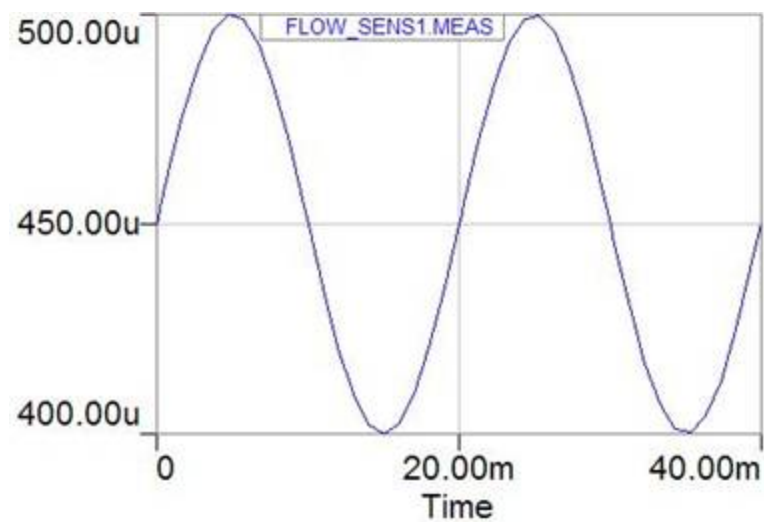


Figure 3. Simulation result

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References

Level 1 Jerk Sensing (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

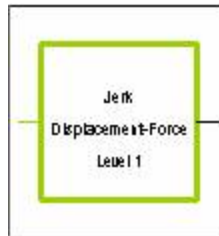


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Description

The Level 1 Jerk Sensing (Displacement-Force) building block is used to measure jerk, the third time derivative of the position at a node in a translational network, and pass the value of the jerk as a real value. The input to the block is via a conservative translational nature pin. The output from the block is a nonconservative output pin.

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Assumptions and Limitations

This is an ideal component, hence no measure losses or delays are considered.

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Mathematical Description

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Netlist Syntax

```
MODEL JERK_DF ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) POS:= %0 ( ) SRC:  
DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POS	Connection to translational network	Rotational

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
MEAS	Jerk as a real number	Output	real

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Example

In this example, a sinusoidal Force Source F_TRB1 is applied to a Mass block MASS_TRB1. The Jerk Sensing (Displacement-Force) block JERK_DF1 measures the jerk of MASS_TRB1 as a result of the applied force. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

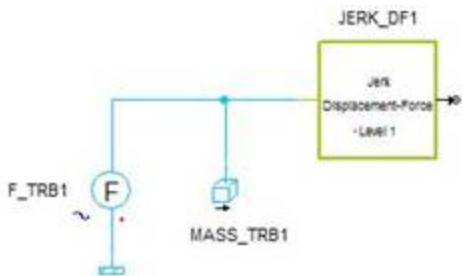


Figure 2. Application example of the Jerk Sensing (Displacement-Force) block

Table 3

Component	Parameter	Value [Unit]

Force Source F_TRB1	AMPL	1 [N]
	FREQ	50 [Hz]
	PHASE	0 [degree]
	OFF	0 [N]
	TDELAY	0 [s]
MASS MASS_TRB1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]

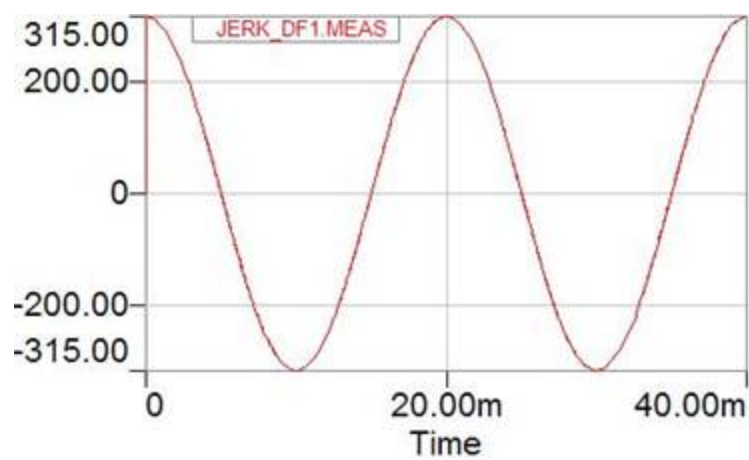


Figure 3. Simulation result

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References

Level 1 Jerk Sensing (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

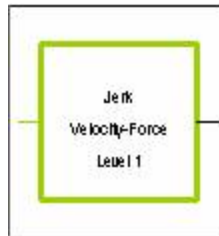


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Description

The Level 1 Jerk Sensing (Velocity-Force) building block is used to measure jerk, the second derivative of the velocity at a node in a translational_v network, and pass the value of the jerk as a real value. The input to the block is via a conservative translational_v nature pin. The output from the block is a nonconservative output pin.

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Assumptions and Limitations

This is an ideal component, hence no measure losses or delays are considered.

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Mathematical Description

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Netlist Syntax

```
MODEL JERK_VF ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) VELOCITY:= %0 ( )
SRC: DB(Lib:=@ModelLibraryName);
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
VELOCITY	Connection to translational_v network	Rotational

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
MEAS	Jerk as a real number	Output	real

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Example

In this example, a sinusoidal Force Source F_TR1 is applied to a Mass block MASS_TR1. The Jerk Sensing (Velocity-Force) block JERK_VF1 measures the jerk of MASS_TR1 as a result of the applied force. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

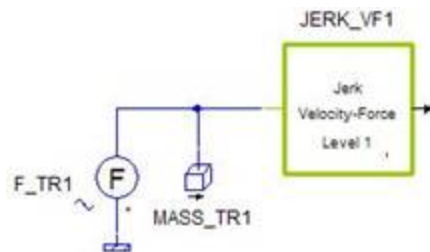


Figure 2. Application example of the Jerk Sensing (Displacement-Force) block

Table 3

Component	Parameter	Value [Unit]

Force Source F_TR1	AMPL	1 [N]
	FREQ	50 [Hz]
	PHASE	0 [degree]
	OFF	0 [N]
	TDELAY	0 [s]
MASS MASS_TR1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]

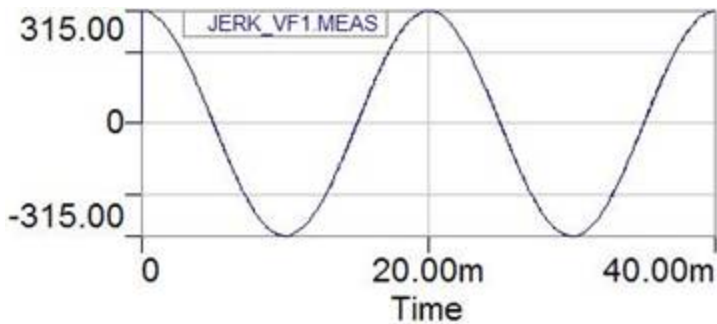


Figure 3. Simulation result

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References

Level 1 Differential Pressure Sensing

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

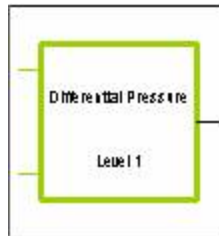


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Description

The Level 1 Differential Pressure Sensing building block is used to measure differential pressure, the pressure difference between two nodes in a fluidic network, and pass the value of the differential pressure as a real value. The inputs to the block are via conservative fluidic nature pins. The output from the block is a nonconservative output pin.

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Assumptions and Limitations

This is an ideal component, hence no measure losses or delays are considered.

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Mathematical Description

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Netlist Syntax

```
MODEL PM_DIFF ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) P1:= %0, P2:= %1 ( )
SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
P1	Measured pressure (positive input)	Rotational
P2	Reference pressure (negative input)	Rotational

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
MEAS	Measured pressure	Output	real

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Example

In this example, a sinusoidal Flow Source Q1 is applied to two linear Orifices – RHYD1 and RHYD2 in series. The Differential Pressure Sensing block measures the pressure applied to RHYD1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

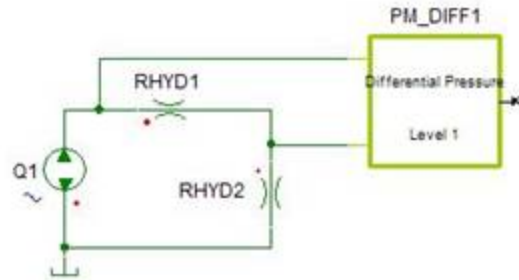


Figure 2. Application example of the Absolute Pressure Sensing block

Table 3

Component	Parameter	Value [Unit]
Linear Orifice RHYD1/RHYD2	K	1n [m ³ /(Pa s)]
Flow Source Q1	AMPL	10u [m ³ /s]
	FREQ	50 [Hz]
	PHASE	0 [degree]
	OFF	100u [Pa]
	TDELAY	0 [s]

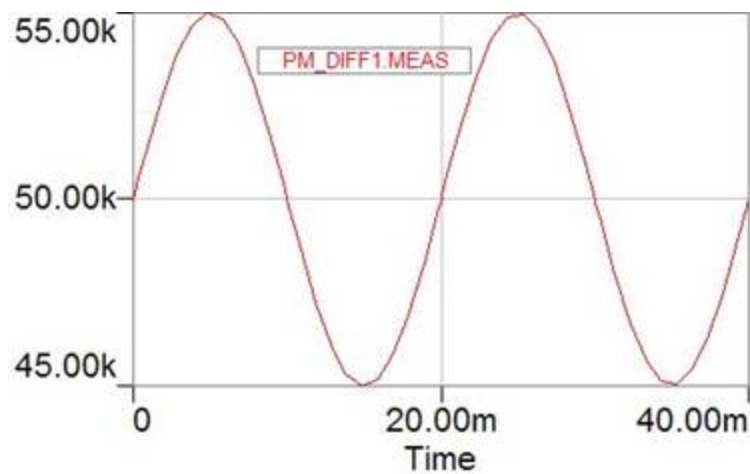


Figure 3. Simulation result

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References

Level 1 Gage Pressure Sensing

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

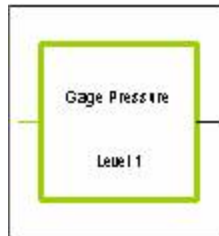


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Description

The Level 1 Gage Pressure Sensing building block is used to measure gage pressure, the difference between the pressure at a node in a fluidic network and atmospheric pressure, and pass the value of the gage pressure as a real value. The input to the block is via a conservative fluidic nature pin. The output from the block is a nonconservative output pin.

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Assumptions and Limitations

This is an ideal component, hence no measure losses or delays are considered.

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Mathematical Description

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Netlist Syntax

MODEL PM_GAGE ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) PRESSURE:= %0 (atmp:= @atmp) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PRESSURE	Measured pressure	Fluidic

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Parameters

Table 2

Name	Description	Data Type	Default Value[Unit]
atmp	Atmospheric Pressure	real	0.101325Meg

Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
MEAS	Gauge pressure as a real number	Output	real

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Example

In this example, a sinusoidal Flow Source Q1 is applied to two linear Orifices – RHYD1 and RHYD2 in series. The Gage Pressure Sensing block PM_GAGE1 measures the pressure applied to RHYD2. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

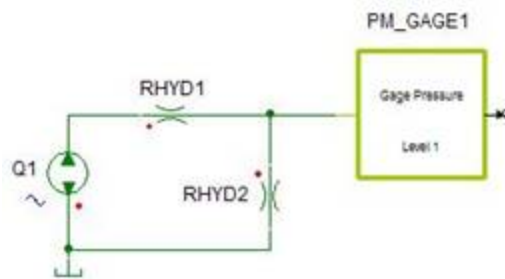


Figure 2. Application example of the Gage Pressure Sensing block

Table 4

Component	Parameter	Value [Unit]
Linear Orifice RHYD1	K	2n [m ³ /(Pa s)]
Linear Orifice RHYD2	K	1n [m ³ /(Pa s)]
Flow Source Q1	AMPL	10u [m ³ /s]
	FREQ	50 [Hz]
	PHASE	0 [degree]
	OFF	1u [Pa]
	TDELAY	0 [s]

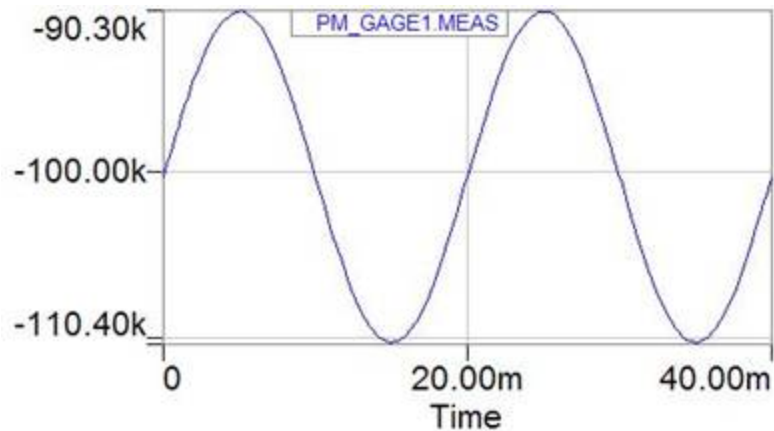


Figure 3. Simulation result

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References

Level 1 Absolute Pressure Sensing

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

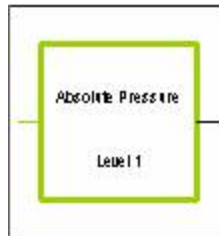


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Description

The Level 1 Absolute Pressure Sensing building block is used to measure absolute pressure in a fluidic network and pass the value of the absolute pressure as a real value. The input to the block is via a conservative fluidic nature pin. The output from the block is a nonconservative output pin.

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Assumptions and Limitations

This is an ideal component, hence no measure losses or delays are considered.

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Mathematical Description

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Netlist Syntax

```
MODEL PMabs ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) P:= %0 ( ) SRC: DB
(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
P	Angular pressure input	Rotational

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
MEAS	Measured absolute pressure as a real number	Output	real

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Example

In this example, a sinusoidal Flow Source Q1 is applied to two linear Orifices - RHYD1 and RHYD2 in series. The Absolute Pressure Sensing block measures the pressure applied to RHYD2. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

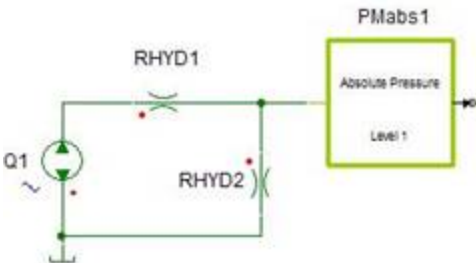
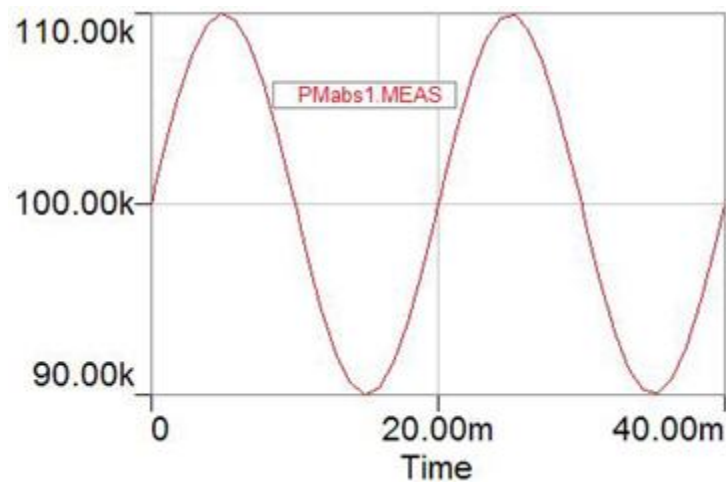


Figure 2. Application example of the Absolute Pressure Sensing block**Table 3**

Component	Parameter	Value [Unit]
Linear Orifice RHYD1/RHYD2	K	1n [m ³ /(Pa s)]
Flow Source Q1	AMPL	10u [m ³ /s]
	FREQ	50 [Hz]
	PHASE	0 [degree]
	OFF	100u [Pa]
	TDELAY	0 [s]

**Figure 3. Simulation result**[Top](#)

References

Level 1 Torque Sensing (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

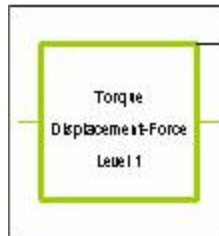


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Description

The Level 1 Torque Sensing (Displacement-Force) building block is used to measure torque through a branch of a rotational network and then pass the value of the torque as a real value. Torque passes in and out of the block via conservative rotational nature pins. The output from the block is a nonconservative output pin.

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Assumptions and Limitations

This is an ideal component, hence no measure losses or delays are considered.

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Mathematical Description

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Netlist Syntax

```
MODEL TORQUE_DF ?InstanceName(@InstanceName):(@Refbase)@(ID)) TORQUE_IN:=
%0, TORQUE_OUT:= %1 ( ) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
TORQUE_IN	Torque entrance (positive node)	Rotational
TORQUE_OUT	Torque exit (negative node)	Rotational

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
MEAS	Torque as a real number	Output	real

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Example

In this example, a sinusoidal Angular Velocity Source V_ROT B1 is applied to a Mass block MASS_ROT B1. The Torque Sensing (Displacement-Force) block TORQUE_DF1 measures the torque through MASS_ROT B1 as a result of V_ROT B1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.



Figure 2. Application example of the Torque Sensing (Displacement-Force) block

Table 3

Component	Parameter	Value [Unit]

Angular Velocity Source V_ROTB1	AMPL	1 [rad/s]
	FREQ	50 [Hz]
	PHASE	0 [rad]
	OFF	0 [rad/s]
	TDELAY	0 [s]
MASS MASS_ROTB1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]

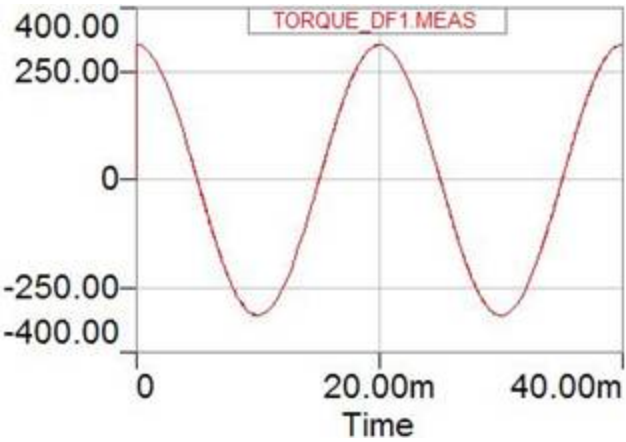


Figure 3. Simulation result

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References

Level 1 Torque Sensing (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

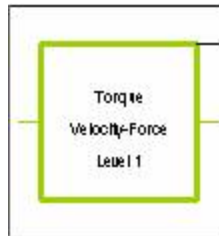


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Description

The Level 1 Torque Sensing (Velocity-Force) building block is used to measure torque through a branch of a rotational_v network and then pass the value of the torque as a real value. Torque passes in and out of the block via conservative rotational_v nature pins. The output from the block is a nonconservative output pin.

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Assumptions and Limitations

This is an ideal component, hence no measure losses or delays are considered.

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Mathematical Description

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Netlist Syntax

MODEL TORQUE_VF ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) TORQUE_IN:= %0, TORQUE_OUT:= %1 () SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
TORQUE_IN	Torque entrance (positive node)	Rotational
TORQUE_OUT	Torque exit (negative node)	Rotational

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Input/Output Quantities

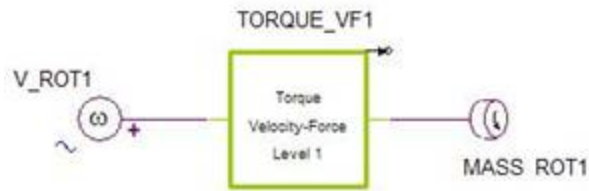
Table 2

Name	Description [Unit]	Direction	Data Type
MEAS	Torque as a real number	Output	real

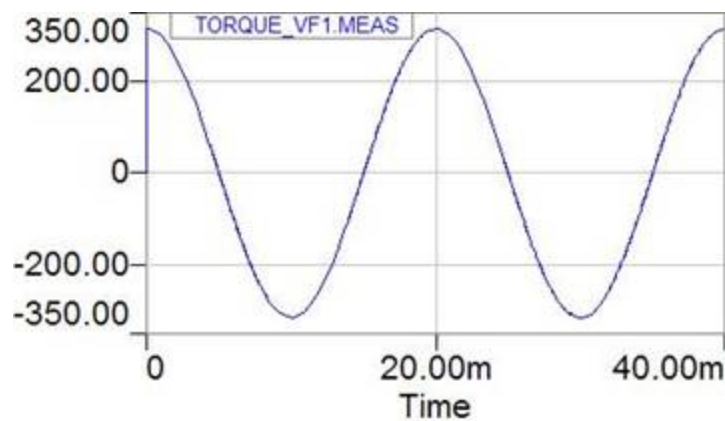
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Example

In this example, a sinusoidal Angular Velocity Source V_ROT1 is applied to a Mass block MASS_ROT1. The Toque Sensing (Velocity-Force) block TORQUE_VF1 measures the torque through MASS_ROT1 as a result of V_ROT1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

**Figure 2. Application example of the Torque Sensing (Velocity-Force) block****Table 3**

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROT1	AMPL	1 [rad/s]
	FREQ	50 [Hz]
	PHASE	0 [rad]
	OFF	0 [rad/s]
	TDELAY	0 [s]
MASS MASS_ROT1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]

**Figure 3. Simulation result**[Top](#)

References

Level 1 Translational (Linear) Acceleration (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

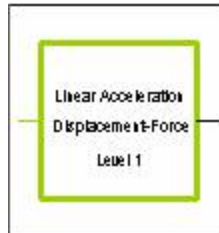


Figure 1. Component symbol

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Description

The Level 1 Translational Acceleration (Displacement-Force) building block is used to measure linear acceleration, the second time derivative of the position at a node in a Translational network, and pass the value of the linear acceleration as a real value. The input to the block is via a conservative translational nature pin. The output from the block is a nonconservative output pin.

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Assumptions and Limitations

This is an ideal component, hence no measure losses or delays are considered.

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Mathematical Description

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Netlist Syntax

```
MODEL TRANS_ACC ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) POS:= %0 ( )
SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POS	Connection to translational network	Translational

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
MEAS	Linear acceleration as a real number	Output	real

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Example

In this example, a constant Force Source F_TRB1 is applied to a Mass block MASS_TRB1. The Translational (Linear) Acceleration (Displacement-Force) measuring block TRANS_ACC1 measures the acceleration of MASS_TRB1 as a result of the applied force. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

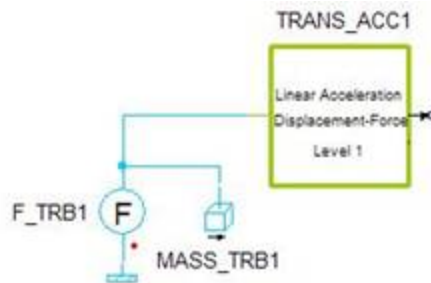


Figure 2. Application example of the Translational (Linear) Acceleration (Displacement-Force) measuring block

Table 3

Component	Parameter	Value [Unit]
Force Source F_TRB1	VALUE	10 [N]
MASS MASS_TRB1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]

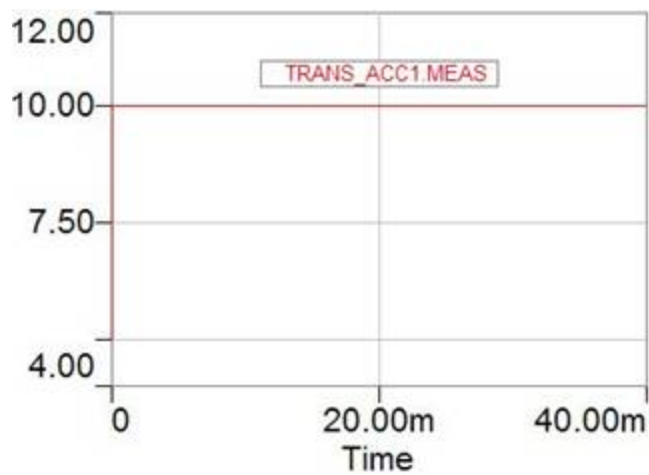


Figure 3. Simulation result

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References

Level 1 Translational (Linear) Acceleration (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

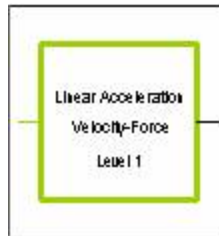


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Description

The Level 1 Translational Acceleration (Velocity-Force) building block is used to measure linear acceleration, the first time derivative of the position at a node in a translational_v network, and pass the value of the linear acceleration as a real value. The input to the block is via a conservative translational nature pin. The output from the block is a nonconservative output pin.

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Assumptions and Limitations

This is an ideal component, hence no measure losses or delays are considered.

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Mathematical Description

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Netlist Syntax

MODEL TRANS_ACC_V ?InstanceName(@InstanceName):(@Refbase)@(ID)) VELOCITY:=%0 () SRC: DB(Lib:@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
VELOCITY	Connection to translational_v network	Translational

[Top](#)

Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
MEAS	Linear acceleration as a real number	Output	real

[Top](#)

Example

In this example, a constant Force Source F_TR1 is applied to a Mass block MASS_TR1. The Translational (Linear) Acceleration (Displacement-Force) measuring block TRANS_ACC_V1 measures the acceleration of MASS_TR1 as a result of the applied force. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

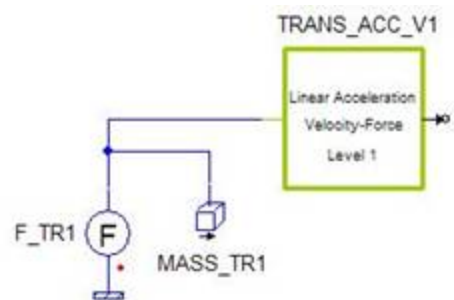


Figure 2. Application example of the Translational (Linear) Acceleration (Velocity-Force) measuring block

Table 3

Component	Parameter	Value [Unit]
Force Source F_TR1	VALUE	1 [N]
MASS MASS_TR1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]

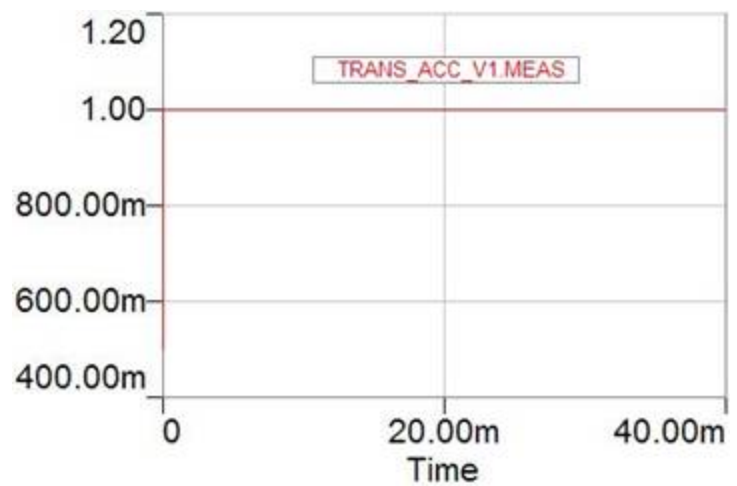


Figure 3. Simulation result

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References

Level 1 Output Signal Blocks

The Level 1 Output Signal Blocks are the third and final blocks used to build ideal sensor models. They are used to translate nonconservative, real signals from processing blocks into electrical signals that can be used in the Twin Builder electrical circuit domain.

The Level 1 Output Signal Blocks are:

- Sinusoidal Voltage (ac_os)
- Capacitance (Cap_os)
- Current (Current_os)
- Differential Capacitance (DCap_os)
- Voltage (EMF_os)
- Inductance (Ind_os)
- 8-bit Binary Number (pbyte)
- Potentiometer (Potentiometer)
- Pulse Voltage (pulse_os)
- Wheatstone Bridge (RES_BRIDGE)
- Resistance (Res_os)

The output signal blocks have nonconservative input pins through which signals from processing blocks are passed. These signals control the behavior of circuit elements, which can then be connected to elements in the Twin Builder electric circuit domain via conservative electrical nature pins.

Level 1 Sinusoidal Voltage Block

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

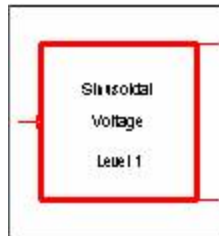


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Description

The Level 1 Sinusoidal Voltage Block provides a sinusoidal voltage output signal whose amplitude is equal to the value that it receives via its nonconservative input. The block has two conservative electrical domain pins, one for its positive terminal, and one for its negative terminal.

The following parameters can be varied: the phase, offset, and frequency of the sinusoidal voltage.

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Assumptions and Limitations

Because the block itself contains no electrical ground, its negative terminal must be grounded if it is not placed into an electrical network in which at least one node is connected to ground. This is an ideal component, hence no internal losses are considered.

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Mathematical Description

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Netlist Syntax

```
MODEL ac_os ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) out_plus:= %0, out_minus:= %1 ( INPUT:= @INPUT, frequency:= @frequency, phase:= @phase, offset:= @offset) SRC: DB(Lib:=@ModelLibraryName);
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
out_plus	Positive output terminal	Electrical
out_minus	Negative output terminal	Electrical

[Top](#)

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
frequency	Frequency of the sinusoidal voltage	real	60
phase	Phase shift of the sinusoidal voltage	real	0
offset	DC offset of the sinusoidal voltage	real	0

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type

INPUT	Input from the processing block	Input	real

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Example

In this example, a constant Pressure Source P1 is applied to a two Linear Orifice – RHYD1 and RHYD2 in series. The Differential Pressure Sensing block PM_DIFF1 measures the Pressure across RHYD2. The Output of PM_DIFF1 is clamped by a Clipped Linear function block CL_LINEAR1. The output of CL_LINEAR is used to decide the amplitude of the Sinusoidal Voltage Output block ac_os1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 4, and the simulation results are shown in Figure 3.

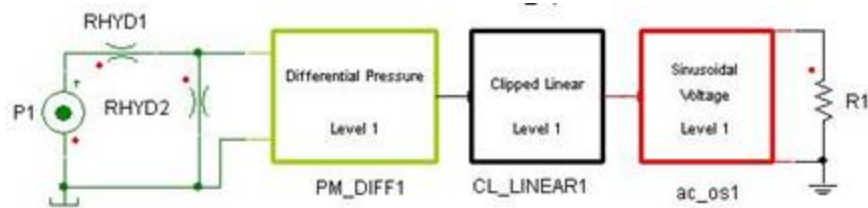


Figure 2. Application example of the Sinusoidal Voltage Output block

Table 4

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	40k [Pa]
Linear Orifice RHYD1/RHYD2	K	1n [$\text{m}^3/(\text{Pa s})$]
Clipped Linear Function CL_LINEAR1	INPUT	PM_DIFF1.MEAS
	max_input	10k
	offset	0
	min_input	0
	full_scale_span	E1.EMF
Sinusoidal Voltage Output block ac_os1	INPUT	CL_LINEAR1.OUTPUT
	frequency	60
	Offset	0
	Phase	0
Resistor R1	R	1k [Ohm]

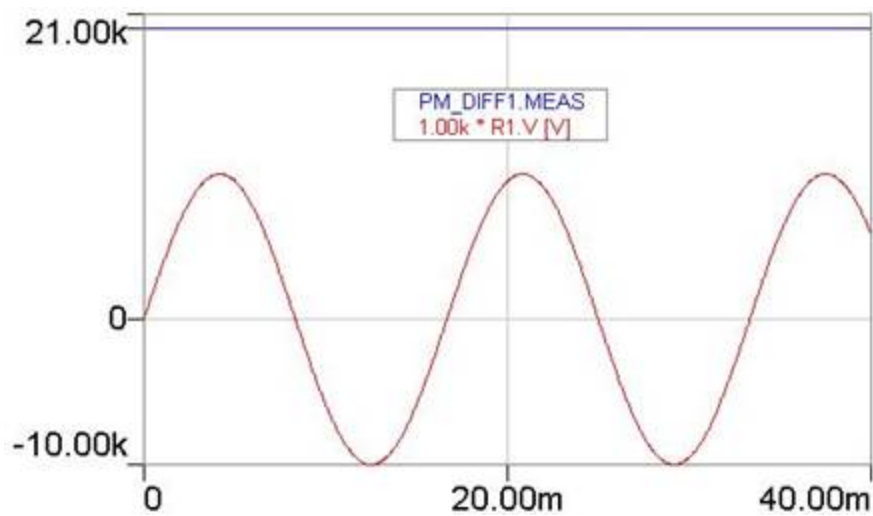


Figure 3. Simulation result-outputs of PM_DIFF1 and ac_os1

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References

Level 1 Capacitance Block

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

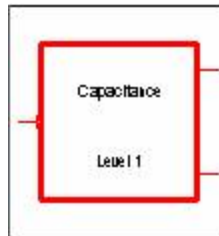


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Description

The Level 1 Capacitance Block provides a capacitance output signal that is equal to the value that it receives via its nonconservative input. The block has two conservative electrical domain pins, one for its positive terminal, and one for its negative terminal. The positive terminal is the terminal into which current flows.

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Assumptions and Limitations

This is an ideal component, hence no internal losses or delays are considered.

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Mathematical Description

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Netlist Syntax

MODEL Cap_os ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) out_plus:= %0, out_minus:= %1 (INPUT:= @INPUT) SRC: DB(Lib:=@ModelLibraryName);

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
out_plus	Positive terminal	Electrical
out_minus	Negative terminal	Electrical

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
INPUT	Input from the processing block	Input	real

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Example

In this example, a sinusoidal Pressure Source P1 is applied to a two Linear Orifice – RHYD1 and RHYD2 in series. The Differential Pressure Sensing block PM_DIFF1 measures the Pressure across RHYD2. The Output of PM_DIFF1 is clamped by a Clipped Linear function block CL_LINEAR1. The output of CL_LINEAR is used to decide the capacitance of Cap_os1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3. Notice that the output of P1 increases linearly with time, and hence the capacitance of Cap_os1 increases linearly while the amplitude of the voltage across Cap_os1 decreases. When the output of P1 reaches the upper limit of CL_LINEAR1, the capacitance of Cap_os1 is clamped to a constant value, and the amplitude of the voltage across Cap_os1 becomes constant.

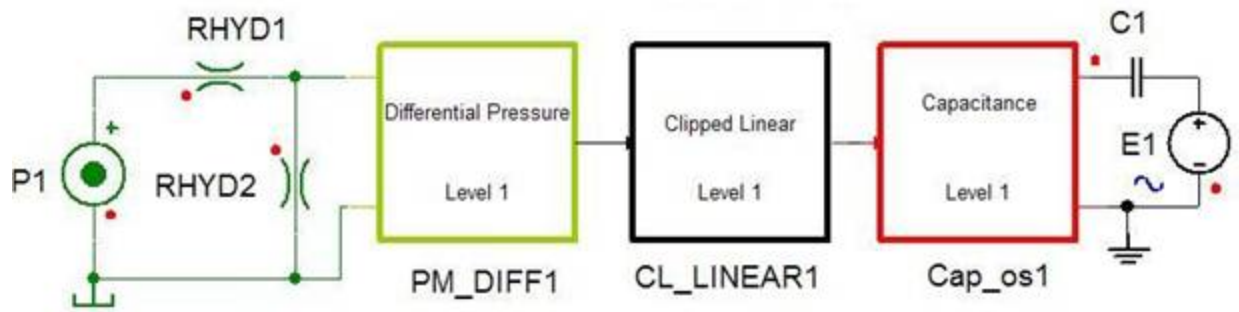


Figure 2. Application example of the Capacitance Block

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	$20k * (t/40m)$ [Pa]
Linear Orifice RHYD1/RHYD2	K	$1n$ [$m^3/(Pa \cdot s)$]
Clipped Linear Function CL_LINEAR1	INPUT	PM_DIFF1.MEAS
	max_input	10k
	offset	0
	min_input	0
	full_scale_span	10
Capacitance Block Cap_os1	INPUT	CL_LINEAR1.OUTPUT
Capacitor C1	C	1μ [F]
Voltage Source (sinusoidal) E1	AMPL	5 [V]
	FREQ	50 [Hz]
	PHASE	0 [rad]
	OFF	0 [rad/s]

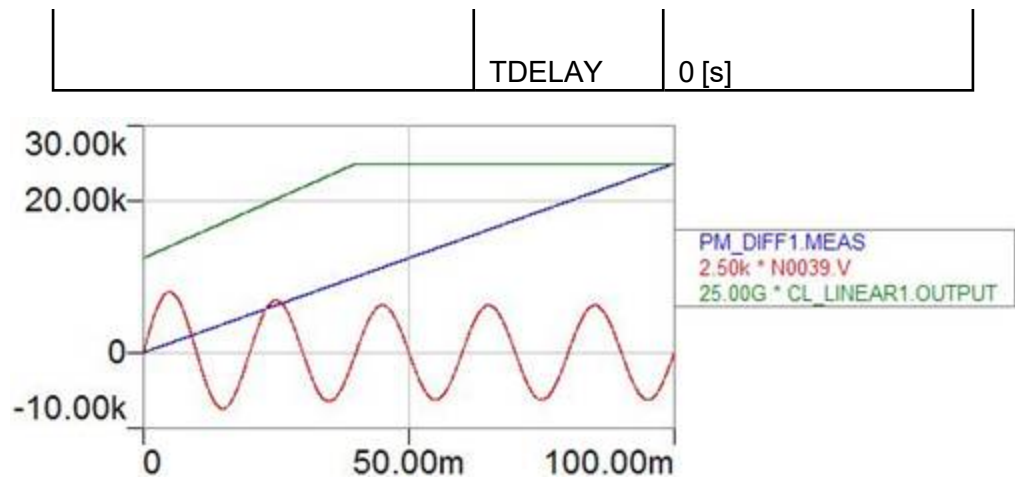


Figure 3. Simulation result-outputs of PM_DIFF1 and CL_LINEAR1, and the voltage across Cap_
os1

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References

Level 1 Current Block

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

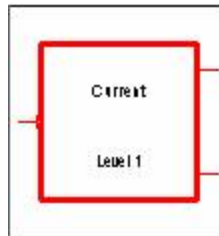


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Description

The Level 1 Current Block provides a current output signal that is equal to the value that it receives via its nonconservative input. The block has two conservative electrical domain pins, one for its positive terminal, and one for its negative terminal. The current flows out of the negative terminal of the block.

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Assumptions and Limitations

This is an ideal component, hence no internal losses or delays are considered.

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Mathematical Description

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Netlist Syntax

MODEL Current_os ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) out_plus:= %0,
out_minus:= %1 (INPUT:= @INPUT) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
out_plus	Positive terminal (current in)	Electrical
out_minus	Negative terminal (current out)	Electrical

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
INPUT	Input from the processing block	Input	real

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Example

In this example, a sinusoidal Pressure Source P1 is applied to a two Linear Orifice – RHYD1 and RHYD2 in series. The Differential Pressure Sensing block PM_DIFF1 measures the Pressure across RHYD2. The Output of PM_DIFF1 is clamped by a Clipped Linear function block CL_LINEAR1, and then converted to a current signal through the Current Block Current_os1. The output current is applied to a resistor R1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

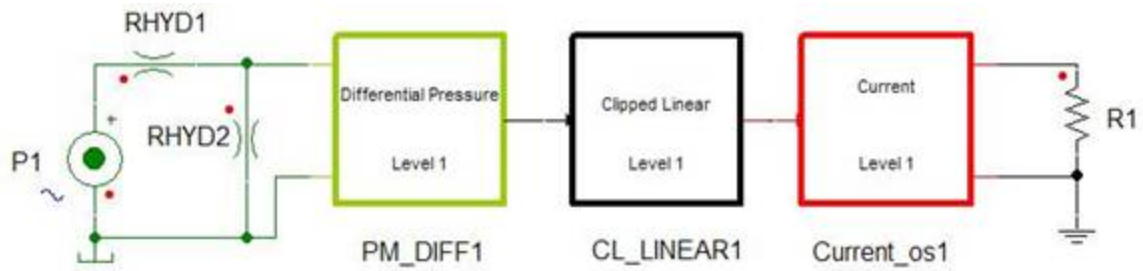


Figure 2. Application example of the Current Block

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	AMPL	40k [Pa]
	FREQ	50 [Hz]
	PHASE	0 [rad]
	OFF	0 [rad/s]
	TDELAY	0 [s]
Linear Orifice RHYD1/RHYD2	K	1n [m ³ /(Pa s)]
Clipped Linear Function CL_LINEAR1	INPUT	PM_DIFF1.MEAS
	max_input	10k
	offset	0
	min_input	0
	full_scale_span	10
Current Block Current_os1	INPUT	CL_LINEAR1.OUTPUT
Resistor R1	R	1k [Ohm]

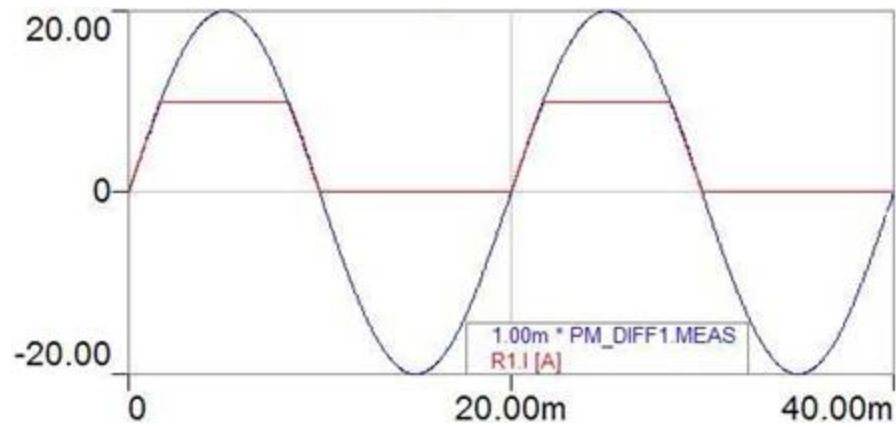


Figure 3. Simulation result-outputs of the Differential Pressure Sensing block and the Current block

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References

Level 1 Differential Capacitance Block

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2



Figure 1. Component symbol

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Description

A differential capacitance output signal is provided by three capacitor plates that form two capacitors connected in series. The middle capacitor plate changes position when an input signal is applied and changes the ratio of the capacitance of one capacitor to the other. The varying capacitance can be used to provide sensor output, such as a variable AC voltage signal.

The Level 1 Differential Capacitance Block consists of two capacitors with a total capacitance whose relative capacitances change according to the input signal received from a processing block. The total equivalent capacitance, which is the sum of the capacitances of the two capacitors, is a block parameter that can be varied.

The block has three conservative electrical nature pins: a positive terminal, into which current flows; a negative terminal; and a third terminal between the two capacitors, from which the output signal can be obtained.

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Assumptions and Limitations

This is an ideal component, hence no internal losses or delays are considered.

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Mathematical Description

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Netlist Syntax

```
MODEL DCap_os ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) pos_input:= %0,
neg_input:= %1, signal:= %2 ( INPUT:= @INPUT, max_pct_change:= @max_pct_change,
total_capacitance:= @total_capacitance, max_input_magnitude:= @max_input_magnitude)
SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
pos_input	Positive input terminal for signal-producing voltage	Electrical
pos_input	Negative terminal (signal ground)	Electrical
signal	Signal voltage output	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
max_pct_change	Maximum percent change in the total capacitance of one capacitor	real	0

max_input_magnitude	Maximum magnitude of the input from the processing block	real	0
total_capacitance	Sum of the capacitances of the two (paired) capacitors	real	0

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
INPUT	Input from the processing block	Input	real

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Example

In this example, a sinusoidal Pressure Source P1 is applied to a two Linear Orifice – RHYD1 and RHYD2 in series. The Differential Pressure Sensing block PM_DIFF1 measures the Pressure across RHYD2. The Output of PM_DIFF1 is clamped by a Clipped Linear function block CL_LINEAR1. The output of CL_LINEAR is used to decide the relative capacitance ratio of DCap_os1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 4, and the simulation results are shown in Figure 3.

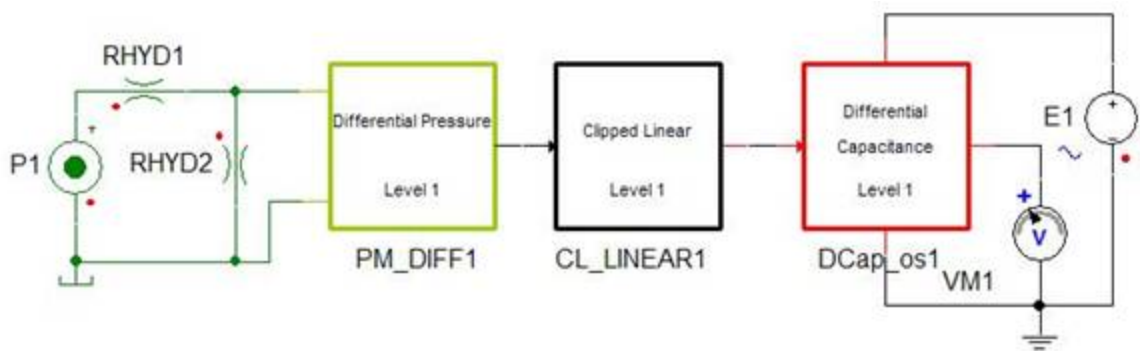


Figure 2. Application example of the Differential Capacitance Block

Table 4

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	20k * (t/40m) [Pa]
Linear Orifice RHYD1/RHYD2	K	1n [m ³ /(Pa s)]
Clipped Linear Function CL_LINEAR1	INPUT	PM_DIFF1.MEAS
	max_input	10k
	offset	0
	min_input	0
	full_scale_span	10
Differential Capacitance Block Cap_os1	INPUT	CL_LINEAR1.OUTPUT
	max_pct_change	90
	max_input_magnitude	1u
	total_capacitance	500n

Voltage Source (sinusoidal) E1	AMPL	5 [V]
	FREQ	50 [Hz]
	PHASE	0 [rad]
	OFF	0 [rad/s]
	TDELAY	0 [s]

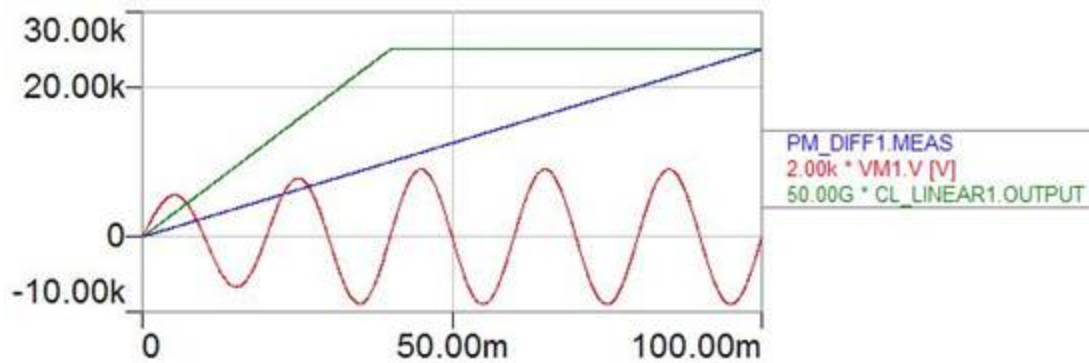


Figure 3. Simulation result-outputs of PM_DIFF1 and CL_LINEAR1, and the voltage across DCap_os1

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References

Level 1 Voltage Block

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

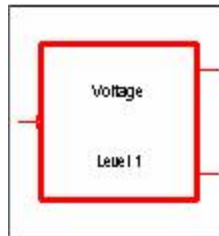


Figure 1. Component symbol

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Description

The Level 1 Voltage Block provides a voltage output signal that is equal to the value that it receives via its nonconservative input. The block has two conservative electrical domain pins, one for its positive terminal, and one for its negative terminal.

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Assumptions and Limitations

Because the block itself contains no electrical ground, its negative terminal must be grounded if it is not placed into an electrical network in which at least one node is connected to ground. Also, this is an ideal component, hence no internal losses or delays are considered.

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Mathematical Description

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Netlist Syntax

MODEL EMF_os ?InstanceName(@InstanceName):(@Refbase)@(ID)) out_plus:= %0, out_minus:= %1 (INPUT:= @INPUT) SRC: DB(Lib:=@ModelLibraryName);

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
out_plus	Positive terminal	Electrical
out_minus	Negative terminal	Electrical

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
INPUT	Input from the processing block	Input	real

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Example

In this example, a sinusoidal Pressure Source P1 is applied to a two Linear Orifice – RHYD1 and RHYD2 in series. The Differential Pressure Sensing block PM_DIFF1 measures the Pressure across RHYD2. The Output of PM_DIFF1 is clamped by a Clipped Linear function block CL_LINEAR1, and then converted to a voltage signal through the Voltage Block EMF_os1. The output voltage is applied to a resistor. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

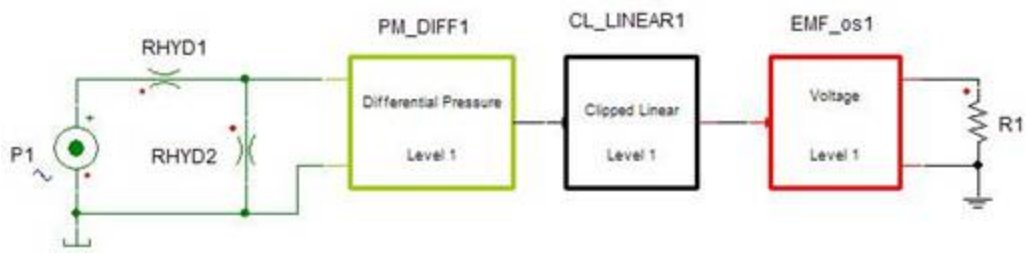


Figure 2. Application example of the Voltage Block

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	AMPL	40k [Pa]
	FREQ	50 [Hz]
	PHASE	0 [rad]
	OFF	0 [rad/s]
	TDELAY	0 [s]
Linear Orifice RHYD1/RHYD2	K	1n [m ³ /(Pa s)]
Clipped Linear Function CL_ LINEAR1	INPUT	PM_ DIFF1.MEAS
	max_input	10k
	offset	0
	min_input	0
	full_scale_ span	10
Voltage Block EMF_os1	INPUT	CL_ LINEAR1.OUTPUT
Resistor R1	R	1k [Ohm]

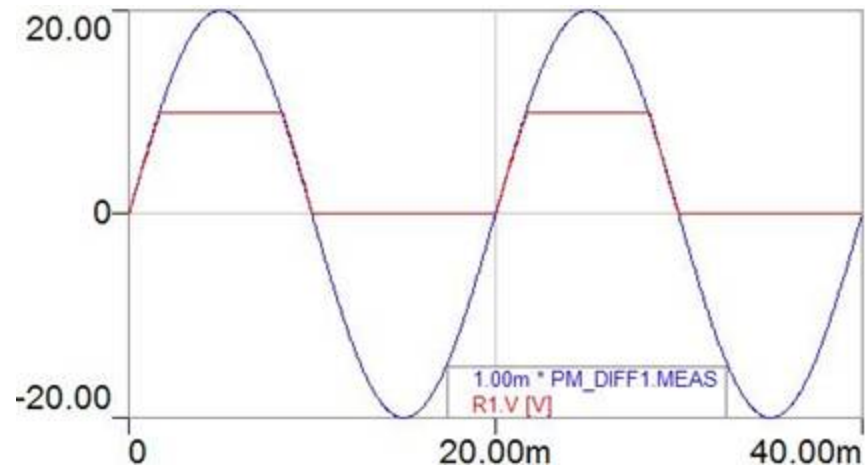


Figure 3. Simulation result-outputs of the Differential Pressure Sensing block and the Voltage block

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References

Level 1 Inductance Block

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

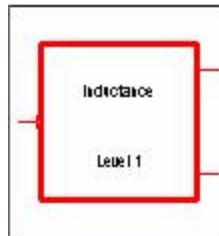


Figure 1. Component symbol

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Description

The Level 1 Inductance Block provides an inductance output signal that is equal to the value that it receives via its nonconservative input. The block has two conservative electrical domain pins, one for its positive terminal, and one for its negative terminal. The positive terminal is the terminal into which current flows.

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Assumptions and Limitations

This is an ideal component, hence no internal losses or delays are considered.

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Mathematical Description

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Netlist Syntax

MODEL Ind_os ?InstanceName(@InstanceName):(@Refbase)@(ID)) out_plus:= %0, out_minus:= %1 (INPUT:= @INPUT) SRC: DB(Lib:=@ModelLibraryName);

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
out_plus	Positive terminal	Electrical
out_minus	Negative terminal	Electrical

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
INPUT	Input from the processing block	Input	real

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Example

In this example, a sinusoidal Pressure Source P1 is applied to a two Linear Orifice – RHYD1 and RHYD2 in series. The Differential Pressure Sensing block PM_DIFF1 measures the Pressure across RHYD2. The Output of PM_DIFF1 is clamped by a Clipped Linear function block CL_LINEAR1. The output of CL_LINEAR is used to decide the inductance of Ind_os1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3. Notice that the output of P1 increases linearly with time, and hence the inductance of and the voltage across Ind_os1 increase accordingly. When the output of P1 reaches the upper limit of CL_LINEAR1, the inductance of Ind_os1 is clamped to a constant value, and the amplitude of the voltage across Ind_os1 becomes constant.

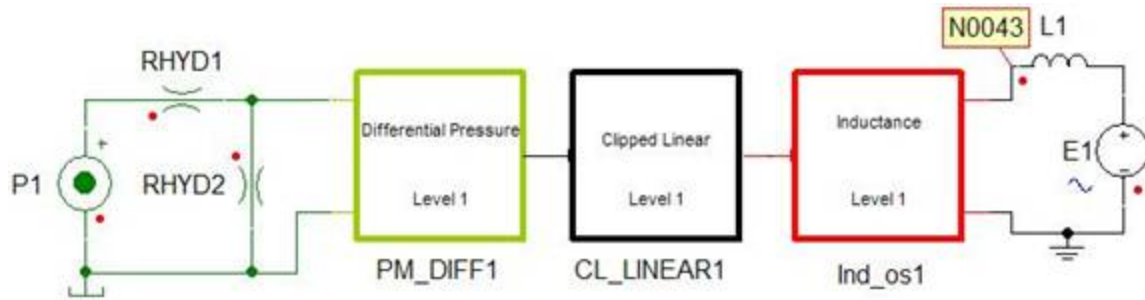


Figure 2. Application example of the Inductance Block**Table 3**

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	$20k * (t/40m)$ [Pa]
Linear Orifice RHYD1/RHYD2	K	$1n$ [m ³ /(Pa s)]
Clipped Linear Function CL_LINEAR1	INPUT	PM_DIFF1.MEAS
	max_input	10k
	offset	0
	min_input	0
	full_scale_span	10
Inductance Block Ind_os1	INPUT	CL_LINEAR1.OUTPUT
Inductor L1	L	1m [H]
Voltage Source (sinusoidal) E1	AMPL	5 [V]
	FREQ	50 [Hz]
	PHASE	0 [rad]
	OFF	0 [rad/s]
	TDELAY	0 [s]

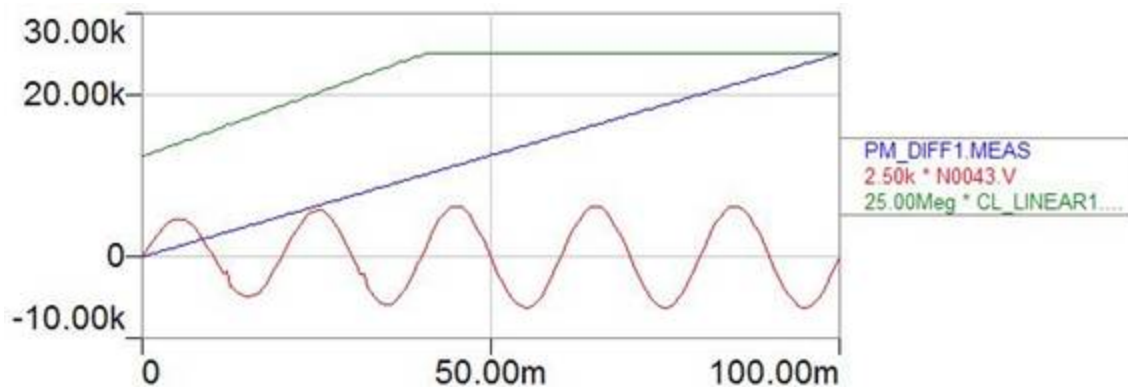


Figure 3. Simulation result-outputs of PM_DIFF1 and CL_LINEAR1, and the voltage across Ind_
os1

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References

Level 1 8-bit Binary Number Block

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

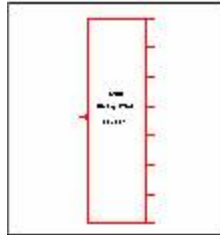


Figure 1. Component symbol

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Description

The Level 1 8-bit Binary Number output signal block is useful for modeling sensors with a natural binary output. The block takes a decimal input via its nonconservative input pin, converts this decimal value to a binary number, and then sets or clears its output bits accordingly. The output bits are modeled by voltage sources, each of which has a single conservative electrical domain pin for its output.

Parameters that may be passed to the block via nonconservative input nodes include the bit-set and bit-cleared output signal amplitudes, the sampling interval for the device, and the reference value for the decimal-to-binary conversion. The block also features two nonconservative nodes that allow it to be connected to other 8-bit Binary Number output blocks to create binary numbers larger than eight bits. These parameters include the LSB_position parameter, which is used to indicate the power of two associated with the LSB output of the block, and the mod_val output parameter, which is connected to the input pin of another 8-bit Binary Number block when more than one of these blocks is connected together. Figure 2 shows how this connection should be made.

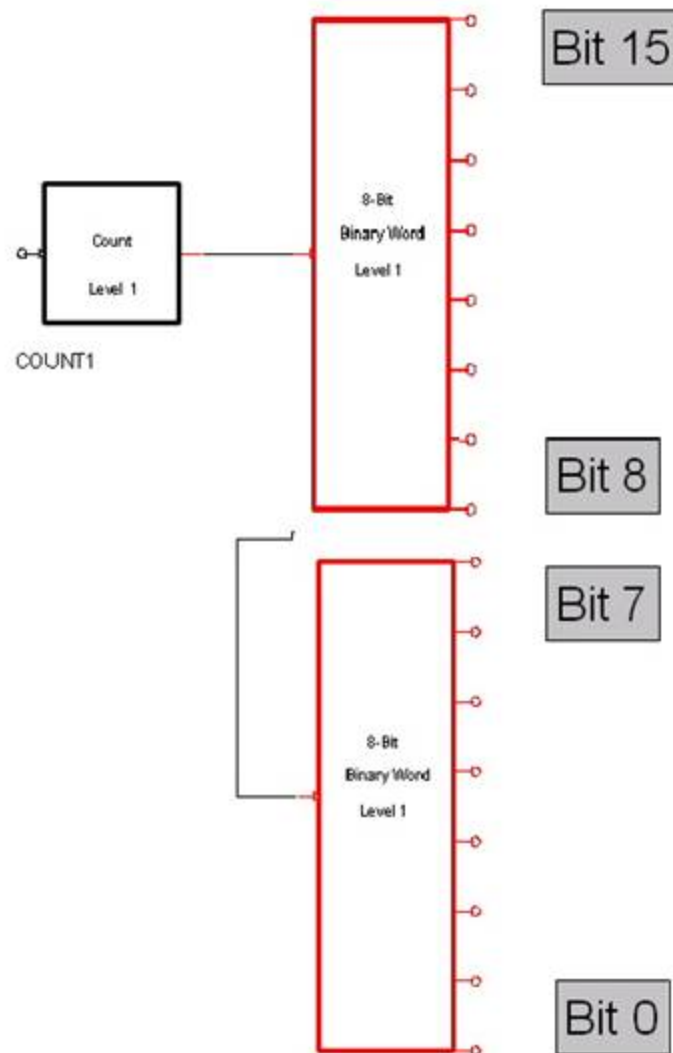


Figure 2. Connection of two 8-bit Binary Number Blocks to creat a 16-bit output

In this illustration, two 8-bit Binary Number blocks are connected to form a 16-bit output. The upper block is used to implement bits 8 through 15. Therefore, its input pin should be connected to a processing block, and its LSB_position parameter is set to 8.

The lower block is used to implement bits 0 through 7. Its input pin is connected to the mod_val pin of the upper block, and its LSB_position parameter is set to 0.

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Assumptions and Limitations

This is an ideal component, hence no internal losses are considered.

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Mathematical Description

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Netlist Syntax

MODEL pbyte ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) bit0:= %0, bit1:= %1, bit2:= %2, bit3:= %3, bit4:= %4, bit5:= %5, bit6:= %6, bit7:= %7 (INPUT:= @INPUT, one_amplitude:= @one_amplitude, zero_amplitude:= @zero_amplitude, sampling_interval:= @sampling_interval, LSB_position:= @LSB_position) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
bit0 (See Note)	Least-significant output bit (LSB) of the block	Electrical
bit1 (See Note)	bit1	Electrical
bit2 (See Note)	bit2	Electrical
bit3 (See Note)	bit3	Electrical
bit4 (See Note)	bit4	Electrical
bit5 (See Note)	bit5	Electrical
bit6 (See Note)	bit6	Electrical
bit7 (See Note)	Most-significant output bit (MSB) of the block	Electrical

Note: Terminal set to No Action when unconnected. Terminal may remain unconnected without generating an error.

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Parameters

Table 2

Name	Description [Unit]	Data Type	Default Value [Unit]
one_amp- litude	Bit-set amplitude (for logic 1)	real	5
zero_amp- litude	Bit-cleared amplitude (for logic 0)	real	0
sampling_ interval	Device sampling interval	real	1m
LSB_pos- ition	Power of two represented by the least-significant bit (the bit number of the block's LSB)	real	0

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
INPUT	Input from the processing block	Input	real
mod_val	Remainder of the initial value from the decimal-to-binary conversion that is to be passed to the cascaded block	Output	real

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Example

In this example, the pressure of a linear Pressure Source P1 is measured by a Absolute Pressure measurement block PMabs1. The output of PMabs1 is sent to a counter COUNT1, which transforms the continuous output of PMabs1 into discrete numbers. The output of COUNT1 is

then sent to an 8-Bit Binary Number block pbyte1. The schematic of the system is shown in Figure 3, system parameters are listed in Table 3, and the simulation results are shown in Figure 4-7.

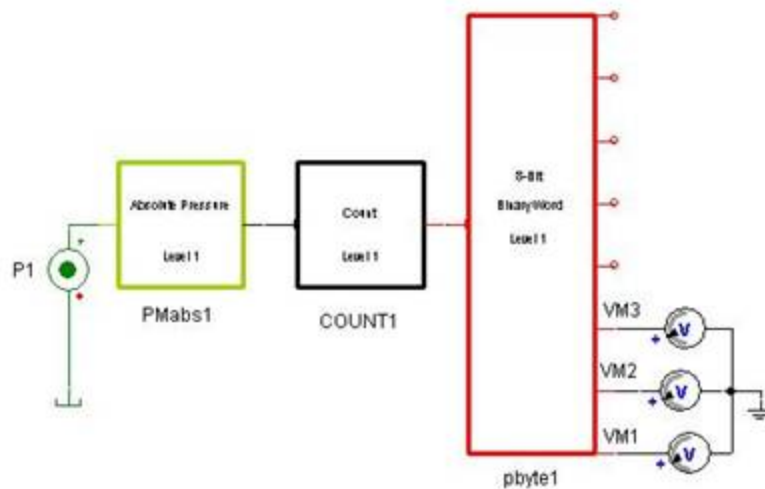


Figure 3. Application example of the 8-Bit Bloinary Numer block

Table 4

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	$75 * (t/45m)$ [Pa]
Counter COUNT1	INPUT	PMabs1.MEAS
	INCREMENT_SIZE	15
	OFFSET	0
8-bit Binary Number block pbyte1	INPUT	COUNT1.OUTPUT
	one_amplitude	5
	zero_amplitude	0
	sampling_interval	1m
	LSB_position	0

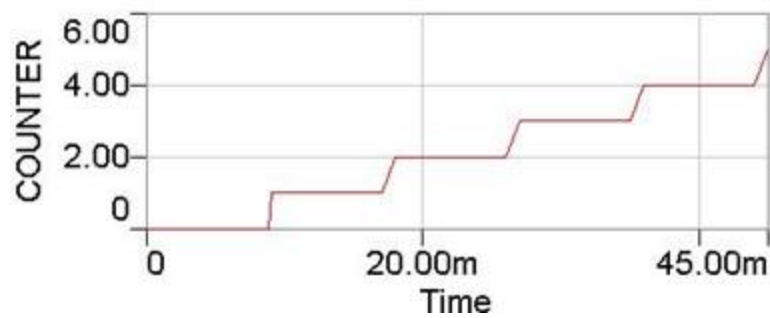


Figure 4. Simulation result-output of COUNT1

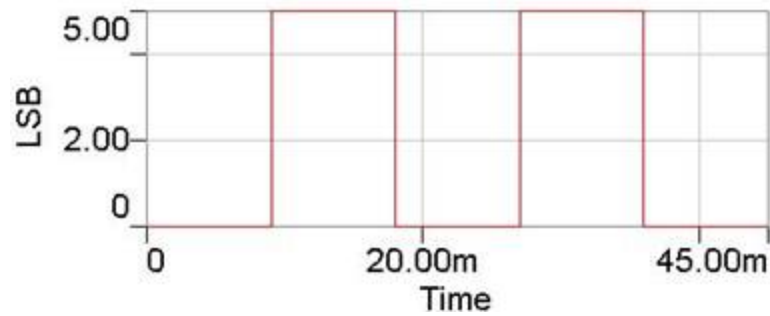


Figure 5. Simulation result-least-significant bit output of pbyte1

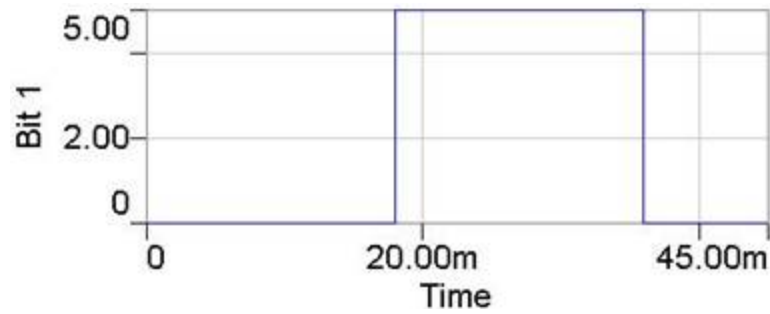


Figure 6. Simulation result-least-bit1 output of pbyte1

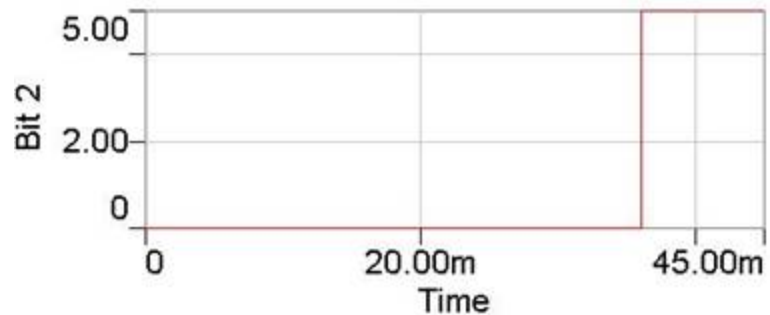


Figure 7. Simulation result-least-bit2 output of pbyte1

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References

Level 1 Potentiometer Block

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

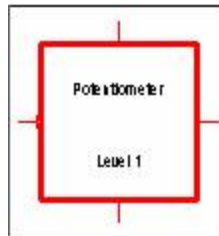


Figure 1. Component symbol

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Description

A Potentiometer output signal is provided by a three-terminal variable resistance element. Two of the device's pins are connected to the potentiometer's power supplies. The third pin is connected to the wiper of the potentiometer and can be used to provide the voltage divider output signal that is established by the potentiometer.

The Level 1 Potentiometer block provides a voltage divider output signal that varies when a power supply voltage and an input signal are applied. The block has three conservative electrical nature pins, positive and negative power supply pins, and a pin from which the potentiometer's output signal can be obtained. The positive power supply terminal is the terminal into which the supply current should flow.

The total resistance of the potentiometer can be changed.

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Assumptions and Limitations

This is an ideal component, hence no measure losses or delays are considered.

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Mathematical Description

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Netlist Syntax

```
MODEL Potentiometer ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) in_1:= %0, In_2:= %1, Out_1:= %2 ( INPUT:= @INPUT, equivalent_resistance:= @equivalent_resistance) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
In_1	Positive input terminal for signal-generating voltage	Electrical
In_2	Negative input terminal (signal ground)	Electrical
Out_1	Output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
equivalent_resistance	Total potentiometer resistance	real	10k

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
INPUT	Input from the processing block	Input	real

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Example

In this example, a sinusoidal Pressure Source P1 is applied to a two Linear Orifice – RHYD1 and RHYD2 in series. The Differential Pressure Sensing block PM_DIFF1 measures the Pressure across RHYD2. The Output of PM_DIFF1 is clamped by a Clipped Linear function block CL_LINEAR1. The output of CL_LINEAR is used to provide the voltage divider output signal for Potentiometer1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 4, and the simulation results are shown in Figure 3.

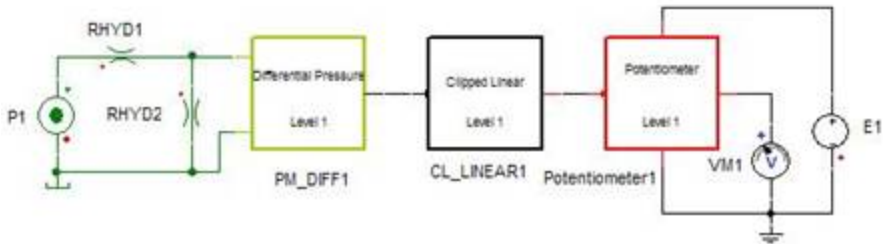


Figure 2. Application example of the Potentiometer Block

Table 4

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	20k * (t/40m) [Pa]
Linear Orifice RHYD1/RHYD2	K	1n [m ³ /(Pa s)]
Clipped Linear Function CL_LINEAR1	INPUT	PM_DIFF1.MEAS
	max_input	10k
	offset	0
	min_input	0

	full_scale_span	E1.EMF
Potentiometer Block Potentiometer1	INPUT	CL_LINEAR1.OUTPUT
	equivalent_resistance	10k
Voltage Source E1	EMF	10 [V]

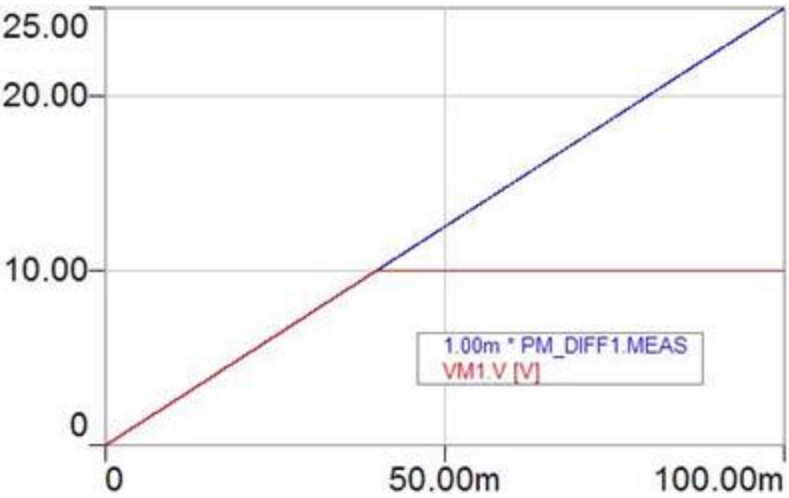


Figure 3. Simulation result-outputs of PM_DIFF1 and Potentiometer1

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References

Level 1 Pulse Voltage Block

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

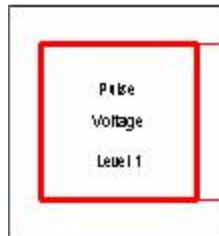


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Description

The Level 1 Pulse Voltage Block provides a pulse voltage output signal whose amplitude, phase shift, offset, or frequency can be made equal to a value that is received via a nonconservative input. The block has two conservative electrical domain pins, one for its positive terminal, and one for its negative terminal.

Parameters that can be varied include the amplitude, phase, offset, and frequency of the pulse voltage.

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Assumptions and Limitations

Because the block itself contains no electrical ground, its negative terminal must be grounded if it is not placed into an electrical network in which at least one node is connected to ground.

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Mathematical Description

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Netlist Syntax

MODEL pulse_os ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) OUT_P:= %0, OUT_M:= %1 (amplitude:= @amplitude, frequency:= @frequency, phase:= @phase, offset:= @offset) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
amplitude	Amplitude of the pulse voltage	real	5
frequency	Frequency of the phase voltage	real	1k
phase	Phase shift of the phase voltage	real	0
offset	DC offset of the phase voltage	real	0

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Example

In this example, a linear Pressure Source P1 is applied to a two Linear Orifice – RHYD1 and RHYD2 in series. The Differential Pressure Sensing block PM_DIFF1 measures the Pressure across RHYD2. The Output of PM_DIFF1 is clamped by a Clipped Linear function block CL_LINEAR1. The output of CL_LINEAR is used to decide the amplitude of the Pulse Voltage

Output block pulse_os1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 4, and the simulation results are shown in Figure 3.

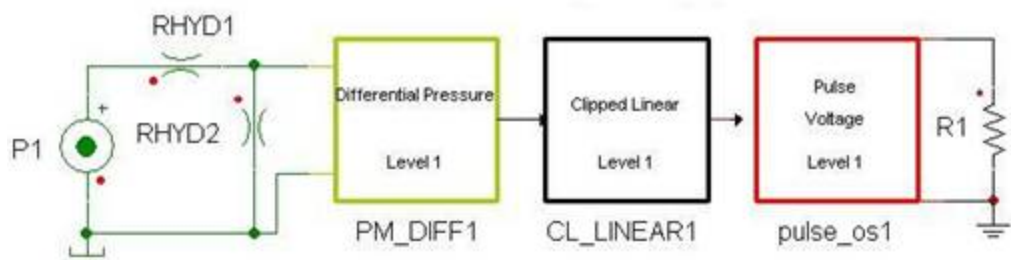


Figure 2. Application example of the Pulse Voltage Output block

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	10k * (t/40m) [Pa]
Linear Orifice RHYD1/RHYD2	K	1n [m ³ /(Pa s)]
Clipped Linear Function CL_LINEAR1	INPUT	PM_DIFF1.MEAS
	max_input	10k
	offset	0
	min_input	0
	full_scale_span	E1.EMF
Pulse Voltage Output block pulse_os1	INPUT	CL_LINEAR1.OUTPUT
	frequency	60
	Offset	0
	Phase	0
Resistor R1	R	1k [Ohm]

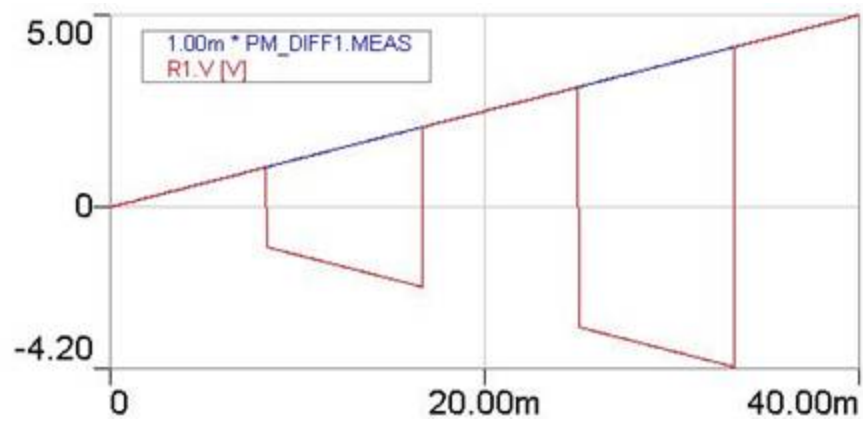


Figure 3. Simulation result-outputs of PM_DIFF1 and pulse_os1

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References

Level 1 Wheatstone Bridge Block

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

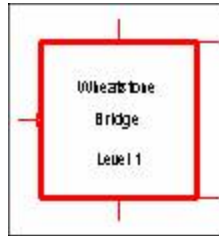


Figure 1. Component symbol

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Description

A Wheatstone bridge output signal is provided by four resistors connected in a bridge configuration, as shown in Figure 2.

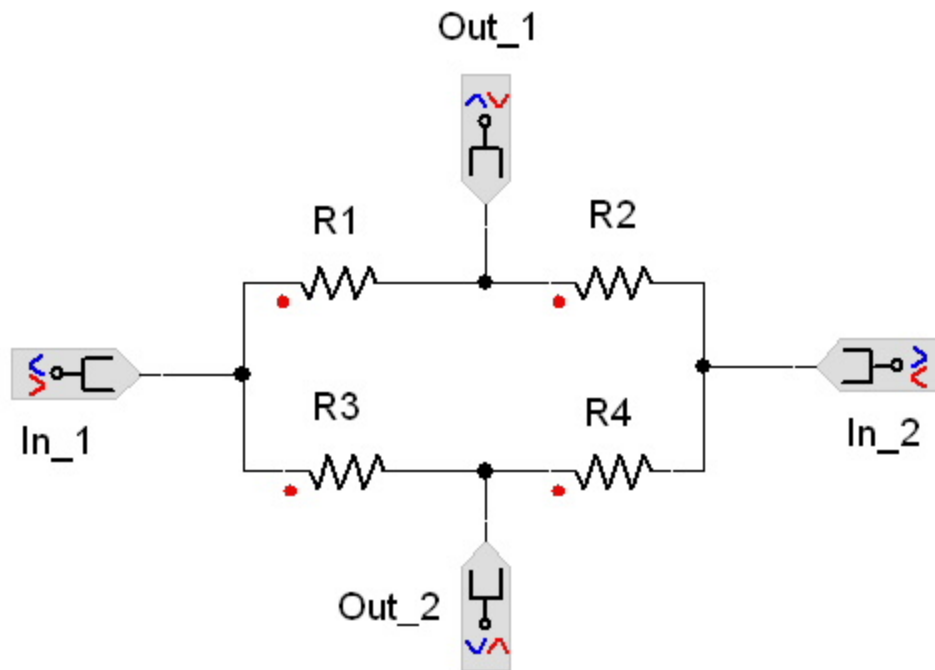


Figure 2. Configuration of the Wheatstone Bridge circuit

When an input signal is applied to the bridge, the resistance of R1 and R4 change by an equal amount. The resistors R2 and R3 change by an amount that is equal in magnitude to the change in R1 and R4, but opposite in sign. This provides a linear differential voltage signal across the pins Out_1 and Out_2.

The block has four conservative electrical nature pins: a positive and negative input terminal, and a positive and negative output terminal. The positive input terminal is the terminal into which the bridge's supply current should flow. The positive output terminal is the terminal at which the voltage becomes positive when a positive input signal is applied.

Parameters that can be varied include the nominal equivalent resistance of the resistor bridge, the temperature at which the bridge experiences its nominal resistance, and the temperature coefficient of the bridge resistors.

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Assumptions and Limitations

This is an ideal component, hence no internal losses or delays are considered.

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Mathematical Description

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Netlist Syntax

MODEL RES_BRIDGE ?InstanceName(@InstanceName):(@Refbase)@(ID)) in_1:= %0, In_2:= %1, Out_1:= %2, Out_2:= %3 (INPUT:= @INPUT, max_pct_change:= @max_pct_change, max_input_magnitude:= @max_input_magnitude, equivalent_resistance:= @equivalent_resistance) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
In_1	Positive input terminal for signal-generating voltage	Electrical
In_2	Negative input terminal (signal ground)	Electrical
Out_1	Positive output terminal	Electrical
Out_1	Negative output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]	
max_pct_change	Maximum percentage of signal-generating voltage allowed at the output (or the maximum percent change in the total capacitance of one capacitor)	real	0	
max_input_magnitude	Maximum magnitude of the input from the processing block	real	0	
equivalent_	Equivalent resistance of the	real	0	

resistance	bridge			

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
INPUT	Input from the processing block	Input	real

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Example

In this example, a sinusoidal Pressure Source P1 is applied to a two Linear Orifice – RHYD1 and RHYD2 in series. The Differential Pressure Sensing block PM_DIFF1 measures the Pressure across RHYD2. The Output of PM_DIFF1 is clamped by a Clipped Linear function block CL_LINEAR1. The output of CL_LINEAR is used to decide the internal resistors of RES_BRIDGE1. The schematic of the system is shown in Figure 3, system parameters are listed in Table 4, and the simulation results are shown in Figure 4.

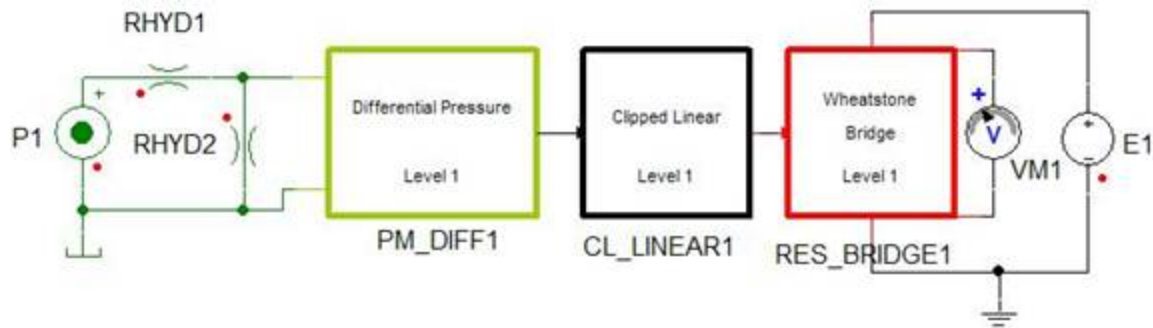


Figure 3. Application example of the Wheatstone Bridge Block

Table 4

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	$20k * (t/40m)$ [Pa]
Linear Orifice RHYD1/RHYD2	K	$1n$ [m ³ /(Pa s)]
Clipped Linear Function CL_LINEAR1	INPUT	PM_DIFF1.MEAS
	max_input	10k

	offset	0
	min_input	0
	full_scale_span	E1.EMF
Wheatstone Bridge Block RES_BRIDGE1	INPUT	CL_LINEAR1.OUTPUT
	max_pct_change	100
	max_input_magnitude	E1.EMF
	equivalent_resistance	10k
Voltage Source E1	EMF	10 [V]

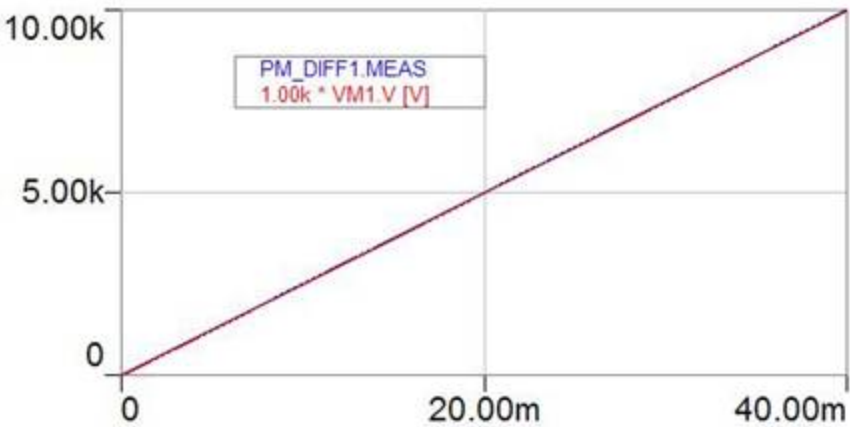


Figure 4. Simulation result-outputs of PM_DIFF1 and CL_LINEAR1, and the voltage across DCap_os1

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References

Level 1 Resistance Block

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

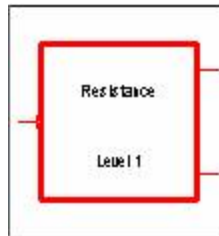


Figure 1. Component symbol

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Description

The Level 1 Resistance Block provides a resistance output signal that is equal to the value that it receives via its nonconservative input. The block has two conservative electrical domain pins, one for its positive terminal, and one for its negative terminal. The positive terminal is the terminal into which current flows.

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Assumptions and Limitations

This is an ideal component, hence no internal losses or delays are considered.

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Mathematical Description

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Netlist Syntax

MODEL Res_os ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) out_plus:= %0, out_minus:= %1 (INPUT:= @INPUT) SRC: DB(Lib:=@ModelLibraryName);

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
out_plus	Positive terminal	Electrical
out_minus	Negative terminal	Electrical

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
INPUT	Input from the processing block	Input	real

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Example

In this example, a sinusoidal Pressure Source P1 is applied to a two Linear Orifice – RHYD1 and RHYD2 in series. The Differential Pressure Sensing block PM_DIFF1 measures the Pressure across RHYD2. The Output of PM_DIFF1 is clamped by a Clipped Linear function block CL_LINEAR1. The output of CL_LINEAR is used to decide the resistance of Res_os1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

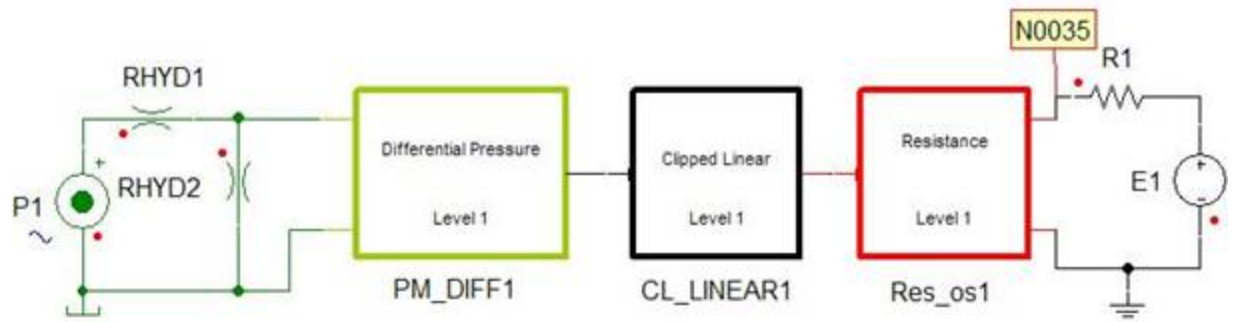


Figure 2. Application example of the Resistance Block

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	AMPL	40k [Pa]
	FREQ	50 [Hz]
	PHASE	0 [rad]
	OFF	0 [rad/s]
	TDELAY	0 [s]
Linear Orifice RHYD1/RHYD2	K	1n [m ³ /(Pa s)]
Clipped Linear Function CL_LINEAR1	INPUT	PM_DIFF1.MEAS
	max_input	10k
	offset	0
	min_input	0
	full_scale_span	10
Resistance Block Current_os1	INPUT	CL_LINEAR1.OUTPUT
Resistor R1	R	1k [Ohm]

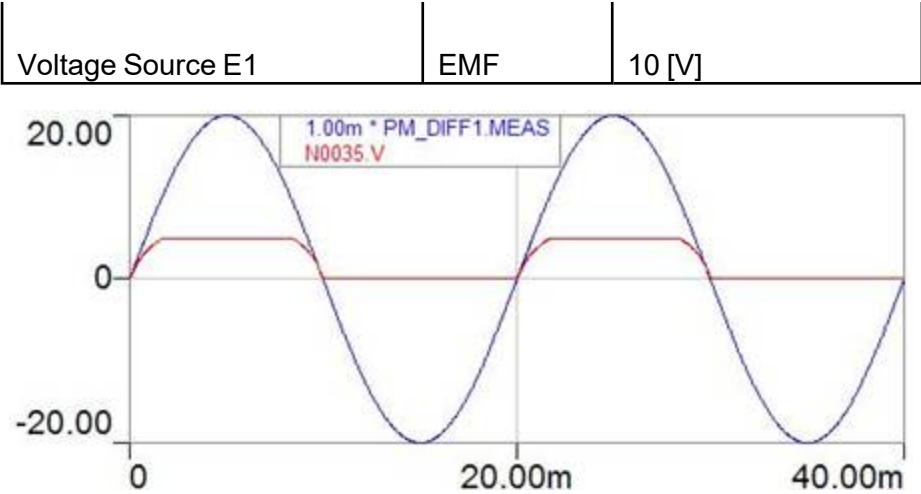


Figure 3. Simulation result-output of the Differential Pressure Sensing block and the voltage across Res_os1

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References

Level 1 Processing Blocks

The Level 1 Processing Blocks contain functions and relations that process the real values that are passed out of measuring blocks. The output from a measuring block enters a processing block via its nonconservative input pin as the independent variable of the function or relation within the block. The block then calculates the value of its dependent variable and passes this value via its nonconservative output pin. The output pin of a processing block is then connected to an output signal block.

The Level 1 Processing Blocks provide the following two-variable functions and relations:

- Angular Incremental Encoding: A relation that returns two pulse signals in quadrature and a reference signal.

[Angular Incremental Encoder Channels \(ANG_ENCODER_CHAN\)](#)

[Linear Incremental Encoder Channels \(LIN_ENCODER_CHAN\)](#)

- [Clipped Linear Function \(CL_LINEAR\)](#): A function that is linear within a specific region and is clipped to upper and lower limits outside that region.
- [Count \(COUNT\)](#): An analog-to-digital conversion function that divides the independent variable by some reference value and returns the integer part of the quotient.
- Thermocouple direct polynomial: A power series that describes the voltage-temperature characteristics of thermocouples.
[Thermocouple Direct Polynomial \(J, T, E, N, B, R, S\) \(direct_thermoc\)](#)
[Thermocouple Direct Polynomial \(K\) \(direct_thermoc_k\)](#)
- [Nernst Voltage Equation \(NERNST_V\)](#): A logarithmic function that calculates a voltage based on the ratio of a measured pressure and a reference pressure.
- [Oxygen-Dependent Resistance \(O2_R_EQ\)](#)
- [Characteristic from File \(SENS_CHAR\)](#): A user-defined function passed as a Twin Builder characteristic.
- [Steinhart-Hart Function \(SH_FUNCTION\)](#): A decaying exponential function that describes the resistance-temperature characteristics of negative temperature coefficient thermistors.
- [Linear Function \(ST_LINEAR\)](#)

Level 1 Angular Incremental Encoder Channels

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2



Figure 1. Component symbol

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Description

The Level 1 Angular Incremental Encoder Channels Block takes the input from an angular position sensing block and outputs the three digital output channels of a typical incremental encoder sensor. The first output, Channel A, goes to its logic 1 value each time the encoder's angle sensor moves past one of the equally-spaced position indicators on the device when the sensor is moving in a clockwise direction. Channel A remains at its logic 1 output until the encoder's angle sensor has traveled one-half the distance to the next position indicator. The second output of the encoder, Channel B, is similar to Channel A but lags it by one-quarter cycle when the angle sensor is rotating in a clockwise direction. When the angle sensor is rotating in a counterclockwise direction, the outputs of Channels A and B are reversed.

The third output, Channel N, goes to its logic 1 value when the sensor detects its zero point and remains high until the sensor has traveled one-quarter of the distance to the next sensing element.

The Level 1 Angular Incremental Encoder channels parameters of processing block features for the following device characteristics: the number of position indicators on the encoder, the zero position of the encoder, and the logic one and zero output amplitudes.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL ANG_ENCODER_CHAN ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) (  
INPUT:= @INPUT, num_lines:= @num_lines, north:= @north, oneamplitude:= @oneamplitude,  
zeroamplitude:= @zeroamplitude) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Parameters

Table 1

Name	Description [Unit]	Data Type	Default Value [Unit]
num_lines	Number of position indicators (or divisions) on the encoder	real	16
north	The angle at which the reference pulses is triggered (zero position of the encoder)	real	0
oneamplitude	Maximum value of the output pulse (amplitude of the logic 1 signal)	real	5
zeroamplitude	Minimum value of the output pulse (amplitude of the logic 0 signal)	real	0

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type

INPUT	Input from the sensing block	Input	real
channel_A	Output of encoder channel A (leading channel during clock-wise rotation)	Output	real
channel_B	Output of encoder channel B (leading channel during counterclockwise rotation)	Output	real
channel_north	Output of encoder channel N (reference channel, the channel with a high output at the zero position only)	Output	real

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Example

In this example, a Position Source S_ROT B1 is applied to a Mass block MASS_ROT B1. The displacement of MASS_ROT B1 is measured by an Angular Displacement sensing block ANG_DIFF_SENS1, and the measurement result is output through an Angular Incremental Encoder ANG_ENCODER_CHAN1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3-6.

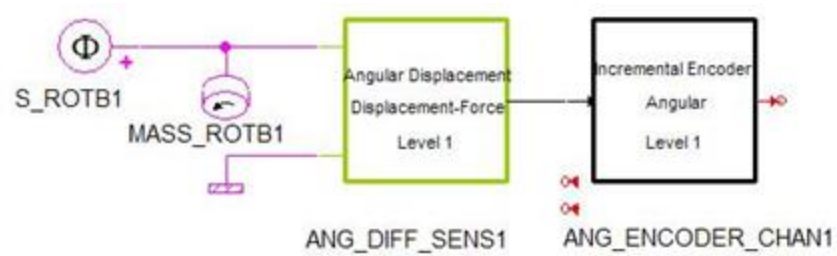


Figure 2. Application example of the Angular Incremental Encoder

Table 3

Component	Parameter	Value [Unit]
Angle Source S_ROT B1	VALUE	$(\pi/2) * (t/40m)$ [rad]
Mass Mass_ROT B1	J	1 [kg m ²]
	PHI0	0 [rad]

	OMEGA0	0 [rad/s]
Angular Incremental Encoder ANG_ENCODER_CHAN1	INPUT	ANG_DIFF_SENS1.MEAS
	num_lines	16
	north	0
	oneamplitude	5
	zeroamplitude	0

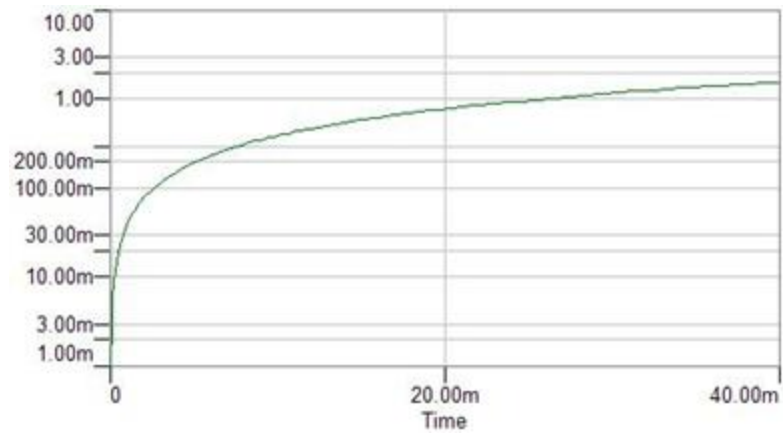
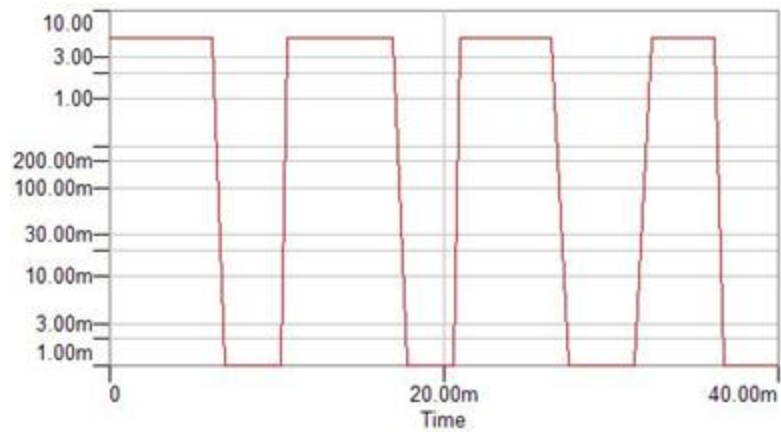
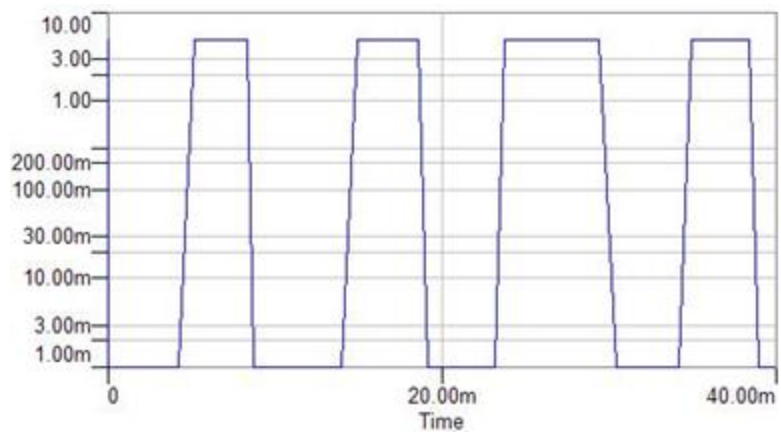
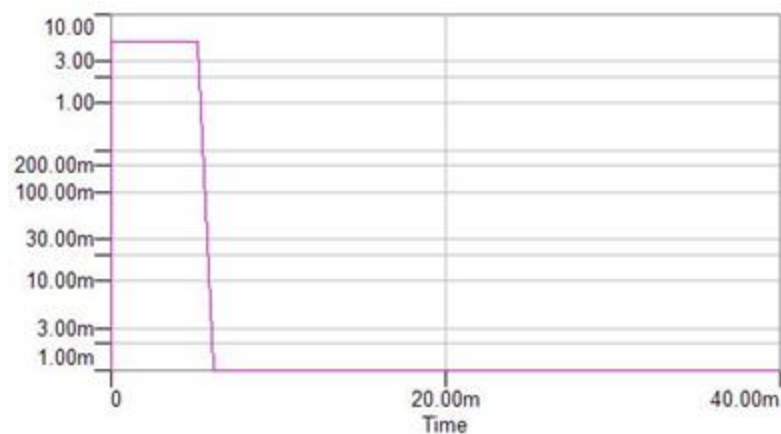


Figure 3. Simulation result-angular displacement of Mass_ROTb1**Figure 4. Simulation result-channel A output of ANG_ENCODER_CHAN1****Figure 5. Simulation result-channel B output of ANG_ENCODER_CHAN1****Figure 6. Simulation result-channel North output of ANG_ENCODER_CHAN1**[Top](#)

References

Level 1 Clipped Linear Function

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

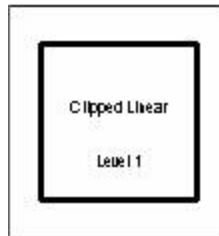


Figure 1. Component symbol

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Description

The Level 1 Clipped Linear Function block provides an output that is a linear function of the input within a specified input range and is clipped to a maximum and minimum value at input values above and below that range. The clipped linear function is shown below.

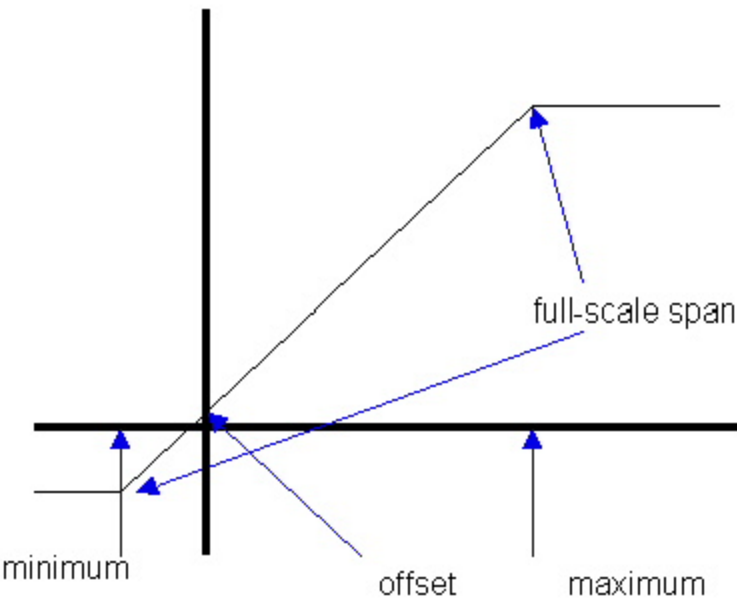


Figure 2. The clipped linear function

Block parameters can be varied include the minimum and maximum input values, the difference of the minimum and maximum output values, and the offset of the clipped linear function.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL CL_LINEAR ?InstanceName(@InstanceName):(@(Refbase)@(ID)) ( INPUT:=
@INPUT, max_input:= @max_input, min_input:= @min_input, full_scale_span:= @full_scale_
span, offset:= @offset) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Parameters

Table 1

Name	Description [Unit]	Data Type	Default Value [Unit]

max_ input	Maximum meaningful input value for the linear output range	real	10k
min_ input	Minimum meaningful input value for the linear output range	real	0
full_ scale_ span	Algebraic difference of outputs at the maximum and minimum meaningful inputs	real	10
offset	Output at the minimum input (y-intercept)	real	0

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
INPUT	Input from the sensing block	Input	real
OUTPUT	Processed output	Output	real

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Example

In this example, a sinusoidal Pressure Source P1 is applied to a two Linear Orifice – RHYD1 and RHYD2 in series. The Differential Pressure Sensing block PM_DIFF1 measures the Pressure across RHYD2. The Output of PM_DIFF1 is clamped by a Clipped Linear function block CL_LINEAR1. The schematic of the system is shown in Figure 3, system parameters are listed in Table 3, and the simulation results are shown in Figure 4.

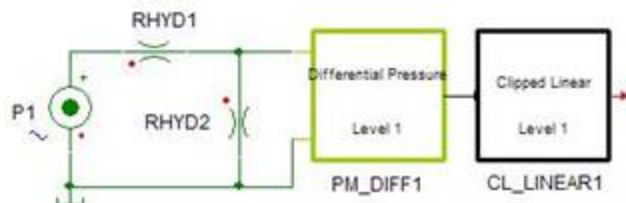


Figure 3. Application example of the Linear Function block

Table 3

Component	Parameter	Value [Unit]

Heat-Flow Source (sinusoidal) H1	AMPL	10 [W]
	FREQ	50 [Hz]
	OFF	0.5 [W]
	PHASE	0 [rad]
	TDELAY	0 [s]
Thermal Resistor RTH1/RTH2	K	1 [K/W]
Linear Function block ST_ LINEAR1	INPUT	ABS_ TEMP1.MEAS
	SENS	2
	OFFSET	5

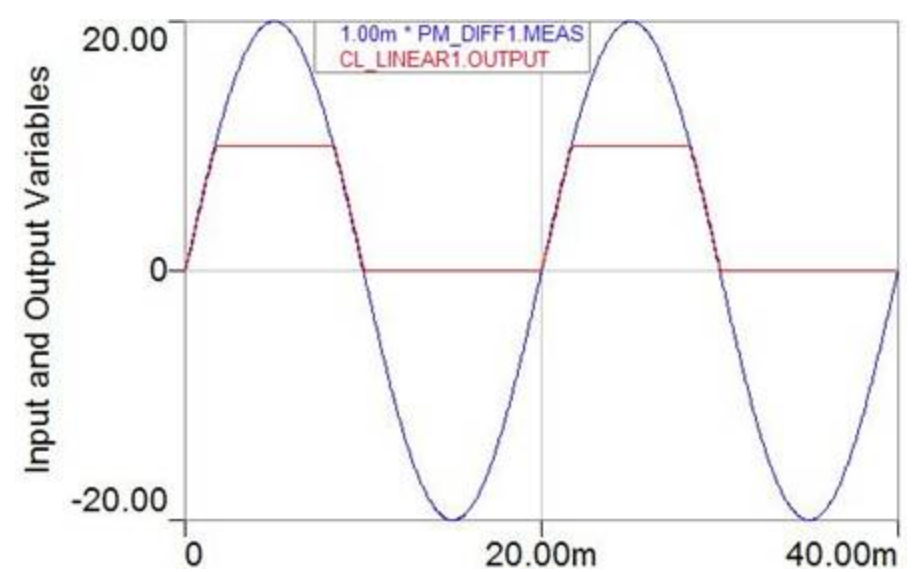


Figure 4. Simulation results-input and output of the Clip Function block CL_LINEAR1

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References

Level 1 Count

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

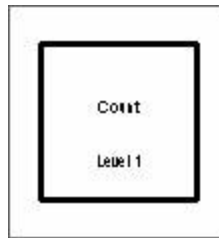


Figure 1. Component symbol

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Description

The Level 1 Count block takes a real-number input and produces an integer output. It is particularly useful for modeling sensors with integrated analog-to-digital conversion.

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Assumptions and Limitations

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Mathematical Description

The output of the block is given by the following function:

$$\text{count} = \text{INT}((\text{input} - \text{offset})/(\text{increment size}))$$

where the offset is the zero of the count, and the increment size is the minimum amount greater than the offset that the integer part of the input must be to increase the output to one.

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Netlist Syntax

MODEL COUNT ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) (INPUT:= @INPUT, INCREMENT_SIZE:= @INCREMENT_SIZE, OFFSET:= @OFFSET) SRC: DB(Lib:- :=@ModelLibraryName) ;

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Parameters

Table 1

Name	Description [Unit]	Data Type	Default Value [Unit]
increment_size	Increment magnitude (which is the minimum amount greater than the offset that the integer portion of the input must be in order to increase the count to 1)	real	1
offset	Offset magnitude (which is the zero point of the count)	real	0

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
INPUT	Input from the sensing block	Input	real
OUTPUT	Processed output	Output	real

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Example

In this example, a heat-flow source H1 is applied to two Thermal Resistors – RTH1 and RTH2. The temperature of RTH2 is measured by a Differential Temperature sensing block DIFF_TEMP1, and the measurement result is output through a Count block COUNT1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

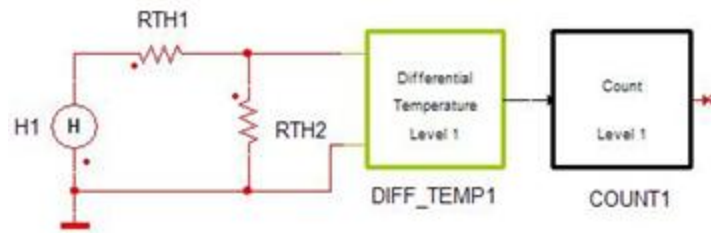


Figure 2. Application example of the Direct Polynomial Thermocouple (J, T, E, N, B, R, S) block

Table 3

Component	Parameter	Value [Unit]
Heat-Flow Source H1	VALUE	$(223 + 250 * (t/40m))$ [W]
Thermal Resistor RTH1/RTH2	K	1 [K/W]
Count block COUNT1	INPUT	DIFF_TEMP1.MEAS
	increment_size	20
	offset	223

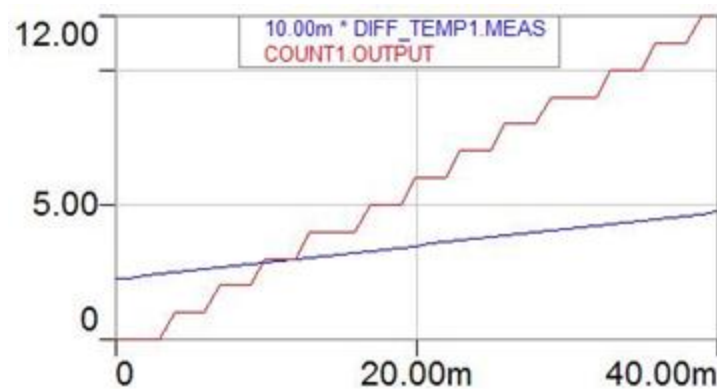


Figure 3. Simulation results-input and output of COUNT1

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References

Level 1 Thermocouple Direct Polynomial (J, T, E, N, B, R, S)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

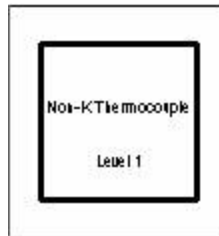


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Description

The Level 1 Thermocouple Direct Polynomial (J, T, E, N, B, R, S) block produces as its output the voltage-temperature curve for thermocouples of types J, T, E, N, B, R, and S and for type K thermocouples that are used at temperatures between -270 and 0 degrees Celsius. The function input is the temperature difference between the measuring and reference junctions of the thermocouple, and the output is a voltage.

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Assumptions and Limitations

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Mathematical Description

The output voltage is calculated the following function:

$$V = \sum_{i=0}^n a_i t^i$$

where a_i are coefficients that are particular to a given thermocouple type, and t is the temperature difference between the measuring and reference junctions of the thermocouple. Block parameters that can be changed include the thermocouple coefficients a_i .

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Netlist Syntax

```
MODEL direct_thermoc ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) ( INPUT:=
@INPUT, a0:= @a0, a1:= @a1, a2:= @a2, a3:= @a3, a4:= @a4, a5:= @a5, a6:= @a6, a7:=
@a7, a8:= @a8, a9:= @a9, a10:= @a10, a11:= @a11, a12:= @a12, a13:= @a13, a14:= @a14,
a15:= @a15) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Parameters

Table 1

Name	Description [Unit]	Data Type	Default Value [Unit]
a0	Zero-order coefficient	real	0
a1	First-order coefficient	real	0
a2	Second-order coefficient	real	0
a3	Third-order coefficient	real	0
a4	Fourth-order coefficient	real	0
a5	Fifth-order coefficient	real	0
a6	Sixth-order coefficient	real	0
a7	Seventh-order coefficient	real	0
a8	Eighth-order coefficient	real	0

a9	Ninth-order coefficient	real	0
a10	Tenth-order coefficient	real	0
a11	Eleventh-order coefficient	real	0
a12	Twelfth-order coefficient	real	0
a13	Thirteenth-order coefficient	real	0
a14	Fourteenth-order coefficient	real	0
a15	Fifteenth-order coefficient	real	0

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
INPUT	Input from the sensing block	Input	real
OUTPUT	Processed output	Output	real

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Example

In this example, a heat-flow source H1 is applied to two Thermal Resistors – RTH1 and RTH2. The temperature of RTH2 is measured by a Differential Temperature sensing block DIFF_TEMP1, and the measurement result is output through a Direct Polynomial Thermocouple (J, T, E, N, B, R, S) direct_thermoc1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

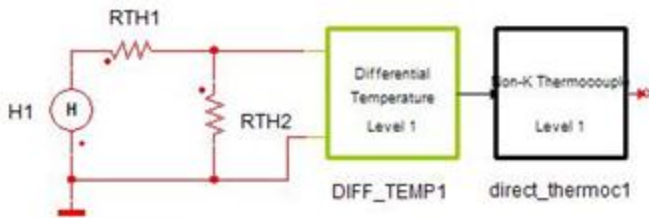


Figure 2. Application example of the Direct Polynomial Thermocouple (J, T, E, N, B, R, S) block**Table 3**

Component	Parameter	Value [Unit]
Heat-Flow Source H1	VALUE	$(223 + 250 * (t/40m))$ [W]
Thermal Resistor RTH1/RTH2	K	1 [K/W]
Direct Polynomial Thermocouple (J, T, E, N, B, R, S) block direct_thermoc1	INPUT	DIFF_TEMP1.MEAS
	a0	0
	a1	0.387481063640e-1
	a2	0.332922278800e-4
	a3	0.206182434040e-6
	a4	-0.218822568460e-8
	a5	0.109968809280e-10
	a6	-0.308157587720e-13
	a7	0.454791352900e-16
	a8	-0.275129016730e-19
	a9	0
	a10	0
	a11	0
	a12	0

	a13	0
	a14	0
	a15	0

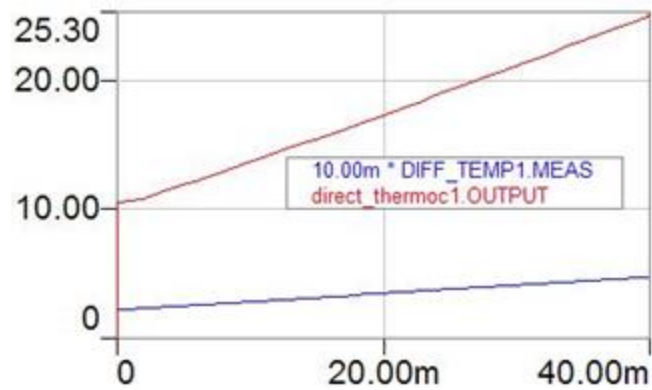


Figure 3. Simulation results-input and output of direct_thermoc1

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References

Level 1 Thermocouple Direct Polynomial (K)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

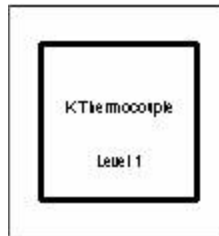


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Description

The Level 1 Thermocouple Direct Polynomial (K) block produces as its output the voltage-temperature curve for K thermocouples that are used at temperatures between 0 and 1372 degrees Celsius. The input of the function is the temperature difference between the measuring and reference junctions of the thermocouple, and the output is a voltage.

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Assumptions and Limitations

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Mathematical Description

The output voltage is calculated by the following function:

$$V = \sum_{i=0}^n a_i t^i + \alpha_0 e^{(\alpha_1(t-126.9686))^2}$$

where:

- a_i , α_0 and α_1 are coefficients that are particular to a K thermocouple.
- t is the temperature difference between the measuring and reference junctions of the thermocouple.

The thermocouple coefficients a_i , α_0 and α_1 are parameters that can be varied.

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Netlist Syntax

```
MODEL direct_thermoc_k ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) ( INPUT:=
@INPUT, a0:= @a0, a1:= @a1, a2:= @a2, a3:= @a3, a4:= @a4, a5:= @a5, a6:= @a6, a7:=
@a7, a8:= @a8, a9:= @a9, a10:= @a10, a11:= @a11, a12:= @a12, a13:= @a13, a14:= @a14,
a15:= @a15, alpha0:= @alpha0, alpha1:= @alpha1) SRC: DB(Lib:=@ModelLibraryName);
```

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Parameters

Table 1

Name	Description [Unit]	Data Type	Default Value [Unit]
a0	Zero-order coefficient	real	0
a1	First-order coefficient	real	0
a2	Second-order coefficient	real	0
a3	Third-order coefficient	real	0
a4	Fourth-order coefficient	real	0
a5	Fifth-order coefficient	real	0
a6	Sixth-order coefficient	real	0
a7	Seventh-order coefficient	real	0
a8	Eighth-order coefficient	real	0
a9	Ninth-order coefficient	real	0
a10	Tenth-order coefficient	real	0
a11	Eleventh-order coefficient	real	0
a12	Twelfth-order coefficient	real	0
a13	Thirteenth-order coefficient	real	0
a14	Fourteenth-order coefficient	real	0
a15	Fifteenth-order coefficient	real	0
alpha0	Exponential term coefficient	real	0
alpha1	Exponential argument exponent coefficient	real	0

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
INPUT	Input from the sensing block	Input	real
OUTPUT	Processed output	Output	real

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Example

In this example, a heat-flow source H1 is applied to two Thermal Resistors – RTH1 and RTH2. The temperature of RTH2 is measured by a Differential Temperature sensing block DIFF_TEMP1, and the measurement result is output through a Direct Polynomial Thermocouple (K) direct_thermoc_k1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

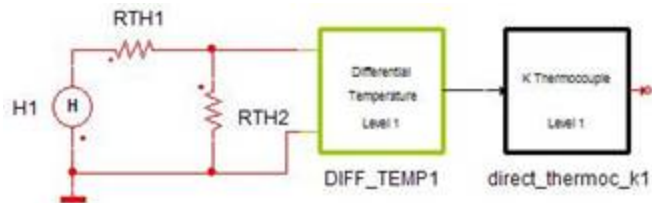


Figure 2. Application example of the Direct Polynomial Thermocouple (K) block

Table 3

Component	Parameter	Value [Unit]
Heat-Flow Source H1	VALUE	$(223 + 250 * (t/40m))$ [W]
Thermal Resistor RTH1/RTH2	K	1 [K/W]
Direct Polynomial Thermocouple (K) block direct_thermoc_k1	INPUT	DIFF_TEMP1.MEAS
	a0	-17.6004m
	a1	38.9212m
	a2	18.5588u
	a3	-99.4576n
	a4	0.318409n
	a5	-0.560728p
	a6	0.560751f
	a7	-3.20207e-019
	a8	9.71511e-023
	a9	-1.21047e-026
	a10	0

a11	0
a12	0
a13	0
a14	0
a15	0
alpha0	0.118598
alpha1	-0.118343m

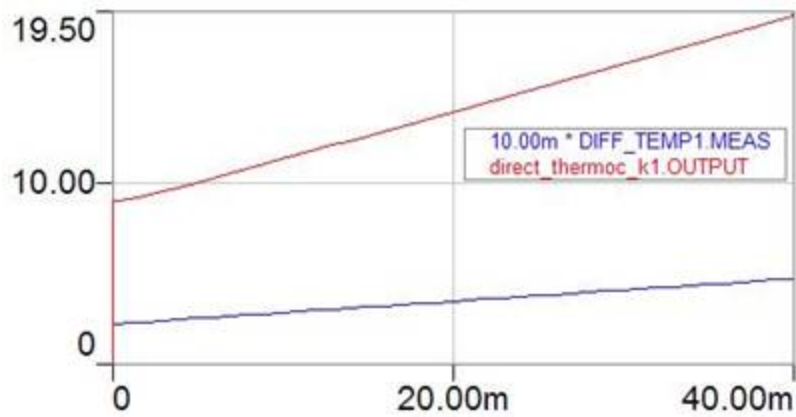


Figure 3. Simulation results-input and output of the Direct Polynomial Thermocouple (K) direct_thermoc_k1

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References

Level 1 Linear Incremental Encoder Channels

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

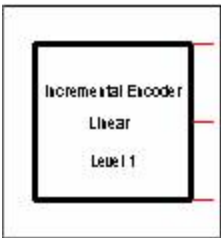


Figure 1. Component symbol

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Description

The Level 1 Linear Incremental Encoder Channels Block takes the input from a linear position sensing block and outputs the three digital output channels of a typical incremental encoder sensor. The first output, Channel A, goes to its logic 1 value each time the encoder's position sensor moves past one of the equally-spaced position indicators on the device when the sensor is moving in the positive direction. Channel A remains at its logic 1 output until the encoder's position sensor has traveled one-half the distance to the next position indicator. The second output of the encoder, Channel B, is similar to Channel A but lags it by one-quarter cycle when the angle sensor is moving in the positive direction. When the position sensor is moving in a negative direction, the outputs of Channels A and B are reversed.

The third output, Channel N, goes to its logic 1 value when the sensor detects its zero point and remains high until the sensor has traveled one-quarter of the distance to the next sensing element.

The Level 1 Linear Incremental Encoder channels the parameters of processing block features for the following device characteristics: the number of position indicators on the encoder, the zero position of the encoder, the logic one and zero output amplitudes, and the maximum and minimum positions measurable by the encoder.

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Mathematical Description

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Netlist Syntax

```
MODEL LIN_ENCODER_CHAN ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) (
INPUT:= @INPUT, num_lines:= @num_lines, north:= @north, oneamplitude:= @oneamplitude,
zeroamplitude:= @zeroamplitude, max_position:= @max_position, min_position:= @min_position) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Parameters

Table 1

Name	Description [Unit]	Data Type	Default Value [Unit]
num_lines	Number of position indicators (or divisions) on the encoder	real	16
north	Zero position of the encoder	real	0
oneamplitude	Amplitude of the logic 1 signal	real	5
zeroamplitude	Amplitude of the logic 0 signal	real	0
max_position	Maximum measurable position	real	5m
min_position	Minimum measurable position	real	-5m

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type

INPUT	Input from the sensing block	Input	real
		Output	real
channel_A	Output of encoder channel A (leading channel when the motion is to the right)	Output	real
channel_B	Output of encoder channel B (leading channel with the motion is to the left)	Output	real
channel_north	Output of encoder channel N (channel with a high output at the zero position only)	Output	real

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Example

In this example, a Position Source S_TRB1 is applied to a Mass block MASS_TRB1. The displacement of MASS_TRB1 is measured by a Linear Displacement sensing block DISP_SENS1, and the measurement result is output through a Linear Incremental Encoder LIN_ENCODER_CHAN1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3-6.

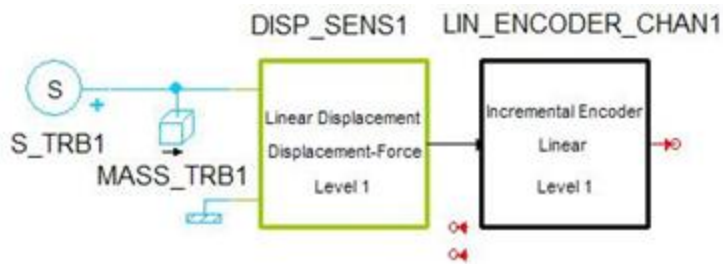


Figure 2. Application example of the Linear Incremental Encoder

Table 3

Component	Parameter	Value [Unit]
Position Source S_TRB1	VALUE	4m * (t/40m) [m]
Mass Mass_TRB1	M	1 [kg]
	S0	0 [m]

	V0	0 [m/s]
Linear Incremental Encoder LIN_ENCODER_CHAN1	INPUT	DISP_ SENS1.MEAS
	num_lines	4
	north	0
	oneamplitude	5
	zeroamplitude	0
	max_position	4m
	min_position	0

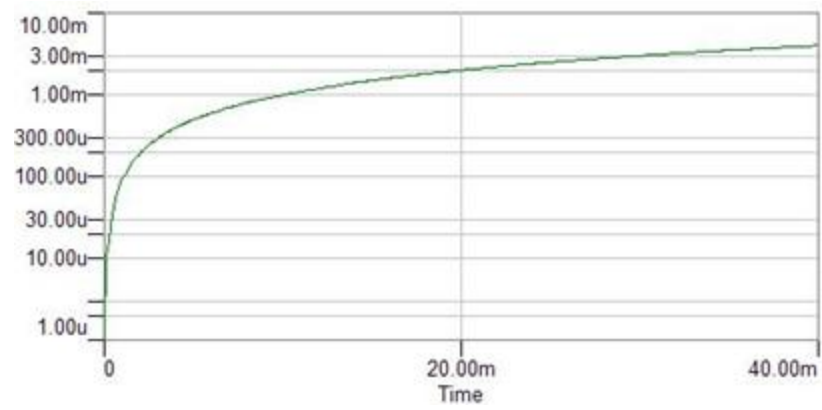
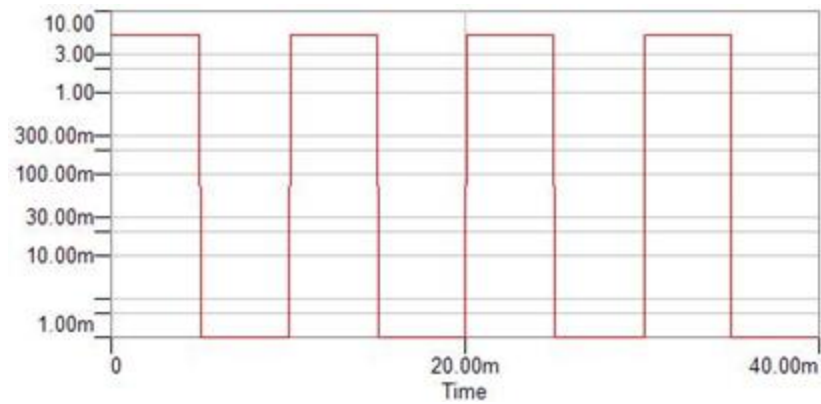
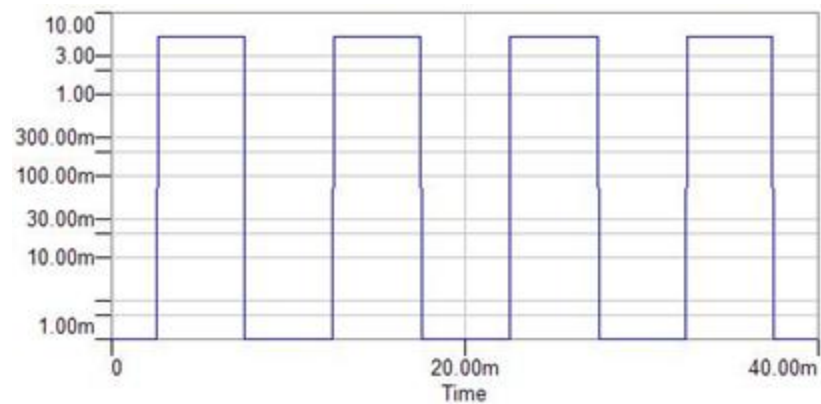
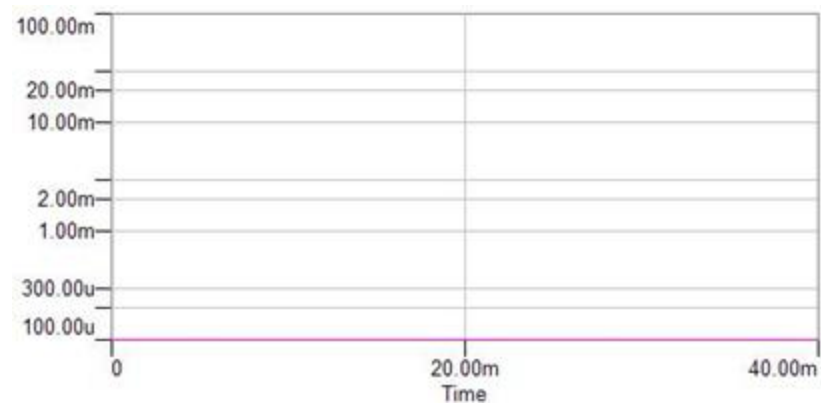


Figure 3. Simulation result-displacement of Mass_TRB1**Figure 4. Simulation result-channel A output of LIN_ENCODER_CHAN1****Figure 5. Simulation result-channel B output of LIN_ENCODER_CHAN1****Figure 6. Simulation result-channel North output of LIN_ENCODER_CHAN1**[Top](#)

References

Level 1 Nernst Voltage Equation

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

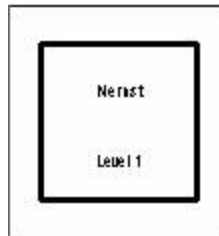


Figure 1. Component symbol

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Description

The Level 1 Nernst Voltage Equation block is used to model a $\lambda = 1$ oxygen sensing devices that produce a voltage output that corresponds to a difference in oxygen concentration.

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Assumptions and Limitations

A check for the value of $\text{INPUT} \cdot \text{INPUT2}$ is performed. When this product is equal to or smaller than zero, their value is clamped to 1 and the resulting OUTPUT is 0.0.

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Mathematical Description

The block uses three nonconservative inputs, INPUT , INPUT2 , and T , which would typically come from pressure and temperature measuring blocks to produce an output according to the following function:

$$\text{OUTPUT} = [T \cdot R / (4 \cdot F)] \cdot \ln(\text{INPUT} / \text{INPUT2})$$

where INPUT2 is the partial pressure of oxygen in a reference medium, INPUT is the partial pressure of oxygen in a measured medium, R is the universal gas constant, T is the absolute temperature of the sensed medium, and F is Faraday's constant.

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Netlist Syntax

```
MODEL NERNST_V ?InstanceName(@InstanceName):(@Refbase@ID)) ( INPUT:=
@INPUT, INPUT2:= @INPUT2, R:= @R, T:= @T, F:= @F) SRC: DB(Lib:-
:=@ModelLibraryName);
```

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Parameters

Table 1

Name	Description [Unit]	Data Type	Default Value [Unit]
R	Universal (or general) gas constant	real	8.31441
T	Absolute temperature in Kelvin	real	0.3k
F	Faraday's constant	real	95.48456k

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
INPUT	Input from the measuring block for the reference pressure	Input	real
OUTPUT	Processed output to the output signal block	Output	real
INPUT2	Input for the measured pressure	Input	real

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Example

In this example, the Nernst Voltage Equation block NERNST_V1 takes the pressure measure results from the Differential Pressure sensing block PM_DIFF1 and that from the Absolute Pressure Sensing block PMabs1, and produces a voltage output accordingly. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

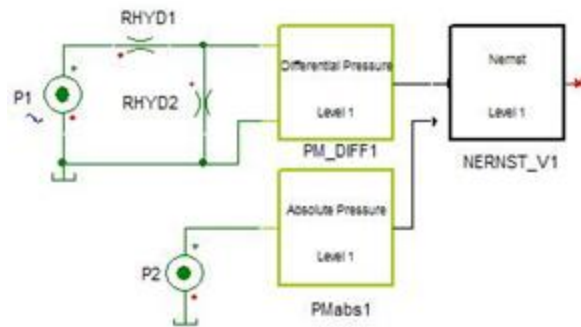


Figure 2. Application example of the Nernst Voltage Equation block

Table 3

Component	Parameter	Value [Unit]
Pressure Source (sinusoidal) P1	AMPL	40k [Pa]
	FREQ	50 [Hz]
	TDELAY	0 [s]
	OFF	0 [Pa]
	PHASE	0 [rad]
Pressure Source P2	VALUE	1E-24 [Pa]
Linear Orifice RHYD1/RHYD2	K	1n [m ³ /(Pa s)]
Nernst Voltage Equation block NERNST_V1	INPUT1	PM_DIFF1.MEAS
	INPUT2	PMabs1.MEAS
	R	8.31441

	T	0.3k
	F	95.48456k

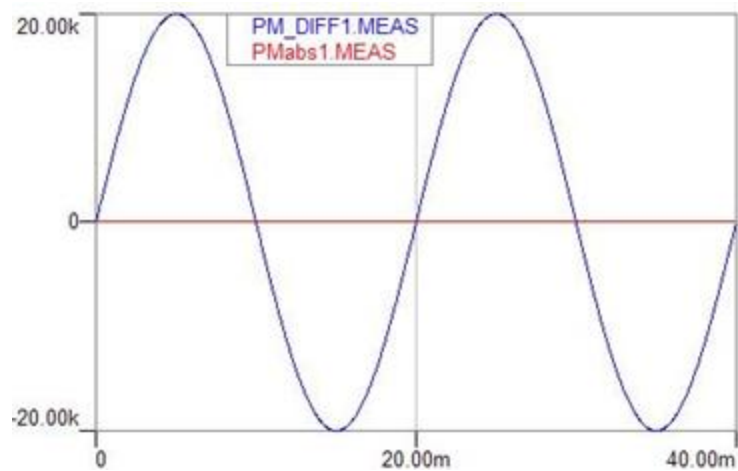


Figure 3. Simulation result-Inputs of NERNST_V1

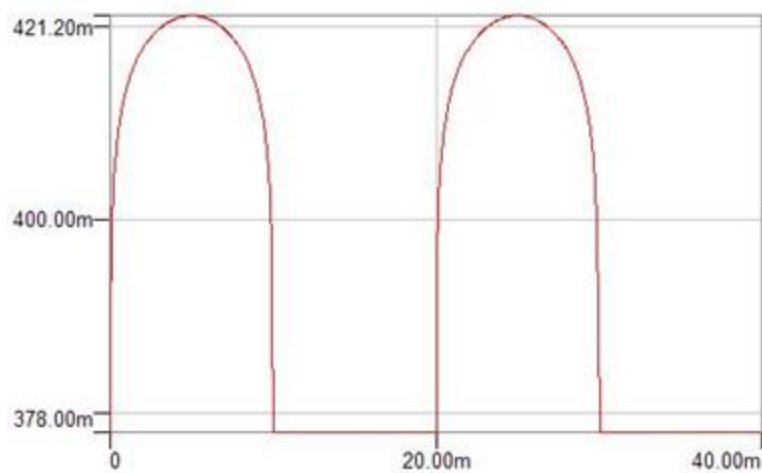


Figure 4. Simulation result-Output voltage of NERNST_V1

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References

Level 1 Oxygen-Dependent Resistor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

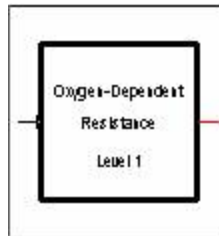


Figure 1. Component symbol

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Description

The Level 1 Oxygen-Dependent Resistor block is used to model I=1 oxygen sensing devices that produce a resistance that varies with oxygen concentration.

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Assumptions and Limitations

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Mathematical Description

The block uses a nonconservative input, P, which would typically come from a pressure measuring block, to produce an output according to the following function:

$$\text{OUTPUT} = \text{ROOT}(\text{INPUT}, 4) \cdot A \cdot \exp(-E/(kT))$$

where A is a material constant, E is the semiconductor material's activation energy, and T is the absolute temperature of the medium surrounding the sensor. The block parameters A, E, and T can all be changed.

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Netlist Syntax

MODEL O2_R_EQ ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) (INPUT:= @INPUT, A:= @A, E:= @E, T:= @T) SRC: DB(Lib:=@ModelLibraryName) ;

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Parameters

Table 1

Name	Description [Unit]	Data Type	Default Value [Unit]
A	Material constant	real	1 [Ohm/Pa]
E	Semiconductor material activation energy	real	1.60e-019 [eV]
T	Absolute temperature	real	300 [K]

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
INPUT	Input from the measuring block	Input	real
OUTPUT	Processed output	Output	real
INPUT2	Input for the measured pressure	Input	real

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Example

In this example, a sinusoidal pressure source and two linear orifices are used to create a differential pressure input to a differential pressure sensor PM_DIFF1. The sensor output is used as an input to an Oxygen-Dependent Resistance O2_R_EQ1 to vary the output value in Ohms. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

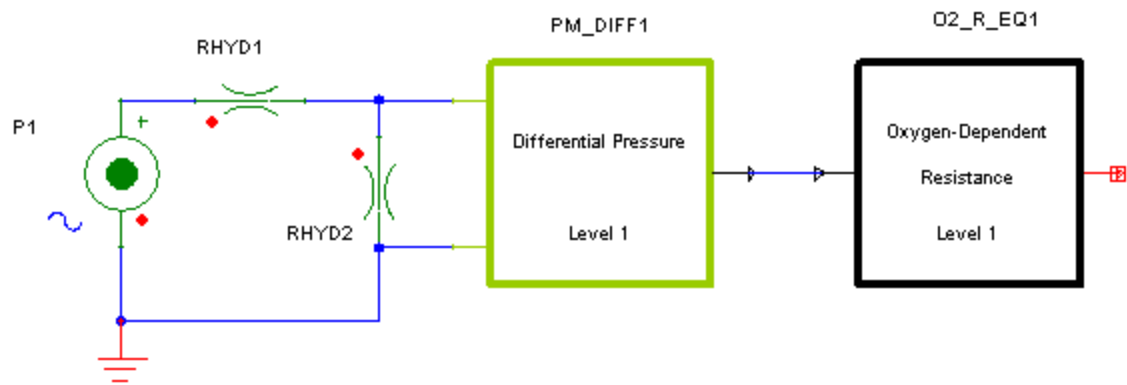


Figure 2. Application example of the Oxygen-Dependent Resistance block

Table 3

Component	Parameter	Value [Unit]
Level 1 Oxygen Dependent Resistance O2_R_EQ1	A	1000 [Ohm/Pa]
	E	0.05 [eV]
	T	300 [K]
	INPUT	PM_DIFF1.MEAS
Level 1 Differential Pressure Sensor PM_DIFF1	Output	PM_DIFF1.MEAS
Pressure Source P1	AMPL	40000 [Pa]
	Time Controlled	Sine
	FREQ	50 [Hz]
	Offset	80000 [Pa]
Linear Orifice RHYD1/RHYD2	Hyd. Conductance	1e-012 [m ³ /Pa]
	P	0 [Pa]

	Q	0 [m ³ /sec]

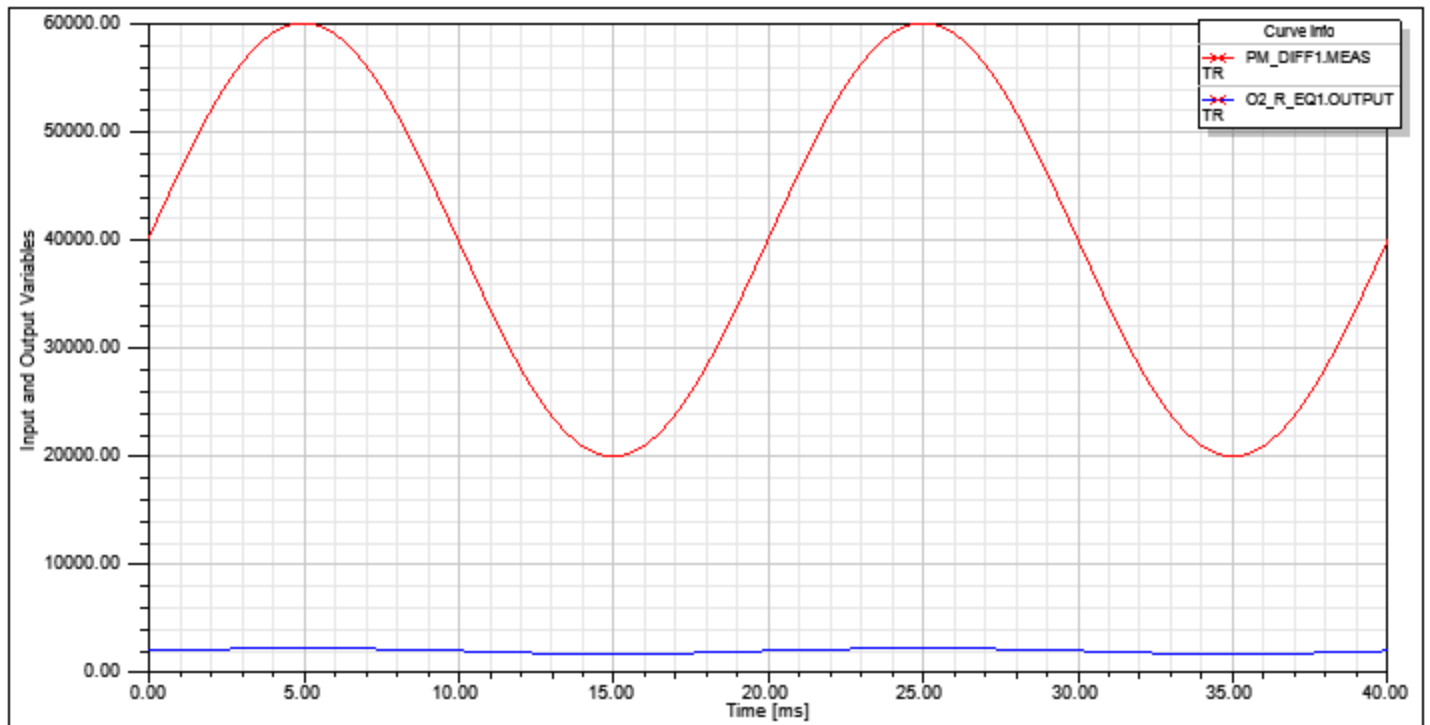
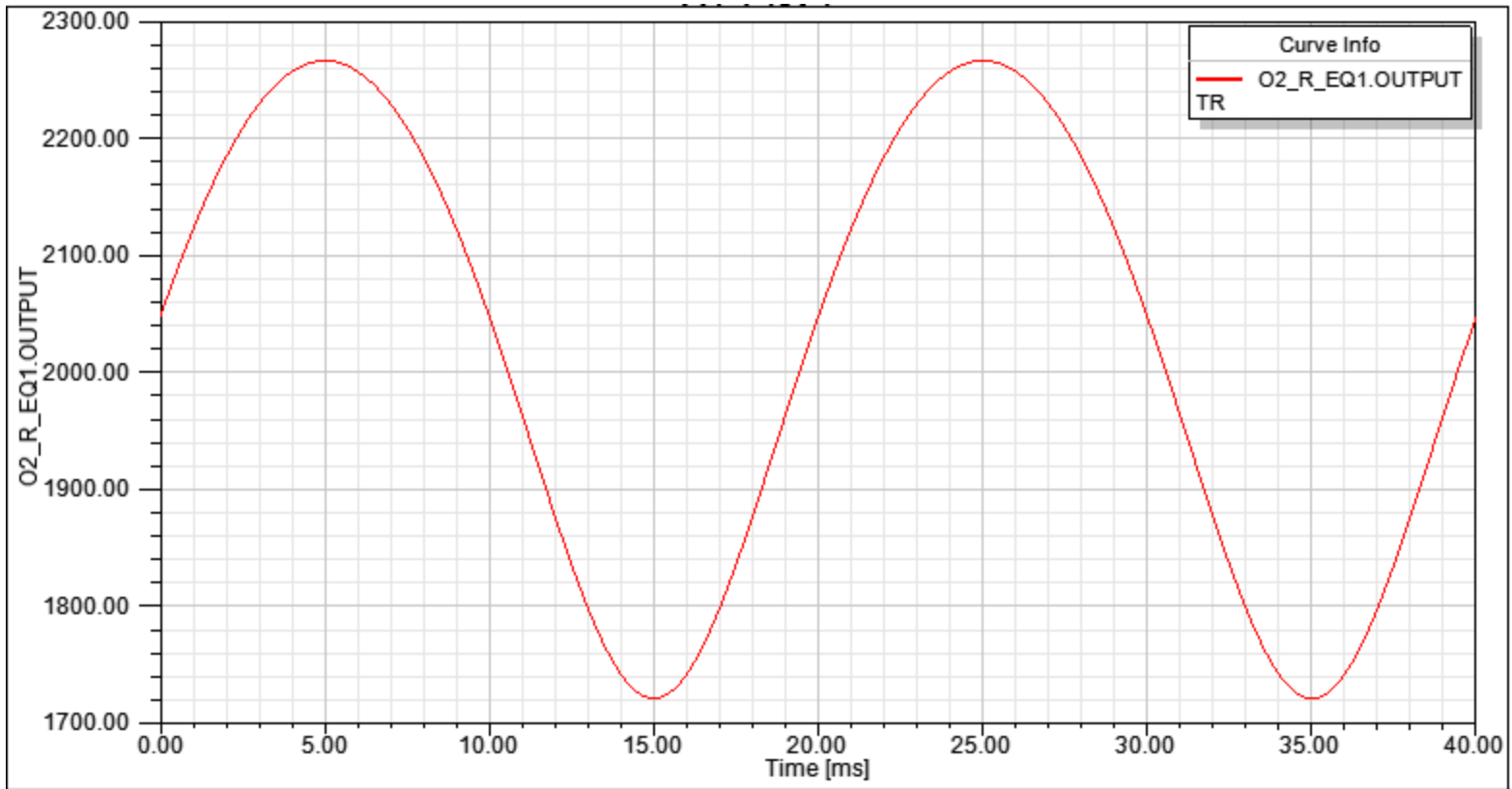


Figure 3. Simulation results-input and output of Oxygen Dependent Resistor O2_R_EQ1**Figure 4. Simulation results-output of Oxygen Dependent Resistor O2_R_EQ1**[Top](#)

References

Level 1 Characteristic From File

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

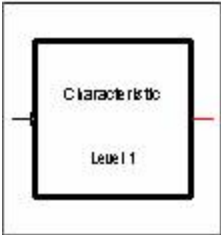


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Description

The Level 1 Characteristic From File block inputs a user-defined characteristic via a non-conservative pin. This characteristic serves as the function that determines the output value of the block from the input value.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL SENS_CHAR ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) ( INPUT:=  
@INPUT, CHAR:= @CHAR) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Parameters

Table 1

Name	Description [Unit]	Data Type	Default Value [Unit]
CHAR	User-defined characteristic	file	0

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
INPUT	Input from the sensing block	Input	real
OUTPUT	Processed output	Output	real

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Example

In this example, the Angular Velocity sensing block ANG_VELOCITY_DF1 measures the angular velocity of the Mass block MASS_ROT B1, and the measurement results is sent to the Characteristics_From_File block SENS_CHAR1. SENS_CHAR1 then determines the output value using the function defined by the specified characteristics file. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.



Figure 2. Application example of the Nernst Voltage Equation block

Table 3

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROT B1	AMPL	5 [rad/s]
	FREQ	50 [Hz]
	TDELAY	0 [s]
	OFF	0 [rad/s]
	PHASE	0 [rad]
	PHI0	0 [rad]
Mass MASS_ROT B1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Characterics_From_File block SENS_CHAR1	INPUT	ANG_VELOCITY_DF1.MEAS
	CHAR	parabola.mdx

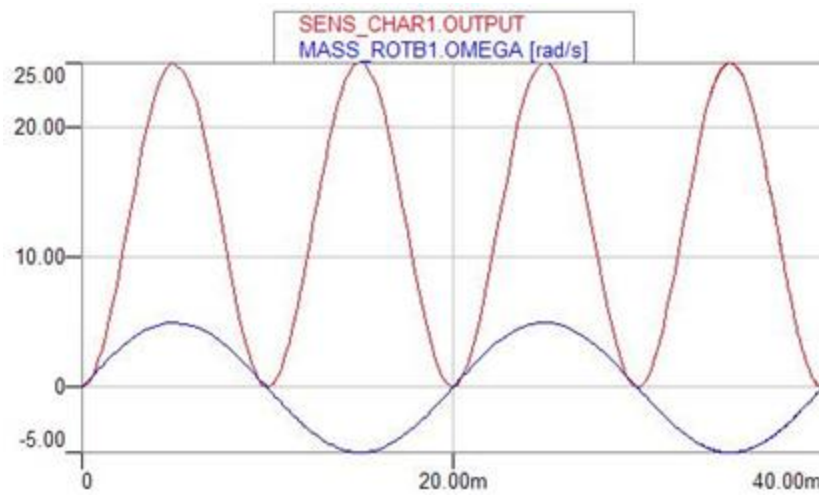


Figure 3. Simulation results-input and output of SENS_CHAR1

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References

Level 1 Steinhart-Hart Function

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

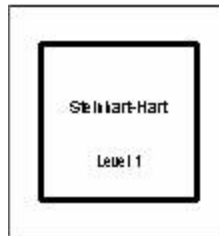


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Description

The Level 1 Steinhart-Hart block produces the resistance-temperature curve of a negative temperature coefficient thermistor as its output.

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Mathematical Description

The block takes in a real value, T , via its nonconservative input pin and produces an output, R , via its nonconservative output pin, according to the following equation:

$$R = e^{[-C/2 + (C^2/4 + Y^3/27)^{1/2}]^{1/3} + [-C/2 - (C^2/4 + Y^3/27)^{1/2}]^{1/3}}$$

where:

- T is the Kelvin temperature.
- $C = a - 1/T$, $Y = b/c$

- a, b, and c are parameters specific to an individual thermistor.

The parameters a, b, and c can be entered into the Steinhart-Hart Function block via non-conservative inputs.

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Netlist Syntax

```
MODEL SH_FUNCTION ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) ( INPUT:=
@INPUT, a:= @a, b:= @b, c:= @c) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Parameters

Table 1

Name	Description [Unit]	Data Type	Default Value [Unit]
a	Steinhart-Hart coefficient parameter "A"	real	0
b	Steinhart-Hart coefficient parameter "B"	real	0
c	Steinhart-Hart coefficient parameter "C"	real	0

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
INPUT	Input from the sensing block	Input	real
OUTPUT	Processed output	Output	real

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Example

In this example, a heat-flow source H1 is applied to two Thermal Resistors – RTH1 and RTH2. The temperature of RTH2 is measured by an Absolute Temperature sensing block ABS_

TEMP1, and the measurement result is output through a Steinhart-Hart SH_FUNCTION2. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

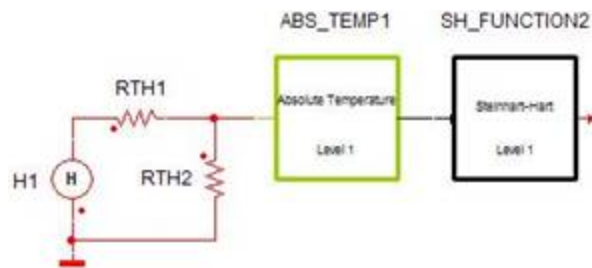


Figure 2. Application example of the Linear Function block

Table 3

Component	Parameter	Value [Unit]
Heat-Flow Source H1	VALUE	$(223 + 250 * (t/40m))$ [W]
Thermal Resistor RTH1/RTH2	K	1 [K/W]
Steinhart-Hart SH_ FUNCTION2	INPUT	ABS_TEMP1.MEAS
	a	1.942952e-3
	b	2.989769e-4
	c	3.504383e-7

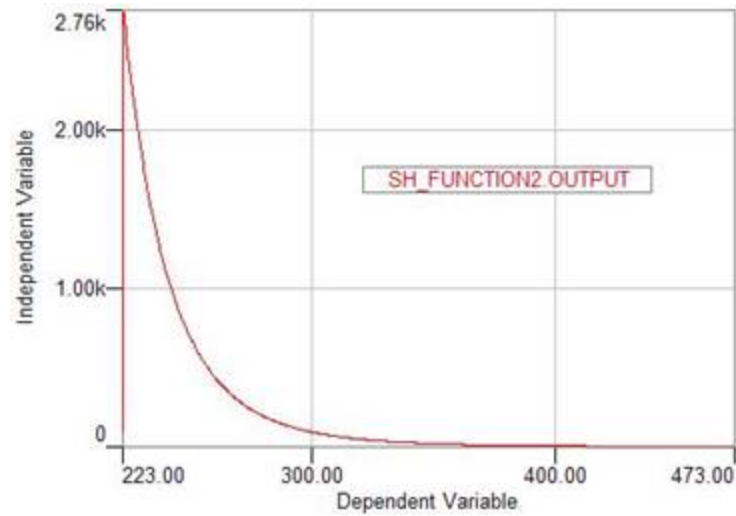


Figure 3. Simulation results-input and output of the Clip Function block CL_LINEAR1

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References

Level 1 Linear Function

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

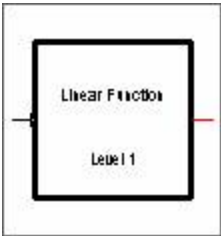


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Description

The Level 1 Linear Function block provides an output that is a linear function of the input. Block parameters that can be varied include the slope and the intercept of the linear function.

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Mathematical Description

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Netlist Syntax

```
MODEL ST_LINEAR ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) ( INPUT:=  
@INPUT, SENS:= @SENS, OFFSET:= @OFFSET) SRC: DB (Lib:=@ModelLibraryName) ;
```

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Parameters

Table 1

Name	Description [Unit]	Data Type	Default Value [Unit]
SENS	Slope of the linear function (device sensitivity)	real	0
OFFSET	Intercept of the linear function (device offset)	real	0

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
INPUT	Input from the sensing block	Input	real
OUTPUT	Processed output	Output	real

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Example

In this example, a sinusoidal heat-flow source is applied to two Thermal Resistors – RTH1 and RTH2. The temperature of RTH2 is measured by an Absolute Temperature sensing block ABS_TEMP1, and the measurement results are output through a Linear Function block ST_LINEAR1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

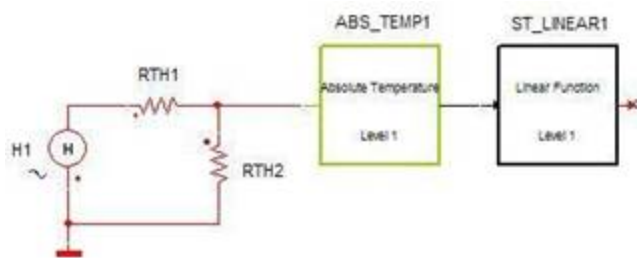


Figure 2. Application example of the Linear Function block

Table 3

Component	Parameter	Value [Unit]
Heat-Flow Source (sinusoidal) H1	AMPL	10 [W]
	FREQ	50 [Hz]
	OFF	0.5 [W]
	PHASE	0 [rad]
	TDELAY	0 [s]
Thermal Resistor RTH1/RTH2	K	1 [K/W]
Linear Function block ST_ LINEAR1	INPUT	ABS_ TEMP1.MEAS
	SENS	2
	OFFSET	5

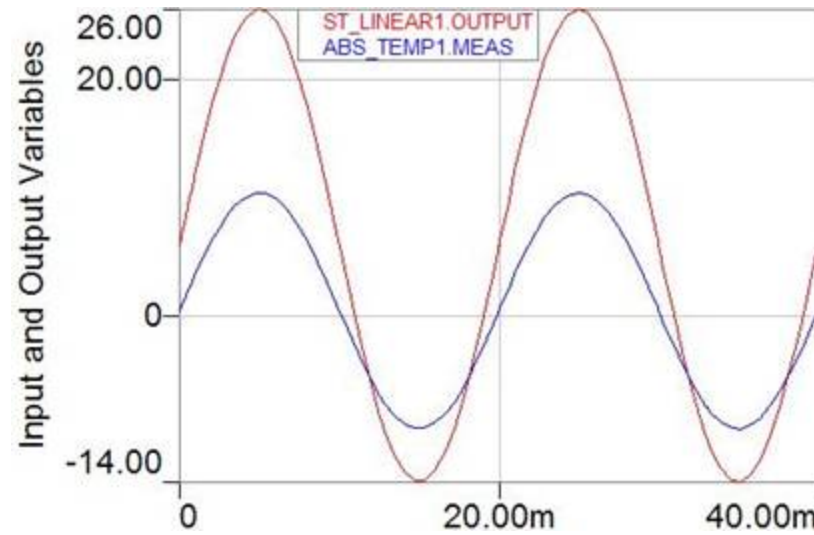


Figure 3. Simulation results-input and output of the Linear Function block ST_LINEAR1

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References

Level 1 Sensor Models

The Level 1 sensor models exhibit ideal device behavior. The models have conservative input pins in one of the Twin Builder physical domains and conservative output pins in the electrical domain. The models may be parameterized with a number of nonconservative inputs. Models of sensor types for a variety of different physical quantities are available.

Level 1 Sensor Models are available for the following physical quantities:

- [Angular Acceleration](#)
- [Angular Position](#)
- [Angular Velocity](#)
- [Exhaust Gas](#) (Oxygen Concentration)
- [Flow](#)
- [Linear Acceleration](#)
- [Linear Position](#)
- [Pressure](#)
- [Temperature](#)
- [Torque](#)
- [Vibration](#)

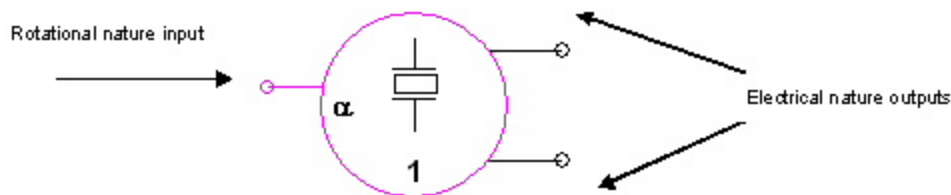
Level 1 sensor models appear in the Twin Builder Sensors library and are available to customers who have purchased a license for this library.

Level 1 Angular Acceleration Sensor Models

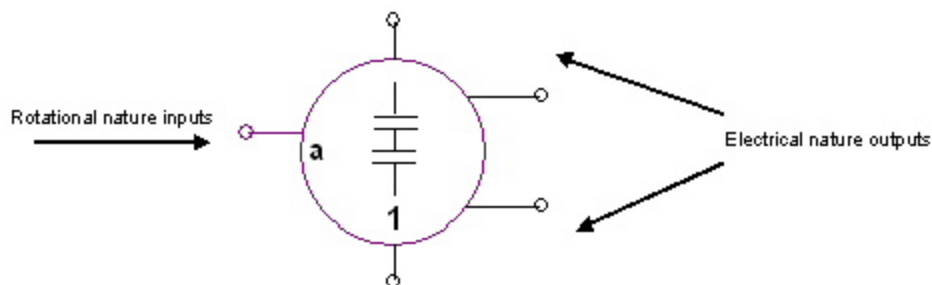
The Level 1 Angular Acceleration Sensor Models simulate the ideal behavior of four different types of angular acceleration sensors. Models are available for use with the Twin Builder *displacement-force* and *velocity-force* rotational domains.

All of the angular acceleration sensor models have conservative input pins that must be connected to a rotational network and conservative output pins that must be connected to an electrical network. The models also feature non-conservative parameters that can be changed in order to tailor the behavior of the model to that of a specific real device.

As shown in the following example, angular acceleration sensor models for the displacement-force rotational domain have pink conservative input pins that must be connected to a displacement-force rotational network. The models also have black conservative pins that must be connected to an electrical network.



Similarly, angular acceleration sensor models for the velocity-force rotational domain have purple rotational-nature input pins and black electrical-nature pins.



The Level 1 Angular Acceleration Sensor Models feature models for the following angular acceleration sensing mechanisms:

- Inertia Switch—a specified threshold acceleration causes a switch contained inside the sensor to change state from open to closed.

Displacement-Force model: ([INERTIA_SWITCH_DF](#))

Velocity-Force model: ([INERTIA_SWITCH_VF](#))

- Piezoelectric—acceleration of the sensor causes the deformation of a piezoelectric element which produces a corresponding voltage output signal.

Displacement-Force model: ([PE_ALPHA_DF](#))

Velocity-Force model: ([PE_ALPHA_VF](#))

- Piezoresistive—acceleration of the sensor causes the deformation of resistors connected in a Wheatstone bridge configuration, producing a corresponding differential voltage output signal.

Displacement-Force model: ([PR_ALPHA_DF](#))

Velocity-Force model: ([PR_ALPHA_VF](#))

- Capacitive—acceleration of the sensor causes the movement of the shared plate in a differential capacitor pair. The sensor responds by producing a change in its linear voltage output signal.

Displacement-Force model: ([C_ALPHA_DF](#))

Velocity-Force model: ([C_ALPHA_VF](#))

Level 1 Capacitive Angular Acceleration Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

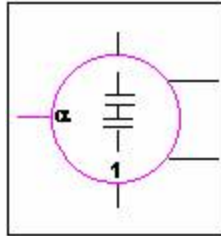


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Description

The Level 1 Capacitive Angular Acceleration (Displacement-Force) sensor model is used to simulate the ideal behavior of a conditioned capacitive angular acceleration sensor in the Twin Builder displacement-force rotational domain. A change in the model's angular acceleration input produces a corresponding change in the model's linear voltage output.

The model has one conservative input pin in the displacement-force rotational domain for its angular acceleration input and four conservative electrical-domain pins. Two of the pins are for the model's power supplies, and two are for its voltage output. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is connected to ground.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

MODEL C_ALPHA_DF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) ANGULAR:= %0, OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 (max_alpha:= @max_alpha, min_alpha:= @min_alpha, full_scale_span:= @full_scale_span, offset:= @offset, supply_current:= @supply_current) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
ANGULAR	Measured angular acceleration	Rotational
OUT_P	Positive terminal	Electrical
OUT_M	Negative terminal	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
max_alpha	Maximum measurable angular acceleration	Real	50 [rad/s ²]
min_alpha	Minimum measurable angular acceleration	Real	0 [rad/s ²]

full_ scale_ span	Difference of the output voltages at the maximum and minimum angular accelerations	Real	5 [V]
supply_ current	Supply current	Real	5m [A]

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Example

In this example, the Capacitive Angular Acceleration (Displacement-Force) sensor C_ALPHA_DF1 measures the angular velocity of the Mass MASS_ROT1. A change in the angular acceleration of MASS_ROT1 produces a corresponding change in the linear voltage output of C_ALPHA_DF1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

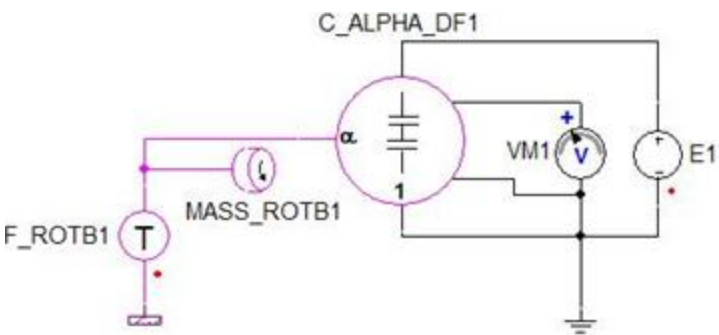


Figure 2. Application example of the Capacitive Angular Acceleration (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROT B1	VALUE	20 * (t/40m) [Nm]
	J	1 [kg m]
	PHI0	0 [rad]
Mass MASS_ROT B1	OMEGA0	0 [rad/s]
	offset	0.1* E1.EMF [V]
	max_alpha	18 [rad/s ²]
Capacitive Angular Acceleration (Displacement-Force) sensor C_ALPHA_DF1	min_alpha	0 [rad/s ²]
	full_scale_span	0.9* E1.EMF [V]
	supply_current	2m [A]

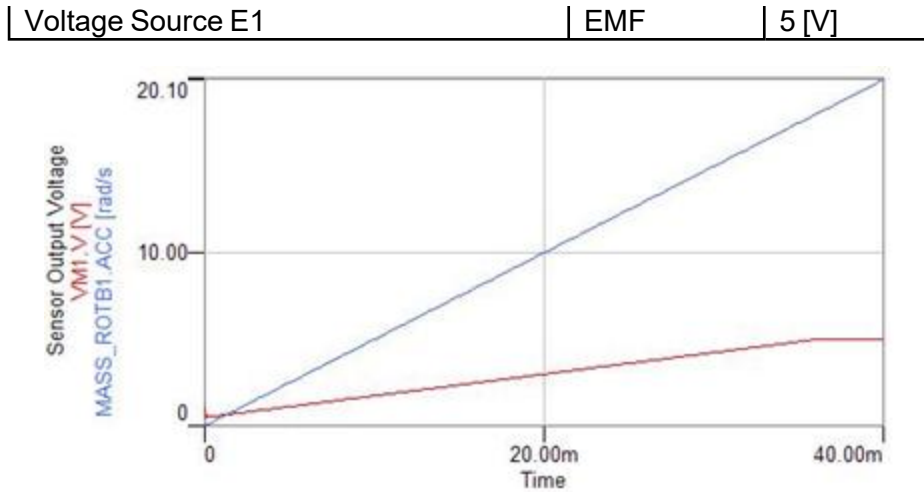


Figure 3. Simulation results-output voltage of C_ALPHA_DF1 and acceleration of MASS_ROT1

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References

Level 1 Inertia Switch Angular Acceleration Sensor (Displacement-force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

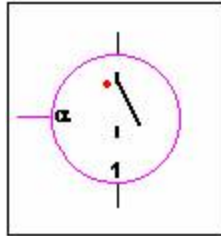


Figure 1. Component symbol

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Description

The Level 1 Inertia Switch Angular Acceleration (Displacement-Force) sensor model is used to simulate the ideal behavior of an inertia switch angular acceleration sensor in the Twin Builder displacement-force rotational domain. When the angular acceleration applied to the sensor exceeds a specified threshold value, its switch changes state from open to close.

The model has one conservative input pin in the displacement-force rotational domain for its angular acceleration input and two conservative electrical-domain pins for its positive and negative terminals. The positive terminal is the one into which current flows.

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Netlist Syntax

```
MODEL INERTIA_SWITCH_DF ?InstanceName(@InstanceName):(@Refbase)@(ID))
ANGULAR:= %0, np:= %1, nm:= %2 ( threshold:= @threshold) SRC: DB(Lib:-
:=@ModelLibraryName);
```

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Table 1

Name	Port/Terminal Description	Nature/Data type
ANGULAR	Measured angular acceleration	Rotational
np	Positive terminal	Electrical
nm	Negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
threshold	Threshold angular acceleration of the switch	Real	50 [rad/s ²]

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Example

In this example, the Inertia Switch Angular Acceleration (Displacement-Force) sensor INERTIA_SWITCH_DF1 measures the angular velocity of the Mass MASS_ROT B1. When the angular acceleration of Mass MASS_ROT B1 exceeds a specified threshold value, INERTIA_SWITCH_DF1 switches from open to close. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

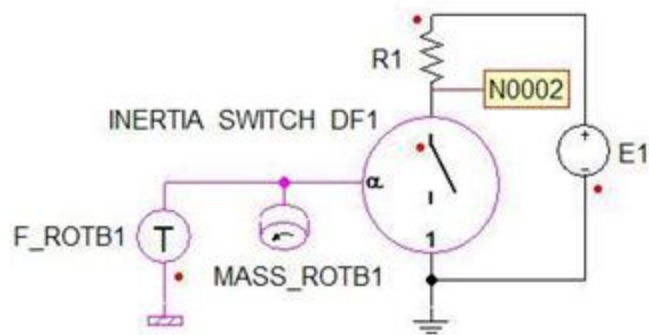


Figure 2. Application example of the Inertia Switch Angular Acceleration (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROT B1	VALUE	5 * (t >=20m) [Nm]
Mass MASS_ROT B1	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Inertia Switch Angular Acceleration (Displacement-Force) sensor INERTIA_SWITCH_DF1	threshold	4.5 [rad/s ²]
Voltage Source E1	EMF	5 [V]
Resistor R1	R	1k [Ohm]

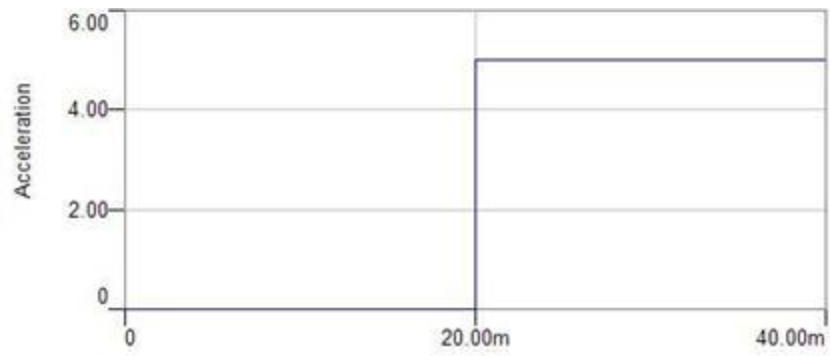


Figure 3. Simulation results-acceleration of MASS_ROT B1

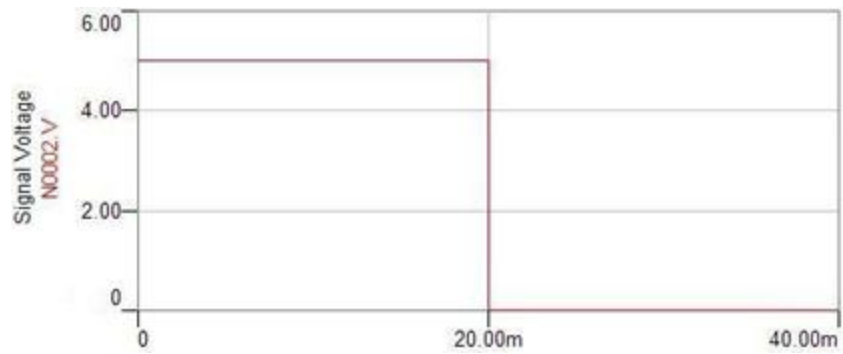


Figure 4. Simulation results-output voltage of INERTIA_SWITCH_DF1

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References

Level 1 Piezoelectric Angular Acceleration Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

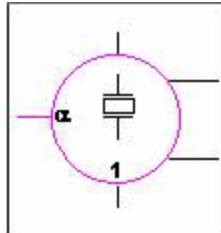


Figure 1. Component symbol

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Description

The Level 1 Piezoelectric Angular Acceleration (Displacement-Force) sensor model is used to simulate the ideal behavior of a piezoelectric angular acceleration sensor in the Twin Builder displacement-force rotational domain. A change in the model's angular acceleration input produces a corresponding change in the model's linear voltage output.

The model has one conservative input pin in the displacement-force rotational domain for its angular acceleration input and four conservative electrical-domain pins, two for its power supply connections and two for its voltage output. The negative output terminal should be connected to an electrical ground if the model is connected to an electrical network in which no other component is grounded.

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Netlist Syntax

MODEL PE_ALPHA_DF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) ANGULAR:= %0, OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 (max_alpha:= @max_alpha, min_alpha:= @min_alpha, full_scale_span:= @full_scale_span, offset:= @offset, supply_current:= @supply_current) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
ANGULAR	Measured angular acceleration	Rotational
OUT_P	Positive terminal	Electrical
OUT_M	Negative terminal	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
max_alpha	Maximum measurable angular acceleration	Real	50 [rad/s ²]
min_alpha	Minimum measurable angular acceleration	Real	0 [rad/s ²]

full_ scale_ span	Difference of the output voltages at the maximum and minimum angular accelerations	Real	5 [V]
supply_ current	Supply current	Real	1m [A]

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Example

In this example, the Piezoelectric Angular Acceleration (Displacement-Force) sensor PE_ALPHA_DF1 measures the angular velocity of the Mass MASS_ROTB1. A change in the MASS_ROTB1's angular acceleration input produces a corresponding change in PE_ALPHA_DF1 's linear voltage output. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

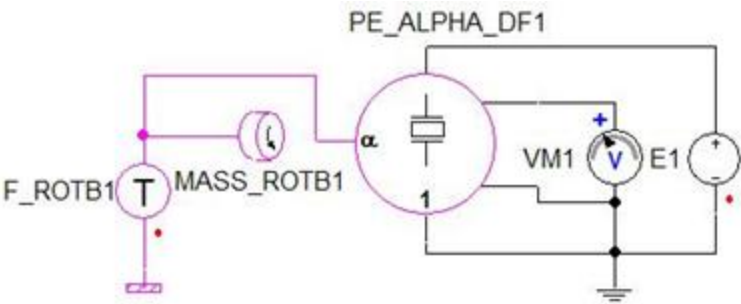


Figure 2. Application example of the Piezoelectric Angular Acceleration (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROTB1	VALUE	20 * (t/40m) [Nm]
	J	1 [kg m]
	PHI0	0 [rad]
Mass MASS_ROTB1	OMEGA0	0 [rad/s]

Piezoelectric Angular Acceleration (Displacement-Force) sensor PE_ALPHA_DF1	offset	0.1 * E1.EMF [V]
	max_alpha	15 [rad/s ²]
	min_alpha	0 [rad/s ²]
	full_scale_span	0.9 * E1.EMF [V]
	supply_current	5m [A]
Voltage Source E1	EMF	5 [V]

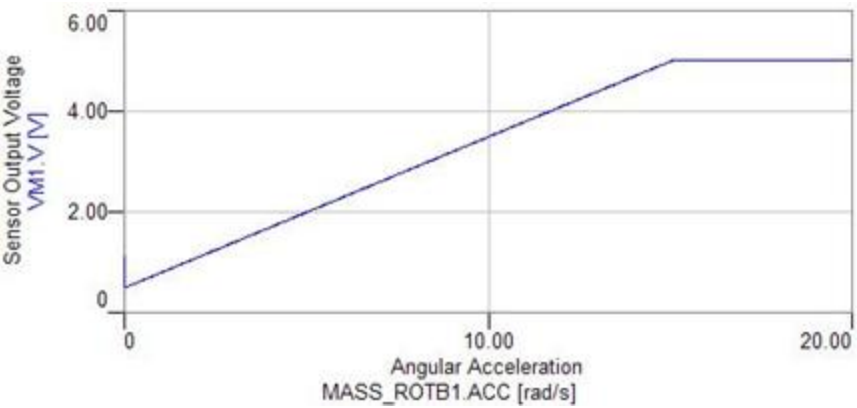


Figure 3. Simulation results-output voltage of PE_ALPHA_DF1 vs. acceleration of MASS_ROT1

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References

Level 1 Piezoresistive Angular Acceleration Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

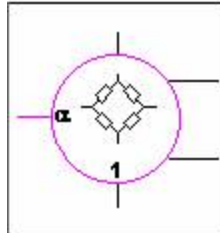


Figure 1. Component symbol

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Description

The Level 1 Piezoresistive Angular Acceleration (Displacement-Force) sensor model is used to simulate the ideal behavior of a piezoresistive angular acceleration sensor in the Twin Builder displacement-force rotational domain. A change in the model's angular acceleration input produces a corresponding change in the model's Wheatstone bridge, which in turn produces a change in the model's linear voltage output.

The model has one conservative input pin in the displacement-force rotational domain for its angular acceleration input and four conservative electrical-domain pins. Two of the pins are for the model's power supplies, and two are for its differential voltage output.

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Netlist Syntax

MODEL PR_ALPHA_DF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) ANGULAR:= %0, OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 (max_alpha:= @max_alpha, min_alpha:= @min_alpha, full_scale_span:= @full_scale_span, offset:= @offset, p_resistance:= @p_resistance) SRC: DB(Lib:=@ModellibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
ANGULAR	Measured angular acceleration	Rotational
OUT_P	Positive terminal	Electrical
OUT_M	Negative terminal	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
max_alpha	Maximum measurable angular acceleration	Real	50 [rad/s ²]
min_alpha	Minimum measurable angular acceleration	Real	0 [rad/s ²]
full_scale_span	Difference of the output voltages at the maximum and minimum	Real	5 [V]

	angular accelerations		
p_res-istance	Bridge resistance	Real	10k [Ohm]

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Example

In this example, the Piezoresistive Angular Acceleration (Displacement-Force) sensor PR_ALPHA_DF1 measures the angular velocity of the Mass MASS_ROTB1. A change in the angular acceleration of MASS_ROTB1 produces a corresponding change in the linear voltage output of PR_ALPHA_DF1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

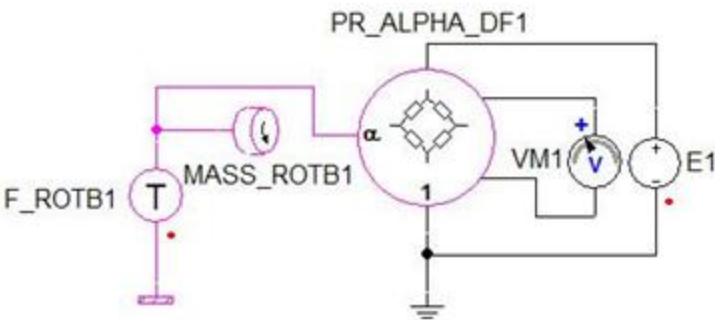


Figure 2. Application example of the Piezoresistive Angular Acceleration (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROTBT1	VALUE	20 * (t/40m) [Nm]
	J	1 [kg m]
	PHI0	0 [rad]
Mass MASS_ROTBT1	OMEGA0	0 [rad/s]
	offset	0.1* E1.EMF

DF1		[V]
	max_alpha	18 [rad/s ²]
	min_alpha	0 [rad/s ²]
	full_scale_span	0.9* E1.EMF [V]
	p_res-istance	1k [Ohm]
Voltage Source E1		EMF 5 [V]

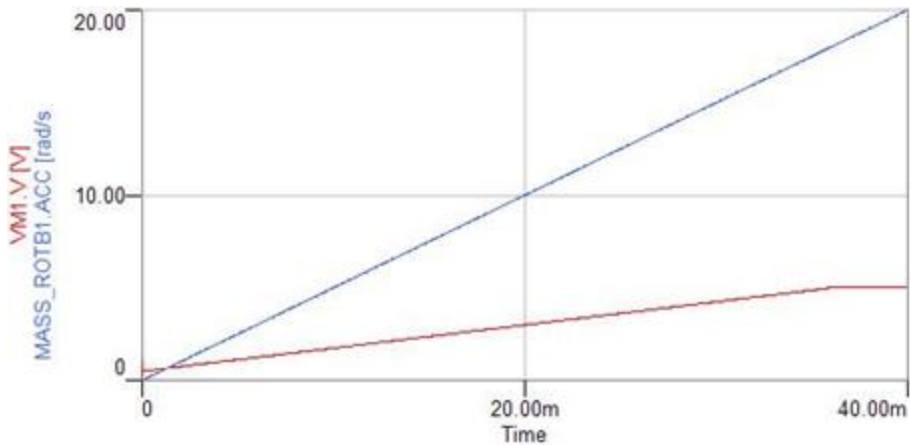


Figure 3. Simulation results-output voltage of PR_ALPHA_DF1 and acceleration of MASS_ROT B1

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References

Level 1 Capacitive Angular Acceleration Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

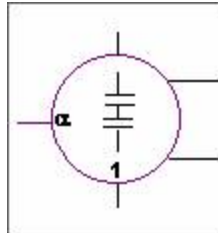


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Description

The Level 1 Capacitive Angular Acceleration (Velocity-Force) sensor model is used to simulate the ideal behavior of a conditioned capacitive angular acceleration sensor in the Twin Builder velocity-force rotational domain. A change in the model's angular acceleration input produces a corresponding change in the model's linear voltage output.

The model has one conservative input pin in the velocity-force rotational domain for its angular acceleration input and four conservative electrical-domain pins. Two of the pins are for the model's power supplies, and two are for its voltage output. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is connected to ground.

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Netlist Syntax

```
MODEL C_ALPHA_VF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) ANGULAR:= %0, OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 ( max_alpha:= @max_alpha, min_alpha:= @min_alpha, full_scale_span:= @full_scale_span, offset:= @offset, supply_current:= @supply_current) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Table 1

Name	Port/Terminal Description	Nature/Data type
ANGULAR	Measured angular acceleration	Rotational_V
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
max_alpha	Maximum measurable angular acceleration	Real	50 [rad/s ²]
min_alpha	Minimum measurable angular acceleration	Real	0 [rad/s ²]

full_ scale_ span	Difference of the output voltages at the maximum and minimum angular accelerations	Real	5 [V]
supply_ current	Supply current	Real	5m [A]

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Example

In this example, the Capacitive Angular Acceleration (Velocity-Force) sensor C_ALPHA_VF1 measures the angular velocity of the Mass MASS_ROT1. A change in the angular acceleration of MASS_ROT1 produces a corresponding change in the linear voltage output of C_ALPHA_VF1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

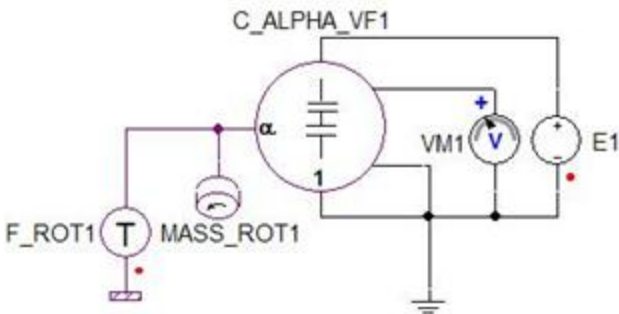


Figure 2. Application example of the Capacitive Angular Acceleration (Velocity-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROT1	VALUE	20 * (t/40m) [Nm]
Mass MASS_ROT1	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Capacitive Angular Acceleration (Dis-	offset	0.1*

placement-Force) sensor C_ALPHA_VF1		E1.EMF [V]
	max_alpha	18 [rad/s ²]
	min_alpha	0 [rad/s ²]
	full_scale_span	0.9* E1.EMF [V]
	supply_current	1m [A]
Voltage Source E1	EMF	5 [V]

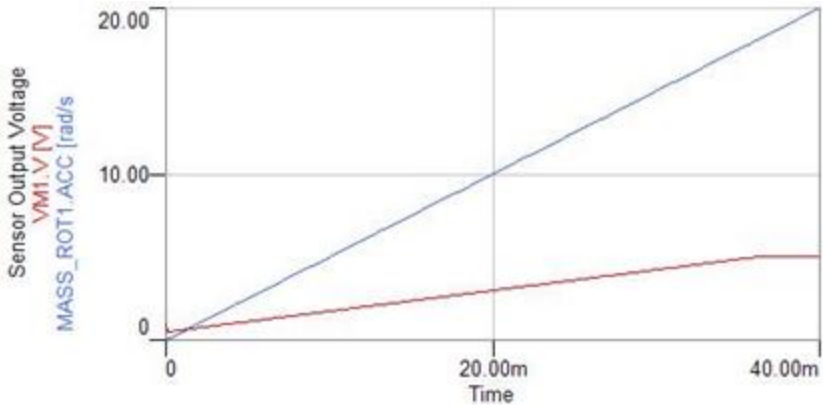


Figure 3. Simulation results-output voltage of C_ALPHA_VF1 and acceleration of MASS_ROT1

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References

Level 1 Inertia Switch Angular Acceleration Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

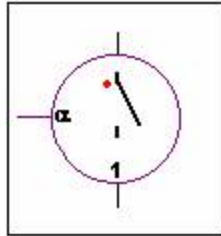


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Description

The Level 1 Inertia Switch Angular Acceleration (Velocity-force) sensor model is used to simulate the ideal behavior of an inertia switch angular acceleration sensor in the Twin Builder velocity-force rotational domain. When the angular acceleration applied to the sensor exceeds a specified threshold value, its switch changes state from open to closed.

The model has one conservative input pin in the velocity-force rotational domain for its angular acceleration input and two conservative electrical-domain pins for its positive and negative terminals. The positive terminal is the one into which current flows.

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Netlist Syntax

```
MODEL INERTIA_SWITCH_VF ?InstanceName(@InstanceName):(@Refbase)@(ID)) np:=
%0, nm:= %1, ANGULAR:= %2 ( threshold:= @threshold) SRC: DB(Lib:=@ModelLibraryName)
;
```

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Table 1

Name	Port/Terminal Description	Nature/Data type
ANGULAR	Measured angular acceleration	Rotational_V
np	Positive terminal	Electrical
nm	Negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
threshold	Threshold angular acceleration of the switch	Real	50 [rad/s ²]

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Example

In this example, the Inertia Switch Angular Acceleration (Velocity-Force) sensor INERTIA_SWITCH_VF1 measures the angular velocity of the Mass MASS_ROT1. When the angular acceleration of Mass MASS_ROT1 exceeds a specified threshold value, INERTIA_SWITCH_VF1 switches from open to close. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

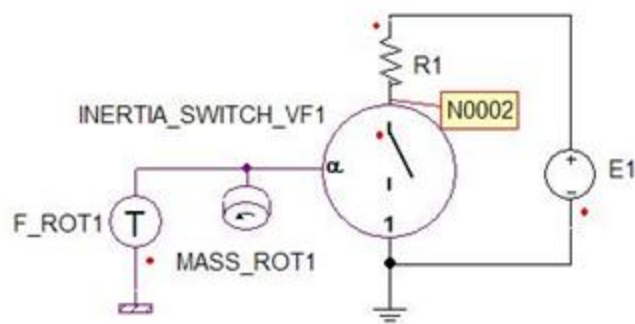


Figure 2. Application example of the Inertia Switch Angular Acceleration (Velocity-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROT1	VALUE	5 * (t >=20m) [Nm]
Mass MASS_ROT1	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Inertia Switch Angular Acceleration (Velocity-Force) sensor INERTIA_SWITCH_VF1	threshold	4.5 [rad/s ²]
Voltage Source E1	EMF	5 [V]
Resistor R1	R	1k [Ohm]

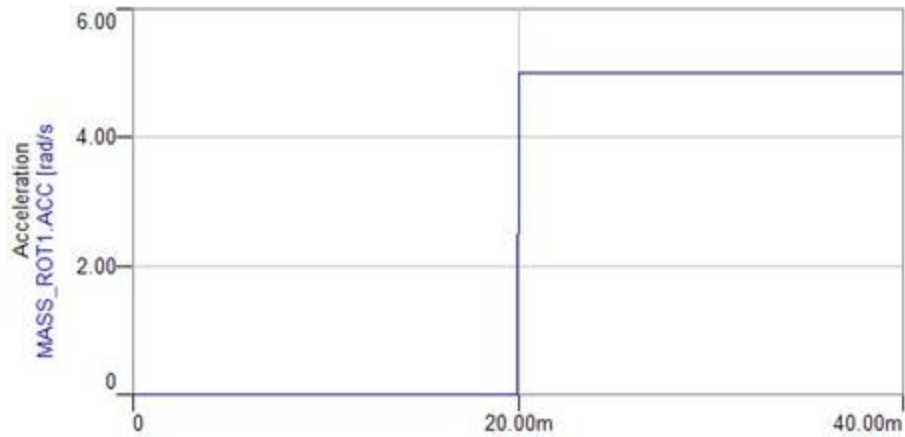


Figure 3. Simulation results-acceleration of MASS_ROT1

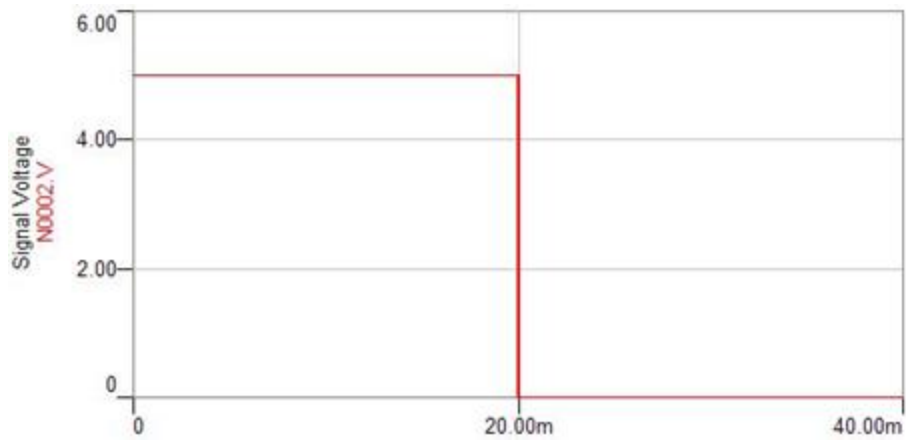


Figure 4. Simulation results-output voltage of INERTIA_SWITCH_VF1

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References

Level 1 Piezoelectric Angular Acceleration Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

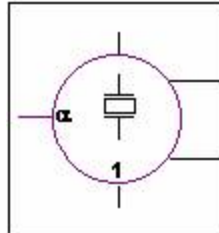


Figure 1. Component symbol

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Description

The Level 1 Piezoelectric Angular Acceleration (Velocity-Force) sensor model is used to simulate the ideal behavior of a piezoelectric angular acceleration sensor in the Twin Builder velocity-force rotational domain. A change in the model's angular acceleration input produces a corresponding change in the model's linear voltage output.

The model has one conservative input pin in the velocity-force rotational domain for its angular acceleration input and four conservative electrical-domain pins, two for its power supply connections and two for its voltage output. The negative output terminal should be connected to an electrical ground if the model is connected to an electrical network in which no other component is grounded.

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Netlist Syntax

```
MODEL PE_ALPHA_VF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) ANGULAR:= %0, OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 ( max_alpha:= @max_alpha, min_alpha:= @min_alpha, full_scale_span:= @full_scale_span, offset:= @offset, supply_current:= @supply_current) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
ANGULAR	Measured angular acceleration	Rotational_V
OUT_P	Positive terminal	Electrical
OUT_M	Negative terminal	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
max_alpha	Maximum measurable angular acceleration	Real	50 [rad/s ²]
min_alpha	Minimum measurable angular acceleration	Real	0 [rad/s ²]

full_ scale_ span	Difference of the output voltages at the maximum and minimum angular accelerations	Real	5 [V]
supply_ current	Supply current	Real	1m [A]

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Example

In this example, the Piezoelectric Angular Acceleration (Velocity-Force) sensor PE_ALPHA_VF1 measures the angular velocity of the Mass MASS_ROT1. A change in the MASS_ROT1's angular acceleration input produces a corresponding change in PE_ALPHA_VF1's linear voltage output. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

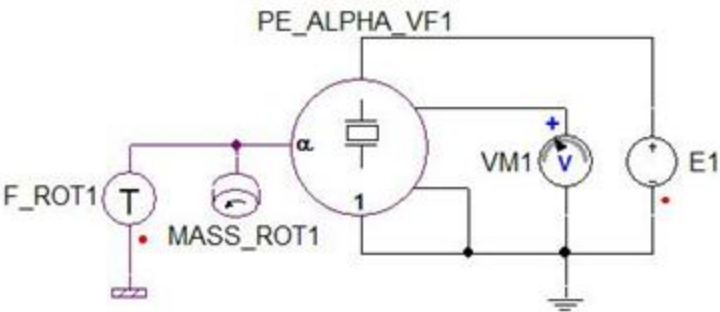


Figure 2. Application example of the Piezoelectric Angular Acceleration (Velocity-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROT1	VALUE	20 * (t/40m) [Nm]
Mass MASS_ROT1	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Piezoelectric Angular Acceleration (Velo-	offset	0.1 *

city-Force) sensor PE_ALPHA_VF1		E1.EMF [V]
	max_alpha	4 [rad/s ²]
	min_alpha	0 [rad/s ²]
	full_scale_span	0.9 * E1.EMF [V]
	supply_current	5m [A]
Voltage Source E1	EMF	5 [V]

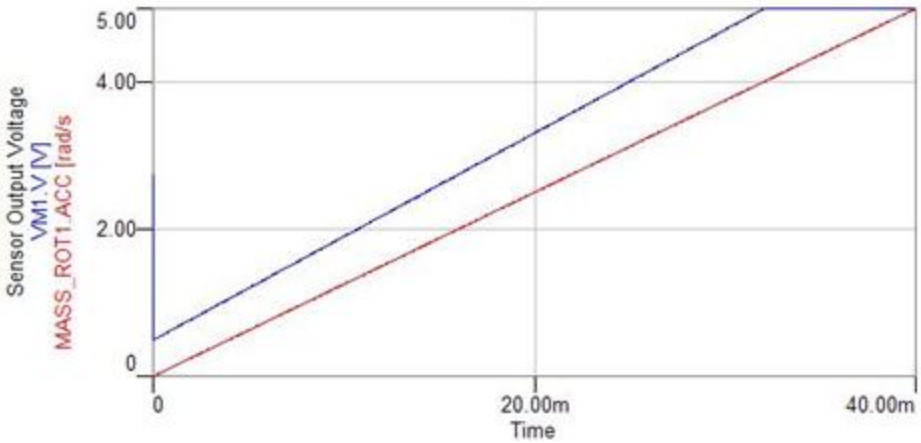


Figure 3. Simulation results-output voltage of PE_ALPHA_VF1 and acceleration of MASS_ROT1

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References

Level 1 Piezoresistive Angular Acceleration Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

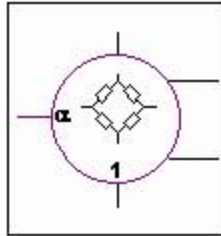


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Description

The Level 1 Piezoresistive Angular Acceleration (Velocity-Force) sensor model is used to simulate the ideal behavior of a piezoresistive angular acceleration sensor in the Twin Builder velocity-force rotational domain. A change in the model's angular acceleration input produces a corresponding change in the model's Wheatstone bridge, which in turn produces a change in the model's linear voltage output.

The model has one conservative input pin in the velocity-force rotational domain for its angular acceleration input and four conservative electrical-domain pins. Two of the pins are for the model's power supplies, and two are for its differential voltage output.

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Netlist Syntax

MODEL PR_ALPHA_VF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) OUT_P:= %0, OUT_M:= %1, Vdd:= %2, Vss:= %3, ANGULAR:= %4 (max_alpha:= @max_alpha, min_alpha:= @min_alpha, full_scale_span:= @full_scale_span, offset:= @offset, p_resistance:= @p_resistance) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
ANGULAR	Measured angular acceleration	Rotational_V
OUT_P	Positive terminal	Electrical
OUT_M	Negative terminal	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
max_alpha	Maximum measurable angular acceleration	Real	50 [rad/s ²]
min_alpha	Minimum measurable angular acceleration	Real	0 [rad/s ²]
full_scale_span	Difference of the output voltages at the maximum and minimum	Real	5 [V]

	angular accelerations		
p_res- istance	Bridge resistance	Real	10k [Ohm]

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Example

In this example, the Piezoresistive Angular Acceleration (Velocity-Force) sensor PR_ALPHA_VF1 measures the angular velocity of the Mass MASS_ROT1. A change in the angular acceleration of MASS_ROT1 produces a corresponding change in the linear voltage output of PR_ALPHA_VF1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

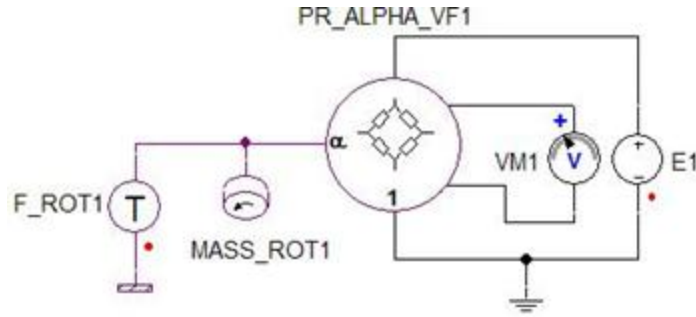


Figure 2. Application example of the Piezoresistive Angular Acceleration (Velocity-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROT1	VALUE	20 * (t/40m) [Nm]
Mass MASS_ROT1	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Piezoresistive Angular Acceleration (Velocity-Force) sensor PR_ALPHA_VF1	offset	0.1* E1.EMF [V]
	max_alpha	18 [rad/s ²]
	min_alpha	0 [rad/s ²]
	full_scale_span	0.9* E1.EMF [V]
	p_res-istance	1k [Ohm]

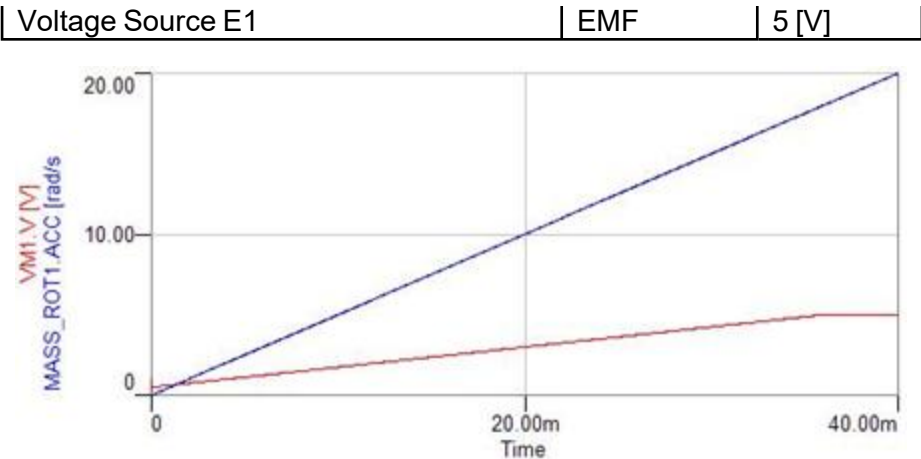


Figure 3. Simulation results-output voltage of PR_ALPHA_VF1 and acceleration of MASS_ROT1

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References

Level 1 Angular Position Sensor Models

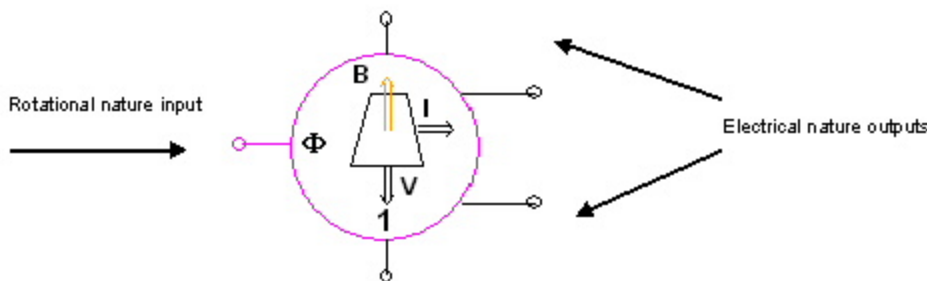
The Level 1 Angular Position Sensor Models simulate the ideal behavior of eight different types of angle sensors. Models are available to use with the Twin Builder *displacement-force* and *velocity-force* rotational domains.

All of the angle sensor models have both of the following:

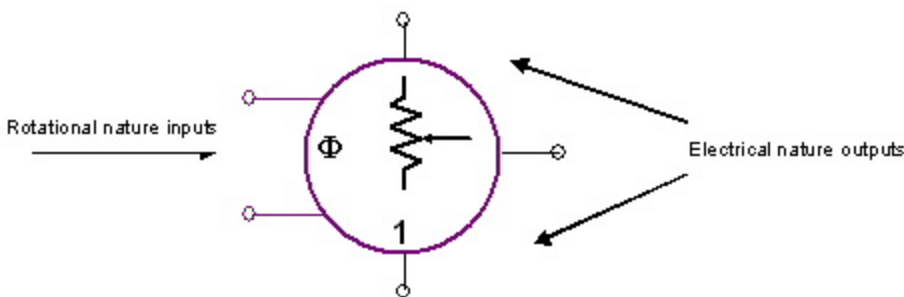
- Conservative input pins that must be connected to a rotational network.
- Conservative output pins that must be connected to an electrical network.

The models also feature nonconservative parameters that can be changed to tailor the behavior of the model to match the behavior of a specific real device.

As shown in the following example, angular position sensor models for the displacement-force rotational domain have pink conservative input pins that must be connected to a displacement-force rotational network. The models also have black conservative pins that must be connected to an electrical network.



Similarly, angular position sensor models for the velocity-force rotational domain have purple rotational nature input pins and black electrical nature pins.



The Level 1 Angular Position Sensor Models feature models for the following angle sensing mechanisms:

- Absolute Encoder: Angular position is encoded as a 6 to 16-bit binary number.
Displacement-Force model: ([ABS_ENCODER_DF](#))
Velocity-Force model: ([ABS_ENCODER_VF](#))

- **Microswitch:** The angular displacement past a specified threshold position causes a switch to toggle from its normally closed pin to its normally open pin.
Displacement-Force model: ([AMSWITCH_DF](#))
Velocity-Force model: ([AMSWITCH_VF](#))
- **Anisotropic Magnetoresistive (AMR):** A change in the angle produces a change in the two AC outputs, which vary as $\sin(2\alpha)$ and $\cos(2\alpha)$.
Displacement-Force model: ([ANG_DISP_AMR_DF](#))
Velocity-Force model: ([ANG_DISP_AMR_VF](#))
- **Potentiometric:** A change in angle moves a potentiometer wiper, producing a change in the voltage divider output signal.
Displacement-Force model: ([ANG_DISP_DF](#))
Velocity-Force model: ([ANG_DISP_VF](#))
- **Hall-Effect:** A change in angular position produces a corresponding linear change in the output voltage signal.
Displacement-Force model: ([ANG_DISP_HE_DF](#))
Velocity-Force model: ([ANG_DISP_HE_VF](#))
- **Incremental Encoder:** When a reference position is passed, an angular displacement produces two output pulse trains in quadrature and a reference pulse.
Displacement-Force model: ([INC_ENCODER_DF](#))
Velocity-Force model: ([INC_ENCODER_VF](#))
- **Synchro Resolver:** Angular motion causes a two-secondary transformer to produce two output signals that vary as the sine and cosine of the angular position.
Displacement-Force model: ([RESOLVER_DF](#))
Velocity-Force model: ([RESOLVER_VF](#))
- **Rotational Variable Differential Transformer (RVDT):** Angular motion changes the extent of the coupling between a primary winding and two secondary windings, producing variations in the amplitude and phase of an AC output signal.
Displacement-Force model: ([RVDT_DF](#))
Velocity-Force model: ([RVDT_VF](#))

Level 1 Absolute Encoder Angular Position Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

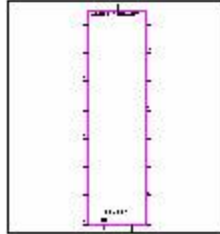


Figure 1. Component symbol

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Description

An absolute encoder angle sensor translates absolute angular position to a natural binary output. The precision of the output (i.e. the number of bits that make up the output) is determined by the number of equally spaced position indicators that are available on the sensor. For example, an angle sensor with sixteen position indicators would have a four-bit output.

The Level 1 Absolute encoder Angular Position (Displacement-Force) sensor model is used to simulate the ideal behavior of a 6 to 16-bit absolute encoder angle sensor in the Twin Builder displacement-force rotational domain. The model has a conservative input pin with a rotational nature and eighteen conservative electrical-nature pins. Two of the pins are used to connect the model to a power supply and a ground. The remaining pins are for the sixteen possible binary outputs.

The model also has nonconservative input nodes for the following parameters:

- Resolution (the number of output bits available)
- Logic one output amplitude
- Logic zero output amplitude

- Device sampling interval
- Device supply current

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Netlist Syntax

MODEL ABS_ENCODER_DF ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) PHI:= %0, Vdd:= %1, Vss:= %2, BIT_15:= %3, BIT_14:= %4, BIT_13:= %5, BIT_12:= %6, BIT_11:= %7, BIT_10:= %8, BIT_9:= %9, BIT_8:= %10, BIT_7:= %11, BIT_6:= %12, BIT_5:= %13, BIT_4:= %14, BIT_3:= %15, BIT_2:= %16, BIT_1:= %17, BIT_0:= %18 (resolution:= @resolution, max_amplitude:= @max_amplitude, min_amplitude:= @min_amplitude, sampling_interval:= @sampling_interval, supply_current:= @supply_current) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical
BIT_0 (See Note)	Output bit zero	Electrical
BIT_1 (See Note)	Output bit one	Electrical
BIT_2 (See Note)	Output bit two	Electrical
BIT_3 (See Note)	Output bit three	Electrical

BIT_4 (See Note)	Output bit four	Electrical
BIT_5 (See Note)	Output bit five	Electrical
BIT_6 (See Note)	Output bit six	Electrical
BIT_7 (See Note)	Output bit seven	Electrical
BIT_8 (See Note)	Output bit eight	Electrical
BIT_9 (See Note)	Output bit nine	Electrical
BIT_10 (See Note)	Output bit ten	Electrical
BIT_11 (See Note)	Output bit eleven	Electrical
BIT_12 (See Note)	Output bit twelve	Electrical
BIT_13 (See Note)	Output bit thirteen	Electrical
BIT_14 (See Note)	Output bit fourteen	Electrical
BIT_15 (See Note)	Output bit fifteen	Electrical

Note: Terminal set to No Action when unconnected. Terminal may remain unconnected without generating an error.

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
resolution	Number of bits available at the output	real	16

max_amp- litude	Logic 1 output amplitude	real	5 [V]
min_amp- litude	Logic 0 output amplitude	real	0 [V]
sampling_ interval	Time interval between samples of angular position	real	0.5m [s]
supply_cur- rent	Supply current	real	20m [A]

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Example

In this example, the Absolute Encoder Angular Position Sensor (Displacement-Force) ABS_ENCODER_DF1 measures the angular position of the Mass MASS_ROT1, and the encoded measurement results are sent out through its output channels. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3-12.

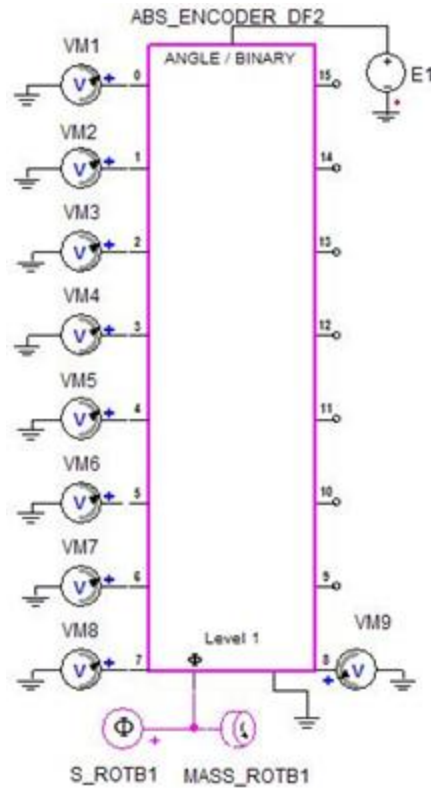


Figure 2. Application example of the Absolute Encoder Angular Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Angle Source S_ROT1	VALUE	$(\pi + (1/2^9)) * ((t \geq 5m) \text{ AND } (t \leq 15m)) + (2 * \pi - (1/2^9)) * (t > 17m)$ [rad]
Voltage Source E1	EMF	5 [V]
Mass MASS_ROT1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Absolute Encoder Angular	resolution	9

Position Sensor (Displacement-Force) ABS_ENCODER_DF1		
	max_amplitude	4 [V]
	min_amplitude	1 [V]
	sampling_interval	10m [s]
	supply_current	30m [A]

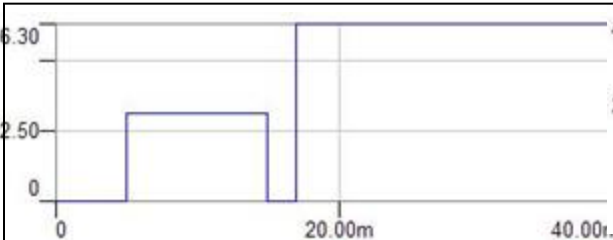


Figure 3. Simulation results- angular position of MASS_ROT B1

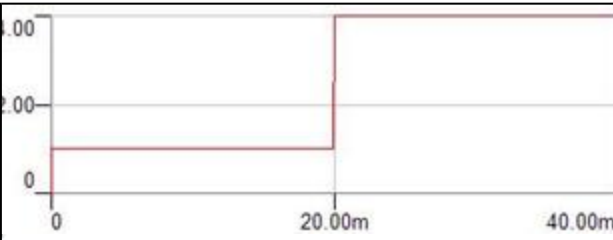


Figure 4. Simulation results- output bit0 of ABS_ENCODER_DF1

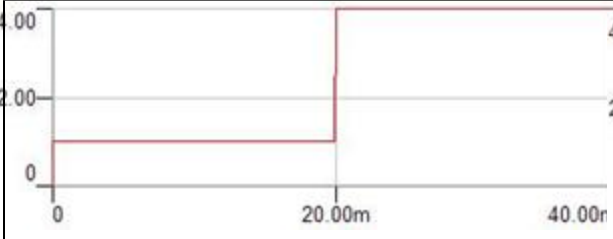


Figure 5. Simulation results- output bit1 of ABS_ENCODER_DF1

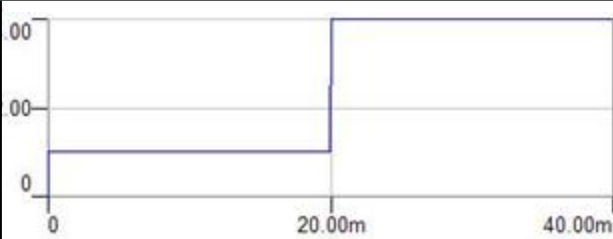


Figure 6. Simulation results- output bit2 of ABS_ENCODER_DF1

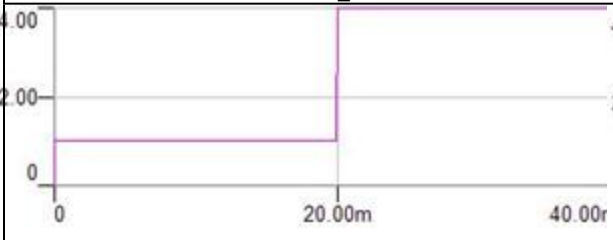


Figure 7. Simulation results- output bit3 of ABS_ENCODER_DF1

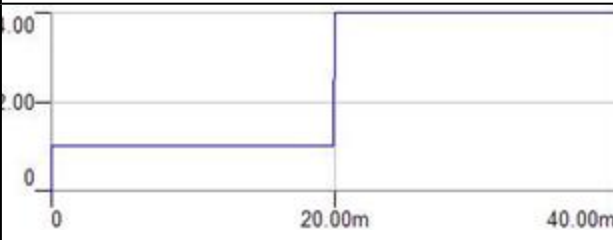


Figure 8. Simulation results- output bit4 of ABS_ENCODER_DF1

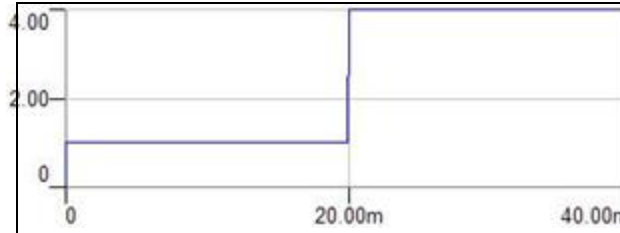


Figure 9. Simulation results-output bit5 of ABS_ENCODER_DF1

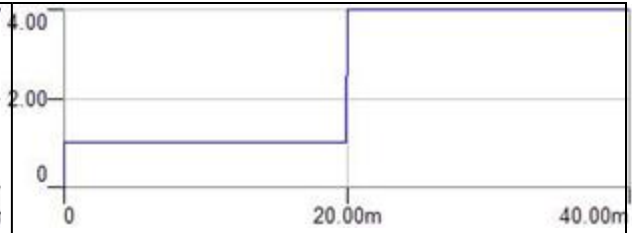


Figure 10. Simulation results-output bit6 of ABS_ENCODER_DF1

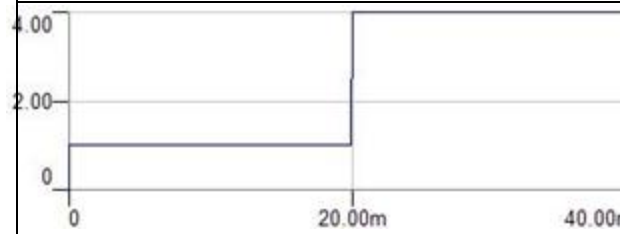


Figure 11. Simulation results-output bit7 of ABS_ENCODER_DF1

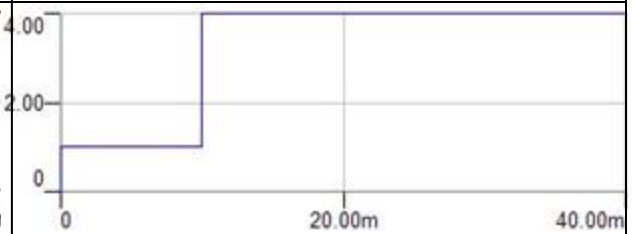


Figure 12. Simulation results-output bit8 of ABS_ENCODER_DF1

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References

Level 1 Microswitch Angular Position Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

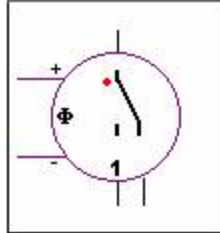


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Description

The Level 1 Microswitch Angular Position (Displacement-Force) sensor model is used to simulate the ideal behavior of a microswitch angle sensor in the Twin Builder displacement-force rotational domain. The microswitch model toggles from its normally closed terminal to its normally open terminal when the specified threshold angular position is exceeded by some element in the displacement -force rotational domain.

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Netlist Syntax

MODEL AMSWITCH_DF ?InstanceName(@InstanceName):(@Refbase)@(ID)) PHI:= %0,
REF:= %1, nmnc:= %2, nmno:= %3, np:= %4 (threshold:= @threshold) SRC: DB(Lib:-
:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational
REF	Reference angle	Rotational
np	Positive terminal	Electrical
nmnc	Normally closed negative terminal	Electrical
nmno	Normally open negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
threshold	Threshold angular displacement for switch closing	real	1.5707963267949 [rad]

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Example

In this example, when the angular position of the Mass MASS_ROT B1 is below the threshold of the Microswitch Angular Position Sensor (Displacement-Force) AMSWITCH_DF1, the resistor Rnc is connected to the current source via AMSWITCH_DF1; AMSWITCH_DF1 toggles from its normally closed terminal to its normally open terminal when the angular position of MASS_ROT B1 exceeds the threshold. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 - 5.

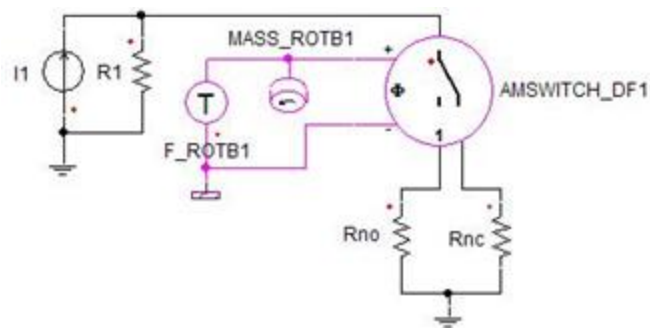


Figure 2. Application example of the Microswitch Angular Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROT B1	VALUE	10k [Nm]
Current Source I1	IS	1 [A]
Resistor Rno/Rnc	R	1k [Ohm]
Resistor R1	R	100k [Ohm]
Mass MASS_ROT B1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Microswitch Angular Position Sensor (Displacement-Force) AMSWITCH_DF1	threshold	1 [rad]

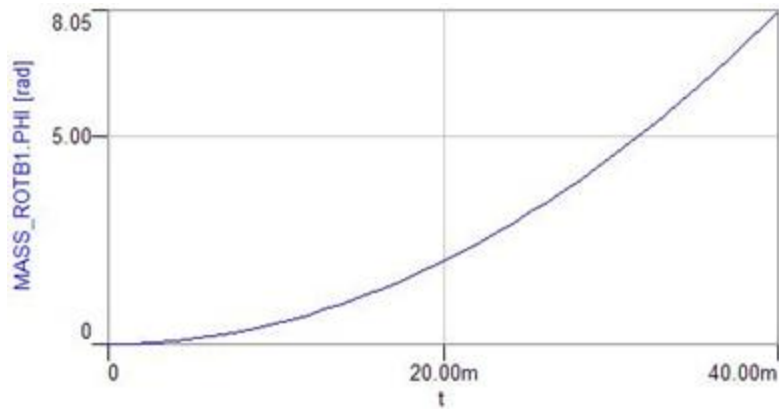


Figure 3. Simulation results- angular position of MASS_ROTBT1

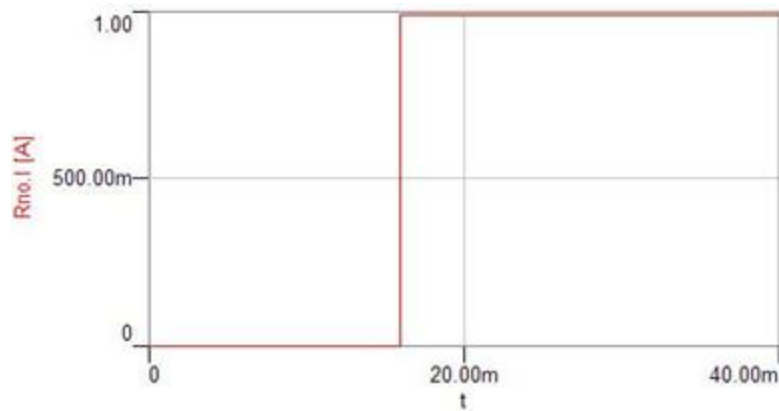


Figure 4. Simulation results- current through Rno

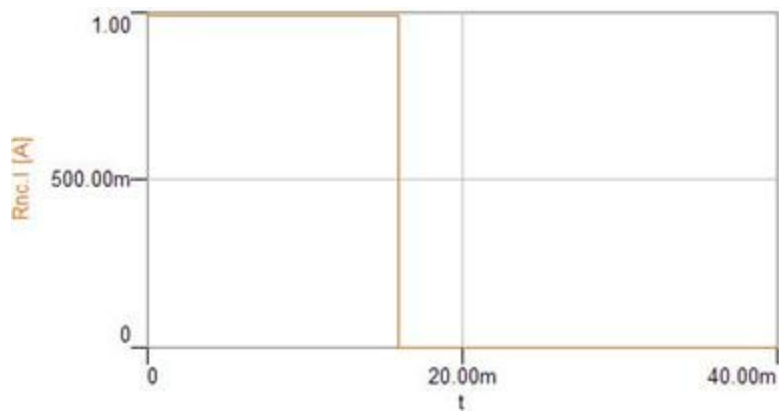


Figure 5. Simulation results- current through Rnc

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References

Level 1 Anisotropic Magnetoresistive Angular Position Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

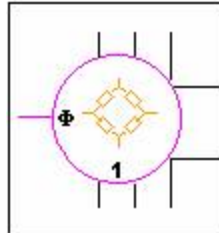


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Description

The Level 1 Anisotropic Magnetoresistive Angular Position (Displacement-Force) sensor model is used to simulate the ideal behavior of an AMR angle sensor in the Twin Builder displacement-force rotational domain. A change in the angular position of an element in the displacement-force rotational domain causes a corresponding change in the sensor model's two differential sinusoidal voltage output signals.

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Mathematical Description

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Netlist Syntax

MODEL ANG_DISP_AMR_DF ?InstanceName(@InstanceName):(@Refbase)@(ID)) Vccs:= %0, Vsss:= %1, out_pluss:= %2, out_minuss:= %3, Vccc:= %4, Vssc:= %5, out_plus:= %6, out_minus:= %7, PHI:= %8 (peak_s:= @peak_s, peak_c:= @peak_c, offset_s:= @offset_s, offset_c:= @offset_c, bridge_s_resistance:= @bridge_s_resistance, bridge_c_resistance:= @bridge_c_resistance) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational
Vccs	Supply for the sine-output bridge	Electrical
Vccc	Supply for the cosine-output bridge	Electrical
Vsss	Ground for the sine-output bridge	Electrical
Vssc	Ground for the cosine-output bridge	Electrical
out_pluss	Positive output terminal for the sine-output bridge	Electrical
out_minuss	Negative output terminal for the sine-output bridge	Electrical
out_plus	Positive output terminal for the cosine-output bridge	Electrical
out_minus	Negative output terminal for the cosine-output bridge	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset_s	Offset for the sine output	real	0 [V]
offset_c	Offset for the cosine output	real	0 [V]
peak_s	Maximum (peak) amplitude for the sine output	real	50m [V]
peak_c	Maximum (peak) amplitude for the cosine output	real	50m [V]
bridge_s_resistance	Resistance of the magnetoresistive for the sine output	real	2k [Ohm]
bridge_c_resistance	Resistance of the magnetoresistive bridge for the cosine output	real	2k [Ohm]

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Example

In this example, the two differential sinusoidal voltage output signals of the Anisotropic Magnetoresistive Angular Position Sensor (Displacement-Force) ANG_DISP_AMR_DF1 change in reponse to the change in angular position of the Mass MASS_ROT1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

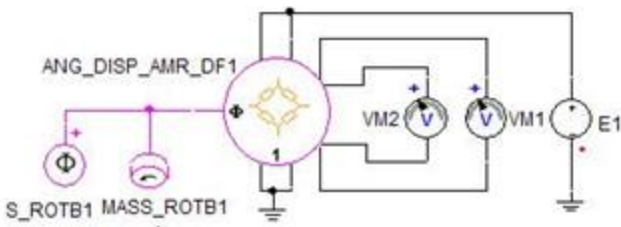


Figure 2. Application example of the Anisotropic Magnetoresistive Angular Position Sensor (Displacement-Force) ANG_DISP_AMR_DF1

Table 3

Component	Parameter	Value [Unit]
Angle Source S_ROT1	VALUE	(4 * pi) *

		(t/40m) [rad]
Voltage Source E1	EMF	5 [V]
Mass MASS_ROT B1	J	1 [kg m ²]
	PHI0	pi/4 [rad]
	OMEGA0	0 [rad/s]
Anisotropic Magnetoresistive Angular Position Sensor (Displacement-Force) ANG_DISP_AMR_DF1	offset_s	2m * E1.EMF [V]
	offset_c	2m * E1.EMF [V]
	peak_s	8m * E1.EMF [V]
	peak_c	8m * E1.EMF [V]
	bridge_s_ resistance	3k [Ohm]
	bridge_c_ resistance	3k [Ohm]

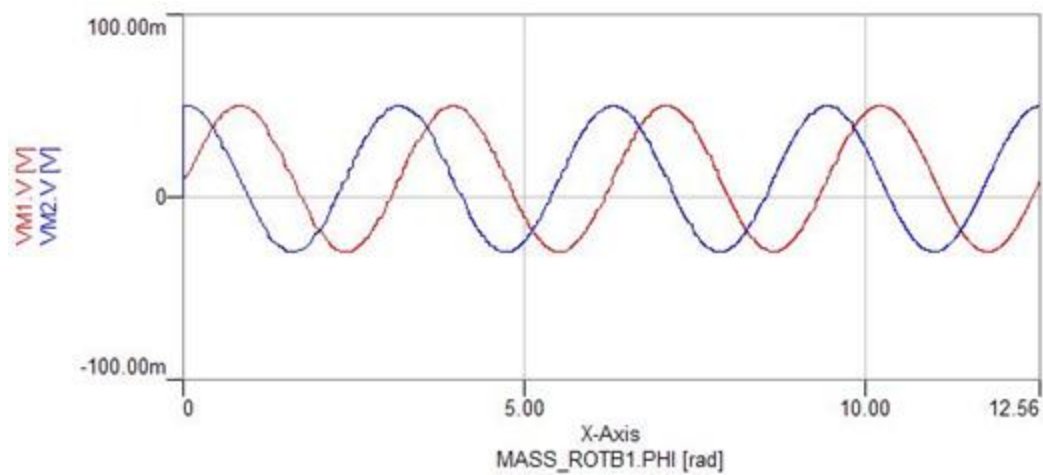


Figure 3. Simulation results- output voltages of ANG_DISP_AMR_DF1 as a function of its input angular position

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References

Level 1 Potentiometric Angular Position Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

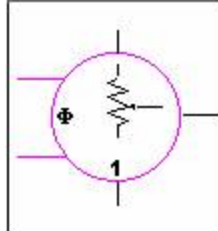


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Description

The Level 1 Potentiometric Angular Position (Displacement-Force) model is used to simulate the ideal behavior of a potentiometer angle sensor in the Twin Builder displacement-force rotational domain. A change in angular position of an element in the displacement-force rotational domain causes a corresponding change in the model's voltage divider output signal.

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Netlist Syntax

```
MODEL ANG_DISP_DF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) RPOS:= %0,
THETA:= %1, Vcc:= %2, Vss:= %3, OUTPUT:= %4 ( max_angle:= @max_angle, min_angle:=
@min_angle, full_scale_span:= @full_scale_span, offset:= @offset, p_resistance:= @p_res-
istance) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
THETA	Measured angle	Rotational
RPOS	Reference angle	Rotational
Vcc	Positive supply voltage	Electrical
Vss	Negative supply voltage	Electrical
OUTPUT	Output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
p_res- istance	Potentiometer res- istance	real	10k [Ohm]
max_angle	Maximum electrically useful angular dis- placement (meas- urable angle)	real	6.28318530717959 [rad]
min_angle	Minimum electrically useful displacement (measurable angle)	real	0 [rad]
full_scale_ span	Difference between the maximum and minimum output voltages (at the max- imum/minimum use- ful displacements)	real	10 [V]
offset	Sensor offset voltage (output at minimum electrically useful angle)	real	0 [V]

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Example

In this example, the output voltage of the Potentiometric Angular Position Sensor (Displacement-Force) ANG_DSP_DF1 changes in response to the change in angular position of the Mass MASS_ROT1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

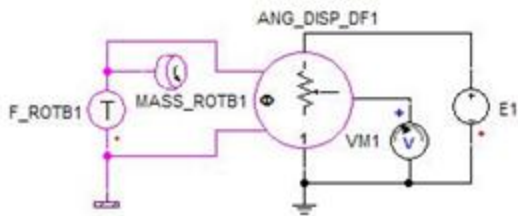


Figure 2. Application example of the the Potentiometric Angular Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROT B1	VALUE	10000 [Nm]
Voltage Source E1	EMF	5 [V]
Mass MASS_ROT B1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Potentiometric Angular Position Sensor (Displacement-Force) ANG_DSP_DF1	p_res-istance	2k [Ohm]
	max_angle	86 [degree]
	min_angle	0 [rad]
	full_scale_span	0.92 * E1.EMF [V]
	offset	0.04 * E1.EMF [V]

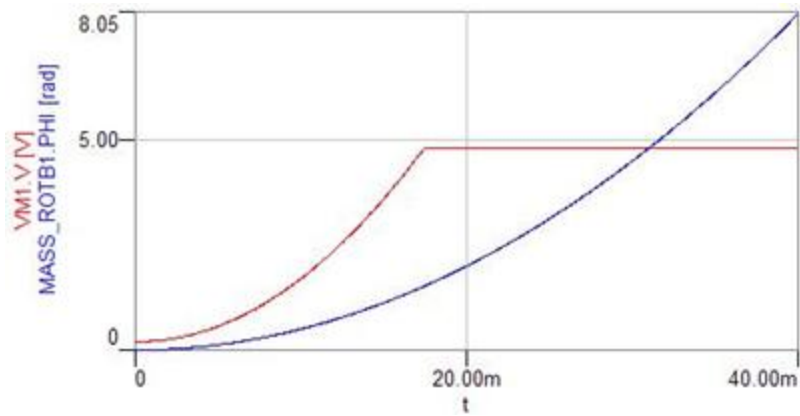


Figure 3. Simulation results-input angular position and output voltage of ANG_DSP_DF1

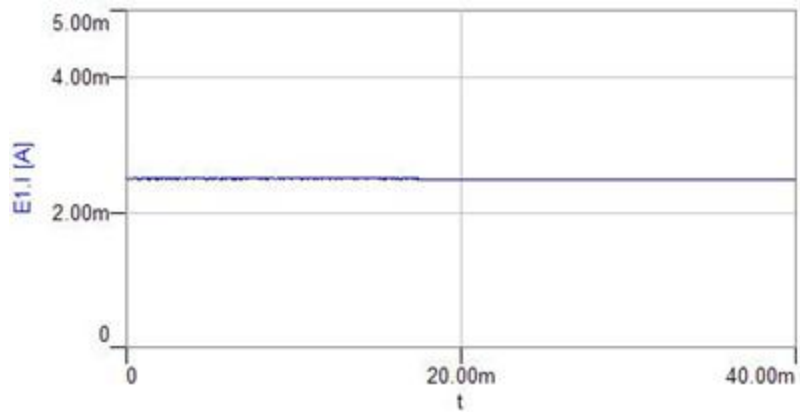


Figure 4 Simulation results-supply current of ANG_DSP_DF1

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References

Level 1 Hall Effect Angular Position Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

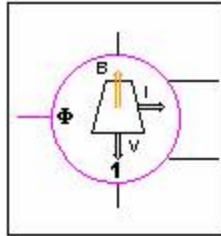


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Description

The Level 1 Hall Effect Angular Position (Displacement-Force) sensor model is used to simulate the ideal behavior of a Hall Effect angle sensor in the Twin Builder displacement-force rotational domain. A change in angular position of an element in the displacement-force rotational domain causes a corresponding change in the model's voltage output signal. The model's voltage output signal can be a clipped linear output, a periodic sawtooth function, or a triangle wave.

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Mathematical Description

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Netlist Syntax

MODEL ANG_DISP_HE_DF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) Vcc:= %0, Vss:= %1, PHI:= %2, out_plus:= %3, out_minus:= %4 (input_current:= @input_current, max_angle:= @max_angle, min_angle:= @min_angle, full_scale_span:= @full_scale_span, offset:= @offset, continuous:= @continuous) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational
Vcc	Positive supply	Rotational
Vss	Negative supply	Electrical
out_plus	Positive output	Electrical
out_minus	Negative output	Electrical

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Input/Output Quantities

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage (output at minimum angle)	real	0 [V]
input_current	Typical nominal input current	real	1m [A]
max_angle	Maximum measurable angle	real	3.14159265358979 [rad]
min_angle	Minimum meas-	real	0 [rad]

	urable angle		
full_scale_ span	Difference between the maximum and minimum output voltages	real	5 [V]
continuous	Output shape	real	0*

* continuous = 0: clipped linear output; 1: periodic sawtooth output; 2: periodic triangular output

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Example

In this example, the output voltage of the Hall Effect Angular Position Sensor (Displacement-Force) ANG_DISP_HE_DF1 changes in reponse to the change in angular position of the Mass MASS_ROT1. Here, the voltage output signal of ANG_DISP_HE_DF1 is set to be a clipped linear output. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

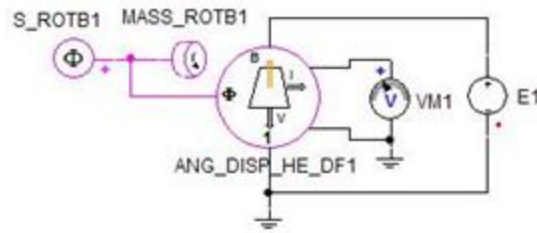


Figure 2. Application example of the Hall Effect Angular Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Angle Source S_ROT B1	VALUE	$-45 + 90 \cdot (t/40m)$ [degree]
Voltage Source E1	EMF	5 [V]
Mass MASS_ROT B1	J	1 [kg m ²]
	PHI0	pi/4 [rad]
	OMEGA0	0 [rad/s]
Hall Effect Angular Position Sensor (Displacement-Force) ANG_DISP_HE_DF1	offset	0.25 [V]
	input_current	15m [A]
	max_angle	45 [degree]
	min_angle	-45 [degree]
	full_scale_span	4.5 [V]
	continuous	0

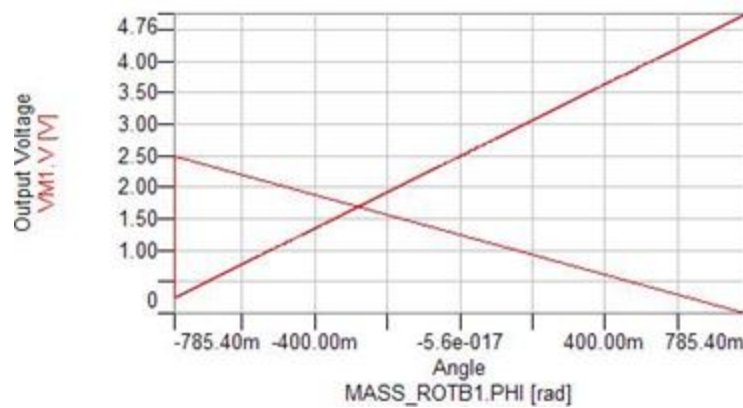


Figure 3. Simulation results- output voltage of ANG_DISP_HE_DF1 as a function of its input angular position

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References

Level 1 Incremental Encoder Angular Position Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

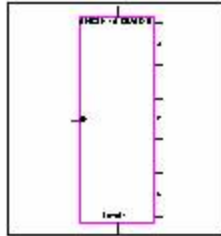


Figure 1. Component symbol

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Description

The Level 1 Incremental encoder Angular Position (Displacement-Force) sensor model is used to simulate the ideal behavior of an incremental encoder angle sensor in the Twin Builder displacement-force rotational domain. An incremental encoder has some number of equally spaced sensing elements, all of which are detected during one revolution of the device. These elements account for two of the device's three outputs: Channel A and Channel B. Channel A is a pulse output that goes to its logic 1 value when a sensing element is detected and remains there until the sensor has traveled one-half of the distance to the next element. Channel B is a second pulse output that lags Channel A by a quarter of a cycle.

The third output of the model is Channel N, which goes to its logic 1 value when the sensor detects the zero point of the sensor and remains high until the sensor has traveled one-quarter of the distance to the next sensing element.

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Mathematical Description

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Netlist Syntax

```
MODEL INC_ENCODER_DF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) PHI:=
%0, A_plus:= %1, A_minus:= %2, B_plus:= %3, B_minus:= %4, N_plus:= %5, N_minus:= %6,
Vdd:= %7, Vss:= %8 ( north:= @north, num_lines:= @num_lines, min_amplitude:= @min_amp-
litude, max_amplitude:= @max_amplitude, supply_current:= @supply_current) SRC: DB(Lib:-
:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational
Vdd	Positive power supply	Electrical
Vss	Negative power supply terminal	Electrical
A_plus (See Note)	Channel A positive output terminal (lead- ing when rotation is clockwise)	Electrical
A_minus (See Note)	Channel A negative output terminal	Electrical
B_plus (See Note)	Channel B positive output terminal (lead- ing when rotation is counterclockwise)	Electrical
B_minus (See Note)	Channel B negative output terminal	Electrical
N_plus (See Note)	Channel north positive output terminal (high only when reference position is passed)	Electrical

N_minus (See Note)	Channel north negative output terminal	Electrical

Note: Terminal set to No Action when unconnected. Terminal may remain unconnected without generating an error.

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Parameters

Table 2

Name	Description [Unit]	Data Type	Default Value [Unit]
north	Zero position of the encoder	real	0 [rad]
num_lines	Number of sensing elements on the sensor	real	16
min_amp- litude	Logic zero output	real	0 [V]
max_amp- litude	Logic one output	real	5 [V]
supply_cur- rent	Supply current	real	20m [A]

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Example

In this example, the Incremental Encoder Angular Position Sensor (Displacement-Force) INC_ENCODER_DF1 measures the angular position of the Mass MASS_ROT1, and the encoded measurement results are sent out through its output channels. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3-5.

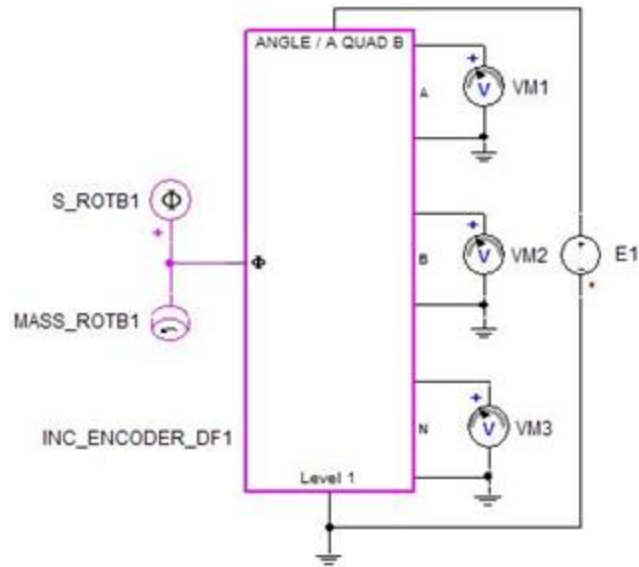


Figure 2. Application example of the Incremental Encoder Angular Position Sensor (Displacement-Force)**Table 3**

Component	Parameter	Value [Unit]
Angle Source S_ROT B1	VALUE	$(\pi/8) - (\pi/4) \cdot (t/40m)$ [rad]
Voltage Source E1	EMF	5 [V]
Mass MASS_ROT B1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Incremental Encoder Angular Position Sensor (Displacement-Force) INC_ENCODER_DF1	north	0 [rad]
	num_lines	128
	min_amplitude	0.3 [V]
	max_amplitude	2.5 [V]
	supply_current	30m [A]

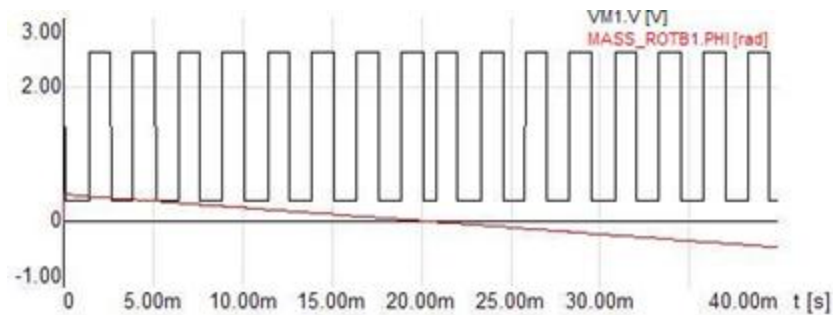


Figure 3. Simulation results- angular position of MASS_ROT1 and Channel A output of INC_ENCODER_DF1

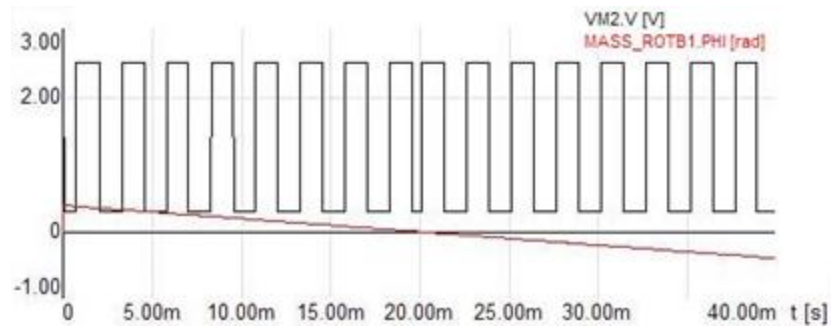


Figure 4. Simulation results- angular position of MASS_ROT1 and Channel B output of INC_ENCODER_DF1

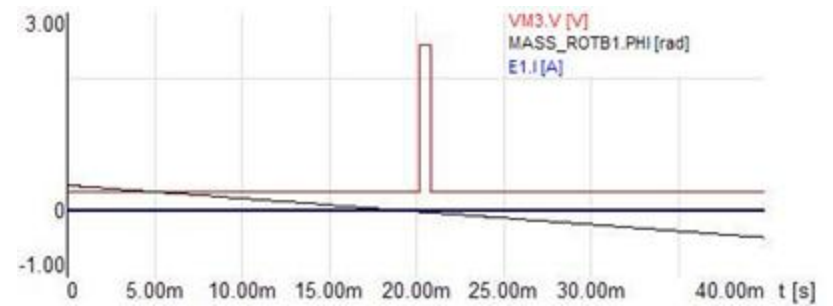


Figure 5. Simulation results- angular position of MASS_ROT1, and Channel A output and supply current of INC_ENCODER_DF1

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References

Level 1 Resolver Angular Position Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

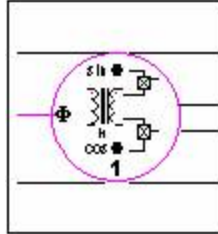


Figure 1. Component symbol

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Description

A synchro resolver angle sensor uses a transformer with one primary winding and two secondary windings that are oriented at 90-degree angles to produce two sinusoidal outputs whose amplitudes vary as the sine and cosine of the current angular position times the current amplitude of the input sinusoid at the primary winding.

The Level 1 Resolver Angular Position (Displacement-Force) sensor model is used to simulate the ideal behavior of a synchro resolver angle sensor in the Twin Builder displacement-force rotational domain. The model has a conservative rotational-nature input for the measured angle and six electrical-nature pins, a positive and negative terminal for the sinusoidal input voltage and positive and negative terminals for both sinusoidal output voltages.

The model also has nonconservative input nodes for the phase shift that occurs in the sinusoidal output signals and the turns ratio of the two secondaries to the primary.

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Assumptions and Limitations

All negative terminals should be connected to an electrical ground if they are not connected to an electrical network in which at least one element is connected to ground.

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Mathematical Description

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Netlist Syntax

MODEL RESOLVER_DF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) REF_POS:= %0, REF_NEG:= %1, PHI:= %2, OUT_SINE_PLUS:= %3, OUT_SINE_MINUS:= %4, OUT_COSINE_PLUS:= %5, OUT_COSINE_MINUS:= %6 (scale_factor:= @scale_factor, phase_shift:= @phase_shift) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational
REF_POS	Positive terminal for the input voltage	Electrical
REF_NEG	Negative terminal for the input voltage	Electrical
OUT_SINE_PLUS	Positive terminal for the sine output	Electrical
OUT_SINE_MINUS	Negative terminal for the sine output	Electrical
OUT_COSINE_PLUS	Positive terminal for the cosine output	Electrical
OUT_COSINE_MINUS	Negative terminal for the cosine output	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
phase_shift	Phase shift for the output voltages	real	0 [rad]
scale_factor	Turns ratio of the secondaries to the primary (coupling factor for transformers)	real	1 [V/V]

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Example

In this example, the Resolver Angular Position Sensor (Displacement-Force) RESOLVER_DF1 measures the angular position of the Mass MASS_ROT1, and the outputs are calculated with the measurement results and the Voltage Source E1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

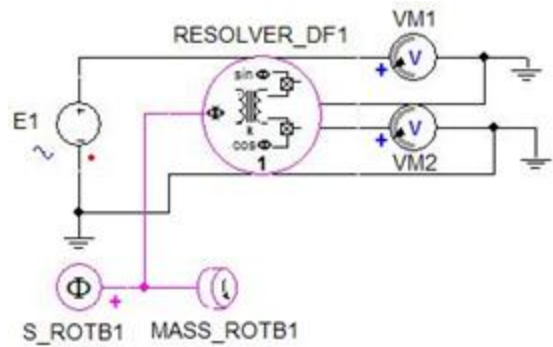


Figure 2. Application example of the Resolver Angular Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Angle Source S_ROT B1	VALUE	$(2 * \pi) * t / 5.6m$ [rad]
Voltage Source (sinusoidal) E1	AMPL	1 [V]
	FREQ	3.4k [Hz]
	PHASE	0 [degree]
	TDELAY	0 [s]
	OFF	0 [V]
Mass MASS_ROT B1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Resolver Angular Position Sensor (Displacement-Force) RESOLVER_DF1	phase_shift	5 [degree]
	scale_factor	0.5 [V/V]

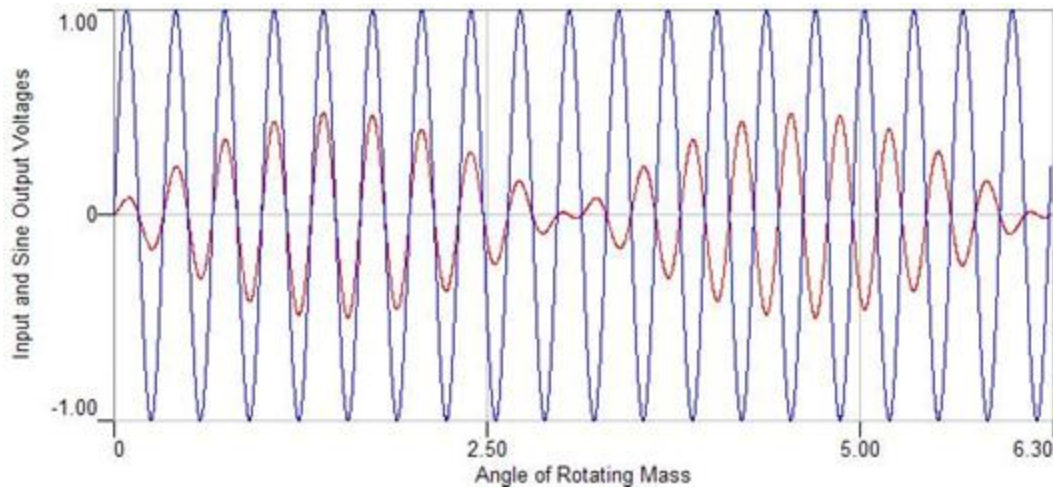


Figure 3. Simulation results-the input and sine output voltage of RESOLVER_DF1 vs. the angular position of MASS_ROT B1

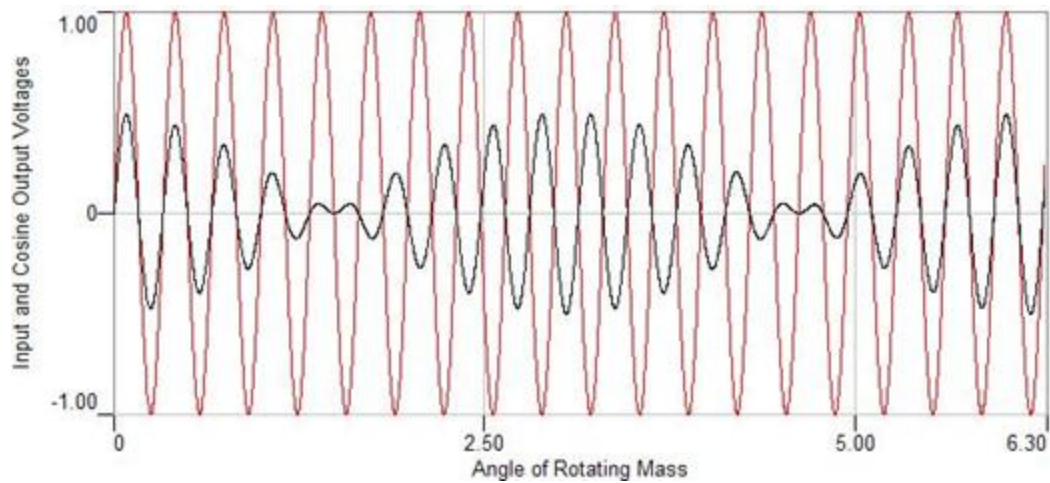


Figure 4. Simulation results-the input and cosine output voltage of RESOLVER_DF1 vs. the angular position of MASS_ROT B1

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References

Level 1 RVDT Angular Position Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

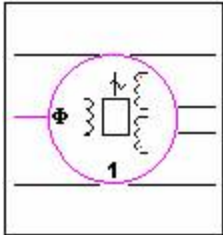


Figure 1. Component symbol

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Description

The Level 1 RVDT Angular position sensor (Displacement-Force) model is used to simulate the ideal behavior of a linear variable differential transformer angular position sensor. A change in angular position produces a corresponding change in the AC voltage output signal.

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Mathematical Description

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Netlist Syntax

```
MODEL RVDT_DF ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) out_1_plus:= %0,
out_1_minus:= %1, out_2_plus:= %2, out_2_minus:= %3, in_plus:= %4, in_minus:= %5, PHI:=
%6 ( sensitivity:= @sensitivity, max_angle:= @max_angle, min_angle:= @min_angle) SRC: DB
(Lib:=@ModelLibraryName) ;
```


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Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational
in_plus	Transformer primary positive terminal	Electrical
in_minus	Transformer primary negative terminal	Electrical
out_1_plus	Transformer secondary 1 positive terminal	Electrical
out_1_minus	Transformer secondary 1 negative terminal	Electrical
out_2_plus	Transformer secondary 2 positive terminal	Electrical
out_2_minus	Transformer secondary 2 negative terminal	Electrical

[Top](#)**Input/Output Quantities****Table 2**

Name	Description [Unit]	Data Type	Default Value [Unit]
max_angle	Maximum measurable electrical angle	real	0.785398163397448 [rad]
min_angle	Minimum measurable electrical angle	real	-0.785398163397448 [rad]

sensitivity	RVDT sensitivity	real	50m [V/V/rad]

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Example

In this example, the RVDT Angular Position Sensor (Displacement-Force) RVDT_DF2 measures the angular position of the Mass MASS_ROTB1. A change in angular position of MASS_ROTB1 produces a corresponding change in the AC voltage output signal of RVDT_DF2. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

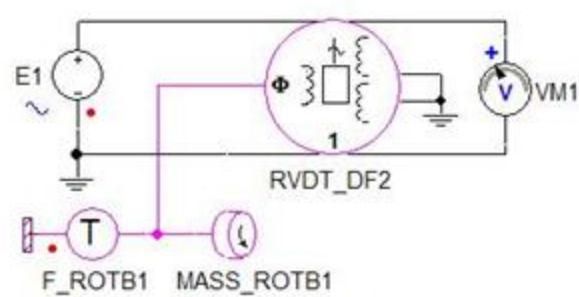


Figure 2. Application example of the RVDT Angular Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROTB1	VALUE	50MEG [Nm]
Voltage Source (sinusoidal) E1	AMPL	3 [V]
	FREQ	10k [Hz]
	PHASE	0 [degree]
	TDELAY	0 [s]
	OFF	0 [V]
Mass MASS_ROTB1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]

RVDT Angular Position Sensor (Displacement-Force) RVDT_DF2	max_angle	70 [rad]
	min_angle	-70 [rad]
	sensitivity	3.6m * (180/pi) [V/V/rad]

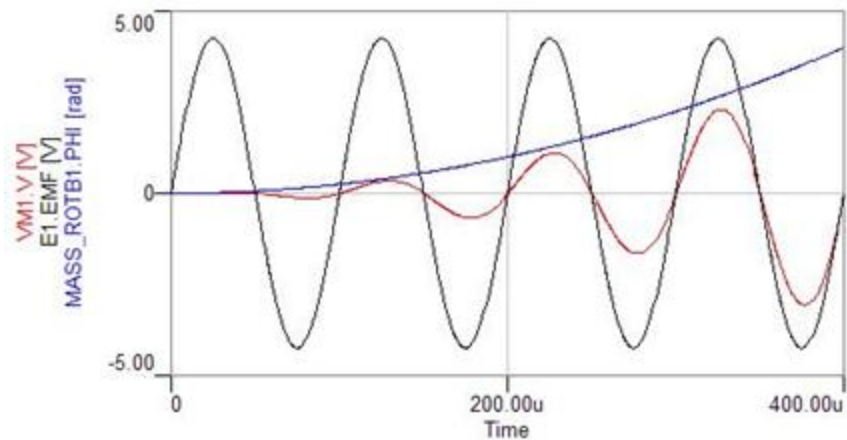


Figure 3. Simulation results-input and output voltages RVDT_DF2, and angular positon of MASS_ROT1

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References

Level 1 Absolute Encoder Angular Position Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

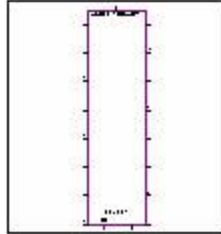


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Description

An absolute encoder angle sensor translates absolute angular position to a natural binary output. The precision of the output (i.e. the number of bits that make up the output) is determined by the number of equally spaced position indicators that are available on the sensor. For example, an angle sensor with sixteen position indicators would have a four-bit output.

The Level 1 Absolute Encoder Angular Position (Velocity-Force) sensor model is used to simulate the ideal behavior of a 6 to 16-bit absolute encoder angle sensor in the Twin Builder velocity-force rotational domain. The model has a conservative input pin with a rotational nature and eighteen conservative electrical-nature pins. Two of the pins are used to connect the model to a power supply and a ground. The remaining pins are for the sixteen possible binary outputs.

The model also has nonconservative input nodes for the following device parameters:

- Resolution (the number of output bits available)
- Logic one output amplitude
- Logic zero output amplitude

- Device sampling interval
- Device supply current

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL ABS_ENCODER_VF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) Vdd:=
%0, Vss:= %1, BIT_15:= %2, BIT_14:= %3, BIT_13:= %4, BIT_12:= %5, BIT_11:= %6, BIT_
10:= %7, BIT_9:= %8, BIT_8:= %9, BIT_7:= %10, BIT_6:= %11, BIT_5:= %12, BIT_4:= %13,
BIT_3:= %14, BIT_2:= %15, BIT_1:= %16, BIT_0:= %17, PHI:= %18 ( resolution:= @resolution,
max_amplitude:= @max_amplitude, min_amplitude:= @min_amplitude, sampling_interval:=
@sampling_interval, phi_init:= @phi_init, supply_current:= @supply_current) SRC: DB(Lib:-
:=@ModelLibraryName);
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical
BIT_0 (See Note)	Output bit zero	Electrical
BIT_1 (See Note)	Output bit one	Electrical
BIT_2 (See Note)	Output bit two	Electrical
BIT_3 (See Note)	Output bit three	Electrical
BIT_4 (See Note)	Output bit four	Electrical
BIT_5 (See Note)	Output bit five	Electrical
BIT_6 (See Note)	Output bit six	Electrical
BIT_7 (See Note)	Output bit seven	Electrical
BIT_8 (See Note)	Output bit eight	Electrical
BIT_9 (See Note)	Output bit nine	Electrical
BIT_10 (See Note)	Output bit ten	Electrical
BIT_11 (See Note)	Output bit eleven	Electrical
BIT_12 (See Note)	Output bit twelve	Electrical
BIT_13 (See	Output bit thirteen	Electrical

Note)		
BIT_14 (See Note)	Output bit fourteen	Electrical
BIT_15 (See Note)	Output bit fifteen	Electrical

Note: Terminal set to No Action when unconnected. Terminal may remain unconnected without generating an error.

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
resolution	Number of bits available at the output	real	16
max_amp-litude	Logic 1 output amplitude	real	5 [V]
min_amp-litude	Logic 0 output amplitude	real	0 [V]
phi_init	Initial sensor angle	real	0 [rad]
sampling_interval	Time interval between samples of angular position	real	0.5m [s]
supply_cur-rent	Supply current	real	0 [A]

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Example

In this example, the Absolute Encoder Angular Position Sensor (Velocity-Force) ABS_ENCODER_VF1 measures the angular postion of the Mass MASS_ROT1, and the encoded measurement results are sent out through its output channels. The schematic of the system is

shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3-12.

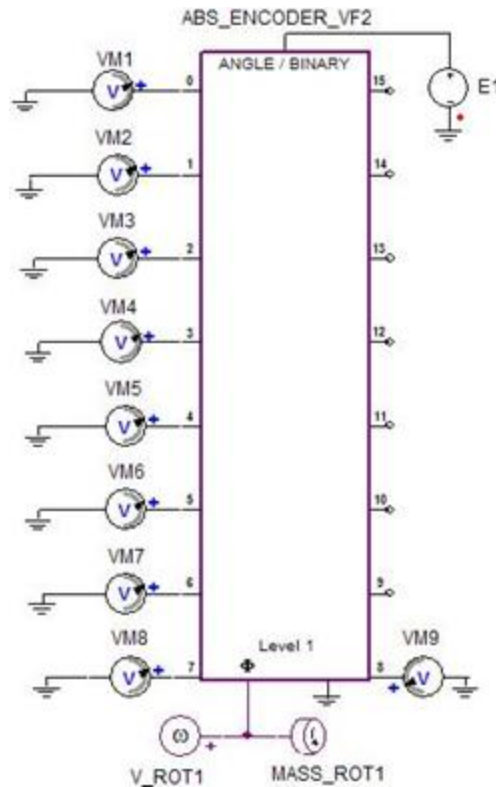


Figure 2. Application example of the Absolute Encoder Angular Position Sensor (Velocity-Force)

Table 3

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROT1	VALUE	$(2 * \pi - (1/2^9))/40\text{m}$ [rad/s]
Voltage Source E1	EMF	5 [V]
Mass MASS_ROT1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Absolute Encoder Angular Position Sensor (Velocity-Force) ABS_	resolution	9

ENCODER_VF1		
	max_amp- litude	4 [V]
	min_amp- litude	1 [V]
	sampling_ interval	10m [s]
	phi_init	MASS_ ROT1.PHI0 [rad]
	supply_cur- rent	30m [A]

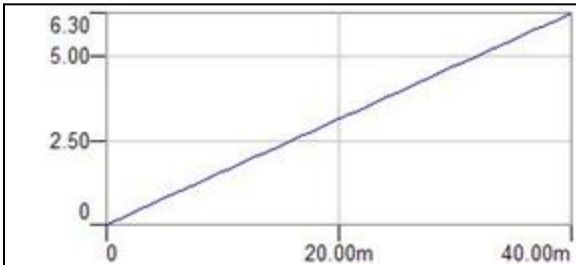


Figure 3. Simulation results- angular position of MASS_ROT1

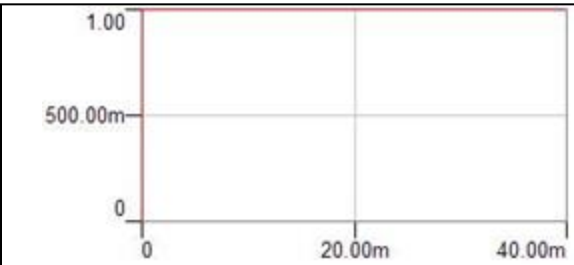


Figure 4. Simulation results- output bit0 of ABS_ENCODER_VF1

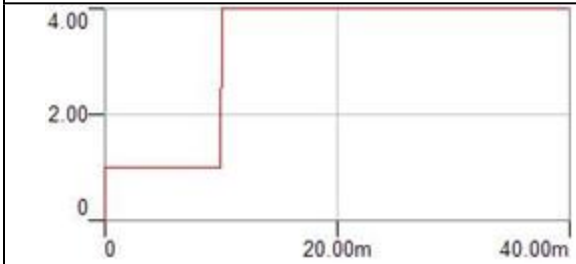


Figure 5. Simulation results- output bit1 of ABS_ENCODER_VF1

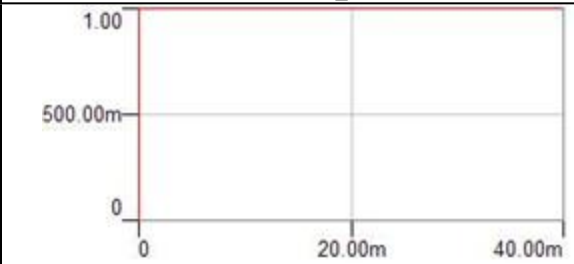


Figure 6. Simulation results- output bit2 of ABS_ENCODER_VF1

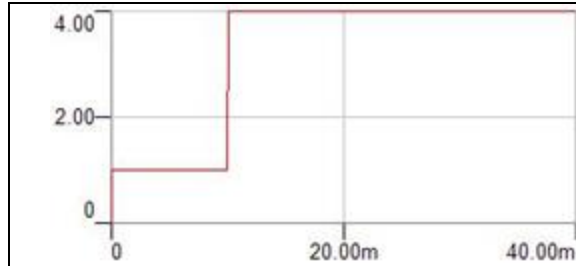


Figure 7. Simulation results- output bit3 of ABS_ENCODER_VF1



Figure 8. Simulation results- output bit4 of ABS_ENCODER_VF1

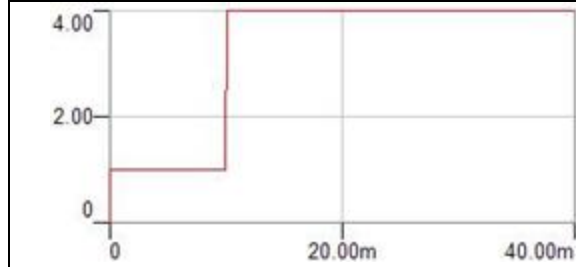


Figure 9. Simulation results- output bit5 of ABS_ENCODER_VF1

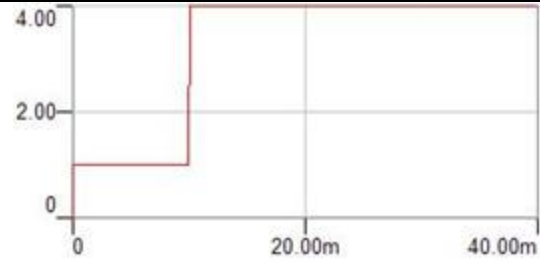


Figure 10. Simulation results- output bit6 of ABS_ENCODER_VF1

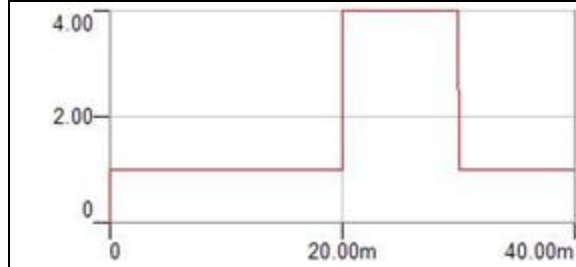


Figure 11. Simulation results- output bit7 of ABS_ENCODER_VF1

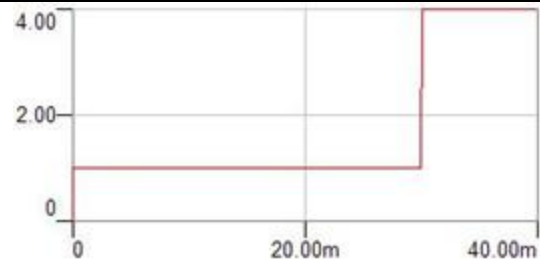


Figure 12. Simulation results- output bit8 of ABS_ENCODER_VF1

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References

Level 1 Microswitch Angular Position Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

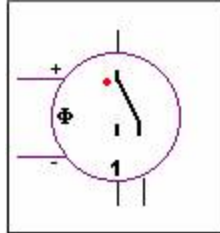


Figure 1. Component symbol

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Description

The Level 1 Microswitch Angular Position (Velocity-Force) sensor model is used to simulate the ideal behavior of a microswitch angle sensor in the Twin Builder velocity-force rotational domain. The microswitch model toggles from its normally closed terminal to its normally open terminal when the specified threshold angular position is exceeded by some element in the velocity-force rotational domain.

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Netlist Syntax

MODEL AMSWITCH_VF ?InstanceName(@InstanceName):(@Refbase)@(ID)) PHI:= %0,
REF:= %1, nmnc:= %2, nmno:= %3, np:= %4 (threshold:= @threshold, phi_init:= @phi_init)
SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational
REF	Reference angle	Rotational
np	Positive terminal	Electrical
nmnc	Normally closed negative terminal	Electrical
nmno	Normally open negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
threshold	Threshold angular displacement for switch closing	real	1.5707963267949 [rad]
phi_init	Initial sensor angle	real	0 [rad]

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Example

In this example, when the angular position of the Mass MASS_ROT1 is below the threshold of the Microswitch Angular Position Sensor (Velocity-Force) AMSWITCH_VF1, the resistor Rnc is connected to the current source via AMSWITCH_VF1; AMSWITCH_VF1 toggles from its

normally closed terminal to its normally open terminal when the angular position of MASS_ROT1 exceeds the threshold. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 - 5.

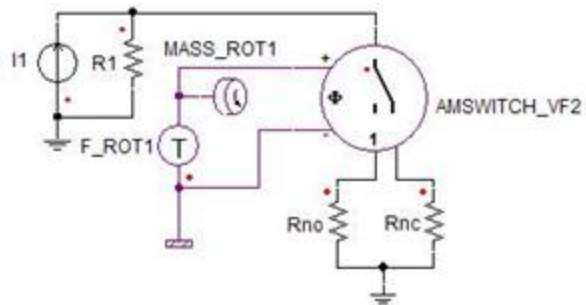


Figure 2. Application example of the Microswitch Angular Position Sensor (Velocity-Force)

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROT1	VALUE	10k [Nm]
Current Source I1	IS	1 [A]
Resistor Rno/Rnc	R	1k [Ohm]
Resistor R1	R	100k [Ohm]
Mass MASS_ROT1	J	1 [kg m ²]
	PHI0	0.5 [rad]
	OMEGA0	0 [rad/s]
Microswitch Angular Position Sensor (Velocity-Force) AMSWITCH_VF1	threshold	1 [rad]
	phi_init	0.5 [rad]

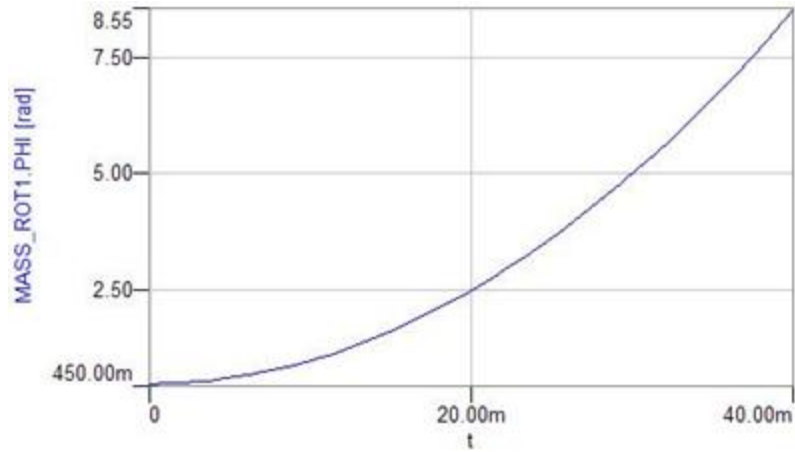


Figure 3. Simulation results- angular position of MASS_ROT1

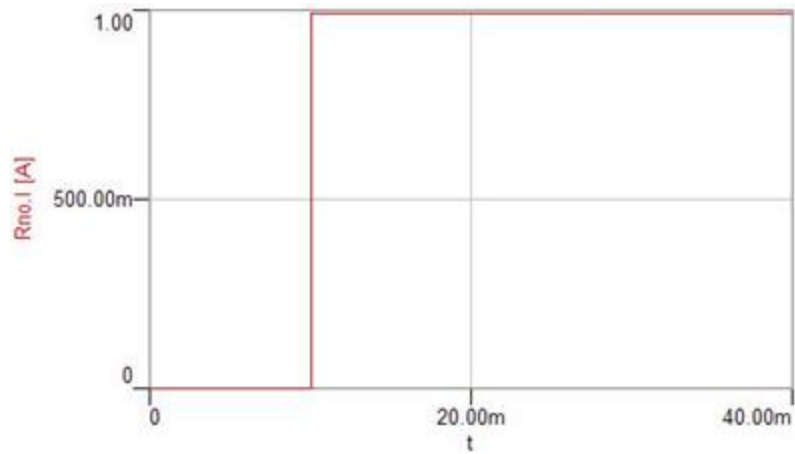


Figure 4. Simulation results- current through Rno

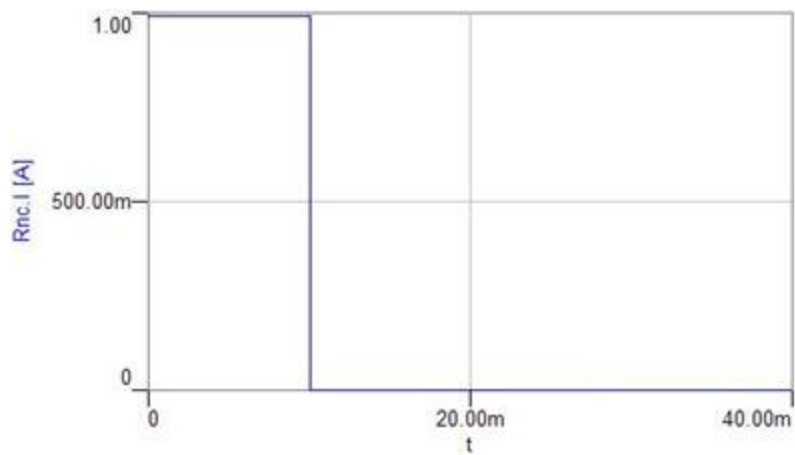


Figure 5. Simulation results- current through Rnc

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References

Level 1 Anisotropic Magnetoresistive Angular Position Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

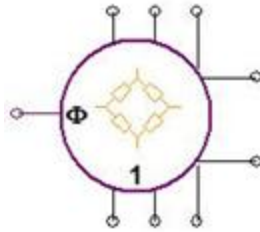


Figure 1. Component symbol

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Description

The Level 1 Microswitch Anisotropic Magnetoresistive Angular Position (Velocity-Force) sensor model is used to simulate the ideal behavior of an AMR angle sensor in the Twin Builder velocity-force rotational domain. A change in the angular position of an element in the velocity-force rotational domain causes a corresponding change in the sensor model's two differential sinusoidal voltage output signals.

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Mathematical Description

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Netlist Syntax

```
MODEL ANG_DISP_AMR_VF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) Vccs:= %0, Vsss:= %1, out_pluss:= %2, out_minuss:= %3, Vccc:= %4, Vssc:= %5, out_plus:= %6, out_minus:= %7, PHI:= %8 ( peak_s:= @peak_s, peak_c:= @peak_c, offset_s:= @offset_s, offset_c:= @offset_c, bridge_s_resistance:= @bridge_s_resistance, bridge_c_resistance:= @bridge_c_resistance, phi_init:= @phi_init) SRC: DB (Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational_V
Vccs	Supply for the sine-output bridge	Electrical
Vccc	Supply for the cosine-output bridge	Electrical
Vsss	Ground for the sine-output bridge	Electrical
Vssc	Ground for the cosine-output bridge	Electrical
Out_pluss	Positive output terminal for the sine-output bridge	Electrical
Out_minuss	Negative output terminal for the sine-output bridge	Electrical
Out_plus	Positive output terminal for the cosine-output bridge	Electrical
Out_minus	Negative output terminal for the cosine-output bridge	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset_s	Offset for the sine output [V]	real	0 [V]
offset_c	Offset for the cosine output [V]	real	0 [V]
peak_s	Maximum (peak) amplitude for the sine output [V]	real	50m [V]
peak_c	Maximum (peak) amplitude for the cosine output [V]	real	50m [V]
bridge_s_resistance	Resistance of the magnetoresistive for the sine output [Ohm]	real	2k [Ohm]
bridge_c_resistance	Resistance of the magnetoresistive bridge for the cosine output [Ohm]	real	2k [Ohm]
phi_init	Initial sensor angle [rad]	real	0 [rad]

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Example

In this example, the two differential sinusoidal voltage output signals of the Anisotropic Magnetoresistive Angular Position Sensor (Velocity-Force) ANG_DISP_AMR_VF1 change in response to the change in angular position of the Mass MASS_ROT1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

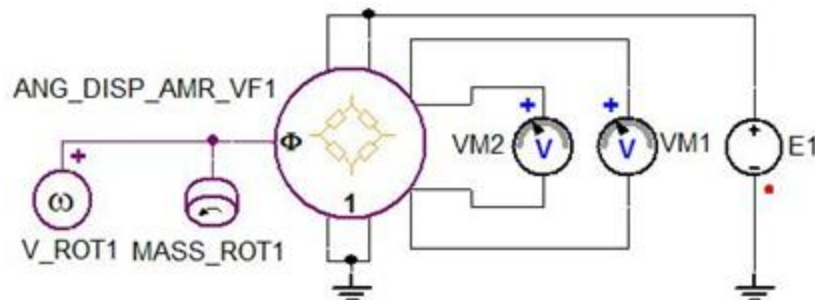


**Figure 2. Application example of the Anisotropic Magnetoresistive Angular Position Sensor
(Velocity-Force) ANG_DISP_AMR_VF1**

Table 3

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROT1	VALUE	$(4 * \pi)/40\text{m}$ [rad/s]
Voltage Source E1	EMF	5 [V]
Mass MASS_ROT1	J	1 [kg m ²]
	PHI0	$\pi/4$ [rad]
	OMEGA0	0 [rad/s]
Anisotropic Magnetoresistive Angular Position Sensor (Velocity-Force) ANG_DISP_AMR_VF1	offset_s	0 [V]
	offset_c	0 [V]
	peak_s	$15.6\text{m} * \text{E1.EMF}$ [V]
	peak_c	$15.6\text{m} * \text{E1.EMF}$ [V]
	bridge_s_ resistance	2.5k [Ohm]
	bridge_c_ resistance	2.5k [Ohm]
	phi_init	MASS_ ROT1.PHI0 [rad]

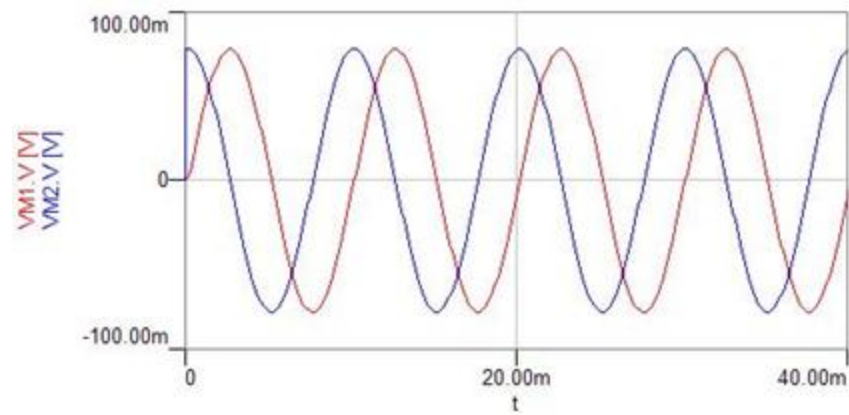


Figure 3. Simulation results- output voltages of ANG_DISP_AMR_VF1

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References

Level 1 Potentiometric Angular Position Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

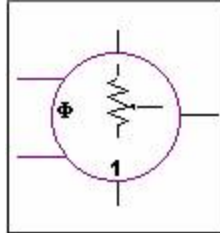


Figure 1. Component symbol

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- [Input/Output Quantities](#)
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Description

The Level 1 Potentiometric Angular Position (Velocity-Force) model is used to simulate the ideal behavior of a potentiometer angle sensor in the Twin Builder velocity-force rotational domain. A change in angular position of an element in the velocity-force rotational domain causes a corresponding change in the model's voltage divider output signal.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL ANG_DISP_VF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) Vcc:= %0,  
Vss:= %1, OUTPUT:= %2, DREF:= %3, PHI:= %4 ( max_angle:= @max_angle, min_angle:=  
@min_angle, full_scale_span:= @full_scale_span, offset:= @offset, p_resistance:= @p_res-  
istance, phi_init:= @phi_init) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational
DREF	Reference angle	Rotational
Vcc	Positive supply voltage	Electrical
Vss	Negative supply voltage	Electrical
OUTPUT	Output terminal	Electrical

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Input/Output Quantities

Table 2

Name	Description	Data Type	Default Value [Unit]
p_res-istance	Potentiometer res-istance	real	10k [Ohm]
max_angle	Maximum electrically useful angular displacement (measurable angle)	real	6.28318530717959 [rad]
min_angle	Minimum electrically useful displacement (measurable angle)	real	0 [rad]
full_scale_span	Difference between the maximum and minimum output voltages (at the maximum/minimum useful displacements)	real	10 [V]
offset	Sensor offset voltage (output at minimum electrically useful angle)	real	0 [V]
phi_init	Initial sensor position	real	0 [rad]

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Example

In this example, the output voltage of the Potentiometric Angular Position Sensor (Velocity-Force) ANG_DSP_VF1 changes in reponse to the change in angular position of the Mass MASS_ROT1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

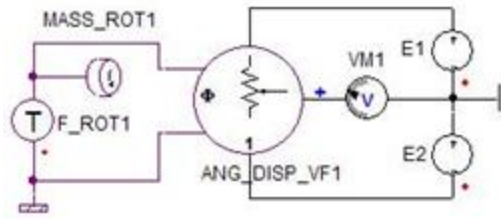


Figure 2. Application example of the Potentiometric Angular Position Sensor (Velocity-Force)

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROT1	VALUE	10k [Nm]
Voltage Source E1/E2	EMF	5 [V]
Mass MASS_ROT1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Potentiometric Angular Position Sensor (Velocity-Force) ANG_DSP_VF1	p_res-istance	2k [Ohm]
	max_angle	86 [degree]
	min_angle	0 [rad]
	full_scale_span	0.92 * (E1.EMF + E2.EMF) [V]
	offset	-0.96 * E2.EMF [V]
	phi0	MASS_ROT1.PHI0 [rad]

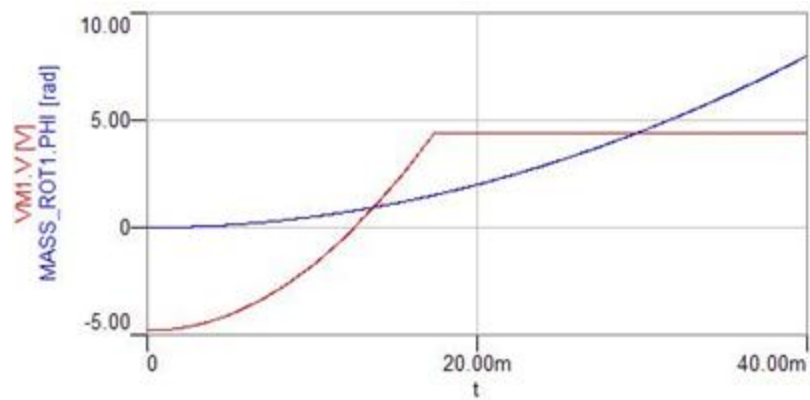


Figure 3. Simulation results-input angular position and output voltage of ANG_DSP_VF1

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References

Level 1 Hall Effect Angular Position Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

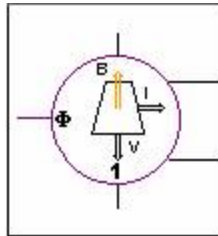


Figure 1. Component symbol

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Description

The Level 1 Hall Effect Angular Position (Velocity-Force) sensor model is used to simulate the ideal behavior of a Hall effect angle sensor in the Twin Builder velocity-force rotational domain. A change in angular position of an element in the velocity-force rotational domain causes a corresponding change in the model's voltage output signal. The model's voltage output signal can be a clipped linear output, a periodic sawtooth function, or a triangle wave.

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Mathematical Description

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Netlist Syntax

```
MODEL ANG_DISP_HE_VF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) Vcc:= %0,
Vss:= %1, PHI:= %2, out_plus:= %3, out_minus:= %4 ( input_current:= @input_current, max_
angle:= @max_angle, min_angle:= @min_angle, full_scale_span:= @full_scale_span, offset:=
@offset, continuous:= @continuous, phi_init:= @phi_init) SRC: DB(Lib:=@ModellibraryName)
;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational
Vcc	Positive supply	Rotational
Vss	Negative supply	Electrical
out_plus	Positive output	Electrical
out_minus	Negative output	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage (output at zero angle) [V]	real	0 [V]
input_current	Typical nominal input current [A]	real	1m [A]
max_angle	Maximum measurable angle [rad]	real	3.14159265358979 [rad]

min_angle	Minimum measurable angle [rad]	real	0 [rad]
full_scale_span	Difference between the maximum and minimum output voltages [V]	real	5 [V]
continuous	Output shape/type (0=clipped, 1=periodic sawtooth, -1=periodic triangular)	real	0*
phi_init	Initial angle of the sensor	real	0 [rad]

* continuous = 0: clipped linear output; 1: periodic sawtooth output; 2: periodic triangular output

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Example

In this example, the output voltage of the Hall Effect Angular Position Sensor (Velocity-Force) ANG_DISP_HE_VF1 changes in response to the change in angular position of the Mass MASS_ROT1. Here, the voltage output signal of ANG_DISP_HE_VF1 is set to be a clipped linear output. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

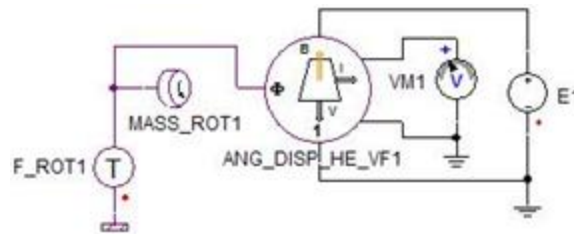


Figure 2. Application example of the Hall Effect Angular Position Sensor (Velocity-Force)

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROT1	VALUE	20k [Nm]
Voltage Source E1	EMF	5 [V]
Mass MASS_ROT1	J	1 [kg m ²]

Hall Effect Angular Position Sensor (Velocity-Force) ANG_DISP_HE_VF1	PHI0	180 [degree]
	OMEGA0	0 [rad/s]
	offset	0.05 * E1.EMF [V]
	input_current	100m [A]
	max_angle	360 [degree]
	min_angle	0 [degree]
	full_scale_span	0.95 * E1.EMF [V]
	continuous	1
	phi_init	MASS_ROT1.PHI0 [rad]

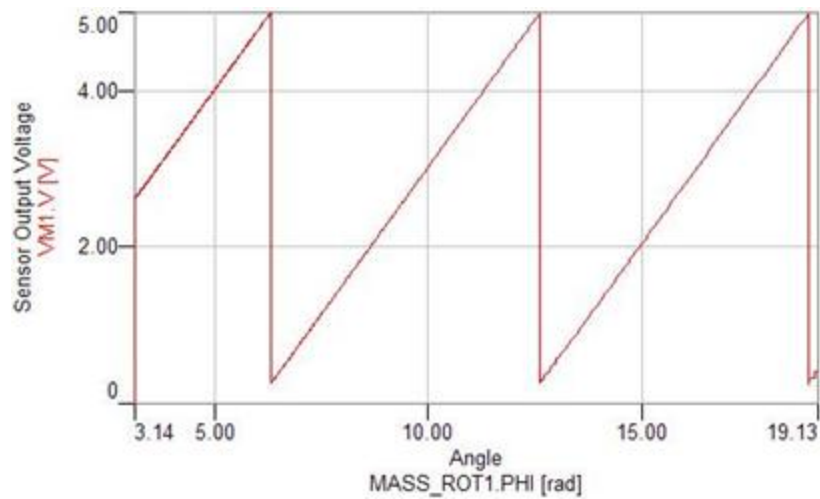


Figure 3. Simulation results- output voltage of ANG_DISP_HE_VF1 as a function of its input angular position

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References

Level 1 Incremental Encoder Angular Position Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

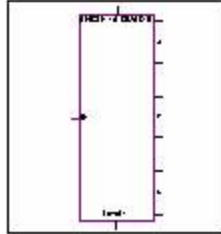


Figure 1. Component symbol

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Description

The Level 1 Incremental encoder Angular Position (Velocity-Force) sensor model is used to simulate the ideal behavior of an incremental encoder angle sensor in the Twin Builder velocity-force rotational domain. An incremental encoder has some number of equally spaced sensing elements, all of which are detected during one revolution of the device. These elements account for two of the device's three outputs: Channel A and Channel B. Channel A is a pulse output that goes to its logic 1 value when a sensing element is detected and remains there until the sensor has traveled one-half of the distance to the next element. Channel B is a second pulse output that lags Channel A by a quarter of a cycle.

The third output of the model is Channel N, which goes to its logic 1 value when the sensor detects the zero point of the sensor and remains high until the sensor has traveled one-quarter of the distance to the next sensing element.

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Mathematical Description

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Netlist Syntax

MODEL INC_ENCODER_VF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) PHI:= %0, A_plus:= %1, A_minus:= %2, B_plus:= %3, B_minus:= %4, N_plus:= %5, N_minus:= %6, Vdd:= %7, Vss:= %8 (phi_init:= @phi_init, north:= @north, num_lines:= @num_lines, min_amplitude:= @min_amplitude, max_amplitude:= @max_amplitude, supply_current:= @supply_current) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational_V
Vdd	Positive power supply	Electrical
Vss	Negative power supply terminal	Electrical
A_plus (See Note)	Channel A positive output terminal (leading when rotation is clockwise)	Electrical
A_minus (See Note)	Channel A negative output terminal	Electrical
B_plus (See Note)	Channel B positive output terminal (leading when rotation is counterclockwise)	Electrical
B_minus (See Note)	Channel B negative output terminal	Electrical
N_plus (See Note)	Channel north positive output terminal (high only when reference position is passed)	Electrical

N_minus (See Note)	Channel north negative output terminal	Electrical

Note: Terminal set to No Action when unconnected. Terminal may remain unconnected without generating an error.

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Parameters

Table 2

Name	Description [Unit]	Data Type	Default Value [Unit]
north	Zero position of the encoder	real	0 [rad]
num_lines	Number of sensing elements on the sensor	real	16
phi_init	Initial sensor angle	real	0 [rad]
min_amp- litude	Logic zero output	real	0 [V]
max_amp- litude	Logic one output	real	5 [V]
supply_cur- rent	Supply current	real	20m [A]

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Example

In this example, the Incremental Encoder Angular Position Sensor (Velocity-Force) INC_ENCODER_VF1 measures the angular position of the Mass MASS_ROT1, and the encoded measurement results are sent out through its output channels. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3-6.

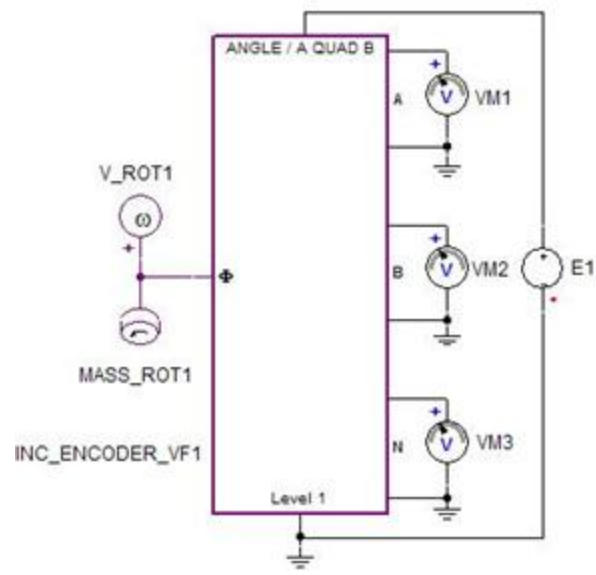


Figure 2. Application example of the Incremental Encoder Angular Position Sensor (Velocity-Force)**Table 3**

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROT1	VALUE	$-(\pi/4)/40\text{m}$ [rad/s]
Voltage Source E1	EMF	5 [V]
Mass MASS_ROT1	J	1 [kg m ²]
	PHI0	$\pi/8$ [rad]
	OMEGA0	0 [rad/s]
Incremental Encoder Angular Position Sensor (Velocity-Force) INC_ENCODER_VF1	north	0 [rad]
	num_lines	128
	min_amplitude	0.3 [V]
	max_amplitude	2.8 [V]
	supply_current	30m [A]
	phi_init	MASS_ROT1.PHI0

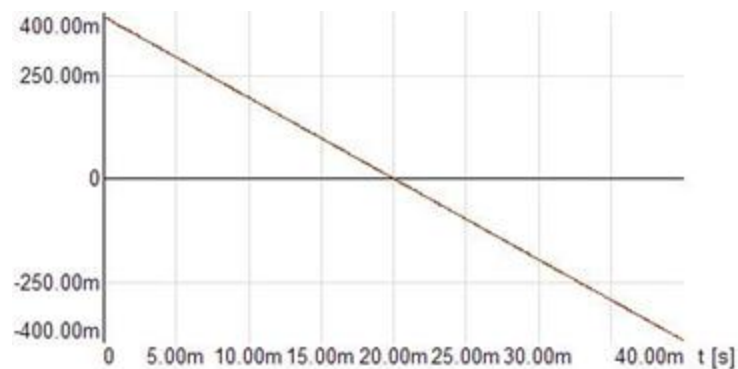


Figure 3. Simulation results- angular position of MASS_ROT1

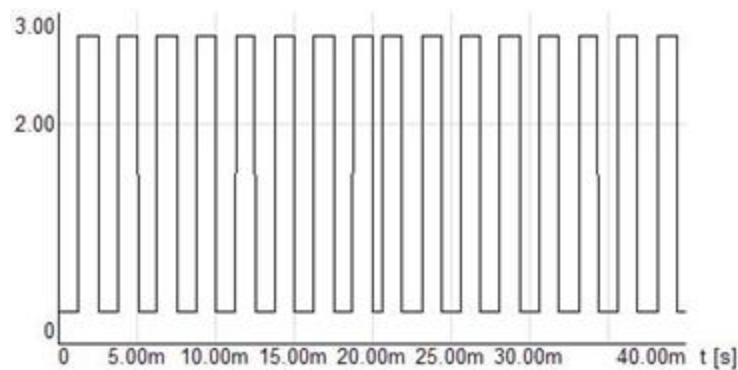


Figure 4. Simulation results-Channel A output of INC_ENCODER_VF1

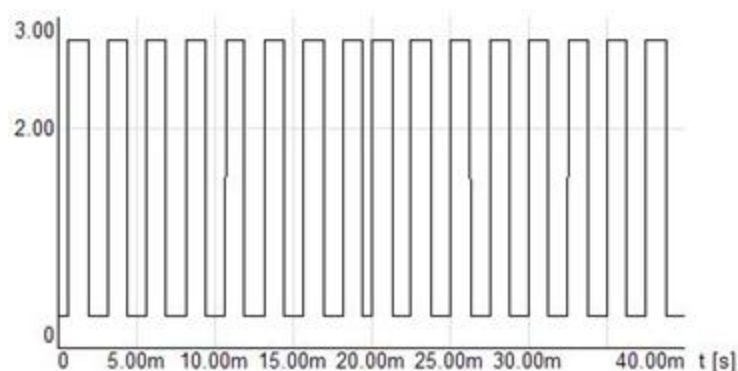


Figure 5. Simulation results-Channel B output of INC_ENCODER_VF1

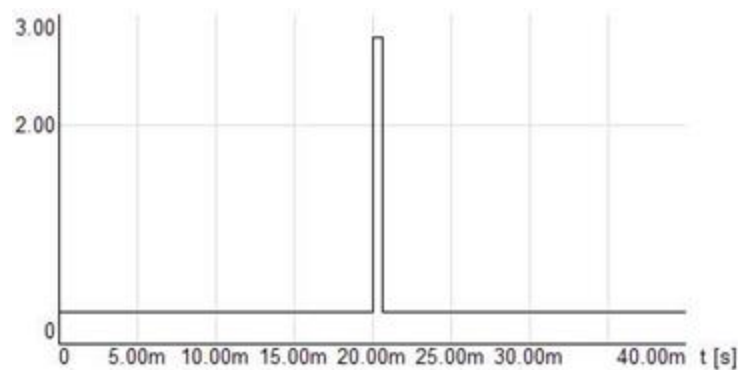


Figure 6. Simulation results-Channel N output of INC_ENCODER_VF1

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References

Level 1 Resolver Angular Position Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

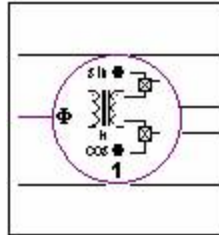


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Description

A synchro resolver angle sensor uses a transformer with one primary winding and two secondary windings that are oriented at 90-degree angles to produce two sinusoidal outputs whose amplitudes vary as the sine and cosine of the current angular position times the current amplitude of the input sinusoid at the primary winding.

The Level 1 Resolver Angular Position (Velocity-Force) sensor model is used to simulate the ideal behavior of a synchro resolver angle sensor in the Twin Builder velocity-force rotational domain. The model has a conservative rotational-nature input for the measured angle and six electrical-nature pins, a positive and negative terminal for the sinusoidal input voltage and positive and negative terminals for both sinusoidal output voltages.

The model also has nonconservative input nodes for the phase shift that occurs in the sinusoidal output signals and the turns ratio of the two secondaries to the primary.

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Assumptions and Limitations

All negative terminals should be connected to an electrical ground if they are not connected to an electrical network in which at least one element is connected to ground.

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Mathematical Description

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Netlist Syntax

MODEL RESOLVER_VF ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) REF_POS:= %0, REF_NEG:= %1, PHI:= %2, OUT_SINE_PLUS:= %3, OUT_SINE_MINUS:= %4, OUT_COSINE_PLUS:= %5, OUT_COSINE_MINUS:= %6 (scale_factor:= @scale_factor, phase_shift:= @phase_shift, phi_init:= @phi_init) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational_V
REF_POS	Positive terminal for the input voltage	Electrical
REF_NEG	Negative terminal for the input voltage	Electrical
OUT_SINE_PLUS	Positive terminal for the sine output	Electrical
OUT_SINE_MINUS	Negative terminal for the sine output	Electrical
OUT_COSINE_PLUS	Positive terminal for the cosine output	Electrical
OUT_COSINE_MINUS	Negative terminal for the cosine output	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
phase_shift	Phase shift for the output voltages	real	0 [rad]
scale_factor	Turns ratio of the secondaries to the primary (coupling factor for transformers)	real	1 [V/V]
phi_init	Initial sensor angle	real	0 [rad]

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Example

In this example, the Resolver Angular Position Sensor (Velocity-Force) RESOLVER_VF1 measures the angular position of the Mass MASS_ROT1, and the outputs are calculated with the measurement results and the Voltage Source E1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

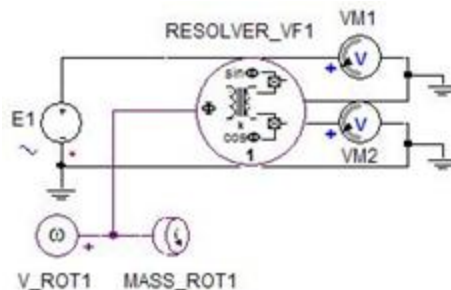


Figure 2. Application example of the Resolver Angular Position Sensor (Velocity-Force)

Table 3

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROT1	VALUE	$(2 * \pi)/5.6\text{m}$ [rad/s]
	AMPL	1 [V]
Voltage Source (sinusoidal) E1		

	FREQ	3.4k [Hz]
	PHASE	0 [degree]
	TDELAY	0 [s]
	OFF	0 [V]
Mass MASS_ROT1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Resolver Angular Position Sensor (Velocity-Force) RESOLVER_VF1	phase_shift	5 [degree]
	scale_factor	0.5 [V/V]
	phi_init	MASS_ROT1.PHI0 [rad]

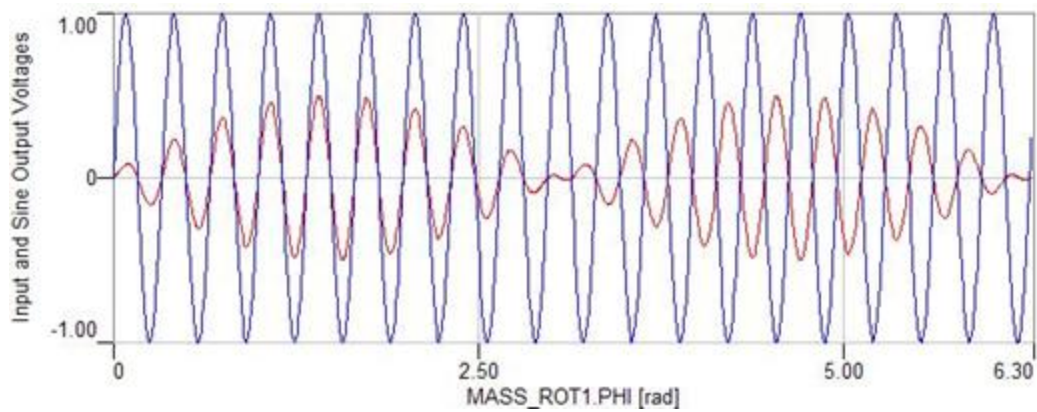


Figure 3. Simulation results-the input and sine output voltage of RESOLVER_VF1 vs. the angular position of MASS_ROT1

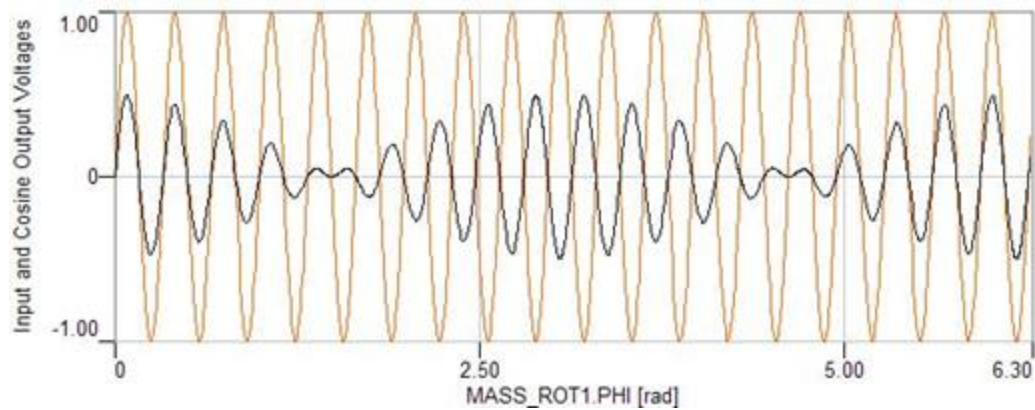


Figure 4. Simulation results-the input and cosine output voltage of RESOLVER_VF1 vs. the angular position of MASS_ROT1

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References

Level 1 RVDT Angular Position Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

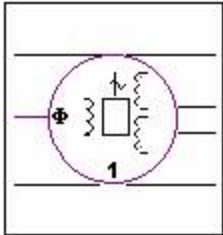


Figure 1. Component symbol

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Description

The Level 1 RVDT Angular position sensor (Velocity-Force) model is used to simulate the ideal behavior of a linear variable differential transformer angular position sensor. A change in angular position produces a corresponding change in the AC voltage output signal.

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Netlist Syntax

```
MODEL RVDT_VF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) out_1_plus:= %0,
out_1_minus:= %1, out_2_plus:= %2, out_2_minus:= %3, in_plus:= %4, in_minus:= %5, PHI:=
%6 ( sensitivity:= @sensitivity, max_angle:= @max_angle, min_angle:= @min_angle, phi_init:=
@phi_init) SRC: DB(Lib:=@ModelLibraryName) ;
```

[Top](#)**Conservative Pins****Table 1**

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational_V
in_plus	Transformer primary positive terminal	Electrical
in_minus	Transformer primary negative terminal	Electrical
out_1_plus	Transformer secondary 1 positive terminal	Electrical
out_1_minus	Transformer secondary 1 negative terminal	Electrical
out_2_plus	Transformer secondary 2 positive terminal	Electrical
out_2_minus	Transformer secondary 2 negative terminal	Electrical

[Top](#)**Input/Output Quantities****Table 2**

Name	Description	Data Type	Default Value [Unit]
max_angle	Maximum measurable electrical angle	real	0.785398163397448 [rad]
min_angle	Minimum measurable electrical angle	real	-0.785398163397448 [rad]

sensitivity	RVDT sensitivity	real	50m [V/V/rad]
phi_init	Initial sensor angle	real	0 [rad]

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Example

In this example, the RVDT Angular Position Sensor (Velocity-Force) RVDT_VF2 measures the angular position of the Mass MASS_ROT1. A change in angular position of MASS_ROT1 produces a corresponding change in the AC voltage output signal of RVDT_VF2. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

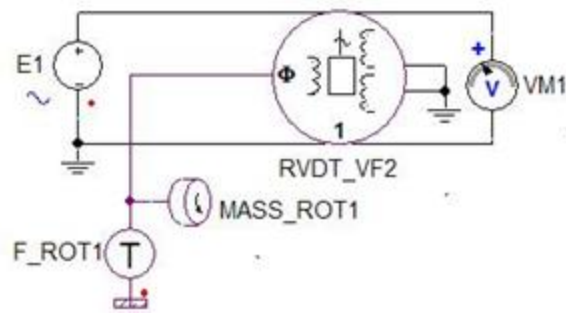


Figure 2. Application example of the RVDT Angular Position Sensor (Velocity-Force)

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROT1	VALUE	100MEG [Nm]
Voltage Source (sinusoidal) E1	AMPL	3 [V]
	FREQ	10k [Hz]
	PHASE	0 [degree]
	TDELAY	0 [s]
	OFF	0 [V]
Mass MASS_ROT1	J	1 [kg m ²]
	PHI0	-70 [degree]
	OMEGA0	0 [rad/s]
RVDT Angular Position Sensor (Velocity-Force) RVDT_VF2	max_angle	70 [degree]
	min_angle	-70 [degree]
	sensitivity	3.6m [V/V/degree]
	phi_init	MASS_ROT1.PHI0 [degree]

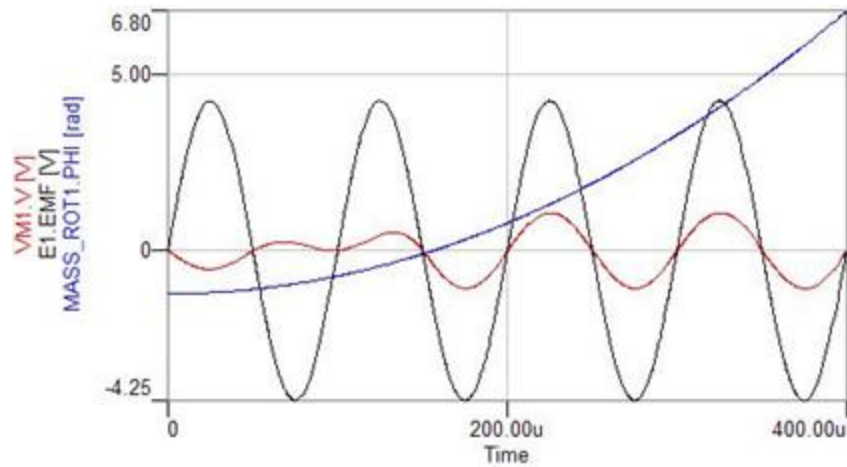


Figure 3. Simulation results-input and output voltages RVDT_VF2, and angular position of MASS_ROT1

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References

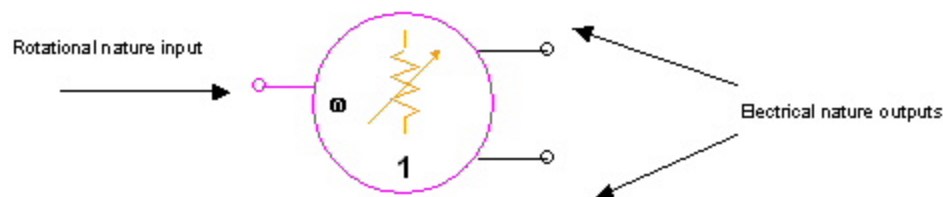
Level 1 Angular Velocity Sensor Models

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

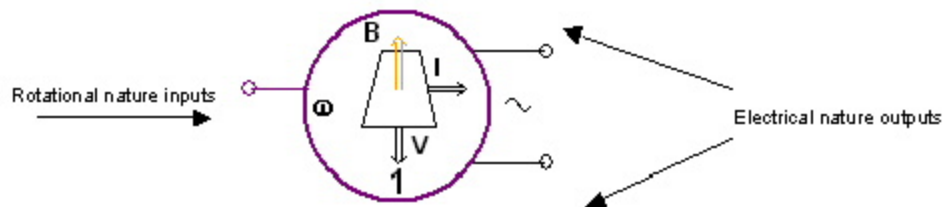
The Level 1 Angular Velocity Sensor Models simulate the ideal behavior of four different types of angular velocity sensors. Models are available for use with the Twin Builder *displacement-force* and *velocity-force* rotational domains.

All of the angular velocity sensor models have conservative input pins that must be connected to a rotational network and conservative output pins that must be connected to an electrical network. The models also feature non-conservative parameters that can be changed in order to tailor the behavior of the model to that of a specific real device.

As shown in the following example, angular velocity sensor models for the displacement-force rotational domain have pink conservative input pins that must be connected to a displacement-force rotational network. The models also have black conservative pins that must be connected to an electrical network.



Similarly, angular velocity sensor models for the velocity-force rotational domain have purple rotational nature input pins and black electrical nature pins.



The Level 1 Angular Velocity Sensor Models feature models for the following angular velocity sensing mechanisms:

- Hall-Effect: A change in angular velocity produces a corresponding linear change in frequency of a *sinusoidal* or *pulsed* voltage output signal.

Displacement-Force Pulse Output model: ([HE_PULSE_OMEGA_DF](#))

Velocity-Force Pulse Output model: ([HE_PULSE_OMEGA_VF](#))

Displacement-Force Sinusoidal Output model: ([HE_SINE_OMEGA_DF](#))

Velocity-Force Sinusoidal Output model: ([HE_SINE_OMEGA_VF](#))

- Variable Reluctance: A change in angular velocity produces a change in the amplitude and frequency of a *sinusoidal* output voltage or a *linear* change in a conditional output signal.

Displacement-Force Linear Output model: (VR_OMEGA)

Velocity-Force Linear Output model: (VR_OMEGA_VF)

Displacement-Force Sinusoidal Output model: (VR_OMEGA_SINE_DF)

Velocity-Force Sinusoidal Output model: (VR_OMEGA_SINE_VF)

Level 1 Hall-Effect (Pulse Output) Angular Velocity Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

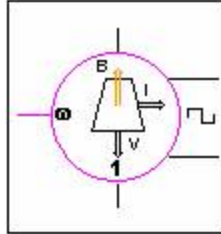


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Description

The Level 1 Hall-Effect (Pulse Output) Angular Velocity (Displacement-Force) sensor model is used to simulate the ideal behavior of a pulse-output, Hall-effect angular velocity sensor in the Twin Builder displacement-force rotational domain. A change in the angular velocity of an element in the displacement-force rotational domain that is connected to the model's input causes a corresponding change in the frequency of the model's pulsed voltage output signal.

The model has one conservative input pin in the displacement-force rotational domain for its angular velocity input and four conservative electrical-domain pins, two for power supply connections and two for the pulsed voltage output. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is grounded.

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Netlist Syntax

```
MODEL HE_PULSE_OMEGA_DF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
OMEGA:= %0, OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 ( max_omega:= @max_
omega, min_omega:= @min_omega, frequency_offset:= @frequency_offset, num_gear_
teeth:= @num_gear_teeth, phase:= @phase, offset:= @offset, amplitude:= @amplitude, sup-
ply_current:= @supply_current) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
OMEGA	Measured angular velocity	Rotational
OUT_P	Positive output	Electrical
OUT_M	Negative output	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
phase	Phase shift of the output sinusoid	Real	0 [rad]
offset	DC offset of the pulse output	Real	0 [V]
amplitude	Amplitude of the	Real	5 [V]

	pulse output		
max_omega	Maximum measurable angular velocity	Real	628.318530717959k [rad/s]
min_omega	Minimum measurable angular velocity	Real	0 [rad/s]
frequency_offset	Output frequency at the minimum angular velocity	Real	0 [Hz]
num_gear_teeth	Number of teeth on measured gear	Real	20
supply_current	Supply current	Real	0.5m [A]

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Example

In this example, the Hall-Effect (Pulse Output) Angular Velocity (Displacement-Force) sensor HE_PULSE_OMEGA_DF1 measures the angular velocity of the Mass MASS_ROT1. The change in the measurement results causes a corresponding change in the frequency of the sinusoidal voltage output of HE_PULSE_OMEGA_DF1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3

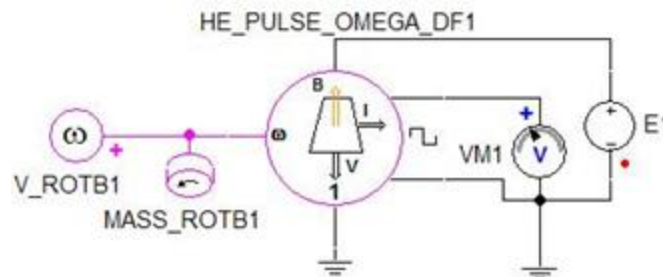


Figure 2. Application example of the Hall-Effect (Pulse Output) Angular Velocity (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]

Angular Velocity Source V_ROT B1	VALUE	5k * (t/400u) [rad/s]
Mass MASS_ROT B1	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Hall-Effect (Pulse Output) Angular Velocity (Displacement-Force) sensor HE_PULSE_OMEGA_DF1	phase	0 [rad]
	offset	2.2 [V]
	amplitude	0.3 [V]
	max_omega	5k [rad/s]
	min_omega	0 [rad/s]
	frequency_offset	0 [Hz]
	num_gear_teeth	20
	supply_current	14.5m [A]
Voltage Source E1	EMF	5 [V]

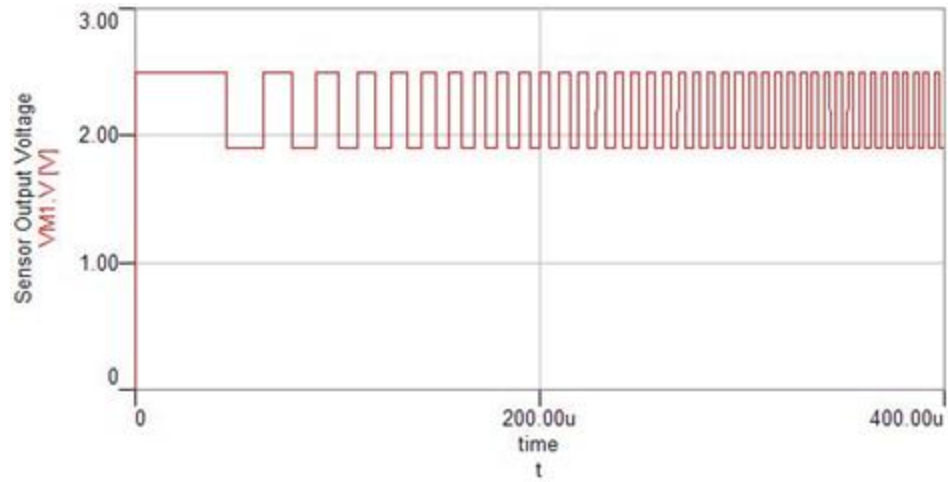


Figure 3. Simulation results-output voltage of HE_PULSE_OMEGA_DF1

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References

Level 1 Hall-Effect (Sinusoidal Output) Angular Velocity Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

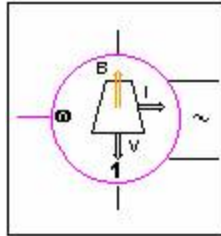


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Description

The Level 1 Hall-Effect (Sinusoidal Output) Angular Velocity (Displacement-Force) sensor model is used to simulate the ideal behavior of a sinusoidal-output, Hall-effect angular velocity sensor in the Twin Builder displacement-force rotational domain. A change in the angular velocity of an element in the displacement-force rotational domain that is connected to the model's input causes a corresponding change in the frequency of the model's sinusoidal voltage output signal.

The model has one conservative input pin in the displacement-force rotational domain for its angular velocity input and four conservative electrical-domain pins, two for power supply connections and two for the sensor output voltage. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is grounded.

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Netlist Syntax

```
MODEL HE_SINE_OMEGA_DF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
OMEGA:= %0, OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 ( max_omega:= @max_
omega, min_omega:= @min_omega, frequency_offset:= @frequency_offset, num_gear_
teeth:= @num_gear_teeth, phase:= @phase, offset:= @offset, amplitude:= @amplitude, sup-
ply_current:= @supply_current) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
OMEGA	Measured angular velocity	Rotational
OUT_P	Positive output	Electrical
OUT_M	Negative output	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
phase	Phase shift of the output sinusoid	Real	0 [rad]
offset	DC offset of the sinusoidal output	Real	0 [V]
amplitude	Amplitude of the	Real	5 [V]

	sinusoidal output		
max_omega	Maximum measurable angular velocity	Real	628.318530717959k [rad/s]
min_omega	Minimum measurable angular velocity	Real	0 [rad/s]
frequency_offset	Output frequency at the minimum angular velocity	Real	0 [Hz]
num_gear_teeth	Number of teeth on measured gear	Real	20
supply_current	Supply current	Real	0.5m [A]

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Example

In this example, the Hall-Effect (Sinusoidal Output) Angular Velocity (Displacement-Force) sensor HE_SINE_OMEGA_DF1 measures the angular velocity of the Mass MASS_ROT B1. The change in the measurement results causes a corresponding change in the frequency of the sinusoidal voltage output of HE_SINE_OMEGA_DF1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

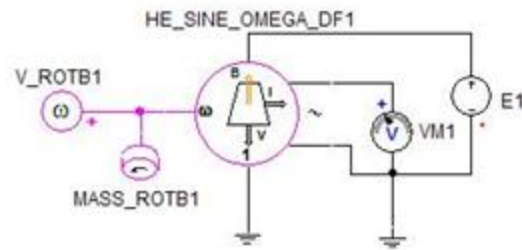


Figure 2. Application example of the Hall-Effect (Sinusoidal Output) Angular Velocity (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROTB1	VALUE	10k + 10k * (t>=200u) [rad/s]
Mass MASS_ROTB1	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Hall-Effect (Sinusoidal Output) Angular Velocity (Displacement-Force) sensor HE_SINE_OMEGA_DF1	phase	0 [rad]
	offset	0 [V]
	amplitude	0.9 * E1.EMF [V]
	max_omega	20k [rad/s]
	min_omega	1k [rad/s]
	frequency_offset	0 [Hz]
	num_gear_teeth	1

	supply_cur- rent	0.5m [A]
Voltage Source E1	EMF	5 [V]

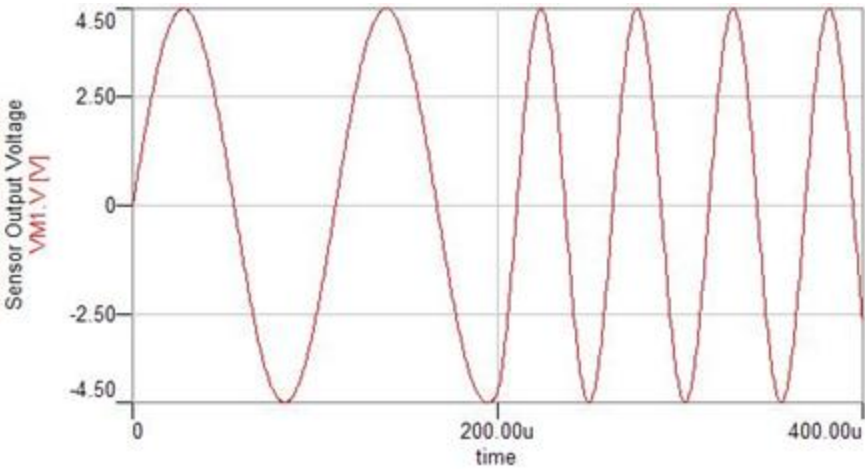


Figure 3. Simulation results-output voltage of HE_SINE_OMEGA_DF1

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References

Level 1 Variable Reluctance Angular Velocity Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

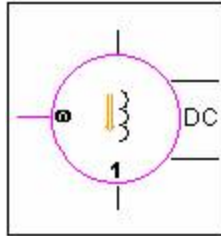


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Description

The Level 1 Variable Reluctance Angular Velocity (Displacement-Force) sensor model is used to simulate the ideal behavior of a conditioned variable reluctance angular velocity sensor in the Twin Builder displacement-force rotational domain. A change in angular velocity of an element in the displacement-force rotational domain that is connected to the model's input causes a corresponding change in the model's linear voltage output signal.

The model has one conservative input pin in the displacement-force rotational domain for its angular velocity input and four conservative electrical-domain pins, two for power supply connections and two for the sensor output voltage. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is grounded.

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Netlist Syntax

```
MODEL VR_OMEGA ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) OMEGA:= %0,  
Vdd:= %1, Vss:= %2, OUT_P:= %3, OUT_M:= %4 ( full_scale_span:= @full_scale_span, off-  
set:= @offset, max_omega:= @max_omega, min_omega:= @min_omega, supply_current:=  
@supply_current) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
OMEGA	Measured angular velocity	Rotational
OUT_P	Positive output	Electrical
OUT_M	Negative output	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
full_ scale_ span	Difference of the output voltages at the maximum and minimum measurable angular velocities	Real	10 [V]
max_	Maximum measurable angular velo-	Real	10 [rad/s]

omega	city		
min_ omega	Minimum measurable angular velocity	Real	0 [rad/s]
supply_ current	Supply current	Real	0.5m [A]

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Example

In this example, the Variable Reluctance Angular Velocity (Displacement-Force) sensor VR_OMEGA1 measures the angular velocity of the Mass MASS_ROT1. The linear voltage output of VR_OMEGA1 changes in response to the measurement results. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

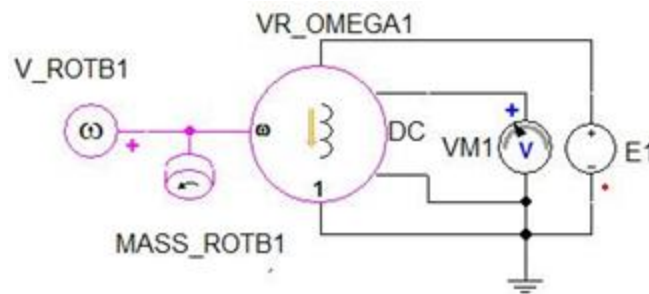


Figure 2. Application example of the Variable Reluctance Angular Velocity (Displacement-Force) Sensor

Table 3

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROT B1	VALUE	110 * (t/40m) [rad/s]
Mass MASS_ROT B1	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Voltage Source E1	EMF	5 [V]
Variable Reluctance Angular Velocity (Displacement-Force) sensor VR_OMEGA1	offset	0.1 * E1.EMF [V]
	full_scale_span	0.9 * E1.EMF [V]
	max_omega	100 [rad/s]
	min_omega	0 [rad/s]

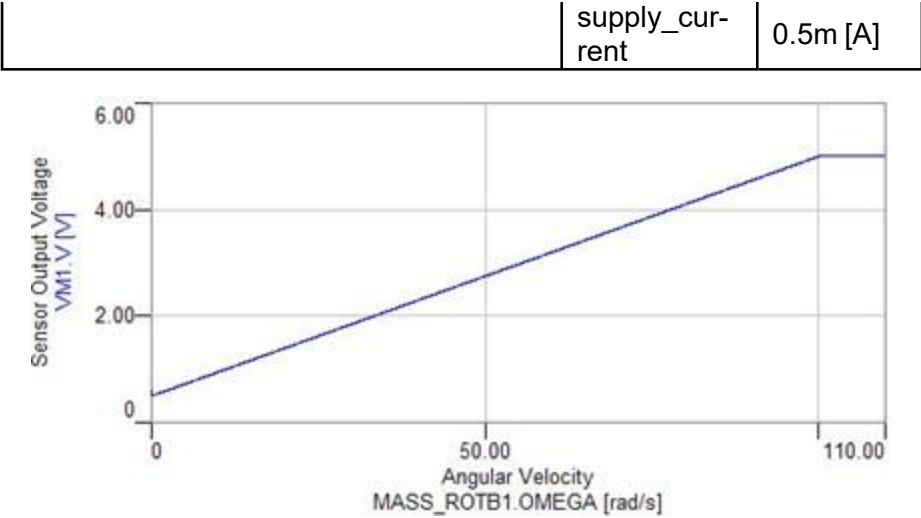


Figure 3. Simulation results-output voltage of VR_OMEGA1 vs. its angular velocity input

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References

Level 1 Variable Reluctance (Sinusoidal Output) Angular Velocity Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

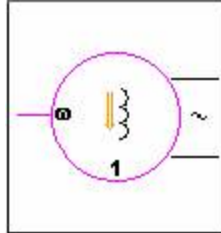


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Description

The Level 1 Variable Reluctance (Sinusoidal Output) Angular Velocity (Displacement-Force) sensor model is used to simulate the ideal behavior of a variable reluctance gear angular velocity sensor in the Twin Builder displacement-force rotational domain. The model produces a sinusoidal output whose amplitude and frequency are dependent on the angular velocity of a rotating gear, the diameter of the gear, and the number of teeth on the gear.

The model has one conservative input pin in the displacement-force rotational domain for its angular velocity input and two conservative electrical-domain pins for its sinusoidal voltage output. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is grounded.

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Netlist Syntax

```
MODEL VR_OMEGA_SINE_DF ?InstanceName(@InstanceName):(@ (Refbase)@(ID))  
OMEGA:= %0, OUT_P:= %1, OUT_M:= %2 ( max_surface_speed:= @max_surface_speed,  
min_surface_speed:= @min_surface_speed, gear_diameter:= @gear_diameter, num_gear_  
teeth:= @num_gear_teeth, full_scale_span:= @full_scale_span, phase:= @phase) SRC: DB  
(Lib:=@ModelLibraryName);
```

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Table 1

Name	Port/Terminal Description	Nature/Data type
OMEGA	Measured angular velocity	Rotational
OUT_P	Positive output	Electrical
OUT_M	Negative output	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
phase	Sensor phase shift	Real	0 [rad]
full_scale_span	Difference in peak-to-peak voltages at maximum and minimum measurable angular velocities	Real	30 [V]
max_surface_speed	Maximum measurable surface speed	Real	100 [m/s]
min_surface_speed	Minimum measurable surface speed	Real	20 [m/s]
gear_diameter	Diameter of sensed gear	Real	50m [m]
num_gear_teeth	Number of teeth on sensed gear	Real	50

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Example

In this example, the Variable Reluctance (Sinusoidal Output) Angular Velocity (Displacement-Force) sensor VR_OMEGA_SINE_DF1 measures the angular velocity of the Mass MASS_ROT2. VR_OMEGA_SINE_DF1 produces a sinusoidal output whose amplitude and frequency are dependent on measurement results. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

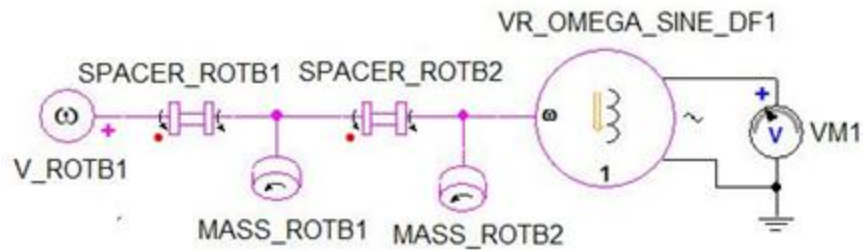


Figure 2. Application example of the Variable Reluctance Angular Velocity (Displacement-Force) Sensor

Table 3

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROT B1	VALUE	$33.3 * (t \geq 200\mu) + 33.3 * (t \geq 400\mu) + 33.4 * (t \geq 600\mu)$ [rad/s]
Spacer SPACER_ROT B1/ SPACER_ROT B2	LEN	0 [rad]
Mass MASS_ROT B1	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Mass MASS_ROT B2	J	2 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Variable Reluctance (Sinusoidal Output) Angular Velocity (Displacement-Force) sensor VR_OMEGA_SINE_DF1	phase	0 [rad]
	full_scale_span	175 [V]
	max_sur-	25.4 [m/s]

	face_speed	
	min_surface_speed	0 [m/s]
	gear_diameter	100m [m]
	num_gear_teeth	100

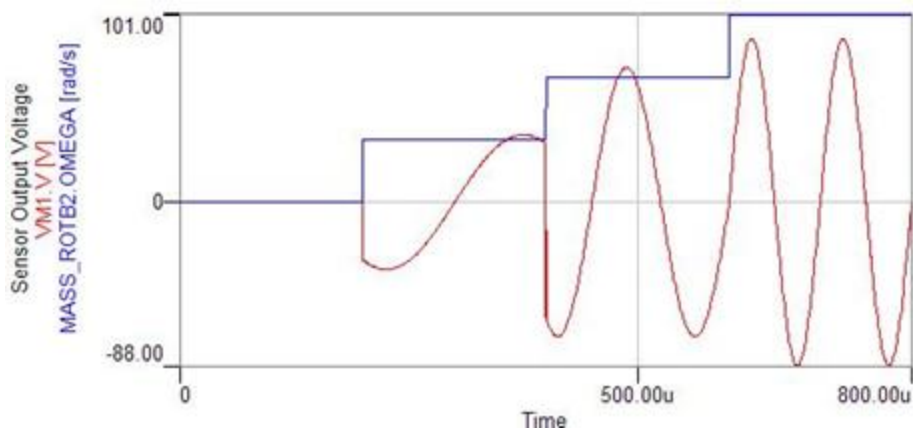


Figure 3. Simulation results-output voltage of VR_OMEGA_SINE_DF1 and the angular velocity of MASS_ROT B2

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References

Level 1 Hall-Effect (Pulse Output) Angular Velocity Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

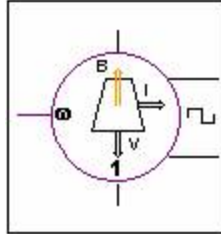


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Description

The Level 1 Hall-Effect (Pulse Output) Angular Velocity (Velocity-Force) sensor model is used to simulate the ideal behavior of a pulse-output, Hall-effect angular velocity sensor in the Twin Builder velocity-force rotational domain. A change in the angular velocity of an element in the velocity-force rotational domain that is connected to the model's input causes a corresponding change in the frequency of the model's pulsed voltage output signal.

The model has one conservative input pin in the velocity-force rotational domain for its angular velocity input and four conservative electrical-domain pins, two for power supply connections and two for the pulsed voltage output. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is grounded.

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Netlist Syntax

```
MODEL HE_PULSE_OMEGA_VF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))  
OMEGA:= %0, OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 ( max_omega:= @max_  
omega, min_omega:= @min_omega, frequency_offset:= @frequency_offset, num_gear_  
teeth:= @num_gear_teeth, phase:= @phase, offset:= @offset, amplitude:= @amplitude, sup-  
ply_current:= @supply_current) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
OMEGA	Measured angular velocity	Rotational_V
OUT_P	Positive output	Electrical
OUT_M	Negative output	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
phase	Phase shift of the output sinusoid	Real	0 [rad]
offset	DC offset of the pulse output	Real	0 [V]
amplitude	Amplitude of the	Real	5 [V]

	pulse output		
max_omega	Maximum measurable angular velocity	Real	628.318530717959k [rad/s]
min_omega	Minimum measurable angular velocity	Real	0 [rad/s]
frequency_offset	Output frequency at the minimum angular velocity	Real	0 [Hz]
num_gear_teeth	Number of teeth on measured gear	Real	20
supply_current	Supply current	Real	0.5m [A]

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Example

In this example, the Hall-Effect (Pulse Output) Angular Velocity (Velocity-Force) sensor HE_PULSE_OMEGA_VF1 measures the angular velocity of the Mass MASS_ROT1. The change in the measurement results causes a corresponding change in the frequency of the sinusoidal voltage output of HE_PULSE_OMEGA_VF1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3

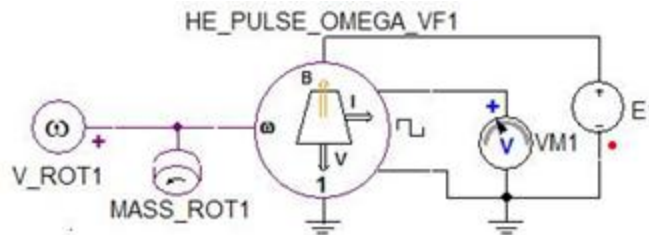


Figure 2. Application example of the Hall-Effect (Pulse Output) Angular Velocity (Velocity-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROT1	VALUE	5k *

		(t/400u) [rad/s]
Mass MASS_ROT1	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Hall-Effect (Pulse Output) Angular Velocity (Velocity-Force) sensor HE_PULSE_OMEGA_VF1	phase	0 [rad]
	offset	2.2 [V]
	amplitude	0.3 [V]
	max_omega	5k [rad/s]
	min_omega	0 [rad/s]
	frequency_offset	0 [Hz]
	num_gear_teeth	20
	supply_current	14.5m [A]
Voltage Source E1	EMF	5 [V]

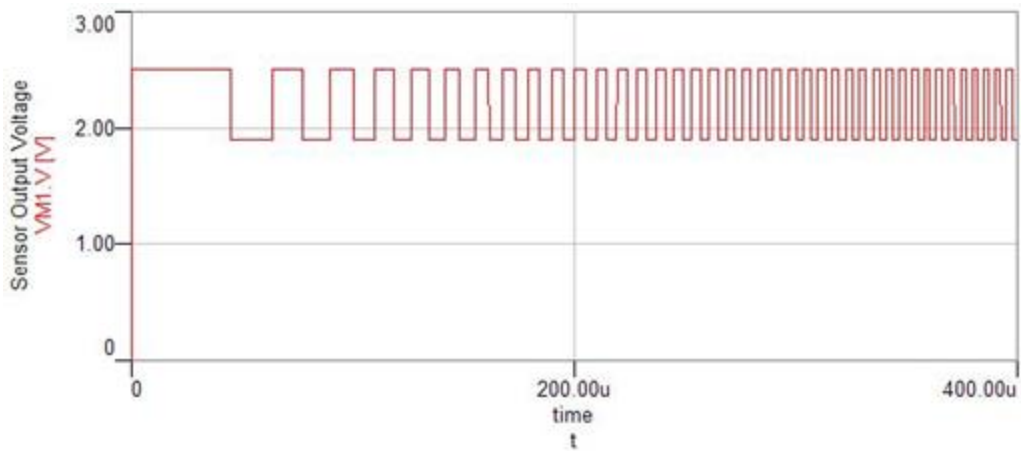


Figure 3. Simulation results-output voltage of HE_PULSE_OMEGA_VF1

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References

Level 1 Hall-Effect (Sinusoidal Output) Angular Velocity Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

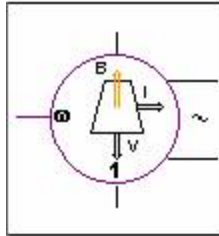


Figure 1. Component symbol

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Description

The Level 1 Hall-Effect (Sinusoidal Output) Angular Velocity (Velocity-Force) sensor model is used to simulate the ideal behavior of a sinusoidal-output, Hall-effect angular velocity sensor in the Twin Builder velocity-force rotational domain. A change in the angular velocity of an element in the velocity-force rotational domain that is connected to the model's input causes a corresponding change in the frequency of the model's sinusoidal voltage output signal.

The model has one conservative input pin in the velocity-force rotational domain for its angular velocity input and four conservative electrical-domain pins, two for power supply connections and two for the sensor output voltage. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is grounded.

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Netlist Syntax

```
MODEL HE_SINE_OMEGA_VF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
OMEGA:= %0, OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 ( max_omega:= @max_
omega, min_omega:= @min_omega, frequency_offset:= @frequency_offset, num_gear_
teeth:= @num_gear_teeth, phase:= @phase, offset:= @offset, amplitude:= @amplitude, sup-
ply_current:= @supply_current) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
OMEGA	Measured angular velocity	Rotational_V
OUT_P	Positive output	Electrical
OUT_M	Negative output	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
phase	Phase shift of the output sinusoid	Real	0 [rad]
offset	DC offset of the sinusoidal output	Real	0 [V]
amplitude	Amplitude of the	Real	5 [V]

	sinusoidal output		
max_omega	Maximum measurable angular velocity	Real	628.318530717959k [rad/s]
min_omega	Minimum measurable angular velocity	Real	0 [rad/s]
frequency_offset	Output frequency at the minimum angular velocity	Real	0 [Hz]
num_gear_teeth	Number of teeth on measured gear	Real	20
supply_current	Supply current	Real	0.5m [A]

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Example

In this example, the Hall-Effect (Sinusoidal Output) Angular Velocity (Velocity-Force) sensor HE_SINE_OMEGA_VF1 measures the angular velocity of the Mass MASS_ROT1. The change in the measurement results causes a corresponding change in the frequency of the sinusoidal voltage output of HE_SINE_OMEGA_VF1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

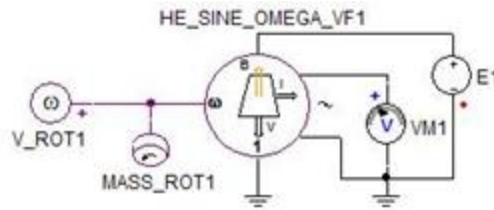


Figure 2. Application example of the Hall-Effect (Sinusoidal Output) Angular Velocity (Velocity-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROT1	VALUE	10k+10k* (t>=200u) [rad/s]
Mass MASS_ROT1	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Hall-Effect (Sinusoidal Output) Angular Velocity (Velocity-Force) sensor HE_SINE_OMEGA_VF1	phase	0 [rad]
	offset	0 [V]
	amplitude	0.9 * E1.EMF [V]
	max_omega	20k [rad/s]
	min_omega	1k [rad/s]
	frequency_offset	0 [Hz]
	num_gear_teeth	1
	supply_cur-	10m [A]

	rent	
Voltage Source E1	EMF	5 [V]

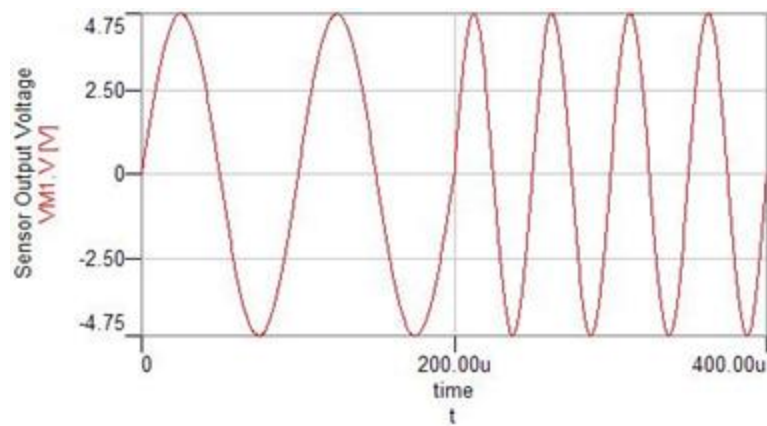


Figure 3. Simulation results-output voltage of HE_SINE_OMEGA_VF1

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References

Level 1 Variable Reluctance Angular Velocity Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

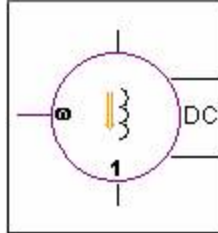


Figure 1. Component symbol

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Description

The Level 1 Variable Reluctance Angular Velocity (Velocity-Force) sensor model is used to simulate the ideal behavior of a conditioned variable reluctance angular velocity sensor in the Twin Builder velocity-force rotational domain. A change in angular velocity of an element in the velocity-force rotational domain that is connected to the model's input causes a corresponding change in the model's linear voltage output signal.

The model has one conservative input pin in the velocity-force rotational domain for its angular velocity input and four conservative electrical-domain pins, two for power supply connections and two for the sensor output voltage. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is grounded.

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Netlist Syntax

MODEL VR_OMEGA_VF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) OMEGA:= %0, Vdd:= %1, Vss:= %2, OUT_P:= %3, OUT_M:= %4 (full_scale_span:= @full_scale_span, offset:= @offset, max_omega:= @max_omega, min_omega:= @min_omega, supply_current:= @supply_current) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
OMEGA	Measured angular velocity	Rotational_V
OUT_P	Positive output	Electrical
OUT_M	Negative output	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
full_scale_span	Difference of the output voltages at the maximum and minimum measurable angular velocities	Real	10 [V]
max_	Maximum measurable angular velo-	Real	10 [rad/s]

omega	city		
min_omega	Minimum measurable angular velocity	Real	0 [rad/s]
supply_current	Supply current	Real	0.5m [A]

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Example

In this example, the Variable Reluctance Angular Velocity (Velocity-Force) sensor VR_OMEGA_VF1 measures the angular velocity of the Mass MASS_ROT1. The linear voltage output of VR_OMEGA_VF1 changes in response to the measurement results. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

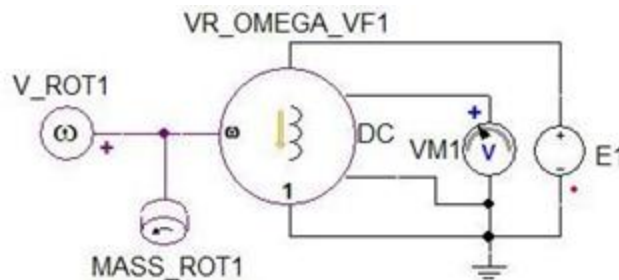


Figure 2. Application example of the Variable Reluctance Angular Velocity (Displacement-Force) Sensor

Table 3

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROT1	VALUE	110 * (t/40m) [rad/s]
Mass MASS_ROT1	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]

Voltage Source E1	EMF	5 [V]
Variable Reluctance Angular Velocity (Velocity-Force) sensor VR_OMEGA_VF1	offset	0.1 * E1.EMF [V]
	full_scale_span	0.9 * E1.EMF [V]
	max_omega	100 [rad/s]
	min_omega	0 [rad/s]
	supply_current	0.5m [A]

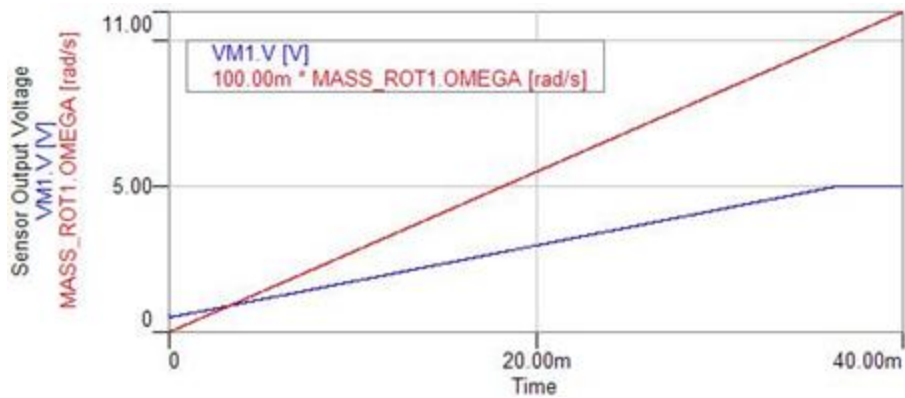


Figure 3. Simulation results-output voltage of VR_OMEGA_VF1 and the angular velocity of MASS_ROT1

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References

Level 1 Variable Reluctance (Sinusoidal Output) Angular Velocity Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

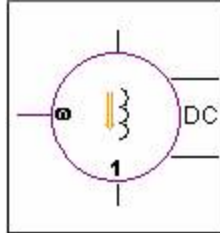


Figure 1. Component symbol

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Description

The Level 1 Variable Reluctance (Sinusoidal Output) Angular Velocity (Velocity-Force) sensor model is used to simulate the ideal behavior of a variable reluctance gear angular velocity sensor in the Twin Builder Velocity-Force rotational domain. The model produces a sinusoidal output whose amplitude and frequency are dependent on the angular velocity of a rotating gear, the diameter of the gear, and the number of teeth on the gear.

The model has one conservative input pin in the Velocity-Force rotational domain for its angular velocity input and two conservative electrical-domain pins for its sinusoidal voltage output. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is grounded.

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Netlist Syntax

MODEL VR_OMEGA_SINE_VF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
OMEGA:= %0, OUT_P:= %1, OUT_M:= %2 (max_surface_speed:= @max_surface_speed,
min_surface_speed:= @min_surface_speed, gear_diameter:= @gear_diameter, num_gear
teeth:= @num_gear_teeth, full_scale_span:= @full_scale_span, phase:= @phase) SRC: DB
(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
OMEGA	Measured angular velocity	Rotational_V
OUT_P	Positive output	Electrical
OUT_M	Negative output	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
phase	Sensor phase shift	Real	0 [rad]
full_scale_span	Difference in peak-to-peak voltages at maximum and minimum measurable angular velocities	Real	30 [V]
max_surface_speed	Maximum measurable surface speed	Real	100 [m/s]
min_surface_speed	Minimum measurable surface speed	Real	20 [m/s]
gear_diameter	Diameter of sensed gear	Real	50m [m]
num_gear_teeth	Number of teeth on sensed gear	Real	50

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Example

In this example, the Variable Reluctance (Sinusoidal Output) Angular Velocity (Velocity-Force) sensor VR_OMEGA_SINE_VF1 measures the angular velocity of the Mass MASS_ROT2. VR_OMEGA_SINE_VF1 produces a sinusoidal output whose amplitude and frequency are dependent on measurement results. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

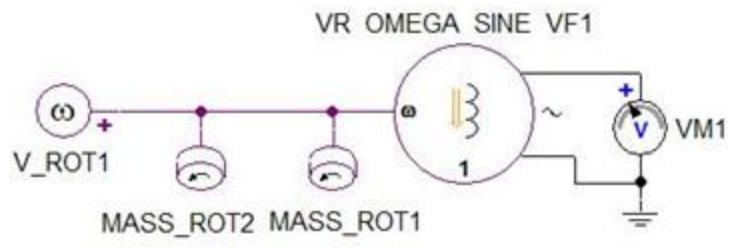


Figure 2. Application example of the Variable Reluctance Angular Velocity (Velocity-Force) Sensor

Table 3

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROT1	VALUE	$33.3 * (t \geq 200u) + 33.3 * (t \geq 400u) + 33.4 * (t \geq 600u)$ [rad/s]
	J	1 [kg m]
	PHI0	0 [rad]
Mass MASS_ROT1/MASS_ROT2	OMEGA0	0 [rad/s]
	phase	0 [rad]
	full_scale_span	175 [V]
Variable Reluctance (Sinusoidal Output) Angular Velocity (Velocity-Force) sensor VR_OMEGA_SINE_VF1	max_surface_speed	25.4 [m/s]
	min_surface_speed	0 [m/s]
	gear_diameter	100m [m]
	num_gear_	100

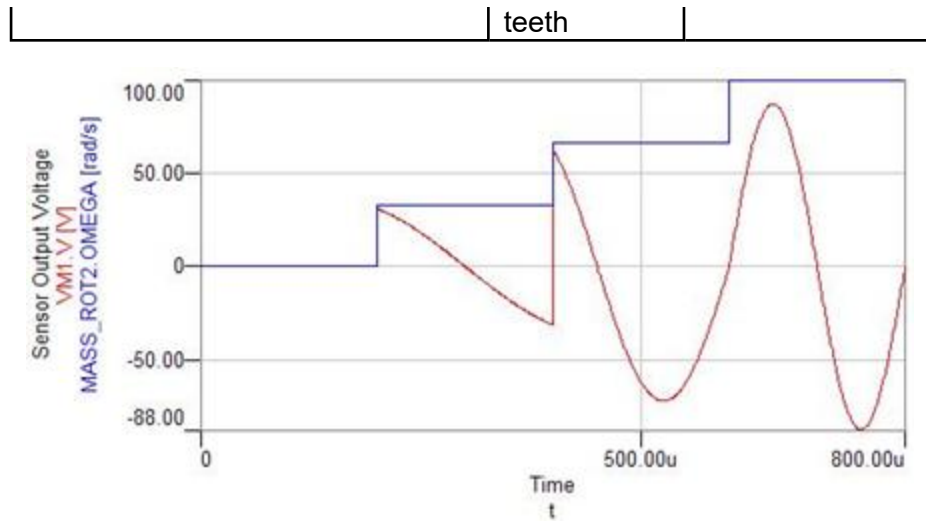


Figure 3. Simulation results-output voltage of VR_OMEGA_SINE_VF1 and the angular velocity of MASS_ROT2

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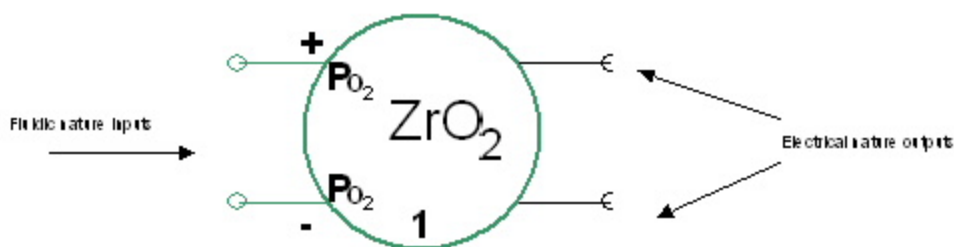
References

Level 1 Exhaust Gas Sensor Models

The Level 1 Exhaust Gas Sensor Models simulate the ideal behavior of automotive exhaust gas sensors.

All of the exhaust gas sensor models have conservative input pins that must be connected to a fluidic network and conservative output pins that must be connected to an electrical network. The models also feature non-conservative parameters that can be changed in order to tailor the behavior of the model to that of a specific real device.

As shown in the following example, Exhaust Gas sensor models for the fluidic domain have green conservative input pins that must be connected to a fluidic network. The models also have black pins that must be connected to an electrical network.



The Level 1 Exhaust Gas Sensor Model features a model for the following Exhaust Gas-sensing mechanism:

- Zirconium Oxide ([NERNST_ZrO2_LE1](#)) -- produces a voltage output signal that is proportional to the natural logarithm of the ratio of the partial pressure of oxygen in the surrounding atmosphere to the partial pressure of oxygen in exhaust gas.

Level 1 Zirconium Oxide (Lambda=1) Exhaust Gas Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

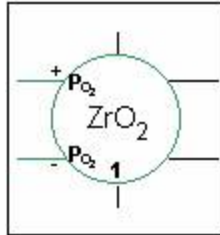


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Description

The Level 1 Zirconium Oxide (Lambda=1) exhaust gas Sensor model simulates the ideal behavior of a Zirconium Oxide exhaust gas sensor. The model produces a voltage signal that is proportional to the natural logarithm of the ratio of the partial pressure of oxygen in the surrounding atmosphere to the partial pressure of oxygen in exhaust gas.

The model has two conservative fluidic-nature pins, one each for the oxygen partial pressures in the atmosphere and in the measured exhaust gas. The model also has four conservative electrical-nature pins, two for the positive and negative power supplies and two for its voltage output. The negative output terminal should be connected to ground if the model is connected to an electrical network in which no other element is grounded.

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Netlist Syntax

```
MODEL NERNST_ZrO2_LE1 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) AIR:=
%0, EXHAUST:= %1, Vdd:= %2, Vss:= %3, OUT_P:= %4, OUT_N:= %5 ( temp:= @temp, cur-
rent_scale_factor:= @current_scale_factor) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
AIR	Atmospheric oxygen partial pres- sure	Fluidic
EXHAUST	Exhaust gas oxygen partial pres- sure	Fluidic
OUT_P	Positive output terminal	Electrical
OUT_N	Negative output terminal	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
temp	Absolute tem- perature	Real	300 [K]
current_scale_factor	Input conductivity	Real	0.2 [S]

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Example

In this example, the Zirconium Oxide (Lambda=1) Exhaust Gas Sensor NERNST_ZrO2_LE11 measures the oxygen partial pressures in the atmosphere and in the measured exhaust gas. The output voltage of NERNST_ZrO2_LE11 is proportional to the natural logarithm of the ratio of the measurement results. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

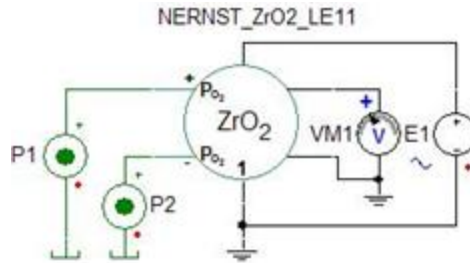


Figure 2. Application example of the Zirconium Oxide (Lambda=1) Exhaust Gas Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	8.47E-32 [Pa]
Pressure Source P2	VALUE	21.778k [Pa]
Zirconium Oxide (Lambda=1) Exhaust Gas Sensor NERNST_ZrO2_LE11	temp	493 [K]
	current_scale_factor	0.104 [S]
Voltage Source (sinusoidal) E1	AMPL	17 [V]
	FREQ	60 [Hz]
	PHASE	0 [degree]
	OFF	0 [V]

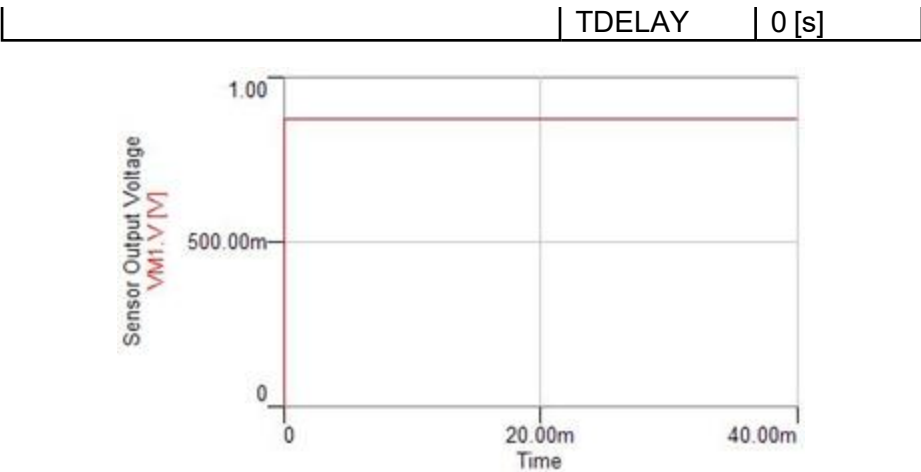


Figure 3. Simulation results-output voltage of NERNST_ZrO2_LE11

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References

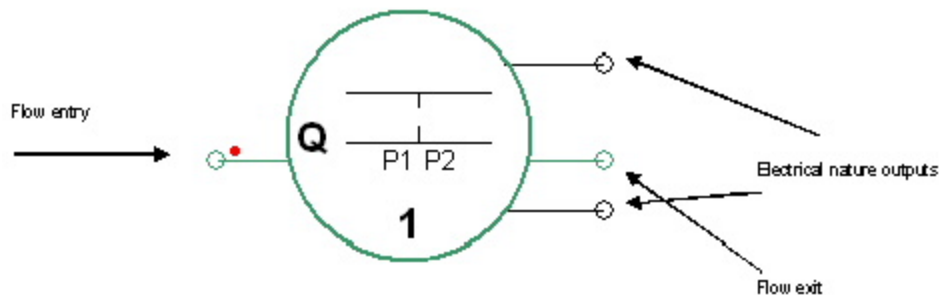
Level 1 Flow Sensor Models

The Level 1 Flow Sensor Models simulate the ideal behavior of four different types of flow sensors.

All of the flow sensor models have conservative pins that must be connected to a fluidic network. Note that because flow is a through quantity, all flow sensor models have one fluidic pin for flow entry and another pin for flow exit.

Like other sensor models, the flow sensor models also have conservative output pins that must be connected to an electrical network and non-conservative parameters that can be changed in order to tailor the behavior of the model to that of a specific real device.

As shown in the following example, the Level 1 Flow Sensor Models have green conservative pins that must be connected to a fluidic network. The pin with the red dot indicates the pin through which the measured flow enters. The models also have black pins that must be connected to an electrical network.



The Level 1 Flow Sensor Models feature models for the following flow-sensing mechanisms:

- Differential Pressure ([FLOW_DP](#)): The sensor causes a small pressure drop across itself and produces an output voltage that is proportional to the square root of this pressure drop.
- Vane ([FLOW_VANE](#)): Fluid flow deflects a vane, which in turn adjusts the wiper of a potentiometer, producing a voltage output signal. The deflection of the vane, and thus the output signal voltage, is proportional to the amount of flow.
- Karmen Vortex ([KVORTEX_FLOW](#)): Fluid flow generates vortices within the sensor, which generate a pulsed output voltage signal. The frequency of the pulsed output is proportional to the flow through the sensor.
- Strain Gauge ([SG_FLOW](#)): Flow deforms resistors connected in a Wheatstone bridge configuration, producing a differential voltage output.
- Thermal Mass-Flow ([T_M_FLOW](#)): The sensor produces a voltage output that is proportional to the amount of mass moving through the sensor.
- Turbine: Flow turns a turbine within the sensor, producing a DC Output, or a pulse or sinusoidal (AC Output) voltage.
AC Output model: ([TURBINE_FLOW](#))
DC Output model: ([TURBINE_FLOW_DC](#))

Level 1 Differential Pressure Flow Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

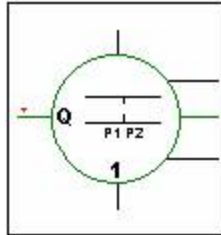


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Description

The Level 1 Differential Pressure Flow Sensor model simulates the ideal behavior of a differential pressure flow sensor. The model produces a voltage output signal that varies linearly with the flow moving through it.

The model has two conservative fluidic-nature pins through which flow enters and exits. The model also has four conservative electrical-nature pins, two for its power supply connections and two for its voltage output. The negative output terminal should be connected to ground if the model is connected to an electrical network in which no other element is grounded.

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Netlist Syntax

```
MODEL FLOW_DP ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) FLOW_IN:= %0,  
FLOW_OUT:= %1, OUT_P:= %2, OUT_M:= %3, Vdd:= %4, Vss:= %5 ( sensor_conductance:=  
@sensor_conductance, sensitivity:= @sensitivity, offset:= @offset, max_output:= @max_out-  
put, min_output:= @min_output, supply_current:= @supply_current) SRC: DB(Lib:-  
:=@ModelLibraryName);
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
FLOW_P	Flow entry	Fluidic
FLOW_M	Flow exit	Fluidic
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
supply_current	Typical supply current	Real	1m [A]
max_output	Maximum output	Real	5 [V]
min_output	Minimum output	Real	0 [V]
offset	Sensor output voltage at min-	Real	0 [V]

	imum flow		
sensor_conductance	Hydraulic conductance of the sensor	Real	1m [m ² / (Pa s)]
sensitivity	Sensitivity to the square root of the differential pressure	Real	1 [V/ (Pa) ^{1/2}]

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Example

In this example, the Differential Pressure Flow Sensor FLOW_DP2 measures the flow through the Linear Orifice RHYD1, and the output voltage of FLOW_DP2 varies linearly with the measurement result. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

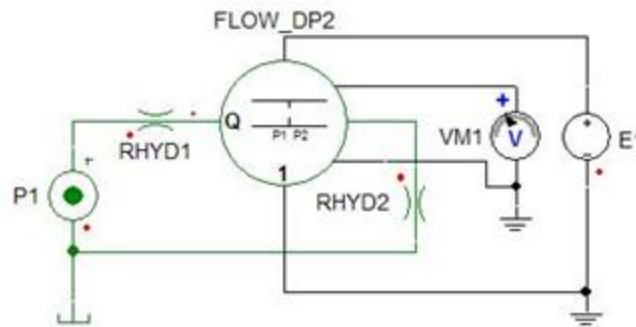


Figure 2. Application example of the Differential Pressure Flow Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	25Meg * (t/50m) [Pa]
Linear Orifice RHYD1	K	1u [k/(Pa s)]
Voltage Source E1	EMF	5 [V]
Differential Pressure Flow Sensor FLOW_DP2	supply_current	500u [A]
	max_output	E1.EMF [V]
	min_output	0 [V]

	offset	0 [V]
	sensor_conductance	1m [m ² /(Pa s)]
	sensitivity	50m [V/(Pa) ^{1/2}]

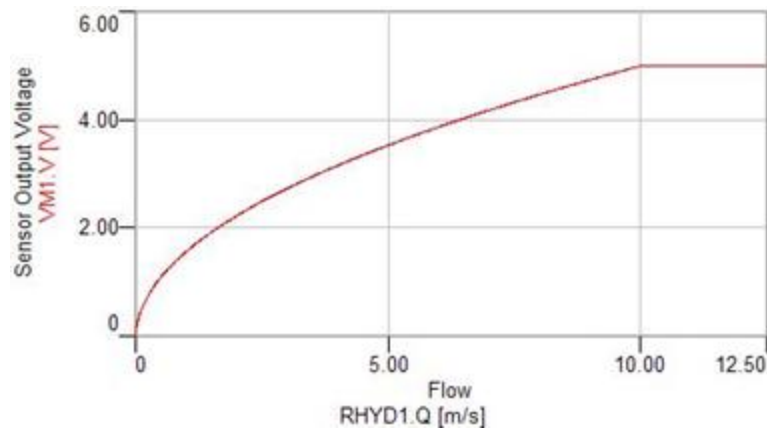


Figure 3. Simulation results-output voltage of FLOW_DP2 vs. its flow input

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References

Level 1 Vane Flow Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

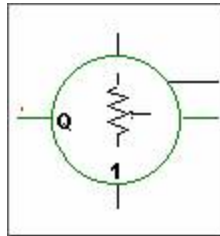


Figure 1. Component symbol

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Description

The Level 1 Vane Flow Sensor model simulates the ideal behavior of a potentiometric vane flow sensor. The voltage divider output of the model changes linearly in response to a change in flow.

The model has two conservative fluidic-nature pins through which flow enters and exits. The model also has three conservative electrical-nature pins: two to connect the model to its power supplies and one for the model's output.

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Mathematical Description

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Netlist Syntax

```
MODEL FLOW_VANE ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) FLOW_P:= %0,  
FLOW_M:= %1, Vdd:= %2, Vss:= %3, OUT:= %4 ( max_flow:= @max_flow, min_flow:= @min_  
flow, full_scale_span:= @full_scale_span, offset:= @offset, p_resistance:= @p_resistance)  
SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
FLOW_P	Flow entry	Fluidic
FLOW_M	Flow exit	Fluidic
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical
OUT	Output	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor output voltage at minimum flow	Real	0 [V]
potentiometer_resistance	Resistance of potentiometer	Real	10k [Ohm]
max_flow	Maximum measurable flow	Real	1 [m ² /s]
min_flow	Minimum measurable flow	Real	0 [m ² /s]
full_scale_span	Difference of outputs at maximum and minimum flows	Real	10 [V]

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Example

In this example, the Vane Flow Sensor FLOW_VANE1 measures the flow through the Linear Orifice RHYD1, and the output voltage of FLOW_VANE1 changes linear in response to the measurement results. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

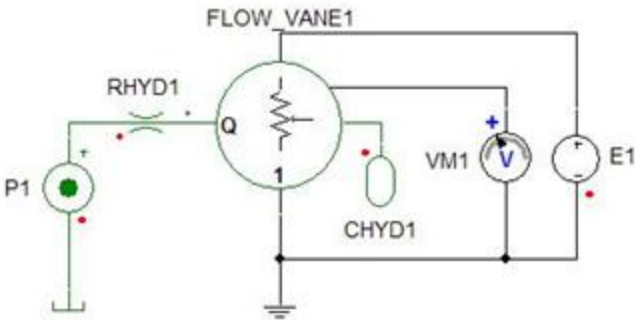


Figure 2. Application example of the Vane Flow Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	1Meg [Pa]
Linear Orifice RHYD1	K	1u [k/(Pa s)]
Hydraulic Capacitance CHYD1	VOL	10n [m]
	B	1 [Pa]
	P0	0 [Pa]
Voltage Source E1	EMF	20 [V]
Vane Flow Sensor FLOW_VANE1	offset	0.1 * E1.EMF [V]
	potentiometer_resistance	5k [Ohm]
	max_flow	0.75 [m ² /s]
	min_flow	0.5 [m ² /s]
	full_scale_span	0.9 * E1.EMF [V]

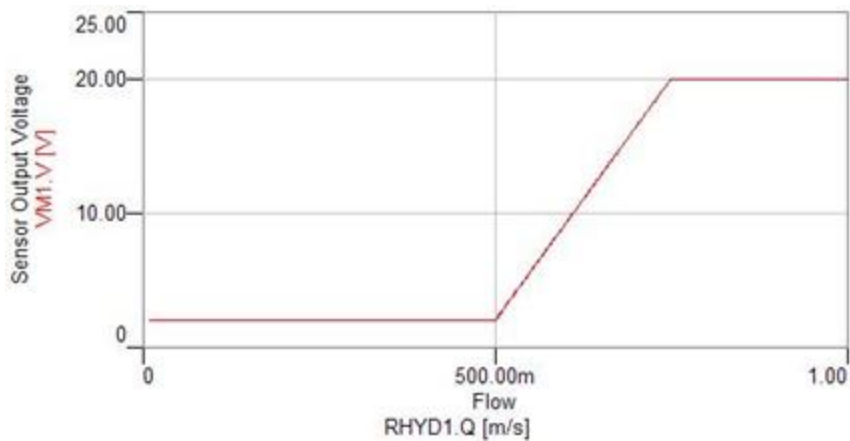


Figure 3. Simulation results-output voltage of FLOW_VANE1 vs. its flow input

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References

Level 1 Karmen Vortex Flow Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

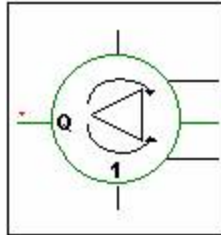


Figure 1. Component symbol

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Description

The Level 1 Karmen Vortex Flow Sensor model simulates the ideal behavior of a Karmen vortex flow sensor. The model produces a pulsed voltage output signal with its frequency proportional to the flow through the sensor.

The model has two conservative fluidic-nature pins through which flow enters and exits. The model also has four conservative electrical-nature pins, two for its power supply connections and two for its pulsed voltage output. The negative output terminal should be connected to ground if the model is connected to an electrical network in which no other element is grounded.

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Mathematical Description

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Netlist Syntax

```
MODEL KVORTEX_FLOW ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) FLOW_IN:=
%0, FLOW_OUT:= %1, OUT_P:= %2, OUT_M:= %3, Vdd:= %4, Vss:= %5 ( max_flow:=
@max_flow, min_flow:= @min_flow, full_scale_span:= @full_scale_span, phase:= @phase,
output_amplitude:= @output_amplitude, supply_current:= @supply_current) SRC: DB(Lib:-
:=@ModelLibraryName);
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
FLOW_IN	Flow entry	Fluidic
FLOW_OUT	Flow exit	Fluidic
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
phase	Phase shift of the output signal	Real	0 [rad]
max_flow	Maximum measurable flow	Real	1 [m ² /s]
min_flow	Minimum measurable flow	Real	0 [m ² /s]

full_scale_span	Difference of outputs at maximum and minimum flows	Real	10k [Hz]
output_amplitude	Amplitude of the output signal	Real	2.5 [V]
supply_current	Typical supply current	Real	1m [A]

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Example

In this example, the Karmen Vortex Flow Sensor KVORTEX_FLOW2 measures the flow through the Linear Orifice RHYD1, and the frequency of the pulse output voltage of KVORTEX_FLOW2 varies response to the measurement result. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

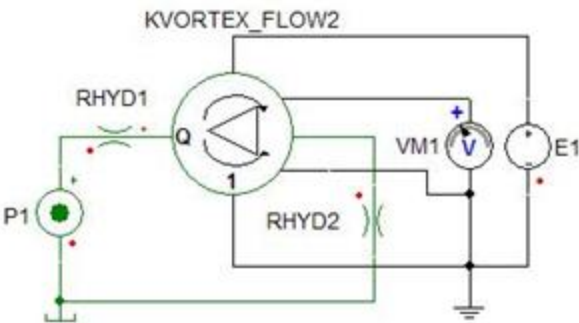


Figure 2. Application example of the Karmen Vortex Flow Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	83.34 * (t/40m) [Pa]
Linear Orifice RHYD1/RHYD2	K	1u [k/(Pa s)]
Voltage Source E1	EMF	20 [V]
Karmen Vortex Flow Sensor KVORTEX_FLOW2	phase	0 [rad]
	max_flow	41.67u [m ² /s]

	min_flow	5u [m ² /s]
	full_scale_span	750 [Hz]
	output_amplitude	E1.EMF [V]
	supply_current	500u [A]

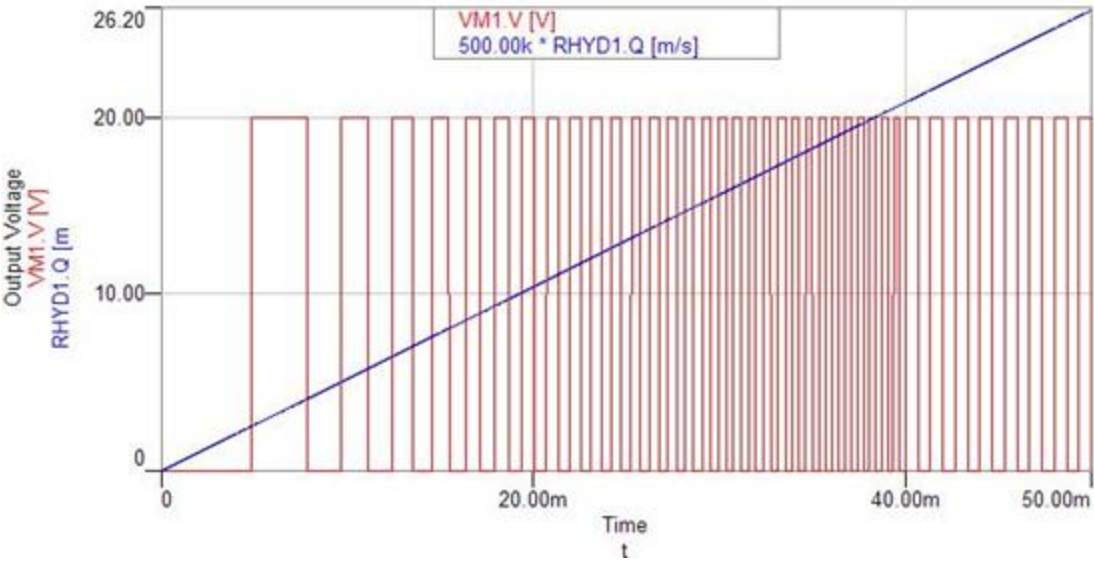


Figure 3. Simulation results-output voltage of KVORTEX_FLOW2
vs. the flow through RHYD1

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References

Level 1 Strain Gauge Flow Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

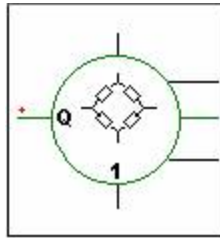


Figure 1. Component symbol

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Description

The Level 1 Strain gauge Flow Sensor model is used to simulate the ideal behavior of a strain-gauge flow sensor. A change in the flow through the sensor produces a corresponding change in the differential voltage output signal.

The Level 1 Strain Gauge Flow Sensor model has two conservative fluidic domain pins through which the measured flow enters and exits the sensor and four conservative electrical domain pins: two for the sensor's power supplies and two for the sensor's differential output.

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Mathematical Description

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Netlist Syntax

```
MODEL SG_FLOW ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) FLOW_IN:= %0,
FLOW_OUT:= %1, Vdd:= %2, Vss:= %3, OUT_P:= %4, OUT_M:= %5 ( max_flow:= @max_
flow, min_flow:= @min_flow, full_scale_span:= @full_scale_span, offset:= @offset, bridge_res-
istance:= @bridge_resistance) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
FLOW_IN	Flow entry	Fluidic
FLOW_OUT	Flow exit	Fluidic
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive supply	Electrical
Vss	Negative supply	Electrical

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
bridge_res-istance	Bridge resistance	Real	10k [Ohm]
max_flow	Maximum measurable flow	Real	1 [m/s]
min_flow	Minimum measurable flow	Real	0 [m/s]

full_scale_span	Difference of maximum and minimum output voltages	Real	5 [V]

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Example

In this example, the Strain gauge Flow Sensor SG_FLOW1 measures the flow rate through the Linear Orifice RHYD1, and a change in the flow through the sensor produces a corresponding change in the differential voltage output signal. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

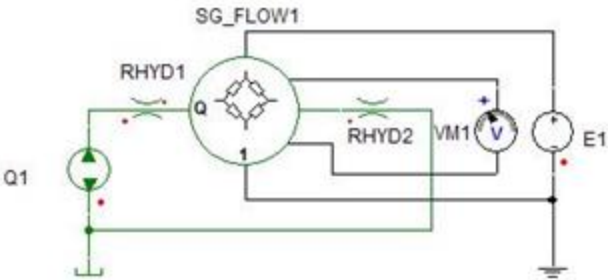


Figure 2. Application example of the Strain gauge Flow Sensor

Table 3

Component	Parameter	Value [Unit]
Flow Source Q1	VALUE	50u * (t/40m) [m/s]
Linear Orifice RHYD1/RHYD2	K	1n [k/(Pa s)]
Voltage Source E1	EMF	10 [V]
Strain gauge Flow Sensor SG_FLOW1	offset	0.1 * E1.EMF [V]
	bridge_resistance	5k [Ohm]
	max_flow	50u [m/s]
	min_flow	0 [m/s]

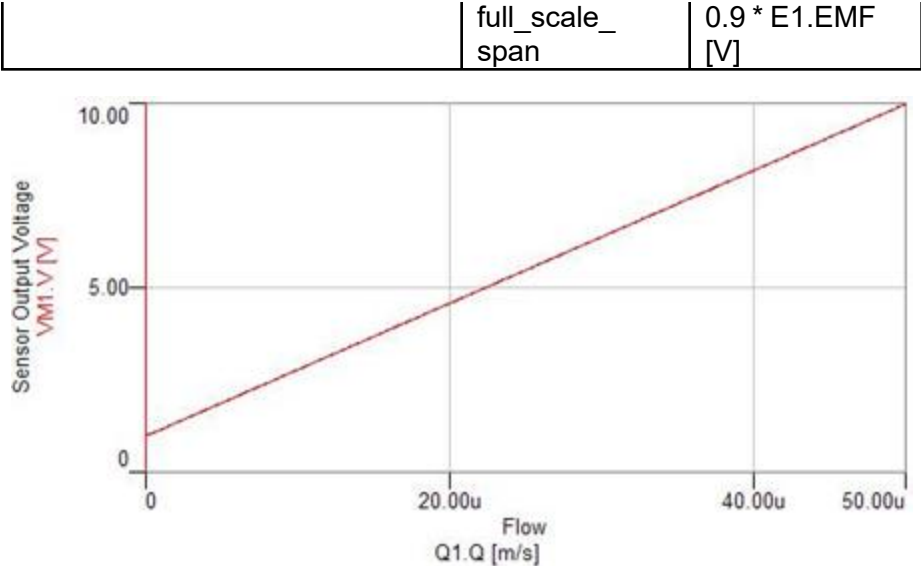


Figure 3. Simulation results-output voltage of SG_FLOW1
vs. the flow rate of Q1

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References

Level 1 Thermal Mass-Flow Flow Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

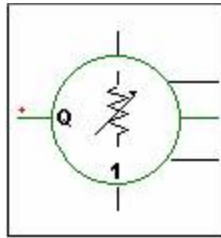


Figure 1. Component symbol

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Description

The Level 1 Thermal Mass-Flow Flow Sensor model simulates the ideal behavior of a thermal mass-flow flow sensor. The model produces a voltage signal that varies according to a user-defined characteristic with the mass or volume of fluid that flows through it. Fluid mass is determined in the model by multiplying the flow through the model by the specified density of the flowing fluid. Fluid density is entered into the model as a parameter through a non-conservative input node.

The model has two conservative fluidic-nature pins through which flow enters and exits. The model also has four conservative electrical-nature pins, two for its power supply connections and two for its voltage output. The negative output terminal should be connected to ground if the model is connected to an electrical network in which no other element is grounded.

The characteristic for the model should be entered via a .mdx file, which can be generated in several ways.

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Netlist Syntax

Netlist generated by [Special Component Dialog](#).

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
FLOW_IN	Flow entry	Fluidic
FLOW_OUT	Flow exit	Fluidic
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
fluid_density	Density of the fluid passing through the sensor	Real	1.225 [kg/m ²]
supply_current	Sensor supply current	Real	0.5m [A]
voltage_char	Sensor voltage-flow characteristic	file	0
calibrated	Sensor calibration (mass flow, volume flow)	Real	0

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Example

In this example, the Thermal Mass Flow Sensor T_M_FLOW2 measures the flow through the Linear Orifice RHYD1, and T_M_FLOW2 produces a voltage signal that varies according to a user-defined characteristic with the mass of fluid that flows through it. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

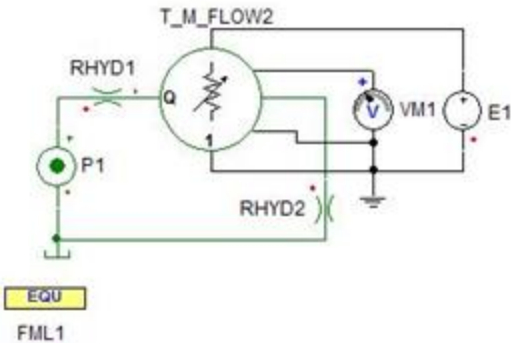


Figure 2. Application example of the Thermal Mass Flow Sensor

Table 3

Component	Parameter	Value [Unit]

Pressure Source P1	VALUE	0.5MEG * (t/50m) [Pa]
Linear Orifice RHYD1/RHYD2	K	1u [k/(Pa s)]
Voltage Source E1	EMF	14 [V]
Thermal Mass Flow Sensor T_M_FLOW2	fluid_density	1.225 [kg/m ²]
	supply_current	800m [A]
	voltage_char	bosch_adj.mdx
	calibrated	mass flow*

* defined by the Equation block FML2 as: $\text{mass\_flow}=1.225 * \text{RHYD1.Q}$

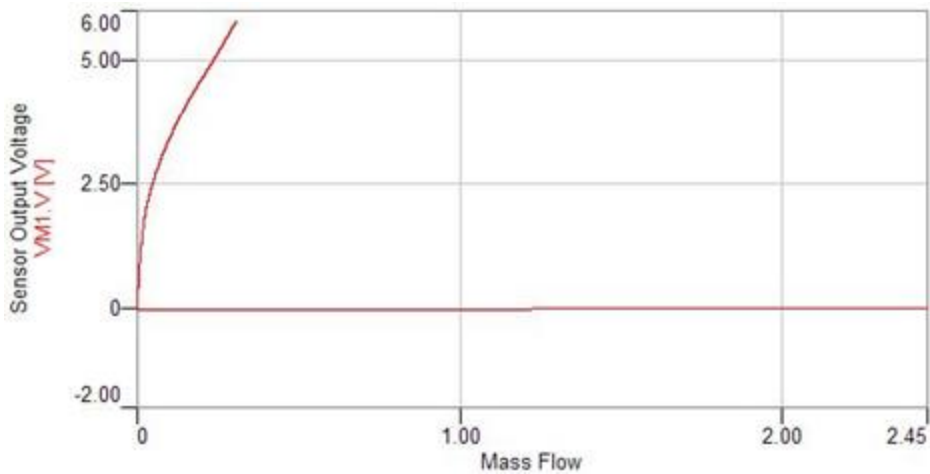


Figure 3. Simulation results-output voltage of T_M_FLOW2 vs. the mass flow through RHYD1

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References

Component Dialog Settings

The following Parameters are set in the Component Dialog for the **Level 1 Sensor Thermal Mass Flow Component**:

Name:

Specify the Name of the component instance. Select the **Show Name** checkbox to display the name on the schematic.

Parameters:

Device Parameters: Enter a numerical value, a variable, or an expression in the text box. Common parameter types. Look their meaning up in the parameter table.

Output Voltage Characteristic Input: The characteristic for the model should be entered via a .mdx file.

See *Characteristics in Simulation Models* in the main Twin Builder help.

Mass or Volume Flow Calibration: Select the calibration type, either **Mass Flow** or **Volume Flow**.

Outputs/Display

For information regarding displaying parameter pins, see *Output/Display Tab* in the main Twin Builder help.

Level 1 Turbine (AC Output) Flow Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

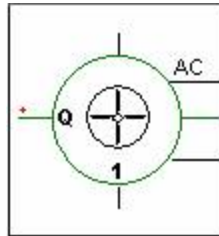


Figure 1. Component symbol

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Description

The Level 1 Turbine (AC Output) Flow Sensor model simulates the ideal behavior of a turbine flow sensor with an AC output. The model produces a pulse or sinusoidal output signal whose frequency varies with the flow moving through it.

The model has two conservative fluidic-nature pins through which flow enters and exits. The model also has two conservative electrical-nature pins for its voltage output and two for its positive and negative power supply pins. The negative output terminal for the output voltage should be connected to ground if the model is connected to an electrical network in which no other element is grounded.

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Netlist Syntax

Netlist generated by [Special Component Dialog](#).

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
FLOW_IN	Flow entry	Fluidic
FLOW_OUT	Flow exit	Fluidic
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
max_flow	Maximum measurable flow rate	Real	5 [m/s]
min_flow	Minimum measurable flow rate	Real	0 [m/s]
offset_frequency	Zero-flow frequency	Real	10k [Hz]
full_scale_span	Difference of maximum and minimum output frequencies	Real	100k [Hz]

amplitude	Amplitude of output voltage signal	Real	5 [V]
output_type	Shape of output (pulse or sinusoid)	Real	0
phase	Phase shift of output voltage	Real	0 [rad]
offset	DC offset of output voltage	Real	0 [V]
supply_current	Sensor supply current	Real	10m [A]

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Example

In this example, the Turbine (AC Output) Flow Sensor TURBINE_FLOW1 measures the flow rate through the Linear Orifice RHYD1, and the frequency of the pulse output voltage of TURBINE_FLOW1 varies response to the measurement result. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

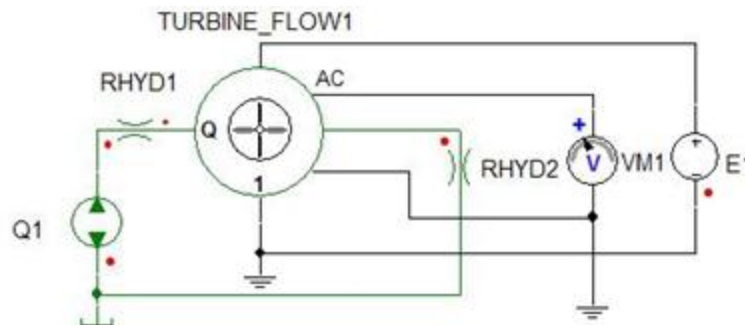


Figure 2. Application example of the Turbine (AC Output) Flow Sensor

Table 3

Component	Parameter	Value [Unit]
Flow Source Q1	VALUE	$50.1u * (t \geq 5m) + 584u * (t \geq 80m)$ [m/s]
Linear Orifice RHYD1/RHYD2	K	1n [k/(Pa s)]
Voltage Source E1	EMF	5 [V]

Turbine (AC Output) Flow Sensor TURBINE_FLOW1	max_flow	6.34E-4 [m/s]
	min_flow	5.01E-5 [m/s]
	offset_fre- quency	22.8 [Hz]
	full_scale_ span	266 [Hz]
	amplitude	5 [V]
	output_type	pulse
	phase	0 [rad]
	offset	0 [V]
	supply_cur- rent	1.5 [mA]

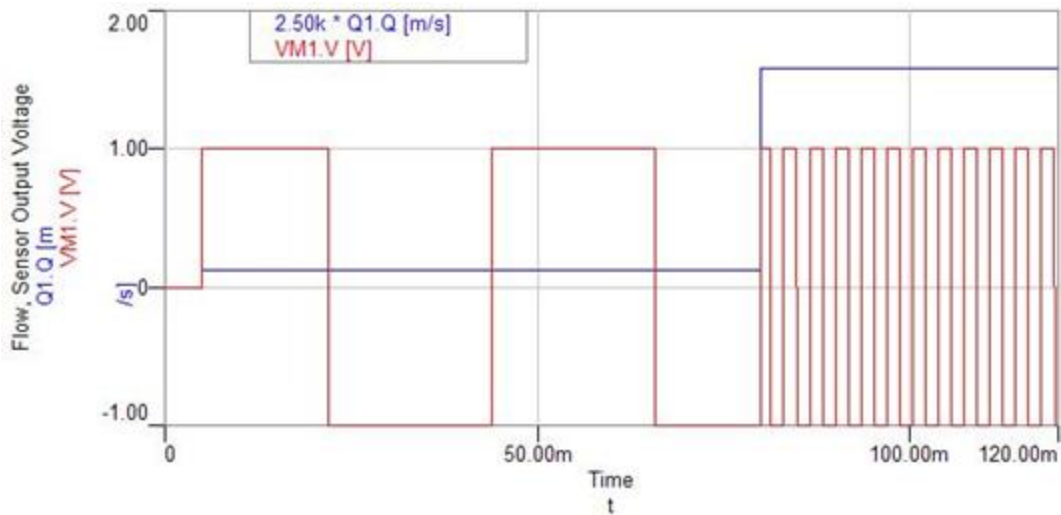


Figure 3. Simulation results-output voltage of TURBINE_FLOW1
And the flow rate of Q1

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References

Component Dialog Settings

The following Parameters are set in the Component Dialog for the **Level 1 Sensor Turbine Flow Component**:

Name:

Specify the Name of the component instance. Select the **Show Name** checkbox to display the name on the schematic.

Parameters:

Device Parameters: Enter a numerical value, a variable, or an expression in the text box. Common parameter types. Look their meaning up in the parameter table.

Output Signal Type: Select the output signal shape, either **Pulse** or **Sinusoidal**.

Outputs/Display

For information regarding displaying parameter pins, see *Output/Display Tab* in the main Twin Builder help.

Level 1 Turbine (DC Output) Flow Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

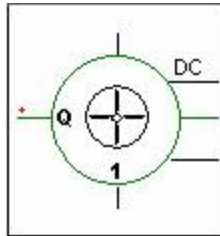


Figure 1. Component symbol

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Description

The Level 1 Turbine (DC Output) Flow Sensor model simulates the ideal behavior of a turbine flow sensor with a conditioned DC output. The model produces a DC output proportional to the flow moving through it.

The model has two conservative fluidic-nature pins through which flow enters and exits. The model also has two conservative electrical-nature pins for its voltage output and two for its positive and negative power supply pins. The negative output terminal for the output voltage should be connected to ground if the model is connected to an electrical network in which no other element is grounded.

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Mathematical Description

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Netlist Syntax

MODEL TURBINE_FLOW_DC ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) Vdd:= %0, Vss:= %1, OUT_P:= %2, OUT_M:= %3, FLOW_IN:= %4, FLOW_OUT:= %5 (supply_current:= @supply_current, max_flow:= @max_flow, min_flow:= @min_flow, full_scale_span:= @full_scale_span, offset:= @offset) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
FLOW_IN	Flow entry	Fluidic
FLOW_OUT	Flow exit	Fluidic
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
max_flow	Maximum measurable flow rate	Real	1 [m/s]
min_flow	Minimum measurable flow rate	Real	0.25 [m/s]
offset	Zero-flow voltage	Real	0 [V]
full_scale_	Difference of maximum and minimum output voltages	Real	5 [V]

span			
supply_ current	Sensor supply current	Real	10m [A]

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Example

In this example, the Turbine (DC Output) Flow Sensor TURBINE_FLOW_DC1 measures the flow rate through the Linear Orifice RHYD1, and TURBINE_FLOW_DC1 produces a DC output voltage proportional to the measurement result. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

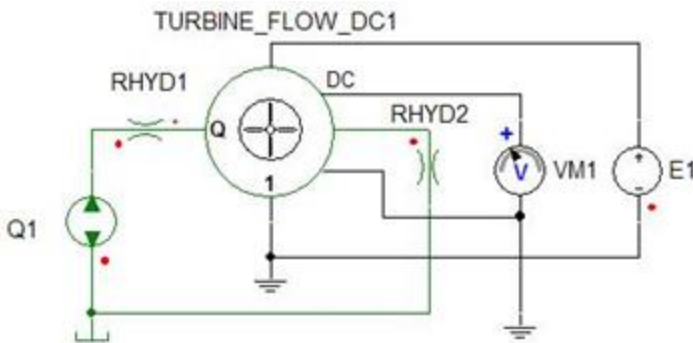


Figure 2. Application example of the Turbine (DC Output) Flow Sensor

Table 3

Component	Parameter	Value [Unit]
Flow Source Q1	VALUE	35u * (t/150m) [m/s]
Linear Orifice RHYD1/RHYD2	K	1n [k/(Pa s)]
Voltage Source E1	EMF	12 [V]
Turbine (DC Output) Flow Sensor TURBINE_FLOW_DC1	max_flow	33.333u [m/s]
	min_flow	1.66666u [m/s]
	offset	0 [V]

	full_scale_ span	5 [V]
	supply_cur- rent	30m [A]

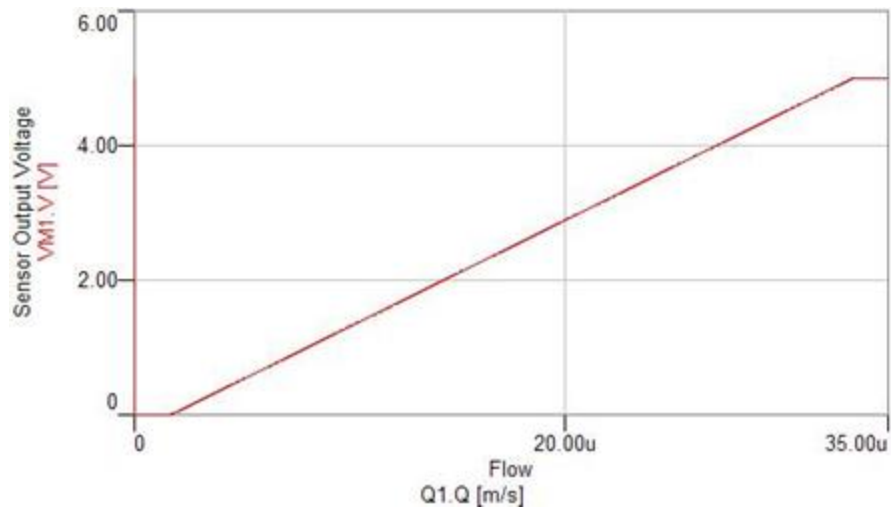


Figure 3. Simulation results-output voltage of TURBINE_FLOW_DC1 vs. the flow rate of Q1

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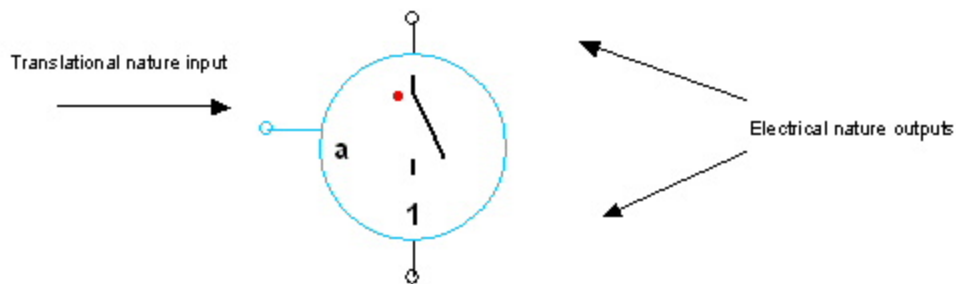
References

Level 1 Linear Acceleration Sensor Models

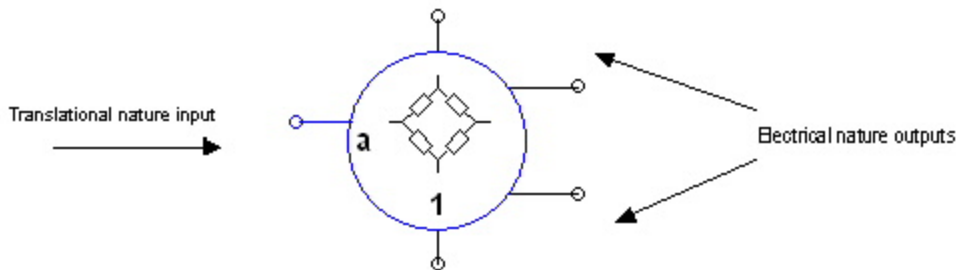
The Level 1 Linear Acceleration Sensor Models simulate the ideal behavior of four different types of linear acceleration sensors. Models are available for use with the Twin Builder *displacement-force* and *velocity-force* translational domains.

All of the linear acceleration sensor models have conservative input pins that must be connected to a translational network and conservative output pins that must be connected to an electrical network. The models also feature nonconservative parameters that can be changed in order to tailor the behavior of the model to that of a specific real device.

As shown in the following example, linear acceleration sensor models for the displacement-force translational domain have light blue conservative input pins that must be connected to a displacement-force translational network. The models also have black conservative pins that must be connected to an electrical network.



Similarly, linear acceleration sensor models for the velocity-force translational domain have dark blue translational-nature input pins and black electrical-nature pins.



The Level 1 Linear Acceleration Sensor Models feature models for the following linear acceleration sensing mechanisms:

- **Capacitive:** acceleration of the sensor causes the movement of the shared plate in a differential capacitor pair. The sensor responds by producing a change in its linear voltage output signal.
Displacement-Force model: ([C_ACC_DF](#))
Velocity-Force model: ([C_ACC_VF](#))
- **Piezoelectric:** acceleration of the sensor causes the deformation of a piezoelectric element which produces a corresponding voltage output signal.

Displacement-Force model: ([PE_ACC_DF](#))

Velocity-Force model: ([PE_ACC_VF](#))

- Piezoresistive: acceleration of the sensor causes the deformation of resistors connected in a Wheatstone bridge configuration, producing a corresponding differential voltage output signal.

Displacement-Force model: ([PR_ACC_DF](#))

Velocity-Force model: ([PR_ACC_VF](#))

- Inertia Switch: - a specified threshold acceleration causes a switch contained inside the sensor to change state from open to closed.

Displacement-Force model: ([TINERTIA_SWITCH_DF](#))

Velocity-Force model: ([TINERTIA_SWITCH_VF](#))

Level 1 Capacitive Linear Acceleration Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

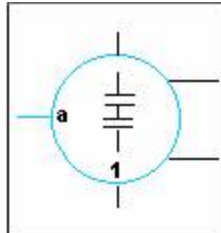


Figure 1. Component symbol

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- [Mathematical Description](#)
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Description

The Level 1 Capacitive Linear Acceleration (Displacement-Force) sensor model is used to simulate the ideal behavior of a conditioned capacitive linear acceleration sensor in the Twin Builder displacement-force translational domain. A change in the model's linear acceleration input produces a corresponding change in the model's linear voltage output.

The model has one conservative input pin in the displacement-force translational domain for its linear acceleration input and four conservative electrical-domain pins. Two of the pins are for the model's power supplies, and two are for its voltage output. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is connected to ground.

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Netlist Syntax

```
MODEL C_ACC_DF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) LINEAR:= %0,  
OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 ( max_ACC:= @max_ACC, min_ACC:=  
@min_ACC, full_scale_span:= @full_scale_span, offset:= @offset, supply_current:= @supply_  
current) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
LINEAR	Measured linear acceleration	Translational
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
max_ACC	Maximum measurable linear acceleration	Real	50 [m/s ²]
min_ACC	Minimum measurable linear acceleration	Real	0 [m/s ²]

full_ scale_ span	Difference of the output voltages at the maximum and minimum linear accelerations	Real	5 [V]
supply_ current	Supply current	Real	1m [A]

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Example

In this example, the Capacitive Linear Acceleration (Displacement-Force) sensor C_ACC_DF2 measures the linear velocity of the Mass MASS_TRB1. A change in the MASS_TRB1's acceleration input produces a corresponding change in C_ACC_DF2's linear voltage output. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

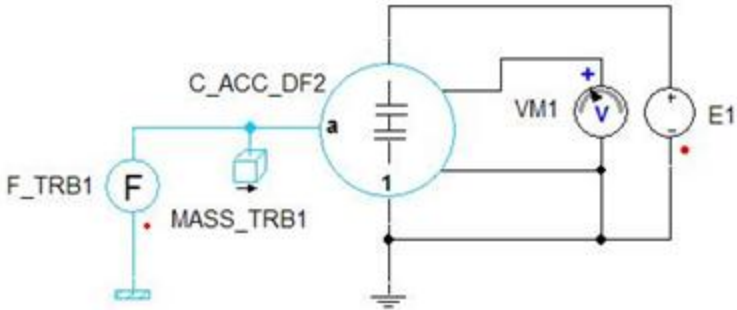


Figure 2. Application example of the Capacitive Linear Acceleration (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Force Source F_TRB1	VALUE	20 * (t/40m) [N]
Mass MASS_TRB1	m	1 [kg]
	S0	0 [m]
	V0	0 [m/s]

Capacitive Linear Acceleration (Displacement-Force) sensor C_ACC_DF2	offset	$0.1 * E1.EMF$ [V]
	max_ACC	18 [m/s ²]
	min_ACC	0 [m/s ²]
	full_scale_span	$0.8 * E1.EMF$ [V]
	supply_current	0.5m [A]
Voltage Source E1	EMF	5 [V]

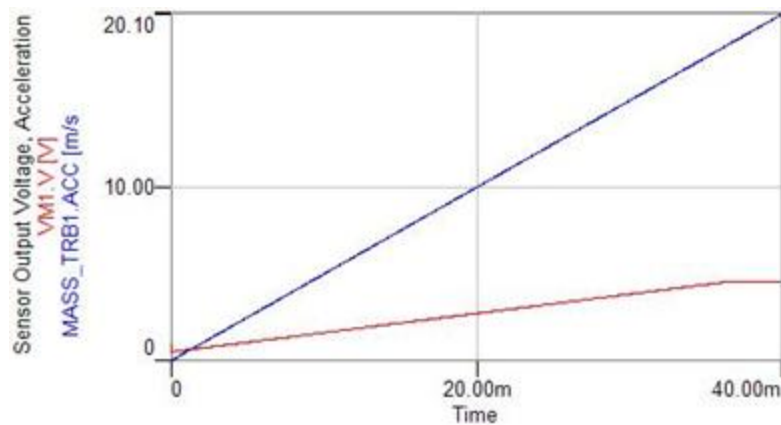


Figure 3. Simulation results-output voltage of C_ACC_DF1 and acceleration of MASS_TRB1

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References

Level 1 Piezoelectric Linear Acceleration Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

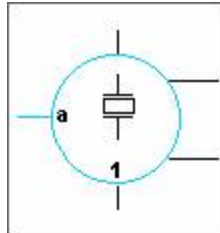


Figure 1. Component symbol

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Description

The Level 1 Piezoelectric Linear Acceleration (Displacement-Force) sensor model is used to simulate the ideal behavior of a piezoelectric linear acceleration sensor in the Twin Builder displacement-force translational domain. A change in the model's linear acceleration input produces a corresponding change in the model's linear voltage output.

The model has one conservative input pin in the displacement-force translational domain for its linear acceleration input and four conservative electrical-domain pins, two for its power supply connections and two for its voltage output. The negative output terminal should be connected to an electrical ground if the model is connected to an electrical network in which no other component is grounded.

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Netlist Syntax

```
MODEL PE_ACC_DF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) LINEAR:= %0,
OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 ( max_ACC:= @max_ACC, min_ACC:=
@min_ACC, full_scale_span:= @full_scale_span, offset:= @offset, supply_current:= @supply_
current) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
LINEAR	Measured linear acceleration	Translational
OUT_P	Positive terminal	Electrical
OUT_M	Negative terminal	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
max_ACC	Maximum measurable linear acceleration	Real	50 [m/s ²]
min_ACC	Minimum measurable linear acceleration	Real	0 [m/s ²]

full_ scale_ span	Difference of the output voltages at the maximum and minimum linear accelerations	Real	5 [V]
supply_ current	Supply current	Real	5m [A]

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Example

In this example, the Piezoelectric Linear Acceleration (Displacement-Force) sensor PE_ACC_DF1 measures the angular velocity of the Mass MASS_TRB1. A change in the MASS_TRB1's acceleration input produces a corresponding change in PE_ACC_DF1 's linear voltage output. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

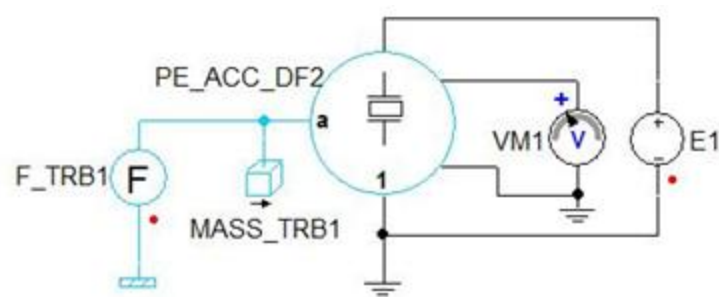


Figure 2. Application example of the Piezoelectric Linear Acceleration (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Force Source F_TRB1	VALUE	20 * t/40m [N]
Mass MASS_TRB1	m	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Piezoelectric Linear Acceleration (Dis-	offset	0.1 *

placement-Force) sensor PE_ACC_DF1		E1.EMF [V]
	max_ACC	18 [m/s ²]
	min_ACC	0 [m/s ²]
	full_scale_ span	0.8 * E1.EMF [V]
	supply_cur- rent	10m [A]
Voltage Source E1	EMF	10 [V]

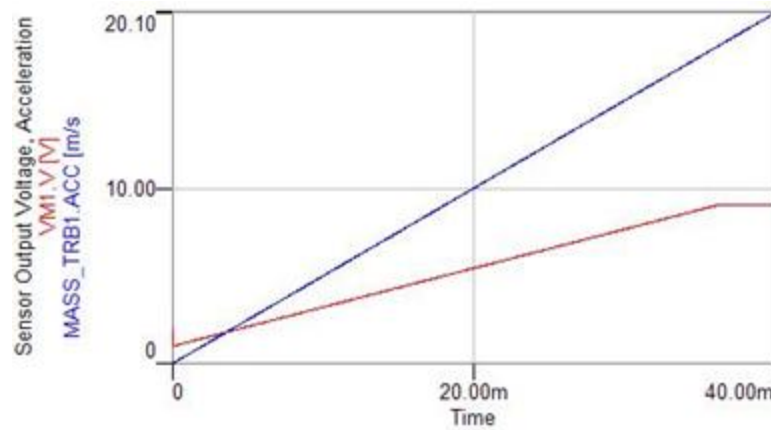


Figure 3. Simulation results-output voltage of PE_ACC_DF1 and acceleration of MASS_TRB1

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References

Level 1 Piezoresistive Linear Acceleration Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

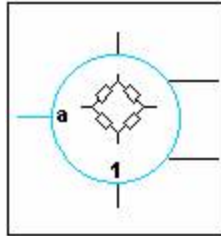


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Description

The Level 1 Piezoresistive Linear Acceleration (Displacement-Force) sensor model is used to simulate the ideal behavior of a piezoresistive linear acceleration sensor in the Twin Builder displacement-force translational domain. A change in the model's linear acceleration input produces a corresponding change in the model's Wheatstone bridge, which in turn produces a change in the model's linear voltage output.

The model has one conservative input pin in the displacement-force translational domain for its linear acceleration input and four conservative electrical-domain pins. Two of the pins are for the model's power supplies, and two are for its differential voltage output.

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Mathematical Description

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Netlist Syntax

MODEL PR_ACC_DF ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) LINEAR:= %0, OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 (max_ACC:= @max_ACC, min_ACC:= @min_ACC, full_scale_span:= @full_scale_span, offset:= @offset, p_resistance:= @p_resistance) SRC: DB(Lib:=@ModelLibraryName) ;

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Table 1

Name	Port/Terminal Description	Nature/Data type
LINEAR	Measured linear acceleration	Translational
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
max_ACC	Maximum measurable linear acceleration	Real	50 [m/s ²]
min_ACC	Minimum measurable linear acceleration	Real	0 [m/s ²]
full_scale_span	Difference of the output voltages at the maximum and minimum	Real	5 [V]

	linear accelerations		
p_res-istance	Bridge resistance	Real	10k [Ohm]

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Example

In this example, the Piezoresistive Linear Acceleration (Displacement-Force) sensor PR_ACC_DF1 measures the linear velocity of the Mass MASS_TRB1. A change in the MASS_TRB1's acceleration input produces a corresponding change in PR_ACC_DF1 's linear voltage output. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

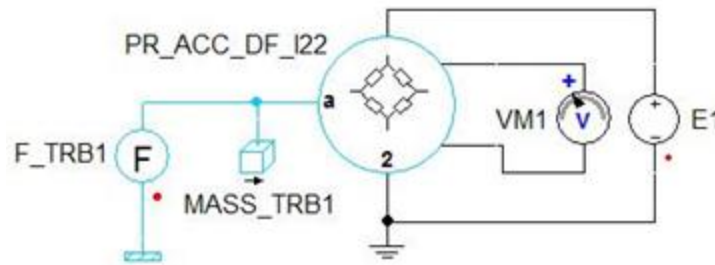


Figure 2. Application example of the Piezoresistive Linear Acceleration (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Force Source F_TRB1	VALUE	$20 * t/40m$ [N]
Mass MASS_TRB1	m	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Piezoresistive Linear Acceleration (Displacement-Force) sensor PR_ACC_DF1	offset	$0.1 * E1.EMF$ [V]
	max_ACC	18 [m/s ²]
	min_ACC	0 [m/s ²]
	full_scale_span	$0.8 * E1.EMF$ [V]
	supply_current	10m [A]
Voltage Source E1	EMF	10 [V]

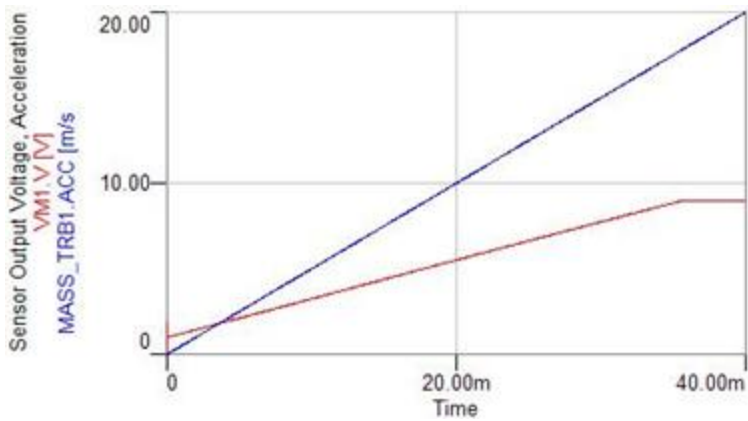


Figure 3. Simulation results-output voltage of PR_ACC_DF1 and acceleration of MASS_TRB1

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References

Level 1 Inertia Switch Linear Acceleration Sensor (Displacement-force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

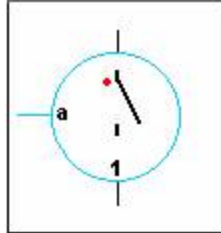


Figure 1. Component symbol

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Description

The Level 1 Inertia Switch Linear Acceleration (Displacement-Force) sensor model is used to simulate the ideal behavior of an inertia switch linear acceleration sensor in the Twin Builder displacement-force translational domain. When the linear acceleration applied to the sensor exceeds a specified threshold value, its switch changes state from open to close.

The model has one conservative input pin in the displacement-force translational domain for its linear acceleration input and two conservative electrical-domain pins for its positive and negative terminals. The positive terminal is the one into which current flows.

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Netlist Syntax

```
MODEL TINERTIA_SWITCH_DF ?InstanceName(@InstanceName):(@ (Refbase)@(ID))
LINEAR:= %0, np:= %1, nm:= %2 ( threshold:= @threshold) SRC: DB(Lib:-
:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
LINEAR	Measured linear acceleration	Translational
np	Positive terminal	Electrical
nm	Negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
threshold	Threshold linear acceleration of the switch	Real	50 [m/s ²]

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Example

In this example, the Inertia Switch Linear Acceleration (Displacement-Force) sensor TINERTIA_SWITCH_DF1 measures the linear acceleration of the Mass MASS_TRB1. When the acceleration of Mass MASS_TRB1 exceeds a specified threshold value, TINERTIA_SWITCH_DF1 switches from open to close. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

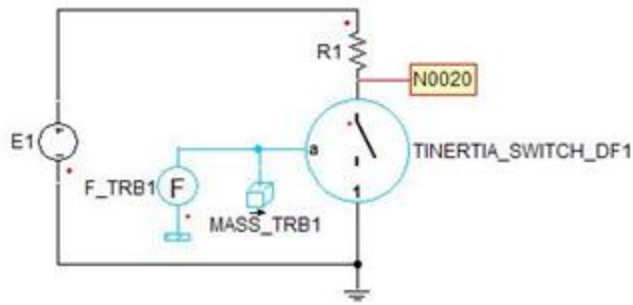


Figure 2. Application example of the Inertia Switch Linear Acceleration (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Force Source F_TRB1	VALUE	40 * (t/40m) [N]
Mass MASS_TRB1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Inertia Switch Linear Acceleration (Displacement-Force) sensor TINERTIA_SWITCH_DF1	threshold	4.5 [m/s ²]
Voltage Source E1	EMF	1 [V]
Resistor R1	R	1k [Ohm]

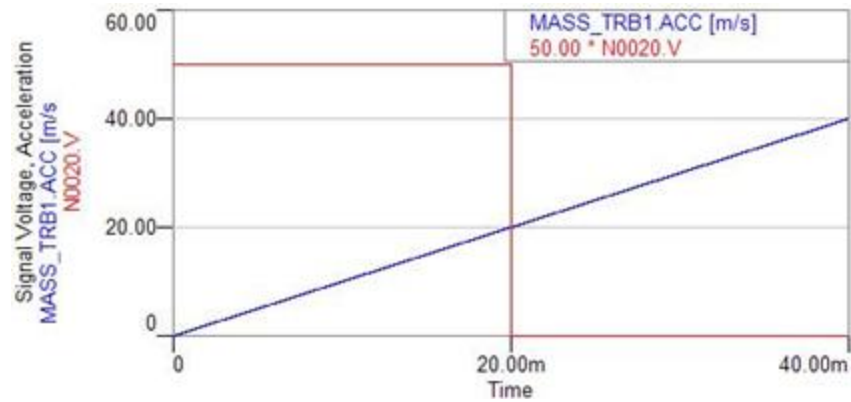


Figure 3. Simulation results-output voltage of TINERTIA_SWITCH_DF1(scaled) and acceleration of MASS_TRB1

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References

Level 1 Capacitive Linear Acceleration Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

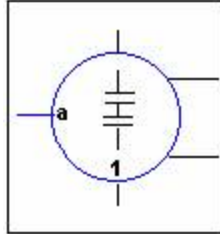


Figure 1. Component symbol

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Description

The Level 1 Capacitive Linear Acceleration (Velocity-Force) sensor model is used to simulate the ideal behavior of a conditioned capacitive linear acceleration sensor in the Twin Builder velocity-force translational domain. A change in the model's linear acceleration input produces a corresponding change in the model's linear voltage output.

The model has one conservative input pin in the velocity-force translational domain for its linear acceleration input and four conservative electrical-domain pins. Two of the pins are for the model's power supplies, and two are for its voltage output. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is connected to ground.

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Mathematical Description

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Netlist Syntax

```
MODEL C_ACC_VF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) OUT_P:= %0,
OUT_M:= %1, LINEAR:= %2, Vdd:= %3, Vss:= %4 ( max_ACC:= @max_ACC, min_ACC:=
@min_ACC, full_scale_span:= @full_scale_span, offset:= @offset, supply_current:= @supply_
current) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
LINEAR	Measured linear acceleration	Translational_V
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
max_ACC	Maximum measurable linear acceleration	Real	50 [m/s ²]
min_ACC	Minimum measurable linear acceleration	Real	0 [m/s ²]

full_ scale_ span	Difference of the output voltages at the maximum and minimum linear accelerations	Real	5 [V]
supply_ current	Supply current	Real	1m [A]

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Example

In this example, the Capacitive Linear Acceleration (Velocity-Force) sensor C_ACC_VF2 measures the linear velocity of the Mass MASS_TR1. A change in the MASS_TR1's acceleration input produces a corresponding change in C_ACC_VF2's linear voltage output. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

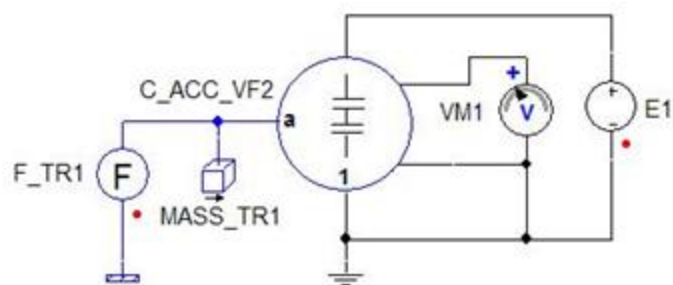


Figure 2. Application example of the Capacitive Linear Acceleration (Velocity-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Force Source F_TR1	VALUE	20 * (t/40m) [N]
Mass MASS_TR1	m	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Capacitive Linear Acceleration (Velocity-Force) sensor C_ACC_VF2	offset	0.1 * E1.EMF [V]
	max_ACC	18 [m/s²]
	min_ACC	0 [m/s²]
	full_scale_span	0.8 * E1.EMF [V]
	supply_current	0.5m [A]

Voltage Source E1	EMF	5 [V]

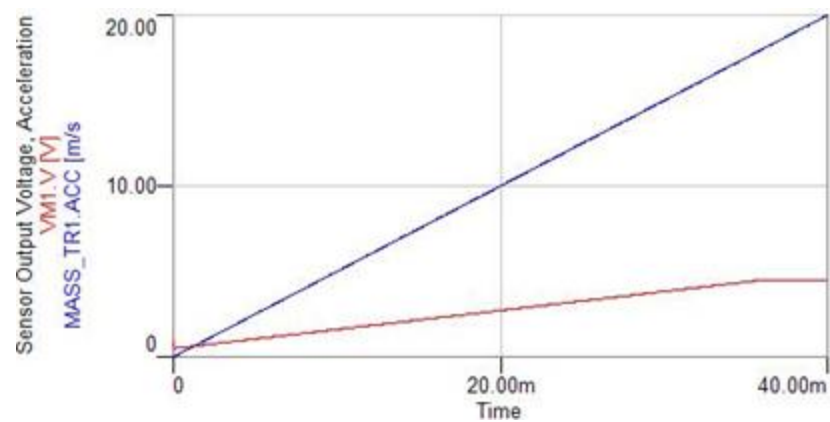


Figure 3. Simulation results-output voltage of C_ACC_VF1 and acceleration of MASS_TR1

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References

Level 1 Piezoelectric Linear Acceleration Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

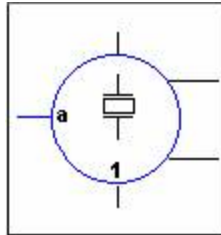


Figure 1. Component symbol

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Description

The Level 1 Piezoelectric Linear Acceleration (Velocity-Force) sensor model is used to simulate the ideal behavior of a piezoelectric linear acceleration sensor in the Twin Builder velocity-force translational domain. A change in the model's linear acceleration input produces a corresponding change in the model's linear voltage output.

The model has one conservative input pin in the velocity-force translational domain for its linear acceleration input and four conservative electrical-domain pins, two for its power supply connections and two for its voltage output. The negative output terminal should be connected to an electrical ground if the model is connected to an electrical network in which no other component is grounded.

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Mathematical Description

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Netlist Syntax

```
MODEL PE_ACC_VF ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) LINEAR:= %0,
OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 ( max_ACC:= @max_ACC, min_ACC:=
@min_ACC, full_scale_span:= @full_scale_span, offset:= @offset, supply_current:= @supply_
current) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
LINEAR	Measured linear acceleration	Translational_V
OUT_P	Positive terminal	Electrical
OUT_M	Negative terminal	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
max_ACC	Maximum measurable linear acceleration	Real	50 [m/s ²]
min_ACC	Minimum measurable linear acceleration	Real	0 [m/s ²]

full_ scale_ span	Difference of the output voltages at the maximum and minimum linear accelerations	Real	5 [V]
supply_ current	Supply current	Real	5m [A]

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Example

In this example, the Piezoelectric Linear Acceleration (Velocity-Force) sensor PE_ACC_VF1 measures the angular velocity of the Mass MASS_TR1. A change in the MASS_TR1's acceleration input produces a corresponding change in PE_ACC_VF1's linear voltage output. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

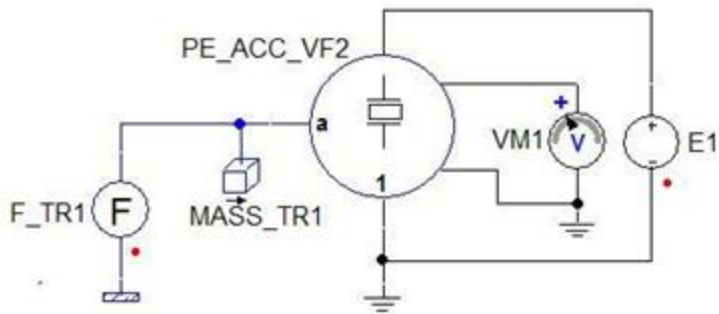


Figure 2. Application example of the Piezoelectric Linear Acceleration (Velocity-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Force Source F_TR1	VALUE	20 * t/40m [N]
Mass MASS_TR1	m	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Piezoelectric Linear Acceleration (Velo-	offset	0.1 *

city-Force) sensor PE_ACC_VF1		E1.EMF [V]
	max_ACC	18 [m/s ²]
	min_ACC	0 [m/s ²]
	full_scale_ span	0.8 * E1.EMF [V]
	supply_cur- rent	10m [A]
Voltage Source E1	EMF	10 [V]

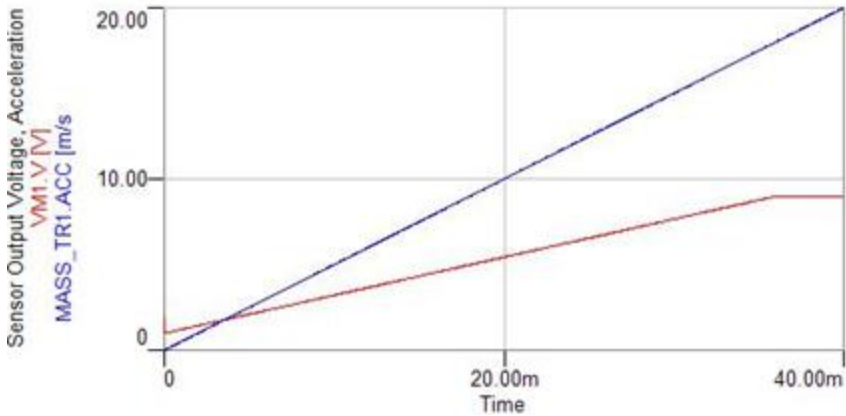


Figure 3. Simulation results-output voltage of PE_ACC_VF1 and acceleration of MASS_TR1

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References

Level 1 Piezoresistive Linear Acceleration Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

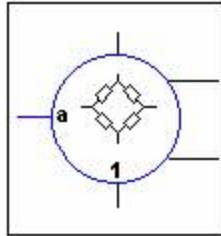


Figure 1. Component symbol

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Description

The Level 1 Piezoresistive Linear Acceleration (Velocity-Force) sensor model is used to simulate the ideal behavior of a piezoresistive linear acceleration sensor in the Twin Builder velocity-force translational domain. A change in the model's linear acceleration input produces a corresponding change in the model's Wheatstone bridge, which in turn produces a change in the model's linear voltage output.

The model has one conservative input pin in the velocity-force translational domain for its linear acceleration input and four conservative electrical-domain pins. Two of the pins are for the model's power supplies, and two are for its differential voltage output.

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Netlist Syntax

MODEL PR_ACC_VF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) OUT_P:= %0, OUT_M:= %1, Vdd:= %2, Vss:= %3, LINEAR:= %4 (max_ACC:= @max_ACC, min_ACC:= @min_ACC, full_scale_span:= @full_scale_span, offset:= @offset, p_resistance:= @p_resistance) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
LINEAR	Measured linear acceleration	Translational_V
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
max_ACC	Maximum measurable linear acceleration	Real	50 [m/s ²]
min_ACC	Minimum measurable linear acceleration	Real	0 [m/s ²]
full_scale_span	Difference of the output voltages at the maximum and minimum	Real	5 [V]

	linear accelerations		
p_res- istance	Bridge resistance	Real	10k [Ohm]

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Example

In this example, the Piezoresistive Linear Acceleration (Velocity-Force) sensor PR_ACC_VF1 measures the linear velocity of the Mass MASS_TR1. A change in the MASS_TR1's acceleration input produces a corresponding change in PR_ACC_VF1's linear voltage output. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

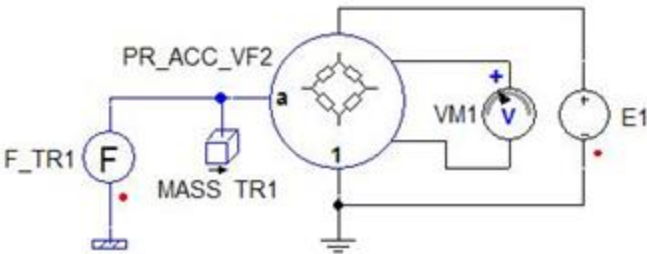


**Figure 2. Application example of the Piezoresistive Linear Acceleration
(Velocity-Force) sensor**

Table 3

Component	Parameter	Value [Unit]
Force Source F_TR1	VALUE	$20 * t/40m$ [N]
Mass MASS_TR1	m	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Piezoresistive Linear Acceleration (Velocity-Force) sensor PR_ACC_VF1	offset	$0.1 * E1.EMF$ [V]
	max_ACC	18 [m/s ²]
	min_ACC	0 [m/s ²]
	full_scale_span	$0.8 * E1.EMF$ [V]
	supply_current	10m [A]
Voltage Source E1	EMF	10 [V]

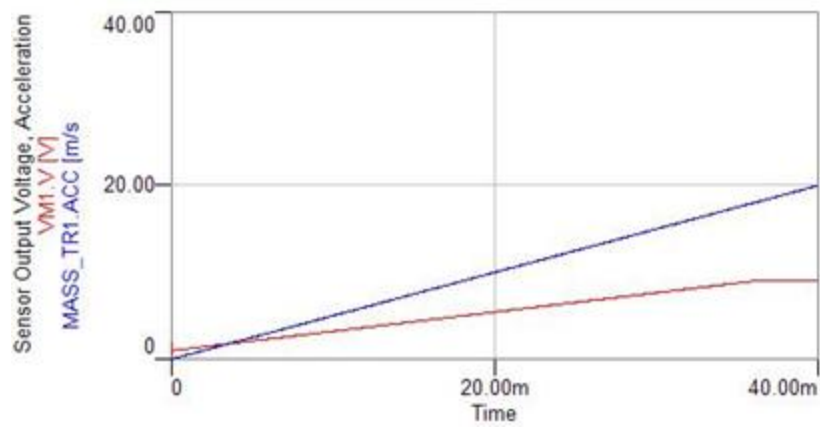


Figure 3. Simulation results-output voltage of PR_ACC_VF1 and acceleration of MASS_TR1

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References

Level 1 Inertia Switch Linear Acceleration Sensor (Velocity-force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

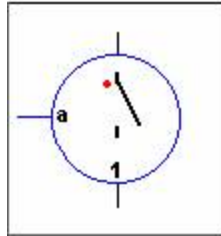


Figure 1. Component symbol

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Description

The Level 1 Inertia Switch Linear Acceleration (Velocity-Force) sensor model is used to simulate the ideal behavior of an inertia switch linear acceleration sensor in the Twin Builder velocity-force translational domain. When the linear acceleration applied to the sensor exceeds a specified threshold value, its switch changes state from open to closed.

The model has one conservative input pin in the velocity-force translational domain for its linear acceleration input and two conservative electrical-domain pins for its positive and negative terminals. The positive terminal is the one into which current flows.

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Mathematical Description

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Netlist Syntax

```
MODEL TINERTIA_SWITCH_VF ?InstanceName(@InstanceName):(@ (Refbase)@(ID))
LINEAR:= %0, np:= %1, nm:= %2 ( threshold:= @threshold) SRC: DB(Lib:-
:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
LINEAR	Measured linear acceleration	Translational_V
np	Positive terminal	Electrical
nm	Negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
threshold	Threshold linear acceleration of the switch	Real	50 [m/s²]

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Example

In this example, the Inertia Switch Linear Acceleration (Velocity-Force) sensor TINERTIA_SWITCH_VF1 measures the linear acceleration of the Mass MASS_TR1. When the acceleration of Mass Mass MASS_TR1 exceeds a specified threshold value, TINERTIA_SWITCH_VF1 switches from open to close. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

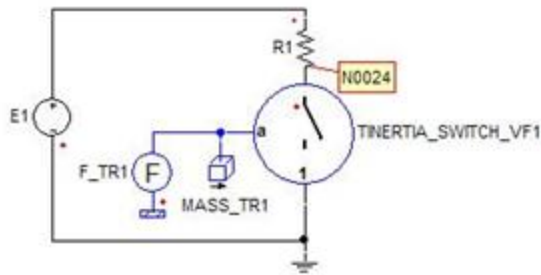


Figure 2. Application example of the Inertia Switch Linear Acceleration (Velocity-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Force Source F_TR1	VALUE	40 * (t/40m) [N]
Mass MASS_TR1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Inertia Switch Linear Acceleration (Velocity-Force) sensor TINERTIA_SWITCH_VF1	threshold	20 [m/s ²]
Voltage Source E1	EMF	1 [V]
Resistor R1	R	1k [Ohm]

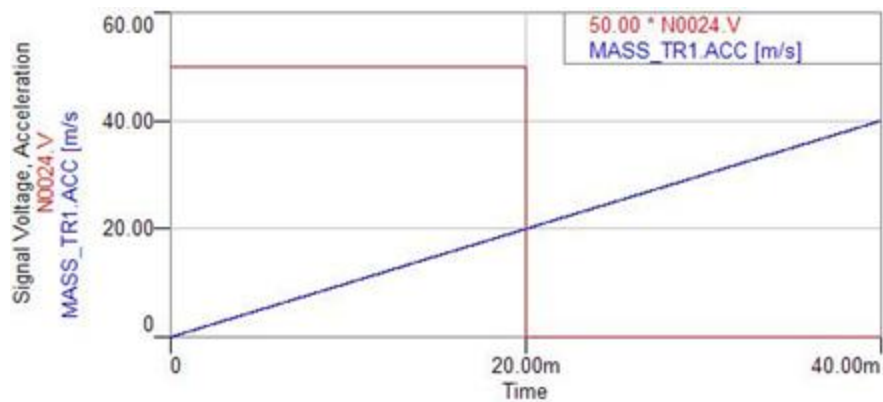


Figure 3. Simulation results-output voltage of TINERTIA_SWITCH_VF1(scaled) and acceleration of MASS_TR1

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References

Level 1 Linear Position Sensor Models

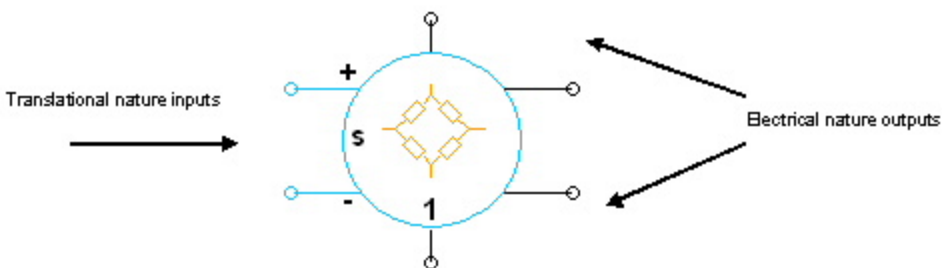
The Level 1 Linear Position Sensor Models simulate the ideal behavior of eight different types of linear position sensors. Models are available to use with the Twin Builder *displacement-force* and *velocity-force* translational domains.

All of the linear position sensor models have both for the following:

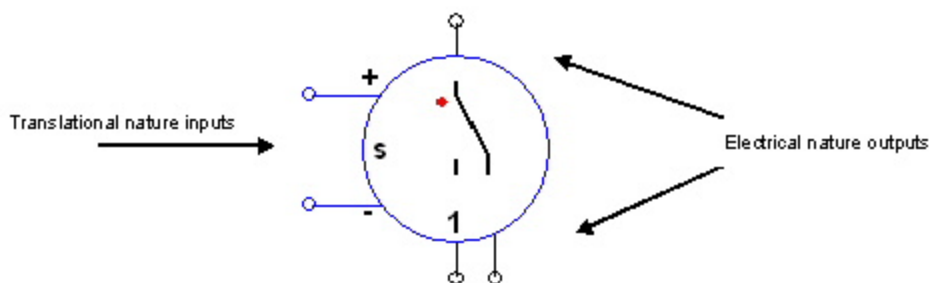
- Conservative input pins that must be connected to a translational network.
- Conservative output pins that must be connected to an electrical network.

The models also feature nonconservative parameters that can be changed to tailor the behavior of the model to the behavior of a specific real device.

As shown in the following example, linear position sensor models for the displacement-force translational domain have light blue conservative input pins that must be connected to a displacement-force translational network. The models also have black pins that must be connected to an electrical network.



Similarly, linear position sensor models for the velocity-force translational domain have dark blue translational nature input pins and black electrical nature pins.



The Level 1 Linear Position Sensor Models feature models for the following linear position sensing mechanisms:

- Anisotropic Magnetoresistive (AMR): A change in linear position produces a corresponding linear change in the output voltage signal.

Displacement-Force model: ([LIN_DISP_AMR_DF](#))

Velocity-Force model: ([LIN_DISP_AMR_VF](#))

- Potentiometric: A change in linear position moves a potentiometer wiper, producing a change in the voltage divider output signal.

Displacement-Force model: ([LIN_DISP_DF](#))

Velocity-Force model: ([LIN_DISP_VF](#))

- Hall-Effect: A change in linear position produces a corresponding linear change in the output voltage signal.

Displacement-Force model: ([LIN_DISP_HE_DF](#))

Velocity-Force model: ([LIN_DISP_HE_VF](#))

- Linear Variable Differential Transformer (LVDT): Linear motion changes the extent of the coupling between a primary winding and two secondary windings, producing variations in the amplitude and phase of an AC output signal.

Displacement-Force model: ([LVDT_DF](#))

Velocity-Force model: ([LVDT_VF](#))

- SCR: A change in linear position changes the inductance of a variable inductor, causing a corresponding change in the output signal at the junction between the variable inductor and a constant-value reference inductor.

Displacement-Force model: ([SCR_DF](#))

Velocity-Force model: ([SCR_VF](#))

- Absolute Encoder: Linear position is encoded as a 6 to 16-bit binary number.

Displacement-Force model: ([TABS_ENCODER_DF](#))

Velocity-Force model: ([TABS_ENCODER_VF](#))

- Incremental Encoder: Linear displacement produces two output pulse trains in quadrature and a reference pulse when a reference position is passed.

Displacement-Force model: ([TINC_ENCODER_DF](#))

Velocity-Force model: ([TINC_ENCODER_VF](#))

- Microswitch: Linear displacement past a specified threshold position causes a switch to toggle from its normally closed pin to its normally open pin.

Displacement-Force model: ([TMSWITCH_DF](#))

Velocity-Force model: ([TMSWITCH_VF](#))

Level 1 Anisotropic Magnetoresistive Linear Position Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

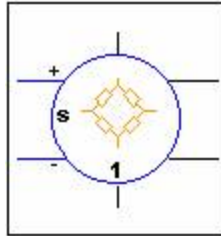


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Description

The Level 1 Anisotropic Magnetoresistive Linear Position (Displacement-Force) sensor model is used to simulate the ideal behavior of an AMR linear position sensor in the Twin Builder displacement-force translational domain. A change in the linear position of an element in the displacement-force translational domain causes a corresponding change in the sensor model's linear voltage output signal.

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Mathematical Description

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Netlist Syntax

```
MODEL LIN_DISP_AMR_DF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) Vcc:= %0, Vss:= %1, POSITION:= %2, REF:= %3, out_plus:= %4, out_minus:= %5 ( input_current:= @input_current, max_displacement:= @max_displacement, min_displacement:= @min_displacement, full_scale_span:= @full_scale_span, offset:= @offset) SRC: DB(Lib:- :=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational
REF	Reference linear position	Translational
Vcc	Positive supply	Electrical
Vss	Negative supply	Electrical
out_plus	Positive terminal	Electrical
out_minus	Negative output	Electrical

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Parameters

Table 2

Name	Description [Unit]	Data Type	Default Value [Unit]
input_current	Typical device input current	real	1m [A]
max_displacement	Maximum measurable displacement	real	10m [m]
min_displacement	Minimum measurable displacement	real	0 [m]

full_scale_span	Difference between the maximum and minimum output voltages	real	10 [V]
offset	Output at minimum displacement	real	0 [V]

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Example

In this example, the Anisotropic Magnetoresistive Linear Position Sensor (Displacement-Force) LIN_DISP_AMR_DF1 measures the linear position of the Mass MASS_TRB1. A change in the linear position of MASS_TR1 produces a corresponding change in the voltage output of LIN_DISP_AMR_DF1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

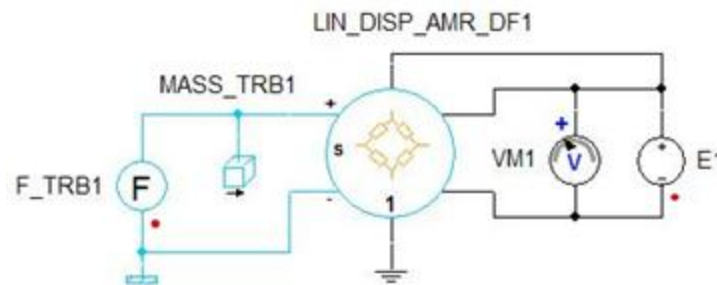


Figure 2. Application example of the Anisotropic Magnetoresistive Linear Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Force Source F_TRB1	VALUE	1k [N]
Voltage Source E1	EMF	5 [V]
Mass MASS_TRB1	M	1 [kg]
	S0	-30 [in]
	V0	0 [m/s]
Anisotropic Magnetoresistive Linear Position Sensor (Displacement-Force)	input_current	5m [A]

LIN_DISP_AMR_DF1		
	max_displacement	500m [m]
	min_displacement	-500 [m]
	full_scale_span	E1.EMF [V]
	offset	0 [V]

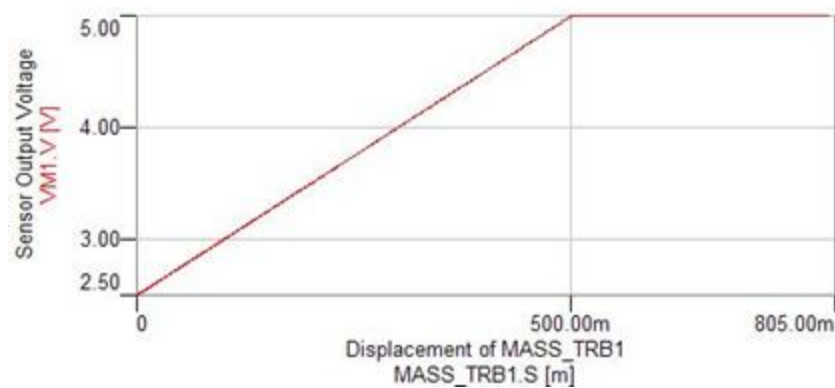


Figure 3. Simulation results- the output voltages of LIN_DISP_AMR_DF1 vs. the displacement of MASS_TRB1

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References

Level 1 Potentiometric Linear Position Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

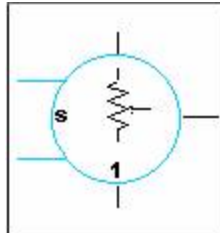


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Description

The Level 1 Potentiometric Linear Position (Displacement-Force) model is used to simulate the ideal behavior of a potentiometric linear position sensor in the Twin Builder displacement-force translational domain. A change in linear position of an element in the displacement-force translational domain causes a corresponding change in the model's voltage divider output signal.

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Netlist Syntax

MODEL LIN_DISP_DF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) REF:= %0,
POSITION:= %1, Vcc:= %2, Vss:= %3, OUTPUT:= %4 (max_displacement:= @max_dis-
placement, min_displacement:= @min_displacement, full_scale_span:= @full_scale_span, off-
set:= @offset, p_resistance:= @p_resistance) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational
REF	Reference linear position	Translational
Vcc	Positive supply voltage	Electrical
Vss	Negative supply voltage	Electrical
OUTPUT	Output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
p_resistance	Potentiometer resistance	Real	1k [Ohm]
max_dis- placement	Maximum measurable dis- placement	Real	0.1 [m]
min_dis- placement	Minimum measurable dis- placement	Real	0 [m]

full_scale_ span	Difference between the maximum and minimum output voltages	Real	10 [V]

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Example

In this example, the Potentiometric Linear Position Sensor (Displacement-Force) LIN_DISP_DF1 measures the linear position of the Mass MASS_TRB1. A change in the linear position of MASS_TRB1 produces a corresponding change in the voltage output of LIN_DISP_DF1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

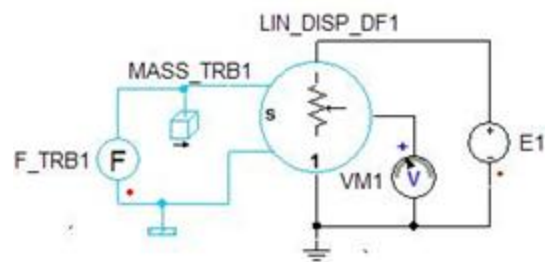


Figure 2. Application example of the Potentiometric Linear Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Force Source F_TRB1	VALUE	1k [N]
Voltage Source E1	EMF	15 [V]
Mass MASS_TRB1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Potentiometric Linear Position Sensor (Displacement-Force) LIN_DISP_DF1	offset	0 [V]
	p_resistance	6k [Ohm]
	max_displacement	6 [m]
	min_displacement	0 [m]
	full_scale_span	E1.EMF [V]

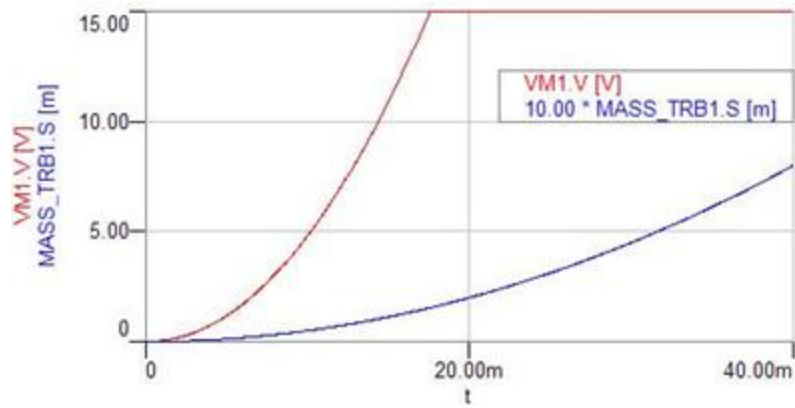


Figure 3. Simulation results-the linear position of MASS_TRB1 and the output voltages of LIN_DISP_DF1

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References

Level 1 Hall-Effect Linear Position Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

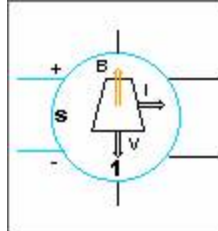


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Description

The Level 1 Hall-Effect Linear Position (Displacement-Force) sensor model is used to simulate the ideal behavior of a Hall-effect linear position sensor in the Twin Builder displacement-force translational domain. A change in the linear position of an element in the displacement-force translational domain causes a corresponding change in the model's voltage output signal.

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Netlist Syntax

```
MODEL LIN_DISP_HE_DF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) Vcc:= %0,
Vss:= %1, POSITION:= %2, REF:= %3, out_plus:= %4, out_minus:= %5 ( input_current:= @in-
put_current, max_displacement:= @max_displacement, min_displacement:= @min_dis-
placement, full_scale_span:= @full_scale_span, offset:= @offset) SRC: DB
(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational
REF	Reference linear position	Translational
Vcc	Positive supply	Electrical
Vss	Negative supply	Electrical
out_plus	Positive terminal	Electrical
out_minus	Negative output	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
input_current	Typical device input current	real	1m [A]
max_dis- placement	Maximum measurable dis- placement	real	10m [m]
min_dis- placement	Minimum measurable dis- placement	real	0 [m]

full_scale_span	Difference between the maximum and minimum output voltages	real	10 [V]
Offset	Output at minimum displacement	real	0 [V]

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Example

In this example, the Hall-Effect Linear Position Sensor (Displacement-Force) LIN_DISP_HE_DF1 measures the linear position of the Mass MASS_TRB1. A change in the linear position of MASS_TRB1 produces a corresponding change in the voltage output of LIN_DISP_HE_DF1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

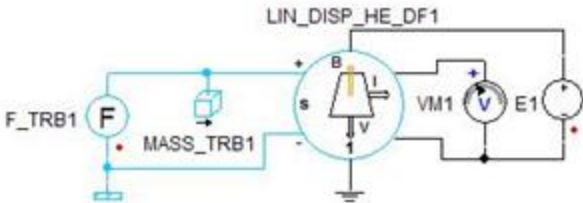


Figure 2. Application example of the Hall-Effect Linear Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Force Source F_TRB1	VALUE	1k [N]
Voltage Source E1	EMF	15 [V]
Mass MASS_TRB1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Hall-Effect Linear Position Sensor (Displacement-Force) LIN_DISP_HE_DF1	input_current	5m [A]
	max_displacement	20 [in]

	min_displacement	1 [in]
	full_scale_span	0.9 * E1.EMF [V]
	Offset	0.1 * E1.EMF [V]

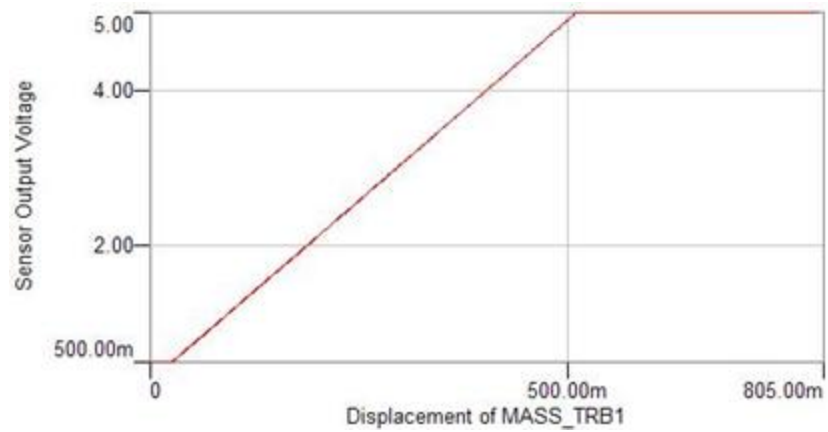


Figure 3. Simulation results- the output voltages of LIN_DISP_HE_DF1 vs. the displacement of MASS_TRB1

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References

Level 1 LVDT Linear Position Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

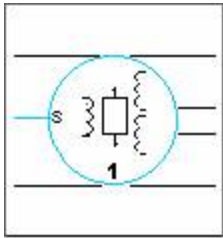


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Description

The Level 1 LVDT Linear position sensor (Displacement-Force) model is used to simulate the ideal behavior of a linear variable differential transformer linear position sensor. A change in linear position produces a corresponding change in the AC voltage output signal.

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Netlist Syntax

```
MODEL LVDT_DF ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) out_1_plus:= %0,
out_1_minus:= %1, out_2_plus:= %2, out_2_minus:= %3, in_plus:= %4, in_minus:= %5,
POSITION:= %6 ( max_position:= @max_position, min_position:= @min_position, sensitivity:=
@ sensitivity) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational
in_plus	Transformer primary positive terminal	Electrical
in_minus	Transformer primary negative terminal	Electrical
out_1_plus	Transformer secondary 1 positive terminal	Electrical
out_1_minus	Transformer secondary 1 negative terminal	Electrical
out_2_plus	Transformer secondary 2 positive terminal	Electrical
out_2_minus	Transformer secondary 2 negative terminal	Electrical

[Top](#)**Parameters****Table 2**

Name	Description	Data Type	Default Value [Unit]
max_position	Maximum measurable linear position	real	1m [m]
min_position	Minimum measurable position	real	-1m [m]

sensitivity	LVDT sensitivity	real	1 [V/V/m]

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Example

In this example, the LVDT Linear position sensor (Displacement-Force) LVDT_DF2 measures the linear position of the Mass MASS_TRB1. A change in the linear position of MASS_TRB1 produces a corresponding change in the output voltage of LVDT_DF2. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

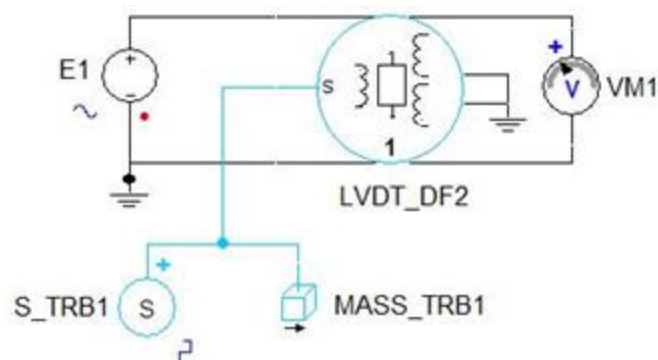


Figure 2. Application example of the SCR Linear Position Sensor (Velocity-Force)

Table 3

Component	Parameter	Value [Unit]
Position Source (pulse) S_TRB1	AMPL	-1.5m [m]
	FREQ	1k [Hz]
	OFF	0 [m]
	TDELAY	0 [s]
	PHASE	0 [degree]
Voltage Source (sinusoidal) E1	AMPL	3 [V]
	FREQ	3k [Hz]
	PHASE	0 [degree]
	OFF	0 [V]

	TDELAY	0 [s]
Mass MASS_TRB1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
LVDT Linear position sensor (Displacement-Force) LVDT_DF2	max_position	1.25 [H]
	min_position	-1.25 [H]
	sensitivity	63 [m]

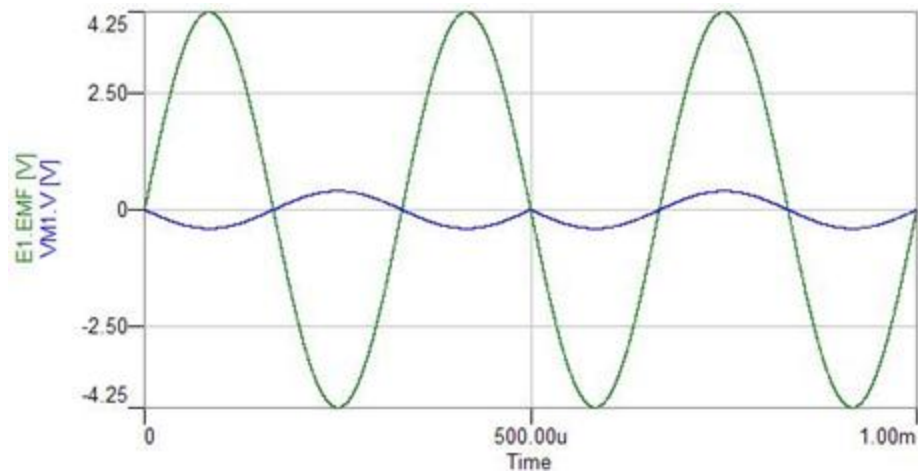


Figure 3. Simulation results- voltage outputs of LVDT_DF2 and E1

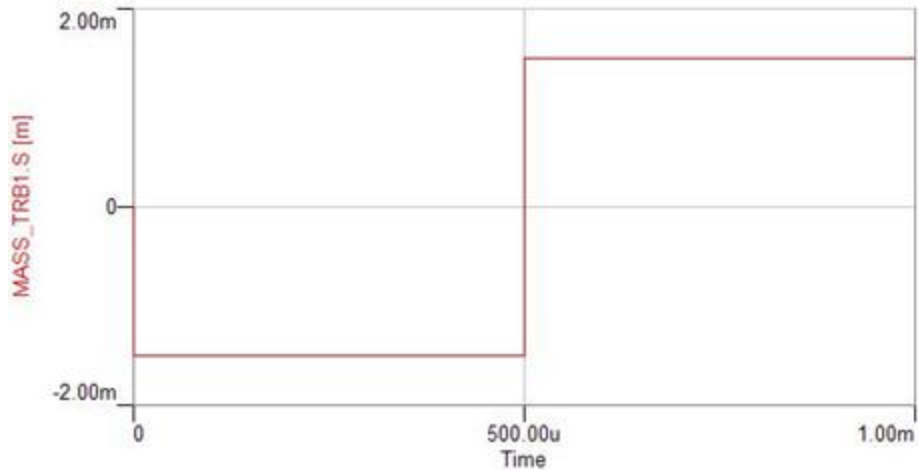


Figure 4. Simulation results-linear displacement of MASS_TRB1

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References

Level 1 SCR Linear Position Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

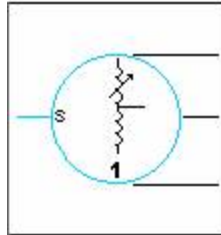


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Description

The Level 1 SCR Linear Position (Displacement-Force) simulates the ideal behavior of a short-circuit ring linear position sensor. The model consists of a variable inductance in series with a reference inductance. As the linear position of an element in the Twin Builder displacement-force translational domain is varied, a corresponding change occurs in the value of the variable inductance. The junction between the variable and reference inductances is where the sensor's output signal, such as a variable AC voltage, can be measured.

The model has a conservative translational-nature pin for measured linear position and three conservative electrical nature pins, two for the reference signal input and output and one for the signal output.

The following device parameters can be entered via nonconservative input nodes:

- Reference inductance value
- Nominal value of variable inductance
- Maximum measurable linear position
- Full scale span of variable inductance

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Netlist Syntax

MODEL SCR_DF ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) POSITION:= %0,
np:= %1, nm:= %2, signal:= %3 (max_position:= @max_position, full_scale_span:= @full_
scale_span, reference_inductance:= @reference_inductance, nominal_inductance:= @nom-
inal_inductance) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational
np	Positive input for the reference voltage or current	Electrical
nm	Negative input for the reference voltage or current	Electrical
signal	Signal output	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
reference_inductance	Inductance of the reference inductor	real	10m [H]

nominal_ inductance	Nominal inductance of the variable inductor	real	1m [H]
max_ position	Maximum measurable linear position	real	10m [m]
full_scale_ span	Difference in variable inductor values at the maximum and zero positions	real	10m [H]

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Example

In this example, the SCR Linear Position Sensor (Displacement-Force) SCR_DF1 measures the linear position of the Mass MASS_TRB1. A change in the linear position of MASS_TRB1 produces a corresponding change in the variable inductance of SCR_DF1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

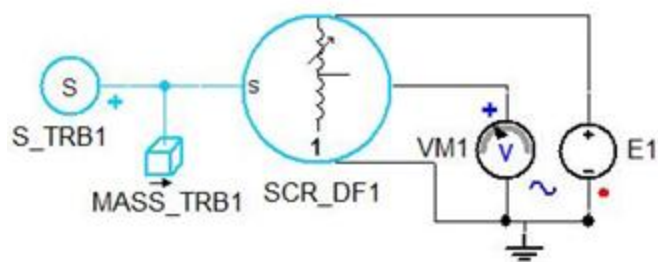


Figure 2. Application example of the SCR Linear Position Sensor(Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Position Source S_TRB1	VALUE	10m * (t/80m) [m]
Voltage Source (sinusoidal) E1	AMPL	5 [V]
	FREQ	100 [Hz]
	PHASE	0 [degree]
	OFF	0 [V]
	TDELAY	0 [s]
Mass MASS_TRB1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
SCR Linear Position Sensor (Dis- placement-Force) SCR_DF1	reference_ inductance	10m [H]
	nominal_ inductance	1m [H]
	max_position	10m [m]
	full_scale_	9m [H]

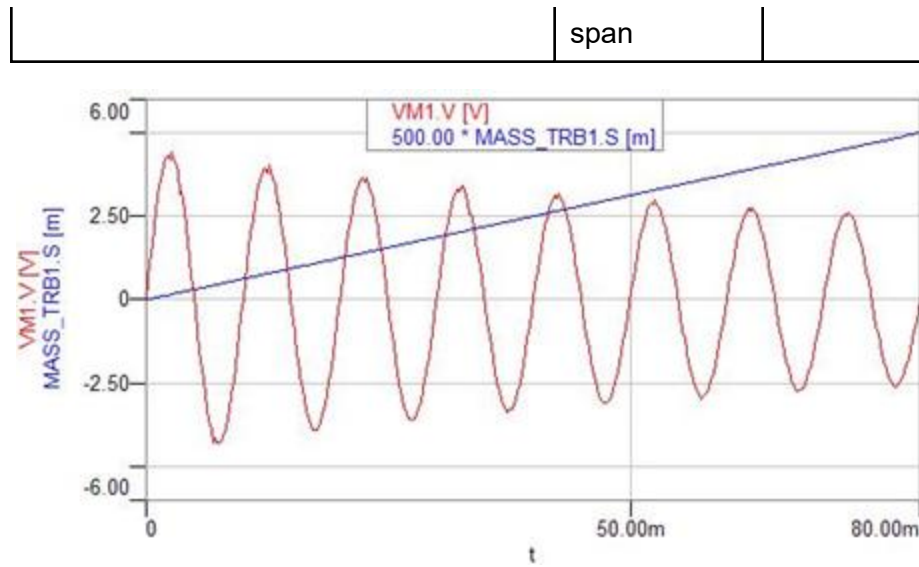


Figure 3. Simulation results-linear displacement of MASS_TRB1 and voltage output of SCR_DF1

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References

Level 1 Absolute Encoder Linear Position Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

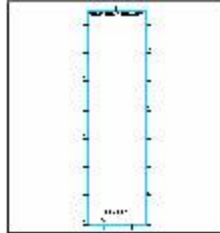


Figure 1. Component symbol

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Description

An absolute encoder linear position sensor translates absolute linear position to a natural binary output. The precision of the output (i.e. the number of bits that make up the output) is determined by the number of equally spaced position indicators that are available on the sensor. For example, a linear position sensor with sixteen position indicators would have a four-bit output.

The Level 1 Absolute encoder Linear Position (Displacement-Force) sensor model is used to simulate the ideal behavior of a 6 to 16-bit absolute encoder linear position sensor in the Twin Builder displacement-force translational domain. The model has a conservative input pin with a translational nature and eighteen conservative electrical-nature pins. Two of the pins are used to connect the model to a power supply and a ground. The remaining pins are for the sixteen possible binary outputs.

The model also has nonconservative input nodes for the following parameters:

- Resolution (the number of output bits available)
- Logic one output amplitude
- Logic zero output amplitude

- Device sampling interval
- Device supply current
- Maximum measurable position

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Netlist Syntax

```
MODEL TABS_ENCODER_DF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) Vdd:= %0, Vss:= %1, BIT_15:= %2, BIT_14:= %3, BIT_13:= %4, BIT_12:= %5, BIT_11:= %6, BIT_10:= %7, BIT_9:= %8, BIT_8:= %9, BIT_7:= %10, BIT_6:= %11, BIT_5:= %12, BIT_4:= %13, BIT_3:= %14, BIT_2:= %15, BIT_1:= %16, BIT_0:= %17, POSITION:= %18 ( resolution:= @resolution, max_amplitude:= @max_amplitude, min_amplitude:= @min_amplitude, sampling_interval:= @sampling_interval, max_position:= @max_position, supply_current:= @supply_current) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical
BIT_0 (See Note)	Output bit zero	Electrical
BIT_1 (See Note)	Output bit one	Electrical
BIT_2 (See Note)	Output bit two	Electrical
BIT_3 (See Note)	Output bit three	Electrical
BIT_4 (See Note)	Output bit four	Electrical
BIT_5 (See Note)	Output bit five	Electrical
BIT_6 (See Note)	Output bit six	Electrical
BIT_7 (See Note)	Output bit seven	Electrical
BIT_8 (See Note)	Output bit eight	Electrical
BIT_9 (See Note)	Output bit nine	Electrical
BIT_10 (See Note)	Output bit ten	Electrical
BIT_11 (See Note)	Output bit eleven	Electrical
BIT_12 (See Note)	Output bit twelve	Electrical
BIT_13 (See	Output bit thirteen	Electrical

Note)		
BIT_14 (See Note)	Output bit fourteen	Electrical
BIT_15 (See Note)	Output bit fifteen	Electrical

Note: Terminal set to No Action when unconnected. Terminal may remain unconnected without generating an error.

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
resolution	Number of bits available at the output	real	16
max_amp-litude	Logic 1 one output	real	5 [V]
min_amp-litude	Logic 0 zero output	real	0 [V]
sampling_interval	Time interval between samples of linear position	real	0.5m [s]
supply_cur-rent	Supply current	real	20m [A]
max_pos-ition	Maximum measurable position	real	10m [m]

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Example

In this example, the Absolute Encoder Linear Position Sensor (Displacement-Force) TABS_ENCODER_DF2 measures the linear displacement of the Mass MASS_TRB1, and the encoded measurement results are sent out through its output channels. The schematic of the system is

shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3-12.

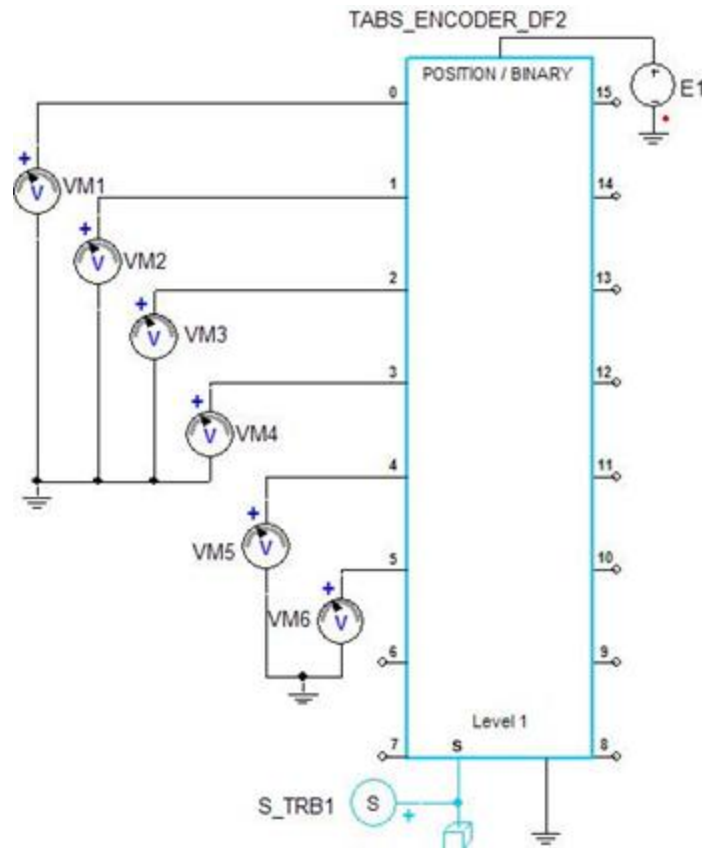


Figure 2. Application example of the Absolute Encoder Linear Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Position Source S_TRB1	VALUE	$(5m + (5.1m/2^6)) * (t > 5m) + (5m - (5m/2^6)) * (t > 20m)$ [m]
Voltage Source E1	EMF	5 [V]
Mass MASS_TRB1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]

Absolute Encoder Linear Position Sensor (Displacement-Force) TABS_ENCODER_DF2	resolution	6
	max_amplitude	4.5 [V]
	min_amplitude	1 [V]
	sampling_interval	10m [s]
	supply_current	40m [A]
	max_position	10m [m]

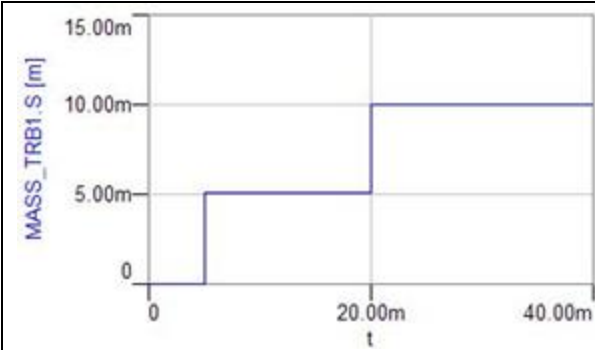


Figure 3. Simulation results-linear displacement of MASS_TRB1

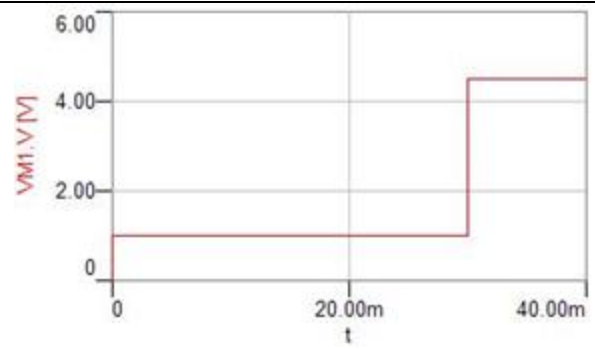


Figure 4. Simulation results- output bit0 of TABS_ENCODER_DF1



Figure 5. Simulation results- output bit1 of TABS_ENCODER_DF1

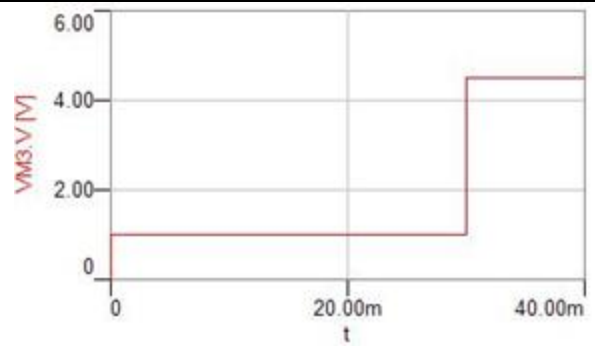


Figure 6. Simulation results- output bit2 of TABS_ENCODER_DF1

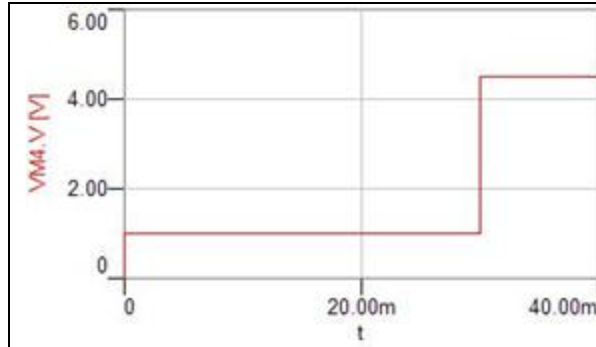


Figure 7. Simulation results- output bit3 of TABS_ENCODER_DF1

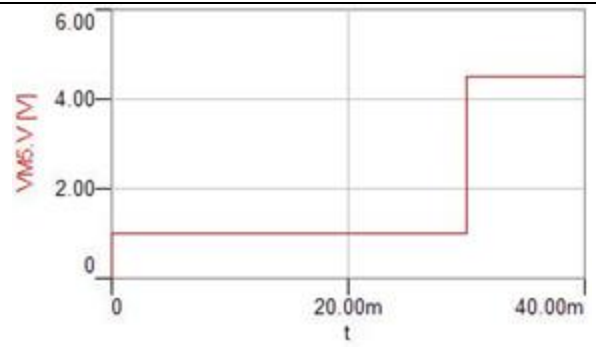


Figure 8. Simulation results- output bit4 of TABS_ENCODER_DF1

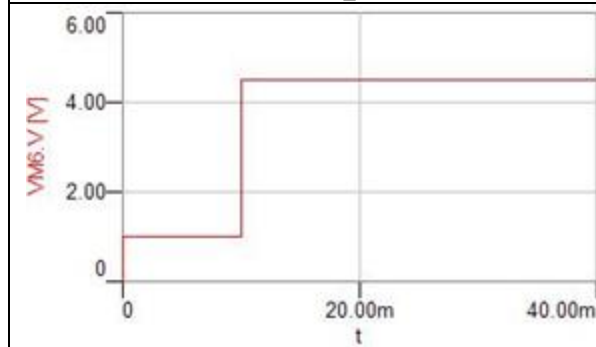


Figure 9. Simulation results- output bit5 of TABS_ENCODER_DF1

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References

Level 1 Incremental Encoder Linear Position Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

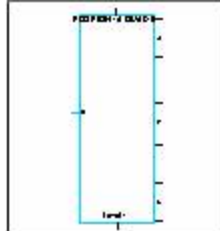


Figure 1. Component symbol

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Description

The Level 1 Incremental encoder Linear Position (Displacement-Force) sensor model is used to simulate the ideal behavior of an incremental encoder linear position sensor in the Twin Builder displacement-force translational domain. An incremental encoder has some number of equally spaced sensing elements, all of which are detected as the device moves from its minimum position to its maximum position. These elements account for two of the device's three outputs: Channel A and Channel B. Channel A is a pulse output that goes to its logic 1 value when a sensing element is detected and remains there until the sensor has traveled one-half of the distance to the next element. Channel B is a second pulse output that lags Channel A by a quarter of a cycle.

The third output of the model is Channel N, which goes to its logic 1 value when the sensor detects the zero point of the sensor and remains high until the sensor has traveled one-quarter of the distance to the next sensing element.

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Mathematical Description

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Netlist Syntax

```
MODEL TINC_ENCODER_DF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) Vdd:= %0, Vss:= %1, A_plus:= %2, A_minus:= %3, B_plus:= %4, B_minus:= %5, N_plus:= %6, N_minus:= %7, POSITION:= %8 ( min_amplitude:= @min_amplitude, max_amplitude:= @max_amplitude, zero_position:= @zero_position, num_lines:= @num_lines, max_position:= @max_position, min_position:= @min_position, supply_current:= @supply_current) SRC: DB(Lib:- :=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical
A_plus (See Note)	Channel A positive output terminal	Electrical
A_minus (See Note)	Channel A negative output terminal	Electrical
B_plus (See Note)	Channel B positive output terminal	Electrical
B_minus (See Note)	Channel B negative output terminal	Electrical
N_plus (See Note)	Channel N positive output terminal	Electrical
N_minus (See Note)	Channel N negative output terminal	Electrical

Note: Terminal set to No Action when unconnected. Terminal may remain unconnected without generating an error.

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
zero_position	Zero position of the encoder	real	0 [m]

num_lines	Number of sensing elements on the sensor	real	10
min_amp- litude	Logic zero output	real	0 [V]
max_amp- litude	Logic one output	real	5 [V]
supply_cur- rent	Supply current	real	50m [A]
max_pos- ition	Maximum measurable linear position	real	5m [m]
min_pos- ition	Minimum measurable linear position	real	0 [m]

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Example

In this example, a Position Source S_TRB1 is applied to a Mass block MASS_TRB1. The displacement of MASS_TRB1 is measured by an Incremental Encoder Linear Position Sensor (Displacement-Force) TINC_ENCODER_DF1, and the encoded measurement result is sent out through the output channels of TINC_ENCODER_DF1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3-6.

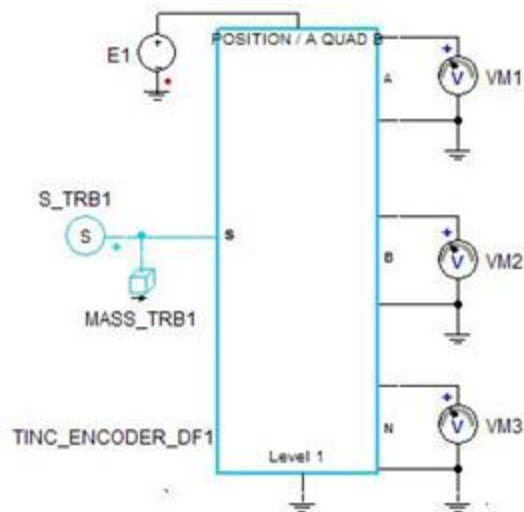


Figure 2. Application example of the Incremental Encoder Linear Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Position Source S_TRB1	VALUE	-50.00 + 22m * (t/40m) [in]
Voltage Source E1	EMF	20 [V]
Mass Mass_TRB1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Incremental Encoder Linear Position Sensor (Displacement-Force) TINC_ENCODER_DF1	zero_position	-49.996 [in]
	num_lines	25k
	min_amplitude	0.5 [V]
	max_amp-	18.5 [V]

	litude	
	supply_current	80m [A]
	max_position	0 [in]
	min_position	-50 [in]

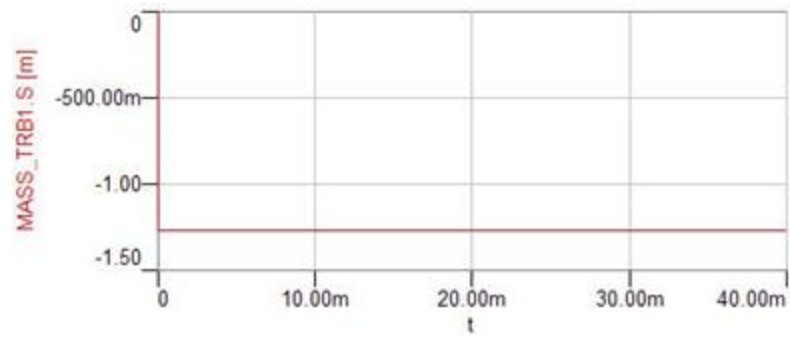
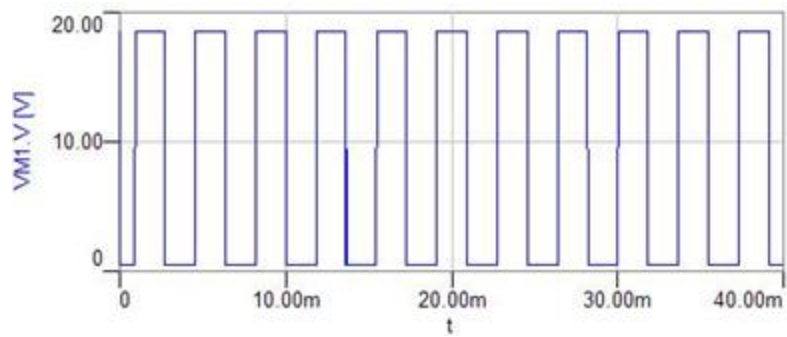
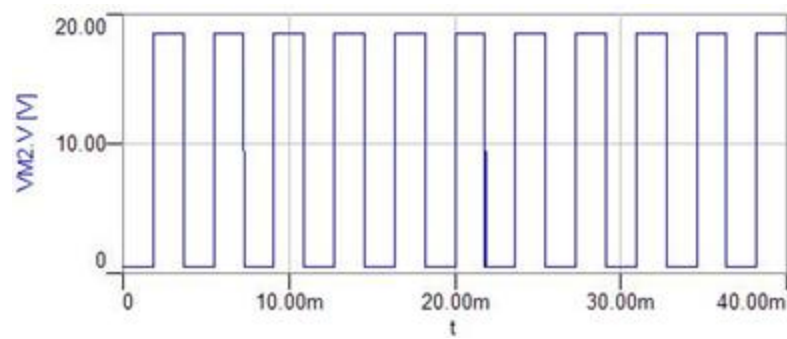
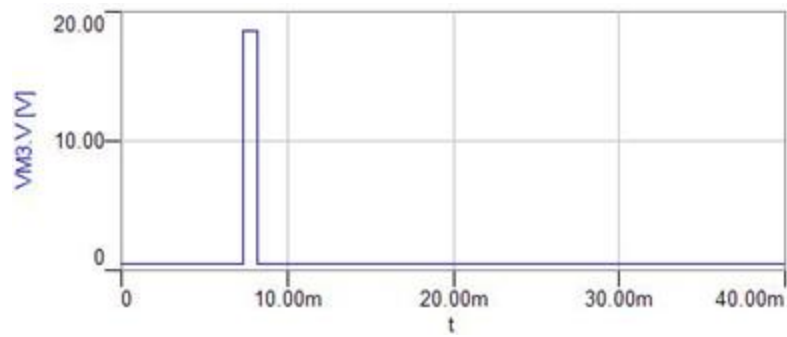


Figure 3. Simulation result-linear displacement of MASS_TRB1**Figure 4. Simulation result-Channel A output of TINC_ENCODER_DF1****Figure 5. Simulation result-Channel B output of TINC_ENCODER_DF1****Figure 6. Simulation result-Channel N output of TINC_ENCODER_DF1**[Top](#)

References

Level 1 Microswitch Linear Position Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

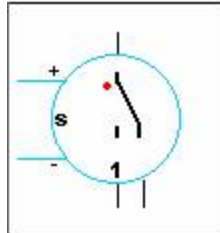


Figure 1. Component symbol

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Description

The Level 1 Microswitch Linear Position (Displacement-Force) sensor model is used to simulate the ideal behavior of a microswitch linear position sensor in the Twin Builder displacement-force translational domain. The microswitch model toggles from its normally closed terminal to its normally open terminal when the specified threshold linear position is exceeded by some element in the displacement-force translational domain.

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Mathematical Description

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Netlist Syntax

MODEL TMSWITCH_DF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) POSITION:= %0, REF:= %1, nmnc:= %2, nmno:= %3, np:= %4 (threshold:= @threshold) SRC: DB(Lib:- :=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational
REF	Reference linear position	Translational
np	Positive terminal	Electrical
nmnc	Normally-closed negative terminal	Electrical
nmno	Normally-open negative terminal	Electrical

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Parameters

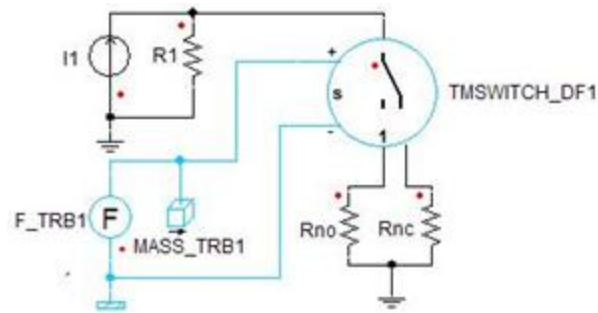
Table 2

Name	Description	Data Type	Default Value [Unit]
Threshold	Threshold linear position	Real	1m [m]

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Example

In this example, when the linear displacement of the Mass MASS_TRB1 is below the threshold of the Microswitch Linear Position Sensor (Displacement-Force) TMSWITCH_DF1, the resistor Rnc is connected to the current source via TMSWITCH_DF1; TMSWITCH_DF1 toggles from its normally closed terminal to its normally open terminal when the linear displacement of MASS_TRB1 exceeds the threshold. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

**Figure 2. Application example of the Microswitch Linear Position Sensor (Displacement-Force)****Table 3**

Component	Parameter	Value [Unit]
Force Source F_TRB1	VALUE	15 [N]
Current Source I1	IS	1 [A]
Resistor Rno/Rnc	R	1k [Ohm]
Resistor R1	R	100k [Ohm]
Mass MASS_TRB1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Microswitch Linear Position Sensor (Displacement-Force) TMSWITCH_DF1	threshold	10m [m]

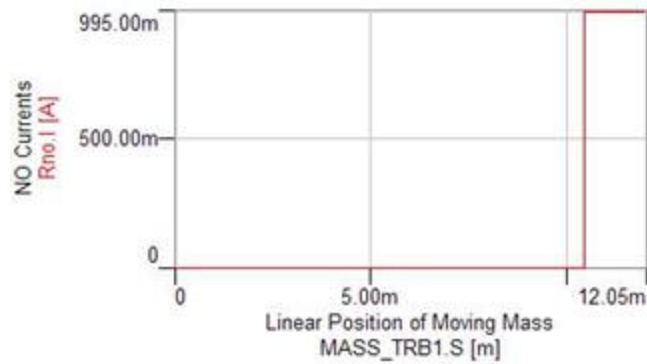


Figure 3. Simulation results- current through Rno vs. linear displacement of MASS_TRB1

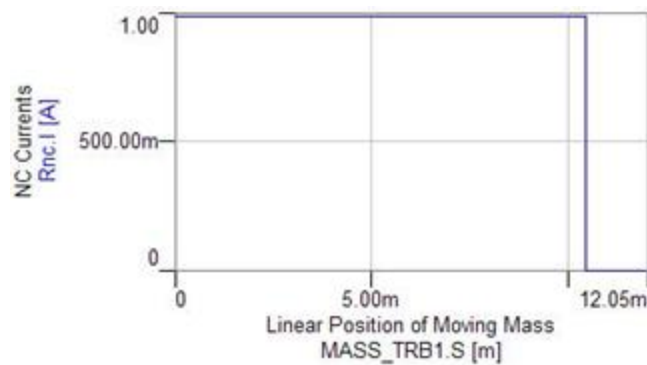


Figure 4. Simulation results- current through Rnc vs. linear displacement of MASS_TRB1

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References

Level 1 Anisotropic Magnetoresistive Linear Position Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

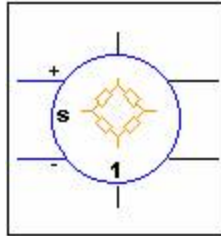


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Description

The Level 1 Anisotropic Magnetoresistive Linear Position (Velocity-Force) sensor model is used to simulate the ideal behavior of an AMR linear position sensor in the Twin Builder velocity-force translational domain. A change in the linear position of an element in the velocity-force translational domain causes a corresponding change in the sensor model's linear voltage output signal.

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Netlist Syntax

```
MODEL LIN_DISP_AMR_VF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) Vcc:= %0,
Vss:= %1, POSITION:= %2, REF:= %3, out_plus:= %4, out_minus:= %5 ( input_current:= @in-
put_current, max_displacement:= @max_displacement, min_displacement:= @min_dis-
placement, s_init:= @s_init, full_scale_span:= @full_scale_span, offset:= @offset) SRC: DB
(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational_V
REF	Reference linear position	Translational_V
Vcc	Positive supply	Electrical
Vss	Negative supply	Electrical
out_plus	Positive terminal	Electrical
out_minus	Negative output	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
input_current	Typical device input current	real	1m [A]
max_dis- placement	Maximum measurable dis- placement	real	10m [m]
min_dis- placement	Minimum measurable dis- placement	real	0 [m]

full_scale_span	Difference between the maximum and minimum output voltages	real	10 [V]
Offset	Output at minimum displacement	real	0 [V]
s_init	Initial position of the sensor	real	0 [m]

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Example

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References

Level 1 Hall-Effect Linear Position Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

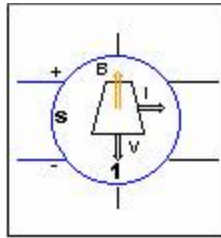


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Description

The Level 1 Hall-Effect Linear Position (Velocity-Force) sensor model is used to simulate the ideal behavior of a Hall-effect linear position sensor in the Twin Builder velocity-force translational domain. A change in the linear position of an element in the velocity-force translational domain causes a corresponding change in the model's voltage output signal.

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Netlist Syntax

```
MODEL LIN_DISP_HE_VF ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) Vcc:= %0,
Vss:= %1, POSITION:= %2, REF:= %3, out_plus:= %4, out_minus:= %5 ( input_current:=
```

@input_current, max_displacement:= @max_displacement, min_displacement:= @min_displacement, s_init:= @s_init, full_scale_span:= @full_scale_span, offset:= @offset) SRC: DB (Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational_V
REF	Reference linear position	Translational_V
Vcc	Positive supply	Electrical
Vss	Negative supply	Electrical
out_plus	Positive terminal	Electrical
out_minus	Negative output	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
input_current	Typical device input current	real	1m [A]
max_displacement	Maximum measurable displacement	real	10m [m]
min_displacement	Minimum measurable displacement	real	0 [m]
full_scale_span	Difference between the maximum and minimum output voltages	real	10 [V]

offset	Output at minimum displacement	real	0 [V]
s_init	Initial position of the sensor	real	0 [m]

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Example

In this example, the Hall-Effect Linear Position Sensor (Velocity-Force) LIN_DISP_HE_VF2 measures the linear position of the Mass MASS_TR1. A change in the linear position of MASS_TR1 produces a corresponding change in the voltage output of LIN_DISP_HE_VF2. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

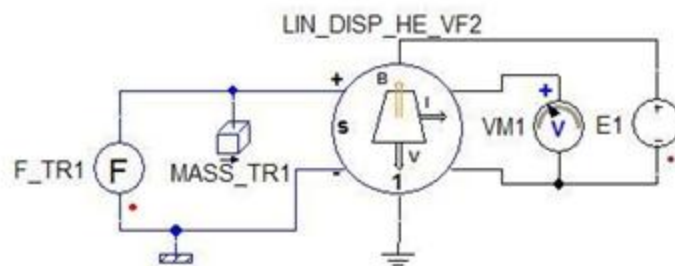


Figure 2. Application example of the Hall-Effect Linear Position Sensor (Velocity-Force)

Table 3

Component	Parameter	Value [Unit]
Force Source F_TR1	VALUE	2k [N]
Voltage Source E1	EMF	15 [V]
Mass MASS_TR1	M	1 [kg]
	S0	-30 [in]
	V0	0 [m/s]
Hall-Effect Linear Position Sensor (Velocity-Force) LIN_DISP_HE_VF2	input_current	5m [A]
	max_displacement	30 [in]
	min_displacement	-30 [in]
	full_scale_span	0.9 * E1.EMF [V]
	offset	0.1 * E1.EMF [V]
	s_init	MASS_TR1.S0

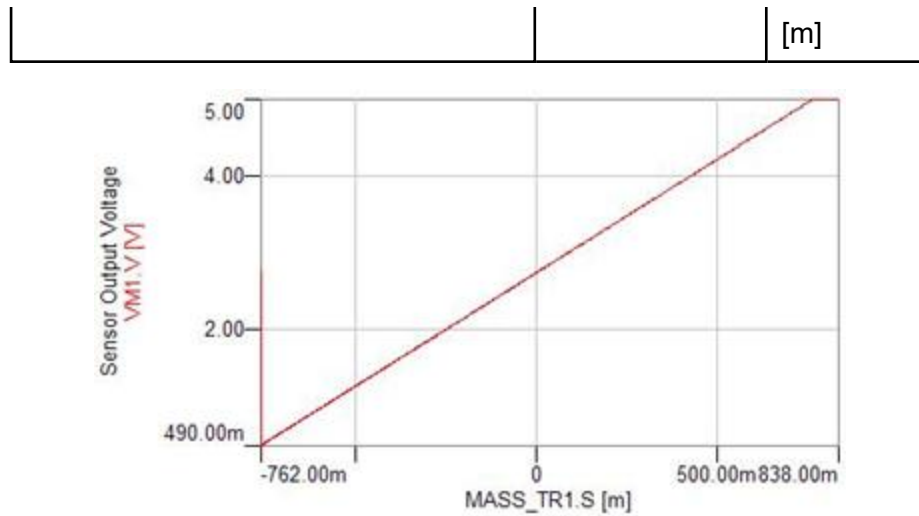


Figure 3. Simulation results- the output voltages of LIN_DISP_HE_VF2 vs. the displacement of MASS_TR1

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References

Level 1 Potentiometric Linear Position Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

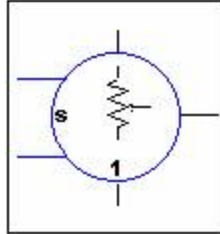


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Description

The Level 1 Potentiometric Linear Position (Velocity-Force) model is used to simulate the ideal behavior of a potentiometric linear position sensor in the Twin Builder velocity-force translational domain. A change in linear position of an element in the velocity-force translational domain causes a corresponding change in the model's voltage divider output signal.

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Netlist Syntax

```
MODEL LIN_DISP_VF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) Vcc:= %0, Vss:= %1, OUTPUT:= %2, DREF:= %3, POSITION:= %4 ( max_displacement:= @max_displacement, min_displacement:= @min_displacement, full_scale_span:= @full_scale_span, offset:= @offset, p_resistance:= @p_resistance, s_init:= @s_init) SRC: DB (Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational_V
DREF	Reference linear position	Translational_V
Vcc	Positive supply voltage	Electrical
Vss	Negative supply voltage	Electrical
OUTPUT	Output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	real	0 [V]
p_resistance	Potentiometer resistance	real	1k [Ohm]
max_displacement	Maximum measurable displacement	real	0.1 [m]
min_dis-	Minimum measurable dis-	real	0 [m]

placement	placement		
full_scale_span	Algebraic difference between the maximum and minimum output voltages	real	10 [V]
s_init	Initial angular position of the sensor	real	0 [rad]

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Example

In this example, the Potentiometric Linear Position Sensor (Velocity-Force) LIN_DISP_VF1 measures the linear position of the Mass MASS_TR1. A change in the linear position of MASS_TR1 produces a corresponding change in the voltage output of LIN_DISP_VF1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

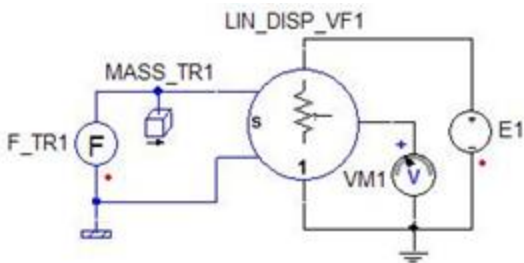


Figure 2. Application example of the Potentiometric Linear Position Sensor (Velocity-Force)

Table 3

Component	Parameter	Value [Unit]
Force Source F_TR1	VALUE	5k [N]
Voltage Source E1	EMF	15 [V]
Mass MASS_TR1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Potentiometric Linear Position Sensor (Velocity-Force) LIN_DISP_VF1	offset	0 [V]

	p_resistance	6k [Ohm]
	max_displacement	6 [in]
	min_displacement	0 [in]
	full_scale_span	E1.EMF [V]
	s_init	MASS_TR1.S0 [in]

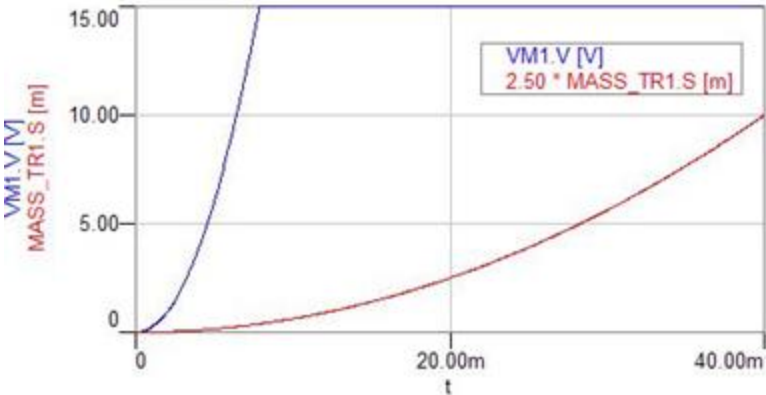


Figure 3. Simulation results-the linear position of MASS_TR1 and the output voltages of LIN_DISP_VF1

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References

Level 1 LVDT Linear Position Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

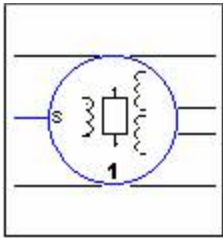


Figure 1. Component symbol

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Description

The Level 1 LVDT Linear position sensor (Velocity-Force) model is used to simulate the ideal behavior of a linear variable differential transformer linear position sensor. A change in linear position produces a corresponding change in the AC voltage output signal.

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Netlist Syntax

```
MODEL LVDT_VF ?InstanceName(@InstanceName):(@(@Refbase)@(ID)) out_1_plus:= %0,
out_1_minus:= %1, out_2_plus:= %2, out_2_minus:= %3, in_plus:= %4, in_minus:= %5,
POSITION:= %6 ( max_position:= @max_position, min_position:= @min_position, sensitivity:=
@sensitivity, s_init:= @s_init) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational
in_plus	Transformer primary positive terminal	Electrical
in_minus	Transformer primary negative terminal	Electrical
out_1_plus	Transformer secondary 1 positive terminal	Electrical
out_1_minus	Transformer secondary 1 negative terminal	Electrical
out_2_plus	Transformer secondary 2 positive terminal	Electrical
out_2_minus	Transformer secondary 2 negative terminal	Electrical

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Parameters

Table 2

Name	Description [Unit]	Data Type	Default Value [Unit]
max_position	Maximum measurable linear position	real	1m [m]
min_position	Minimum measurable position	real	-1m [m]

sensitivity	LVDT sensitivity	real	1 [V/V/m]
s_init	Initial sensor position	real	0 [m]

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Example

In this example, the LVDT Linear position sensor (Velocity-Force) LVDT_VF2 measures the linear position of the Mass MASS_TR1. A change in the linear position of MASS_TR1 produces a corresponding change in the output voltage of LVDT_VF2. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 - 5.

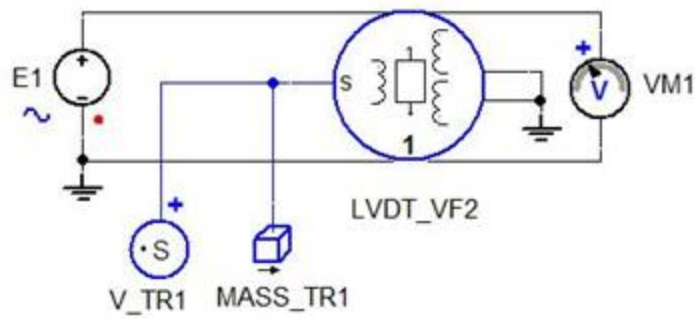


Figure 2. Application example of the LVDT Linear Position Sensor (Velocity-Force)

Table 3

Component	Parameter	Value [Unit]
Velocity Source (pulse) S_TR1	VALUE	3m/1m [m/s]
Voltage Source (sinusoidal) E1	AMPL	3 [V]
	FREQ	3k [Hz]
	PHASE	0 [degree]
	OFF	0 [V]
	TDELAY	0 [s]
Mass MASS_TR1	M	1 [kg]
	S0	-1.5m [m]
	V0	0 [m/s]
LVDT Linear position sensor (Velocity-Force) LVDT_VF2	max_position	1.25 [H]
	min_position	-1.25 [H]
	sensitivity	63 [m]
	s_init	MASS_

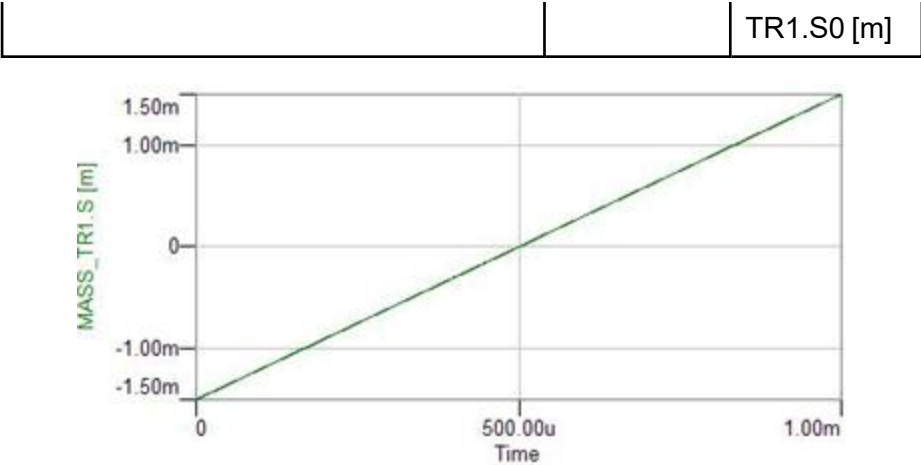


Figure 3. Simulation results-linear displacement of MASS_TR1

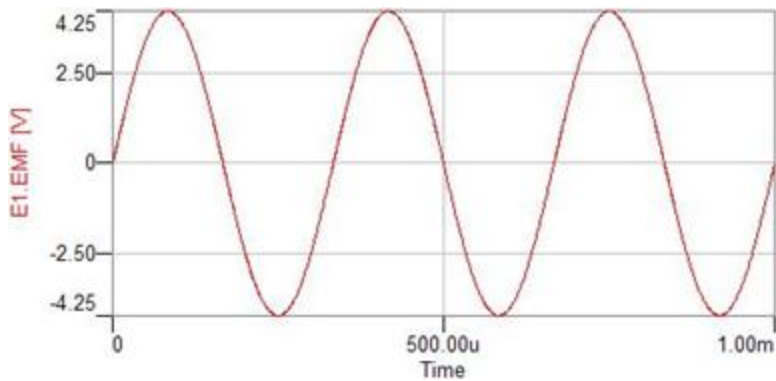


Figure 4. Simulation results- voltage outputs of E1

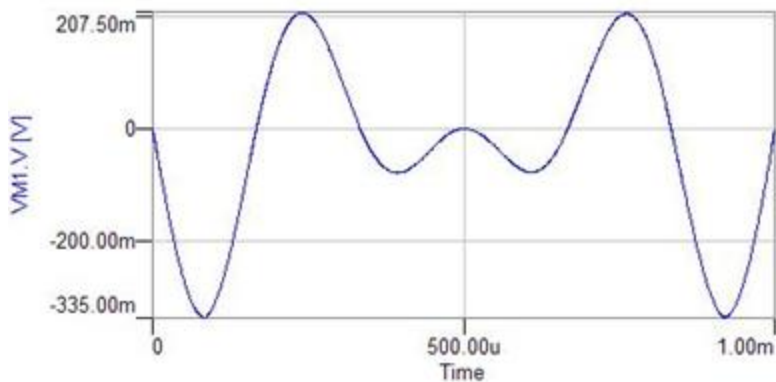


Figure 5. Simulation results- voltage outputs of LVDT_VF2

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References

Level 1 SCR Linear Position Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

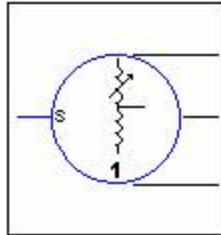


Figure 1. Component symbol

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Description

The Level 1 SCR Linear Position (Velocity-Force) simulates the ideal behavior of a short-circuit ring linear position sensor. The model consists of a variable inductance in series with a reference inductance. As the linear position of an element in the Twin Builder velocity-force translational domain is varied, a corresponding change occurs in the value of the variable inductance. The junction between the variable and reference inductances is where the sensor's output signal, such as a variable AC voltage, can be measured.

The model has a conservative translational_v-nature pin for measured linear position and three conservative electrical nature pins, two for the reference signal input and output and one for the signal output.

The following device parameters can be entered via nonconservative input nodes:

- Reference inductance value
- Nominal value of variable inductance
- Maximum measurable linear position
- Full scale span of variable inductance

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Netlist Syntax

MODEL SCR_VF ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) np:= %0, nm:= %1, signal:= %2, POSITION:= %3 (max_position:= @max_position, full_scale_span:= @full_scale_span, reference_inductance:= @reference_inductance, nominal_inductance:= @nominal_inductance, s_init:= @s_init) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational
np	Positive input for the reference voltage or current	Electrical
nm	Negative input for the reference voltage or current	Electrical
signal	Signal output	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
reference_inductance	Inductance of the reference inductor	real	10m [H]

nominal_ inductance	Nominal inductance of the variable inductor	real	1m [H]
max_ position	Maximum measurable linear position	real	10m [m]
full_scale_ span	Difference in variable inductor values at the maximum and zero positions	real	10m [H]
s_init	Initial sensor position	real	0 [m]

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Example

In this example, the SCR Linear Position Sensor (Displacement-Force) SCR_DF1 measures the linear position of the Mass MASS_TRB1. A change in the linear position of MASS_TRB1 produces a corresponding change in the variable inductance of SCR_DF1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

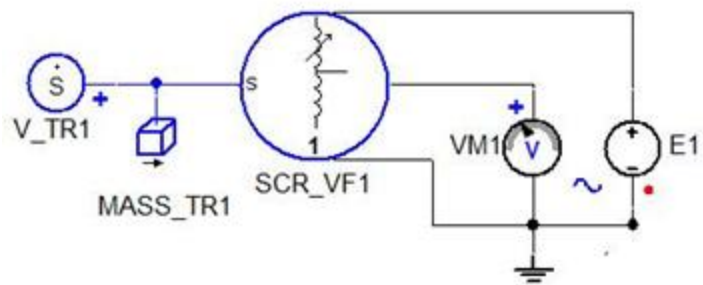


Figure 2. Application example of the SCR Linear Position Sensor (Velocity-Force)

Table 3

Component	Parameter	Value [Unit]
Position Source S_TR1	VALUE	5m/80m [m]
Voltage Source (sinusoidal) E1	AMPL	5 [V]
	FREQ	100 [Hz]
	PHASE	0 [degree]
	OFF	0 [V]
	TDELAY	0 [s]
Mass MASS_TR1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
SCR Linear Position Sensor (Velocity-Force) SCR_VF1	reference_inductance	10m [H]
	nominal_inductance	1m [H]
	max_position	5m [m]
	full_scale_	9m [H]

	span	
	s_init	MASS_ TR1.S0

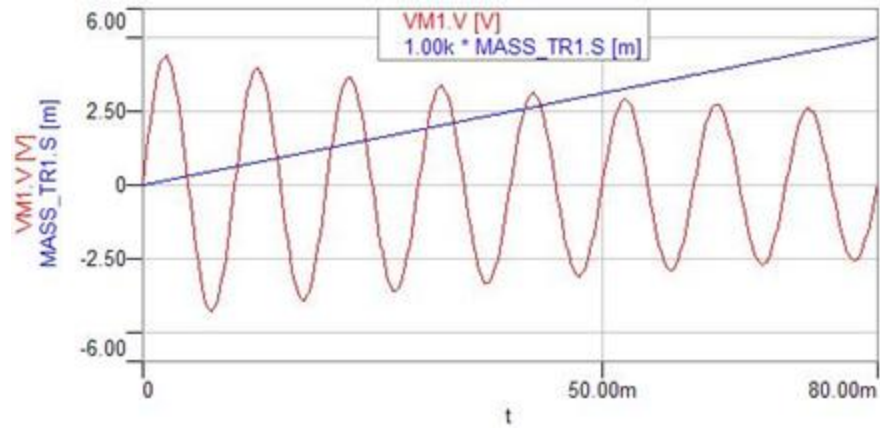


Figure 3. Simulation results-linear displacement of MASS_TR1 and voltage output of SCR_VF1

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References

Level 1 Absolute Encoder Linear Position Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

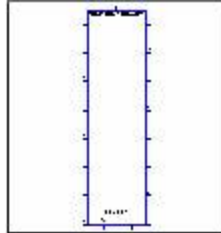


Figure 1. Component symbol

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Description

An absolute encoder linear position sensor translates absolute linear position to a natural binary output. The precision of the output (i.e. the number of bits that make up the output) is determined by the number of equally spaced position indicators that are available on the sensor. For example, a linear position sensor with sixteen position indicators would have a four-bit output.

The Level 1 Absolute encoder Linear Position (Velocity-Force) sensor model is used to simulate the ideal behavior of a 6 to 16-bit absolute encoder linear position sensor in the Twin Builder velocity-force translational domain. The model has a conservative input pin with a translational_v nature and eighteen conservative electrical-nature pins. Two of the pins are used to connect the model to a power supply and a ground. The remaining pins are for the sixteen possible binary outputs.

The model also has nonconservative input nodes for the following parameters:

- Resolution (the number of output bits available)
- Logic one output amplitude
- Logic zero output amplitude

- Device sampling interval
- Device supply current
- Maximum measurable position

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Netlist Syntax

```
MODEL TABS_ENCODER_VF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) Vdd:=
%0, Vss:= %1, BIT_15:= %2, BIT_14:= %3, BIT_13:= %4, BIT_12:= %5, BIT_11:= %6, BIT_
10:= %7, BIT_9:= %8, BIT_8:= %9, BIT_7:= %10, BIT_6:= %11, BIT_5:= %12, BIT_4:= %13,
BIT_3:= %14, BIT_2:= %15, BIT_1:= %16, BIT_0:= %17, POSITION:= %18 ( resolution:= @res-
olution, max_amplitude:= @max_amplitude, min_amplitude:= @min_amplitude, sampling_inter-
val:= @sampling_interval, max_position:= @max_position, s_init:= @s_init, supply_current:=
@supply_current) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational_V
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical
BIT_0 (See Note)	Output bit zero	Electrical
BIT_1 (See Note)	Output bit one	Electrical
BIT_2 (See Note)	Output bit two	Electrical

BIT_3 (See Note)	Output bit three	Electrical
BIT_4 (See Note)	Output bit four	Electrical
BIT_5 (See Note)	Output bit five	Electrical
BIT_6 (See Note)	Output bit six	Electrical
BIT_7 (See Note)	Output bit seven	Electrical
BIT_8 (See Note)	Output bit eight	Electrical
BIT_9 (See Note)	Output bit nine	Electrical
BIT_10 (See Note)	Output bit ten	Electrical
BIT_11 (See Note)	Output bit eleven	Electrical
BIT_12 (See Note)	Output bit twelve	Electrical
BIT_13 (See Note)	Output bit thirteen	Electrical
BIT_14 (See Note)	Output bit fourteen	Electrical
BIT_15 (See Note)	Output bit fifteen	Electrical

Note: Terminal set to No Action when unconnected. Terminal may remain unconnected without generating an error.

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
resolution	Number of bits available at the output	real	16
max_amp- litude	Logic 1 one output	real	5 [V]
min_amp- litude	Logic 0 zero output	real	0 [V]
sampling_ interval	Time interval between samples of linear position	real	0.5m [s]
supply_cur- rent	Supply current	real	20m [A]
max_pos- ition	Maximum measurable position	real	10m [m]
s_init	Initial position of the sensors	real	0 [m]

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Example

In this example, the Absolute Encoder Linear Position Sensor (Displacement-Force) TABS_ENCODER_DF2 measures the linear displacement of the Mass MASS_TRB1, and the encoded measurement results are sent out through its output channels. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3-12.

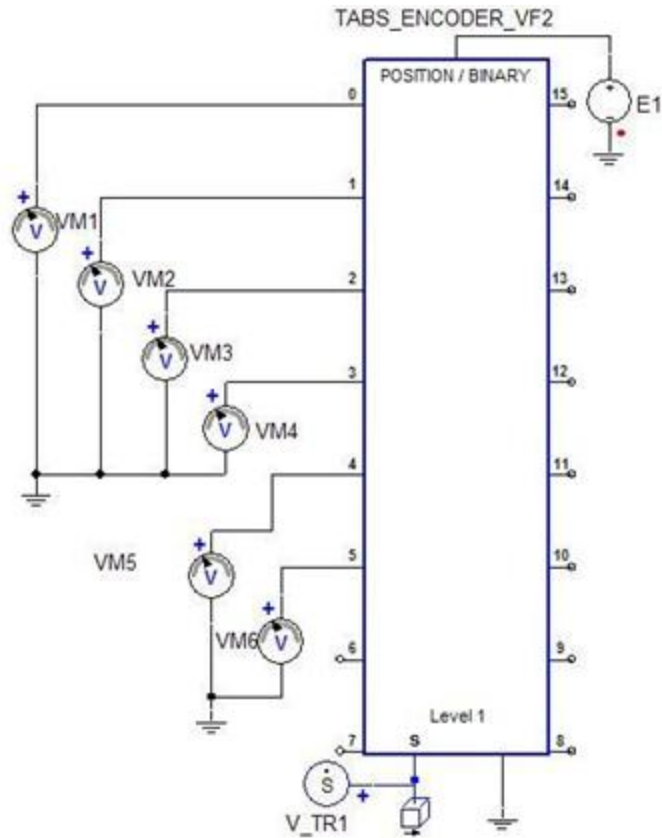


Figure 2. Application example of the Absolute Encoder Linear Position Sensor (Velocity-Force)**Table 3**

Component	Parameter	Value [Unit]
Velocity Source V_TR1	VALUE	0.25 [m/s]
Voltage Source E1	EMF	1 [V]
Mass MASS_TR1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Absolute Encoder Linear Position Sensor (Velocity-Force) TABS_ENCODER_VF2	resolution	6
	max_amp- litude	4.5 [V]
	min_amp- litude	1 [V]
	sampling_ interval	10m [s]
	supply_cur- rent	40m [A]
	max_pos- ition	10m [m]
	s_init	MASS_ TR1.S0 [m]

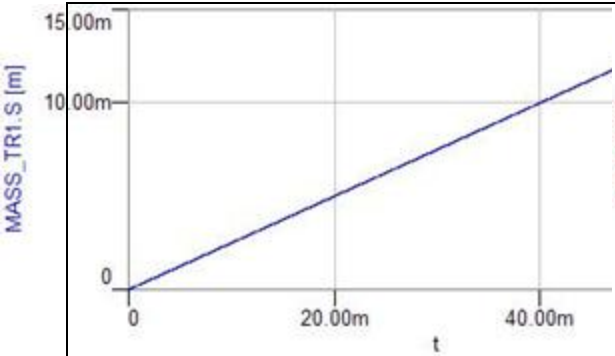


Figure 3. Simulation results-linear displacement of MASS_TR1

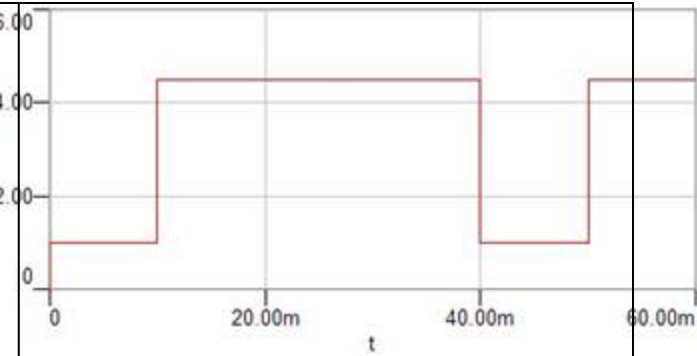


Figure 4. Simulation results- output bit0 of TABS_ENCODER_VF1

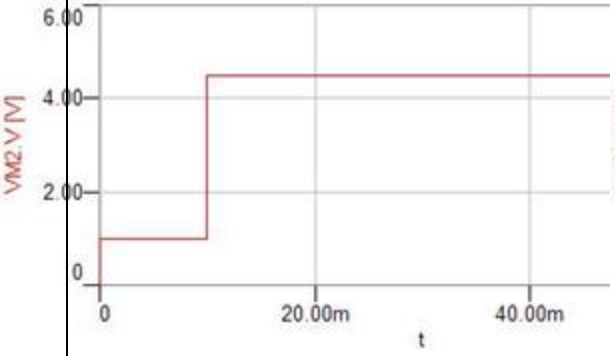


Figure 5. Simulation results- output bit1 of TABS_ENCODER_VF1

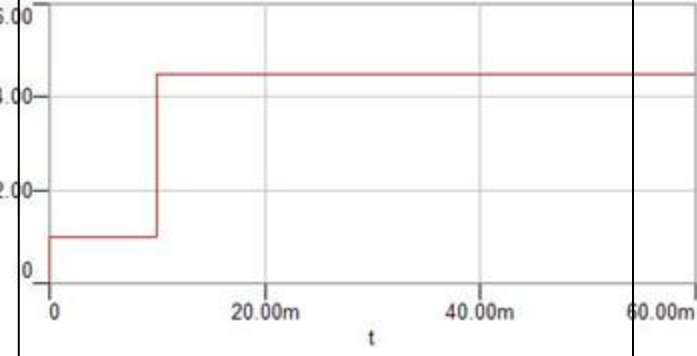


Figure 6. Simulation results- output bit2 of TABS_ENCODER_VF1

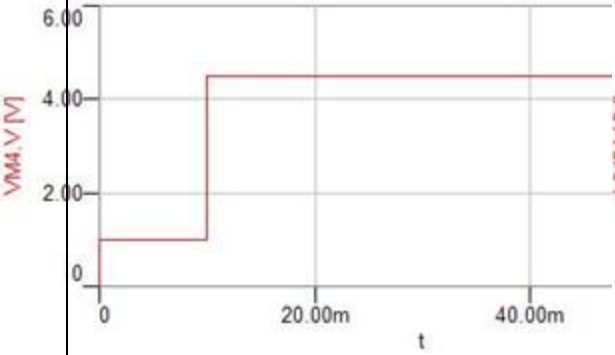


Figure 7. Simulation results- output bit3 of TABS_ENCODER_VF1

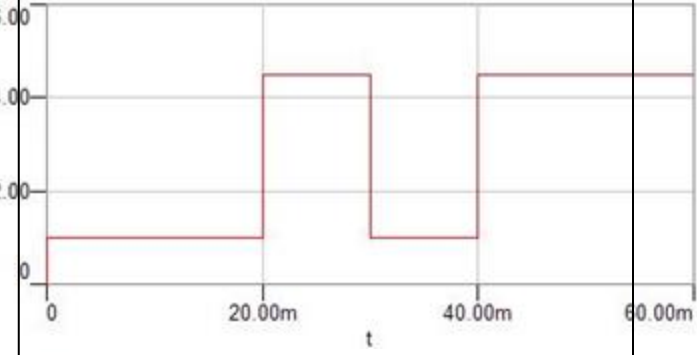


Figure 8. Simulation results- output bit4 of TABS_ENCODER_VF1

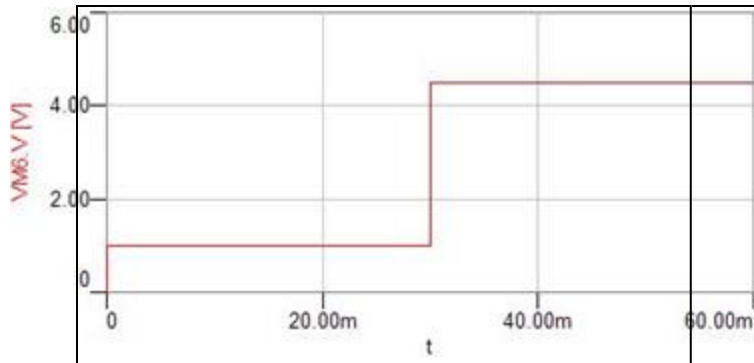


Figure 9. Simulation results- output bit5 of TABS_ENCODER_VF1

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References

Level 1 Incremental Encoder Linear Position Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

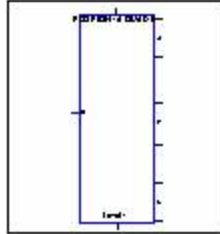


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Description

The Level 1 Incremental encoder Linear Position (Velocity-Force) sensor model is used to simulate the ideal behavior of an incremental encoder linear position sensor in the Twin Builder velocity-force translational domain. An incremental encoder has some number of equally spaced sensing elements, all of which are detected as the device moves from its minimum position to its maximum position. These elements account for two of the device's three outputs: Channel A and Channel B. Channel A is a pulse output that goes to its logic 1 value when a sensing element is detected and remains there until the sensor has traveled one-half of the distance to the next element. Channel B is a second pulse output that lags Channel A by a quarter of a cycle.

The third output of the model is Channel N, which goes to its logic 1 value when the sensor detects the zero point of the sensor and remains high until the sensor has traveled one-quarter of the distance to the next sensing element.

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Netlist Syntax

```
MODEL TINC_ENCODER_VF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) Vdd:=
%0, Vss:= %1, A_plus:= %2, A_minus:= %3, B_plus:= %4, B_minus:= %5, N_plus:= %6, N_
minus:= %7, POSITION:= %8 ( min_amplitude:= @min_amplitude, max_amplitude:= @max_
amplitude, zero_position:= @zero_position, num_lines:= @num_lines, max_position:= @max_
position, min_position:= @min_position, supply_current:= @supply_current, s_init:= @s_init)
SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational_ V*
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical
A_plus (See Note)	Channel A positive output terminal	Electrical
A_minus (See Note)	Channel A negative output terminal	Electrical
B_plus (See Note)	Channel B positive output terminal	Electrical
B_minus (See Note)	Channel B negative output terminal	Electrical
N_plus (See Note)	Channel N positive output terminal	Electrical
N_minus (See Note)	Channel N negative output terminal	Electrical

Note: Terminal set to No Action when unconnected. Terminal may remain unconnected without generating an error.

* Translational in velocity-force representation.

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
zero_position	Zero position of the encoder [m]	real	0 [m]
num_lines	Number of sensing elements on the sensor	real	10
min_amplitude	Logic zero output [V]	real	0 [V]
max_amplitude	Logic one output [V]	real	5 [V]
supply_current	Supply current [A]	real	50m [A]
max_position	Maximum measurable linear position [m]	real	5m [m]
min_position	Minimum measurable linear position [m]	real	0 [m]
s_init	Initial encoder position [m]	real	0 [m]

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Example

In this example, a Velocity Source V_TR1 is applied to a Mass block MASS_TR1. The displacement of MASS_TR1 is measured by an Incremental Encoder Linear Position Sensor (Velocity-Force) TINC_ENCODER_VF1, and the encoded measurement result is sent out through the output channels of TINC_ENCODER_VF1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3-6.

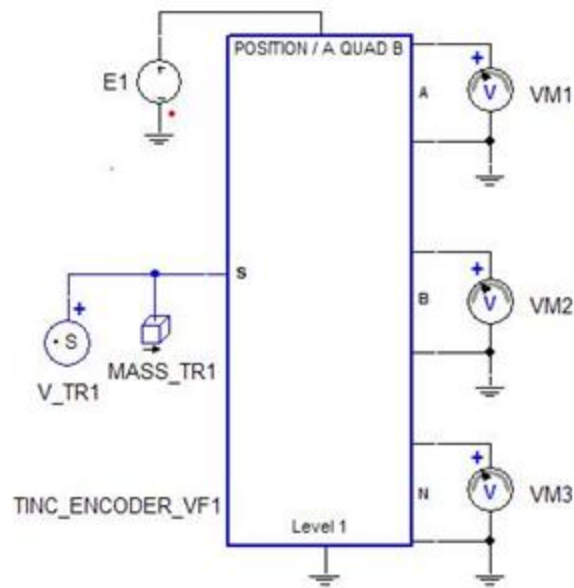


Figure 2. Application example of the Incremental Encoder Linear Position Sensor (Velocity-Force)

Table 3

Component	Parameter	Value [Unit]
Velocity Source V_TR1	VALUE	(5.08E-4)/40m [m/s]
Voltage Source E1	EMF	20 [V]
Mass Mass_TR1	M	1 [kg]
	S0	-50.002 [in]
	V0	0 [m/s]
Incremental Encoder Linear Position Sensor (Velocity-Force) TINC_ENCODER_VF1	zero_position	-50 [in]
	num_lines	25k
	min_amplitude	0.5 [V]

	max_amp- litude	18.5 [V]
	supply_cur- rent	80m [A]
	max_pos- ition	0 [in]
	min_pos- ition	-50 [in]
	s_init	MASS_ TR1.S0 [m]

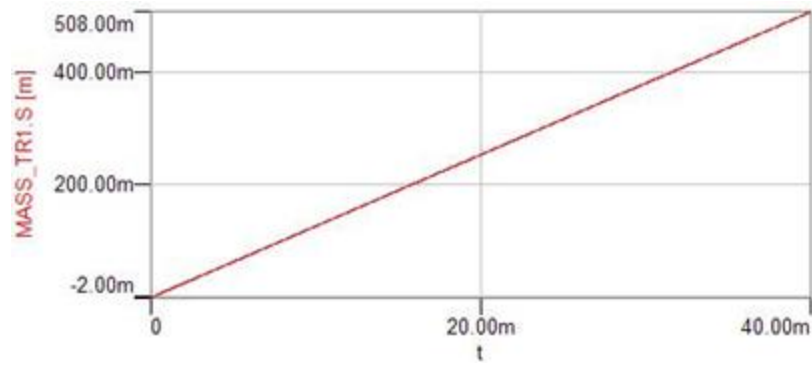


Figure 3. Simulation result-linear displacement of MASS_TR1

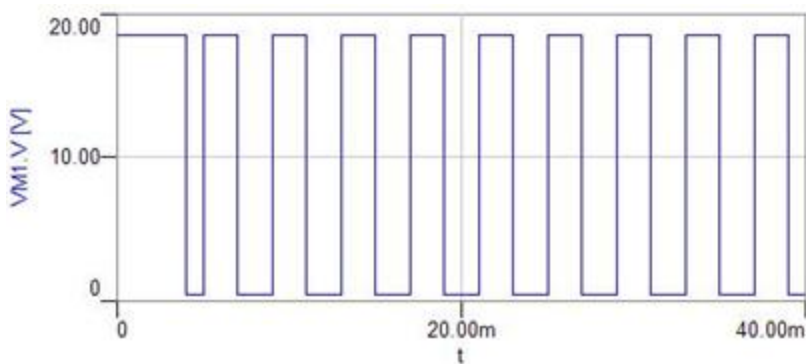


Figure 4. Simulation result-Channel A output of TINC_ENCODER_VF1

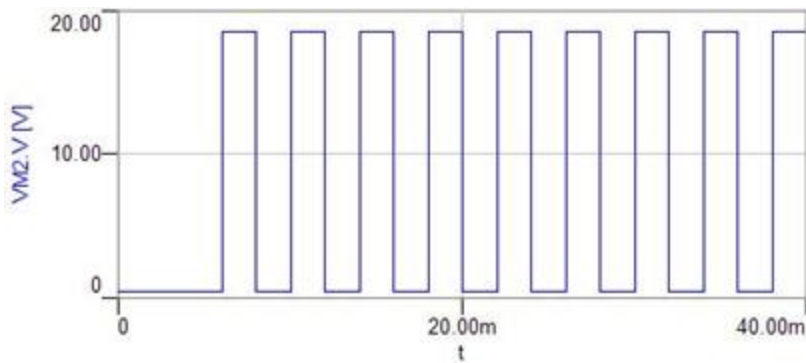


Figure 5. Simulation result-Channel B output of TINC_ENCODER_VF1

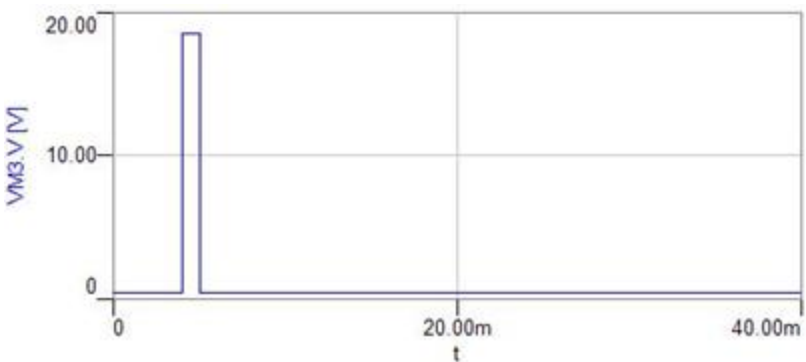


Figure 6. Simulation result-Channel N output of TINC_ENCODER_VF1

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References

Level 1 Microswitch Linear Position Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

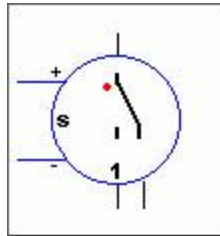


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Description

The Level 1 Microswitch Linear Position (Velocity-Force) sensor model is used to simulate the ideal behavior of a microswitch linear position sensor in the Twin Builder velocity-force translational domain. The microswitch model toggles from its normally closed terminal to its normally open terminal when the specified threshold linear position is exceeded by some element in the velocity-force translational domain.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL TMSWITCH_VF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) POSITION:=
%0, REF:= %1, nmnc:= %2, nmno:= %3, np:= %4 ( threshold:= @threshold, s_init:= @s_init)
```

SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational
REF	Reference linear position	Translational
np	Positive terminal	Electrical
nmnc	Normally-closed negative terminal	Electrical
nmno	Normally-open negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
threshold	Threshold linear position	real	1m [m]
s_init	Initial sensor position	real	0 [m]

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Example

In this example, when the linear displacement of the Mass MASS_TR1 is below the threshold of the Microswitch Linear Position Sensor (Velocity-Force) TMSWITCH_VF2, the resistor Rnc is connected to the current source via TMSWITCH_VF2; TMSWITCH_VF2 toggles from its normally closed terminal to its normally open terminal when the linear displacement of MASS_TR1 exceeds the threshold. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3-5.

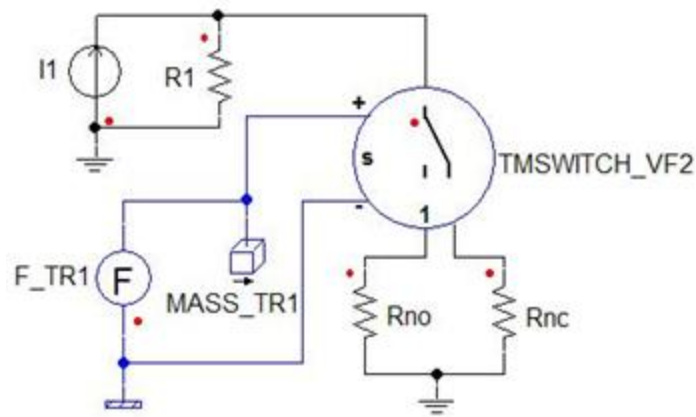


Figure 2. Application example of the Microswitch Linear Position Sensor (Velocity-Force)

Table 3

Component	Parameter	Value [Unit]
Force Source F_TR1	VALUE	15 [N]
Current Source I1	IS	1 [A]
Resistor Rno/Rnc	R	1k [Ohm]
Resistor R1	R	100k [Ohm]
Mass MASS_TR1	M	1 [kg]
	S0	5 [mm]
	V0	0 [m/s]
Microswitch Linear Position Sensor (Velocity-Force) TMSWITCH_VF2	threshold	10m [m]
	s_init	MASS_TR1.S0 [m]

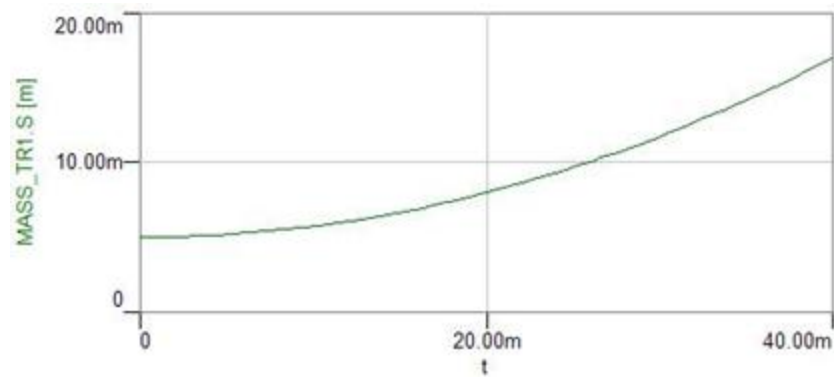


Figure 3. Simulation results-linear displacement of MASS_TR1

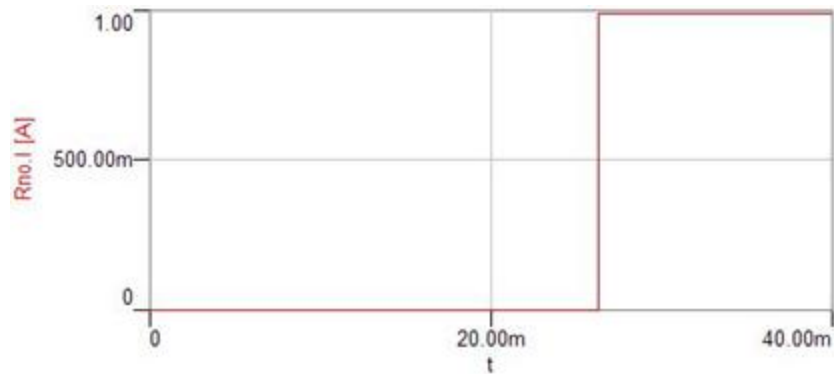


Figure 4. Simulation results- current through Rno

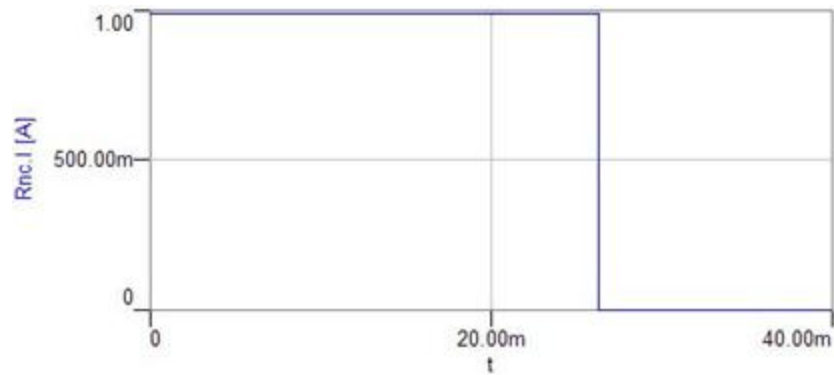


Figure 5. Simulation results- current through Rnc

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References

Level 1 Pressure Sensors

The Level 1 models simulate the ideal behavior of pressure sensors. Level 1 Pressure Sensor models are available for sensing *absolute*, *differential*, and *gage* pressure. The models for the different pressure types differ in the following ways:

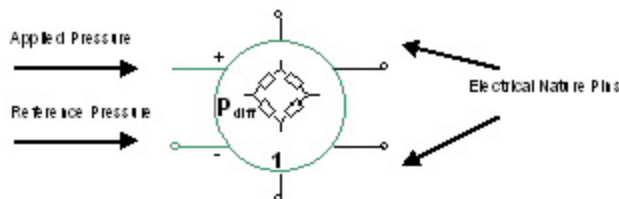
- Absolute pressure sensors measure the applied pressure versus vacuum. The absolute pressure sensor models have one conservative input pin, colored green, which must be connected to a fluidic network. The pressure at the connected fluidic node is the pressure measured by the sensor model.

The electrical nature pins of the model are colored black.



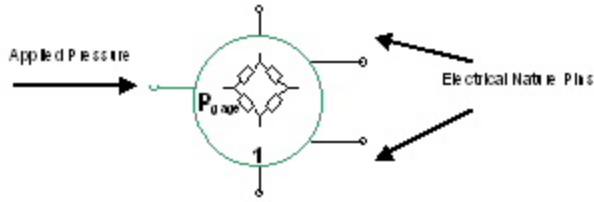
- Differential pressure sensors measure the applied pressure versus a reference pressure. The differential pressure sensor models have two conservative input pins, colored green, that must be connected to a fluidic network. The pressure at the pin labeled with a plus sign (+) is the measured applied pressure, and the pressure at the pin labeled with a minus sign (-) is the reference pressure. The applied pressure minus the reference pressure is the pressure measured by the sensor model.

The electrical nature pins of the model are colored black.



- Gage pressure sensors measure the applied pressure versus atmospheric pressure. The gage pressure sensor models have one conservative input pin, colored green, that must be connected to a fluidic network. The pressure at this pin is the applied pressure. The atmospheric pressure is entered by the user via a nonconservative pin. The applied pressure minus the atmospheric pressure is the pressure measured by the sensor model.

The electrical nature pins of the model are colored black.



Each model has three versions, one each for absolute, differential, and gage pressure sensing.

The sensor model library contains models (each with the three versions) for the following pressure-sensing mechanisms:

- Piezoresistive: The applied pressure deforms the resistors in a Wheatstone bridge configuration, resulting in a differential voltage output signal.
Absolute model: ([abs_press_bridge](#))
Differential model: ([DIFF_PRESS_BRIDGE](#))
Gage model: ([gage_press_bridge](#))
- Uncompensated Capacitive: The applied pressure brings the plates of a capacitor closer together, providing a variable capacitance output signal.
Absolute model: ([ABS_PRESS_CAP](#))
Differential model: ([DIFF_PRESS_CAP](#))
Gage model: ([GAGE_PRESS_CAP](#))
- LVDT (Linear Variable Differential Transformer): The applied pressure changes the extent of coupling between a primary and two oppositely wound secondaries, producing a differential AC output signal.
Absolute model: ([ABS_PRESS_LVDT](#))
Differential model: ([DIFF_PRESS_LVDT](#))
Gage model: ([GAGE_PRESS_LVDT](#))
- Piezoelectric: The applied pressure deforms a piezoelectric element, resulting in a corresponding change in a voltage output signal.
Absolute model: ([ABS_PRESS_PE](#))
Differential model: ([DIFF_PRESS_PE](#))
Gage model: ([GAGE_PRESS_PE](#))
- Potentiometric: The applied pressure moves the wiper of a potentiometer, resulting in a change in the voltage output signal.
Absolute model: ([ABS_PRESS_POTEN](#))
Differential model: ([DIFF_PRESS_POTEN](#))
Gage model: ([GAGE_PRESS_POTEN](#))
- Pressure switch: The applied pressure toggles an SPDT switch at a defined threshold pressure.
Absolute model: ([ABS_PRESS_SW](#))
Differential model: ([DIFF_PRESS_SW](#))
Gage model: ([GAGE_PRESS_SW](#))

Level 1 Piezoresistive Absolute Pressure Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

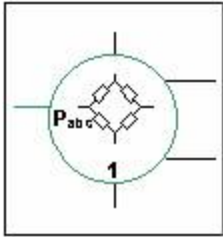


Figure 1. Component symbol

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- [Mathematical Description](#)
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Description

The Level 1 Piezoresistive Absolute Pressure Sensor model is used to simulate the ideal behavior of a strain-gauge absolute pressure sensor. A change in the applied pressure produces a corresponding change in the differential voltage output signal.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL abs_press_bridge ?InstanceName(@InstanceName):(@@Refbase)@(ID))
PRESSURE:= %0, Vcc:= %1, Vcc_m:= %2, out_plus:= %3, out_minus:= %4 ( max_pressure:=
@max_pressure, min_pressure:= @min_pressure, full_scale_span:= @full_scale_span, off-
set:= @offset, bridge_resistance:= @bridge_resistance) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PRESSURE	Applied pressure	Fluidic
Vcc	Positive power supply	Electrical
Vcc_m	Negative power supply	Electrical
out_plus	Positive output terminal pin	Electrical
out_minus	Negative output terminal pin	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage (output voltage at zero absolute pressure)	real	20m [V]
bridge_resistance	Equivalent bridge resistance	real	10k [Ohm]
max_pressure	Maximum measurable pressure	real	10k [Pa]
min_pressure	Minimum measurable pressure	real	0 [Pa]
full_scale_span	Algebraic difference between the output voltages at the maximum and minimum measurable pressure	real	55m [Pa]

	asures		

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Example

In this example, the Piezoresistive Absolute Pressure Sensor `abs_press_bridge2` measures the pressure across the Linear Orifice `RHYD2`, and converted it into a voltage signal. This voltage output is then sent out Analog-Digital Converter `adc1` through a voltage follower circuit. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

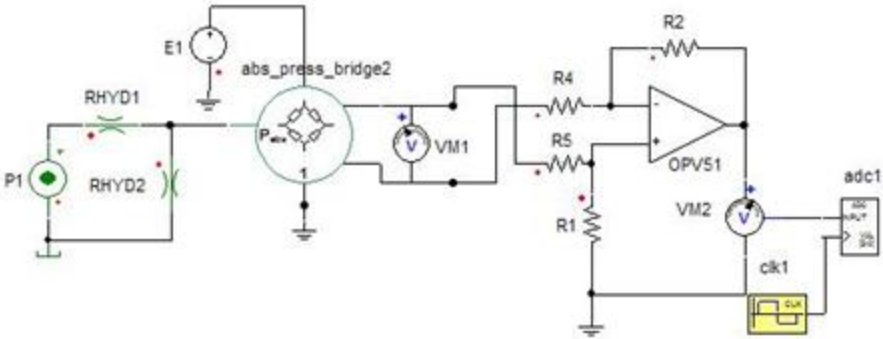


Figure 2. Application example of the Piezoresistive Absolute Pressure Sensor model

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	$10k + 20k * (t \geq 20m)$ [Pa]
Linear Orifice RHYD1/RHYD2	K	1n [m ³ /(Pa s)]
Piezoresistive Absolute Pressure Sensor <code>abs_press_bridge2</code>	offset	20m [V]
	bridge_resistance	500 [Ohm]
	max_pressure	10k [Pa]
	min_pressure	0 [Pa]
	full_scale_span	55m [Pa]

Voltage Source E1	EMF	3 [V]
Resistor R1/R2	R	40M [Ohm]
Resistor R4/R5	R	1M [Ohm]
Analog-Digital Converter adc1	min	0.8
	max	3
	clk	clk1.val
	input	VM2.V
Clock Source clk1	ped	10m
	del	0
	periodical	1



Figure 3. Simulation results-input and output of `abs_press_bridge2`

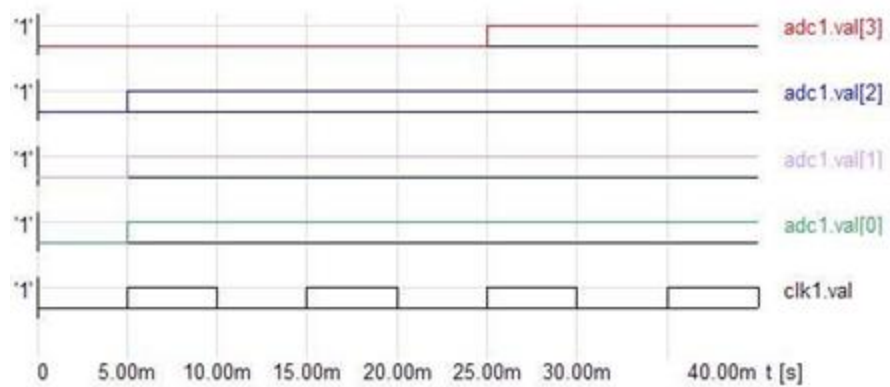


Figure 4. Simulation results- outputs of `adc1` and the clock signal

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References

Level 1 Uncompensated Capacitive Absolute Pressure Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

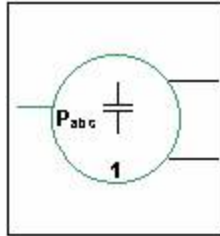


Figure 1. Component symbol

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Description

The Level 1 Uncompensated Capacitive Absolute Pressure Sensor model is used to simulate the ideal behavior of a capacitor absolute pressure sensor. A change in the applied pressure produces a corresponding change in the variable capacitance.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL ABS_PRESS_CAP ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) out_plus:=
%0, out_minus:= %1, PRESSURE:= %2 ( nominal_capacitance:= @nominal_capacitance,
max_pressure:= @max_pressure, min_pressure:= @min_pressure, full_scale_span:= @full_
scale_span) SRC: DB(Lib:=@ModellibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
out_plus	Positive capacitor terminal	Electrical
out_minus	Negative capacitor terminal	Electrical
PRESSURE	Measured pressure	Fluidic

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
nominal_capacitance	Capacitance at zero absolute pressure	real	0.1n [F]
max_pressure	Maximum measurable pressure	real	1k [Pa]
min_pressure	Minimum measurable pressure	real	0 [Pa]
full_scale_span	Difference between the capacitor outputs at the maximum and minimum pressures	real	50p [F]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
capacitance	Sensor capacitance	Output	real

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Example

In this example, the output capacitance of the Uncompensated Capacitive Absolute Pressure Sensor ABS_PRESS_CAP2 changes in reponse to the applied pressure. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

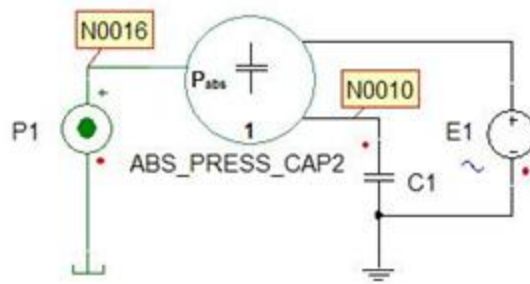


Figure 2. Application example of the Uncompensated Capacitive Absolute Pressure Sensor

Table 4

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	1.2k * (t/70m) [Pa]
Uncompensated Capacitive Absolute Pressure Sensor ABS_PRESS_CAP2	nominal_capacitance	50p [F]
	max_pressure	500 [Pa]
	min_pressure	100 [Pa]
	full_scale_span	50p [F]
Voltage Source (sinusoidal) E1	AMPL	5 [V]
	FREQ	50 [Hz]
	OFF	0 [V]
	TDELAY	0 [s]
	PHASE	0 [degree]
Capacitor C1	C	100p [F]
	V0	0 [V]

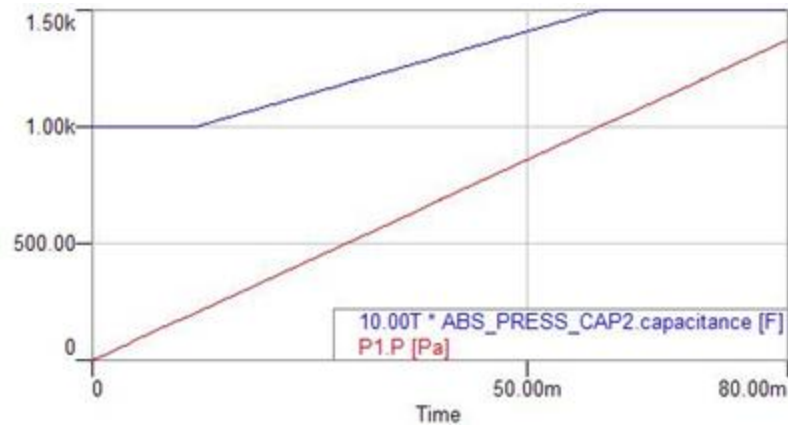


Figure 3. Simulation results-pressure output of P1 and the output capacitance of ABS_PRESS_CAP2

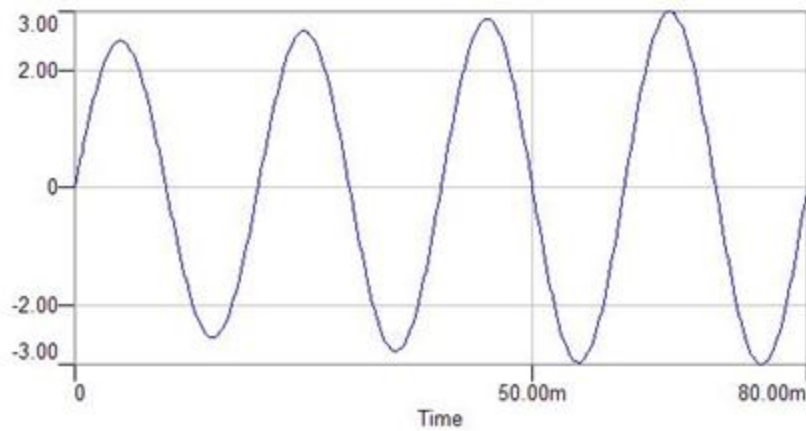


Figure 4. Simulation results-voltage across C1

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References

Level 1 LVDT Absolute Pressure Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

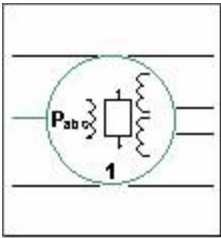


Figure 1. Component symbol

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Description

The Level 1 LVDT Absolute Pressure Sensor model is used to simulate the ideal behavior of a linear variable differential transformer absolute pressure sensor. A change in the applied pressure produces a corresponding change in the AC voltage output signal.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL ABS_PRESS_LVDT ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) out_1_
plus:= %0, out_1_minus:= %1, out_2_plus:= %2, out_2_minus:= %3, in_plus:= %4, in_minus:=
%5, PRESSURE:= %6 ( max_pressure:= @max_pressure, min_pressure:= @min_pressure,
sensitivity:= @sensitivity) SRC: DB(Lib:=@ModelLibraryName) ;
```

[Top](#)**Conservative Pins****Table 1**

Name	Port/Terminal Description	Nature/Data type
out_1_plus	Transformer secondary 1 positive terminal	Fluidic
out_1_minus	Transformer secondary 1 negative terminal (connect to out_2_minus for differential output)	Electrical
out_2_plus	Transformer secondary 2 positive terminal	Electrical
out_2_minus	Transformer secondary 2 negative terminal (connect to out_1_minus for differential output)	Electrical
in_plus	Transformer primary positive terminal	Electrical
in_minus	Transformer primary negative terminal	Electrical
PRESSURE	Measured pressure	Fluidic

[Top](#)**Parameters****Table 2**

Name	Description	Data Type	Default Value [Unit]
max_pressure	Maximum measurable pressure	real	10k [Pa]
min_pressure	Minimum measurable pressure	real	0 [Pa]

sensitivity	LVDT device sensitivity in V/V/Pa above or below the midrange pressure	real	0.1m [V/V/Pa]

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Example

In this example, the change in the ouptput pressure of the Pressure Source P1 produces a corresponding change in the AC voltage output signal of the LVDT Absolute Pressure Sensor ABS_PRESS_LVDT1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

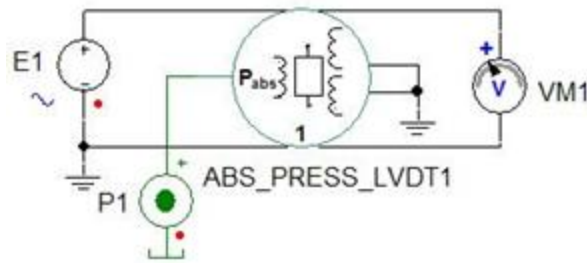


Figure 2. Application example of the LVDT Absolute Pressure Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	$10k + 2.5k * (t \geq 250\mu) + 5k * (t \geq 500\mu) + 2.5k * (t \geq 750\mu)$ [Pa]
Voltage Source (sinusoidal) E1	AMPL	10 [V]
	FREQ	3k [Hz]
	OFF	0 [V]
	PHASE	0 [degree]
	TDELAY	0 [s]
LVDT Absolute Pressure Sensor ABS_PRESS_LVDT1	max_pressure	20k [Pa]
	min_pressure	10k [Pa]
	sensitivity	0.1m [V/V/Pa]

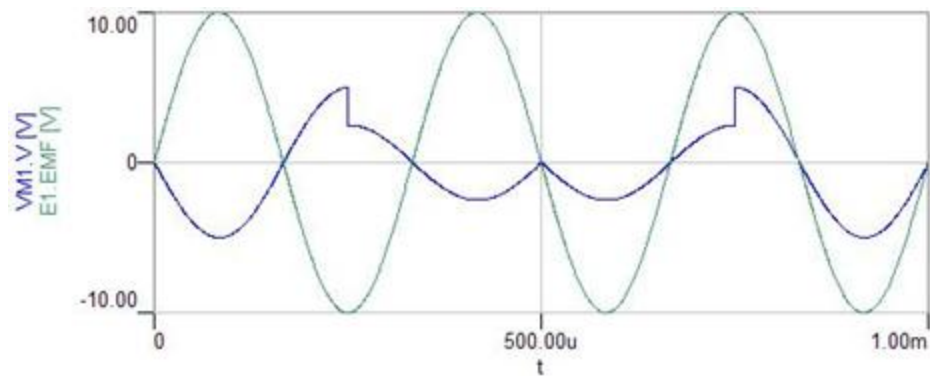


Figure 3. Simulation results-primary and secondary voltage of ABS_PRESS_LVDT1

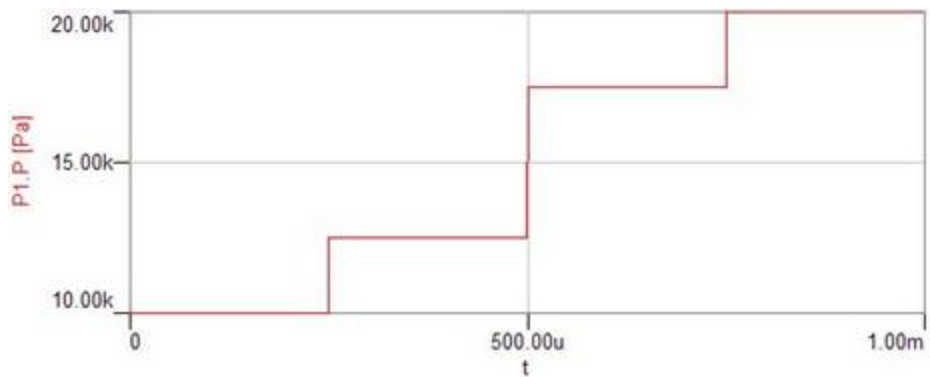


Figure 4. Simulation results-output pressure of P1

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References

Level 1 Piezoelectric Absolute Pressure Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

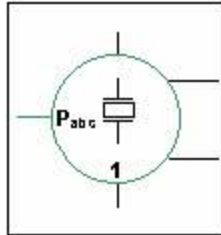


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Description

The Level 1 Piezoelectric Absolute Pressure Sensor model is used to simulate the ideal behavior of a piezoelectric crystal absolute pressure sensor. A change in the applied pressure produces a corresponding change in the voltage output signal.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL ABS_PRESS_PE ?InstanceName(@InstanceName):(@ (Refbase) @ (ID))
PRESSURE:= %0, out_plus:= %1, out_minus:= %2, Vdd:= %3, Vss:= %4 ( max_pressure:=
@max_pressure, min_pressure:= @min_pressure, full_scale_span:= @full_scale_span,
```

offset:= @offset, nom_supply_current:= @nom_supply_current) SRC: DB(Lib:-
:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PRESSURE	Measured pressure	Fluidic
out_plus	Positive output	Electrical
out_minus	Negative output	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Output voltage at zero pressure	real	0 [V]
max_pres- sure	Maximum measurable pressure	real	1k [Pa]
min_pres- sure	Minimum measurable pressure	real	0 [Pa]
full_scale_ span	Difference between the output voltages at the maximum and minimum measurable pressures	real	5 [V]
nom_sup- ply_cur-	Typical nominal supply current	real	1m [A]

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Example

In this example, the Piezoelectric Absolute Pressure Sensor ABS_PRESS_PE1 measures the pressure of the Hydraulic Capacitance CHYD1, and the output voltage of ABS_PRESS_PE1 changes in reponse to the applied pressure. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

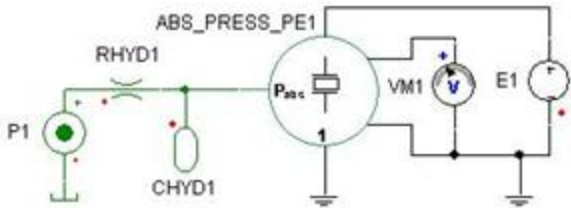


Figure 2. Application example of the Piezoelectric Absolute Pressure Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	2E8 [Pa]
Linear Orifice RHYD1	K	10m [m ³ / (Pa s)]
Hydraulic Capacitance CHYD1	VOL	0.1u [m ³]
	B	1 [Pa]
	P0	0 [Pa]
Piezoelectric Absolute Pressure Sensor ABS_PRESS_PE1	offset	9 [V]
	max_pres-sure	2000 [bar]
	min_pres-sure	0 [bar]
	full_scale_span	5 [V]

	nom_supply_ current	4 [mA]
Voltage Source E1	EMF	20 [V]

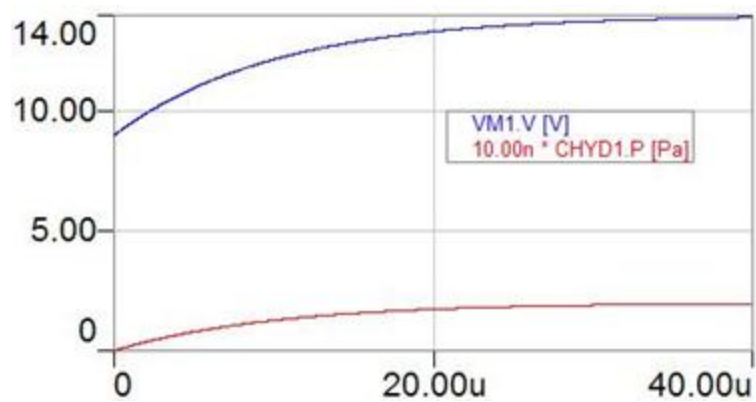


Figure 3. Simulation results-input pressure and output voltage of ABS_PRESS_PE1



Figure 4. Simulation results-supply current of ABS_PRESS_PE1

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References

Level 1 Potentiometric Absolute Pressure Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

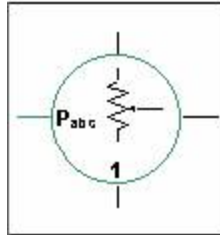


Figure 1. Component symbol

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Description

The Level 1 Potentiometric Absolute Pressure Sensor model is used to simulate the ideal behavior of a potentiometer absolute pressure sensor. A change in the applied pressure produces a corresponding change in the voltage divider output signal.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL ABS_PRESS_POTEN ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
PRESSURE:= %0, OUT:= %1, Vdd:= %2, Vss:= %3 ( max_pressure:= @max_pressure, min_
```

pressure:= @min_pressure, full_scale_span:= @full_scale_span, offset:= @offset, p_resistance:= @p_resistance) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
Vdd	Positive supply	Electrical
Vss	Negative supply	Electrical
OUT	Output terminal	Electrical
PRESSURE	Measured pressure	Fluidic

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage (device output at zero pressure)	real	0 [V]
p_resistance	Potentiometer resistance	real	10k [Ohm]
max_pressure	Maximum measurable absolute pressure	real	10k [Pa]
min_pressure	Minimum measurable absolute pressure	real	0 [Pa]
full_scale_span	Difference between the maximum and minimum output voltages at the maximum/minimum pressures	real	10 [V]

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Example

In this example, the output voltage of the Potentiometric Absolute Pressure Sensor ABS_PRESS_POTEN1 changes in response to the applied pressure source P1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

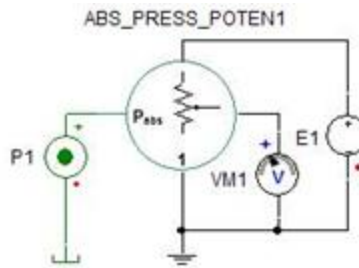


Figure 2. Application example of the Pressure Switch Gage Pressure Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	$(6894.757 * 5k) * (t/40m)$ [Pa]
Voltage Source E1	EMF	10 [V]
Potentiometric Absolute Pressure Sensor ABS_PRESS_POTEN1	offset	$.10 * E1.EMF$ [V]
	p_res-istance	5k [Ohm]
	max_pres-sure	5k [Pa]
	min_pres-sure	0 [Pa]
	full_scale_span	$0.9 * E1.EMF$ [V]

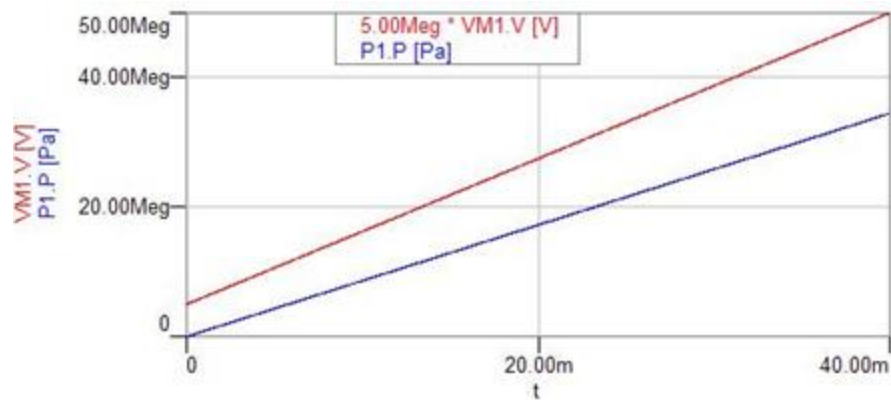


Figure 3. Simulation results-input pressure and output voltage of ABS_PRESS_POTEN1

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References

Level 1 Pressure Switch Absolute Pressure Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

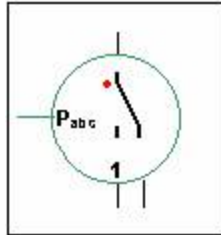


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Description

The Level 1 Pressure Switch Absolute Pressure Sensor model is used to simulate the ideal behavior of an absolute pressure-sensing switch. If the pressure applied to the switch exceeds the switch's threshold pressure, the switch changes position from its normally closed terminal to its normally open terminal.

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Netlist Syntax

```
MODEL ABS_PRESS_SW ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
PRESSURE:= %0, nmnc:= %1, nmno:= %2, np:= %3 ( threshold_pressure:= @threshold_
```

pressure) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PRESSURE	Measured pressure	Fluidic
nmnc	Normally closed negative terminal	Electrical
nmno	Normally open negative terminal	Electrical
np	Positive terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
threshold_pres-sure	Switch threshold pres-sure	real	0.101325Meg [Pa]

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Example

In this example, when the output pressure of the Pressure Source P1 is below the pressure limit of the Pressure Switch Absolute Pressure Sensor ABS_PRESS_SW1, the resistor Rno is connected to the current source via ABS_PRESS_SW1; when te output pressure of P1 exceeds the pressure limit of ABS_PRESS_SW1, the switch changes position from its normally closed terminal to its normally open terminal, and hence connects Rnc to the current source instead. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 - 5.

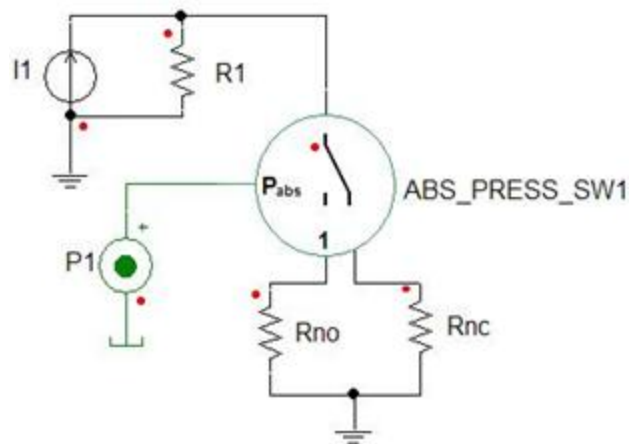


Figure 2. Application example of the Pressure Switch Absolute Pressure Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	1Meg * t/40m [Pa]
Current Source I1	IS	1 [A]
Resistor Rno/Rnc	R	1k [Ohm]
Resistor R1	R	100k [Ohm]
Pressure Switch Absolute Pressure Sensor ABS_PRESS_SW1	threshold_ pressure	500k [Pa]

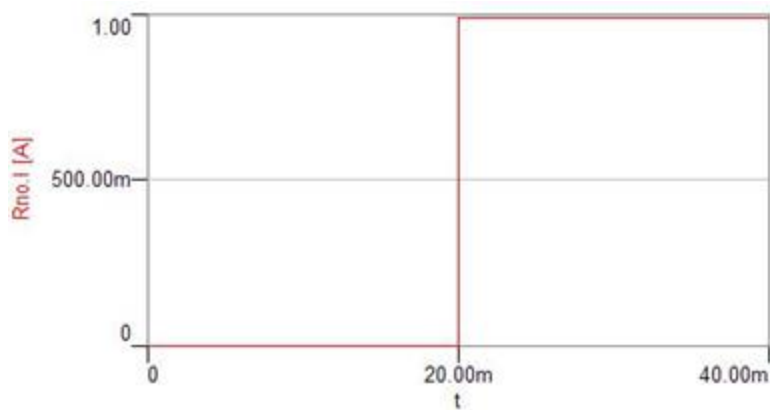


Figure 3. Simulation results-current through Rno

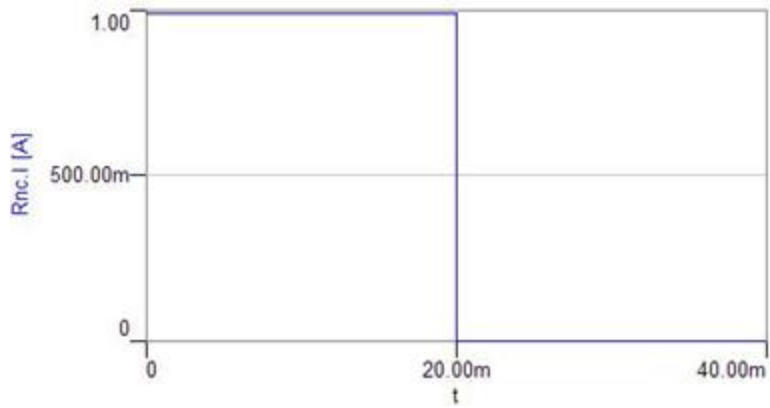


Figure 4. Simulation results-current through Rnc

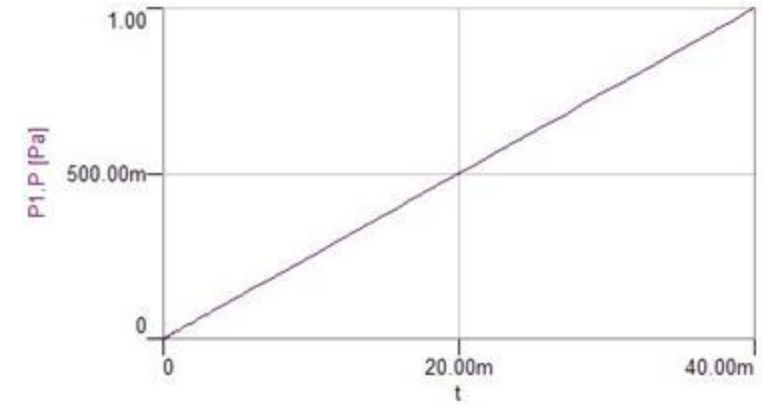


Figure 5. Simulation results-output pressure of P1

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References

Level 1 Piezoresistive Differential Pressure Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

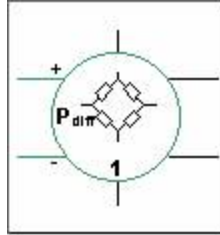


Figure 1. Component symbol

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Description

The Level 1 Piezoresistive Differential Pressure Sensor model is used to simulate the ideal behavior of a strain-gauge differential pressure sensor. A change in the measured pressure or the reference pressure produces a corresponding change in the differential voltage output signal.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL DIFF_PRESS_BRIDGE ?InstanceName(@InstanceName):(@Refbase)@(ID)) Vcc:=
%0, Vcc_m:= %1, out_plus:= %2, out_minus:= %3, PRESSURE1:= %4, PRESSURE2:= %5 (
max_pressure:= @max_pressure, min_pressure:= @min_pressure, full_scale_span:= @full_
```

```
scale_span, offset:= @offset, bridge_resistance:= @bridge_resistance) SRC: DB(Lib:-
:=@ModelLibraryName);
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
Vcc	Positive supply	Electrical
Vcc_m	Negative supply	Electrical
out_plus	Positive output	Electrical
out_minus	Negative output	Electrical
PRESSURE1	Applied pressure	Fluidic
PRESSURE2	Reference pressure	Fluidic

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage (output voltage at zero differential pressure)	real	20m [V]
bridge_resistance	Equivalent bridge resistance	real	10k [Ohm]
max_pressure	Maximum measurable differential pressure	real	10k [Pa]
min_pressure	Minimum measurable differential pressure	real	0 [Pa]

full_scale_span	Algebraic difference between the output voltages at the maximum and minimum measurable pressures	real	55m [Pa]

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Example

In this example, the Piezoresistive Differential Pressure Sensor DIFF_PRESS_BRIDGE2 measures the pressure across the Linear Orifice RHYD2, and converted it into a voltage signal. This voltage output is measured by a Voltage Meter VM1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

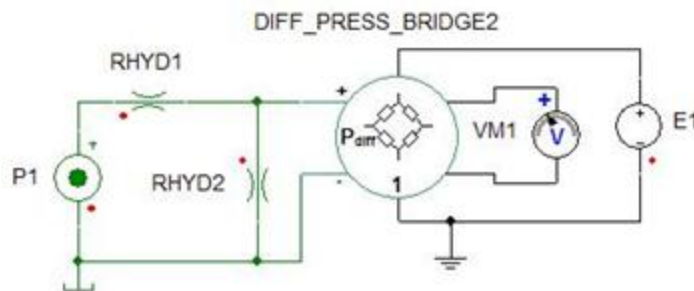


Figure 2. Application example of the Piezoresistive Absolute Pressure Sensor model

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	$10k + 20k * (t > 20m)$ [Pa]
Linear Orifice RHYD1/RHYD2	K	$1n$ [m ³ /(Pa s)]
Piezoresistive Differential Pressure Sensor DIFF_PRESS_BRIDGE2	offset	20m [V]
	bridge_resistance	500 [Ohm]
	max_pressure	10k [Pa]
	min_pressure	0 [Pa]

	full_scale_ span	55m [Pa]
Voltage Source E1	EMF	3 [V]

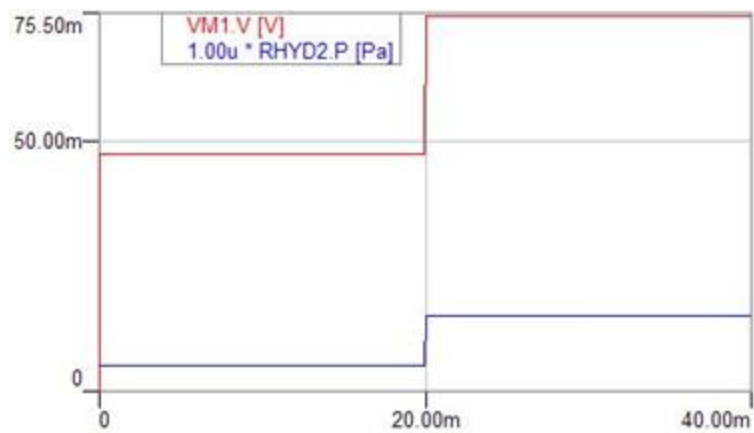


Figure 3. Simulation results-input and output of DIFF_PRESS_BRIDGE2

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References

Level 1 Uncompensated Capacitive Differential Pressure Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

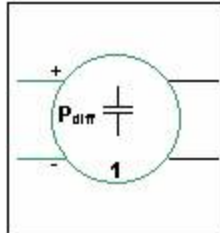


Figure 1. Component symbol

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Description

The Level 1 Uncompensated Capacitive Differential Pressure Sensor model is used to simulate the ideal behavior of a capacitor differential pressure sensor. A change in the measured pressure or the reference pressure produces a corresponding change in the variable capacitance output signal.

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Mathematical Description

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Netlist Syntax

MODEL DIFF_PRESS_CAP ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) out_plus:= %0, out_minus:= %1, PRESSURE1:= %2, PRESSURE2:= %3 (nominal_capacitance:= @nominal_capacitance, max_pressure:= @max_pressure, min_pressure:= @min_pressure, full_scale_span:= @full_scale_span) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
out_plus	Positive capacitor terminal	Electrical
out_minus	Negative capacitor terminal	Electrical
PRESSURE1	Measured pressure	Fluidic
PRESSURE2	Reference pressure	Fluidic

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
nominal_capacitance	Capacitance at zero differential pressure	real	0.1n [F]
max_pressure	Maximum measurable differential pressure	real	1k [Pa]
min_pressure	Minimum measurable differential pressure	real	0 [Pa]
full_scale_span	Difference between the capacitor outputs at the maximum and minimum differential pressures	real	50p [F]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
capacitance	Sensor capacitance	Output	real

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Example

In this example, the Uncompensated Capacitive Differential Pressure Sensor DIFF_PRESS_CAP2 measures the pressure of the Hydraulic Capacitance CHYD1, and the output capacitance of DIFF_PRESS_CAP2 changes in response to the applied pressure. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3-5.

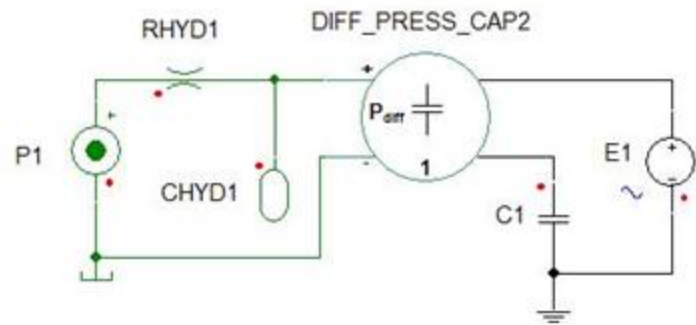


Figure 2. Application example of the Uncompensated Capacitive Differential Pressure Sensor

Table 4

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	500 [Pa]
Linear Orifice RHYD1	K	15m [m ³ / (Pa s)]
Hydraulic Capacitance CHYD1	VOL	0.2m [m ³]
	B	1 [Pa]
	P0	0 [Pa]
Uncompensated Capacitive Differential Pressure Sensor DIFF_PRESS_CAP2	nominal_capa- cittance	50p [F]
	max_pres- sure	500 [Pa]
	min_pressure	100 [Pa]
	full_scale_ span	50p [F]
Voltage Source (sinusoidal) E1	AMPL	5 [V]
	FREQ	50 [Hz]
	OFF	0 [V]

Capacitor C1	TDELAY	0 [s]
	PHASE	0 [degree]
	C	100p [F]
	V0	0 [V]

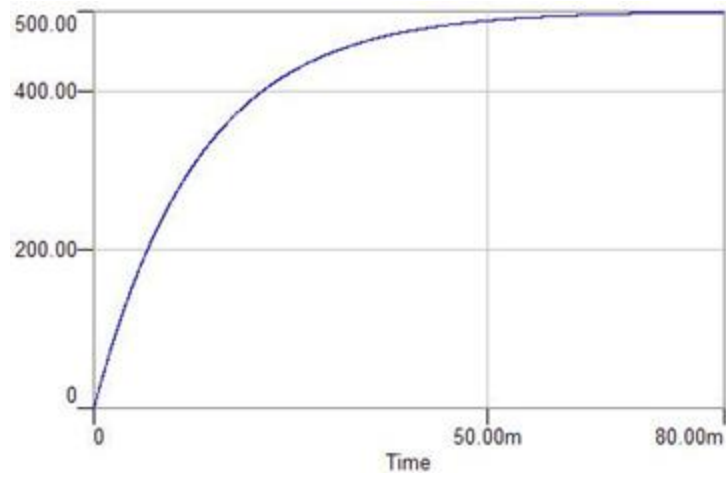
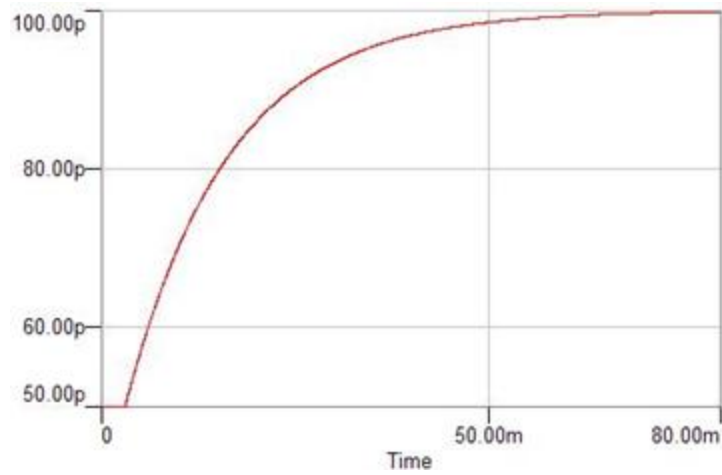
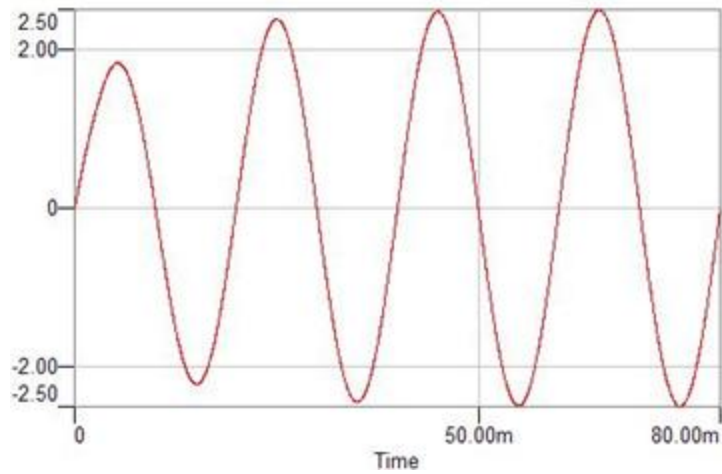


Figure 3. Simulation results-pressure of CHYD2**Figure 4. Simulation results-output capacitance of DIFF_PRESS_CAP2****Figure 5. Simulation results-voltage across C1**[Top](#)

References

Level 1 LVDT Differential Pressure Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

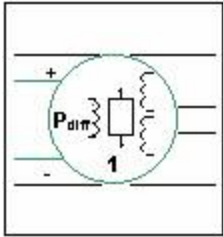


Figure 1. Component symbol

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Description

The Level 1 LVDT Differential Pressure Sensor model is used to simulate the ideal behavior of a linear variable differential transformer differential pressure sensor. A change in the applied pressure or the reference pressure produces a corresponding change in the AC voltage output signal.

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Mathematical Description

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Netlist Syntax

```
MODEL DIFF_PRESS_LVDT ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) out_1_
plus:= %0, out_1_minus:= %1, out_2_plus:= %2, out_2_minus:= %3, in_plus:= %4, in_minus:=
```

%5, PRESSURE1:= %6, PRESSURE2:= %7 (max_pressure:= @max_pressure, min_pressure:= @min_pressure, sensitivity:= @sensitivity) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PRESSURE1	Measured pressure 1	Fluidic
PRESSURE2	Measured pressure 2	Fluidic
out_1_plus	Transformer secondary 1 positive terminal	Electrical
out_1_minus	Transformer secondary 1 negative terminal (connect to out_2_minus for differential output)	Electrical
out_2_plus	Transformer secondary 2 positive terminal	Electrical
out_2_minus	Transformer secondary 2 negative terminal (connect to out_1_minus for differential output)	Electrical
in_plus	Transformer primary positive terminal	Electrical
in_minus	Transformer primary negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]

max_pres- sure	Maximum measurable dif- ferential pressure	real	10k [Pa]
min_pres- sure	Minimum measurable dif- ferential pressure	real	-10k [Pa]
sensitivity	LVDT device sensitivity in V/V/Pa above or below the midrange pressure	real	1 [V/V/Pa]

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Example

In this example, the change in the ouptup pressure of the Pressure Source P1 produces a cor-
responding change in the AC voltage output signal of the LVDT Differential Pressure Sensor
DIFF_PRESS_LVDT1. The schematic of the system is shown in Figure 2, system parameters
are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

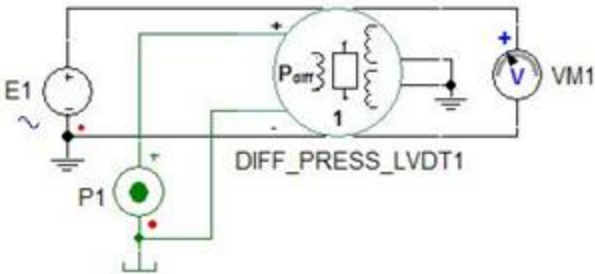


Figure 2. Application example of the LVDT Differential Pressure Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	2k * (t>=100u) + 1k * (t>=250u) + 1k * (t >=500u) + 1k * (t>=750u) [Pa]
Voltage Source (sinus- oidal) E1	AMPL	10 [V]
	FREQ	3k [Hz]
	OFF	0 [V]
	PHASE	0 [degree]
	TDELAY	0 [s]

LVDT Differential Pressure Sensor DIFF_PRESS_LVDT1	max_pressure	10k [Pa]
	min_pressure	5k [Pa]
	sensitivity	0.1m [V/V/Pa]

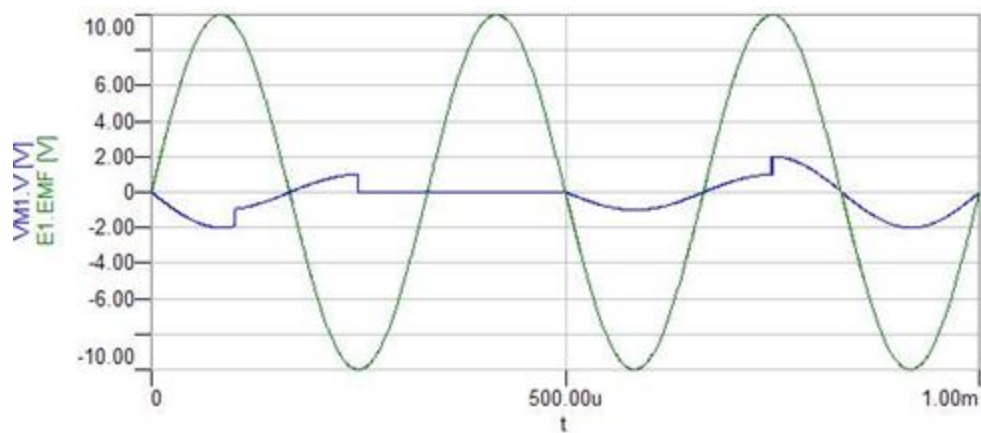


Figure 3. Simulation results-primary and secondary voltage of DIFF_PRESS_LVDT1

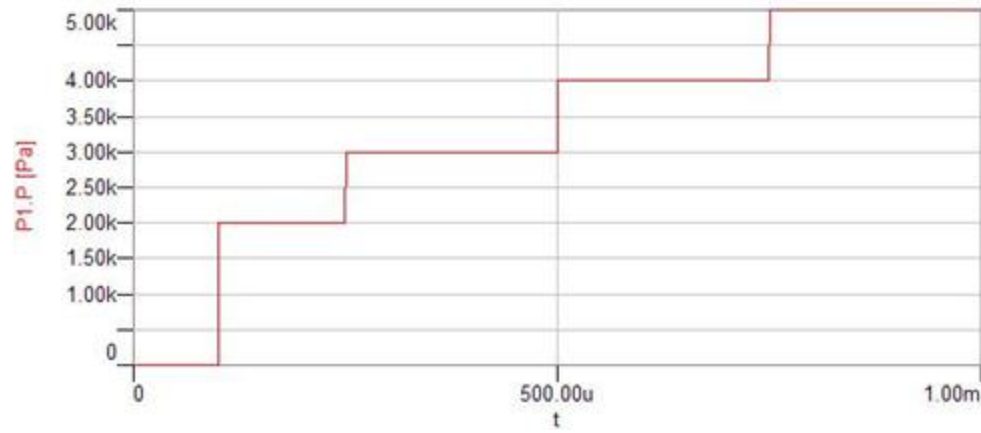


Figure 4. Simulation results-output pressure of P1

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References

Level 1 Piezoelectric Differential Pressure Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

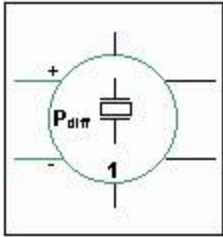


Figure 1. Component symbol

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Description

The Level 1 Piezoelectric Differential Pressure Sensor model is used to simulate the ideal behavior of a piezoelectric crystal differential pressure sensor. A change in the measured pressure or the reference pressure produces a corresponding change in the voltage output signal.

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Mathematical Description

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Netlist Syntax

```
MODEL DIFF_PRESS_PE ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) out_plus:=
%0, out_minus:= %1, Vdd:= %2, Vss:= %3, PRESSURE1:= %4, PRESSURE2:= %5 ( max_
pressure:= @max_pressure, min_pressure:= @min_pressure, full_scale_span:= @full_scale_
```

span, offset:= @offset, nom_supply_current:= @nom_supply_current) SRC: DB(Lib:-
:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PRESSURE1	Measured pressure	Fluidic
PRESSURE2	Reference pressure	Fluidic
out_plus	Positive capacitor terminal	Electrical
out_minus	Negative capacitor terminal	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Output voltage at zero pressure	real	0 [V]
max_pressure	Maximum measurable pressure	real	1k [Pa]
min_pressure	Minimum measurable pressure	real	0 [Pa]
full_scale_span	Difference between the output voltages at the maximum and minimum measurable pressures	real	5 [V]
nom_supply_current	Typical nominal supply current	real	1m [A]

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Example

In this example, the Piezoelectric Differential Pressure Sensor DIFF_PRESS_PE1 measures the pressure of the Hydraulic Capacitance CHYD1, and the output voltage of DIFF_PRESS_PE1 changes in reponse to the applied pressure. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 - 5.

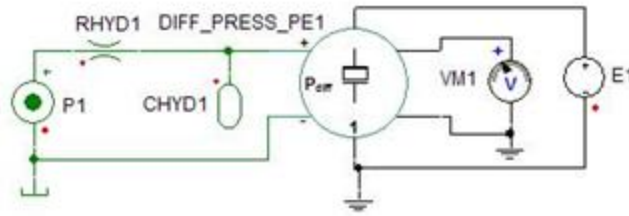


Figure 2. Application example of the Piezoelectric Differential Pressure Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	2E8 [Pa]
Linear Orifice RHYD1	K	10m [m ³ / (Pa s)]
Hydraulic Capacitance CHYD1	VOL	50n [m ³]
	B	1 [Pa]
	P0	0 [Pa]
Piezoelectric Differential Pressure Sensor DIFF_PRESS_PE1	offset	9 [V]
	max_pres- sure	2000 [bar]
	min_pres- sure	0 [bar]
	full_scale_ span	5 [V]
	nom_sup- ply_current	4 [mA]
Voltage Source E1	EMF	20 [V]

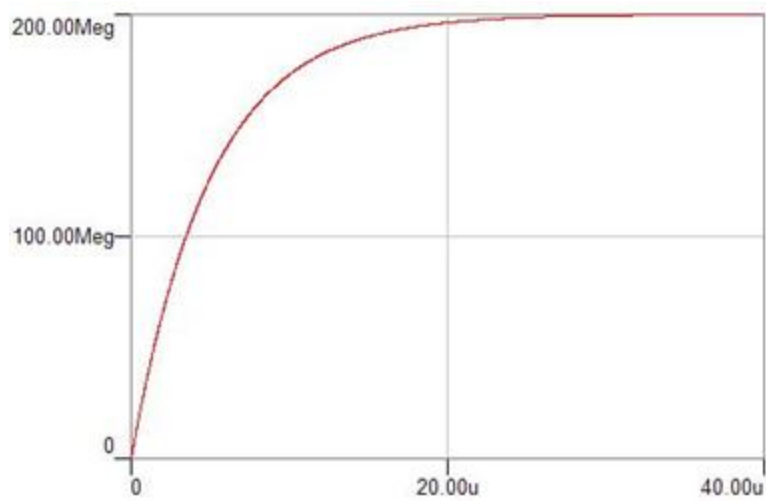
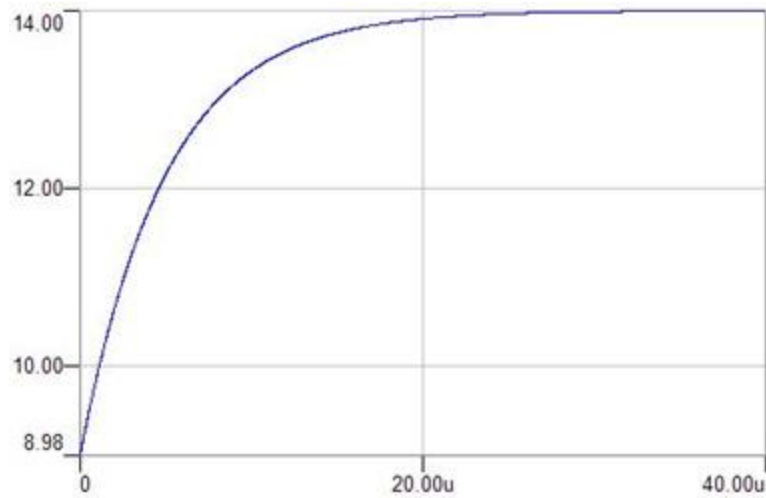
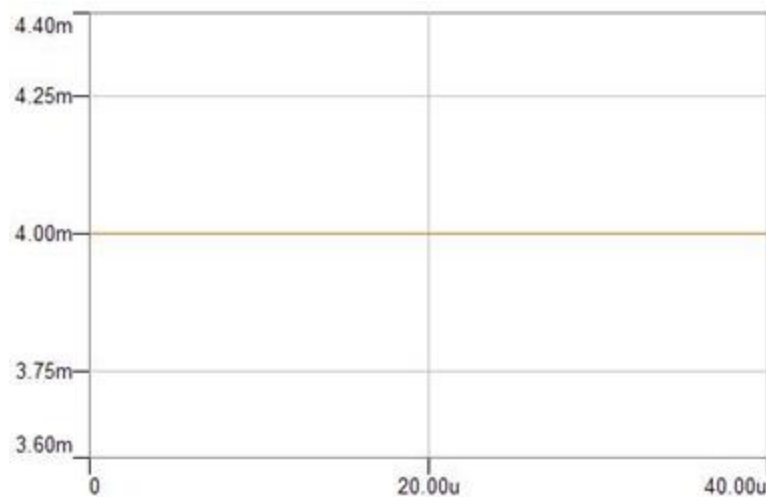


Figure 3. Simulation results-input pressure of DIFF_PRESS_PE1**Figure 4. Simulation results-output voltage of DIFF_PRESS_PE1****Figure 5. Simulation results-supply current of DIFF_PRESS_PE1**[Top](#)

References

Level 1 Potentiometric Differential Pressure Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

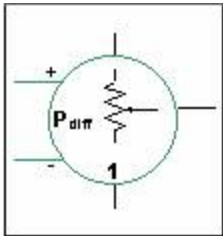


Figure 1. Component symbol

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Description

The Level 1 Potentiometric Differential Pressure Sensor model is used to simulate the ideal behavior of a potentiometer differential pressure sensor. A change in the applied pressure or the reference pressure produces a corresponding change in the voltage divider output signal.

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Mathematical Description

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Netlist Syntax

```
MODEL DIFF_PRESS_POTEN ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) OUT:= %0, Vdd:= %1, Vss:= %2, PRESSURE1:= %3, PRESSURE2:= %4 ( max_pressure:= @max_pressure, min_pressure:= @min_pressure, full_scale_span:= @full_scale_span, offset:= @offset, p_resistance:= @p_resistance) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Name	Port/Terminal Description	Nature/Data type
Vdd	Positive supply	Electrical
Vss	Negative supply	Electrical
OUT	Output terminal	Electrical
PRESSURE1	Measured pressure	Fluidic
PRESSURE2	Reference pressure	Fluidic

[Top](#)**Parameters****Table 2**

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage (output at zero differential pressure) [V]	real	
p_res-istance	Potentiometer resistance [Ohm}	real	
max_pres-sure	Maximum measurable differential pressure [Pa]	real	
min_pres-sure	Minimum measurable differential pressure [Pa]	real	
full_scale_span	Difference between the maximum and minimum output voltages at the maximum/minimum pressures [V]	real	

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Example

In this example, the output voltage of the Potentiometric Differential Pressure Sensor DIFF_PRESS_POTEN1 changes in reponse to the applied pressure source P1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

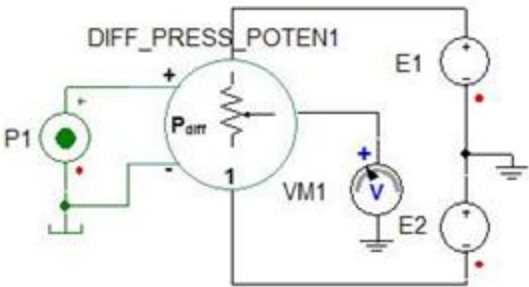


Figure 2. Application example of the Pressure Switch Gage Pressure Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	$(6894.757 * 6k) * (t/40m)$ [Pa]
Voltage Source E1/E2	EMF	5 [V]
Potentiometric Absolute Pressure Sensor ABS_PRESS_POTEN1	offset	$0.8 * E2.EMF$ [V]
	p_res-istance	5k [Ohm]
	max_pres-sure	5k [Pa]
	min_pres-sure	0 [Pa]
	full_scale_span	$1.8 * E1.EMF$ [V]

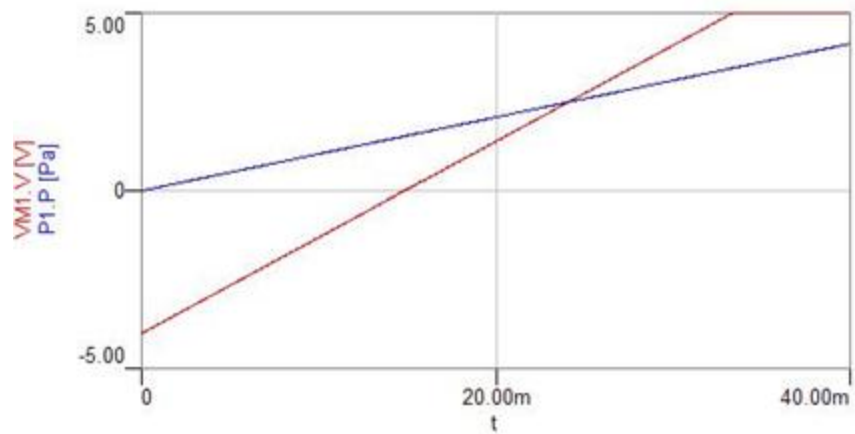


Figure 3. Simulation results-input pressure and output voltage of DIFF_PRESS_POTEN1

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References

Level 1 Pressure Switch Differential Pressure Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

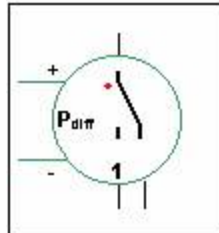


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Description

The Level 1 Pressure Switch Differential Pressure Sensor model is used to simulate the ideal behavior of a differential pressure-sensing switch. If the differential pressure applied to the switch exceeds the switch's threshold pressure, the switch changes position from its normally closed terminal to its normally open terminal.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL DIFF_PRESS_SW ?InstanceName(@InstanceName):(@Refbase)@(ID))
PRESSURE1:= %0, PRESSURE2:= %1, nmnc:= %2, nmno:= %3, np:= %4 ( threshold_pres-
sure:= @threshold_pressure) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
nmnc	Normally closed negative terminal	Electrical
nmno	Normally open negative terminal	Electrical
np	Positive terminal	Electrical
PRESSURE1	Measured pressure	Fluidic
PRESSURE2	Reference pressure	Fluidic

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
threshold_pressure	Switch threshold pressure	real	0.101325Meg [Pa]

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Example

In this example, when the output pressure of the Pressure Source P1 is below the pressure limit of the Pressure Switch Differential Pressure Sensor DIFF_PRESS_SW1, the resistor Rno is connected to the current source via DIFF_PRESS_SW1; when the output pressure of P1 exceeds the pressure limit of DIFF_PRESS_SW1, the switch changes position from its normally closed terminal to its normally open terminal, and hence connects Rnc to the current source instead. The

schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 - 5.

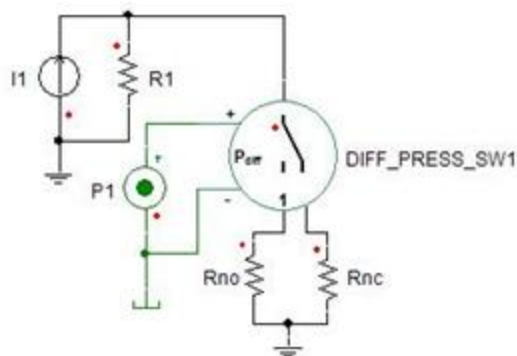


Figure 2. Application example of the Pressure Switch Differential Pressure Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	1Meg * t/40m [Pa]
Current Source I1	IS	1 [A]
Resistor Rno/Rnc	R	1k [Ohm]
Resistor R1	R	100k [Ohm]
Pressure Switch Differential Pressure Sensor DIFF_PRESS_SW1	threshold_ pressure	500k [Pa]

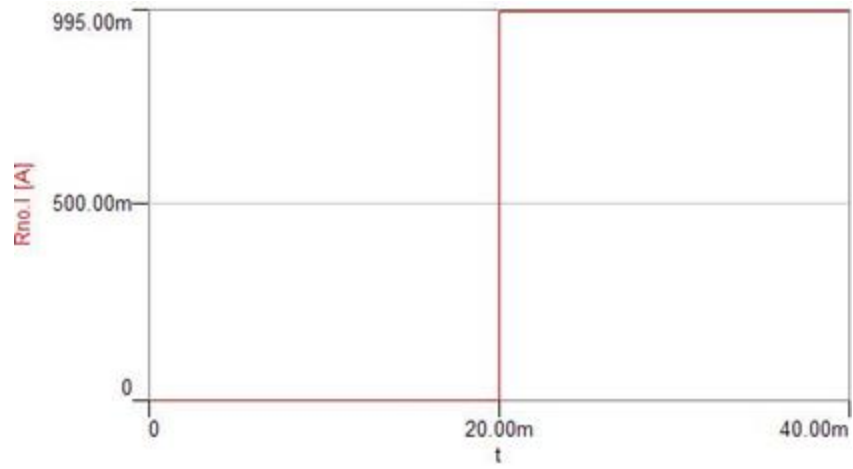


Figure 3. Simulation results-current through Rno

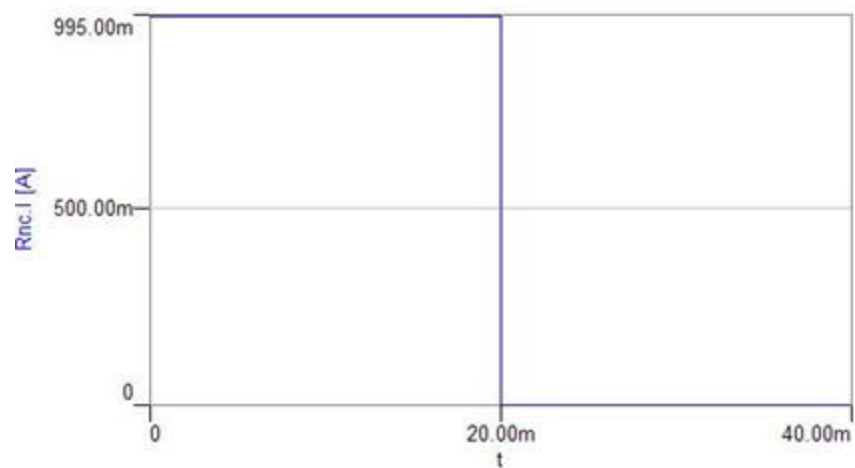


Figure 4. Simulation results-current through Rnc

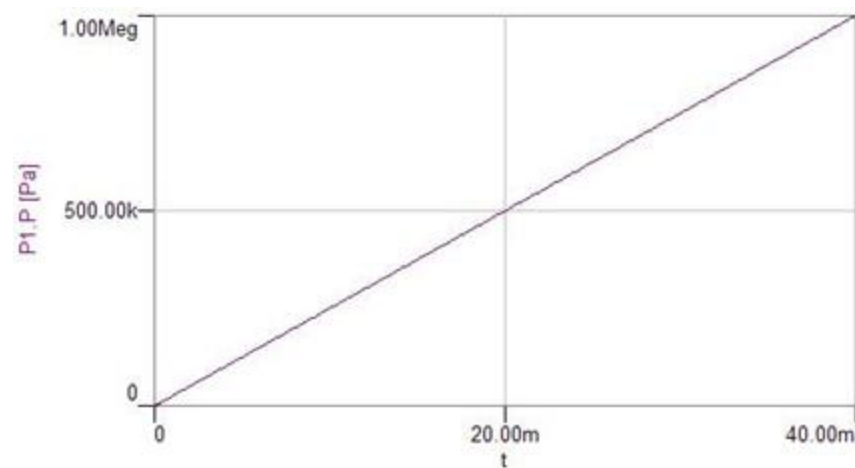


Figure 5. Simulation results-output pressure of P1

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References

Level 1 Piezoresistive Gage Pressure Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

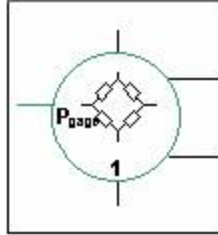


Figure 1. Component symbol

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- [Mathematical Description](#)
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Description

The Level 1 Piezoresistive Gage Pressure Sensor model is used to simulate the ideal behavior of a strain-gauge gage pressure sensor. A change in the measured pressure or the atmospheric pressure produces a corresponding change in the differential voltage output signal.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL gage_press_bridge ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
PRESSURE:= %0, Vcc:= %1, Vcc_m:= %2, out_plus:= %3, out_minus:= %4 ( max_pressure:=
@max_pressure, min_pressure:= @min_pressure, full_scale_span:= @full_scale_span, off-
```

```
set:= @offset, bridge_resistance:= @bridge_resistance, atmp:= @atmp) SRC: DB(Lib:-
:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PRESSURE	Applied pressure	Fluidic
Vcc	Positive power supply	Electrical
Vcc_m	Negative power supply	Electrical
out_plus	Positive output	Electrical
out_minus	Negative output	Electrical

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Input/Output Quantities

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage (output voltage at zero gage pressure)	real	20m [Pa]
bridge_resistance	Equivalent bridge resistance	real	10k [Ohm]
max_pressure	Maximum measurable gage pressure	real	10k [Pa]
min_pressure	Minimum measurable gage pressure	real	0 [Pa]
full_scale_span	Algebraic difference between the output voltages at the maximum and minimum meas-	real	55m [V]

	urable pressures		
atmp	Ambient atmospheric pressure	real	101.325k [Pa]

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Example

In this example, the Piezoresistive Gage Pressure Sensor gage_press_bridge2 measures the output pressure of the Pressure Source P1, and converted it into a voltage signal. This voltage output is measured by a Voltage Meter VM1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

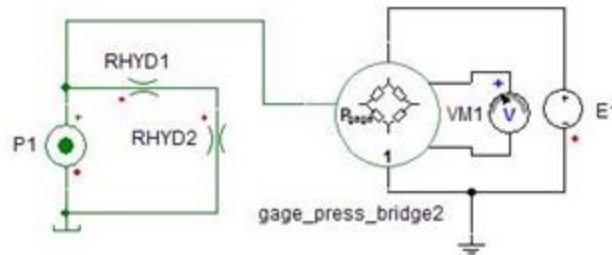


Figure 2. Application example of the Piezoresistive Gage Pressure Sensor model

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	101.325k + (5k + 10k * (t>20m)) [Pa]
Linear Orifice RHYD1/RHYD2	K	1n [m ³ /(Pa s)]
Piezoresistive Gage Pressure Sensor gage_press_bridge2	offset	20m [V]
	bridge_resistance	500 [Ohm]
	max_pressure	10k [Pa]
	min_pressure	0 [Pa]
	full_scale_span	55m [Pa]

	atmp	0.101325Meg [Pa]
Voltage Source E1	EMF	3 [V]

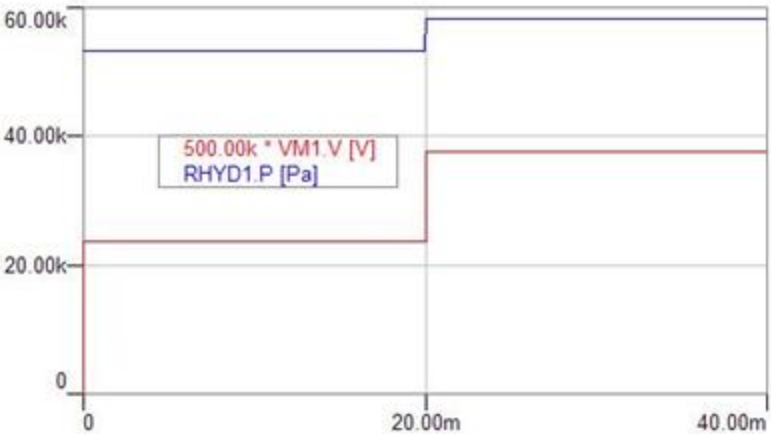


Figure 3. Simulation results-input and output of gage_press_bridge2

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References

Level 1 Uncompensated Capacitive Gage Pressure Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

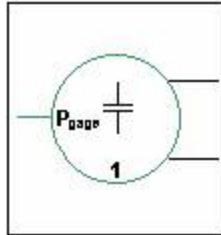


Figure 1. Component symbol

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Description

The Level 1 Uncompensated Capacitive Gage Pressure Sensor model is used to simulate the ideal behavior of a capacitor gage pressure sensor. A change in the measured pressure or the atmospheric pressure produces a corresponding change in the variable capacitance output signal.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

MODEL GAGE_PRESS_CAP ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) out_plus:= %0, out_minus:= %1, PRESSURE:= %2 (nominal_capacitance:= @nominal_capacitance, max_pressure:= @max_pressure, min_pressure:= @min_pressure, full_scale_span:= @full_scale_span, atmp:= @atmp) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
out_plus	Positive capacitor terminal	Electrical
out_minus	Negative capacitor terminal	Electrical
PRESSURE	Measured pressure	Fluidic

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
nominal_capacitance	Capacitance at zero gage pressure	real	0.1n [F]
atmp	Ambient atmospheric pressure	real	0.101325Meg [Pa]
max_pressure	Maximum measurable gage pressure	real	1k [Pa]
min_pressure	Minimum measurable gage pressure	real	0 [Pa]
full_scale_span	Difference between the capacitor outputs at the maximum and minimum gage pressures	real	50p [F]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
capacitance	Sensor capacitance	Output	real

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Example

In this example, the output capacitance of the Uncompensated Capacitive Gage Pressure Sensor GAGE_PRESS_CAP2 changes in response to the applied pressure. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3-5.

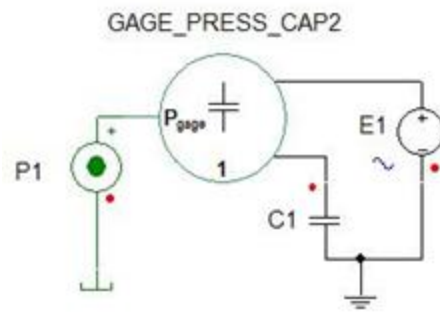


Figure 2. Application example of the Uncompensated Capacitive Gage Pressure Sensor**Table 4**

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	$101.325k + (500) * (t/60m)$ [Pa]
Uncompensated Capacitive Gage Pressure Sensor GAGE_PRESS_CAP2	nominal_capacitance	50p [F]
	max_pressure	500 [Pa]
	min_pressure	100 [Pa]
	full_scale_span	50p [F]
	atmp	0.101325Meg [Pa]
Voltage Source (sinusoidal) E1	AMPL	5 [V]
	FREQ	50 [Hz]
	OFF	0 [V]
	TDELAY	0 [s]
	PHASE	0 [degree]
Capacitor C1	C	100p [F]
	V0	0 [V]

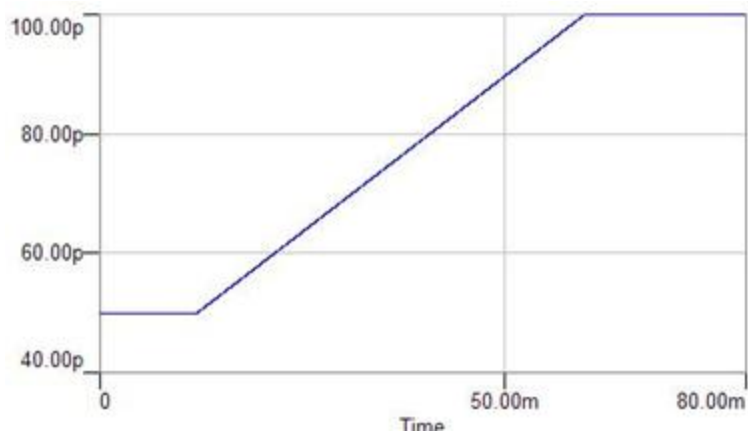


Figure 3. Simulation results-output capacitance of ABS_PRESS_CAP2

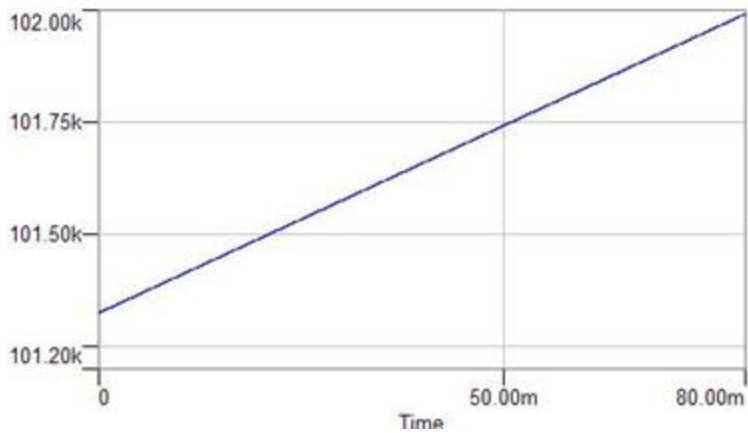


Figure 4. Simulation results-pressure output of P1

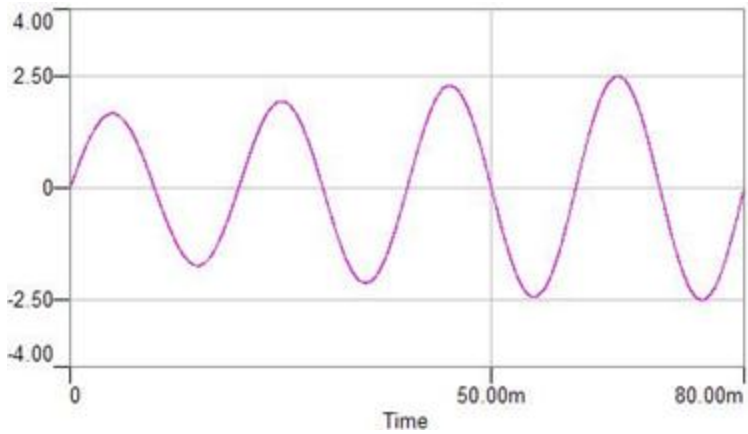


Figure 5. Simulation results-voltage across C1

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References

Level 1 LVDT Gage Pressure Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

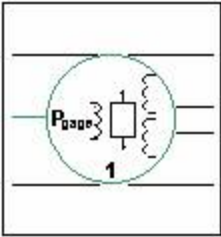


Figure 1. Component symbol

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Description

The Level 1 LVDT Gage Pressure Sensor model is used to simulate the ideal behavior of a linear variable differential transformer gage pressure sensor. A change in the applied pressure or the atmospheric pressure produces a corresponding change in the AC voltage output signal.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL GAGE_PRESS_LVDT ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) out_1_
plus:= %0, out_1_minus:= %1, out_2_plus:= %2, out_2_minus:= %3, in_plus:= %4, in_minus:=
%5, PRESSURE:= %6 ( max_pressure:= @max_pressure, min_pressure:= @min_pressure,
sensitivity:= @sensitivity, atmp:= @atmp) SRC: DB(Lib:=@ModelLibraryName) ;
```


[Top](#)**Conservative Pins****Table 1**

Name	Port/Terminal Description	Nature/Data type
out_1_plus	Transformer secondary 1 positive terminal	Fluidic
out_1_minus	Transformer secondary 1 negative terminal (connect to out_2_minus for differential output)	Electrical
out_2_plus	Transformer secondary 2 positive terminal	Electrical
out_2_minus	Transformer secondary 2 negative terminal (connect to out_1_minus for differential output)	Electrical
in_plus	Transformer primary positive terminal	Electrical
in_minus	Transformer primary negative terminal	Electrical
PRESSURE	Measured pressure	Fluidic

[Top](#)**Parameters****Table 2**

Name	Description	Data Type	Default Value [Unit]
max_pressure	Maximum measurable gage pressure	real	10k [Pa]
min_pressure	Minimum measurable gage pressure	real	-10k [Pa]

sensitivity	LVDT device sensitivity in V/V/Pa above or below the midrange pressure	real	0.1m [V/V/Pa]
atmp	Ambient atmospheric pressure	real	0.101325Meg [Pa]

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Example

In this example, the change in the ouptput pressure of the Pressure Source P1 produces a corresponding change in the AC voltage output signal of the LVDT Gage Pressure Sensor Gage_PRESS_LVDT1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

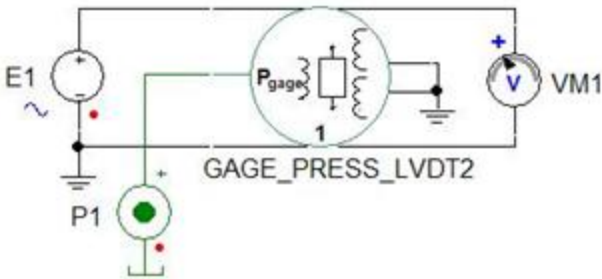


Figure 2. Application example of the LVDT Gage Pressure Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	0.101325Meg -10k + 5k * (t>=250u) + 10k * (t>=500u) + 5k * (t>=750u) [Pa]
Voltage Source (sinusoidal) E1	AMPL	10 [V]
	FREQ	3k [Hz]
	OFF	0 [V]
	PHASE	0 [degree]
	TDELAY	0 [s]
LVDT Gage Pressure	max_pres-	10k [Pa]

Sensor GAGE_PRESS_LVDT1	sure	
	min_pres-sure	-10k [Pa]
	sensitivity	0.1m [V/V/Pa]
	atmp	0.101325Meg [Pa]

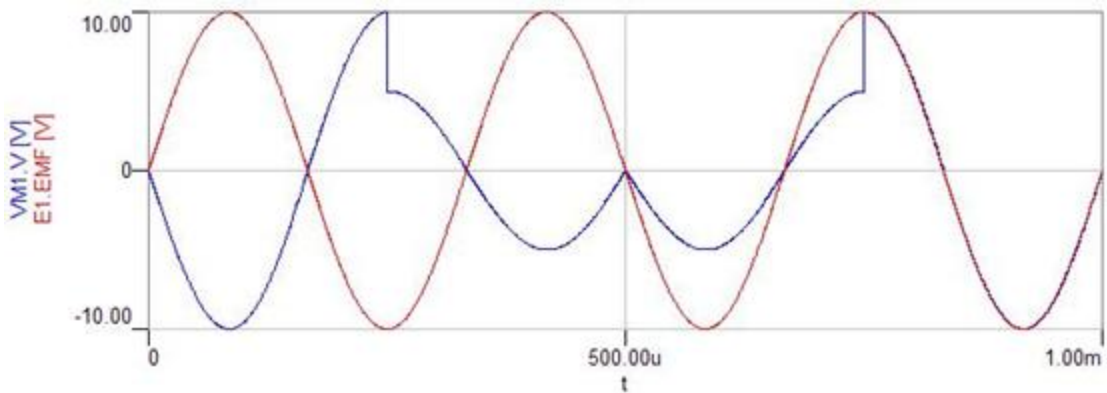


Figure 3. Simulation results-primary and secondary voltage of GAGE_PRESS_LVDT1

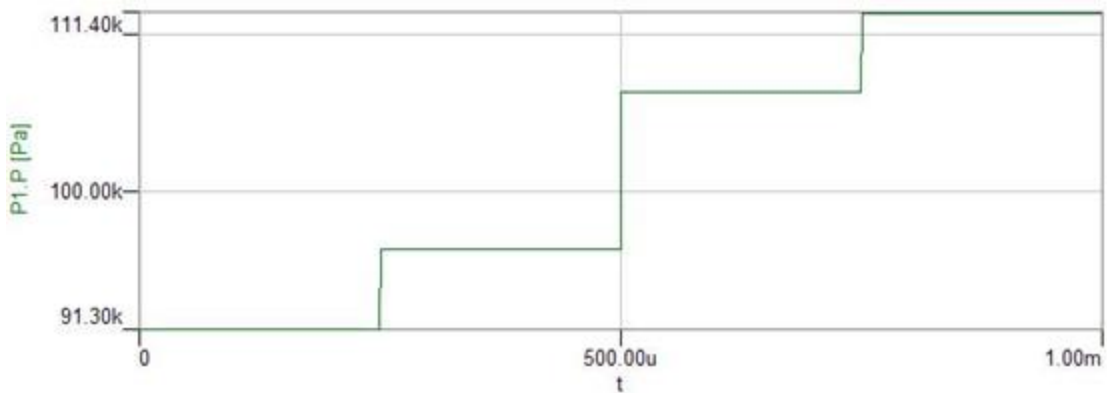


Figure 4. Simulation results-output pressure of P1

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References

Level 1 Piezoelectric Gage Pressure Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

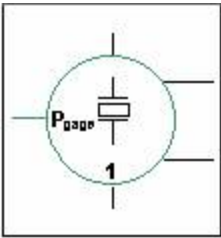


Figure 1. Component symbol

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Description

The Level 1 Piezoelectric Gage Pressure Sensor model is used to simulate the ideal behavior of a piezoelectric crystal gage pressure sensor. A change in the applied pressure or the atmospheric pressure produces a corresponding change in the voltage output signal.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL GAGE_PRESS_PE ?InstanceName(@InstanceName):(@ (Refbase)@(ID))
PRESSURE:= %0, out_plus:= %1, out_minus:= %2, Vdd:= %3, Vss:= %4 ( max_pressure:=
@max_pressure, min_pressure:= @min_pressure, full_scale_span:= @full_scale_span, off-
```

set:= @offset, nom_supply_current:= @nom_supply_current, atmp:= @atmp) SRC: DB(Lib:-
:=@ModelLibraryName);

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PRESSURE	Measured pressure	Fluidic
out_plus	Positive output	Electrical
out_minus	Negative output	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Output voltage at zero gage pressure	real	0 [V]
max_pres- sure	Maximum measurable gage pressure	real	1k [Pa]
min_pres- sure	Minimum measurable gage pressure	real	0 [Pa]
full_scale_ span	Difference between the out- put voltages at the max- imum and minimum measurable gage pressures	real	5 [V]
nom_sup-	Typical nominal supply cur-	real	1m [A]

ply_cur- rent	rent		
atmp	Ambient atmospheric pres- sure	real	0.101325Meg [Pa]

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Example

In this example, the Piezoelectric Gage Pressure Sensor GAGE_PRESS_PE1 measures the pressure of the Hydraulic Capacitance CHYD1, and the output voltage of Gage_PRESS_PE1 changes in reponse to the applied pressure. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 - 5.

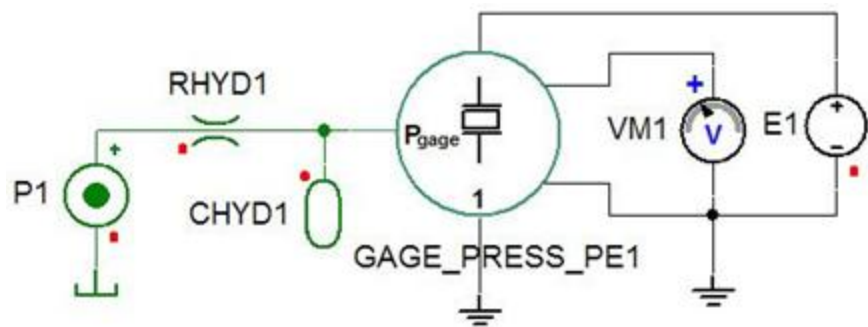


Figure 2. Application example of the Piezoelectric Gage Pressure Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	2E8 + 101.325k [Pa]
Linear Orifice RHYD1	K	10m [m ³ /(Pa s)]
Hydraulic Capacitance CHYD1	VOL	50n [m ³]
	B	1 [Pa]
	P0	0 [Pa]
Piezoelectric Gage Pressure Sensor GAGE_PRESS_PE1	offset	9 [V]
	max_pres- sure	2000 [bar]

	min_pres- sure	0 [bar]
	full_scale_ span	5 [V]
	nom_sup- ply_current	4 [mA]
	atmp	0.101325Meg [Pa]
Voltage Source E1	EMF	20 [V]

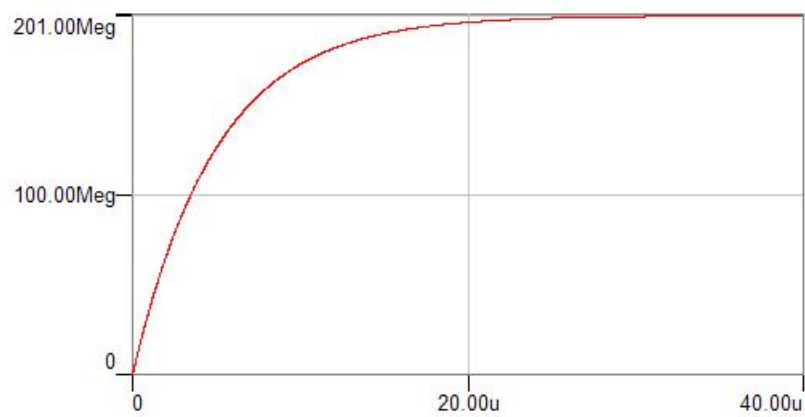


Figure 3. Simulation results-input pressure of GAGE_PRESS_PE1

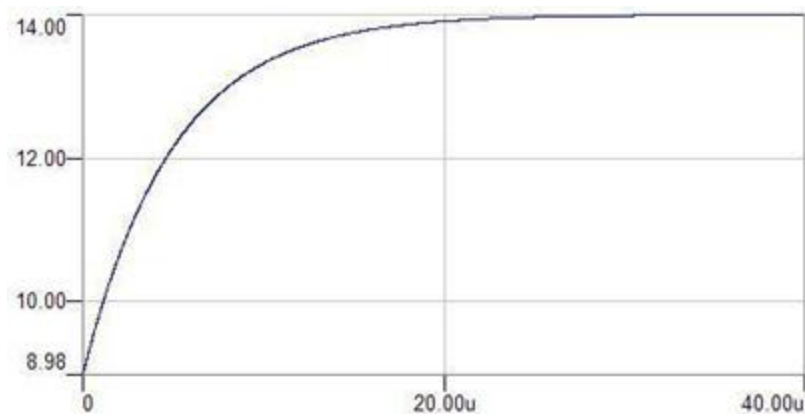


Figure 4. Simulation results-output voltage of GAGE_PRESS_PE1

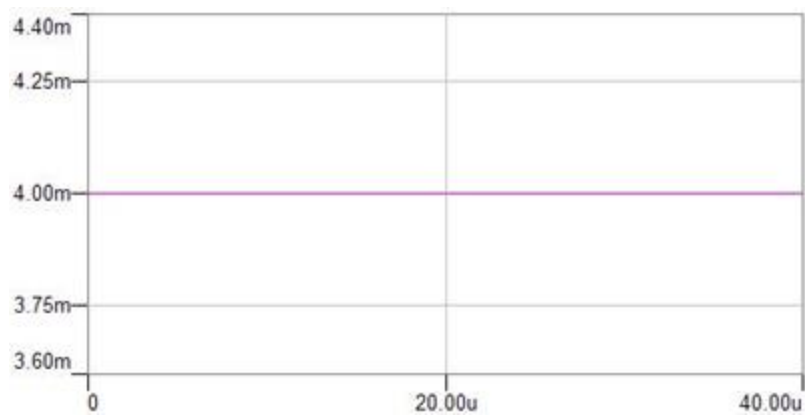


Figure 5. Simulation results-supply current of GAGE_PRESS_PE1

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References

Level 1 Potentiometric Gage Pressure Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

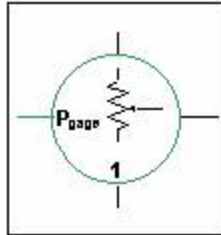


Figure 1. Component symbol

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Description

The Level 1 Potentiometric Gage Pressure Sensor model is used to simulate the ideal behavior of a potentiometer gage pressure sensor. A change in the applied pressure or the atmospheric pressure produces a corresponding change in the voltage divider output signal.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL GAGE_PRESS_POTEN ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
PRESSURE:= %0, OUT:= %1, Vdd:= %2, Vss:= %3 ( max_pressure:= @max_pressure, min_
```

```
pressure:= @min_pressure, full_scale_span:= @full_scale_span, offset:= @offset, p_res-
istance:= @p_resistance, atmp:= @atmp) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
Vdd	Positive supply	Electrical
Vss	Negative supply	Electrical
OUT	Output terminal	Electrical
PRESSURE	Measured pressure	Fluidic

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage (device output at ambient atmospheric pressure)	real	0 [V]
atmp	Ambient atmospheric pressure	real	0.101325Meg
p_resistance	Potentiometer resistance	real	10k [Ohm]
max_pressure	Maximum measurable gage pressure [Pa]	real	10k [Pa]
min_pressure	Minimum measurable gage pressure [Pa]	real	0 [Pa]
full_scale_span	Difference between the maximum and minimum output voltages at the maximum/minimum pressures [V]	real	10 [V]

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Example

In this example, the output voltage of the Potentiometric Differential Pressure Sensor GAGE_PRESS_POTEN1 changes in response to the applied pressure source P1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

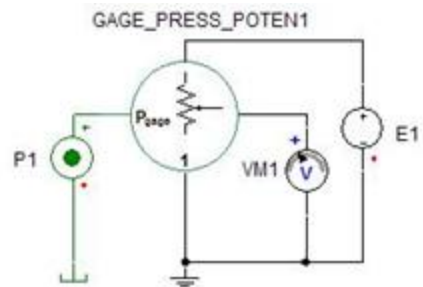


Figure 2. Application example of the Pressure Switch Gage Pressure Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	$(6894.757 * 5k) * (t/40m) + 101.325k$ [Pa]
Voltage Source E1	EMF	10 [V]
Potentiometric Gage Pressure Sensor Gage_PRESS_POTEN1	offset	$0.1 * E1.EMF$ [V]
	p_res-istance	5k [Ohm]
	max_pres-sure	5k [Pa]
	min_pres-sure	0 [Pa]
	full_scale_span	$E1.EMF * 0.9$ [V]
	Atmp	0.101325Meg [Pa]

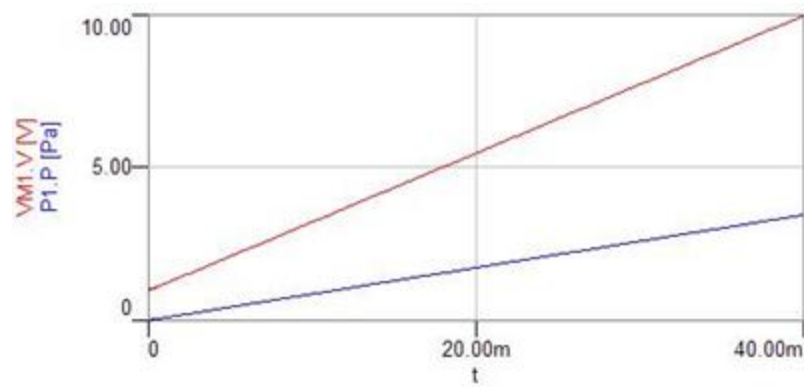


Figure 3. Simulation results-input pressure and output voltage of GAGE_PRESS_POTEN1

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References

Level 1 Pressure Switch Gage Pressure Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

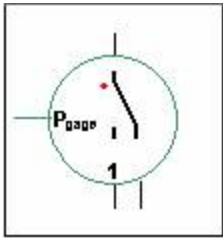


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Description

The Level 1 Pressure Switch Gage Pressure Sensor model is used to simulate the ideal behavior of a gage pressure-sensing switch. If the gage pressure applied to the switch exceeds the switch's threshold pressure, the switch changes position from its normally closed terminal to its normally open terminal.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL GAGE_PRESS_SW ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
PRESSURE:= %0, nmnc:= %1, nmno:= %2, np:= %3 ( threshold_pressure:= @threshold_pres-
sure, atmp:= @atmp) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
nmnc	Normally closed negative terminal	Electrical
nmno	Normally open negative terminal	Electrical
np	Positive terminal	Electrical
PRESSURE	Measured pressure	Fluidic

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
threshold_pressure	Switch threshold pressure	real	0.101325Meg [Pa]
atmp	Ambient atmospheric pressure	real	0.101325Meg [Pa]

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Example

In this example, when the output pressure of the Pressure Source P1 is below the pressure limit of the Pressure Switch Gage Pressure Sensor GAGE_PRESS_SW1, the resistor Rno is connected to the current source via GAGE_PRESS_SW1; when the output pressure of P1 exceeds the pressure limit of GAGE_PRESS_SW1, the switch changes position from its normally closed terminal to its normally open terminal, and hence connects Rnc to the current source instead. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 - 5.

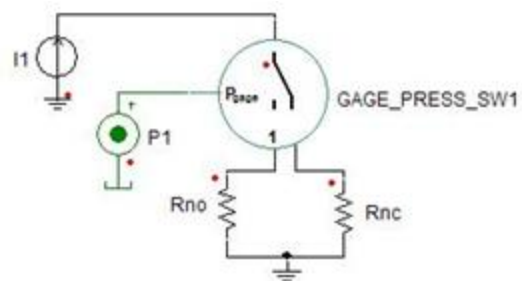


Figure 2. Application example of the Pressure Switch Gage Pressure Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	1Meg * t/40m + 101325 [Pa]
Current Source I1	IS	1 [A]
Resistor Rno/Rnc	R	1k [Ohm]
Pressure Switch Gage Pressure Sensor GAGE_PRESS_SW1	threshold_pressure	500k [Pa]
	atmp	0.101325Meg [Pa]

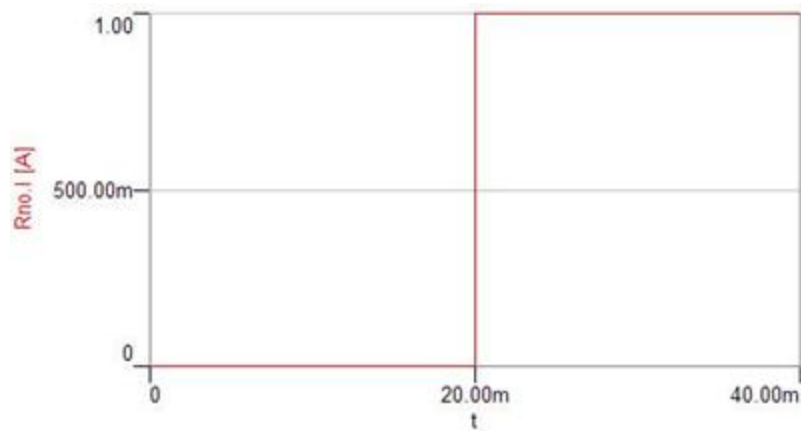


Figure 3. Simulation results-current through Rno

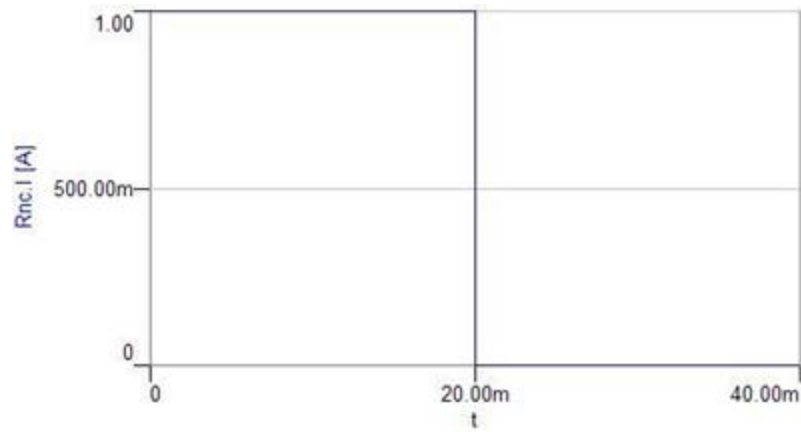


Figure 4. Simulation results-current through Rnc

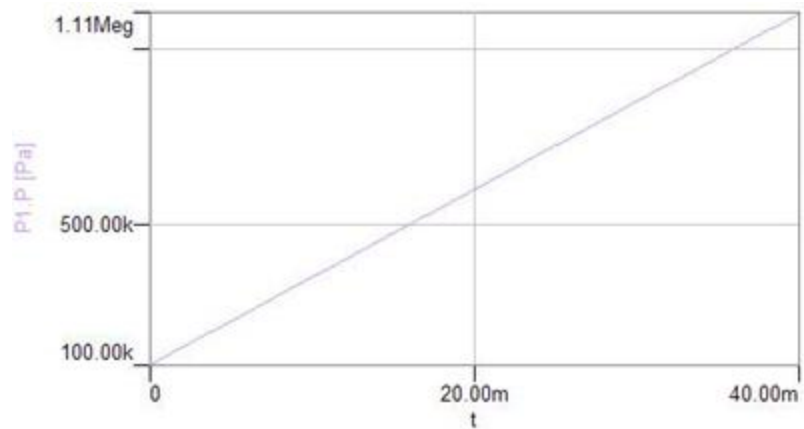


Figure 5. Simulation results-output pressure of P1

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References

Level 1 Temperature Sensor Models

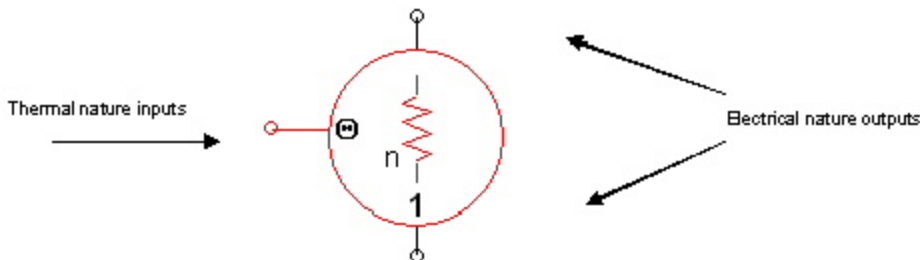
The Level 1 Temperature Sensor Models simulate the ideal behavior of seven different types of temperature sensors.

All of the temperature sensor models have both of the following:

- Conservative input pins that must be connected to a thermal network.
- Conservative output pins that must be connected to an electrical network.

The models also feature nonconservative parameters that can be changed to tailor the behavior of the model to that of a specific real device.

As shown in the following example, temperature sensor models for the thermal domain have red conservative input pins that must be connected to a thermal network. The models also have black pins that must be connected to an electrical network.



The Level 1 Temperature Sensor Models feature models for the following temperature-sensing mechanisms:

- Voltage-Output IC ([IC_V](#)): A change in temperature causes a linear change in the output voltage of a temperature-sensing integrated circuit.
- Thermocouple: A temperature differential at two points along a bimetallic wire junction produces an output voltage.
Type K: ([K_THERMOCOUPLE](#))
Types J, T, E, N, B, R, S: ([NK_THERMOC](#))
- NTC Thermistor ([NTC_THERMISTOR](#)): A change in temperature causes an exponential change in the resistance of a negative temperature coefficient thermistor.
- Potentiometric ([PT_THETA](#)): A change in temperature moves a potentiometer wiper, producing a change in the voltage divider output signal.
- RTD ([RTD](#)): A change in temperature causes a linear change in the resistance of a temperature-dependent resistor.
- Temperature Switch ([TEMP_SWITCH](#)): The absolute temperature at a specified threshold causes a bimetallic switch to change state from closed to open or from open to closed.

Level 1 Voltage-Output IC Temperature Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

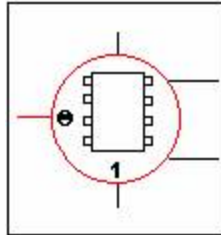


Figure 1. Component symbol

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Description

The Level 1 Voltage-Output IC Temperature Sensor model simulates the ideal behavior of an integrated-circuit temperature sensor with a linear voltage output.

The model has one conservative thermal-nature pin for its temperature input and four conservative electrical-nature pins. Two of the electrical pins are to connect the model to its power supply and to ground. The other two nodes are for its voltage output. The negative output node should be connected to ground if the model is connected to an electrical network in which no other element is connected to ground.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL IC_V ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) THETA:= %0, Vdd:= %1,  
Vss:= %2, out_plus:= %3, out_minus:= %4 ( input_current:= @input_current, max_temp:=  
@max_temp, min_temp:= @min_temp, full_scale_span:= @full_scale_span, offset:= @offset)  
SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
THETA	Measured temperature	Thermal
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical
out_plus	Positive output terminal	Electrical
out_minus	Negative output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
input_current	Typical sensor input current	Real	5m [A]
offset	Output voltage at minimum temperature	Real	0 [V]
max_temp	Maximum measurable temperature	Real	473 [K]
min_	Minimum measurable temperature	Real	223 [K]

temp			
full_ scale_ span	Difference between outputs at the maximum and minimum temperatures	Real	4.5 [V]

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Example

In this example, the Voltage-Output IC Temperature Sensor IC_V1 measures the temperature of the Temperature Source T1, and the voltage output of IC_V1 changes accordingly. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

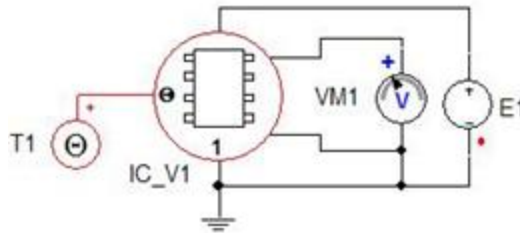


Figure 2. Application example of the Voltage-Output IC Temperature Sensor

Table 3

Component	Parameter	Value [Unit]
Temperature Source T1	VALUE	$-100 + 450 * (t/80m)$ [°F]
Voltage-Output IC Temperature Sensor IC_V1	input_current	90 [A]
	offset	-0.5 [V]
	max_temp	300 [°F]
	min_temp	-50 [°F]
	full_scale_span	3.5 [V]
Voltage Source E1	EMF	5 [V]

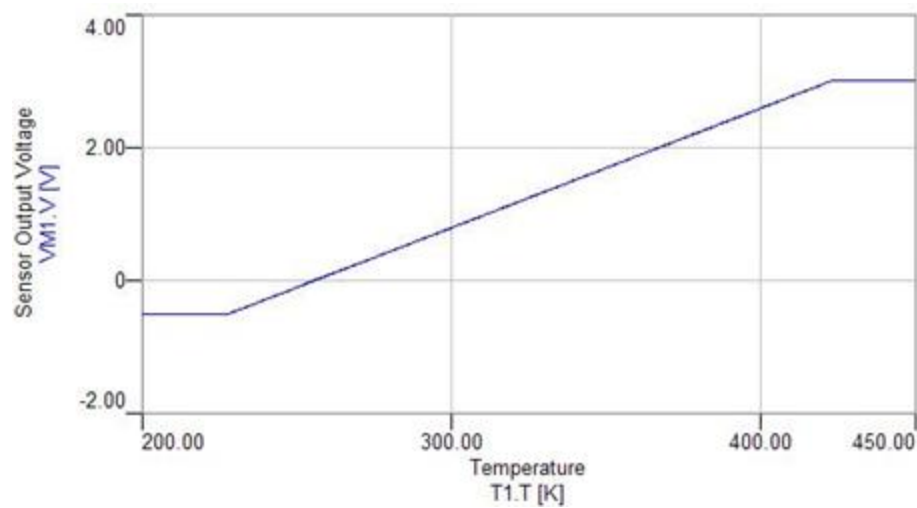


Figure 3. Simulation results-output voltage of IC_V1 vs. temperature of T1

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References

Level 1 Thermocouple (Type K) Temperature Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

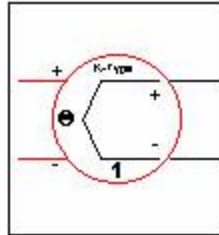


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Description

The Level 1 Thermocouple (Type K) Temperature Sensor model simulates the ideal behavior of type K thermocouples in temperatures above zero degrees Celsius.

The model has two conservative thermal-nature pins for its absolute and reference temperature inputs and two conservative electrical-nature pins for its voltage output. The negative output pin of the thermocouple should be connected to an electrical ground if it is connected to an electrical network in which at least one other element is not grounded.

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Assumptions and Limitations

Note: In Simplorer V8, unconnected pins on the thermocouple will generate an error.

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Mathematical Description

The relationship between the temperature difference (T) and the output voltage (v) of Thermocouple (Type K) Temperature Sensor is nonlinear and is given by a polynomial interpolation,

shown as following:

$$T = \sum_{i=0}^N a_i v^i$$

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Netlist Syntax

```
MODEL K_THERMOCOUPLE ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
THETA:= %0, REF:= %1, OUT_p:= %2, OUT_m:= %3 ( a0:= @a0, a1:= @a1, a2:= @a2, a3:=
@a3, a4:= @a4, a5:= @a5, a6:= @a6, a7:= @a7, a8:= @a8, a9:= @a9, a10:= @a10, a11:=
@a11, a12:= @a12, a13:= @a13, a14:= @a14, a15:= @a15, alpha0:= @alpha0, alpha1:= @al-
pha1) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
THETA	Measured temperature	Thermal
REF	Reference temperature	Thermal
OUT_p	Positive output terminal	Electrical
OUT_m	Negative output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
a0	Zero-order coefficient	Real	-17.6004m [V]
a1	First-order coefficient	Real	38.9212m [V/K]
a2	Second-order coefficient	Real	18.5588u [V/K ²]
a3	Third-order coefficient	Real	-99.4576n [V/K ³]
a4	Fourth-order coefficient	Real	0.318409n [V/K ⁴]
a5	Fifth-order coefficient	Real	-0.560728p [V/K ⁵]
a6	Sixth-order coefficient	Real	0.560751f [V/K ⁶]
a7	Seventh-order coefficient	Real	-3.20207e-019 [V/K ⁷]
a8	Eighth-order coefficient	Real	9.71511e-023 [V/K ⁸]
a9	Ninth-order coefficient	Real	-1.21047e-026 [V/K ⁹]
a10	Tenth-order coefficient	Real	0 [V/K ¹⁰]
a11	Eleventh-order coefficient	Real	0 [V/K ¹¹]
a12	Twelfth-order coefficient	Real	0 [V/K ¹²]
a13	Thirteenth-order coefficient	Real	0 [V/K ¹³]

a14	Fourteenth-order coefficient	Real	0 [V/K ¹⁴]
a15	Fifteenth-order coefficient	Real	0 [V/K ¹⁵]
alpha0	Exponential term coefficient	Real	0.118598 [V]
alpha1	Exponential exponent coefficient	Real	-0.118343m [1/K ²]

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Example

In this example, the Thermocouple (Type K) Temperature Sensor K_THERMOCOUPLE1 measures the temperature of the Thermal Resistor RTH2, and the output voltage of K_THERMOCOUPLE1 changes accordingly. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

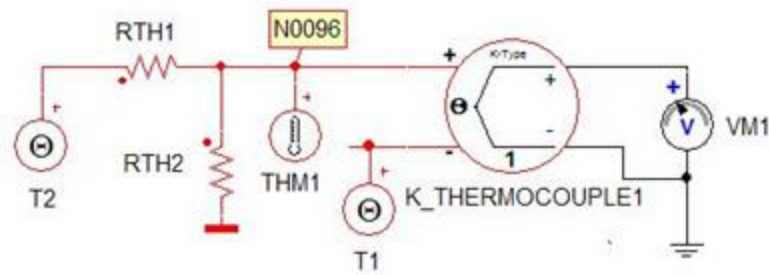


Figure 2. Application example of the Thermocouple (Type K) Temperature Sensor

Table 3

Component	Parameter	Value [Unit]
Temperature Source T1	VALUE	273 [K]
Temperature Source T2	VALUE	$(273 + 750 \cdot (t/80m)) \cdot 2$ [K]
Thermocouple (Type K) Temperature Sensor K_THERMOCOUPLE1	a0	-17.6004m [V]
	a1	38.9212m [V/K]
	a2	18.5588u [V/K ²]
	a3	-99.4576n [V/K ³]
	a4	0.318409n [V/K ⁴]
	a5	-0.560728p [V/K ⁵]
	a6	0.560751f [V/K ⁶]
	a7	-3.20207e-019 [V/K ⁷]
	a8	9.71511e-023 [V/K ⁸]
	a9	-1.21047e-026 [V/K ⁹]
	a10	0 [V/K ¹⁰]

	a11	0 [V/K ¹¹]
	a12	0 [V/K ¹²]
	a13	0 [V/K ¹³]
	a14	0 [V/K ¹⁴]
	a15	0 [V/K ¹⁵]
	alpha0	0.118598 [V]
	alpha1	-0.118343m [1/K ²]
Thermal Resistance RTH1/RTH2	K	1 [K/W]

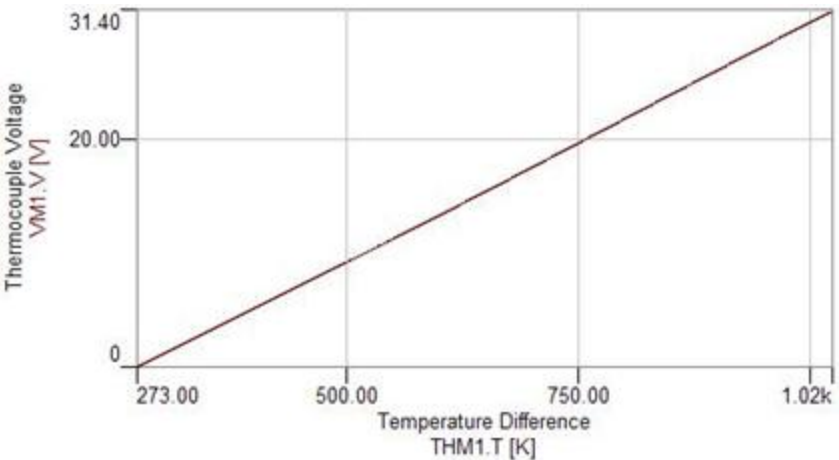


Figure 3. Simulation results-voltage output of K_THERMOCOUPLE1 vs. it temperature difference input

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References

Level 1 Thermocouple (Types J, T, E, N, B, R, S) Temperature Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

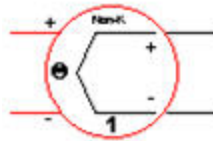


Figure 1. Component symbol

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Description

The Level 1 Thermocouple (Types J, T, E, N, B, R, S) Temperature Sensor model simulates the ideal behavior of non-type K thermocouples in any temperature range and type K thermocouples in temperatures below zero degrees Celsius.

The model has two conservative thermal-nature pins for its absolute and reference temperature inputs and two conservative electrical-nature pins for its voltage output. The negative output pin of the thermocouple should be connected to an electrical ground if it is connected to an electrical network in which at least one other element is not grounded.

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Mathematical Description

The relationship between the temperature difference (T) and the output voltage (v) of Thermocouple (Types J, T, E, N, B, R, S) Temperature Sensor is nonlinear and is given by a polynomial interpolation, shown as following:

$$T = \sum_{i=0}^N a_i v^i$$

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Netlist Syntax

```
MODEL NK_THERMOC ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) THETA:= %0,
REF:= %1, OUT_p:= %2, OUT_m:= %3 ( a0:= @a0, a1:= @a1, a2:= @a2, a3:= @a3, a4:=
@a4, a5:= @a5, a6:= @a6, a7:= @a7, a8:= @a8, a9:= @a9, a10:= @a10, a11:= @a11, a12:=
@a12, a13:= @a13, a14:= @a14, a15:= @a15) SRC: DB(Lib:=@ModelLibraryName);
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
THETA	Measured temperature	Thermal
REF	Reference temperature	Thermal
OUT_p	Positive output terminal	Electrical
OUT_m	Negative output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
a0	Zero-order coefficient	Real	0 [V]
a1	First-order coefficient	Real	0 [V/K]
a2	Second-order coefficient	Real	0 [V/K ²]
a3	Third-order coefficient	Real	0 [V/K ³]
a4	Fourth-order coefficient	Real	0 [V/K ⁴]
a5	Fifth-order coefficient	Real	0 [V/K ⁵]
a6	Sixth-order coefficient	Real	0 [V/K ⁶]
a7	Seventh-order coefficient	Real	0 [V/K ⁷]
a8	Eighth-order coefficient	Real	0 [V/K ⁸]
a9	Ninth-order coefficient	Real	0 [V/K ⁹]
a10	Tenth-order coefficient	Real	0 [V/K ¹⁰]
a11	Eleventh-order coefficient	Real	0 [V/K ¹¹]
a12	Twelfth-order coefficient	Real	0 [V/K ¹²]
a13	Thirteenth-order coefficient	Real	0 [V/K ¹³]
a14	Fourteenth-order coefficient	Real	0 [V/K ¹⁴]

a15	Fifteenth-order coefficient	Real	0 [V/K ¹⁵]

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Example

In this example, the Thermocouple (Types J, T, E, N, B, R, S) Temperature Sensor NK_THERMOC1 measures the temperature of the Thermal Resistor RTH2, and the output voltage of NK_THERMOC1 changes accordingly. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

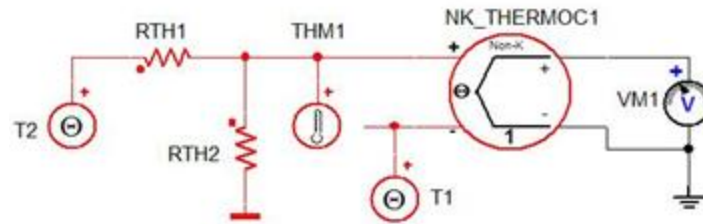


Figure 2. Application example of the Thermocouple (Types J, T, E, N, B, R, S) Temperature Sensor

Table 3

Component	Parameter	Value [Unit]
Temperature Source T1	VALUE	273 [K]
Temperature Source T2	VALUE	$(123 + 900 * (t/80m)) * 2$ [K]
Thermocouple (Type K) Temperature Sensor NK_THERMOC1	a0	0 [V]
	a1	5.0381187815E-2 [V/K]
	a2	3.0475836930E-5 [V/K ²]
	a3	-8.5681065720E-8 [V/K ³]
	a4	1.3228195295E-10 [V/K ⁴]

	a5	-1.7052958337E-13 [V/K ⁵]
	a6	2.0948090697E-16 [V/K ⁶]
	a7	-1.2538395336E-19 [V/K ⁷]
	a8	1.5631725697E-23 [V/K ⁸]
	a9	0 [V/K ⁹]
	a10	0 [V/K ¹⁰]
	a11	0 [V/K ¹¹]
	a12	0 [V/K ¹²]
	a13	0 [V/K ¹³]
	a14	0 [V/K ¹⁴]
	a15	0 [V/K ¹⁵]
	Thermal Resistance RTH1/RTH2	K 1 [K/W]

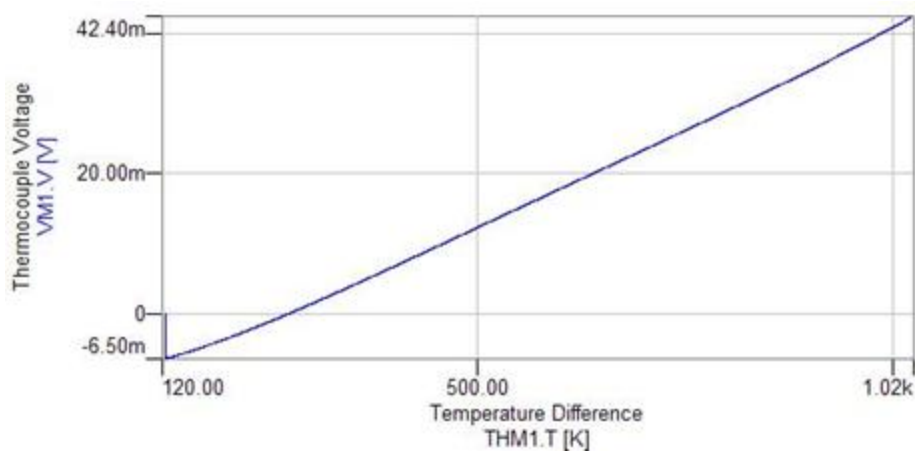


Figure 3. Simulation results-voltage output of NK_THERMOC1 vs. it temperature difference input

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References

Level 1 NTC Thermistor Temperature Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

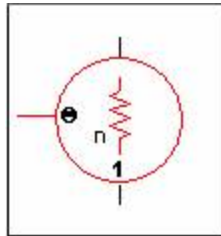


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Description

The Level 1 NTC Thermistor Temperature Sensor model simulates the ideal behavior of a negative temperature coefficient thermistor. As the absolute temperature of the thermistor model varies, its resistance varies along an exponential curve described by the Steinhart-Hart equation and three device specific parameters a , b , and c .

The model has a conservative thermal-nature pin for its absolute temperature input and two conservative electrical-nature pins for the thermistor's positive and negative terminals. The positive terminal is the terminal into which current flows.

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Mathematical Description

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Netlist Syntax

MODEL NTC_THERMISTOR ?InstanceName(@InstanceName):(@Refbase)@(ID)) TEMP:= %0, Rp:= %1, Rm:= %2 (a:= @a, b:= @b, c:= @c) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
TEMP	Absolute temperature	Thermal
Rp	Positive thermistor terminal	Electrical
Rm	Negative thermistor terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
a	Steinhart-Hart coefficient "a"	Real	0 [1/K]
b	Steinhart-Hart coefficient "b"	Real	0 [1/K]
c	Steinhart-Hart coefficient "c"	Real	0 [1/K]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
R	Thermistor resistance [Ohm]	Output	real

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Example

In this example, the NTC Thermistor Temperature Sensor NTC_THERMISTOR2 measures the temperature of the Temperature Source T1, and the resistance of NTC_THERMISTOR2 changes accordingly. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

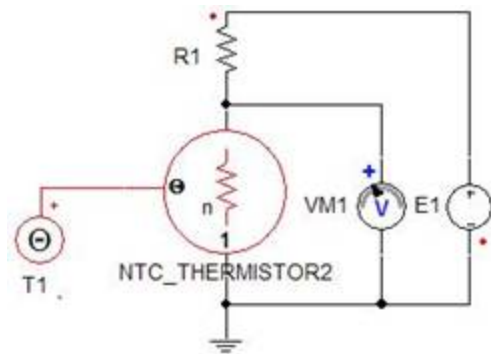


Figure 2. Application example of the NTC Thermistor Temperature Sensor

Table 4

Component	Parameter	Value [Unit]
Temperature Source T1	VALUE	-58 + 360 * (t/40m) [°C]
NTC Thermistor Temperature Sensor NTC_THERMISTOR2	a	1.659880E- 03 [1/K]
	b	2.396775E- 04 [1/K]
	c	1.168094E- 07 [1/K]
Voltage Source E1	EMF	5 [V]

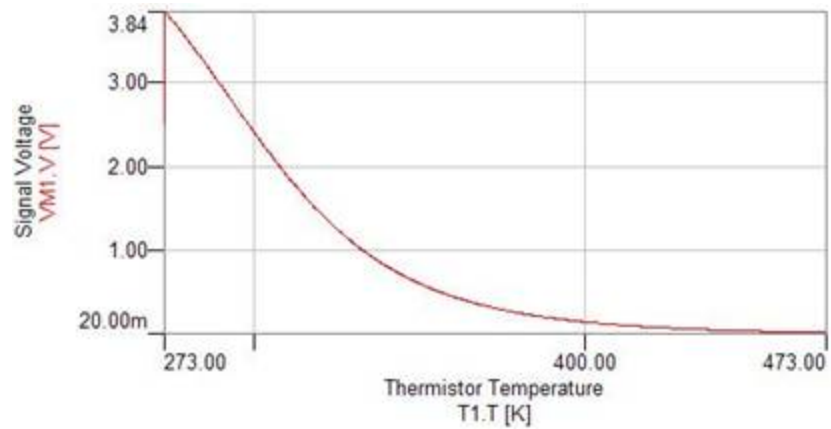


Figure 3. Simulation results-voltage across NTC_THERMISTOR2 vs. temperature of T1

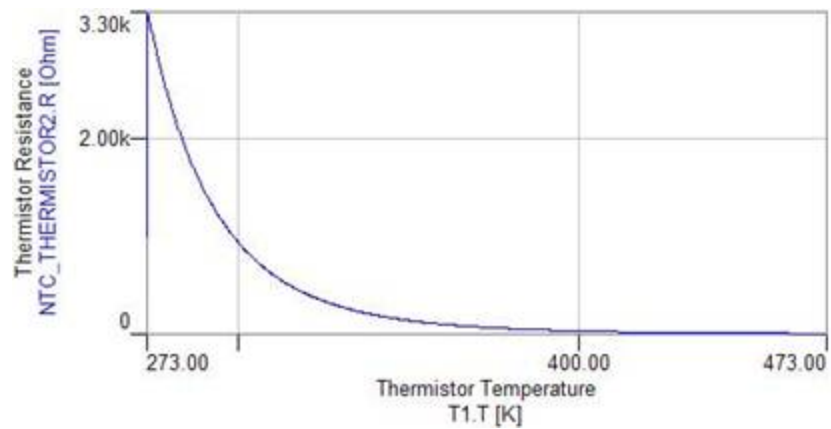


Figure 4. Simulation results-resistance of NTC_THERMISTOR2 vs. temperature of T1

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References

Level 1 Potentiometric Temperature Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

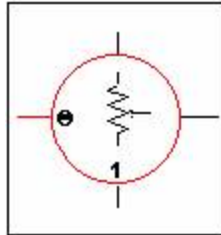


Figure 1. Component symbol

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Description

The Level 1 Potentiometric Temperature Sensor model simulates the ideal behavior of a potentiometric temperature sensor. The voltage divider output of the potentiometer model changes linearly in response to a change in temperature.

The model has one conservative thermal-nature pin for its temperature input and three conservative electrical-nature pins. Two of the electrical pins are to connect the model to its power supplies. The remaining node is for the model's output.

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Mathematical Description

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Netlist Syntax

MODEL PT_THETA ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) OUT:= %0, Vdd:= %1, Vss:= %2, TEMP:= %3 (max_temp:= @max_temp, min_temp:= @min_temp, full_scale_span:= @full_scale_span, offset:= @offset, potentiometer_resistance:= @potentiometer_resistance) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
TEMP	Measured temperature	Thermal
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical
OUT	Output	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor output voltage at minimum temperature	Real	0 [V]
potentiometer_resistance	Resistance of potentiometer	Real	10k [Ohm]
max_temp	Maximum measurable temperature	Real	423 [K]
min_temp	Minimum measurable temperature	Real	223 [K]

full_scale_span	Difference of outputs at maximum and minimum temperatures	Real	10 [V]

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Example

In this example, the Potentiometric Temperature Sensor PT_THETA1 measures the temperature of the Temperature Source T1, and the output voltage of PT_THETA1 changes accordingly. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

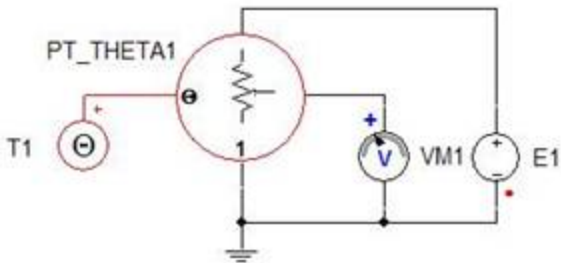


Figure 2. Application example of the Potentiometric Temperature Sensor

Table 3

Component	Parameter	Value [Unit]
Temperature Source T1	VALUE	$-58 + 360 * (t/40m)$ [°C]
Potentiometric Temperature Sensor PT_THETA1	offset	$0.05 * E1.EMF$ [V]
	potentiometer_resistance	5k [Ohm]
	max_temp	150 [oC]
	min_temp	-50 [oC]
	full_scale_span	$0.95 * E1.EMF$ [V]
Voltage Source E1	EMF	5 [V]

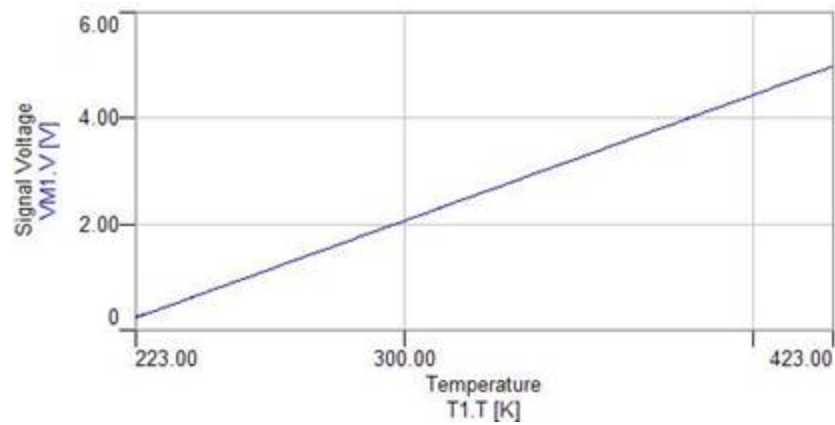


Figure 3. Simulation results-output voltage of PT_THETA1 vs. temperature of T1

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References

Level 1 RTD Temperature Sensor

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

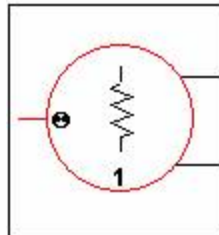


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Description

The Level 1 RTD Temperature Sensor model simulates the ideal behavior of a resistance temperature detector (RTD). As the absolute temperature of the RTD model varies, its resistance varies linearly according to its temperature coefficient.

The RTD model has a conservative thermal-nature pin for its absolute temperature input and two conservative electrical-nature pins for the its positive and negative terminals. The positive terminal is the terminal into which current flows.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

MODEL RTD ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) THETA:= %0, np:= %1, nm:= %2 (nom_resistance:= @nom_resistance, nom_res_temp:= @nom_res_temp, temperature_coefficient:= @temperature_coefficient) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
THETA	Absolute temperature	Thermal
np	Positive RTD terminal	Electrical
nm	Negative RTD terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
temperature_coefficient	RTD temperature coefficient	Real	0.385 [Ohm/K]
nom_resistance	Nominal resistance	Real	100 [Ohm]
nom_res_temp	Temperature at which the RTD assumes nominal resistance	Real	0 [K]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
R	RTD resistance [Ohm]	Input	real

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Example

In this example, the RTD Temperature Sensor RTD1 measures the temperature of the Temperature Source T1, and the output resistance of RTD1 changes accordingly. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

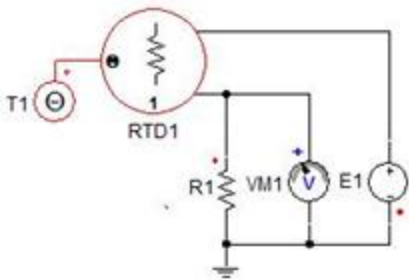


Figure 2. Application example of the RTD Temperature Sensor

Table 4

Component	Parameter	Value [Unit]
Temperature Source T1	VALUE	-58 + (450) * (t/80m) [°F]
RTD Temperature Sensor RTD1	temperature_coef-ficient	3.85 [Ohm/°C]
	nom_resistance	1k [Ohm]
	nom_res_temp	0 [K]
Voltage Source E1	EMF	5 [V]
Resistor R1	R	1k [Ohm]

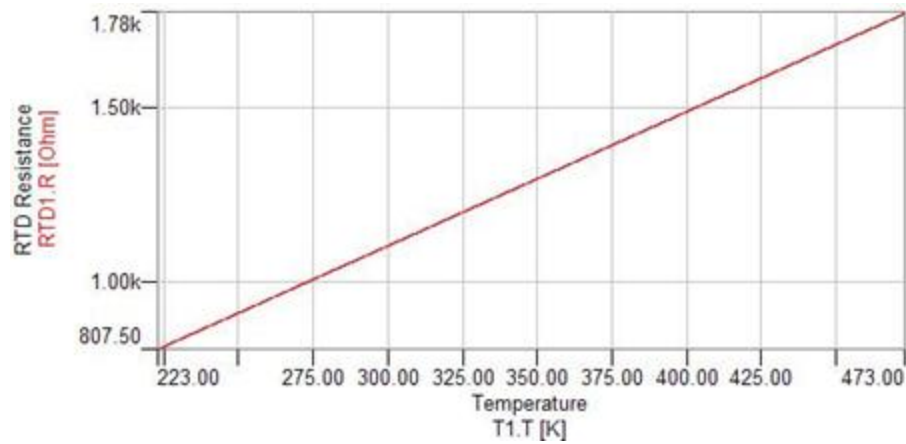


Figure 3. Simulation results-output resistor RTD1 vs. temperature of T1

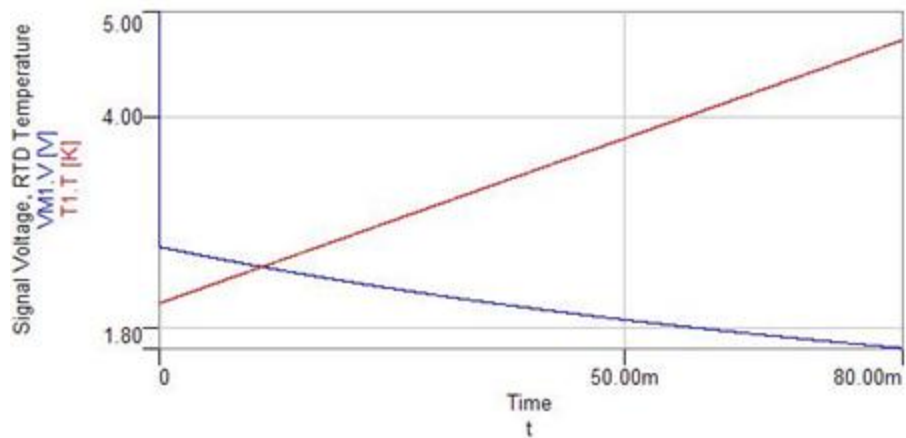


Figure 4. Simulation results-voltage across RTD1 and temperature of T1 vs. time

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References

Level 1 Temperature Switch

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

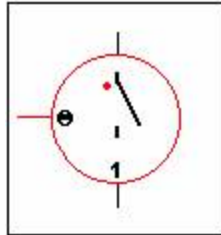


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Description

The Level 1 Temperature Switch model simulates the ideal behavior of a temperature switch. At a specified threshold temperature, the switch model changes state from closed to open or open to closed.

The model has one conservative thermal-nature pin for its temperature input and two conservative electrical-nature pins for the positive and negative terminals of the switch. The positive terminal is the terminal into which current flows.

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Netlist Syntax

Netlist generated by [Special Component Dialog](#).

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
TEMP	Measured temperature	Thermal
np	Positive terminal	Electrical
nm	Negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
threshold_temp	Switch threshold temperature	Real	373 [K]
reset_temp	Switch reset temperature	Real	323 [K]
init_state	Switch normal state (open, closed)	Real	0

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Example

In this example, the temperature of the Temperature Source T1 decides the switching status of the Temperature Switch TEMP_SWITCH2. TEMP_SWITCH2 is initially closed; when the temperature of T1 is below the switch threshold temperature of TEMP_SWITCH2, the switch is open, and Rno is disconnected from the Current Source I1; when the temperature of T1 is over the switch reset temperature of TEMP_SWITCH2, the switch resumes its initial status-closed. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

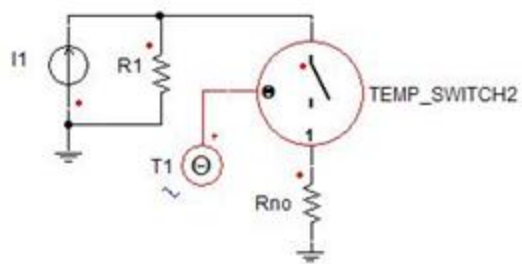


Figure 2. Application example of the Temperature Switch

Table 3

Component	Parameter	Value [Unit]
Temperature Source T1	AMPL	100 [K]
	FREQ	50 [Hz]
	PHASE	0 [degree]
	OFF	300 [K]
	TDELAY	0 [s]
Temperature Switch TEMP_SWITCH2	threshold_temp	373 [K]
	reset_temp	323 [K]
	init_state	closed
Current Source I1	IS	100m [A]
Resistor	R	100k [Ohm]

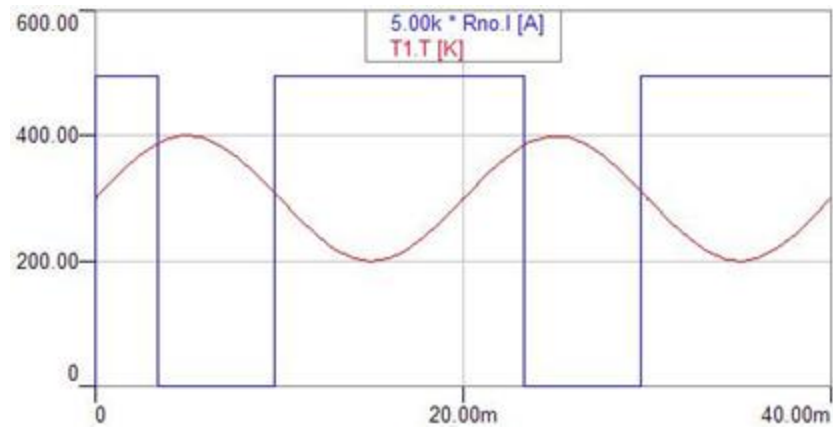


Figure 3. Simulation results-temperature of T1 and the current through Rno (scaled)

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References

Component Dialog Settings

The following Parameters are set in the Component Dialog for the **Level 1 Temperature Switch Component**:

Name:

Specify the Name of the component instance. Select the **Show Name** checkbox to display the name on the schematic.

Parameters:

Device Parameters: Enter a numerical value, a variable, or an expression in the text box. Common parameter types. Look their meaning up in the parameter table.

Switch Initial State: Select the initial state of the switch, either **Open** or **Closed**.

Outputs/Display

For information regarding displaying parameter pins, see *Output/Display Tab* in the main Twin Builder help.

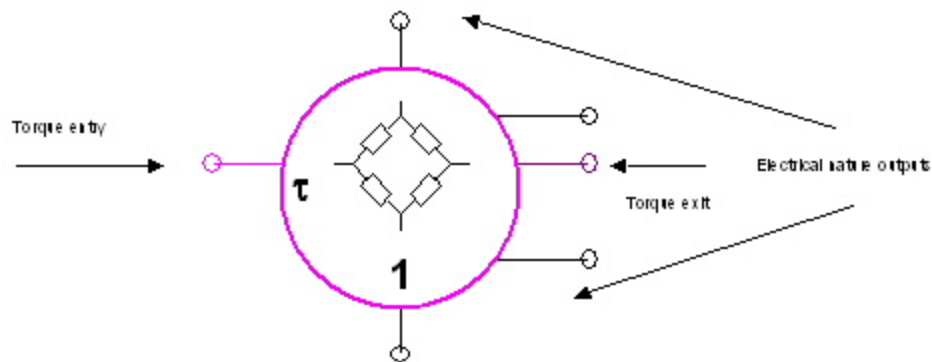
Level 1 Torque Sensor Models

The Level 1 Torque Sensor Models simulate the ideal behavior of torque sensors.

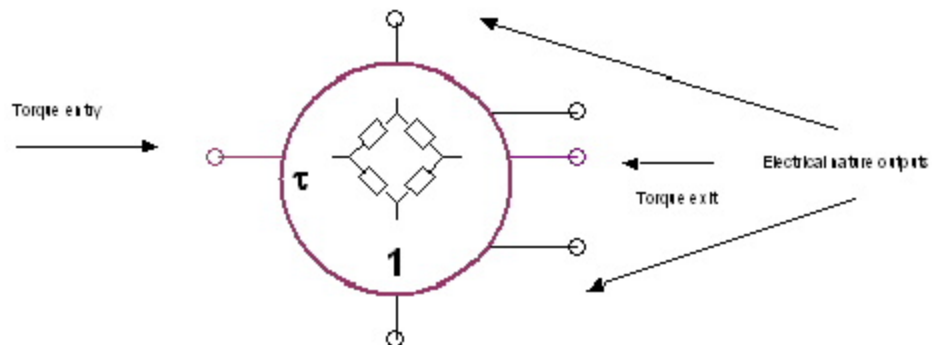
All of the torque sensor models have conservative pins that must be connected to a rotational network. Note that because torque is a through quantity, all torque sensor models have one rotational pin for torque entry and another pin for torque exit.

Like other sensor models, the torque sensor models also have conservative output pins that must be connected to an electrical network and nonconservative parameters that can be changed in order to tailor the behavior of the model to that of a specific real device.

As shown in the following example, torque sensor models for the *displacement-force* rotational domain have pink conservative input pins that must be connected to a rotational network. The pin on the left side of the model is the pin at which the measured torque should enter. The models also have black pins that must be connected to an electrical network.



Similarly, torque sensor models for the *velocity-force* rotational domain have purple rotational-nature pins and black electrical nature pins:



The Level 1 Torque Sensor Models feature models for the following torque-sensing mechanisms:

- Strain Gauge: - applied torque deforms the resistors in a Wheatstone bridge, producing a change in the sensor's differential voltage output signal.
Displacement-Force model: ([SG_TORQUE_DF](#))
Velocity-Force model: ([SG_TORQUE_VF](#))

Level 1 Strain Gauge Torque Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

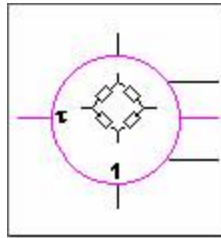


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Description

The Level 1 Strain gauge Torque (Displacement-Force) sensor model is used to simulate the ideal behavior of a strain gauge torque sensor in the Twin Builder displacement-force rotational domain. A change in the model's torque input produces a corresponding change in the model's Wheatstone bridge, which in turn produces a change in the model's linear voltage output.

The model has two conservative input pins in the displacement-force rotational domain for its torque input and output and four conservative electrical-domain pins. Two of the electrical-domain pins are for the model's power supplies, and two are for its differential voltage output.

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Netlist Syntax

```
MODEL SG_TORQUE_DF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) TORQUE_
IN:= %0, TORQUE_OUT:= %1, OUT_P:= %2, OUT_M:= %3, Vdd:= %4, Vss:= %5 ( max_
torque:= @max_torque, min_torque:= @min_torque, full_scale_span:= @full_scale_span, off-
set:= @offset, p_resistance:= @p_resistance) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
TORQUE_IN	Torque entrance	Rotational
TORQUE_OUT	Torque exit	Rotational
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
max_torque	Maximum measurable torque	Real	50 [Nm]
min_torque	Minimum measurable torque	Real	0 [Nm]
full_scale_	Difference in the output voltages	Real	5 [V]

span	at the maximum and minimum torques		
p_res-istance	Bridge resistance	Real	10k [Ohm]

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Example

In this example, the Strain Gauge Torque (Displacement-Force) sensor SG_TORQUE_DF1 measures the torque output of the Torque Source F_ROT B1, and produces a corresponding change in its linear voltage output. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

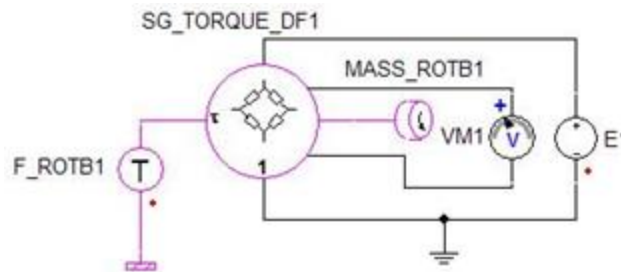


Figure 2. Application example of the Strain Gauge Torque (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROT B1	VALUE	2800 * (t/30m) [N]
Mass MASS_ROT B1	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Voltage Source E1	EMF	10 [V]
Strain Gauge Torque (Displacement-Force) sensor SG_TORQUE_DF1	offset	0 [V]

	max_torque	2714 [Nm]
	min_torque	0 [Nm]
	full_scale_span	2m * E1.EMF [V]
	p_res- istance	350 [Ohm]

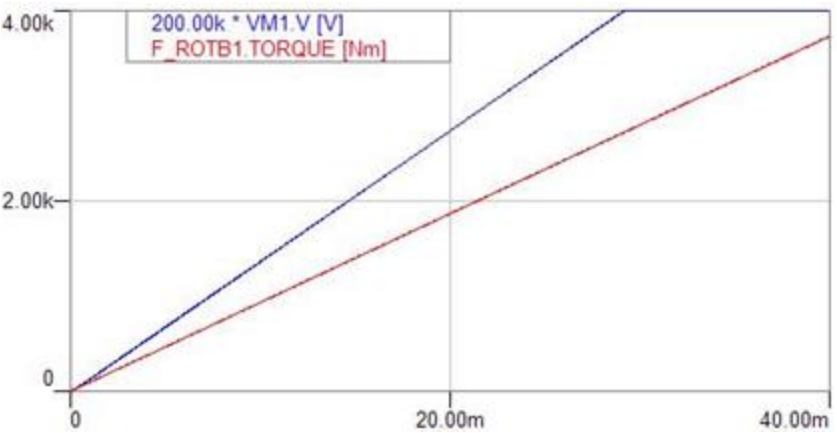


Figure 3. Simulation results-output voltage of SG_TORQUE_DF1 (scaled) and torque output of F_ROTBI

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References

Level 1 Strain Gauge Torque Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

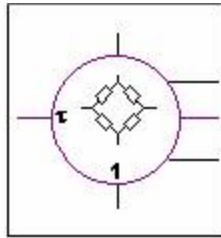


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Description

The Level 1 Strain gauge Torque (Velocity-Force) sensor model is used to simulate the ideal behavior of a strain gauge torque sensor in the Twin Builder velocity-force rotational domain. A change in the model's torque input produces a corresponding change in the model's Wheatstone bridge, which in turn produces a change in the model's linear voltage output.

The model has two conservative input pins in the velocity-force rotational domain for its torque input and output and four conservative electrical-domain pins. Two of the electrical-domain pins are for the model's power supplies, and two are for its differential voltage output.

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Netlist Syntax

```
MODEL SG_TORQUE_VF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) OUT_P:= %0, OUT_M:= %1, Vdd:= %2, Vss:= %3, TORQUE_IN:= %4, TORQUE_OUT:= %5 ( max_torque:= @max_torque, min_torque:= @min_torque, full_scale_span:= @full_scale_span, offset:= @offset, p_resistance:= @p_resistance) SRC: DB(Lib:=@ModelLibraryName);
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
TORQUE_IN	Torque entrance	Rotational_V
TORQUE_OUT	Torque exit	Rotational_V
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
max_torque	Maximum measurable torque	Real	50 [Nm]
min_torque	Minimum measurable torque	Real	0 [Nm]
full_scale_span	Difference in the output voltages at the maximum and minimum torques	Real	5 [V]
p_resistance	Bridge resistance	Real	10k [Ohm]

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Example

In this example, the Strain Gauge Torque (Velocity-Force) sensor SG_TORQUE_VF1 measures the torque output of the Torque Source F_ROT1, and produces a corresponding change in its linear voltage output. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

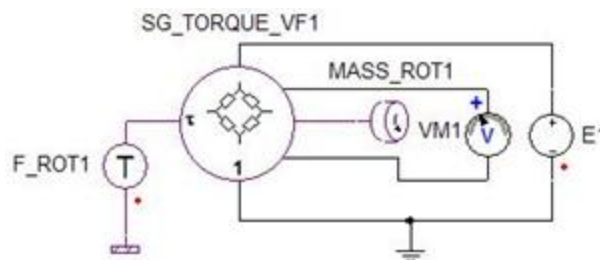


Figure 2. Application example of the Strain Gauge Torque (Velocity-Force) sensor

Table 3

Component	Parameter	Value [Unit]

Torque Source F_ROT1	VALUE	2800 * (t/40m) [N]
Mass MASS_ROT1	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Voltage Source E1	EMF	10 [V]
Strain Gauge Torque (Velocity-Force) sensor SG_TORQUE_VF1	offset	0 [V]
	max_torque	2714 [Nm]
	min_torque	0 [Nm]
	full_scale_span	2m * E1.EMF [V]
	p_res- istance	350 [Ohm]

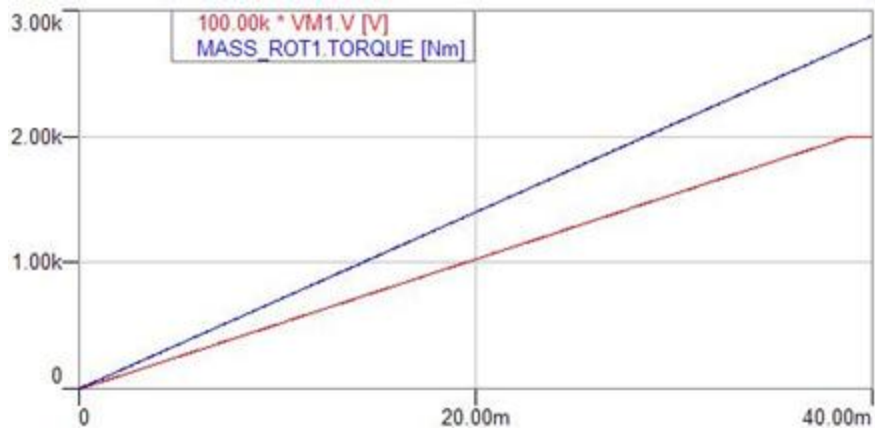


Figure 3. Simulation results-output voltage of SG_TORQUE_VF1 (scaled) and torque output of F_ROT1

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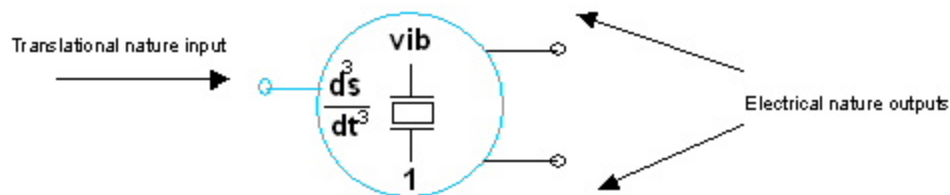
References

Level 1 Vibration Sensor Models

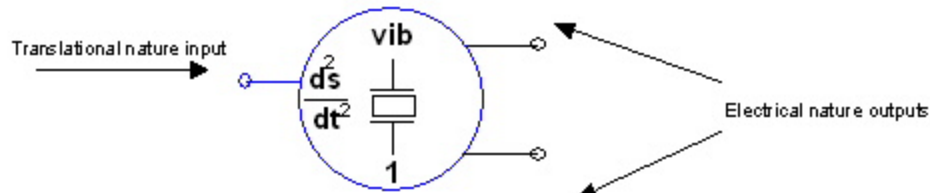
The Level 1 Vibration Sensor Models simulate the ideal behavior of two different types of vibration sensors. Models are available for use with the Twin Builder *displacement-force* and *velocity-force* translational domains.

All of the vibration sensor models have conservative input pins that must be connected to a translational network and conservative output pins that must be connected to an electrical network. The models also feature nonconservative parameters that can be changed in order to tailor the behavior of the model to that of a specific real device.

As shown in the following example, vibration sensor models for the displacement-force translational domain have light blue conservative input pins that must be connected to a displacement-force translational network. The models also have black conservative pins that must be connected to an electrical network.



Similarly, vibration sensor models for the velocity-force translational domain have dark blue translational-nature input pins and black electrical-nature pins.



The Level 1 Vibration Sensor Models feature models for the following vibration- sensing mechanisms:

- Acceleration-sensing - a piezoelectric crystal is oriented such that it is sensitive only to the second derivative (acceleration) of a translational displacement within a small range of frequencies. The voltage output of the sensor is proportional to the measured acceleration.
Displacement-Force model: ([ACC_VIB_DF](#))
Velocity-Force model: ([ACC_VIB_VF](#))
- Jerk-sensing - a piezoelectric crystal is oriented such that it is sensitive only to the third derivative (jerk) of a translational displacement within a small range of frequencies. The voltage output of the sensor is proportional to the measured jerk.
Displacement-Force model: ([JERK_VIB_DF](#))
Velocity-Force model: ([JERK_VIB_VF](#))

Level 1 Acceleration-Sensing Vibration Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

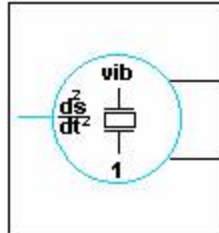


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Description

The Level 1 Acceleration-Sensing Vibration (Displacement-Force) sensor model is used to simulate the ideal behavior of an acceleration-sensing vibration sensor in the Twin Builder Displacement-Force translational domain. A change in the second derivative of the model's translational input produces a corresponding change in the model's linear voltage output.

The model has one conservative input pin in the displacement-force translational domain for its vibration input and two conservative electrical-domain pins for its voltage output. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is connected to ground.

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Netlist Syntax

MODEL ACC_VIB_DF ?InstanceName(@InstanceName):(@Refbase)@(ID)) POSITION:= %0, OUT_P:= %1, OUT_M:= %2 (knock_resonant_frequency:= @knock_resonant_frequency, q_factor:= @q_factor, peak_sens:= @peak_sens, offset:= @offset) SRC: DB(Lib:- :=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured vibration	Translational
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
knock_resonant_frequency	Resonant frequency of the target vibration	Real	2k [Hz]
q_factor (must be a positive nonzero value)	Q-factor of the internal filter	Real	2
peak_sens	Sensor sensitivity	Real	0.5m [V/(m/s)]
offset	Sensor offset voltage	Real	0 [V]

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Example

In this example, a change in the second derivative of the position of MASS_TRB1 produces a corresponding change in the linear voltage output of the Acceleration-Sensing Vibration (Displacement-Force) sensor ACC_VIB_DF2. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

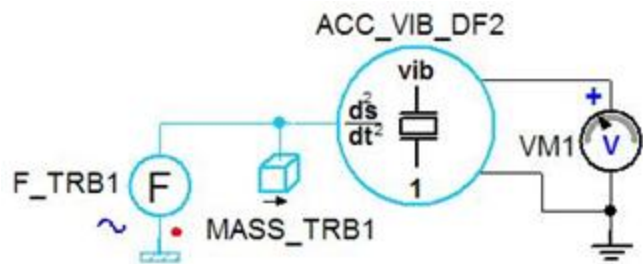


Figure 2. Application example of the Acceleration-Sensing Vibration (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Force Source F_TRB1	AMPL	9.8 [N]
	FREQ	5.2k [Hz]
	PHASE	0 [degree]
	OFF	0 [N]
	TDELAY	0 [s]
Mass MASS_TRB1	M	1 [kg]
	S0	5.2k
	V0	0 [m/s]
Acceleration-Sensing Vibration (Displacement-Force) sensor ACC_VIB_DF2	knock_resonant_frequency	5200 [Hz]
	q_factor	26
	peak_sens	0.204 [V/(m/s)]

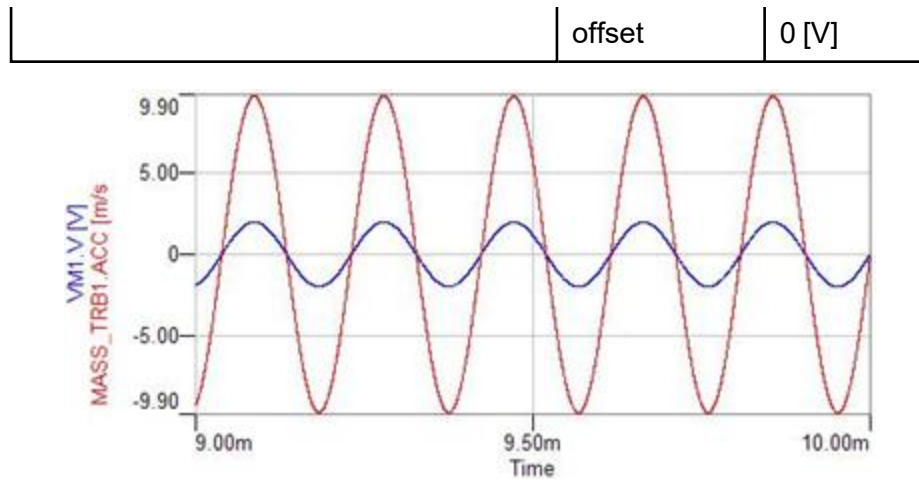


Figure 3. Simulation results-output voltage of ACC_VIB_DF2 and acceleration of MASS_TRB1

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References

Level 1 Jerk-Sensing Vibration Sensor (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

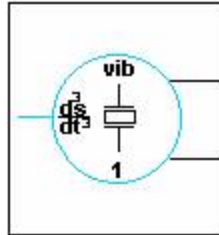


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Description

The Level 1 Jerk-Sensing Vibration (Displacement-Force) sensor model is used to simulate the ideal behavior of a jerk-sensing vibration sensor in the Twin Builder Displacement-Force translational domain. A change in the third derivative of the model's translational input produces a corresponding change in the model's linear voltage output.

The model has one conservative input pin in the displacement-force translational domain for its vibration input and two conservative electrical-domain pins for its voltage output. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is connected to ground.

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Netlist Syntax

```
MODEL JERK_VIB_DF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) POSITION:= %0, OUT_P:= %1, OUT_M:= %2 ( knock_resonant_frequency:= @knock_resonant_frequency, Q_factor:= @Q_factor, peak_sensitivity:= @peak_sensitivity, offset:= @offset) SRC: DB(Lib:- :=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured vibration	Translational
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
knock_resonant_frequency	Resonant frequency of the target vibration	Real	2k [Hz]
Q_factor (must be a positive nonzero value)	Q-factor of the internal filter	Real	2
sensitivity	Sensor sensitivity	Real	0.5 [V/ (m/s)]
offset	Sensor offset voltage	Real	0 [V]

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Example

In this example, a change in the third derivative of MASS_TRB1's position produces a corresponding change in the linear voltage output of the Jerk-Sensing Vibration (Displacement-Force) sensor JERK_VIB_DF2. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

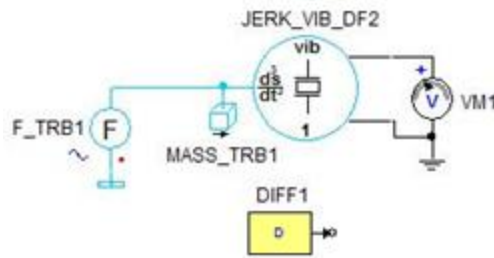


Figure 2. Application example of the Jerk-Sensing Vibration (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Force Source F_TRB1	AMPL	1m [N]
	FREQ	2k [Hz]
	PHASE	0 [degree]
	OFF	0 [N]
	TDELAY	0 [s]
Mass MASS_TRB1	m	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Jerk-Sensing Vibration (Displacement-Force) sensor JERK_VIB_DF2	knock_resonant_frequency	2k [Hz]
	Q_factor	2
	sensitivity	0.2 [V/(m/s)]
	offset	0 [V]
Derivative DIFF1	INPUT	MASS_

		TRB1.ACC
	KD	1
	Y0	0
	UL	0
	UU	0
	TS	System*

* System – simulation time step

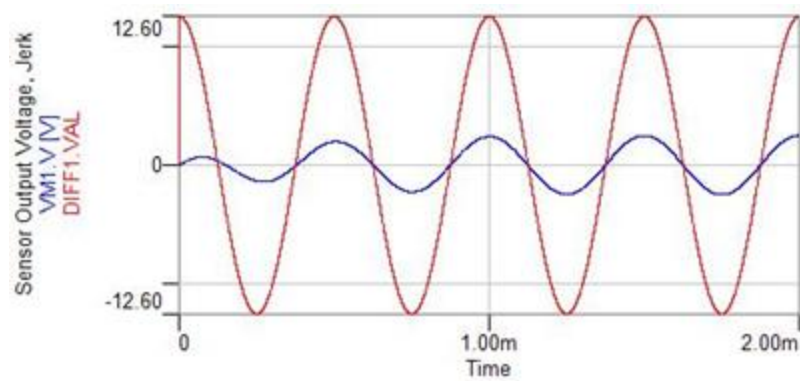


Figure 3. Simulation results-output voltage of JERK_VIB_DF2 and Jerk of MASS_TRB1

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References

Level 1 Acceleration-Sensing Vibration Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

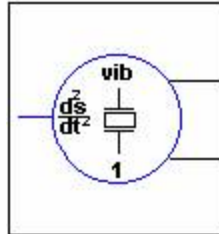


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Description

The Level 1 Acceleration-Sensing Vibration (Velocity-Force) sensor model is used to simulate the ideal behavior of an acceleration-sensing vibration sensor in the Twin Builder Velocity-Force translational domain. A change in the second derivative of the model's translational input produces a corresponding change in the model's linear voltage output.

The model has one conservative input pin in the velocity-force translational domain for its vibration input and two conservative electrical-domain pins for its voltage output. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is connected to ground.

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Netlist Syntax

MODEL ACC_VIB_VF ?InstanceName(@InstanceName):(@Refbase)@(ID)) POSITION:= %0, OUT_P:= %1, OUT_M:= %2 (knock_resonant_frequency:= @knock_resonant_frequency, q_factor:= @q_factor, peak_sens:= @peak_sens, offset:= @offset) SRC: DB(Lib:- :=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured vibration	Translational_V
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
knock_resonant_frequency	Resonant frequency of the target vibration	Real	2k [Hz]
q_factor (must be a positive nonzero value)	Q-factor of the internal filter	Real	2
peak_sens	Sensor sensitivity	Real	0.5m [V/(m/s)]
offset	Sensor offset voltage	Real	0 [V]

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Example

In this example, a change in the second derivative of MASS_TR1's position produces a corresponding change in the linear voltage output of the Acceleration-Sensing Vibration (Velocity-Force) sensor ACC_VIB_VF2. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

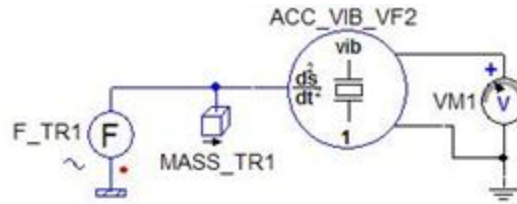


Figure 2. Application example of the Acceleration-Sensing Vibration (Velocity-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Force Source F_TR1	AMPL	9.8 [N]
	FREQ	5.2k [Hz]
	PHASE	0 [degree]
	OFF	0 [N]
	TDELAY	0 [s]
Mass MASS_TR1	M	1 [kg]
	S0	5.2k
	V0	0 [m/s]
Acceleration-Sensing Vibration (Velocity-Force) sensor ACC_VIB_VF2	knock_resonant_frequency	5200 [Hz]
	q_factor	26

	peak_sens	0.204 [V/ (m/s)]
	offset	0 [V]

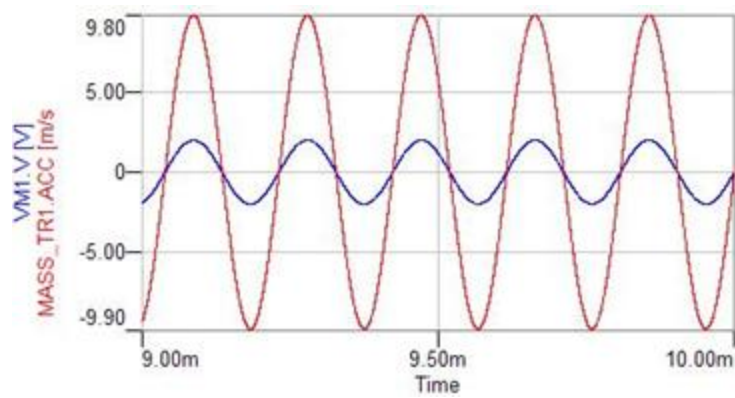


Figure 3. Simulation results-output voltage of ACC_VIB_VF2 and acceleration of MASS_TR1

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References

Level 1 Jerk-Sensing Vibration Sensor (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

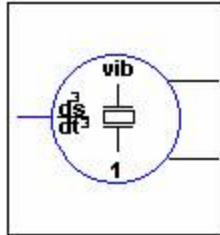


Figure 1. Component symbol

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- [Conservative Pins](#)
- [Parameters](#)
- [Example](#)
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Description

The Level 1 Jerk-Sensing Vibration (Velocity-Force) sensor model is used to simulate the ideal behavior of a jerk-sensing vibration sensor in the Twin Builder Velocity-Force translational domain. A change in the third derivative of the model's translational input produces a corresponding change in the model's linear voltage output.

The model has one conservative input pin in the velocity-force translational domain for its vibration input and two conservative electrical-domain pins for its voltage output. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is connected to ground.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

MODEL JERK_VIB_VF ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) POSITION:= %0, OUT_P:= %1, OUT_M:= %2 (knock_resonant_frequency:= @knock_resonant_frequency, Q_factor:= @Q_factor, peak_sensitivity:= @peak_sensitivity, offset:= @offset) SRC: DB(Lib:- :=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured vibration	Translational_V
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
knock_resonant_frequency	Resonant frequency of the target vibration	Real	2k [Hz]
Q_factor (must be a positive nonzero value)	Q-factor of the internal filter	Real	2
sensitivity	Sensor sensitivity	Real	0.5 [V/ (m/s)]
offset	Sensor offset voltage	Real	0 [V]

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Example

In this example, a change in the third derivative of MASS_TR1's position produces a corresponding change in the linear voltage output of the Jerk-Sensing Vibration (Velocity-Force) sensor JERK_VIB_VF2. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

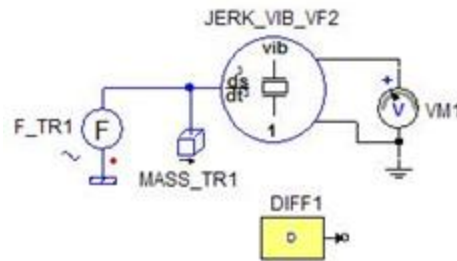


Figure 2. Application example of the Jerk-Sensing Vibration (Velocity-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Force Source F_{TR1}	AMPL	1m [N]
	FREQ	2k [Hz]
	PHASE	0 [degree]
	OFF	0 [N]
	TDELAY	0 [s]
Mass $MASS_{TR1}$	m	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Jerk-Sensing Vibration (Velocity-Force) sensor $JERK\_VIB\_VF2$	knock_resonant_frequency	2k [Hz]
	Q_factor	2

Derivative DIFF1	sensitivity	0.2 [V/ (m/s)]
	offset	0 [V]
	INPUT	MASS_ TR1.ACC
	KD	1
	Y0	0
	UL	0
	UU	0
	TS	System*

* System – simulation time step

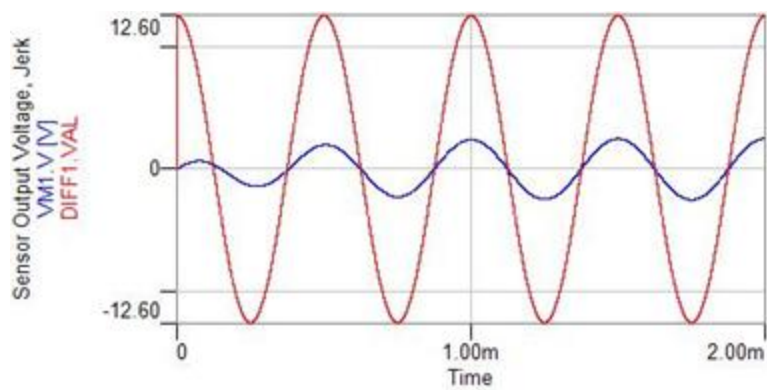


Figure 3. Simulation results-output voltage of JERK_VIB_VF2 and Jerk of MASS_TR1

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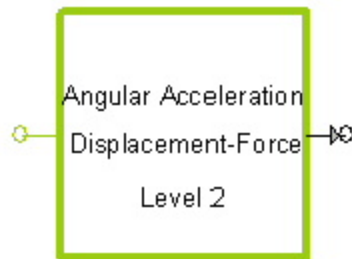
References

Level 2 Sensor Model Building Blocks

The Level 2 Sensor Model Building Block library consists of components that can be used to build non-ideal sensor models that are parameterizable using common manufacturer datasheet parameters. There are three types of models available in the library, green measuring blocks, black processing blocks, and red output signal blocks. One of each is necessary to build a typical sensor model. More information is given below about each type of block:

- **Measuring Blocks:** These blocks measure a physical quantity in one of the Twin Builder physical domains through conservative pins in that physical domain. This measured value is then passed out of the block by a nonconservative output pin. The block shown here is for measuring angular acceleration in the Twin Builder Displacement-Force rotational domain:

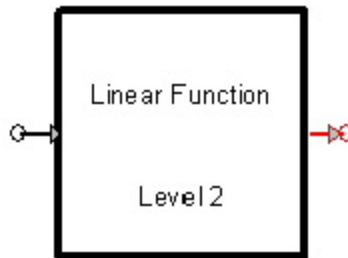
The block's green pin is a conservative pin with a displacement-force rotational nature and must



be connected to a node in a displacement-force rotational network. The block then takes the second time derivative of the rotational position at the node to determine the angular acceleration at the node. This value can then be passed to any of the processing blocks by the black pin, which is a nonconservative pin.

Unlike Level 1 measuring blocks, Level 2 measuring blocks have parameters that can be added for certain types of non-ideal behavior. The Level 2 angular acceleration sensing block shown above has a parameter for the corner frequency of the angular acceleration input signal.

- **Processing Blocks:** These blocks take a real value that is passed from one of the measuring blocks as its independent variable. Additional independent variables may be passed through nonconservative nodes for most blocks. The block then calculates its dependent variable via a function that is determined by user-input parameters and outputs the value of the dependent variable through a nonconservative pin. The processing block shown here is for a linear function:

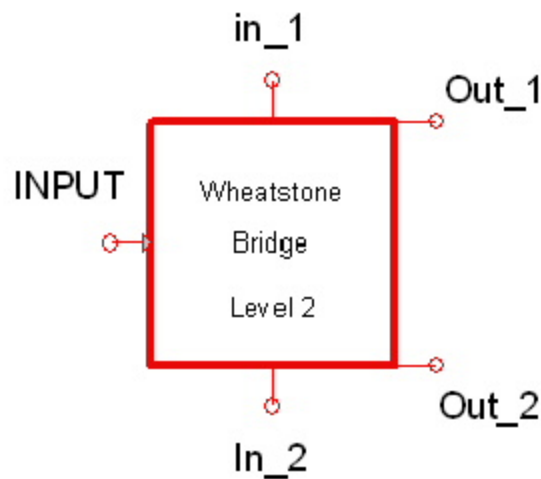


The block's black pin is a nonconservative input pin, which should be connected to the black output pin of a processing block. The block then calculates the value of its output according to a linear function which has the parameters listed in the component dialog box.

The parameter INPUT, is the function's first independent variable, which is typically obtained from connecting the block's input pin to the output pin of a measuring block. The parameters SENS and OFFSET are the linear function's slope and intercept associated with the first independent variable and can be input by the user. The variable temp is the second independent variable of the linear function, and temp_sens is the slope associated with the second independent variable.

When the value of the block's dependent variable is calculated, it is passed out of the block by the red nonconservative output pin.

- **Output Signal Blocks:** These blocks take a real value from the output of a processing block. This value is used to control the behavior of a circuit element or combination of circuit elements that is connected to a Twin Builder electric circuit network through one or more conservative pins with an electrical nature. Some output signal blocks also allow the user to input one or more parameters. The block shown here is for a Wheatstone resistor bridge.



The red nonconservative input pin INPUT takes the value of the output from a processing block. The four conservative electrical-nature pins in_1, In_2, Out_1, and Out_2 are, respectively, the positive and negative input pins and positive and negative output pins of the Wheatstone bridge.

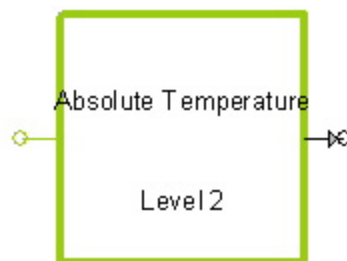
The four conservative pins are used to connect the block into a Twin Builder electrical circuit network.

The parameter INPUT is the value that controls the Wheatstone bridge's resistors and is usually taken from the output pin of a processing block. The parameters max_pct_change, max_input_magnitude, and equivalent_resistance are parameters for the maximum percent change in the bridge resistors' values, the maximum input that the block will receive from a processing block, and the equivalent resistance of the Wheatstone bridge. The parameters resistor_tempco, nominal_res_temp, and temp are for the bridge resistors' temperature coefficients, the temperature at which the bridge resistors have their nominal value, and the current temperature of the bridge. All of these parameters are input by the user.

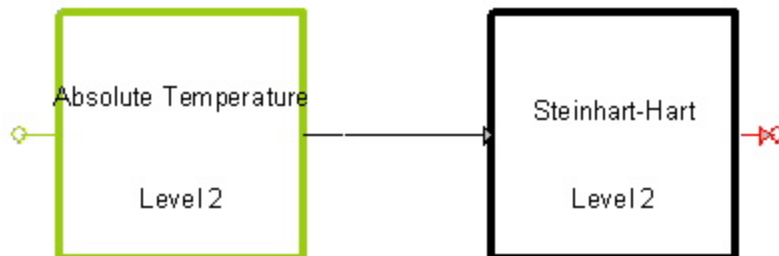
Example

The following example shows how to build a Level 2 model for a 100-ohm negative temperature coefficient thermistor using elements from the Level 2 Sensor building blocks library.

1. Since a thermistor responds to absolute temperature, the first step is to drop an Absolute Temperature measuring block on a Twin Builder schematic sheet:



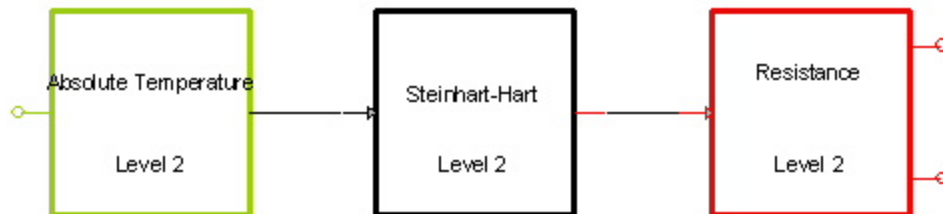
2. The second step is to parameterize the absolute temperature measuring block. The parameter that can be added to this block is the first-order time constant of the temperature measuring process. For the thermistor that is being modeled here, this value is 1ms.
3. The third step is to connect the black output pin of the measuring block to the input pin of a processing block. Since the sensor to be modeled is an NTC thermistor, the block that should be connected to the measuring block is the Steinhart-Hart function block:



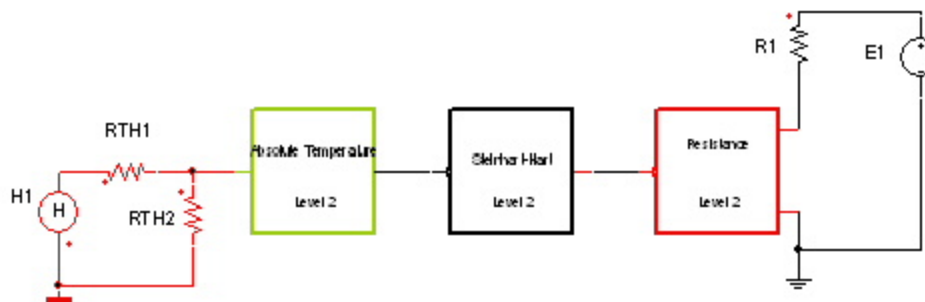
4. The fourth step is to add the parameters to the processing block. The Steinhart-Hart parameters a , b , and c for a typical 100-ohm thermistor are $a=1.94295\text{E-}3$, $b=2.989769\text{E-}4$, and $c=3.504383\text{E-}7$. The percent deviation from the nominal resistance value has a maximum value

of 2%, which will be used for this model. These parameters can be entered via the dialog for the Steinhart-Hart processing block.

5. Since the output signal of a thermistor is a variable resistance, the fifth step is to connect the nonconservative input pin of a Resistance output signal block to the output of the processing block.



6. Finally, the conservative thermal nature pin of the measuring block can be connected to a node in a thermal network, and the conservative electrical nature pins of the output block can be connected to an electrical network. The model is now ready to simulate.



Level 2 Measuring Blocks

The Level 2 Measuring Blocks are the first blocks used in building sensor models. They are used to measure physical quantities in the Twin Builder physical domains.

The Level 2 Measuring Blocks measure the following physical quantities:

- Absolute temperature

[Absolute Temperature Sensing \(ABS_TEMP_I2\)](#)

- Angular acceleration

[Rotational Acceleration Sensing \(Displacement-Force\) \(ANG_ACC_I2\)](#)

[Rotational Acceleration Sensing \(Velocity-Force\) \(ANG_ACC_V_I2\)](#)

- Angular displacement

[Rotational Displacement Sensing \(Displacement-Force\) \(ANG_DIFF_SENS_I2\)](#)

[Rotational Displacement Sensing \(Velocity-Force\) \(ANG_DISP_SENS_V_I2\)](#)

- Angular velocity

[Angular Velocity Sensing \(Displacement-Force\) \(ANG_VELOCITY_DF_I2\)](#)

[Angular Velocity Sensing \(Velocity-Force\) \(ANG_VELOCITY_VF_I2\)](#)

- Magnetic field

[Magnetic Field Sensing \(B_SENS_I2\)](#)

- Differential temperature

[Differential Temperature Sensing \(DIFF_TEMP_I2\)](#)

- Linear displacement

[Translational \(Linear\) Displacement Sensing \(Displacement-Force\) \(DISP_SENS_I2\)](#)

[Translational \(Linear\) Displacement Sensing \(Velocity-Force\) \(DISP_SENS_V_I2\)](#)

- Flow

[Flow Sensing \(FLOW_SENS_I2\)](#)

- Jerk

[Jerk Sensing \(Displacement-Force\) \(JERK_DF_I2\)](#)

[Jerk Sensing \(Velocity-Force\) \(JERK_VF_I2\)](#)

- Differential pressure

[Differential Pressure Sensing \(PM_DIFF_I2\)](#)

- Gage pressure

[Gage Pressure Sensing \(PM_GAGE_I2\)](#)

- Absolute pressure

[Absolute Pressure Sensing \(PMabs_I2\)](#)

- Torque

[Torque Sensing \(Displacement-Force\) \(TORQUE_DF_I2\)](#)

[Torque Sensing \(Velocity-Force\) \(TORQUE_VF_I2\)](#)

- Linear acceleration

[Translational \(Linear\) Acceleration Sensing \(Displacement-Force\) \(TRANS_ACC_I2\)](#)

[Translational \(Linear\) Acceleration Sensing \(Velocity-Force\) \(TRANS_ACC_V_I2\)](#)

The measuring blocks are connected to physical domain networks via conservative pins. The internal components of the blocks then measure some specific physical quantity, such as displacement, pressure, or temperature. Finally, the value of the measured physical quantity is passed from the block by a nonconservative output pin, which can be connected to a processing block.

Level 2 Absolute Temperature Sensing

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

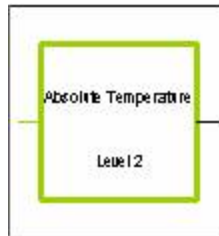


Figure 1. Component symbol

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Description

The Level 2 Absolute Temperature Sensing building block is for measuring absolute temperature, the temperature at a single node in a thermal network, and passing the value of the absolute temperature as a real value. The input to the block is through a conservative thermal nature pin. The output from the block is a nonconservative output pin.

The Level 2 Absolute Temperature measuring block also models the time constant of the temperature measuring process. A parameter for the time constant can be entered through a non-conservative node. A value of zero entered through this parameter indicates that the measuring process has no time constant and occurs instantaneously.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

MODEL ABS_TEMP_I2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) TEMP:= %0 (
time_constant:= @time_constant) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
TEMP	Absolute temperature input	Thermal

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
time_constant	Time constant for temperature measuring process	Real	0 [s]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
MEAS	Measured absoluteTemperature as a real number	Output	real

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Example

In this example, the Absolute Temperature Sensing building block ABS_TEMP_I21 measures the temperature of the Thermal Resistance RTH2, and output the value of the temperature as a real value. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

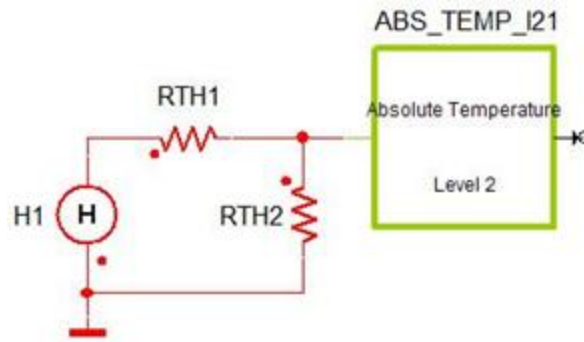


Figure 2. Application example of the Level 2 Absolute Temperature Sensing building block

Table 4

Component	Parameter	Value [Unit]
Heat Source H1	VALUE	1 [W]
Thermal Resistance RTH1	K	2 [K/W]
Thermal Resistance RTH2	K	1 [K/W]
Absolute Temperature Sensing building block ABS_TEMP_I21	time_constant	5m [s]

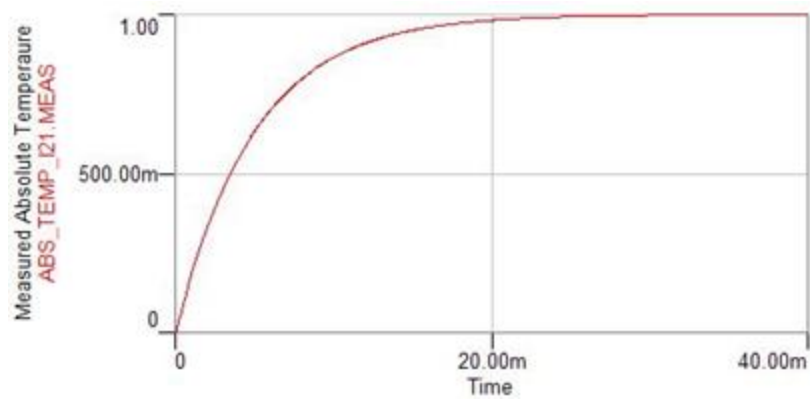


Figure 3. Simulation results-measured temperature of ABS_TEMP_I21

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References

Level 2 Rotational Acceleration (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2



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Description

The Level 2 Rotational Acceleration (Displacement-Force) building block is for measuring angular acceleration, the second time derivative of the angle at a node in a rotational network, and passing the value of the angular acceleration as a real value. The input to the block is through a conservative rotational nature pin. The output from the block is a nonconservative output pin.

The Level 2 Rotational Acceleration measuring block also models the frequency response of the rotational acceleration measuring process. The corner frequency of the angular acceleration input signal can be entered through a nonconservative input node. A value of zero for this parameter indicates that the measuring process has no frequency response and that the input signal will be measured at its full value at any frequency.

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Mathematical Description

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Netlist Syntax

MODEL ANG_ACC_I2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) ANGLE:= %0 (
corner_frequency:= @corner_frequency) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
ANGLE	Connection to rotational network	Rotational

[Top](#)

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
corner_fre- quency	Corner frequency of the accel- eration input signal	Real	0 [Hz]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
MEAS	Angular acceleration as a real number	Output	real

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Example

In this example, the Rotational Acceleration (Displacement-Force) building block ANG_ACC_I21 measures angular acceleration of the Mass MASS_ROT B1, and output the value of the linear acceleration as a real value. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

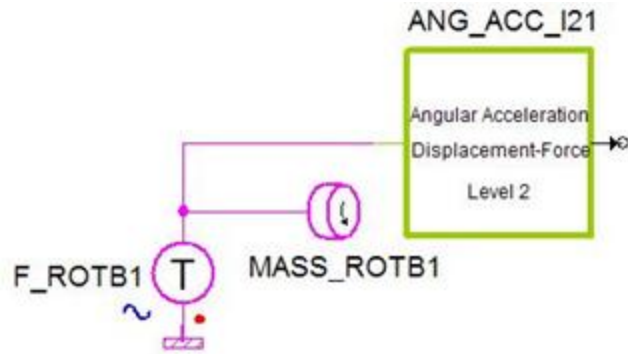


Figure 2. Application example of the Rotational Acceleration (Displacement-Force) building block

Table 4

Component	Parameter	Value [Unit]
Torque Source F_ROT B1	AMPL	1 [Nm]
	FREQ	50 [Hz]
	PHASE	0 [degree]
	OFF	0 [N]
	TDELAY	0 [s]
Mass MASS_ROT B1	J	1 [kg m]
	S0	0 [rad]
	V0	0 [rad/s]
Rotational Acceleration (Displacement-	corner_fre-	50 [Hz]

Force) building block ANG_ACC_I21	quency	

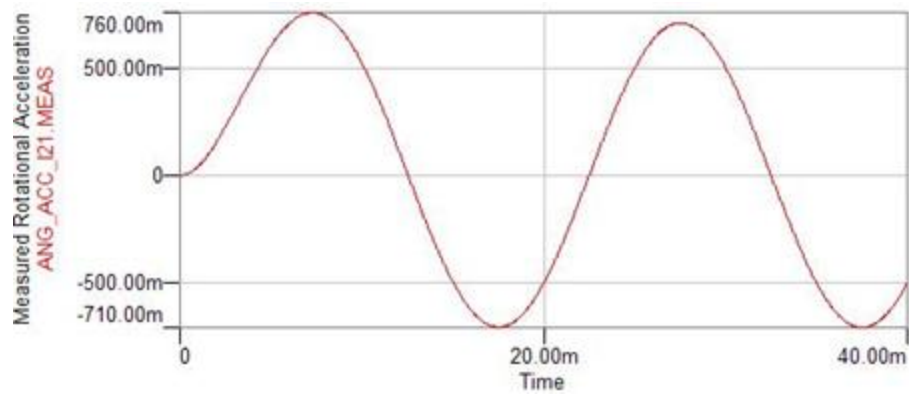


Figure 3. Simulation results-measured angular acceleration of ANG_ACC_I21

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References

Level 2 Rotational Acceleration (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2



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Description

The Level 2 Rotational Acceleration (Velocity-Force) building block is for measuring angular acceleration, first time derivative of the angular velocity at a node in a rotational_v network, and passing the value of the angular acceleration as a real value. The input to the block is through a conservative rotational_v nature pin. The output from the block is a nonconservative output pin.

The Level 2 Rotational Acceleration measuring block also models the frequency response of the rotational acceleration measuring process. The corner frequency of the angular acceleration input signal can be entered through a nonconservative input node. A value of zero for this parameter indicates that the measuring process has no frequency response and that the input signal will be measured at its full value at any frequency.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

MODEL ANG_ACC_V_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) OMEGA:= %0 (corner_frequency:= @corner_frequency) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
OMEGA	Connection to rotational_v network	Rotational_V

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
corner_frequency	Corner frequency of the rotational acceleration input signal	Real	0 [Hz]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
MEAS	Angular acceleration as a real number	Output	real

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Example

In this example, the Rotational Acceleration (Velocity-Force) building block ANG_ACC_V_I21 measures angular acceleration of the Mass MASS_ROT1, and output the value of the linear acceleration as a real value. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

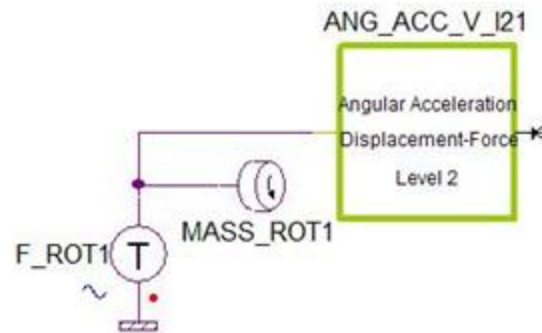


Figure 2. Application example of the Rotational Acceleration (Velocity-Force) building block

Table 4

Component	Parameter	Value [Unit]
Torque Source F_ROT1	AMPL	1 [Nm]
	FREQ	50 [Hz]
	PHASE	0 [degree]
	OFF	0 [N]
	TDELAY	0 [s]
Mass MASS_ROT1	J	1 [kg m]
	S0	0 [rad]
	V0	0 [rad/s]
Rotational Acceleration (Velocity-Force) building block ANG_ACC_V_I21	corner_frequency	50 [Hz]

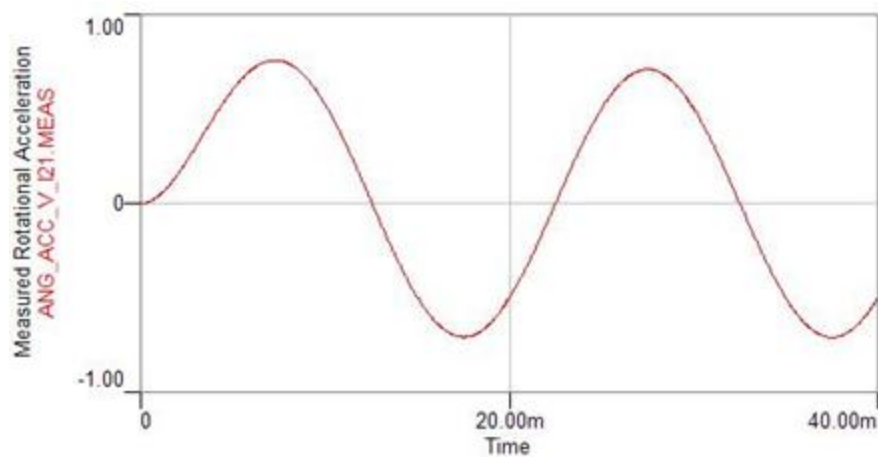


Figure 3. Simulation results-measured angular acceleration of ANG_ACC_V_I21

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References

Level 2 Rotational Displacement (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2



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Description

The Level 2 Rotational Displacement (Displacement-Force) building block is for measuring rotational displacement, the position difference between two nodes in a rotational network, and passing the value of the rotational displacement as a real value. The inputs to the block are through conservative rotational nature pins. The output from the block is a nonconservative output pin.

The Level 2 Rotational Displacement measuring block also models the time constant of the rotational displacement measuring process. A parameter for the time constant can be entered through a nonconservative node. A value of zero entered through this parameter indicates that the measuring process has no time constant and occurs instantaneously.

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Mathematical Description

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Netlist Syntax

MODEL ANG_DIFF_SENS_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) REF:= %0, POSITION:= %1 (time_constant:= @time_constant) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured position	Rotational
REF	Reference position	Rotational

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
time_constant	Time constant of the rotational displacement measuring process	Real	0 [s]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
MEAS	Rotational displacement as a real number	Output	real

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Example

In this example, the Rotational Displacement (Displacement-Force) building block ANG_DIFF_SENS_I21 measures angular displacement of the Mass MASS_ROT1, and output the value of the angular displacement as a real value. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

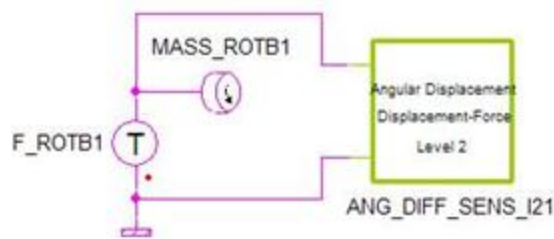


Figure 2. Application example of the Rotational Displacement (Displacement-Force) building block

Table 4

Component	Parameter	Value [Unit]
Torque Source F_ROT1	VALUE	1 [Nm]
Mass MASS_ROT1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Rotational Displacement (Displacement-Force) building block ANG_DIFF_SENS_I21	time_constant	5m [s]

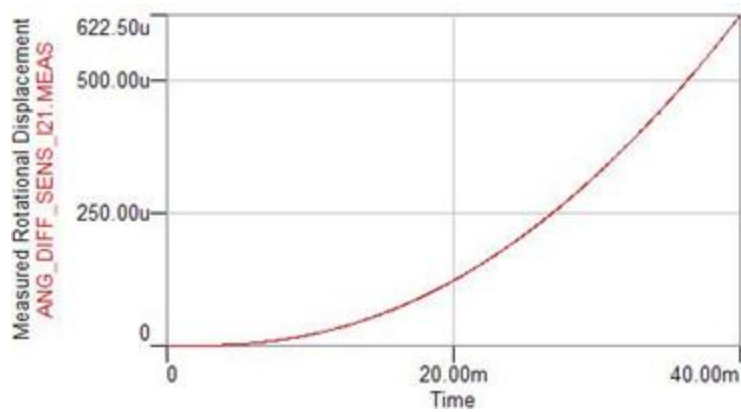


Figure 3. Simulation results-measured angular displament of ANG_DIFF_SENS_I21

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References

Level 2 Rotational Displacement (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

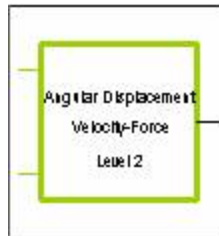


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Description

The Level 2 Rotational Displacement (Velocity-Force) building block is for measuring rotational displacement, the position difference between two nodes in a rotational_v network, and passing the value of the Rotational displacement as a real value. The inputs to the block are through conservative rotational_v nature pins. The output from the block is a nonconservative output pin.

The Level 2 Rotational Displacement measuring block also models the time constant of the rotational displacement measuring process. A parameter for the time constant can be entered through a nonconservative node. A value of zero entered through this parameter indicates that the measuring process has no time constant and occurs instantaneously.

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Netlist Syntax

MODEL ANG_DISP_SENS_V_I2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID))
REF:= %0, POSITION:= %1 (time_constant:= @time_constant, phi_init:= @phi_init) SRC: DB
(Lib:=@ModelLibraryName) ;

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Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured position	Rotational_V
REF	Reference position	Rotational_V

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
phi_init	Initial sensor angle	Real	0 [rad]
time_constant	Time constant of the rotational displacement measuring process	Real	0 [s]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
MEAS	Rotational displacement as a real	Output	real

	number		

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Example

In this example, the Rotational Displacement (Velocity-Force) building block ANG_DISP_SENS_V_I21 measures angular displacement of the Mass MASS_ROT1, and output the value of the angular displacement as a real value. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

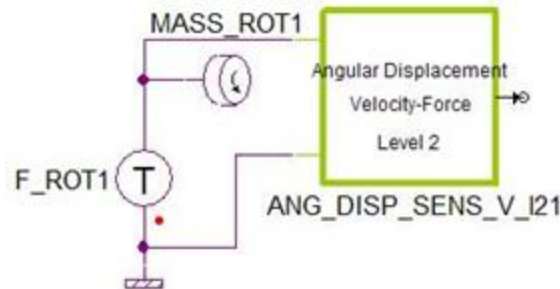


Figure 2. Application example of the Rotational Displacement (Velocity-Force) building block

Table 4

Component	Parameter	Value [Unit]
Torque Source F_ROT1	VALUE	1 [Nm]
Mass MASS_ROT1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Rotational Displacement (Velocity-Force) building block ANG_DISP_SENS_V_I21	time_constant	5m [s]
	phi_init	0 [rad]

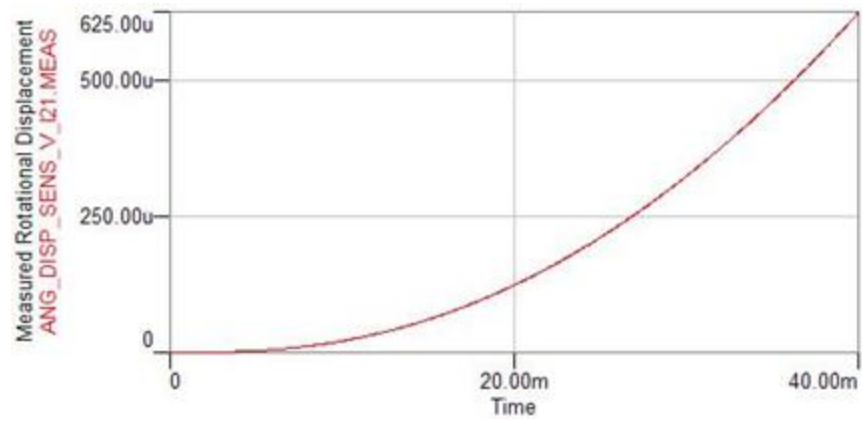


Figure 3. Simulation results-measured angular displament of ANG_DIFF_SENS_V_I21

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References

Angular Velocity (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2



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Description

The Level 2 Angular Velocity (Displacement-Force) building block is for measuring angular velocity in a rotational network and passing the value of the angular velocity as a real value. The input to the block is through a conservative rotational nature pin. The output from the block is a nonconservative output pin. The Level 2 angular velocity measuring block also allows the corner frequency of the angular velocity input signal to be entered through a nonconservative node.

A value of zero entered for the corner frequency parameter indicates that there is no corner frequency for the input signal and that it will be measured at its full value at any frequency.

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Netlist Syntax

```
MODEL ANG_VELOCITY_DF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID))
OMEGA:= %0 ( corner_frequency:= @corner_frequency) SRC: DB(Lib:=@ModelLibraryName)
;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
OMEGA	Angular velocity input	Rotational

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
corner_frequency	Corner frequency of the angular velocity input signal	Real	0 [Hz]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
MEAS	Measured angular velocity as a real number	Output	real

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Example

In this example, the Angular Velocity (Displacement-Force) building block ANG_VELOCITY_DF_I21 measures the angular velocity of Mass block MASS_ROT B1 in a rotational network and output the value of the angular velocity as a real value. The schematic of the system is shown in

Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

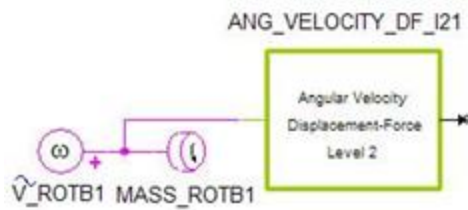


Figure 2. Application example of the Level 2 Angular Velocity (Displacement-Force) Building Block

Table 4

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROT B1	AMPL	1 [rad/s]
	FREQ	50 [Hz]
	PHASE	0 [rad]
	OFF	0 [rad/s]
	PHI0	0 [rad]
	TDELAY	0 [s]
Mass MASS_ROT B1	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Angular Velocity (Displacement-Force) building block ANG_VELOCITY_DF_I21	corner_frequency	50 [Hz]

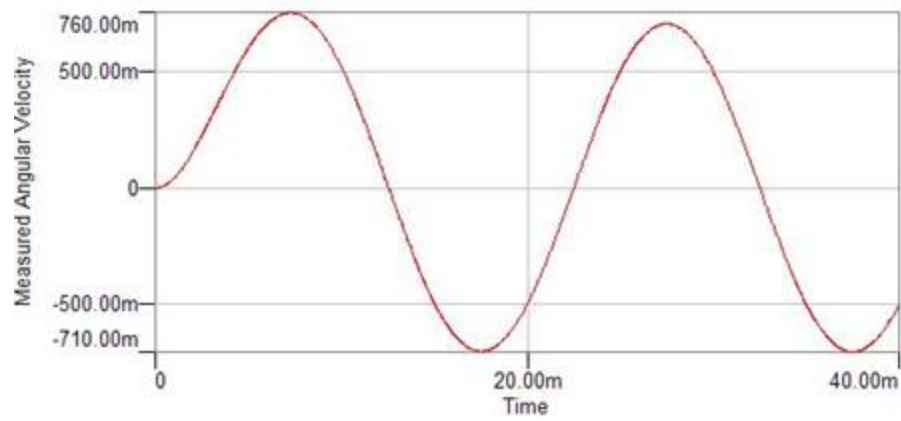


Figure 3. Simulation results-measured angular velocity of ANG_VELOCITY_DF_I21

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References

Angular Velocity (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2



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Description

The Level 2 Angular Velocity (Velocity-Force) building block is for measuring angular velocity in a rotational network and passing the value of the angular velocity as a real value. The input to the block is through a conservative rotational $\_v$ nature pin. The output from the block is a non-conservative output pin. The Level 2 angular velocity measuring block also allows the corner frequency of the angular velocity input signal to be entered through a nonconservative node.

A value of zero entered for the corner frequency parameter indicates that there is no corner frequency for the input signal and that it will be measured at its full value at any frequency.

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Mathematical Description

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Netlist Syntax

```
MODEL ANG_VELOCITY_VF_I2 ?InstanceName(@InstanceName):(@Refbase)@(ID))
OMEGA:= %0 ( corner_frequency:= @corner_frequency) SRC: DB(Lib:=@ModelLibraryName)
;
```

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Table 1

Name	Port/Terminal Description	Nature/Data type
OMEGA	Angular velocity input	Rotational_V

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
corner_frequency	Corner frequency of the angular velocity input signal	Real	0 [Hz]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
MEAS	Measured angular velocity as a real number	Output	real

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Example

In this example, the Angular Velocity (Velocity-Force) building block ANG_VELOCITY_VF_I21 measures the angular velocity of Mass block MASS_ROT1 in a rotational network and output the

value of the angular velocity as a real value. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

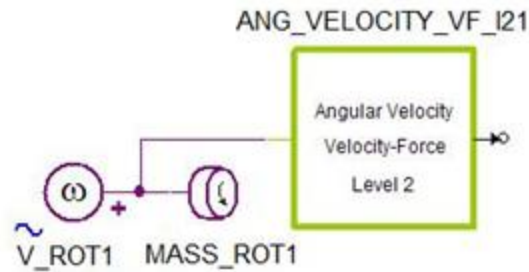


Figure 2. Application example of the Level 2 Angular Velocity (Velocity-Force) Building Block

Table 4

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROT1	AMPL	1 [rad/s]
	FREQ	50 [Hz]
	PHASE	0 [rad]
	OFF	0 [rad/s]
	PHI0	0 [rad]
	TDELAY	0 [s]
Mass $MASS\_ROT1$	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Angular Velocity (Velocity-Force) building block $ANG\_VELOCITY\_VF\_I21$	corner_frequency	50 [Hz]

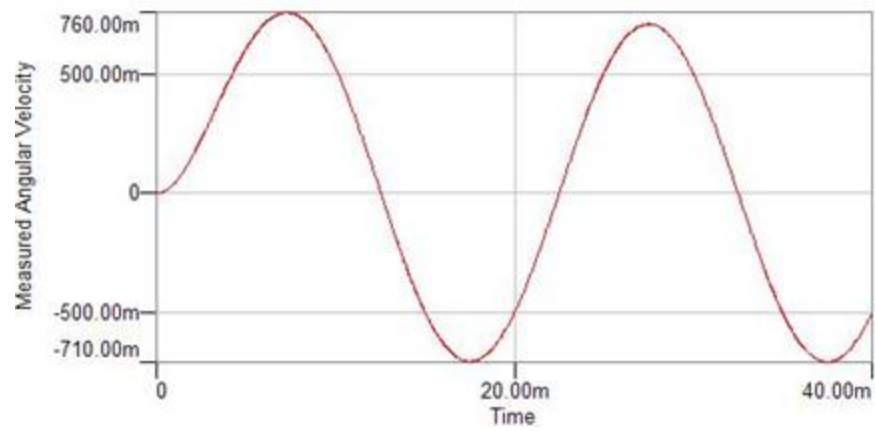


Figure 3. Simulation results-measured angular velocity of ANG_VELOCITY_VF_I21

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References

Level 2 Magnetic Field Sensing

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

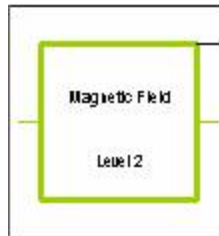


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Description

The Level 2 Magnetic Field Sensing building block is for measuring magnetic field, flux through an element in a magnetic network divided by its area, and passing the value of the magnetic field as a real value. Magnetic flux passes in and out of the block through conservative magnetic nature pins. The output from the block is a nonconservative output pin.

The Level 2 Magnetic Field measuring block also models the frequency response of the sensing process. A parameter for the corner frequency of the input magnetic flux signal can be entered through a nonconservative node. A value of zero entered for this parameter indicates that the measuring process has no frequency response and that the input signal will be measured at its full value at any frequency.

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Netlist Syntax

MODEL B_SENS_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) FLUX_IN:= %0,
FLUX_OUT:= %1 (AREA:= @AREA, corner_frequency:= @corner_frequency) SRC: DB(Lib:-
:=@ModelLibraryName);

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
FLUX_IN	Flux entrance	Magnetic
FLUX_OUT	Flux exit	Magnetic

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
AREA	Area of the sensor	Real	10n [m ²]
corner_fre- quency	Corner frequency of the mag- netic field input signal	Real	0 [Hz]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
MEAS	Magnetic field as a real number	Output	real

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Example

In this example, the Magnetic Field Sensing building block B_SENS_I21 measures the magnetic flux through the Magnetoresistor RMAG1, divided by the AREA, and output the value of the magnetic field as a real value. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

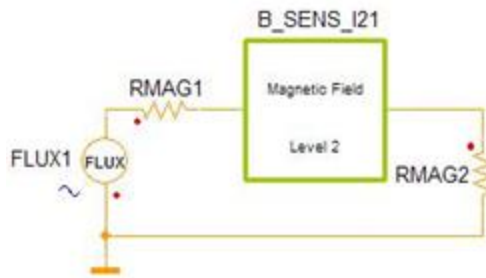


Figure 2. Application example of the Magnetic Field Sensing building block

Table 4

Component	Parameter	Value [Unit]
Flux Source FLUX1	AMPL	4.5 [Wb]
	FREQ	50 [Hz]
	PHASE	0 [degree]
	OFF	0 [Wb]
	TDELAY	0 [s]
Magnetoresistor RMAG1/RMAG2	K	1e9 [A/Wb]
Magnetic Field Sensing building block B_SENS_I21	AREA	10m [m ²]
	corner_frequency	50 [Hz]

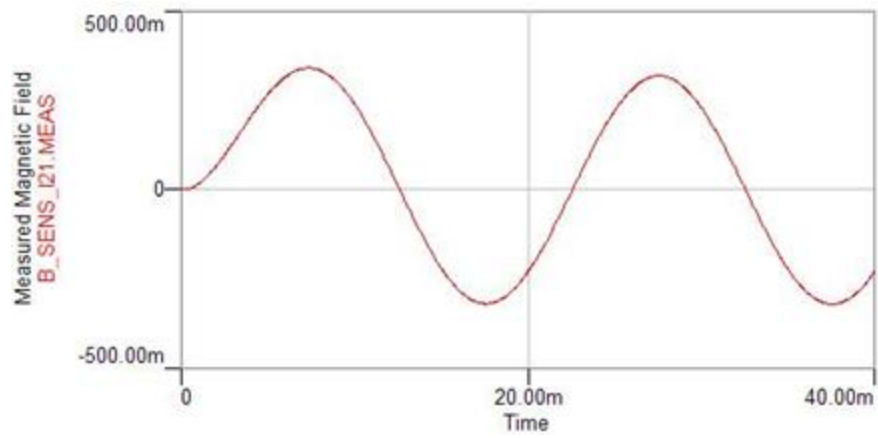


Figure 3. Simulation results-measured Magnetic Field of B_SENS_I21

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References

Level 2 Differential Temperature Sensing

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

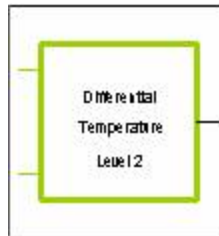


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Description

The Level 2 Differential Temperature Sensing building block is for measuring differential temperature, the temperature difference between two nodes in a thermal network, and passing the value of the differential Temperature as a real value. The inputs to the block are conservative thermal nature pins. The output from the block is a nonconservative output pin.

The Level 2 Differential Temperature measuring block also models the time constant of the temperature measuring process. A parameter for the time constant can be entered through a non-conservative node. A value of zero entered through this parameter indicates that the measuring process has no time constant and occurs instantaneously.

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Netlist Syntax

```
MODEL DIFF_TEMP_I2 ?InstanceName(@InstanceName):(@Refbase)@(ID)) REF:= %0,  
TEMP:= %1 ( time_constant:= @time_constant) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
TEMP	Measured temperature	Thermal
REF	Reference Pressure	Thermal

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
time_constant	Time constant of the absolute pressure measuring process	Real	0 [s]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
MEAS	Differential pressure as a real number	Output	real

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Example

In this example, the Differential Temperature Sensing building block DIFF_TEMP_I21 measures the temperature difference between the Heat Source H1 and the Thermal resistance RTH2, and output the value of the differential temperature as a real value. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

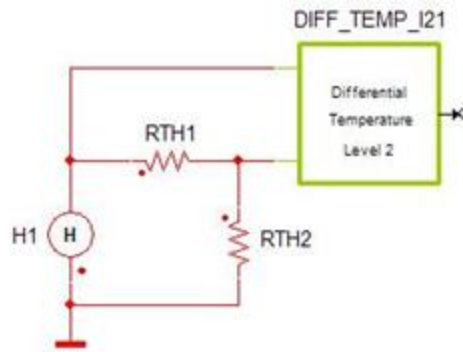


Figure 2. Application example of the Level 2 Absolute Temperature Sensing building block

Table 4

Component	Parameter	Value [Unit]
Heat Source H1	VALUE	1 [W]
Thermal Resistance RTH1	K	2 [K/W]
Thermal Resistance RTH2	K	1 [K/W]
Differential Temperature Sensing building block DIFF_TEMP_I21	time_constant	5m [s]

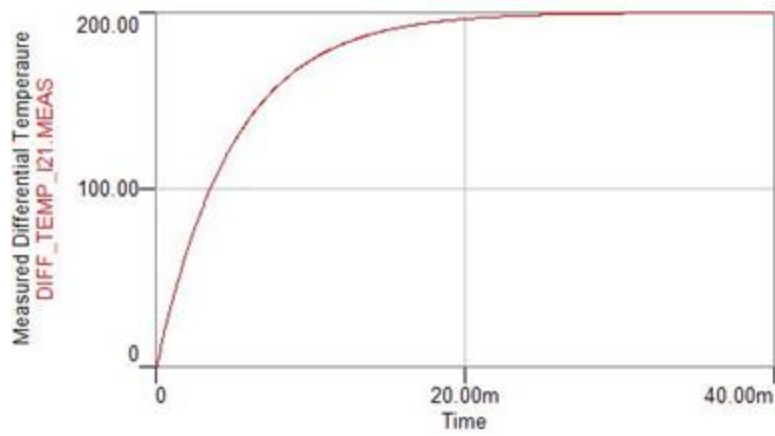


Figure 3. Simulation results-measured temperature of DIFF_TEMP_I21

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References

Level 2 Translational Displacement (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2



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Description

The Level 2 Linear Displacement (Displacement-Force) building block is for measuring linear displacement, the position difference between two nodes in a translational network, and passing the value of the linear displacement as a real value. The inputs to the block are through conservative Translational nature pins. The output from the block is a nonconservative output pin.

The Level 2 Linear Displacement measuring block also models the time constant of the displacement measuring process. This time constant can be entered into the block through a non-conservative node. A value of zero entered for the time constant indicates that the measuring process has no time constant and takes place instantaneously.

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Netlist Syntax

MODEL DISP_SENS_I2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) REF:= %0,
POSITION:= %1 (time_constant:= @time_constant) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured position	Translational
REF	Reference position	Translational

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
time_constant	Time constant of the measuring process	Real	0 [s]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
MEAS	Linear displacement as a real number	Output	real

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Example

In this example, the Linear Displacement (Displacement-Force) building block DISP_SENS_I21 measures displacement of the Mass MASS_TRB1, and output the value of the displacement as a real value. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

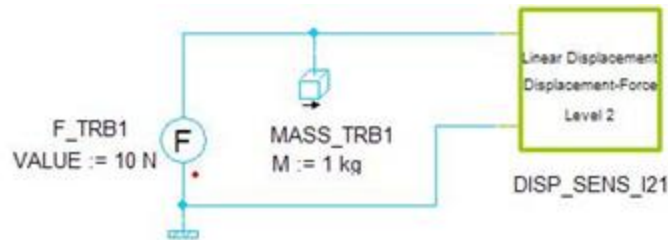


Figure 2. Application example of the Linear Displacement (Displacement-Force) building block

Table 4

Component	Parameter	Value [Unit]
Force Source F1	VALUE	10 [N]
Mass MASS_TRB1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Linear Displacement (Displacement-Force) building block DISP_SENS_I21	time_constant	5m [s]

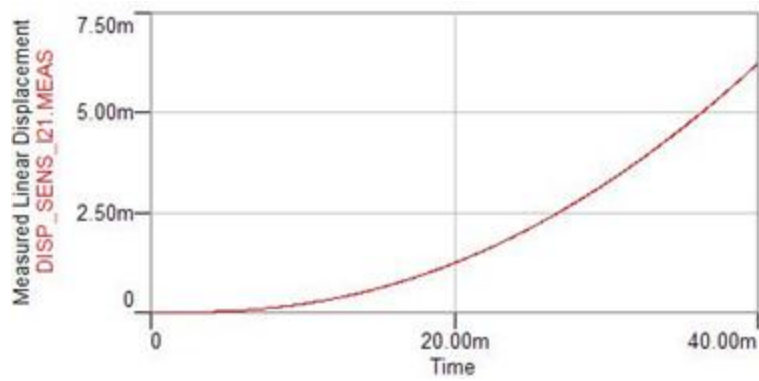


Figure 3. Simulation results-measured displament of DISP_SENS_I21

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References

Level 2 Translational Displacement (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2



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Description

The Level 2 Translational Displacement (Velocity-Force) building block is for measuring Translational displacement, the position difference between two nodes in a Translational_V network, and passing the value of the Translational displacement as a real value. The inputs to the block are through conservative Translational_V nature pins. The output from the block is a non-conservative output pin.

The Level 2 Linear Displacement measuring block also models the time constant of the displacement measuring process. This time constant can be entered into the block through a non-conservative node. A value of zero entered for this parameter indicates that the measuring process has no time constant and occurs instantaneously.

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Mathematical Description

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Netlist Syntax

MODEL DISP_SENS_V_I2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) REF:= %0,
POSITION:= %1 (time_constant:= @time_constant, s_init:= @s_init) SRC: DB(Lib:-
:=@ModelLibraryName);

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Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured position	Translational_V
REF	Reference position	Translational_V

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
s_init	Initial sensor position	Real	0 [m]
time_constant	Time constant of the measuring process	Real	0 [s]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
MEAS	Translational displacement as a real number	Output	real

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Example

In this example, the Linear Displacement (Displacement-Force) building block DISP_SENS_I21 measures displacement of the Mass MASS_TRB1, and output the value of the displacement as a real value. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

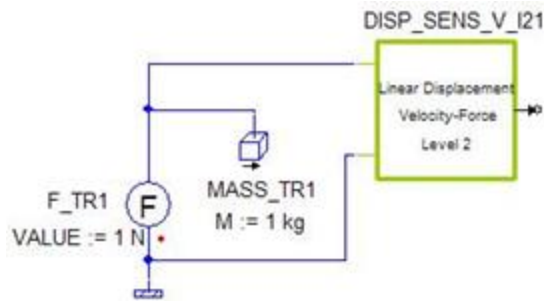


Figure 2. Application example of the Linear Displacement (Displacement-Force) building block

Table 4

Component	Parameter	Value [Unit]
Force Source F1	VALUE	1 [N]
Mass MASS_TR1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Linear Displacement (Velocity-Force) building block DISP_SENS_V_I21	time_constant	5m [s]
	s_init	0 [m]

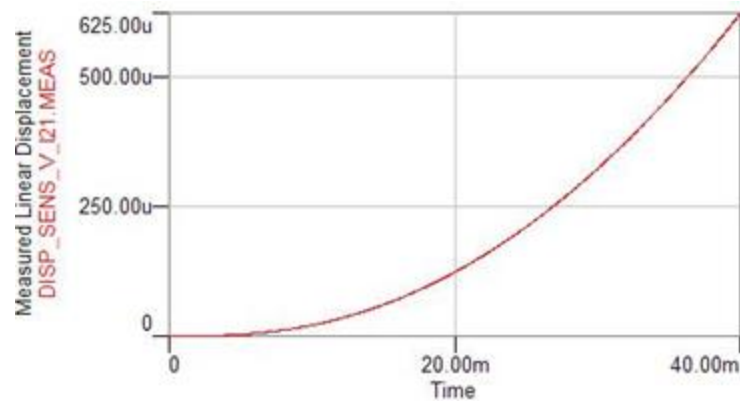


Figure 3. Simulation results-measured displament of DISP_SENS_V_I21

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References

Level 2 Flow Sensing

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

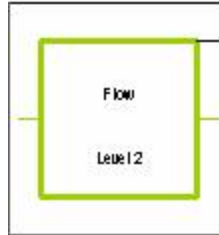


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Description

The Level 2 Flow Sensing building block is for measuring flow through a branch of a fluidic network and passing the value of the flow as a real value. Fluid flow passes in and out of the block through conservative fluidic nature pins. The output from the block is a nonconservative output pin.

The Level 2 Flow Sensing block also allows the addition of parameters for the corner frequency of the input flow signal and the parasitic hydraulic conductance of the flow sensing mechanism. These parameters can be entered through nonconservative nodes. Note that a value of zero entered for the corner frequency parameter indicates that there is no corner frequency for the input signal and that it will be measured at its full value at any frequency.

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Mathematical Description

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Netlist Syntax

```
MODEL FLOW_SENS_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) FLOW_P:=
%0, FLOW_M:= %1 ( conductance:= @conductance, corner_frequency:= @corner_frequency)
SRC: DB(Lib:=@ModelLibraryName);
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
FLOW_P	Flow entrance	Fluidic
FLOW_M	Flow exit	Fluidic

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
conductance	Parasitic hydraulic conductance	Real	1G [m ³ /(Pa s)]
corner_frequency	Corner frequency of the flow input signal	Real	0 [Hz]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
MEAS	Flow as a real number	Output	real

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Example

In this example, the Flow Sensing building block FLOW_SENS_I21 measures the flow through the Linear Orifice RHYD1 and output the value of the flow as a real value. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

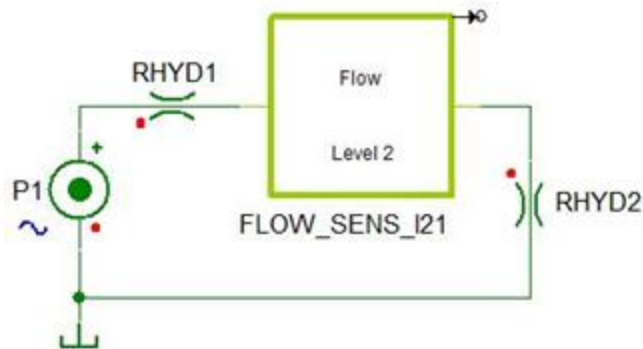


Figure 2. Application example of the Flow Sensing building block

Table 4

Component	Parameter	Value [Unit]
Pressure Source P1	AMPL	100k [Pa]
	FREQ	50 [Hz]
	PHASE	0 [degree]
	OFF	0 [Pa]
	TDELAY	0 [s]
Linear Orifice RHYD1/RHYD2	K	1n [m/(Pa s)]
Flow Sensing building block FLOW_SENS_I21	conductance	1meg [m ³ / (Pa s)]
	corner_frequency	50 [Hz]

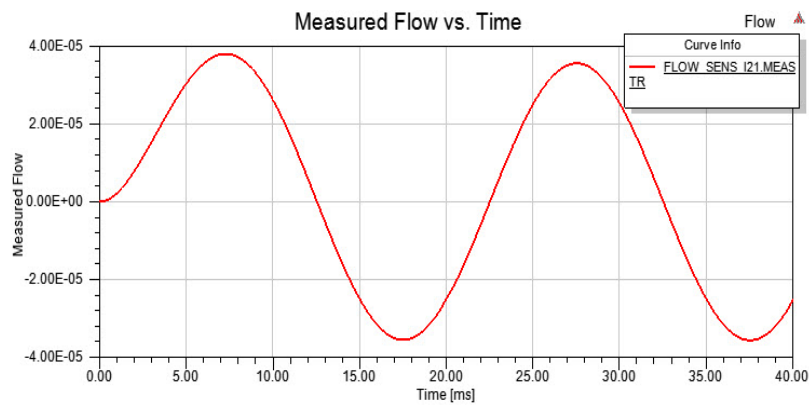


Figure 3. Simulation results-measured flow of FLOW_SENS_I21

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References

Level 2 Jerk Sensing (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

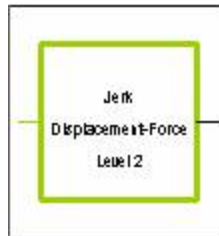


Figure 1. Component symbol

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Description

The Level 2 Jerk Sensing (Displacement-Force) building block is for measuring jerk, the third time derivative of the position at a node in a translational network, and passing the value of the jerk as a real value. The input to the block is through a conservative translational nature pin. The output from the block is a nonconservative output pin.

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Mathematical Description

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Netlist Syntax

```
MODEL JERK_DF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) POS:= %0 ( )
SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POS	Connection to translational network	Translational

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
MEAS	Jerk as a real number	Output	real

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Example

In this example, the Jerk Sensing (Displacement-Force) building block JERK_DF_I21 measures the jerk of the Mass MASS_TRB1 and output the value of the jerk as a real value. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

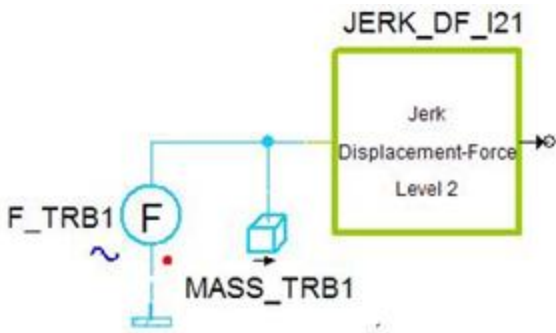


Figure 2. Application example of the Jerk Sensing (Displacement-Force) building block

Table 3

Component	Parameter	Value [Unit]
Force Source F_TRB1	AMPL	1 [N]

	FREQ	50 [Hz]
	PHASE	0 [degree]
	OFF	0 [N]
	TDELAY	0 [s]
Mass MASS_TRB1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]

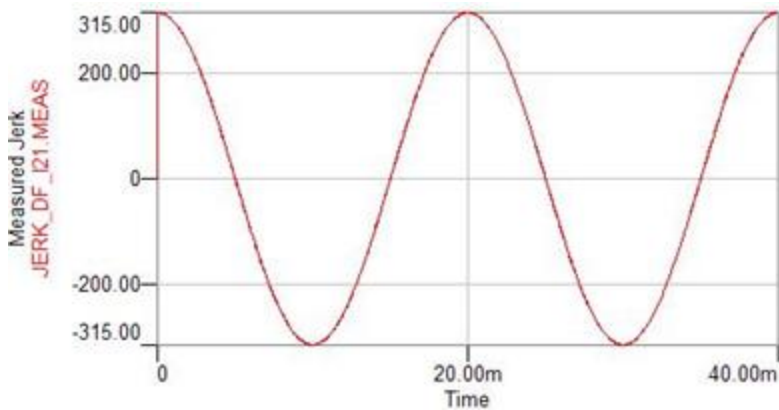


Figure 3. Simulation results-measured Jerk of JERK_DF_I21

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References

Level 2 Jerk Sensing (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

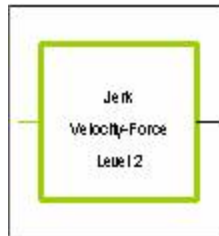


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Description

The Level 2 Jerk Sensing (Velocity-Force) building block is for measuring jerk, the second derivative of the velocity at a node in a translational_v network, and passing the value of the jerk as a real value. The input to the block is through a conservative translational_v nature pin. The output from the block is a nonconservative output pin.

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Mathematical Description

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Netlist Syntax

```
MODEL JERK_VF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) VELOCITY:= %0  
( ) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
VELOCITY	Connection to translational_v network	Translational_V

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
MEAS	Jerk as a real number	Output	real

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Example

In this example, the Jerk Sensing (Velocity-Force) building block JERK_VF_I21 measures the jerk of the Mass MASS_TR1 and output the value of the jerk as a real value. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

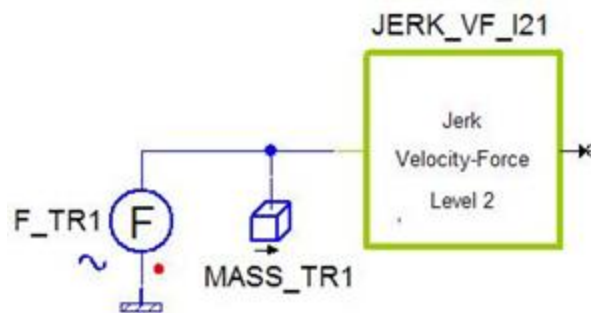


Figure 2. Application example of the Jerk Sensing (Velocity-Force) building block

Table 3

Component	Parameter	Value [Unit]
Force Source F_TR1	AMPL	1 [N]

	FREQ	50 [Hz]
	PHASE	0 [degree]
	OFF	0 [N]
	TDELAY	0 [s]
	M	1 [kg]
Mass MASS_TR1	S0	0 [m]
	V0	0 [m/s]

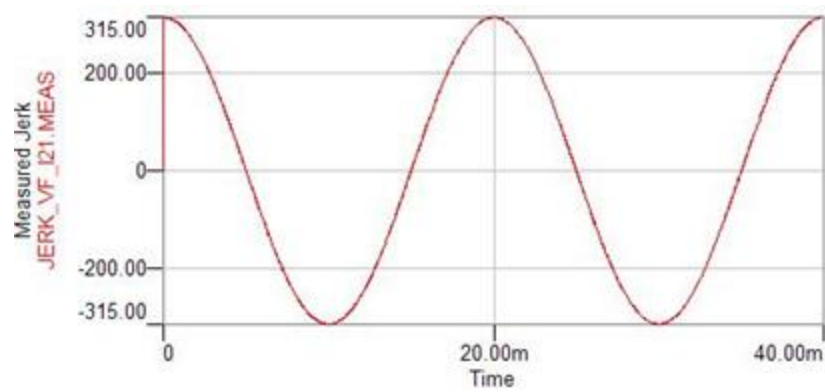


Figure 3. Simulation results-measured Jerk of JERK_VF_I21

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References

Level 2 Differential Pressure Sensing

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

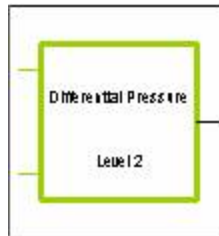


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Description

The Level 2 Differential Pressure Sensing building block is for measuring differential pressure, the pressure difference between two nodes in a fluidic network, and passing the value of the differential pressure as a real value. The inputs to the block are through conservative fluidic nature pins. The output from the block is a nonconservative output pin.

The Level 2 Differential Pressure measuring block also models the time constant of the pressure measuring process. This time constant can be entered into the block through a nonconservative node. A value of zero entered for the time constant indicates that the measuring process has no time constant and takes place instantaneously.

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Netlist Syntax

MODEL PM_DIFF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) P1:= %0, P2:= %1 (time_constant:= @time_constant) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
P1	Measured pressure	Fluidic
P2	Reference Pressure	Fluidic

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
time_constant	Time constant of the absolute pressure measuring process	Real	0 [s]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
MEAS	Differential pressure as a real number	Output	real

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Example

In this example, the Differential Pressure Sensing building block PM_DIFF_I21 measures the pressure difference between the Flow Source Q1 and the Linear Orifice RHYD2, and output the value of the differential pressure as a real value. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

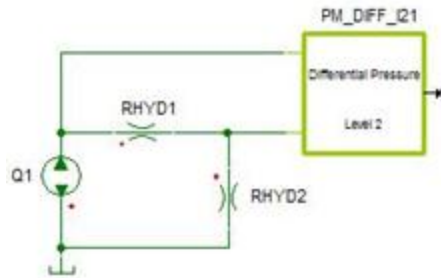


Figure 2. Application example of the Level 2 Differential Pressure Sensing Building Block

Table 4

Component	Parameter	Value [Unit]
Flow Source Q1	VALUE	100u [m/s]
Linear Orifice RHYD1	K	2n [m/ (Pa s)]
Linear Orifice RHYD2	K	1n [m/ (Pa s)]
Differential Pressure Sensing building block PM_DIFF_I21	time_constant	5m [s]

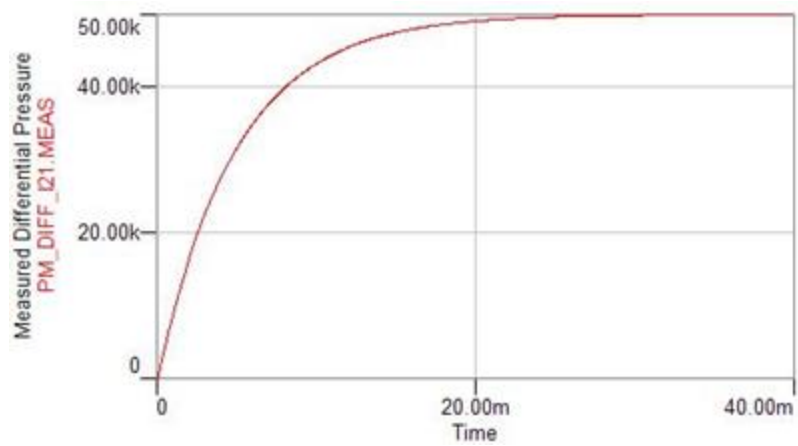


Figure 3. Simulation results-measured differential pressure of PM_DIFF_I21

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References

Level 2 Gage Pressure Sensing

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2



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Description

The Level 2 Gage Pressure Sensing building block is for measuring gage pressure, the difference between the pressure at a node in a fluidic network and atmospheric pressure, and passing the value of the gage pressure as a real value. The input to the block is through a conservative fluidic nature pin. The output from the block is a nonconservative output pin.

The Level 2 Gage Pressure measuring block also models the time constant of the pressure measuring process. This time constant can be entered into the block through a nonconservative node. A value of zero entered for the time constant indicates that the measuring process has no time constant and takes place instantaneously.

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Netlist Syntax

MODEL PM_GAGE_I2 ?InstanceName(@InstanceName):(@Refbase)@(ID)) PRESSURE:= %0 (atmp:= @atmp, time_constant:= @time_constant) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PRESSURE	Measured pressure	Fluidic

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
atmp	Atmospheric pressure	Real	101.325k [Pa]
time_constant	Time constant of the absolute pressure measuring process	Real	0 [s]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
MEAS	Gage pressure as a real number	Output	real

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Example

In this example, the Gage Pressure Sensing building block PM_GAGE_I21 measures the difference between the pressure applied to RHYD2 and atmospheric pressure, and output the value of the gage pressure as a real value. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

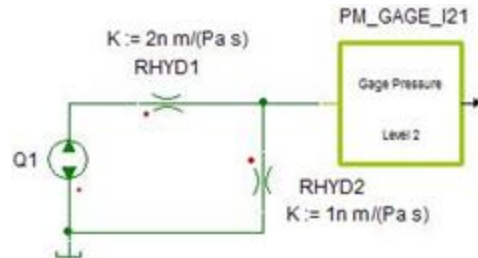


Figure 2. Application example of the Level 2 Gage Pressure Sensing building block

Table 4

Component	Parameter	Value [Unit]
Flow Source Q1	VALUE	100u [m/s]
Linear Orifice RHYD1	K	2n [m/(Pa s)]
Linear Orifice RHYD2	K	1n [m/(Pa s)]
Gage Pressure Sensing building block PM_GAGE_I21	time_constant	5m [s]
	atmp	0.101325Meg [Pa]

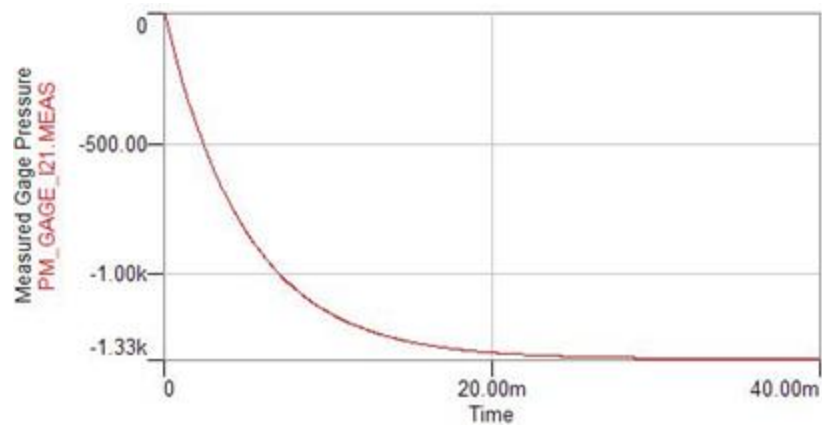


Figure 3. Simulation results-measured gage pressure of PM_GAGE_I21

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References

Level 2 Absolute Pressure Sensing

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

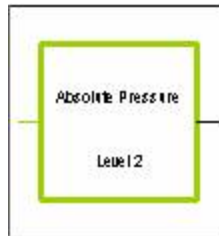


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Description

The Level 2 Absolute Pressure Sensing building block is for measuring absolute pressure in a fluidic network and passing the value of the absolute pressure as a real value. The input to the block is through a conservative fluidic nature pin. The output from the block is a nonconservative output pin.

The Level 2 Absolute Pressure measuring block also models the time constant of the absolute pressure measuring process. This time constant can be entered into the block through a non-conservative node. Note that a value of zero entered for the time constant indicates that the measuring process has no time constant and takes place instantaneously.

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Netlist Syntax

MODEL PMabs_I2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) P:= %0 (time_constant:= @time_constant) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
P	Absolute pressure input	Fluidic

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
time_constant	Time constant of the absolute pressure measuring process	Real	0 [s]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
MEAS	Measured absolute pressure as a real number	Output	real

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Example

In this example, the Absolute Pressure Sensing building block PMabs_I21 measures the pressure applied to the Linear Orifice RHYD2, and output the value of the pressure as a real value. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

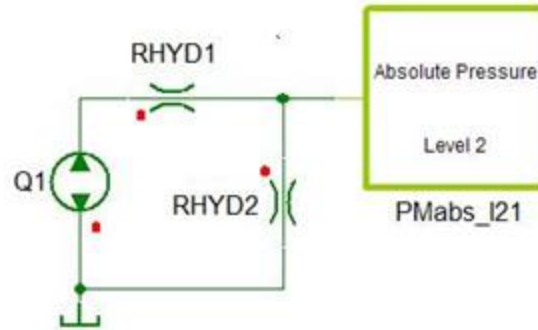


Figure 2. Application example of the Level 2 Absolute Pressure Sensing Building Block

Table 4

Component	Parameter	Value [Unit]
Flow Source Q1	VALUE	100u [m/s]
Linear Orifice RHYD1/RHYD2	K	1n [m/(Pa s)]
Absolute Pressure Sensing building block PMabs_I21	time_constant	5m [s]

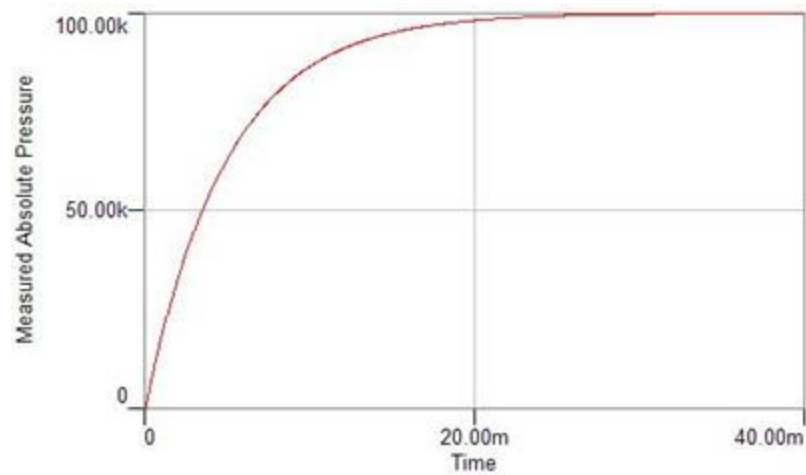


Figure 3. Simulation results-measured pressure of PMabs_I21

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References

Level 2 Torque Sensing (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

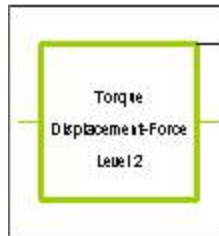


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Description

The Level 2 Torque Sensing (Displacement-Force) building block is for measuring torque through a branch of a rotational network and passing the value of the torque as a real value. Torque passes in and out of the block through conservative rotational nature pins. The output from the block is a nonconservative output pin.

The Level 2 Torque measuring block also models the moment of inertia and the frequency response of the torque-sensing element. Parameters for the moment of inertia of the torque sensing element and the corner frequency of the torque input signal can be entered into the block through nonconservative input nodes.

A value of zero entered for the corner frequency parameter indicates that the torque measuring process has no frequency response and that torque will be measured at its full value at all frequencies.

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Mathematical Description

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Netlist Syntax

MODEL TORQUE_DF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) TORQUE_IN:= %0, TORQUE_OUT:= %1 (moment_inertia:= @moment_inertia, corner_frequency:= @corner_frequency) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
TORQUE_IN	Torque entrance	Rotational
TORQUE_OUT	Torque exit	Rotational

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
moment_inertia	Moment of inertia of the sensing element	Real	0 [kg m ²]
corner_frequency	Corner frequency of the torque input signal	Real	0 [Hz]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type

MEAS	Torque as a real number	Output	real

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Example

In this example, the Torque Sensing (Displacement-Force) building block TORQUE_DF_I21 measures the torque applied to Mass MASS_ROT B1, and output the value of the torque as a real value. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.



Figure 2. Application example of the Torque Sensing (Displacement-Force) building block

Table 4

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROT B1	AMPL	1 [rad/s]
	FREQ	50 [Hz]
	PHASE	0 [degree]
	OFF	0 [rad/s]
	TDELAY	0 [s]
Mass MASS_ROT B1	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Torque Sensing (Displacement-Force) building block TORQUE_DF_I21	moment_inertia	0 [kg m ²]

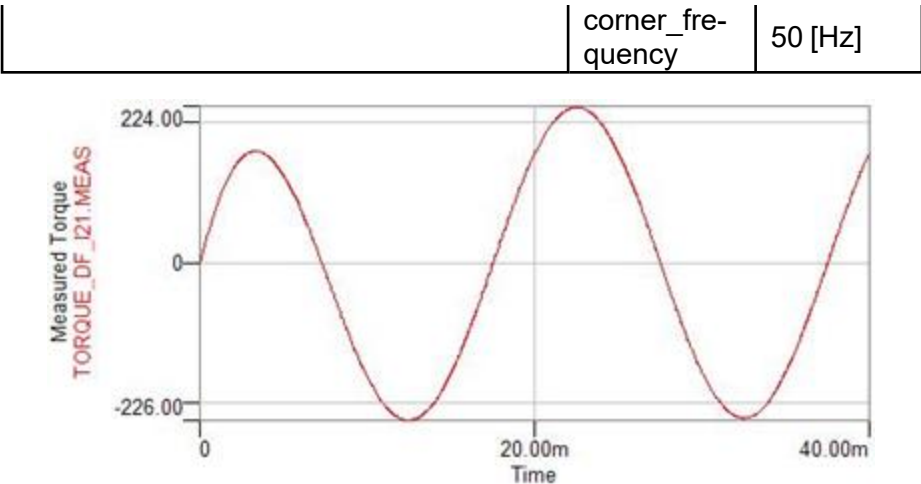


Figure 3. Simulation results-measured torque of TORQUE_DF_I21

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References

Level 2 Torque Sensing (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

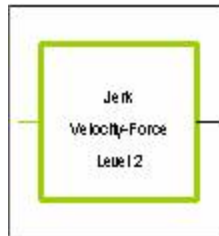


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Description

The Level 2 Torque Sensing (Velocity-Force) building block is for measuring torque through a branch of a rotational_v network and passing the value of the torque as a real value. Torque passes in and out of the block through conservative rotational_v nature pins. The output from the block is a nonconservative output pin.

The Level 2 Torque measuring block also models the moment of inertia and the frequency response of the torque-sensing element. Parameters for the moment of inertia of the torque sensing element and the corner frequency of the torque input signal can be entered into the block through nonconservative input nodes.

A value of zero entered for the corner frequency parameter indicates that the torque measuring process has no frequency response and that torque will be measured at its full value at all frequencies.

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Mathematical Description

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Netlist Syntax

```
MODEL TORQUE_VF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) TORQUE_
IN:= %0, TORQUE_OUT:= %1 ( moment_inertia:= @moment_inertia, corner_frequency:=
@corner_frequency) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
TORQUE_IN	Torque entrance	Rotational_V
TORQUE_OUT	Torque exit	Rotational_V

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
moment_inertia	Moment of inertia of the sensing element	Real	0 [kg m ²]
corner_frequency	Corner frequency of the torque input signal	Real	0 [Hz]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type

MEAS	Torque as a real number	Output	real

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Example

In this example, the Torque Sensing (Velocity-Force) building block TORQUE_VF_I21 measures the torque applied to Mass MASS_ROT1, and output the value of the torque as a real value. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

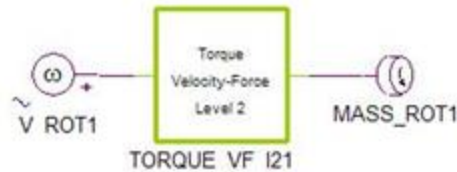


Figure 2. Application example of the Torque Sensing (Velocity-Force) building block

Table 4

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROT1	AMPL	1 [rad/s]
	FREQ	50 [Hz]
	PHASE	0 [degree]
	OFF	0 [rad/s]
	TDELAY	0 [s]
Mass MASS_ROT1	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Torque Sensing (Velocity-Force) building block TORQUE_VF_I21	moment_inertia	0 [kg m ²]

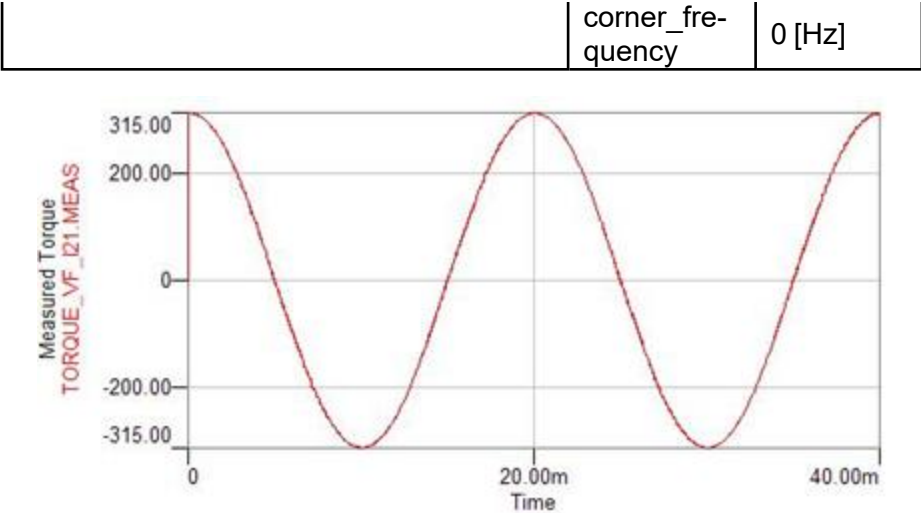


Figure 3. Simulation results-measured torque of TORQUE_VF_I21

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References

Level 2 Translational Acceleration (Displacement-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

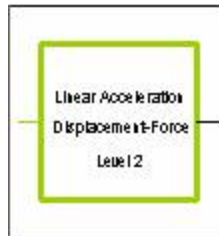


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Description

The Level 2 Translational Acceleration (Displacement-Force) building block is for measuring linear acceleration, the second time derivative of the position at a node in a Translational network, and passing the value of the linear acceleration as a real value. The input to the block is through a conservative translational nature pin. The output from the block is a nonconservative output pin.

The Level 2 Translational Acceleration block also allows a parameter for the corner frequency of the translational acceleration input signal to be entered through a nonconservative node. Note that a value of zero entered for the corner frequency parameter indicates that there is no corner frequency for the input signal and that it will be measured at its full value at any frequency.

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Mathematical Description

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Netlist Syntax

MODEL TRANS_ACC_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) POS:= %0 (
corner_frequency:= @corner_frequency) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POS	Connection to translational network	Translational

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
corner_fre- quency	Corner frequency of the accel- eration input signal	Real	0 [Hz]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
MEAS	Linear acceleration as a real number	Output	real

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Example

In this example, the Translational Acceleration (Displacement-Force) building block TRANS_ACC_I21 measures linear acceleration of the Mass MASS_TRB1, and output the value of the linear acceleration as a real value. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

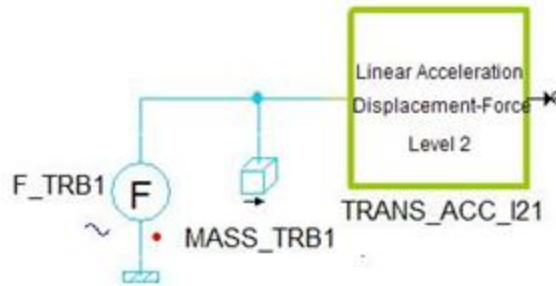


Figure 2. Application example of the Translational Acceleration (Displacement-Force) building block

Table 4

Component	Parameter	Value [Unit]
Force Source F_TRB1	AMPL	10 [N]
	FREQ	50 [Hz]
	PHASE	0 [degree]
	OFF	0 [N]
	TDELAY	0 [s]
Mass MASS_TRB1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Translational Acceleration (Displacement-Force) building block TRANS_ACC_I21	corner_frequency	50 [Hz]

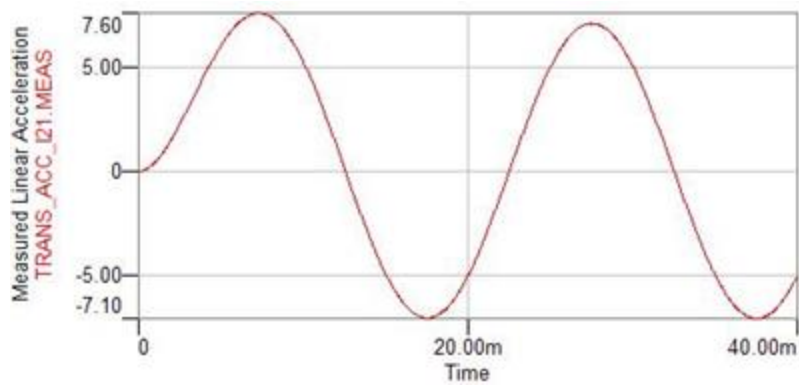


Figure 3. Simulation results-measured angular displament of TRANS_ACC_I21

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References

Level 2 Translational Acceleration (Velocity-Force)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

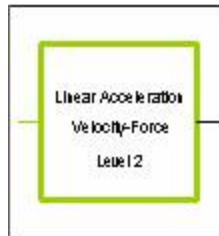


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Description

The Level 2 Translational Acceleration (Velocity-Force) building block is for measuring linear acceleration, the first time derivative of the position at a node in a translational_v network, and passing the value of the linear acceleration as a real value. The input to the block is through a conservative translational nature pin. The output from the block is a nonconservative output pin.

The Level 2 Translational Acceleration block also allows a parameter for the corner frequency of the translational acceleration input signal to be entered through a nonconservative node. Note that a value of zero entered for the corner frequency parameter indicates that there is no corner frequency for the input signal and that it will be measured at its full value at any frequency.

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Netlist Syntax

MODEL TRANS_ACC_V_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
VELOCITY:= %0 (corner_frequency:= @corner_frequency) SRC: DB(Lib:-
:=@ModelLibraryName);

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
VELOCITY	Connection to translational_v network	Translational_V

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
corner_frequency	Corner frequency of the acceleration input signal	Real	0 [Hz]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
MEAS	Linear acceleration as a real number	Output	real

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Example

In this example, the Translational Acceleration (Velocity-Force) building block TRANS_ACC_V_I21 measures linear acceleration of the Mass MASS_TR1, and output the value of the linear acceleration as a real value. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

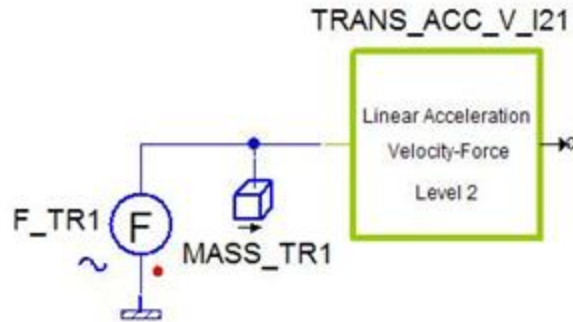


Figure 2. Application example of the Translational Acceleration (Velocity-Force) building block

Table 4

Component	Parameter	Value [Unit]
Force Source F_TR1	AMPL	10 [N]
	FREQ	50 [Hz]
	PHASE	0 [degree]
	OFF	0 [N]
	TDELAY	0 [s]
Mass MASS_TR1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Translational Acceleration (Velocity-Force) building block TRANS_ACC_V_I21	corner_frequency	50 [Hz]

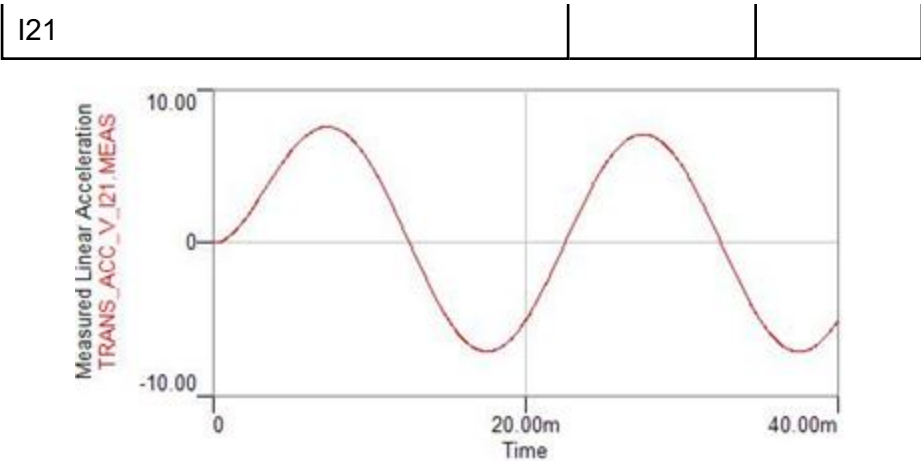


Figure 3. Simulation results-measured linear acceleration of TRANS_ACC_V_I21

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References

Level 2 Output Signal Blocks

The Level 2 Output Signal Blocks are the third and final blocks used in building non-ideal sensor models. They are used to translate nonconservative, real signals from processing blocks into electrical signals that can be used in the Twin Builder electrical circuit domain.

The Level 2 Output Signal Blocks can produce electrical signals by the following means:

- [Sinusoidal Voltage \(ac_os_I2\)](#)
- [Capacitance \(Cap_os_I2\)](#)
- [Current \(Current_os_I2\)](#)
- [Differential Capacitance \(Diff_cap_I2\)](#)
- [Voltage \(EMF_os_I2\)](#)
- [Inductance \(Ind_os_I2\)](#)
- [8-bit Binary Number \(pbyte_I2\)](#)
- [Potentiometer \(Potentiometer_I2\)](#)
- [Pulse Voltage \(pulse_os_I2\)](#)
- [Wheatstone Bridge \(RES_BRIDGE_I2\)](#)
- [Resistance \(Res_os_I2\)](#)

The output signal blocks have nonconservative input pins, through which signals from processing blocks are passed. These signals control the behavior of circuit elements which can be connected to elements in the Twin Builder electric circuit domain via conservative electrical nature pins.

Level 2 Sinusoidal Voltage Block

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

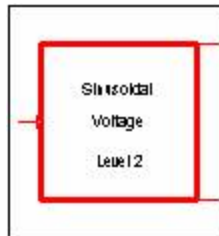


Figure 1. Component symbol

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Description

The Level 2 Voltage Block provides a sinusoidal voltage output signal whose amplitude is equal to the value that it receives through its nonconservative input. The block has two conservative electrical domain pins, one for its positive terminal, and one for its negative terminal. Note that the block itself contains no electrical ground and that its negative terminal must be grounded if it is not placed into an electrical network in which at least one node is connected to ground.

The phase, offset, and frequency of the sinusoidal voltage are parameters of the block that can be changed. In the Level 2 model, the source resistance of the sinusoidal voltage source can also be changed through a parameter.

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Mathematical Description

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Netlist Syntax

MODEL ac_os_l2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) out_plus:= %0, out_minus:= %1 (INPUT:= @INPUT, output_resistance:= @output_resistance, frequency:= @frequency, phase:= @phase, offset:= @offset) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
out_plus	Positive terminal	Electrical
out_minus	Negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
INPUT	Input from the processing block	Real	0
frequency	Frequency of the sinusoidal voltage	Real	60 [Hz]
phase	Phase shift of the sinusoidal voltage	Real	0 [rad]
offset	DC offset of the sinusoidal voltage	Real	0
output_resistance	Source resistance	Real	0 [Ohm]

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Example

In this example, the Pressure Source P1 is applied to two Linear Orifice – RHYD1 and RHYD2 in series. The Differential Pressure Sensing block PM_DIFF_I21 measures the pressure across RHYD2. The Output of PM_DIFF_I21 is clamped by a Clipped Linear function block CL_LINEAR_I21. The output of CL_LINEAR_I21 is used to decide the amplitude of the output voltage of the Sinusoidal Voltage Block ac_os_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

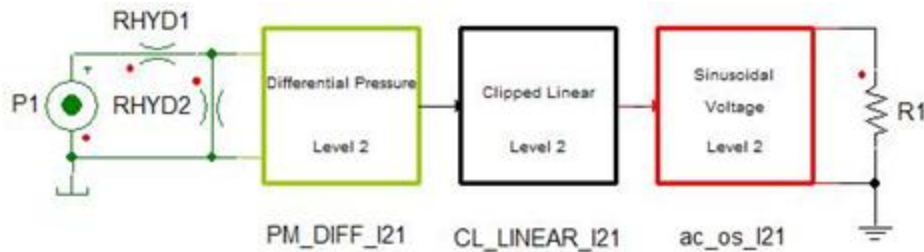


Figure 2. Application example of the Potentiometer block

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	$10k * (t/40m)$ [Pa]
Linear Orifice RHYD1/RHYD2	K	$1n$ [m ³ /(Pa s)]
Clipped Linear Function CL_LINEAR_I21	INPUT	PM_DIFF_I21.MEAS
	max_input	10k
	offset	0
	min_input	0
	full_scale_span	E1.EMF
	temp	27
	max_non-linearity	0

	hysteresis	0
	min_temp	-40
	max_temp	0.125k
	temp_hys- teresis	0
	tempco_span	0
	temp_sens_ offset	0
Differential Pressure block PM_DIFF_I21	Time_con- stant	0
Sinusoidal Voltage Block ac_ os_I21	INPUT	CL_LINEAR_ I21.OUTPUT
	frequency	60 [Hz]
	phase	0 [rad]
	offset	0
	output_res- istance	100 [Ohm]
Resistor R1	R	1k [Ohm]

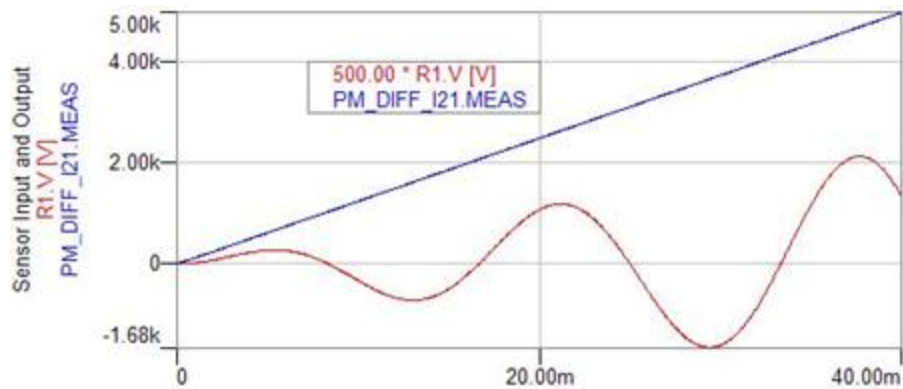


Figure 3. Simulation result-outputs of PM_DIFF_I21 and ac_os_I21 (scaled)

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References

Level 2 Capacitance Block

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

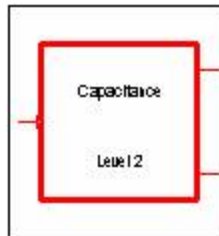


Figure 1. Component symbol

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Description

The Level 2 Capacitance Block provides a capacitance output signal that is equal to the value that it receives through its nonconservative input. The block has two conservative electrical domain pins, one for its positive terminal, and one for its negative terminal. The positive terminal is the terminal into which current flows.

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Mathematical Description

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Netlist Syntax

```
MODEL Cap_os_I2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) out_plus:= %0, out_minus:= %1 ( INPUT:= @INPUT) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
out_plus	Positive terminal	Electrical
out_minus	Negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
INPUT	Input from the processing block	Real	0

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Example

In this example, the Pressure Source P1 is applied to two Linear Orifice – RHYD1 and RHYD2 in series. The Differential Pressure Sensing block PM_DIFF_I21 measures the pressure across RHYD2. The Output of PM_DIFF_I21 is clamped by a Clipped Linear function block CL_LINEAR_I21. The output of CL_LINEAR_I21 is used to decide the capacitance of the Capacitance block Cap_os_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

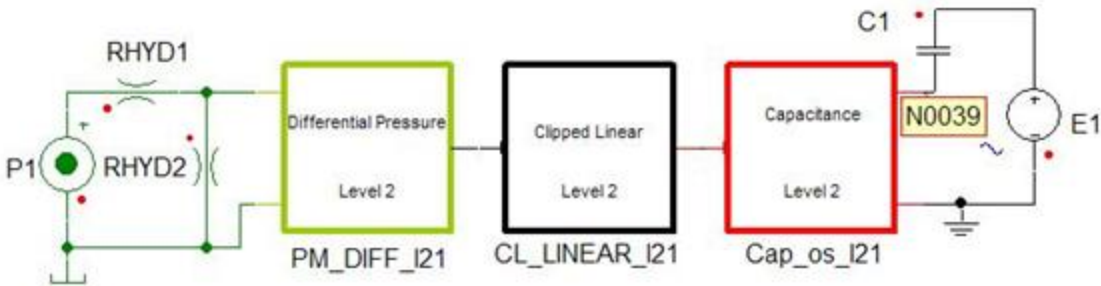


Figure 2. Application example of the Capacitance Block

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	20k * (t/40m) [Pa]
Linear Orifice RHYD1/RHYD2	K	1n [m ³ /(Pa s)]
Clipped Linear Function CL_LINEAR_I21	INPUT	PM_DIFF_I21.MEAS
	max_input	10k
	offset	500n
	min_input	0
	full_scale_span	500n
	temp	27
	max_non-linearity	0
	hysteresis	0
	min_temp	-40
	max_temp	0.125k
	temp_hysteresis	0
	tempco_span	0
	temp_sens_offset	0
Differential Pressure block PM_DIFF_I21	Time_constant	0
Capacitance Block Cap_os_I21	INPUT	CL_LINEAR_I21.OUTPUT

Inductor L1	L	1m [H]
Voltage (sinusoidal) E1	AMPL	5 [V]
	FREQ	50 [Hz]
	OFF	0 [V]
	PHASE	0 [degree]
	TDELAY	0 [s]

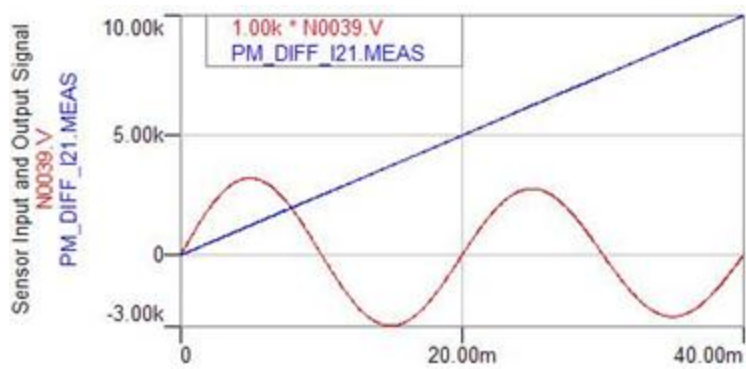


Figure 3. Simulation result-outputs of PM_DIFF_I21 and Cap_os_I21 (scaled)

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References

Current Block

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

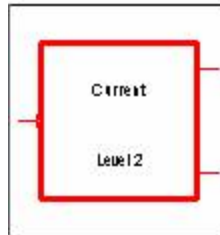


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Description

The Level 2 Current Block provides a current output signal that is equal to the value that it receives through its nonconservative input. The block has two conservative electrical domain pins, one for its positive terminal, and one for its negative terminal. The current flows out of the negative terminal of the block.

The Level 2 Current output signal block also models the source resistance of the current source within the block. The value of this resistance can be entered into the block as a parameter through a nonconservative input node.

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Netlist Syntax

MODEL Current_os_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) out_plus:= %0, out_minus:= %1 (INPUT:= @INPUT, output_resistance:= @output_resistance) SRC: DB(Lib:- :=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
out_plus	Positive terminal	Electrical
out_minus	Negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
INPUT	Input from the processing block	Real	0
output_resistance	Current source resistance	Real	0 [Ohm]

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Example

In this example, the Pressure Source P1 is applied to two Linear Orifice – RHYD1 and RHYD2 in series. The Differential Pressure Sensing block PM_DIFF_I21 measures the Pressure across RHYD2. The Output of PM_DIFF_I21 is clamped by a Clipped Linear function block CL_LINEAR_I21, and then converted to a current signal through the Current Block Current_os_I21. The output current is applied to a resistor. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

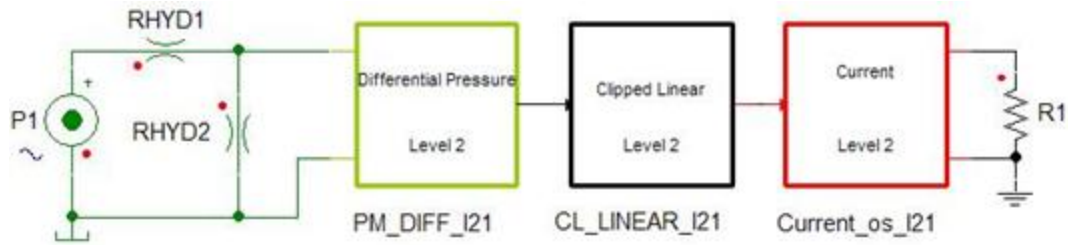


Figure 2. Application example of the Current Block

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	AMPL	40k [Pa]
	FREQ	50 [Hz]
	PHASE	0 [rad]
	OFF	0 [rad/s]
	TDELAY	0 [s]
Linear Orifice RHYD1/RHYD2	K	1n [m ³ /(Pa s)]
Clipped Linear Function CL_ LINEAR_I21	INPUT	PM_DIFF_ I21.MEAS
	max_input	10k
	offset	0
	min_input	0
	full_scale_ span	10
	temp	27
	max_non- linearity	0
	hysteresis	0
	min_temp	-40
	max_temp	0.125k
	temp_hys-	0

	teresis	
	tempco_span	0
	temp_sens_offset	0
Differential Pressure block PM_DIFF_I21	Time_constant	0
Current Block Current_os_I21	INPUT	CL_LINEAR_I21.OUTPUT
	output_resistance	100 [Ohms]
Resistor R1	R	1k [Ohm]

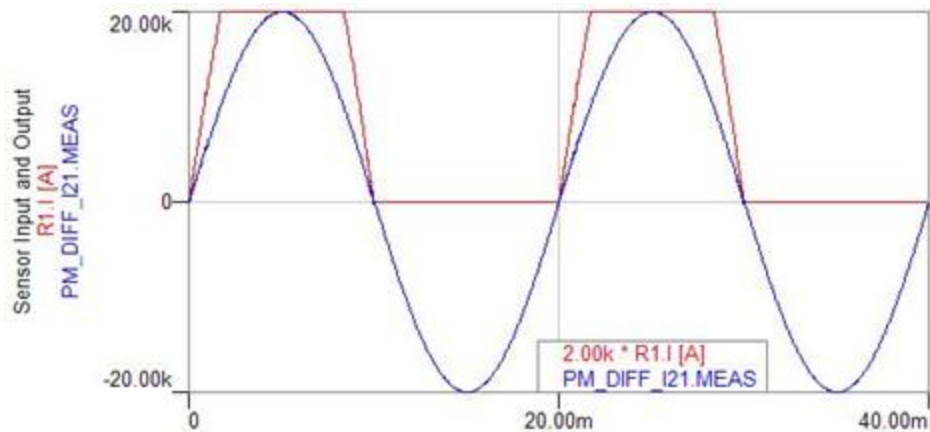


Figure 3. Simulation result-outputs of PM_DIFF_I21 and Current_os_I21

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References

Level 2 Differential Capacitance Block

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2



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Description

A differential capacitance output signal is provided by three capacitor plates that form two capacitors connected in series. The middle capacitor plate changes position when an input signal is applied and changes the ratio of the capacitance of one capacitor to the other. The varying capacitance can be used to provide sensor output such as a variable AC voltage signal.

The Level 2 Differential Capacitance Block consists of two capacitors with a total capacitance whose relative capacitances change according to the input signal received from a processing block. The total equivalent capacitance, which is the sum of the capacitances of the two capacitors, is a parameter of the block that can be changed. The Level 2 block also models the signal output resistance of the differential capacitor pair. The value of this resistance can be entered as a parameter via a nonconservative input node.

The block has three conservative electrical nature pins: a positive terminal, into which current flows, a negative terminal, and a third terminal between the two capacitors from which the output signal can be obtained.

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Netlist Syntax

```
MODEL Diff_cap_l2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) pos_input:= %0,
neg_input:= %1, signal:= %2 ( INPUT:= @INPUT, max_pct_change:= @max_pct_change,
total_capacitance:= @total_capacitance, max_input_magnitude:= @max_input_magnitude, out-
put_resistance:= @output_resistance, delay:= @delay) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
pos_input	Positive terminal	Electrical
neg_input	Negative terminal	Electrical
signal	Signal output	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
INPUT	Input from the processing block	Real	0
max_pct_change	Maximum percent change in the capacitance of one capacitor	Real	0
max_input_	Maximum magnitude of the	Real	0

magnitude	input from the processing block		
total_capacitance	Sum of the capacitances of the two capacitors	Real	0 [F]
output_resistance	Output resistance	Real	0 [Ohm]
delay	rise time from 10% to 90% in response to step input	Real	0 [s]

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Example

In this example, the Pressure Source P1 is applied to two Linear Orifice – RHYD1 and RHYD2 in series. The Differential Pressure Sensing block PM_DIFF_I21 measures the pressure across RHYD2. The Output of PM_DIFF_I21 is clamped by a Clipped Linear function block CL_LINEAR_I21. The output of CL_LINEAR_I21 is used to decide the equivalent capacitance of the Differential Capacitance block Diff_Cap_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

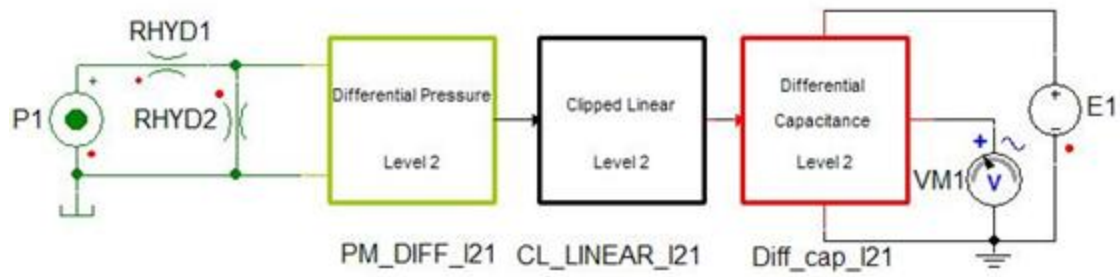


Figure 2. Application example of the Capacitance Block**Table 3**

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	20k * (t/40m) [Pa]
Linear Orifice RHYD1/RHYD2	K	1n [m ³ /(Pa s)]
Clipped Linear Function CL_LINEAR_I21	INPUT	PM_DIFF_I21.MEAS
	max_input	10k
	offset	500n
	min_input	0
	full_scale_span	500n
	temp	27
	max_non-linearity	0
	hysteresis	0
	min_temp	-40
	max_temp	0.125k
	temp_hysteresis	0
	tempco_span	0
	temp_sens_offset	0
Differential Pressure block	Time_constant	0

PM_DIFF_I21		
Differential Capacitance block Diff_Cap_I21	INPUT	CL_LINEAR_I21.OUTPUT
	max_pct_change	90
	max_input_magnitude	500n
	total_capacitance	1u [F]
	output_resistance	0 [Ohm]
	delay	100u [s]
Voltage (sinusoidal) E1	AMPL	5 [V]
	FREQ	50 [Hz]
	OFF	0 [V]
	PHASE	0 [degree]
	TDELAY	0 [s]

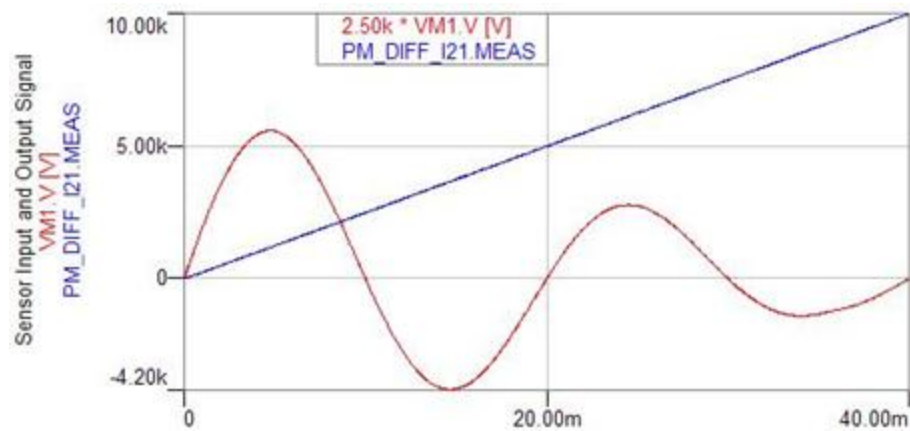


Figure 3. Simulation result-outputs of PM_DIFF_I21 and Diff_Cap_I21 (scaled)

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References

Voltage Block

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

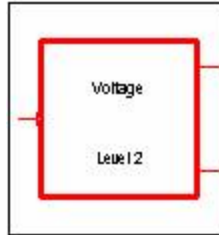


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Description

The Level 2 Voltage Block provides a voltage output signal that is equal to the value that it receives through its nonconservative input. The block has two conservative electrical domain pins, one for its positive terminal, and one for its negative terminal. The block itself contains no electrical ground, and its negative terminal must be grounded if it is not placed into an electrical network in which at least one node is connected to ground.

The Level 2 Voltage output signal block also models the source resistance of the voltage source within the block. The value of this resistance can be entered into the block as a parameter through a nonconservative input node.

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Mathematical Description

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Netlist Syntax

```
MODEL EMF_os_I2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) out_plus:= %0,
out_minus:= %1 ( INPUT:= @INPUT, output_resistance:= @output_resistance) SRC: DB(Lib:-
:=@ModelLibraryName);
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
out_plus	Positive terminal	Electrical
out_minus	Negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
INPUT	Input from the processing block	Real	0
output_resistance	Source resistance	Real	0 [Ohms]

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Example

In this example, the Pressure Source P1 is applied to two Linear Orifice – RHYD1 and RHYD2 in series. The Differential Pressure Sensing block PM_DIFF_I21 measures the Pressure across RHYD2. The Output of PM_DIFF_I21 is clamped by a Clipped Linear function block CL_LINEAR_I21, and then converted to a voltage signal through the Voltage Block EMF_os_I21. The output voltage is applied to a resistor. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

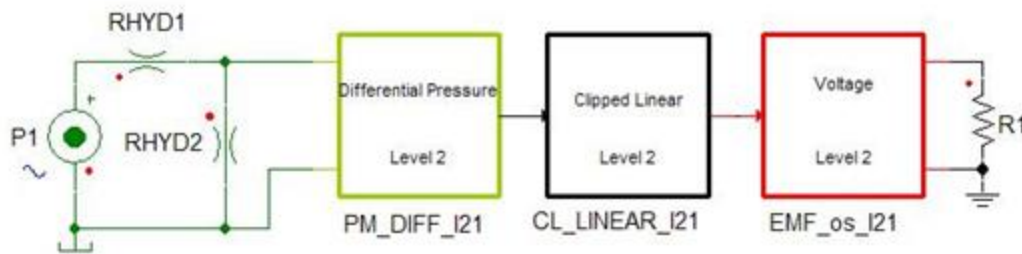


Figure 2. Application example of the Voltage Block

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	AMPL	40k [Pa]
	FREQ	50 [Hz]
	PHASE	0 [rad]
	OFF	0 [rad/s]
	TDELAY	0 [s]
Linear Orifice RHYD1/RHYD2	K	1n [m ³ /(Pa s)]
Clipped Linear Function CL_LINEAR_I21	INPUT	PM_DIFF_I21.MEAS
	max_input	10k
	offset	0
	min_input	0
	full_scale_span	10
	temp	27
	max_non-linearity	0

	hysteresis	0
	min_temp	-40
	max_temp	0.125k
	temp_hys- teresis	0
	tempco_span	0
	temp_sens_ offset	0
Differential Pressure block PM_DIFF_I21	Time_con- stant	0
Voltage Block EMF_os_I21	INPUT	CL_LINEAR_ I21.OUTPUT
	output_res- istance	100 [Ohms]
Resistor R1	R	1k [Ohm]

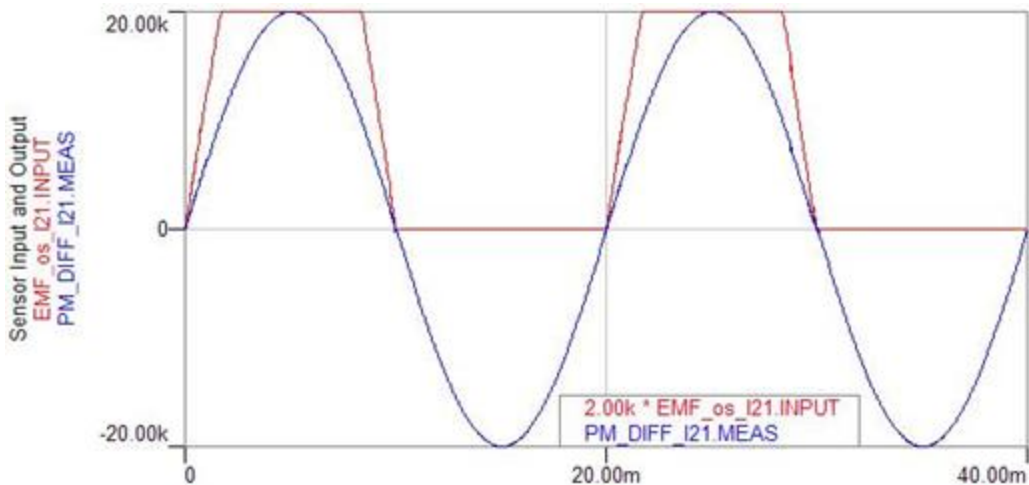


Figure 3. Simulation result-outputs of PM_DIFF_I21 and EMF_os_I21

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References

Level 2 Inductance Block

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

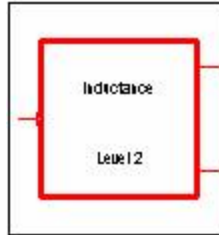


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Description

The Level 2 Inductance Block provides an inductance output signal that is equal to the value that it receives through its nonconservative input. The block has two conservative electrical domain pins, one for its positive terminal, and one for its negative terminal. The positive terminal is the terminal into which current flows.

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Netlist Syntax

```
MODEL Ind_os_I2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) out_plus:= %0, out_minus:= %1 ( INPUT:= @INPUT) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
out_plus	Positive terminal	Electrical
out_minus	Negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
INPUT	Input from the processing block	Real	0

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Example

In this example, the Pressure Source P1 is applied to two Linear Orifice – RHYD1 and RHYD2 in series. The Differential Pressure Sensing block PM_DIFF_I21 measures the pressure across RHYD2. The Output of PM_DIFF_I21 is clamped by a Clipped Linear function block CL_LINEAR_I21. The output of CL_LINEAR_I21 is used to decide the inductance of the Inductance block Ind_os_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

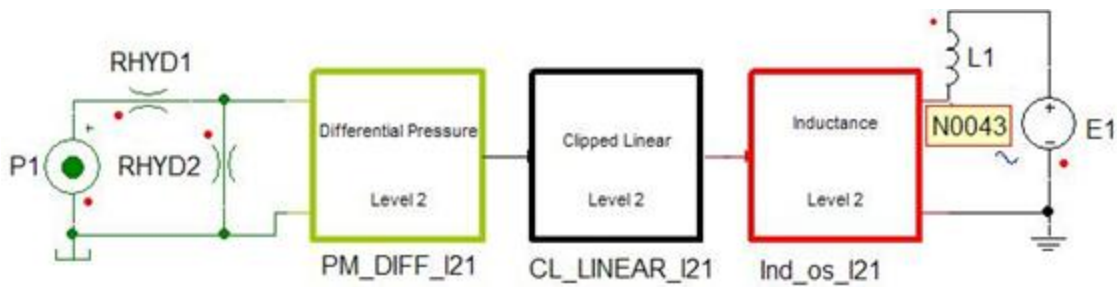


Figure 2. Application example of the Current Block

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	20k * (t/40m) [Pa]
Linear Orifice RHYD1/RHYD2	K	1n [m ³ /(Pa s)]
Clipped Linear Function CL_LINEAR_I21	INPUT	PM_DIFF_I21.MEAS
	max_input	10k
	offset	500u
	min_input	0
	full_scale_span	500u
	temp	27
	max_non-linearity	0
	hysteresis	0
	min_temp	-40
	max_temp	0.125k
	temp_hysteresis	0
	tempco_span	0
	temp_sens_offset	0
Differential Pressure block PM_DIFF_I21	Time_constant	0
Inductance Block Ind_os_I21	INPUT	CL_LINEAR_I21.OUTPUT

Inductor L1	L	1m [H]
Voltage (sinusoidal) E1	AMPL	5 [V]
	FREQ	50 [Hz]
	OFF	0 [V]
	PHASE	0 [degree]
	TDELAY	0 [s]

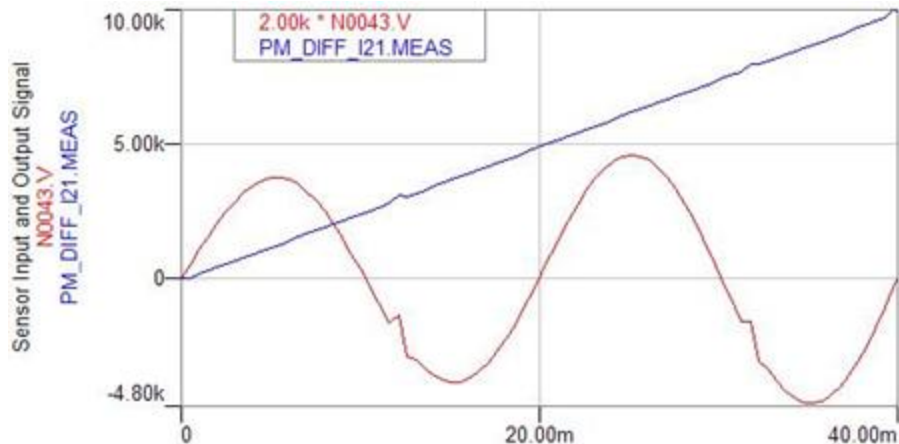


Figure 3. Simulation result-outputs of PM_DIFF_I21 and Ind_os_I21 (scaled)

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References

Level 2 8-bit Binary Number Block

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

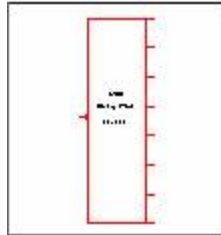


Figure 1. Component symbol

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Description

The Level 2 8-bit Binary Number output signal block is useful for modeling sensors with natural binary output. The block takes a decimal input through its nonconservative input pin, converts this decimal value to a binary number, and then sets or clears its output bits accordingly when the output enable signal is greater than the specified threshold voltage. The output bits are modeled by voltage sources, each of which has a single conservative electrical domain pin for its output.

Parameters that may be passed to the block through nonconservative input nodes include the following:

- the bit-set and bit-cleared output signal amplitudes
- the output enable threshold value
- the time lapse between the rise of the enable signal and the change of the binary output
- the output resistance at each output pin
- the reference value for the decimal-to-binary conversion.

The block also features two nonconservative nodes that allow it to be connected to other 8-bit Binary number output blocks in order to create binary numbers larger than eight bits. These are the `LSB_position` parameter which is used to indicate the power of two associated with the LSB output of the block, and the `mod_decimal` output, which is connected to the input pin of another 8-bit Binary Number block when more than one of these blocks is connected together. The illustration below shows how this connection should be made.

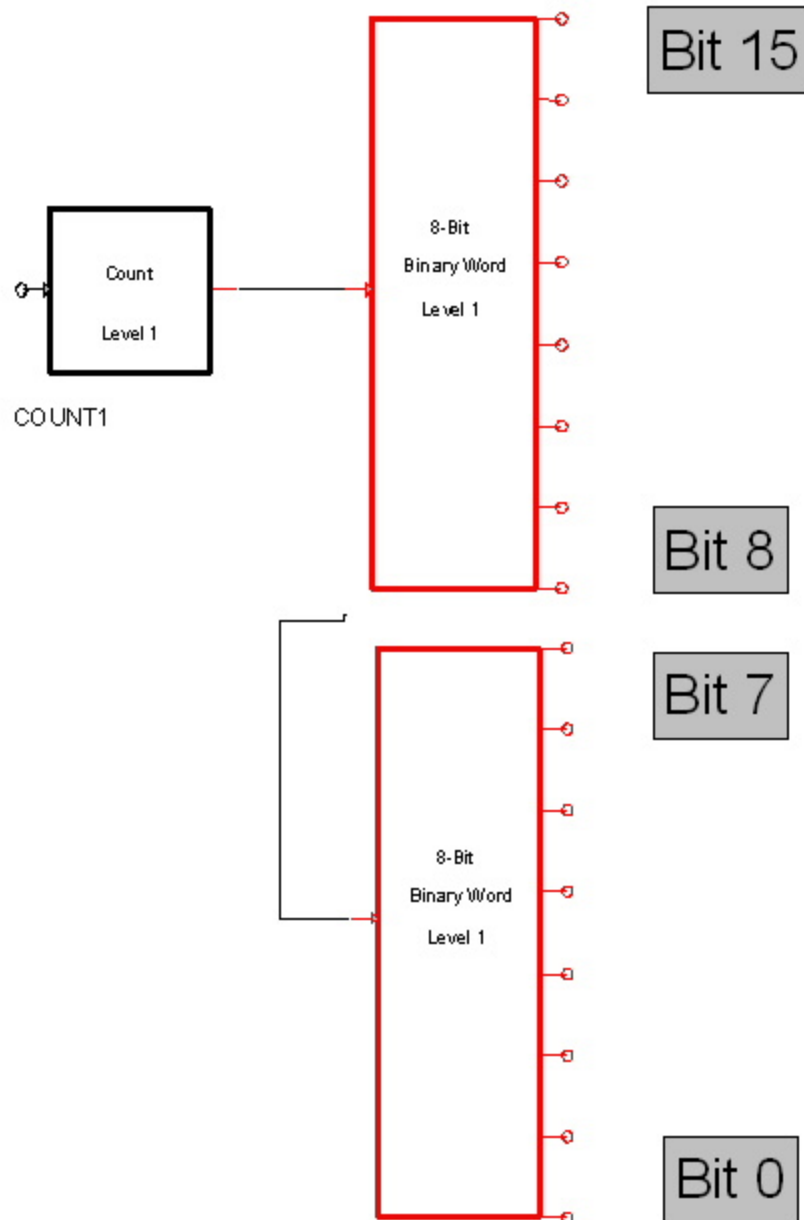


Figure 2. Connection of two 8-bit Binary Number Blocks to creat a 16-bit output

In this illustration, two 8-bit Binary Number blocks are connected to form a 16-bit output. The upper block is used to implement bits 8 through 15. Therefore, its input pin should be connected to a processing block and its LSB_position parameter is set to 8.

The lower block is used to implement bits 0 through 7. Its input pin is connected to the mod_decimal pin of the upper block, and its LSB_position parameter is set to 0.

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Mathematical Description

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Netlist Syntax

```
MODEL pbyte_l2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) bit0:= %0, bit1:= %1,
bit2:= %2, bit3:= %3, bit4:= %4, bit5:= %5, bit6:= %6, bit7:= %7, latch_enable:= %8 ( INPUT:=
@INPUT, one_amplitude:= @one_amplitude, zero_amplitude:= @zero_amplitude, latch_
threshold:= @latch_threshold, output_resistance:= @output_resistance, reaction_time:= @re-
action_time, LSB_position:= @LSB_position) SRC: DB(Lib:=@ModelLibraryName);
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
bit0 (See Note)	Least-significant output bit	Electrical
bit1 (See Note)	Bit 1	Electrical
bit2 (See Note)	Bit 2	Electrical
bit3 (See Note)	Bit 3	Electrical
bit4 (See Note)	Bit 4	Electrical
bit5 (See Note)	Bit 5	Electrical
bit6 (See Note)	Bit 6	Electrical

bit7 (See Note)	Most-significant output bit	Electrical
latch_enable	Output enable input pin	Electrical

Note: Terminal set to No Action when unconnected. Terminal may remain unconnected without generating an error.

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
INPUT	Input from the processing block	Real	0
one_amplitude	Bit-set amplitude	Real	5 [V]
zero_amplitude	Bit-cleared amplitude	Real	0 [V]
LSB_position	Power of two represented by the least-significant bit	Real	0
Latch_threshold	Threshold voltage for output enable	Real	2.5 [V]
output_resistance	Output resistance for each bit channel	Real	0 [Ohm]
reaction_time	Time lapse between the rise of the enable signal and the change in the binary output	Real	0 [s]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data

			Type
mod_ decimal	Remainder from the decimal-to-binary conversion to be passed to the cascaded block	Input	real

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Example

In this example, the pressure of a linear Pressure Source P1 is measured by an Absolute Pressure measurement block PMabs_I21. The output of PMabs1 is sent to a counter COUNT_I21, which transforms the continuous output of PMabs1 into discrete numbers. The output of COUNT1 is then sent to an 8-Bit Binary Number block pbyte_I22. The schematic of the system is shown in Figure 3, system parameters are listed in Table 3, and the simulation results are shown in Figure 4-7.

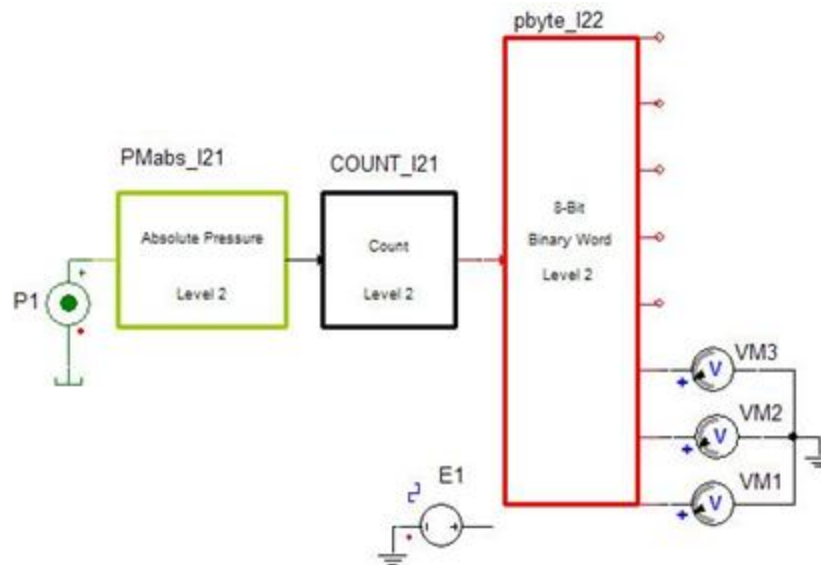


Figure 3. Application example of the 8-Bit Bloinary Numer block

Table 4

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	$75 * (t/45m)$ [Pa]
Absolute Pressure measurement block PMabs_I21	time_constant	0 [s]
Counter COUNT_I21	INPUT	PMabs1.MEAS

	INCREMENT_SIZE	15
	OFFSET	0
	error	0
8-bit Binary Number block pbyte_I22	INPUT	COUNT1.OUTPUT
	one_amplitude	5 [V]
	zero_amplitude	0 [V]
	LSB_position	0
	Latch_threshold	2.5 [V]
	output_resistance	0 [Ohm]
	reaction_time	100u [s]

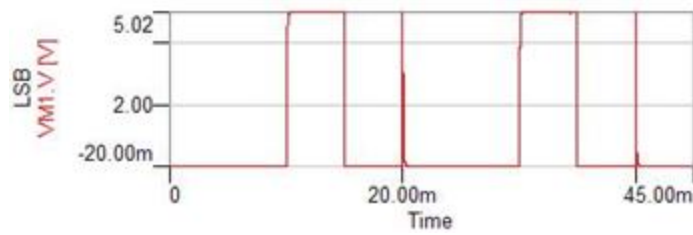


Figure 4. Simulation result-least-significant bit output of pbyte_I22

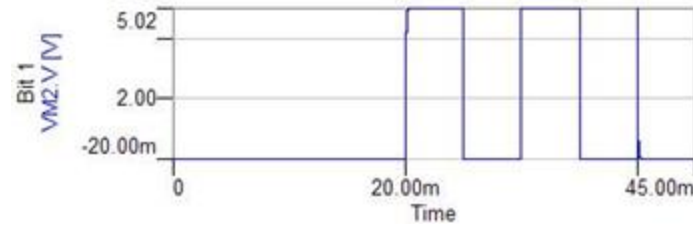


Figure 5. Simulation result- bit1 output of pbyte_I22

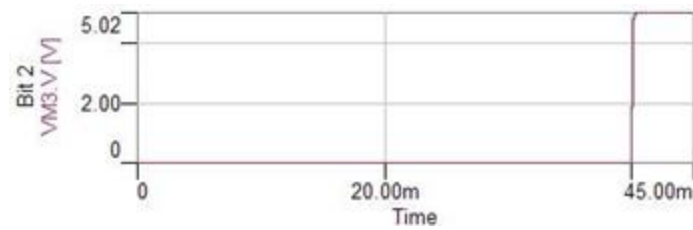


Figure 6. Simulation result- bit2 output of pbyte_I22

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References

Level 2 Potentiometer Block

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

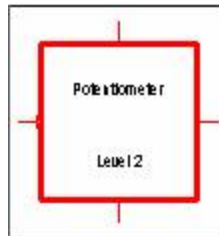


Figure 1. Component symbol

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Description

A Potentiometer output signal is provided by a three-terminal variable resistance element. Two of the device's pins are connected to the potentiometer's power supplies. The third pin is connected to the wiper of the potentiometer and can be used to provide the voltage divider output signal that is established by the potentiometer.

The Level 2 Potentiometer block provides a voltage divider output signal that varies when a power supply voltage and an input signal are applied. The block has three conservative electrical nature pins, positive and negative power supply pins, and a pin from which the potentiometer's output signal can be obtained. The positive power supply terminal is the terminal into which the supply current should flow.

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Mathematical Description

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Netlist Syntax

MODEL Potentiometer_I2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) in_1:= %0, In_2:= %1, Out_1:= %2 (INPUT:= @INPUT, wiper_resistance:= @wiper_resistance, equivalent_resistance:= @equivalent_resistance) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
in_1	Positive power supply terminal	Electrical
in_2	Negative power supply terminal	Electrical
out_1	Output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
INPUT	Input from the processing block	Real	0
equivalent_resistance	Potentiometer resistance	Real	10k [Ohm]
wiper_resistance	Potentiometer wiper resistance	Real	0 [Ohm]

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Example

In this example, the Pressure Source P1 is applied to two Linear Orifice – RHYD1 and RHYD2 in series. The Differential Pressure Sensing block PM_DIFF_I21 measures the pressure across RHYD2. The Output of PM_DIFF_I21 is clamped by a Clipped Linear function block CL_LINEAR_I21. The output of CL_LINEAR_I21 is used to decide the output voltage of the

Potentiometer block Potentiometer_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

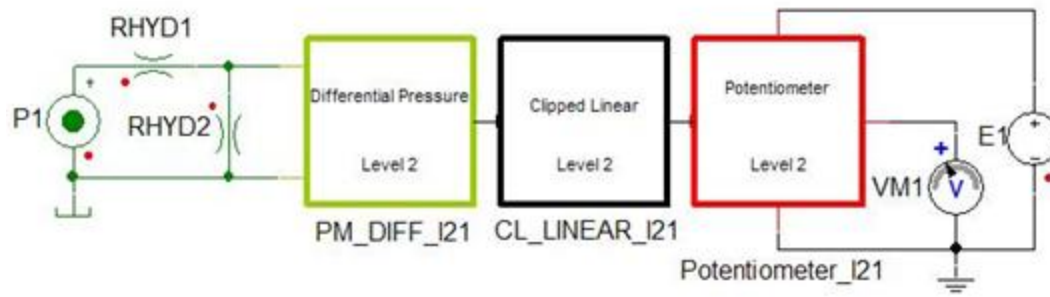


Figure 2. Application example of the Potentiometer block**Table 3**

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	20k * (t/40m) [Pa]
Linear Orifice RHYD1/RHYD2	K	1n [m ³ /(Pa s)]
Clipped Linear Function CL_ LINEAR_I21	INPUT	PM_DIFF_ I21.MEAS
	max_input	10k
	offset	0
	min_input	0
	full_scale_span	E1.EMF
	temp	27
	max_non- linearity	0
	hysteresis	0
	min_temp	-40
	max_temp	0.125k
	temp_hys- teresis	0
	tempco_span	0
	temp_sens_off- set	0
Differential Pressure block PM_DIFF_I21	Time_constant	0

Potentiometer block Potentiometer_I21	INPUT	CL_LINEAR_I21.OUTPUT
	equivalent_resistance	10k [Ohm]
	wiper_resistance	0 [Ohm]
Voltage E1	EMF	10 [V]

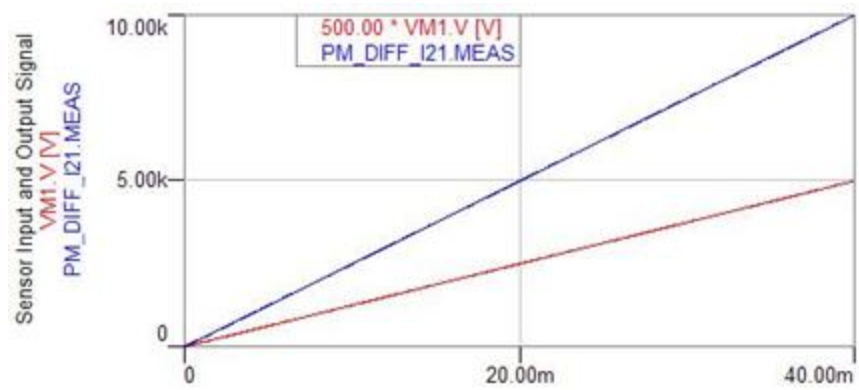


Figure 3. Simulation result-outputs of PM_DIFF_I21 and Potentiometer_I21 (scaled)

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References

Level 2 Pulse Voltage Block

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

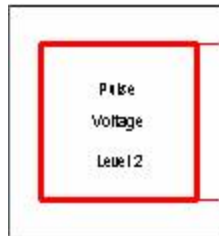


Figure 1. Component symbol

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Description

The Level 2 Pulse Voltage Block provides a pulse voltage output signal whose amplitude, phase shift, offset, or frequency can be made equal to a value that is received through a non-conservative input. The block has two conservative electrical domain pins, one for its positive terminal, and one for its negative terminal. Note that the block itself contains no electrical ground and that its negative terminal must be grounded if it is not placed into an electrical network in which at least one node is connected to ground.

The amplitude, phase, offset, and frequency of the pulse voltage are parameters of the block that can be changed. The Level 2 model also features parameters for the rise time of the pulse output signal and for the output resistance of the pulse voltage source.

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Netlist Syntax

MODEL pulse_os_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) OUT_P:= %0,
OUT_M:= %1 (amplitude:= @amplitude, frequency:= @frequency, phase:= @phase, offset:=
@offset, output_resistance:= @output_resistance, delay:= @delay) SRC: DB(Lib:-
:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
OUT_P	Positive terminal	Electrical
OUT_M	Negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
amplitude	Amplitude of the pulse voltage	Real	5 [V]
frequency	Frequency of the pulse voltage	Real	1k [Hz]
phase	Phase shift of the pulse voltage	Real	0 [rad]
offset	DC offset of the pulse voltage	Real	0
output_resistance	Source resistance	Real	0 [Ohm]
delay	Pulse signal rise time	Real	0 [s]

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Example

In this example, the sinusoidal Pressure Source P1 is applied to two Linear Orifice – RHYD1 and RHYD2 in series. The Differential Pressure Sensing block PM_DIFF_I21 measures the pressure across RHYD2. The Output of PM_DIFF_I21 is clamped by a Clipped Linear function block CL_LINEAR_I21. The output of CL_LINEAR_I21 is used to decide the amplitude of the output voltage of the Pulse Voltage Block pulse_os_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

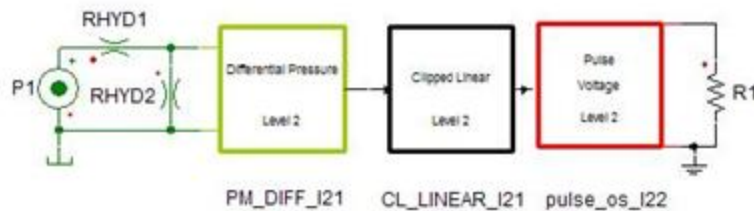


Figure 2. Application example of the Potentiometer block

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	$10k * (t/40m)$ [Pa]
Linear Orifice RHYD1/RHYD2	K	$1n$ [$m^3/(Pa \cdot s)$]
Clipped Linear Function CL_LINEAR_I21	INPUT	PM_DIFF_I21.MEAS
	max_input	10k
	offset	0
	min_input	0
	full_scale_span	E1.EMF
	temp	27
	max_non-linearity	0
	hysteresis	0

	min_temp	-40
	max_temp	0.125k
	temp_hys- teresis	0
	tempco_span	0
	temp_sens_ offset	0
Differential Pressure block PM_DIFF_I21	Time_con- stant	0
Pulse Voltage Block pulse_ os_I21	INPUT	CL_LINEAR_ I21.OUTPUT
	frequency	60 [Hz]
	phase	0 [rad]
	offset	0
	output_res- istance	100 [Ohm]
	delay	0 [s]
Resistor R1	R	1k [Ohm]

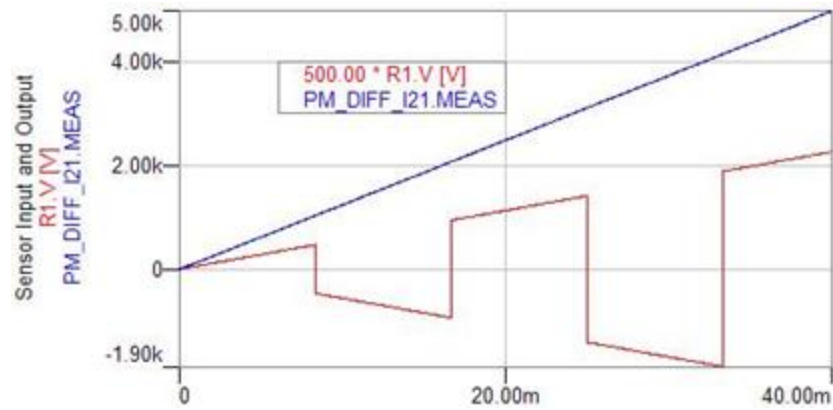


Figure 3. Simulation result-outputs of PM_DIFF_I21 and pulse_os_I21 (scaled)

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References

Level 2 Wheatstone Bridge Block

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

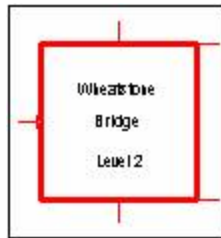
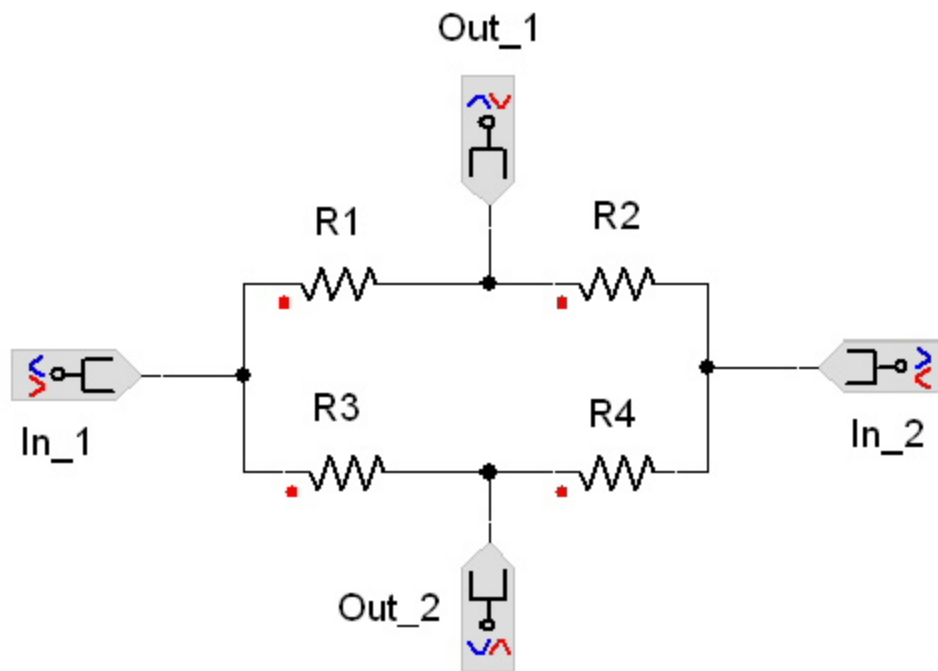


Figure 1. Component symbol

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Description

A Wheatstone bridge output signal is provided by four resistors connected in a bridge configuration as shown here:



When an input signal is applied to the bridge, the resistors R1 and R4 change by an equal amount. The resistors R2 and R3 change by an amount that is equal in magnitude to the change in R1 and R4, but opposite in sign. This provides a linear differential voltage signal across the pins Out_1 and Out_2.

The block has four conservative electrical nature pins: a positive and negative input terminal, and a positive and negative output terminal. The positive input terminal is the terminal into which the bridge's supply current should flow. The positive output terminal is the terminal at which the voltage will become positive when a positive input signal is applied.

The nominal equivalent resistance of the resistor bridge, the temperature at which the bridge has its nominal resistance, and the temperature coefficient of the bridge resistors are parameters of the block that can be changed.

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Netlist Syntax

```
MODEL RES_BRIDGE_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) in_1:= %0,  
In_2:= %1, Out_1:= %2, Out_2:= %3 ( INPUT:= @INPUT, max_pct_change:= @max_pct_  
change, max_input_magnitude:= @max_input_magnitude, equivalent_resistance:= @equi-
```

valent_resistance, resistor_tempco:= @resistor_tempco, nominal_res_temp:= @nominal_res_temp, temp:= @temp) SRC: DB(Lib:=@ModelLibraryName);

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
In_1	Positive input terminal	Electrical
In_2	Negative input terminal	Electrical
Out_1	Positive output terminal	Electrical
Out_2	Negative output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
INPUT	Input from processing block	Real	0
max_pct_change	Maximum percent change in the capacitance of one resistor	Real	90
max_input_magnitude	Maximum magnitude of input from processing block	Real	0
equivalent_resistance	Equivalent resistance of the bridge	Real	50k [Ohm]
resistor_tem_pco	Temperature coefficient of bridge resistors	Real	0 [Ohm/ °C]
nominal_res_temp	Temperature at which bridge has its nominal resistance	Real	25 [°C]
temp	Bridge temperature	Real	25 [°C]

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Example

In this example, the Pressure Source P1 is applied to two Linear Orifice – RHYD1 and RHYD2 in series. The Differential Pressure Sensing block PM_DIFF_I21 measures the pressure across RHYD2. The Output of PM_DIFF_I21 is clamped by a Clipped Linear function block CL_LINEAR_I21. The output of CL_LINEAR_I21 is used to decide the resistance change in the four resistors of the Wheatstone Bridge block RES_BRIDGE_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

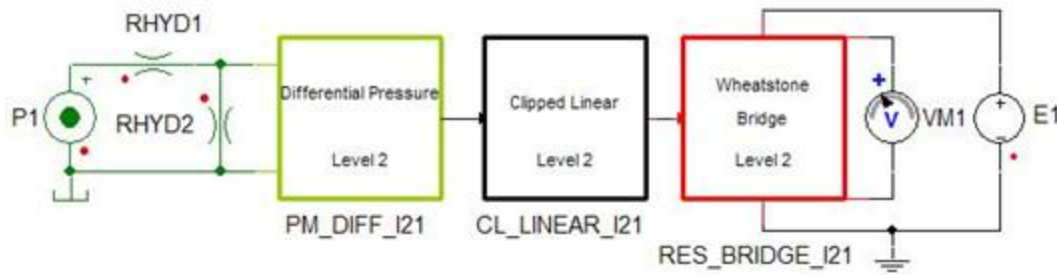


Figure 2. Application example of the Wheatstone Bridge block

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	$20k * (t/40m)$ [Pa]
Linear Orifice RHYD1/RHYD2	K	$1n$ [$m^3/(Pa \cdot s)$]
Clipped Linear Function CL_LINEAR_I21	INPUT	PM_DIFF_I21.MEAS
	max_input	10k
	offset	500n
	min_input	0
	full_scale_span	500n
	temp	27
	max_non-linearity	0
	hysteresis	0
	min_temp	-40
	max_temp	0.125k

	temp_hys- teresis	0
	tempco_span	0
	temp_sens_off- set	0
Differential Pressure block PM_DIFF_I21	Time_constant	0
Wheatstone Bridge block RES_BRIDGE_I21	INPUT	CL_LINEAR_ I21.OUTPUT
	max_pct_ change	100
	max_input_ magnitude	E1.EMF
	equivalent_res- istance	10k [Ohm]
	resistor_tem- pco	0 [Ohm/°C]
	nominal_res_ temp	25 [°C]
	temp	THETA*
Voltage E1	EMF	10 [V]

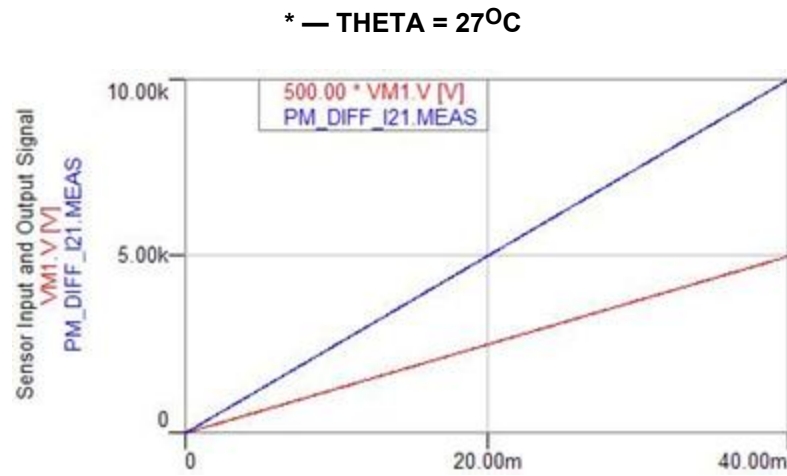


Figure 3. Simulation result-outputs of PM_DIFF_I21 and RES_BRIDGE_I21 (scaled)

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References

Level 2 Resistance Block

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

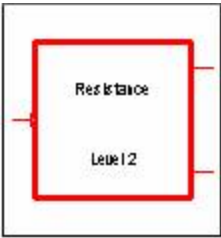


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Description

The Level 2 Resistance Block provides a resistance output signal that is equal to the value that it receives through its nonconservative input. The block has two conservative electrical domain pins, one for its positive terminal, and one for its negative terminal. The positive terminal is the terminal into which current flows.

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Netlist Syntax

```
MODEL Res_os_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) out_plus:= %0, out_minus:= %1 ( INPUT:= @INPUT) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
out_plus	Positive terminal	Electrical
out_minus	Negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
INPUT	Input from the processing block	Real	0

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Example

In this example, the Pressure Source P1 is applied to two Linear Orifice – RHYD1 and RHYD2 in series. The Differential Pressure Sensing block PM_DIFF_I21 measures the Pressure across RHYD2. The Output of PM_DIFF_I21 is clamped by a Clipped Linear function block CL_LINEAR_I21. The output of CL_LINEAR_I21 is used to decide the resistance of Res_os_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

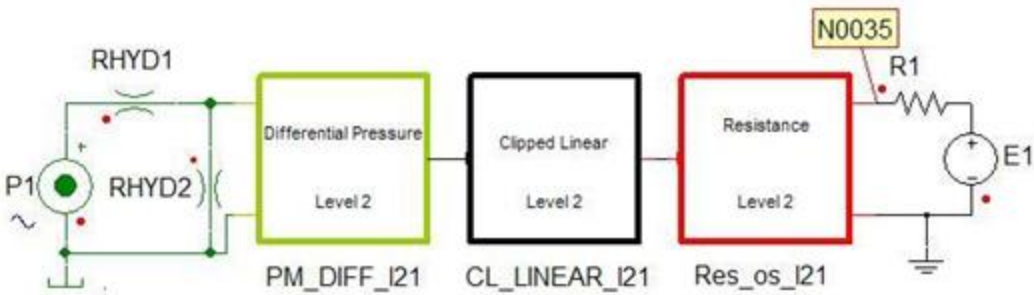


Figure 2. Application example of the Current Block

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	AMPL	40k [Pa]
	FREQ	50 [Hz]
	PHASE	0 [rad]
	OFF	0 [rad/s]
	TDELAY	0 [s]
Linear Orifice RHYD1/RHYD2	K	1n [m ³ /(Pa s)]
Clipped Linear Function CL_ LINEAR_I21	INPUT	PM_DIFF_ I21.MEAS
	max_input	10k
	offset	0
	min_input	0
	full_scale_ span	10
	temp	27
	max_non- linearity	0
	hysteresis	0
	min_temp	-40
	max_temp	0.125k
	temp_hys- teresis	0
	tempco_span	0

	temp_sens_offset	0
Differential Pressure block PM_DIFF_I21	Time_constant	0
Resistance Block Res_os_I21	INPUT	CL_LINEAR_I21.OUTPUT
Resistor R1	R	1k [Ohm]
Voltage E1	EMF	10 [V]

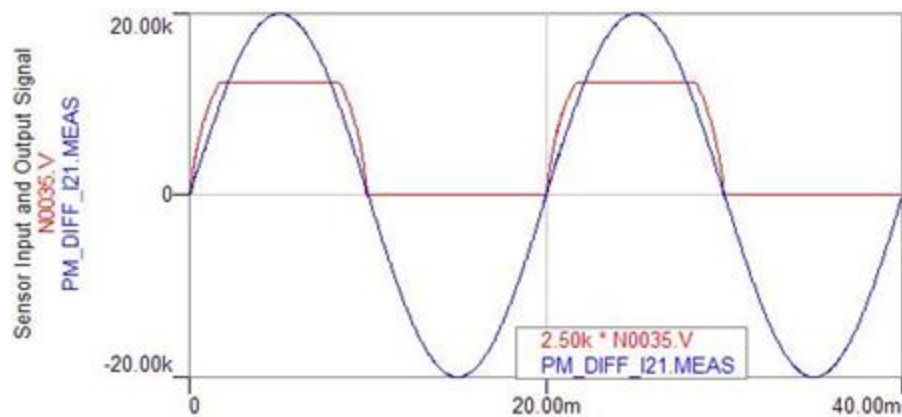


Figure 3. Simulation result-outputs of PM_DIFF_I21 and Res_os_I21

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References

Level 2 Processing Blocks

The Level 2 Processing Blocks contain functions and relations that process the real values that are passed out of measuring blocks. The output from a measuring block enters a processing block through its nonconservative input pin as the independent variable of the function or relation within the block. The block then calculates the value of its dependent variable and passes this value through its nonconservative output pin. The output pin of a processing block is then connected to an output signal block.

The Level 2 Processing Blocks provide the following two-variable functions and relations:

- Angular Incremental Encoding: A relation that returns two pulse signals in quadrature and a reference signal.

[Angular Incremental Encoder Channels \(ANG_ENCODER_CHAN_I2\)](#)

[Linear Incremental Encoder Channels \(LIN_ENCODER_CHAN_I2\)](#)

- [Clipped Linear Function \(CL_LINEAR_I2\)](#): A function that is linear within a specific region and is clipped to upper and lower limits outside that region. The Level 2 clipped linear function is also subject to nonlinear distortion.

- [Count \(COUNT_I2\)](#): An analog-to-digital conversion function that divides the independent variable by some reference value and returns the integer part of the quotient.

- Thermocouple direct polynomial: A power series that describes the voltage-temperature characteristics of thermocouples.

[Thermocouple Direct Polynomial \(J, T, E, N, B, R, S\) \(direct_thermoc_I2\)](#)

[Thermocouple Direct Polynomial \(K\) \(direct_thermoc_k_I2\)](#)

- [Nernst Voltage Equation \(NERNST_V_I2\)](#): A logarithmic function that calculates a voltage based on the ratio of a measured pressure and a reference pressure.

- [Oxygen-Dependent Resistance \(O2_R_EQ_I2\)](#)

- [Characteristic from File \(SENS_CHAR_I2\)](#): A user-defined function passed as a Twin Builder characteristic.

- [Steinhart-Hart Function \(SH_FUNCTION_I2\)](#): A decaying exponential function that describes the resistance-temperature characteristics of negative temperature coefficient thermistors.

- [Linear Function \(ST_LINEAR_I2\)](#): Three-dimensional linear function.

Level 2 Angular Incremental Encoder Channels

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

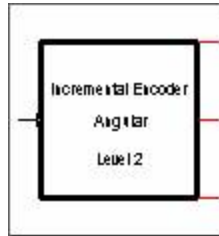


Figure 1. Component symbol

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Description

The Level 2 Angular Incremental Encoder Channels Block takes the input from an angular position sensing block and produces the three digital output channels of a typical incremental encoder sensor as its outputs. The first output, Channel A, goes to its logic 1 value each time the encoder's angle sensor moves past one of the equally-spaced position indicators on the device when the sensor is moving in a clockwise direction. Channel A remains at its logic one output until the encoder's angle sensor has traveled one-half the distance to the next position indicator. The second output of the encoder, Channel B, is similar to Channel A, but lags it by one-quarter cycle when the angle sensor is rotating in a clockwise direction. When the angle sensor is rotating in a counterclockwise direction, the outputs of Channels A and B are reversed.

The third output, Channel N, goes to its logic 1 value when the sensor detects the zero point of the sensor and remains high until the sensor has traveled one-quarter of the distance to the next sensing element.

The Level 2 angular encoder channels processing block features the same parameters that are available on the Level 1 block: the number of position indicators on the encoder, the zero position of the encoder, and the logic one and zero output amplitudes. In addition, the Level 2 model features a parameter for the percent measuring error of the device.

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Netlist Syntax

MODEL ANG_ENCODER_CHAN_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) (
INPUT:= @INPUT, num_lines:= @num_lines, north:= @north, oneamplitude:= @oneamplitude,
zeroamplitude:= @zeroamplitude, pct_error:= @pct_error) SRC: DB(Lib:-
:=@ModelLibraryName) ;

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Parameters

Table 1

Name	Description	Data Type	Default Value [Unit]
INPUT	Input from the measuring block	Real	0
num_lines	Number of position indicators on the encoder	Real	16
north	Zero position of the encoder	Real	0
oneamplitude	Amplitude of logic 1 signal	Real	5
zeroamplitude	Amplitude of logic 0 signal	Real	0
pct_error	Percent measuring error	Real	0

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
channel_A	Output of encoder channel A	Output	real
channel_B	Output of encoder channel B	Output	real
channel_N	Output of encoder channel N	Output	real

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Example

In this example, a Position Source S_ROT1 is applied to a Mass block MASS_ROT1. The displacement of MASS_ROT1 is measured by an Angular Displacement sensing block ANG_DIFF_SENS_I21, and the measurement result is output through an Angular Incremental Encoder ANG_ENCODER_CHAN_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3-6.

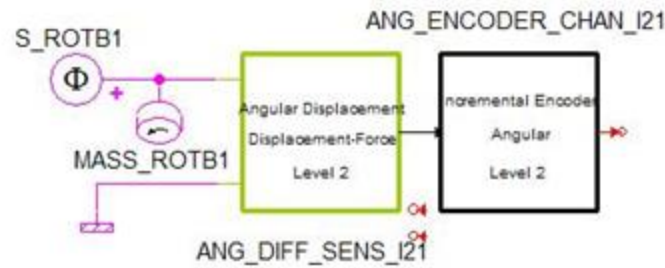


Figure 2. Application example of the Angular Incremental Encoder

Table 3

Component	Parameter	Value [Unit]
Angle Source S_ROT B1	VALUE	$(\pi/2) * (t/40m)$ [rad]
Mass Mass_ROT B1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Angular Displacement sensing block ANG_DIFF_SENS_I21	time_constant	0
Angular Incremental Encoder ANG_ENCODER_CHAN_I21	INPUT	ANG_DIFF_SENS_I21.MEAS
	num_lines	16
	north	0
	oneamplitude	5
	zeroamplitude	0
	pct_error	1

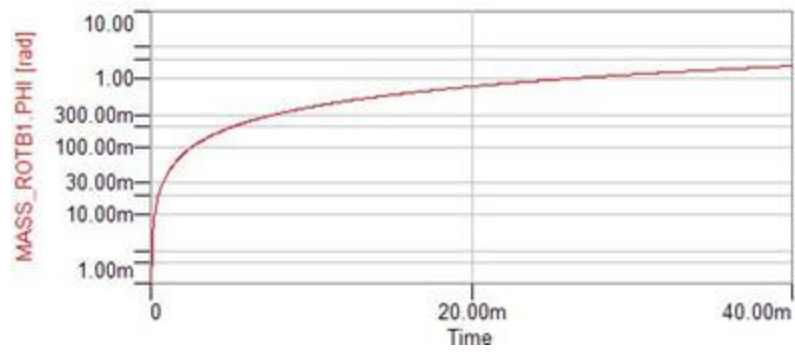


Figure 3. Simulation result-angular displacement of Mass_ROTB1

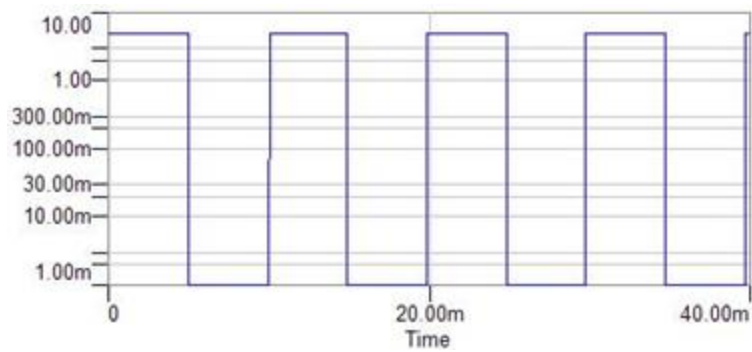


Figure 4. Simulation result-channel A output of ANG_ENCODER_CHAN_I21

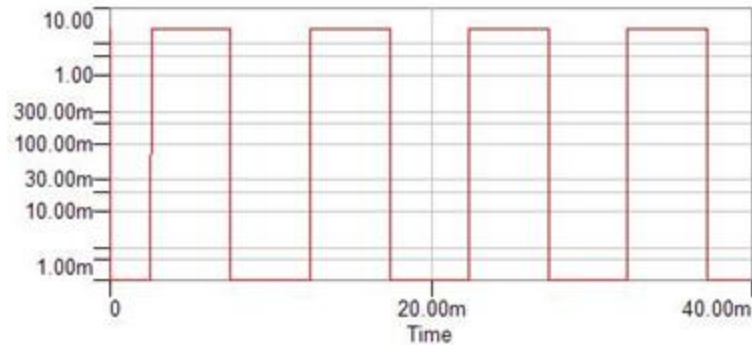


Figure 5. Simulation result-channel B output of ANG_ENCODER_CHAN_I21

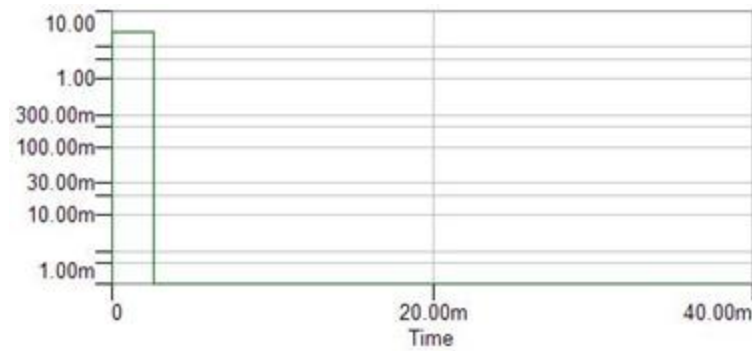


Figure 6. Simulation result-channel North output of ANG_ENCODER_CHAN_I21

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References

Level 2 Clipped Linear Function

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

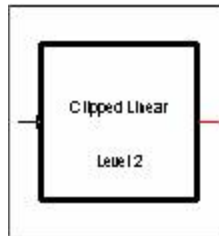


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Description

The Level 2 Clipped Linear Function block provides an output that is, in the ideal case, a linear function of the input within a specified input range and is clipped to a maximum and minimum value at input values above and below that range. The Level 2 clipped linear function allows for a number of nonlinear behaviors in the non-ideal case, including hysteresis, nonlinearity, and span and offset sensitivity to a second independent variable. The Level 2 clipped linear function is shown here:

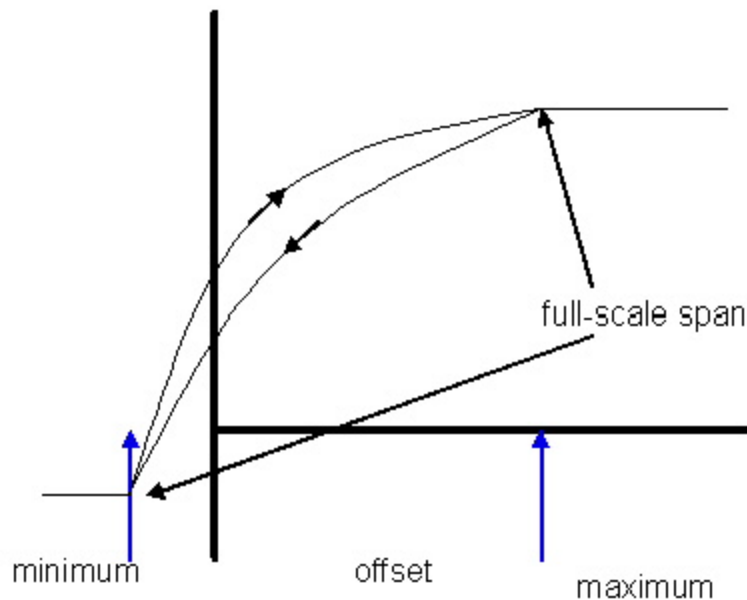


Figure 2. The clipped linear function

Parameters affecting both the ideal and nonideal behavior of the block can be entered into the block through nonconservative pins. When the parameters that cause non-ideal behavior are set to zero, the block has ideal output identical to that of the Level 1 Clipped Linear processing block.

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Mathematical Description

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Netlist Syntax

```
MODEL CL_LINEAR_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) ( INPUT:=  
@INPUT, max_input:= @max_input, min_input:= @min_input, full_scale_span:= @full_scale_  
span, offset:= @offset, max_nonlinearity:= @max_nonlinearity, hysteresis:= @hysteresis, min_  
temp:= @min_temp, max_temp:= @max_temp, temp:= @temp, temp_hysteresis:= @temp_hys-  
teresis, tempco_span:= @tempco_span, temp_sens_offset:= @temp_sens_offset) SRC: DB  
(Lib:=@ModelLibraryName) ;
```

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Parameters

Table 1

Name	Description	Data Type	Default Value [Unit]
INPUT	Input from the measuring block, first independent variable	Real	0
min_input	Minimum input value for the linear output range	Real	0
max_input	Maximum input value for the linear output range	Real	1k
full_scale_span	Difference of outputs at the maximum and minimum inputs	Real	5
offset	Output at the minimum input	Real	0
max_non-linearity	Nonlinearity as a percentage of full-scale span. (Nonlinearity is at its maximum value at the mid-point of the span.)	Real	0
hysteresis	Hysteresis as a percentage of full-scale-span	Real	0
temp	Current temperature	Real	27
min_temp	Minimum operating temperature	Real	-40
max_temp	Maximum operating temperature	Real	125
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0
temco_span	Span temperature sensitivity as a percentage of full-scale span	Real	0

temp_sens_offset	Offset temperature sensitivity	Real	0

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
OUTPUT	Processed output	Output	real
pnl	Current percent nonlinearity[%]	Output	real
ph	Current percent hysteresis [%]	Output	real
pth	Current percent temperature hysteresis[%]	Output	real
ptd	Current percent temperature change of the full-scale-span	Output	real

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Example

In this example, a Pressure Source P1 is applied to a two Linear Orifice – RHYD1 and RHYD2 in series. The Differential Pressure Sensing block PM_DIFF_I21 measures the Pressure across RHYD2. The Output of PM_DIFF_I21 is clamped by a Clipped Linear function block CL_LINEAR_I21. The schematic of the system is shown in Figure 3, system parameters are listed in Table 3, and the simulation results are shown in Figure 4.

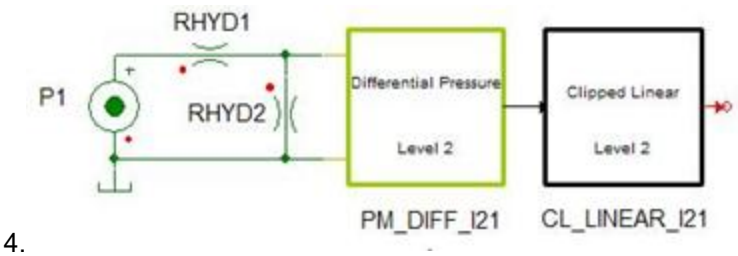


Figure 3. Application example of the Clipped Linear Function block

Table 3

Component	Parameter	Value [Unit]

Pressure Source P1	VALUE	1k * (t/40m) [W]
Linear Orifice RHYD1/RHYD2	K	1n [m/(Pa s)]
Differential Pressure Sensing block PM_DIFF_I21	time_constant	0
Clipped Linear Function block CL_LINEAR_I21	INPUT	PM_DIFF_I21.MEAS
	min_input	0
	max_input	1k
	full_scale_span	10
	offset	0
	max_non-linearity	0
	hysteresis	0
	temp	27
	min_temp	-40
	max_temp	125
	temp_hysteresis	0
	temco_span	0
	temp_sens_offset	0

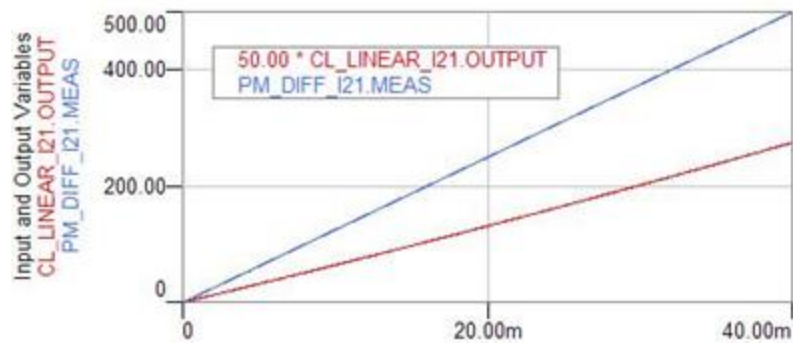


Figure 4. Simulation results-input and output of the Clip Function block CL_LINEAR1

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References

Level 2 Count

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

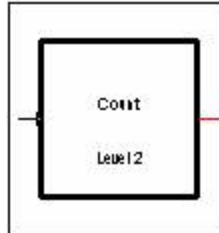


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Description

The Level 2 Count block takes a real-number input and produces an integer output. It is particularly useful for modeling sensors with integrated analog-to-digital conversion. The output of the block is given by the function

$$\text{count} = \text{INT}((\text{input} - \text{offset})(1 + \% \text{error}/100) / (\text{increment size}))$$

where the offset is the zero of the count, %error is the percent measurement error of the device, and the increment size is the minimum amount greater than the offset that the integer portion of the input must be in order to increase the output to one.

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Mathematical Description

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Netlist Syntax

```
MODEL COUNT_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) ( INPUT:=  
@INPUT, INCREMENT_SIZE:= @INCREMENT_SIZE, OFFSET:= @OFFSET, error:= @error)  
SRC: DB(Lib:=@ModelLibraryName) ;
```

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Parameters

Table 1

Name	Description	Data Type	Default Value [Unit]
INPUT	Input from the measuring block	Real	0
offset	Zero point of count	Real	0
increment_size	Minimum amount greater than the offset that the integer portion of the input must be in order to increase the count to 1	Real	1
error	Percent measurement of error	Real	0

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
OUTPUT	Processed output	Output	real

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Example

In this example, a heat-flow source H1 is applied to two Thermal Resistors – RTH1 and RTH2. The temperature of RTH2 is measured by a Differential Temperature sensing block DIFF_TEMP_I21, and the measurement result is output through a Count block COUNT_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

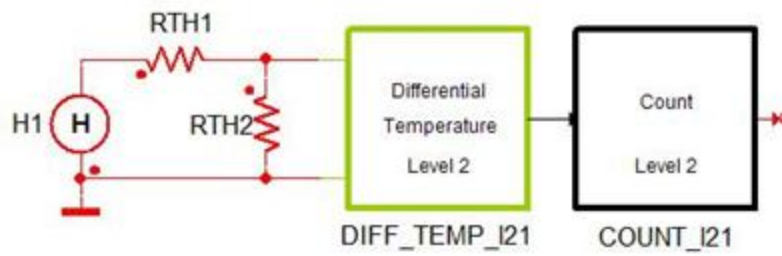


Figure 2. Application example of the Count block

Table 3

Component	Parameter	Value [Unit]
Heat-Flow Source H1	VALUE	$(223 + 250 * (t/40m))$ [W]
Thermal Resistor RTH1/RTH2	K	1 [K/W]
Differential Temperature Sensing block PM_DIFF_I21	time_constant	0
Count block COUNT_I21	INPUT	DIFF_TEMP1.MEAS
	increment_size	20
	error	0
	offset	223

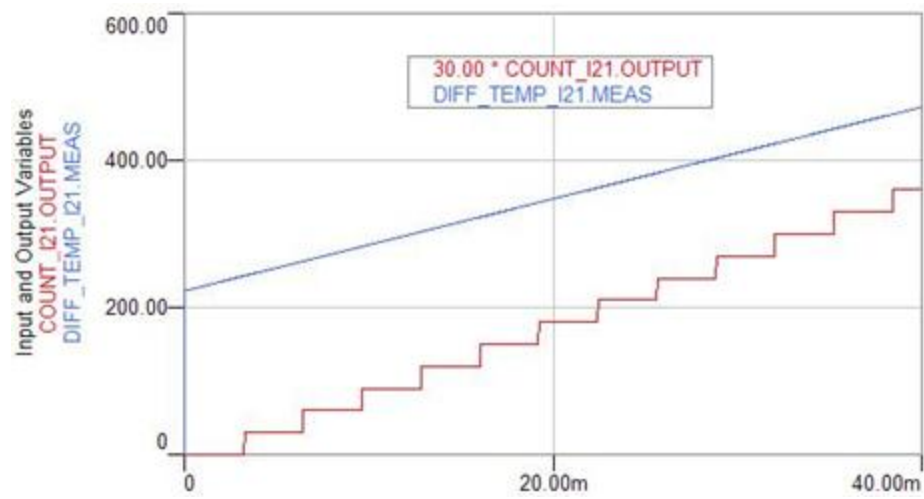


Figure 3. Simulation results-input and output of COUNT_I21

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References

Level 2 Thermocouple Direct Polynomial (K)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

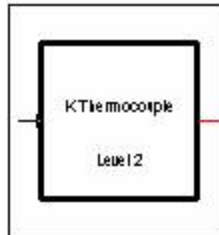


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Description

The Level 2 Thermocouple Direct Polynomial (K) block produces as its output the voltage-temperature curve for K thermocouples that are used in at temperatures between 0 and 1372 degrees Celsius. The input of the function is the temperature difference between the measuring and reference junctions of the thermocouple, and the output is a voltage that is described by the function

$$V = \sum_{i=0}^n a_i t^i + \alpha_0 e^{(\alpha_1(t - 126.9686)^2)}$$

where a_i , α_0 , and α_1 , are coefficients that are particular to a K thermocouple, and t is the temperature difference between the measuring and reference junctions of the thermocouple plus or minus the measurement error of the device. The thermocouple coefficients a_i , 0, and 1, as well as the percent measurement error of the thermocouple, are parameters of the block that can be changed.

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Mathematical Description

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Netlist Syntax

```
MODEL direct_thermoc_k_l2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) ( INPUT:=  
@INPUT, a0:= @a0, a1:= @a1, a2:= @a2, a3:= @a3, a4:= @a4, a5:= @a5, a6:= @a6, a7:=  
@a7, a8:= @a8, a9:= @a9, a10:= @a10, a11:= @a11, a12:= @a12, a13:= @a13, a14:= @a14,  
a15:= @a15, alpha0:= @alpha0, alpha1:= @alpha1, error:= @error) SRC: DB(Lib:-  
:=@ModelLibraryName);
```

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Parameters

Table 1

Name	Description	Data Type	Default Value [Unit]
INPUT	Input from the measuring block	Real	0
a0	Zero-order coefficient	Real	0
a1	First-order coefficient	Real	0
a2	Second-order coefficient	Real	0
a3	Third-order coefficient	Real	0
a4	Fourth-order coefficient	Real	0
a5	Fifth-order coefficient	Real	0
a6	Sixth-order coefficient	Real	0
a7	Seventh-order coefficient	Real	0

a8	Eighth-order coefficient	Real	0
a9	Ninth-order coefficient	Real	0
a10	Tenth-order coefficient	Real	0
a11	Eleventh-order coefficient	Real	0
a12	Twelfth-order coefficient	Real	0
a13	Thirteenth-order coefficient	Real	0
a14	Fourteenth-order coefficient	Real	0
a15	Fifteenth-order coefficient	Real	0
alpha0	Exponential term coefficient	Real	0
alpha1	Exponential exponent coefficient	Real	0
error	Percent measurement error	Real	0

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
OUTPUT	Processed output	Output	real

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Example

In this example, a heat-flow source H1 is applied to two Thermal Resistors – RTH1 and RTH2. The temperature of RTH2 is measured by a Differential Temperature sensing block DIFF_TEMP_I21, and the measurement result is output through a Direct Polynomial Thermocouple (K) direct_thermoc_k_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

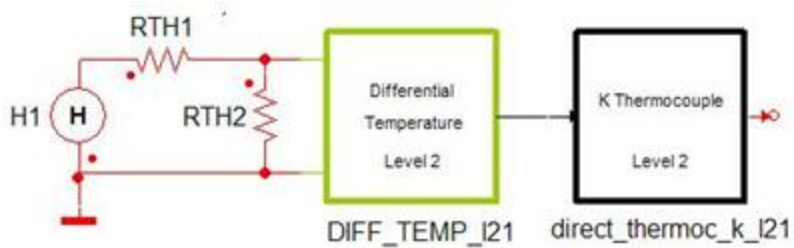


Figure 2. Application example of the Direct Polynomial Thermocouple (K) block

Table 3

Component	Parameter	Value [Unit]
Heat-Flow Source H1	VALUE	$(223 + 250 * (t/40m))$ [W]
Thermal Resistor RTH1/RTH2	K	1 [K/W]
Differential Temperature Sensing block PM_DIFF_I21	time_constant	0
Direct Polynomial Thermocouple (K) thermoc_k_I21	INPUT	DIFF_TEMP_I21.MEAS
	a0	-17.6004m
	a1	38.9212m
	a2	18.5588u
	a3	-99.4576n
	a4	0.318409n
	a5	-0.560728p
	a6	0.560751f
	a7	-3.20207e-019
	a8	9.71511e-023

a9	-1.21047e-026
a10	0
a11	0
a12	0
a13	0
a14	0
a15	0
alpha0	0.118598
alpha1	-0.118343m
error	5

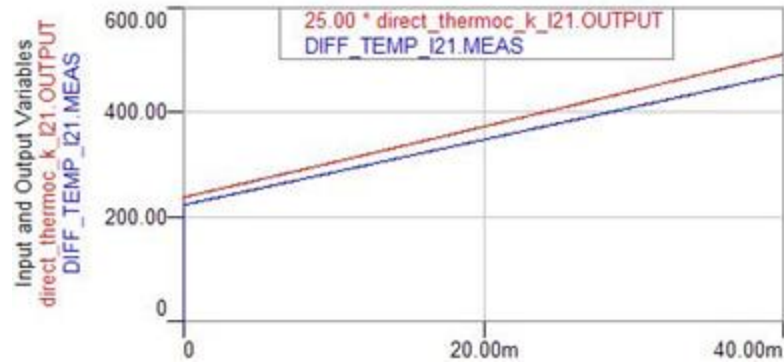


Figure 3. Simulation results-input and output of the direct_thermoc_k_I21

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References

Level 2 Thermocouple Direct Polynomial (J, T, E, N, B, R, S)

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

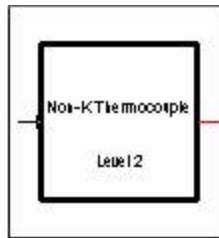


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Description

The Level 2 Thermocouple Direct Polynomial (J, T, E, N, B, R, S) block produces as its output the voltage-temperature curve for thermocouples of types J, T, E, N, B, R, and S and for type K thermocouples that are used in at temperatures between -270 and 0 degrees Celsius. The input of the function is the temperature difference between the measuring and reference junctions of the thermocouple, and the output is a voltage that is described by the function

$$V = \sum_{i=0}^n a_i t^i$$

where a_i are coefficients that are particular to a given thermocouple type, and t is the temperature difference between the measuring and reference junctions of the thermocouple plus or minus the measuring error of the thermocouple. The thermocouple coefficients a_i and the percent measuring error of the device are parameters of the block that can be changed.

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Mathematical Description

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Netlist Syntax

```
MODEL direct_thermoc_l2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) ( INPUT:=
@INPUT, a0:= @a0, a1:= @a1, a2:= @a2, a3:= @a3, a4:= @a4, a5:= @a5, a6:= @a6, a7:=
@a7, a8:= @a8, a9:= @a9, a10:= @a10, a11:= @a11, a12:= @a12, a13:= @a13, a14:= @a14,
a15:= @a15, error:= @error) SRC: DB(Lib:=@ModelLibraryName);
```

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Parameters

Table 1

Name	Description	Data Type	Default Value [Unit]
INPUT	Input from the measuring block	Real	0
a0	Zero-order coefficient	Real	0 [V]
a1	First-order coefficient	Real	0 [V/K]
a2	Second-order coefficient	Real	0 [V/K ²]
a3	Third-order coefficient	Real	0 [V/K ³]
a4	Fourth-order coefficient	Real	0 [V/K ⁴]
a5	Fifth-order coefficient	Real	0 [V/K ⁵]
a6	Sixth-order coefficient	Real	0 [V/K ⁶]
a7	Seventh-order coefficient	Real	0 [V/K ⁷]
a8	Eighth-order coefficient	Real	0 [V/K ⁸]

a9	Ninth-order coefficient	Real	0 [V/K ⁹]
a10	Tenth-order coefficient	Real	0 [V/K ¹⁰]
a11	Eleventh-order coefficient	Real	0 [V/K ¹¹]
a12	Twelfth-order coefficient	Real	0 [V/K ¹²]
a13	Thirteenth-order coefficient	Real	0 [V/K ¹³]
a14	Fourteenth-order coefficient	Real	0 [V/K ¹⁴]
a15	Fifteenth-order coefficient	Real	0 [V/K ¹⁵]
alpha0	Exponential term coefficient	Real	0 [V]
error	Percent measuring error of thermocouple	Real	0 [%]

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
OUTPUT	Processed output	Output	real

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Example

In this example, a heat-flow source H1 is applied to two Thermal Resistors – RTH1 and RTH2. The temperature of RTH2 is measured by a Differential Temperature sensing block DIFF_TEMP_I21, and the measurement result is output through a Thermocouple Direct Polynomial (J, T, E, N, B, R, S) direct_thermoc_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

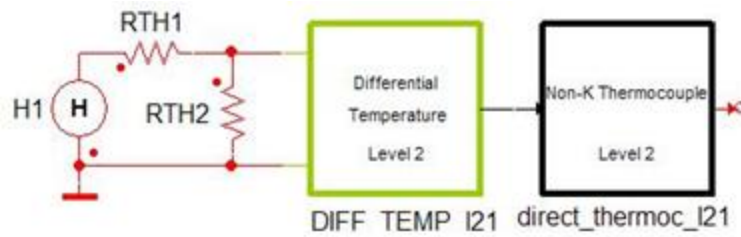


Figure 2. Application example of the Thermocouple Direct Polynomial (J, T, E, N, B, R, S)

Table 3

Component	Parameter	Value [Unit]
Heat-Flow Source H1	VALUE	$(223 + 250 * (t/40m))$ [W]
Thermal Resistor RTH1/RTH2	K	1 [K/W]
Differential Temperature Sensing block PM_DIFF_I21	time_constant	0
Direct Polynomial Thermocouple (K) direct_thermoc_I21	INPUT	DIFF_TEMP_I21.MEAS
	a0	0
	a1	0.387481063640e-1
	a2	0.332922278800e-4
	a3	0.206182434040e-6
	a4	-0.218822568460e-8
	a5	0.109968809280e-10
	a6	-0.308157587720e-13
	a7	0.454791352900e-

		16
	a8	-0.275129016730e-19
	a9	0
	a10	0
	a11	0
	a12	0
	a13	0
	a14	0
	a15	0
	error	5

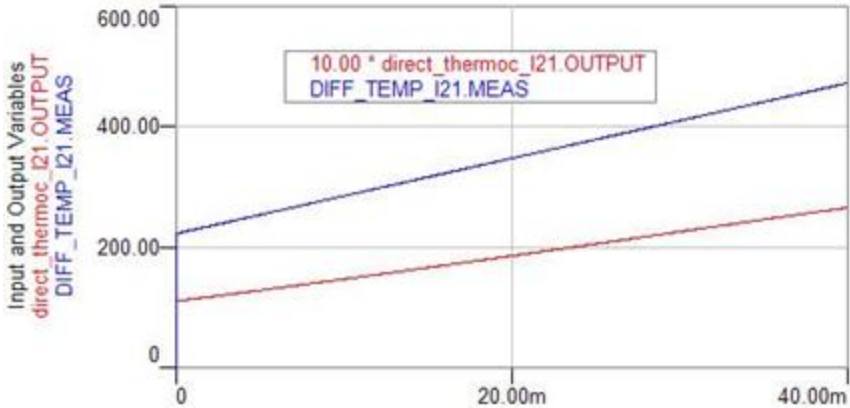


Figure 3. Simulation results-input and output of the direct_thermoc_I21

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References

Level 2 Linear Incremental Encoder Channels

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

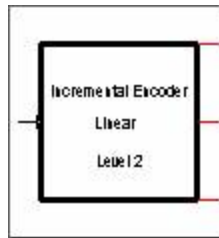


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Description

The Level 2 Linear Incremental Encoder Channels Block takes the input from a linear position sensing block and produces the three digital output channels of a typical incremental encoder sensor as its outputs. The first output, Channel A, goes to its logic 1 value each time the encoder's position sensor moves past one of the equally-spaced position indicators on the device when the sensor is moving in the positive direction. Channel A remains at its logic one output until the encoder's position sensor has traveled one-half the distance to the next position indicator. The second output of the encoder, Channel B, is similar to Channel A, but lags it by one-quarter cycle when the angle sensor is moving in the positive direction. When the position sensor is moving in a negative direction, the outputs of Channels A and B are reversed.

The third output, Channel N, goes to its logic 1 value when the sensor detects the zero point of the sensor and remains high until the sensor has traveled one-quarter of the distance to the next sensing element.

The Level 2 linear incremental encoder channels processing block features the same parameters as the Level 1 block: the number of position indicators on the encoder, the zero position of the encoder, the logic one and zero output amplitudes, and the maximum and minimum pos-

itions measurable by the encoder. In addition, the Level 2 block features a parameter for the percent measuring error of the device.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL LIN_ENCODER_CHAN_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) (
INPUT:= @INPUT, num_lines:= @num_lines, north:= @north, oneamplitude:= @oneamplitude,
zeroamplitude:= @zeroamplitude, max_position:= @max_position, min_position:= @min_pos-
ition, pct_error:= @pct_error) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Parameters

Table 1

Name	Description	Data Type	Default Value [Unit]
INPUT	Input from the measuring block	Real	0
num_lines	Number of position indicators on the encoder	Real	16
north	Zero position of the encoder	Real	0
oneamplitude	Amplitude of logic 1 signal	Real	5
zeroamplitude	Amplitude of logic 0 signal	Real	0
max_position	Maximum measurable position	Real	5m
min_position	Minimum measurable position	Real	-5m

pct_error	Percent measuring error	Real	0

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
channel_A	Output of encoder channel A	Output	real
channel_B	Output of encoder channel B	Output	real
channel_N	Output of encoder channel N	Output	real

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Example

In this example, a Position Source S_TRB1 is applied to a Mass block MASS_TRB1. The displacement of MASS_TRB1 is measured by a Linear Displacement sensing block DISP_SENS_I21, and the measurement result is output through a Linear Incremental Encoder LIN_ENCODER_CHAN_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3-6.

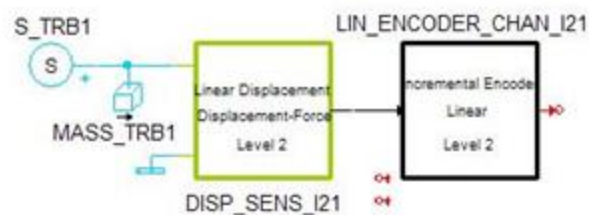


Figure 2. Application example of the Linear Incremental Encoder

Table 3

Component	Parameter	Value [Unit]
Position Source S_TRB1	VALUE	$4\text{m} * (t/40\text{m})$ [m]
Mass Mass_TRB1	M	1 [kg]
	S0	0 [m]

	V0	0 [m/s]
Linear Displacement sensing block DISP_SENS_I21	time_constant	0
Linear Incremental Encoder LIN_ ENCODER_CHAN_I21	INPUT	DISP_ SENS_ I21.MEAS
	num_lines	4
	north	0
	oneamplitude	5
	zeroamplitude	0
	max_position	4m
	min_position	0
	pct_error	1

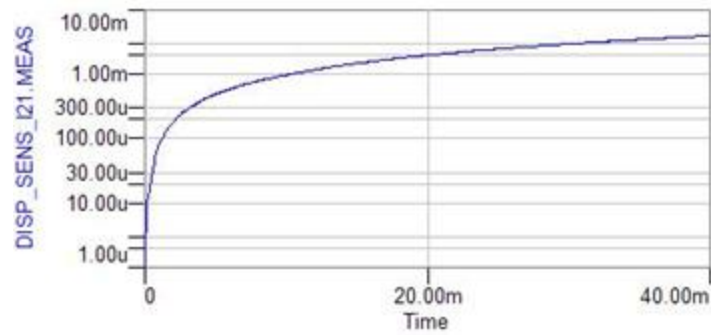


Figure 3. Simulation result-displacement of Mass_TRB1

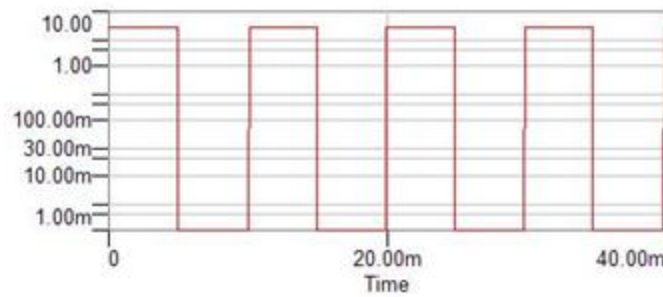


Figure 4. Simulation result-channel A output of LIN_ENCODER_CHAN_I21

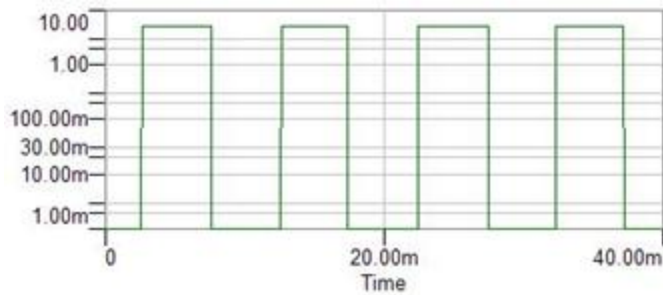


Figure 5. Simulation result-channel B output of LIN_ENCODER_CHAN_I21

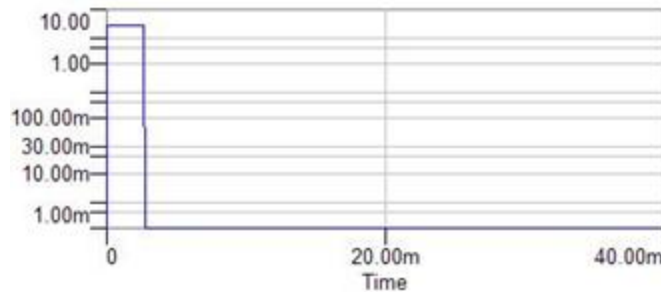


Figure 6. Simulation result-channel North output of LIN_ENCODER_CHAN_I21

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References

Level 2 Nernst Voltage Equation

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

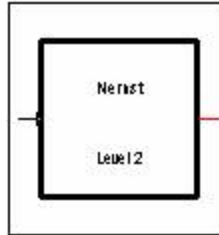


Figure 1. Component symbol

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Description

The Level 2 Nernst Voltage Equation block is useful for modeling $\lambda = 1$ oxygen sensing devices that produce a voltage output that corresponds to a difference in oxygen concentration.

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Assumptions and Limitations

A check for the value of $\text{INPUT} \cdot \text{INPUT2}$ is performed. When this product is equal to or smaller than zero, their value is clamped to 1 and the resulting OUTPUT is 0.0.

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Mathematical Description

The block uses three nonconservative inputs, INPUT, INPUT2, and T, which would typically come from pressure and temperature measuring blocks to produce an output according to the following function:

$$\text{OUTPUT} = [T \cdot R / (4 \cdot F)] \cdot \ln(\text{INPUT} / \text{INPUT2})$$

where INPUT2 is the partial pressure of oxygen in a reference medium, INPUT is the partial pressure of oxygen in a measured medium, R is the universal gas constant, T is the absolute temperature of the sensed medium, and F is Faraday's constant.

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Netlist Syntax

```
MODEL NERNST_V_I2 ?InstanceName(@InstanceName):(@Refbase)@(ID)) ( INPUT:=
@INPUT, INPUT2:= @INPUT2, T:= @T) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Parameters

Table 1

Name	Description	Data Type	Default Value [Unit]
T	Absolute temperature	Real	300

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
OUTPUT	Processed output	Output	real
INPUT	Input from the measuring block for the reference pressure	Input	real
INPUT2	Input for the measured pressure	Input	real

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Example

In this example, the Nernst Voltage Equation block NERNST_V_I21 takes the pressure measure results from the Different Pressure sensing block PM_DIFF_I21 and that from the Absolute Pressure Sensing block PMabs_I21, and produces a voltage output accordingly. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

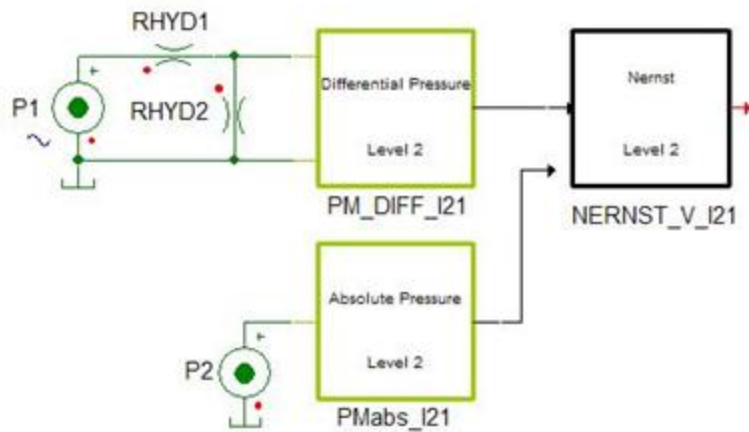


Figure 2. Application example of the Nernst Voltage Equation block

Table 3

Component	Parameter	Value [Unit]
Pressure Source (sinusoidal) P1	AMPL	40k [Pa]
	FREQ	50 [Hz]
	TDELAY	0 [s]
	OFF	0 [Pa]
	PHASE	0 [rad]
Pressure Source P2	VALUE	1E-24 [Pa]
Linear Orifice RHYD1/RHYD2	K	1n [m ³ /(Pa s)]
Nernst Voltage Equation block NERNST_V1	INPUT1	PM_ DIFF1.MEAS
	INPUT2	PMabs1.MEAS
	T	300 [K]

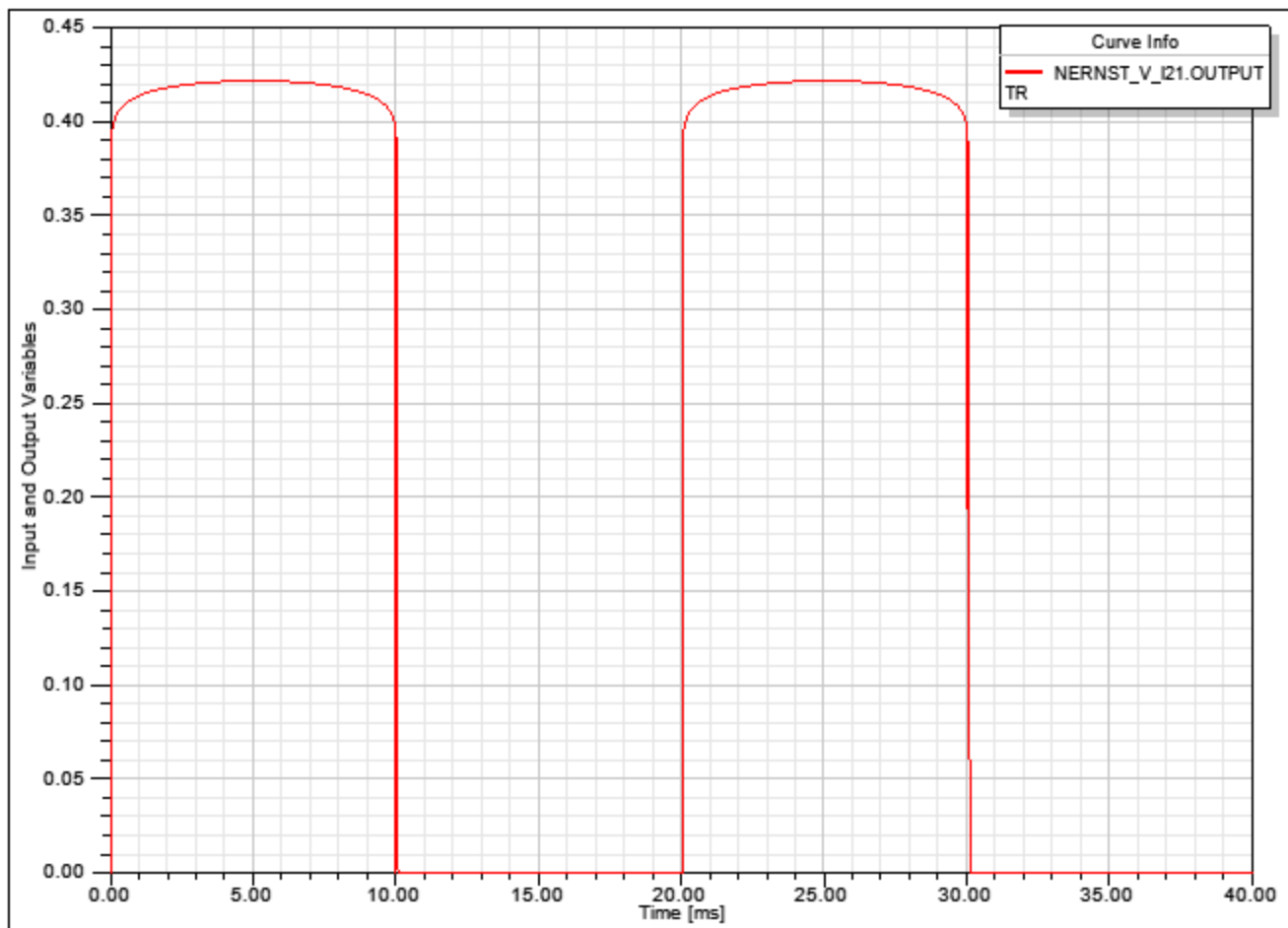


Figure 3. Simulation result-Output voltage of NERNST_V_I21

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References

Level 2 Oxygen-Dependent Resistor

Library: Add Ons/ sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

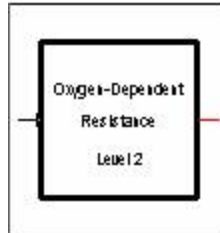


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Description

The Level 2 Oxygen-Dependent Resistor block is useful for modeling =1 oxygen sensing devices that produce a resistance that varies with oxygen concentration. The block uses a non-conservative input P, which would typically come from a pressure measuring block, to produce an output according to the following function:

$$\text{OUTPUT} = \text{ROOT}(\text{INPUT}, 4) \cdot A \cdot \exp(-E/(kT))$$

where A is a material constant, E is the semiconductor material's activation energy, and T is the absolute temperature of the medium surrounding the sensor. A, E, and T are parameters of the block that can be changed.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL O2_R_EQ_I2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) ( INPUT:=
@INPUT, A:= @A, E:= @E, T:= @T) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Parameters

Table 1

Name	Description	Data Type	Default Value [Unit]
INPUT	Input from the measuring block	Real	0
A	Material constant	Real	1 [Ohm/Pa]
E	Semiconductor material activation energy	Real	1.60e-019
T	Absolute temperature	Real	300 [K]

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
OUTPUT	Processed output	Output	real

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Example

In this example, a sinusoidal pressure source and two linear orifices are used to create a differential pressure input to a differential pressure sensor PM_DIFF_I21. The sensor output is used as an input to an Oxygen-Dependent Resistance O2_R_EQ_I21 to vary the output value in Ohms. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

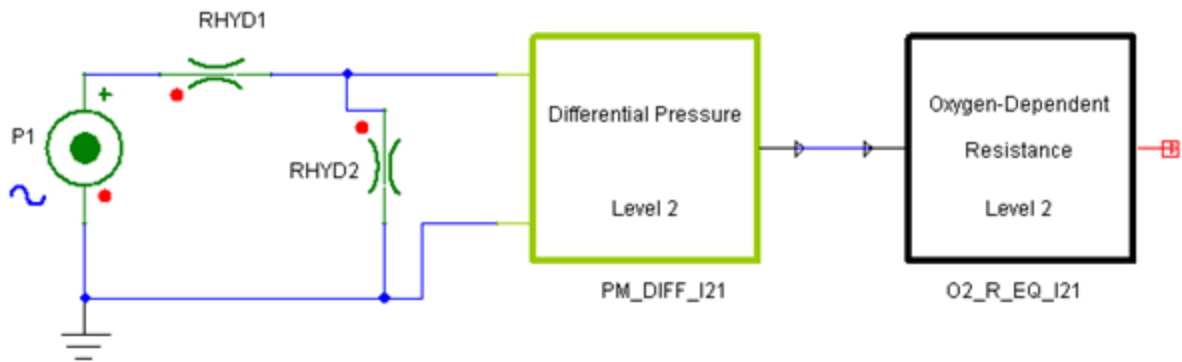


Figure 2. Application example of the Level 2 Oxygen-Dependent Resistance block

Table 3

Χομπονεντ	Παραμετερ	ζαλνε [Υνιτ]
Level 2 Oxygen Dependent Resistance O2_R_EQI21	A	1000 [Ohm/Pa]
	E	0.05 [eV]
	T	300 [K]
	INPUT	PM_DIFF_I21.MEAS
Level 2 Differential Pressure Sensor PM_DIFF_I21	Output	PM_DIFF_I21.MEAS
Pressure Source P1	AMPL	40000 [Pa]
	Time Controlled	Sine
	FREQ	50 [Hz]
	Offset	80000 [Pa]
Linear Orifice RHYD1/RHYD2	Hyd. Conductance	1e-012 [m ³ /Pa]
	P	0 [Pa]

	Q	0 [m ³ /sec]

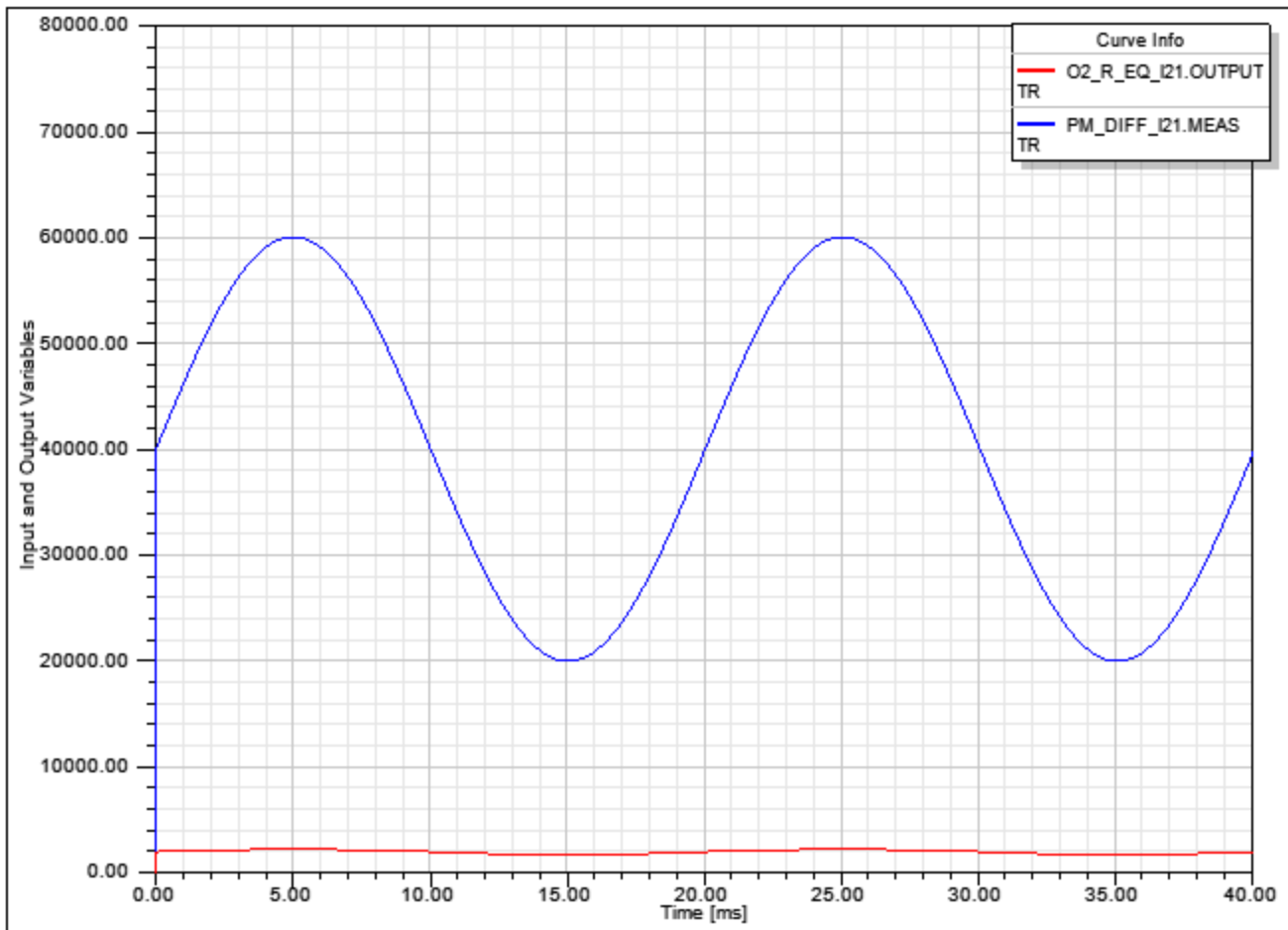


Figure 3. Simulation results-input and output of Oxygen Dependent Resistor O2_R_EQ_I21

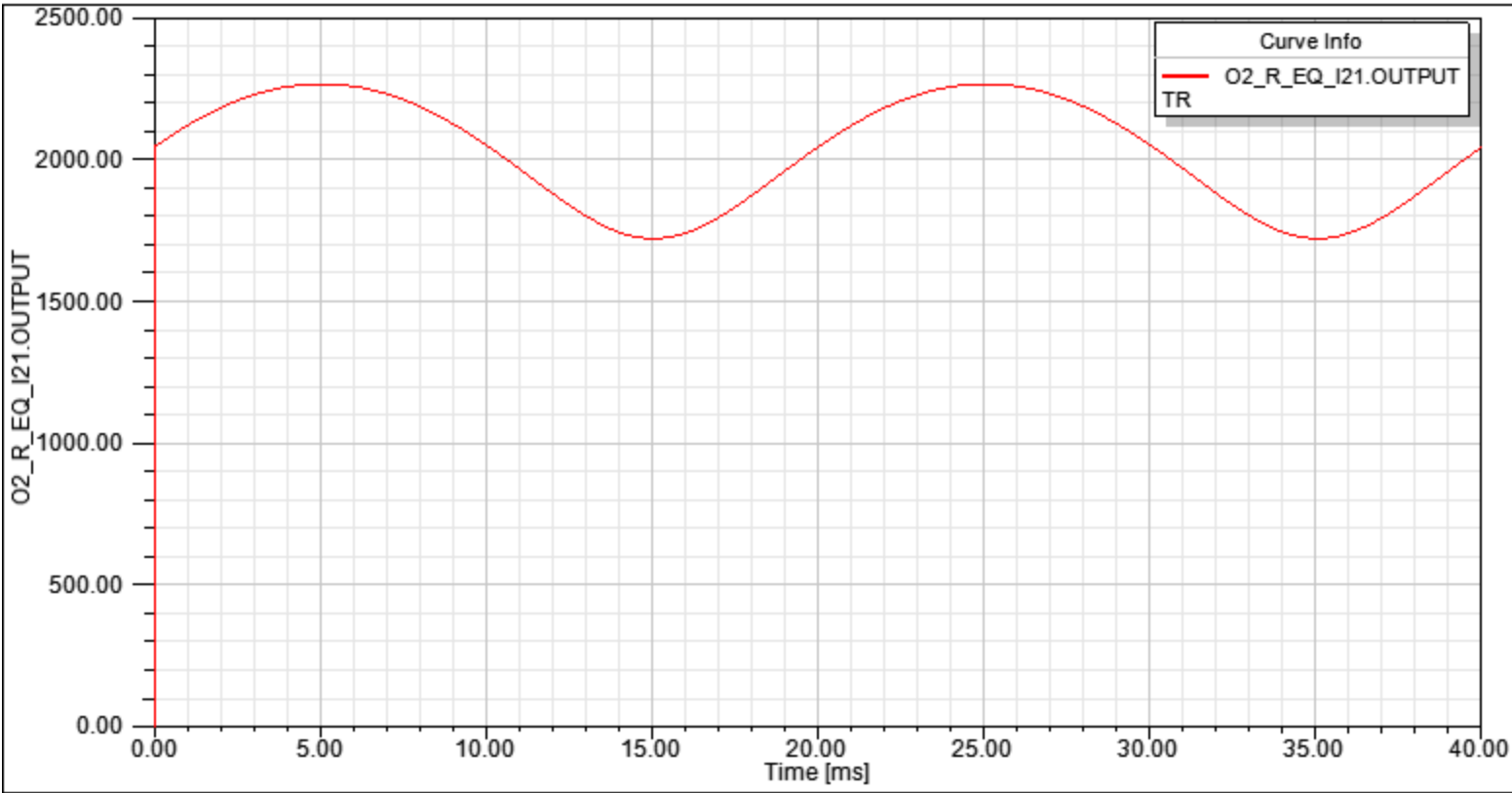


Figure 4. Simulation results-output of Oxygen Dependent Resistor O2_R_EQ_I21

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References

Level 2 Characteristic From File

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

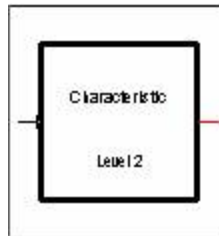


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Description

The Level 2 Characteristic from File block takes in a two-dimensional user-defined characteristic through a nonconservative pin. This characteristic serves as the function that determines the output value of the block from the input values.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL SENS_CHAR_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) ( INPUT:=
@INPUT, CHAR:= @CHAR, error:= @error) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Parameters

Table 1

Name	Description	Data Type	Default Value [Unit]
INPUT	Input from the measuring block: first independent variable	Real	0
CHAR	User-defined characteristic	file	0
error	Percent error	Real	0

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
OUTPUT	Processed output	Output	real

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Example

In this example, the Angular Velocity sensing block ANG_VELOCITY_DF_I21 measures the angular velocity of the Mass block MASS_ROT1, and the measurement results is sent to the Characteristics_From_File block SENS_CHAR_I21. SENS_CHAR_I21 then determines the output value using the function defined by the specified characteristics file The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

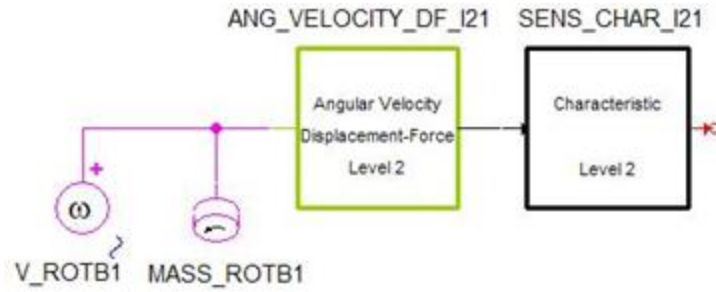


Figure 2. Application example of the Characteristics_From_File block

Table 3

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROT B1	AMPL	5 [rad/s]
	FREQ	50 [Hz]
	TDELAY	0 [s]
	OFF	0 [rad/s]
	PHASE	0 [rad]
	PHI0	0 [rad]
Mass MASS_ROT B1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Angular Velocity sensing block ANG_VELOCITY_DF_I21	corner_frequency	0 [Hz]
Characterics_From_File block SENS_CHAR_I21	INPUT	ANG_VELOCITY_DF_I21.MEAS
	CHAR	parabola.mdx

	error	0

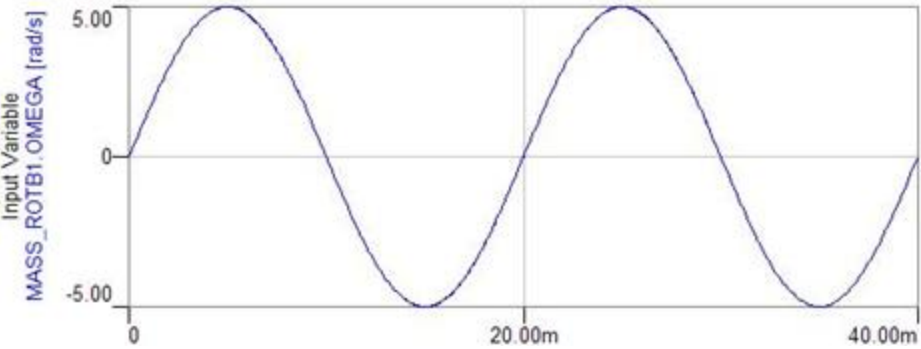


Figure 3. Simulation results- angular velocity of MASS_ROT B1

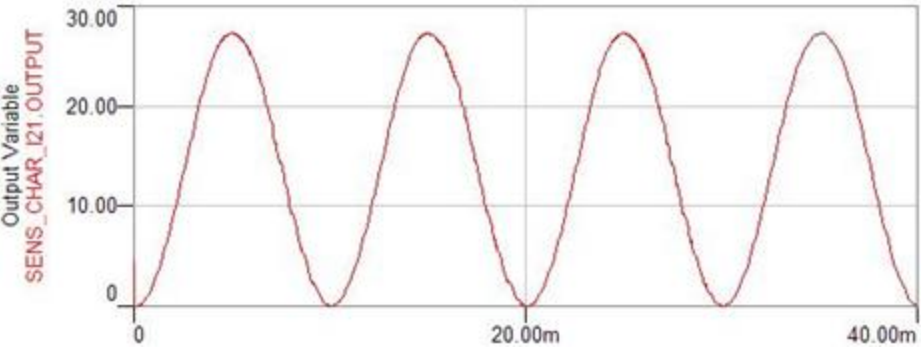


Figure 4. Simulation results-output of SENS_CHAR_I21

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References

Level 2 Steinhart-Hart Function

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

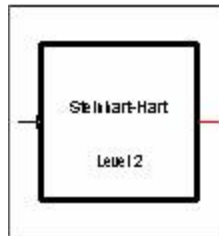


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Description

The Level 2 Steinhart-Hart block produces the resistance-temperature curve of a negative temperature coefficient thermistor as its output. The block takes in a real value through its non-conservative input pin, and produces an output R through its nonconservative output pin according to the following equation:

$$R = e^{[(-X/2 + (X^2/4 + \Psi^3/27)^{1/2})^{1/3} + (-X/2 - (X^2/4 + \Psi^3/27)^{1/2})^{1/3}]}$$

Where Ψ is the Kelvin temperature plus or minus the measuring error of the thermistor, $X = a - 1/T$, $\Psi = b/c$, and a, b, and c are parameters specific to an individual thermistor. The parameters a, b, and c, as well as the percent measuring error of the thermistor, can be entered into the Steinhart-Hart Function block through nonconservative inputs.

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Mathematical Description

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Netlist Syntax

MODEL SH_FUNCTION_I2 ?InstanceName(@InstanceName):(@Refbase)@(ID)) (INPUT:=
@INPUT, a:= @a, b:= @b, c:= @c, dev:= @dev) SRC: DB(Lib:=@ModelLibraryName) ;

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Parameters

Table 1

Name	Description	Data Type	Default Value [Unit]
INPUT	Input from the measuring block, first independent variable	Real	0
a	Steinhart-Hart parameter "a"	Real	0
b	Steinhart-Hart parameter "b"	Real	0
c	Steinhart-Hart parameter "c"	Real	0
dev	Percent measurement error of the thermistor	Real	0

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
OUTPUT	Processed output	Output	real

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Example

In this example, a heat-flow source H1 is applied to two Thermal Resistors – RTH1 and RTH2. The temperature of RTH2 is measured by an Absolute Temperature sensing block ABS_TEMP_I21, and the measurement result is output through a Steinhart-Hart SH_FUNCTION_I22. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

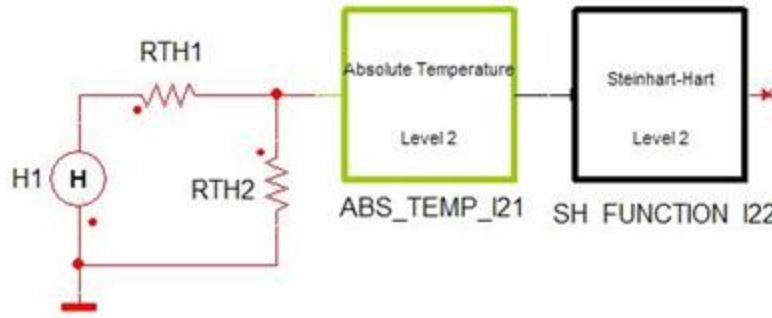


Figure 2. Application example of the Steinhart-Hart Function block

Table 3

Component	Parameter	Value [Unit]
Heat-Flow Source H1	VALUE	$(223 + 250 * (t/40m))$ [W]
Thermal Resistor RTH1/RTH2	K	1 [K/W]
Absolute Temperature sensing block ABS_TEMP_I21	time_constant	0
Steinhart-Hart SH_FUNCTION_I22	INPUT	ABS_TEMP_I21.MEAS
	a	1.942952e-3
	b	2.989769e-4
	c	3.504383e-7
	dev	1

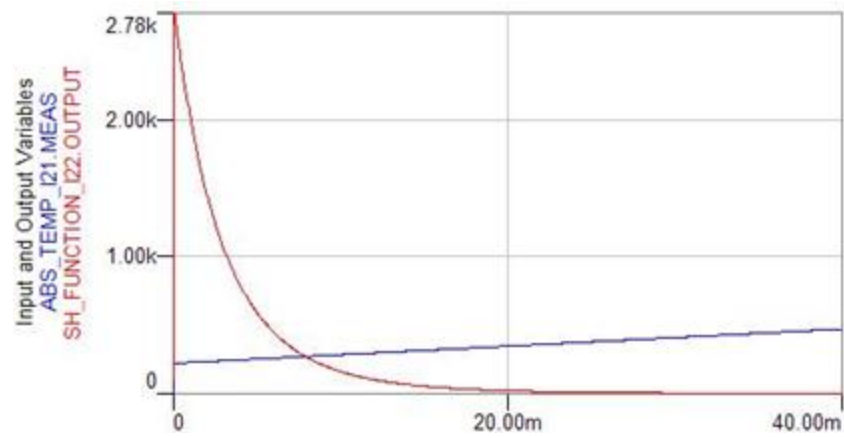


Figure 3. Simulation results-input and output of the Steinhart-Hart SH_FUNCTION_I22

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References

Linear Function

Library: Sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

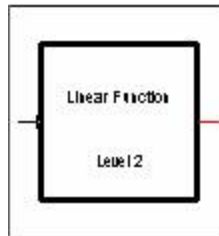


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Description

The Level 2 Linear Function block provides an output that is a linear function of two inputs. The slope and intercept of the linear function with respect to one input and the slope with respect to the second input are parameters of the block that can be changed.

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Mathematical Description

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Netlist Syntax

```
MODEL ST_LINEAR_I2 ?InstanceName(@InstanceName):(@@Refbase)@(ID)) ( INPUT:=
@INPUT, SENS:= @SENS, OFFSET:= @OFFSET, temp_sens:= @temp_sens, temp:=
@temp) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Parameters

Table 1

Name	Description	Data Type	Default Value [Unit]
INPUT	Input from the measuring block, first independent variable	Real	0
Temp	Second independent variable	Real	27
SENS	Slope of the linear function with respect to the first independent variable	Real	0
OFFSET	Intercept of the linear function	Real	0
temp_sens	Slope of the linear function with respect to the second independent variable	Real	0

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Input/Output Quantities

Table 2

Name	Description [Unit]	Direction	Data Type
OUTPUT	Processed output	Output	real

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Example

In this example, a sinusoidal heat-flow source is applied to two Thermal Resistors – RTH1 and RTH2. The temperation of RTH2 is measured by an Absolute Temperature sensing block ABS_TEMP_I21, and the measurement results is output through a Linear Function block ST_LINEAR_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

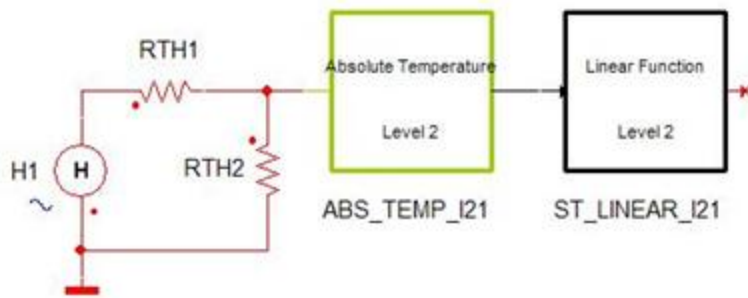


Figure 2. Application example of the Linear Function block

Table 3

Component	Parameter	Value [Unit]
Heat-Flow Source (sinusoidal) H1	AMPL	10 [W]
	FREQ	50 [Hz]
	OFF	0.5 [W]
	PHASE	0 [rad]
	TDELAY	0 [s]
Thermal Resistor RTH1/RTH2	K	1 [K/W]
Absolute Temperature sensing block ABS_TEMP_I21	time_constant	0
Linear Function block ST_LINEAR_I11	INPUT	ABS_TEMP1.MEAS
	Temp	27
	SENS	2
	OFFSET	1
	temp_sens	0.5

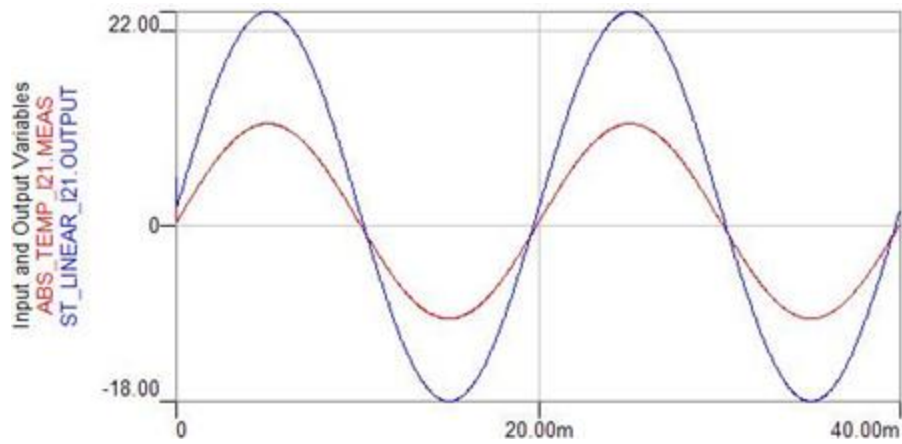


Figure 3. Simulation results-input and output of the Linear Function block ST_LINEAR_I21

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References

Level 2 Sensor Models

The Level 2 sensor models exhibit non-ideal device behavior that is more realistic than the ideal behavior exhibited by the Level 1 sensor models. The Level 2 models have conservative input pins in one of the Twin Builder physical domains, and conservative output pins in the electrical domain. The models may be parameterized with a number of nonconservative inputs. Models of sensor types for a variety of different physical quantities are available.

Level 2 Sensor Models are available for the following physical quantities:

- Pressure
- Angle
- Linear Position
- Temperature
- Flow
- Oxygen Concentration
- Angular Velocity
- Angular Acceleration
- Linear Acceleration
- Vibration
- Torque

Level 2 sensor models appear in the Twin Builder Sensors library and are available to customers who have purchased a license for this library.

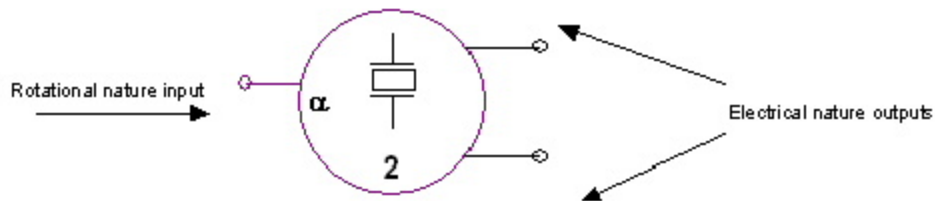
Level 2 Angular Acceleration Sensor Models

The Level 2 Angular Acceleration Sensor Models simulate the non-ideal behavior of four different types of angular acceleration sensors. Models are available for use with the Twin Builder *displacement-force* and *velocity-force* rotational domains.

All of the angular acceleration sensor models have conservative input pins that must be connected to a rotational network and conservative output pins that must be connected to an electrical network. The models also feature nonconservative parameters that can be changed in order to tailor the behavior of the model to that of a specific real device.

As shown in the following example, angular acceleration sensor models for the displacement-force rotational domain have pink conservative input pins that must be connected to a displacement-force rotational network. The models also have black conservative pins that must be connected to an electrical network.

Similarly, angular acceleration sensor models for the velocity-force rotational domain have purple rotational-nature input pins and black electrical-nature pins.



The Level 2 Angular Acceleration Sensor Models feature models for the following angular acceleration sensing mechanisms:

- **Capacitive**—acceleration of the sensor causes the movement of the shared plate in a differential capacitor pair. The sensor responds by producing a change in its linear voltage output signal.

Displacement-Force model: ([C_ALPHA_DF_I2](#))

Velocity-Force model: ([C_ALPHA_VF_I2](#))

- **Inertia Switch**—a specified threshold acceleration causes a switch contained inside the sensor to change state from open to closed.

Displacement-Force model: ([INERTIA_SWITCH_DF_I2](#))

Velocity-Force model: ([INERTIA_SWITCH_VF_I2](#))

- **Piezoelectric**—acceleration of the sensor causes the deformation of a piezoelectric element which produces a corresponding voltage output signal.

Displacement-Force model: ([PE_ALPHA_DF_I2](#))

Velocity-Force model: ([PE_ALPHA_VF_I2](#))

- **Piezoresistive**—acceleration of the sensor causes the deformation of resistors connected in a Wheatstone bridge configuration, producing a corresponding differential voltage output signal.

Displacement-Force model: ([PR_ALPHA_DF_I2](#))

Velocity-Force model: ([PR_ALPHA_VF_I2](#))

Level 2 Capacitive Angular Acceleration Sensor (Displacement-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

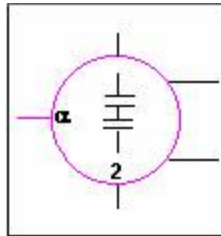


Figure 1. Component symbol

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Description

The Level 2 Capacitive Angular Acceleration (Displacement-Force) sensor model is used to simulate the non-ideal behavior of a conditioned capacitive angular acceleration sensor in the Twin Builder displacement-force rotational domain. A change in the model's angular acceleration input produces a corresponding change in the model's linear voltage output.

The model has one conservative input pin in the displacement-force rotational domain for its angular acceleration input and four conservative electrical-domain pins. Two of the pins are for the model's power supplies, and two are for its voltage output. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is connected to ground.

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Netlist Syntax

```
MODEL C_ALPHA_DF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) ANGULAR:=
%0, OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 ( max_alpha:= @max_alpha, min_
alpha:= @min_alpha, full_scale_span:= @full_scale_span, offset:= @offset, supply_current:=
@supply_current, nonlinearity:= @nonlinearity, hysteresis:= @hysteresis, max_temp:= @max_
temp, min_temp:= @min_temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tem-
pco_span, temp_sens_offset:= @temp_sens_offset, corner_frequency:= @corner_frequency,
temp:= @temp, output_resistance:= @output_resistance) SRC: DB(Lib:=@ModelLibraryName)
;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
ANGULAR	Measured angular acceleration	Rotational
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
corner_fre-	Input signal corner frequency	Real	0 [Hz]

quency			
temp	Device temperature	Real	27 [°C]
output_resistance	Output resistance	Real	0 [Ohm]
max_alpha	Maximum measurable angular acceleration	Real	50 [rad/s ²]
min_alpha	Minimum measurable angular acceleration	Real	0 [rad/s ²]
full_scale_span	Difference of output voltages at maximum and minimum angular accelerations	Real	5 [V]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	150 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
supply current	Typical supply current	Real	5m [A]
nonlinearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]

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Example

In this example, the Capacitive Angular Acceleration (Displacement-Force) sensor C_ALPHA_DF_I21 measures the angular velocity of the Mass MASS_ROT B1. A change in the angular acceleration of MASS_ROT B1 produces a corresponding change in the linear voltage output of C_ALPHA_DF_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

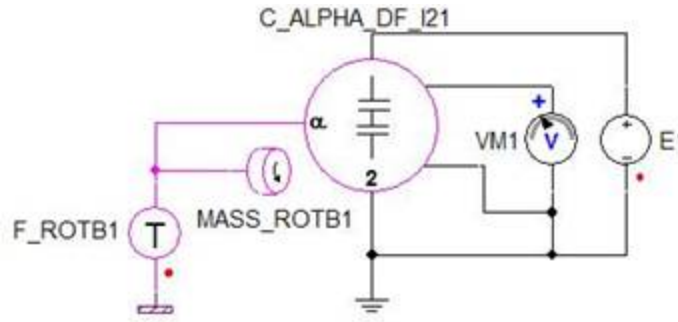


Figure 2. Application example of the Capacitive Angular Acceleration (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROT B1	VALUE	20 * (t/40m) [Nm]
Mass MASS_ROT B1	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Capacitive Angular Acceleration (Displacement-Force) sensor C_ALPHA_DF_I21	offset	0.1* E1.EMF [V]
	corner_frequency	0 [Hz]
	temp	27 [°C]

	output_resistance	0 [Ohm]
	max_alpha	18 [rad/s ²]
	min_alpha	0 [rad/s ²]
	full_scale_span	0.8 * E1.EMF [V]
	hysteresis	0 [%]
	max_temp	150 [°C]
	min_temp	-50 [°C]
	temp_hysteresis	0 [%]
	tempco_span	0.2 [%/ (°C)]
	temp_sens_offset	0 [V/(°C)]
	supply current	2m [A]
	nonlinearity	1 [%]
Voltage Source E1	EMF	5 [V]

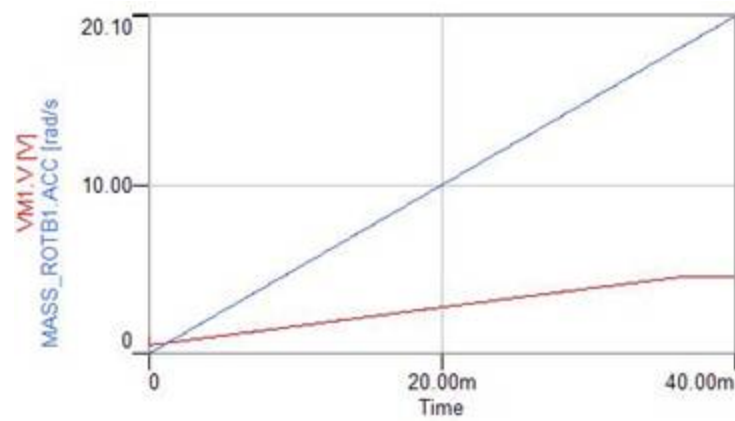


Figure 3. Simulation results-output voltage of C_ALPHA_DF_I21 and acceleration of MASS_ROTBI

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References

Level 2 Inertia Switch Angular Acceleration Sensor (Displacement-force)

Library: Add Ons/-sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

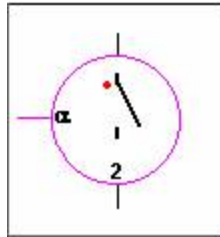


Figure 1. Component symbol

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Description

The Level 2 Inertia Switch Angular Acceleration (Displacement-Force) sensor model is used to simulate the non-ideal behavior of an inertia switch angular acceleration sensor in the Twin Builder displacement-force rotational domain. When the angular acceleration applied to the sensor exceeds a specified threshold value, its switch changes state from open to closed.

The model has one conservative input pin in the displacement-force rotational domain for its angular acceleration input and two conservative electrical-domain pins for its positive and negative terminals. The positive terminal is the one into which current flows.

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Mathematical Description

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Netlist Syntax

MODEL INERTIA_SWITCH_DF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
 ANGULAR:= %0, np:= %1, nm:= %2 (threshold:= @threshold, switch_resistance:= @switch_
 resistance, meas_error:= @meas_error) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
ANGULAR	Measured angular acceleration	Rotational
np	Positive terminal	Electrical
nm	Negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
threshold	Threshold angular acceleration of the switch	Real	50 [Rad/s ²]
switch_resistance	Switch on-state resistance	Real	0 [Ohm]
meas_error	Percent measurement error	Real	0 [%]

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Example

In this example, the Inertia Switch Angular Acceleration (Displacement-Force) sensor INERTIA_SWITCH_DF_I21 measures the angular velocity of the Mass MASS_ROT B1. When the angular acceleration of Mass MASS_ROT B1 exceeds a specified threshold value, INERTIA_SWITCH_DF_I21 switches from open to close. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

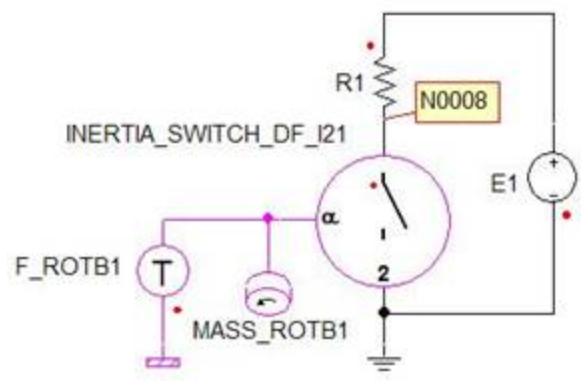


Figure 2. Application example of the Inertia Switch Angular Acceleration (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROT B1	VALUE	$6 * ((t-20m)/20m) * (t \geq 20m)$ [Nm]
	J	1 [kg m]
	PHI0	0 [rad]
Mass MASS_ROT B1	OMEGA0	0 [rad/s]
	threshold	4.5 [rad/s ²]
	switch_resistance	10 [Ohm]
Inertia Switch Angular Acceleration (Displacement-Force) sensor INERTIA_SWITCH_DF_I21	meas_error	-10 [%]
	EMF	5 [V]
	R	1k [Ohm]

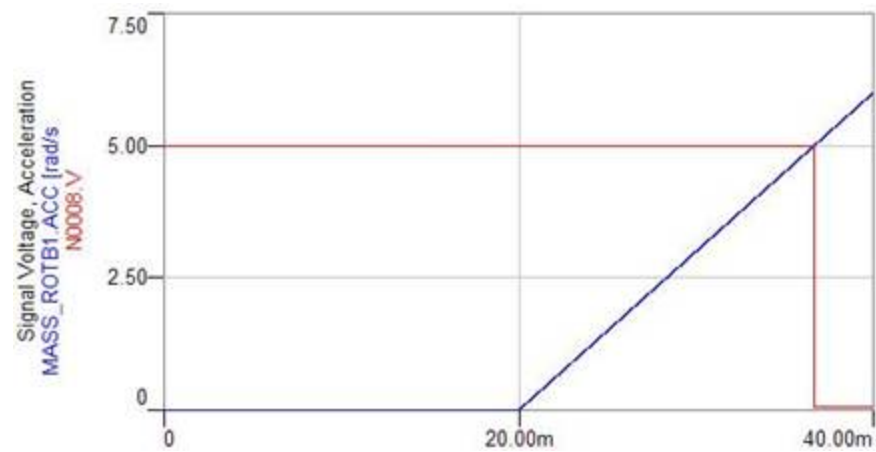


Figure 3. Simulation results-acceleration of MASS_ROT B1 and output voltage of INERTIA_SWITCH_DF_I21

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References

Level 2 Piezoelectric Angular Acceleration Sensor (Displacement-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

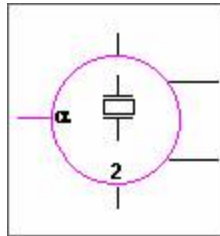


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Description

The Level 2 Piezoelectric Angular Acceleration (Displacement-Force) sensor model is used to simulate the non-ideal behavior of a piezoelectric angular acceleration sensor in the Twin Builder displacement-force rotational domain. A change in the model's angular acceleration input produces a corresponding change in the model's linear voltage output.

The model has one conservative input pin in the displacement-force rotational domain for its angular acceleration input and four conservative electrical-domain pins, two for its power supply connections and two for its voltage output. The negative output terminal should be connected to an electrical ground if the model is connected to an electrical network in which no other component is grounded.

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Netlist Syntax

```
MODEL PE_ALPHA_DF_I2 ?InstanceName(@InstanceName):(@Refbase)@(ID))
ANGULAR:= %0, OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 ( max_alpha:= @max_
alpha, min_alpha:= @min_alpha, full_scale_span:= @full_scale_span, offset:= @offset, sup-
ply_current:= @supply_current, nonlinearity:= @nonlinearity, hysteresis:= @hysteresis, max_
temp:= @max_temp, min_temp:= @min_temp, temp_hysteresis:= @temp_hysteresis, tempco_
span:= @tempco_span, temp_sens_offset:= @temp_sens_offset, corner_frequency:=
@corner_frequency, temp:= @temp, output_resistance:= @output_resistance) SRC: DB(Lib:-
:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
ANGULAR	Measured angular acceleration	Rotational
OUT_P	Positive terminal	Electrical
OUT_M	Negative terminal	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
corner_fre-	Input signal corner frequency	Real	0 [Hz]

quency			
temp	Device temperature	Real	27 [°C]
output_resistance	Output resistance	Real	0 [Ohm]
max_alpha	Maximum measurable angular acceleration	Real	50 [rad/s ²]
min_alpha	Minimum measurable angular acceleration	Real	0 [rad/s ²]
full_scale_span	Difference of output voltages at maximum and minimum angular accelerations	Real	5 [V]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	150 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
supply_current	Supply current	Real	1m [A]
nonlinearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]

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Example

In this example, the Piezoelectric Angular Acceleration (Displacement-Force) sensor PE_ALPHA_DF_I21 measures the angular velocity of the Mass MASS_ROT B1. A change in the angular acceleration input of MASS_ROT B1 produces a corresponding change in the linear voltage output of PE_ALPHA_DF_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

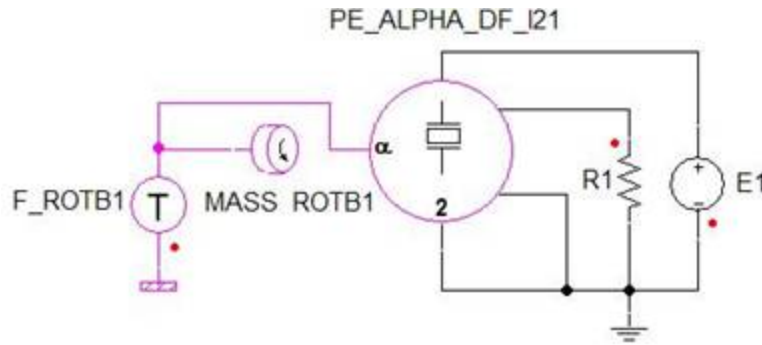


Figure 2. Application example of the Piezoelectric Angular Acceleration (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROT B1	VALUE	20 * (t/40m) [Nm]
Mass MASS_ROT B1	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Piezoelectric Angular Acceleration (Displacement-Force) sensor PE_ALPHA_DF_I21	offset	0.1 * E1.EMF [V]
	corner_frequency	0 [Hz]
	temp	27 [°C]

	output_resistance	10 [Ohm]
	max_alpha	18 [rad/s ²]
	min_alpha	0 [rad/s ²]
	full_scale_span	0.9 * E1.EMF [V]
	hysteresis	0 [%]
	max_temp	150 [°C]
	min_temp	-50 [°C]
	temp_hysteresis	0 [%]
	tempco_span	0.2 [%/ (°C)]
	temp_sens_offset	0 [V/(°C)]
	supply_current	5m [A]
	nonlinearity	1 [%]
Voltage Source E1	EMF	5 [V]

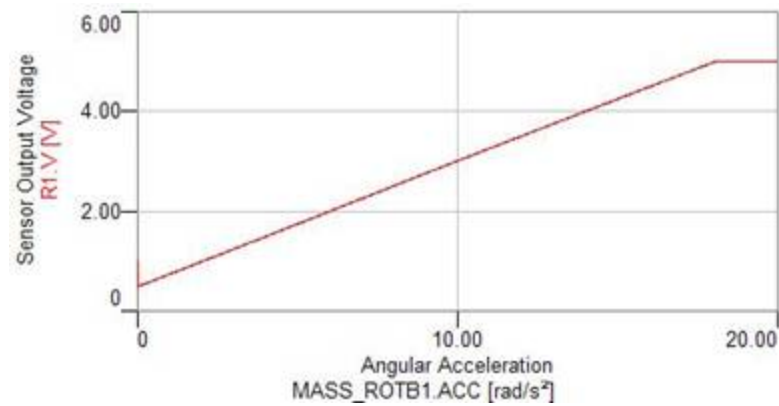


Figure 3. Simulation results-output voltage of PE_ALPHA_DF_I21 vs. acceleration of MASS_ROT1

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References

Level 2 Piezoresistive Angular Acceleration Sensor (Displacement-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

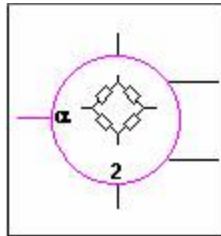


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Description

The Level 2 Piezoresistive Angular Acceleration (Displacement-Force) sensor model is used to simulate the non-ideal behavior of a piezoresistive angular acceleration sensor in the Twin Builder displacement-force rotational domain. A change in the model's angular acceleration input produces a corresponding change in the model's Wheatstone bridge, which in turn produces a change in the model's linear voltage output.

The model has one conservative input pin in the displacement-force rotational domain for its angular acceleration input and four conservative electrical-domain pins. Two of the pins are for the model's power supplies, and two are for its differential voltage output.

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Netlist Syntax

```
MODEL PR_ALPHA_DF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
ANGULAR:= %0, OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 ( max_alpha:= @max_
alpha, min_alpha:= @min_alpha, full_scale_span:= @full_scale_span, offset:= @offset, max_
nonlinearity:= @max_nonlinearity, hysteresis:= @hysteresis, max_temp:= @max_temp, min_
temp:= @min_temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span,
temp_sens_offset:= @temp_sens_offset, corner_frequency:= @corner_frequency, temp:=
@temp, resistor_tempco:= @resistor_tempco, nominal_res_temp:= @nominal_res_temp, p_
resistance:= @p_resistance) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
ANGULAR	Measured angular acceleration	Rotational
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
corner_fre-	Input signal corner frequency	Real	0 [Hz]

quency			
temp	Device temperature	Real	27 [°C]
max_alpha	Maximum measurable angular acceleration	Real	50 [rad/s ²]
min_alpha	Minimum measurable angular acceleration	Real	0 [rad/s ²]
full_scale_span	Difference of output voltages at maximum and minimum angular accelerations	Real	5 [V]
max_non-linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	150 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
p_resistance	Bridge resistance	Real	10k [Ohm]
resistor_tempco	Bridge resistor temperature coefficient	Real	0 [%/(°C)]
nominal_res_	Temperature for bridge resistor	Real	25 [°C]

temp	nominal resistance		

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Example

In this example, the Piezoresistive Angular Acceleration (Displacement-Force) sensor PR_ALPHA_DF_I22 measures the angular velocity of the Mass MASS_ROTB1. A change in the angular acceleration of MASS_ROTB1 produces a corresponding change in the linear voltage output of PR_ALPHA_DF_I22. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

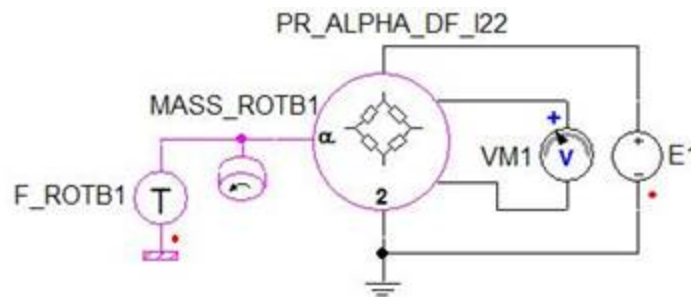


Figure 2. Application example of the Piezoresistive Angular Acceleration (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROTB1	VALUE	20 * (t/40m) [Nm]
Mass MASS_ROTB1	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Piezoresistive Angular Acceleration (Displacement-Force) sensor PR_ALPHA_DF_I22	offset	0.1 * E1.EMF [V]
	corner_frequency	18 [Hz]

	temp	27 [°C]
	max_alpha	50 [rad/s ²]
	min_alpha	0 [rad/s ²]
	full_scale_span	0.9 * E1.EMF [V]
	max_non-linearity	0 [%]
	hysteresis	0 [%]
	max_temp	150 [°C]
	min_temp	-50 [°C]
	temp_hys-teresis	0 [%]
	tempco_span	0.2 [%/ (°C)]
	temp_sens_offset	1m [V/(°C)]
	p_resistance	2k [Ohm]
	resistor_tem-pco	0 [%/(°C)]
	nominal_res_temp	25 [°C]
Voltage Source E1	EMF	5 [V]

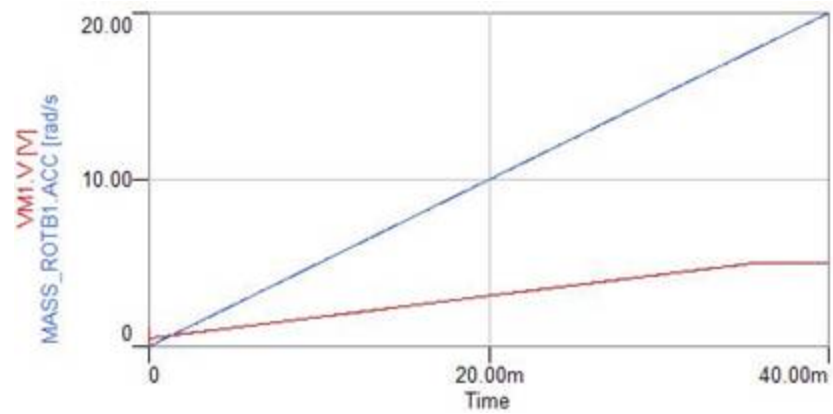


Figure 3. Simulation results-output voltage of PR_ALPHA_DF_I22 and acceleration of MASS_ROT1

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References

Level 2 Capacitive Angular Acceleration Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

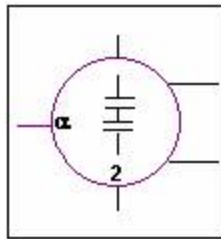


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Description

The Level 2 Capacitive Angular Acceleration (Velocity-Force) sensor model is used to simulate the non-ideal behavior of a conditioned capacitive angular acceleration sensor in the Twin Builder velocity-force rotational domain. A change in the model's angular acceleration input produces a corresponding change in the model's linear voltage output.

The model has one conservative input pin in the velocity-force rotational domain for its angular acceleration input and four conservative electrical-domain pins. Two of the pins are for the model's power supplies, and two are for its voltage output. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is connected to ground.

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Netlist Syntax

```
MODEL C_ALPHA_VF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) ANGULAR:=
%0, OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 ( max_alpha:= @max_alpha, min_
alpha:= @min_alpha, full_scale_span:= @full_scale_span, offset:= @offset, supply_current:=
@supply_current, nonlinearity:= @nonlinearity, hysteresis:= @hysteresis, max_temp:= @max_
temp, min_temp:= @min_temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tem-
pco_span, temp_sens_offset:= @temp_sens_offset, corner_frequency:= @corner_frequency,
temp:= @temp, output_resistance:= @output_resistance) SRC: DB(Lib:=@ModelLibraryName)
;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
ANGULAR	Measured angular acceleration	Rotational_V
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
corner_fre-	Input signal corner frequency	Real	0 [Hz]

quency			
temp	Device temperature	Real	27 [°C]
output_resistance	Output resistance	Real	0 [Ohm]
max_alpha	Maximum measurable angular acceleration	Real	50 [rad/s ²]
min_alpha	Minimum measurable angular acceleration	Real	0 [rad/s ²]
full_scale_span	Difference of output voltages at maximum and minimum angular accelerations	Real	5 [V]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	150 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
supply_current	Typical supply current	Real	5m [A]
nonlinearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]

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Example

In this example, the Capacitive Angular Acceleration (Velocity-Force) sensor C_ALPHA_VF_I21 measures the angular velocity of the Mass MASS_ROT1. A change in the angular acceleration of MASS_ROT1 produces a corresponding change in the linear voltage output of C_ALPHA_VF_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

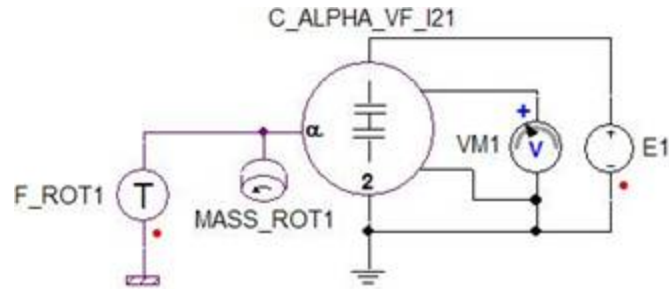


Figure 2. Application example of the Capacitive Angular Acceleration (Velocity-Force) sensor**Table 3**

Component	Parameter	Value [Unit]
Torque Source F_ROT1	VALUE	20 * (t/40m) [Nm]
Mass MASS_ROT1	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Capacitive Angular Acceleration (Velocity-Force) sensor C_ALPHA_VF_I21	offset	0.1* E1.EMF [V]
	corner_frequency	0 [Hz]
	temp	27 [°C]
	output_resistance	0 [Ohm]
	max_alpha	18 [rad/s ²]
	min_alpha	0 [rad/s ²]
	full_scale_span	0.8 * E1.EMF [V]
	hysteresis	0 [%]
	max_temp	150 [°C]

	min_temp	-50 [°C]
	temp_hys-teresis	0 [%]
	tempco_span	0.2 [%/(°C)]
	temp_sens_offset	0 [V/(°C)]
	supply cur-rent	2m [A]
	nonlinearity	1 [%]
Voltage Source E1	EMF	5 [V]

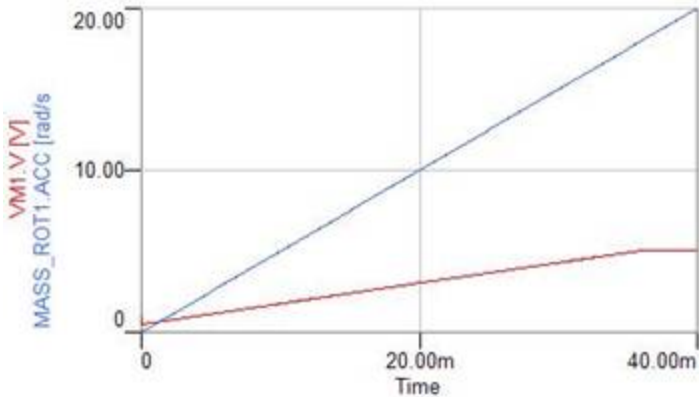


Figure 3. Simulation results-output voltage of C_ALPHA_VF_I21 and acceleration of MASS_ROT1

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References

Level 2 Inertia Switch Angular Acceleration Sensor (Velocity-force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

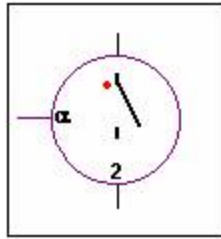


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Description

The Level 2 Inertia Switch Angular Acceleration (Velocity-Force) sensor model is used to simulate the non-ideal behavior of an inertia switch angular acceleration sensor in the Twin Builder velocity-force rotational domain. When the angular acceleration applied to the sensor exceeds a specified threshold value, its switch changes state from open to closed.

The model has one conservative input pin in the velocity-force rotational domain for its angular acceleration input and two conservative electrical-domain pins for its positive and negative terminals. The positive terminal is the one into which current flows.

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Netlist Syntax

MODEL INERTIA_SWITCH_VF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID))
np:= %0, nm:= %1, ANGULAR:= %2 (threshold:= @threshold, switch_resistance:= @switch_
resistance, meas_error:= @meas_error) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
ANGULAR	Measured angular acceleration	Rotational_V
np	Positive terminal	Electrical
nm	Negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
threshold	Threshold angular acceleration of the switch	Real	50 [rad/s ²]
switch_resistance	Switch on-state resistance	Real	0 [Ohm]
meas_error	Percent measurement error	Real	0 [%]

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Example

In this example, the Inertia Switch Angular Acceleration (Velocity-Force) sensor INERTIA_SWITCH_VF_I21 measures the angular velocity of the Mass MASS_ROT1. When the angular acceleration of Mass MASS_ROT1 exceeds a specified threshold value, INERTIA_SWITCH_VF_I21 switches from open to close. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

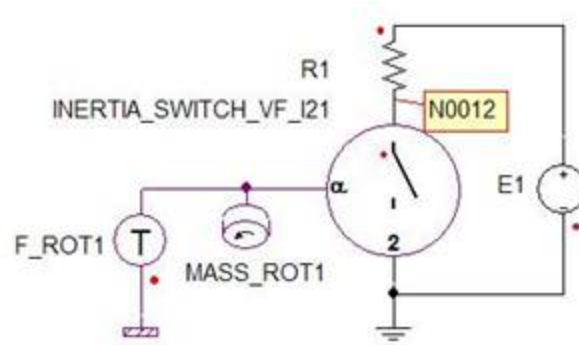


Figure 2. Application example of the Inertia Switch Angular Acceleration (Velocity-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROT1	VALUE	$6 * ((t-20m)/20m) * (t>20m)$ [Nm]
Mass $MASS\_ROT1$	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Inertia Switch Angular Acceleration (Velocity-Force) sensor $INERTIA\_SWITCH\_VF\_I21$	threshold	4.5 [rad/s ²]
	switch_resistance	10 [Ohm]
	meas_error	-10 [%]
Voltage Source $E1$	EMF	5 [V]
Resistor $R1$	R	1k [Ohm]

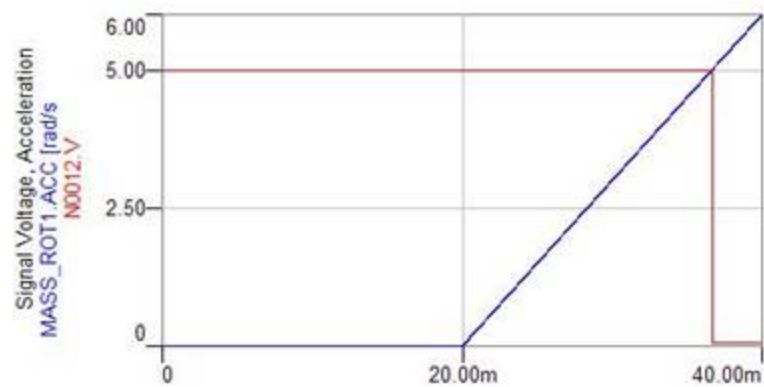


Figure 3. Simulation results-acceleration of MASS_ROT1 and output voltage of INERTIA_SWITCH_VF_I21

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References

Level 2 Piezoelectric Angular Acceleration Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

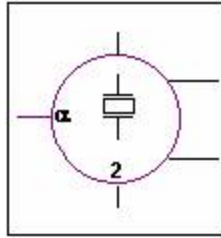


Figure 1. Component symbol

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Description

The Level 2 Piezoelectric Angular Acceleration (Velocity-Force) sensor model is used to simulate the non-ideal behavior of a piezoelectric angular acceleration sensor in the Twin Builder velocity-force rotational domain. A change in the model's angular acceleration input produces a corresponding change in the model's linear voltage output.

The model has one conservative input pin in the velocity-force rotational domain for its angular acceleration input and four conservative electrical-domain pins, two for its power supply connections and two for its voltage output. The negative output terminal should be connected to an electrical ground if the model is connected to an electrical network in which no other component is grounded.

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Netlist Syntax

```
MODEL PE_ALPHA_VF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
ANGULAR:= %0, OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 ( max_alpha:= @max_
alpha, min_alpha:= @min_alpha, full_scale_span:= @full_scale_span, offset:= @offset, sup-
ply_current:= @supply_current, nonlinearity:= @nonlinearity, hysteresis:= @hysteresis, max_
temp:= @max_temp, min_temp:= @min_temp, temp_hysteresis:= @temp_hysteresis, tempco_
span:= @tempco_span, temp_sens_offset:= @temp_sens_offset, corner_frequency:=
@corner_frequency, temp:= @temp, output_resistance:= @output_resistance) SRC: DB(Lib:-
:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
ANGULAR	Measured angular acceleration	Rotational_V
OUT_P	Positive terminal	Electrical
OUT_M	Negative terminal	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
corner_fre-	Input signal corner frequency	Real	0 [Hz]

quency			
temp	Device temperature	Real	27 [°C]
output_resistance	Output resistance	Real	0 [Ohm]
max_alpha	Maximum measurable angular acceleration	Real	50 [rad/s ²]
min_alpha	Minimum measurable angular acceleration	Real	0 [rad/s ²]
full_scale_span	Difference of output voltages at maximum and minimum angular accelerations	Real	5 [V]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	150 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
supply_current	Supply current	Real	1m [A]
nonlinearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]

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Example

In this example, the Piezoelectric Angular Acceleration (Velocity-Force) sensor PE_ALPHA_VF_I21 measures the angular velocity of the Mass MASS_ROT1. A change in the angular acceleration input of MASS_ROT1 produces a corresponding change in the linear voltage output of PE_ALPHA_VF_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

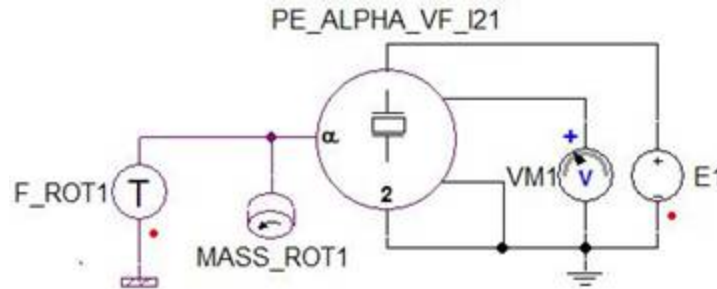


Figure 2. Application example of the Piezoelectric Angular Acceleration (Velocity-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROT1	VALUE	20 * (t/40m) [Nm]
Mass MASS_ROT1	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Piezoelectric Angular Acceleration (Velocity-Force) sensor PE_ALPHA_VF_I21	offset	0.1 * E1.EMF [V]
	corner_frequency	0 [Hz]
	temp	27 [°C]
	output_res-	10 [Ohm]

	istance	
	max_alpha	18 [rad/s ²]
	min_alpha	0 [rad/s ²]
	full_scale_span	0.8 * E1.EMF [V]
	hysteresis	0 [%]
	max_temp	150 [°C]
	min_temp	-50 [°C]
	temp_hys- teresis	0 [%]
	tempco_span	0.2 [%/ (°C)]
	temp_sens_ offset	0 [V/(°C)]
	supply_cur- rent	5m [A]
	nonlinearity	1 [%]
Voltage Source E1	EMF	5 [V]

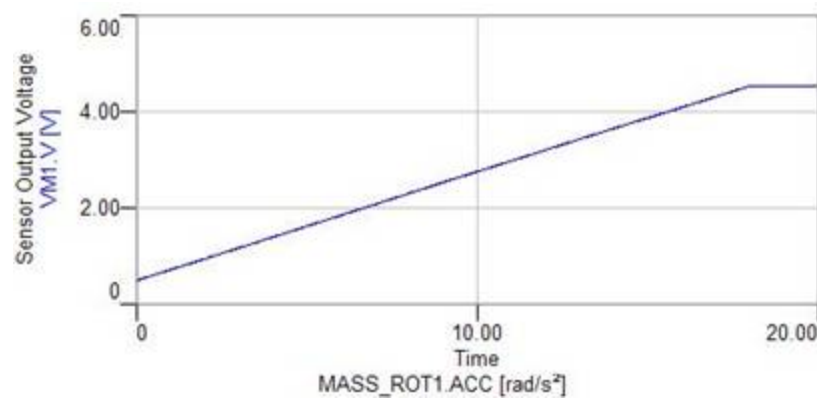


Figure 3. Simulation results-output voltage of PE_ALPHA_VF_I21 vs. acceleration of MASS_ROT1

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References

Level 2 Piezoresistive Angular Acceleration Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

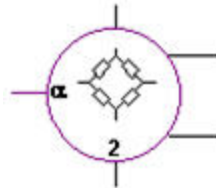


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Description

The Level 2 Piezoresistive Angular Acceleration (Velocity-Force) sensor model is used to simulate the non-ideal behavior of a piezoresistive angular acceleration sensor in the Twin Builder velocity-force rotational domain. A change in the model's angular acceleration input produces a corresponding change in the model's Wheatstone bridge, which in turn produces a change in the model's linear voltage output.

The model has one conservative input pin in the velocity-force rotational domain for its angular acceleration input and four conservative electrical-domain pins. Two of the pins are for the model's power supplies, and two are for its differential voltage output.

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Netlist Syntax

```
MODEL PR_ALPHA_VF_I2 ?InstanceName(@InstanceName):(@Refbase)@(ID))
ANGULAR:= %0, OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 ( max_alpha:= @max_
alpha, min_alpha:= @min_alpha, full_scale_span:= @full_scale_span, offset:= @offset, max_
nonlinearity:= @max_nonlinearity, hysteresis:= @hysteresis, max_temp:= @max_temp, min_
temp:= @min_temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span,
temp_sens_offset:= @temp_sens_offset, corner_frequency:= @corner_frequency, temp:=
@temp, resistor_tempco:= @resistor_tempco, nominal_res_temp:= @nominal_res_temp, p_
resistance:= @p_resistance) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
ANGULAR	Measured angular acceleration	Rotational_V
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
corner_fre-	Input signal corner frequency	Real	0 [Hz]

quency			
temp	Device temperature	Real	27 [°C]
max_alpha	Maximum measurable angular acceleration	Real	50 [rad/s ²]
min_alpha	Minimum measurable angular acceleration	Real	0 [rad/s ²]
full_scale_span	Difference of output voltages at maximum and minimum angular accelerations	Real	5 [V]
max_non-linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	150 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
p_resistance	Bridge resistance	Real	10k [Ohm]
resistor_tempco	Bridge resistor temperature coefficient	Real	0 [%/(°C)]
nominal_res_	Temperature for bridge resistor	Real	25 [°C]

temp	nominal resistance		

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Example

In this example, the Piezoresistive Angular Acceleration (Velocity-Force) sensor PR_ALPHA_VF_I22 measures the angular velocity of the Mass MASS_ROT1. A change in the angular acceleration of MASS_ROT1 produces a corresponding change in the linear voltage output of PR_ALPHA_VF_I22. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

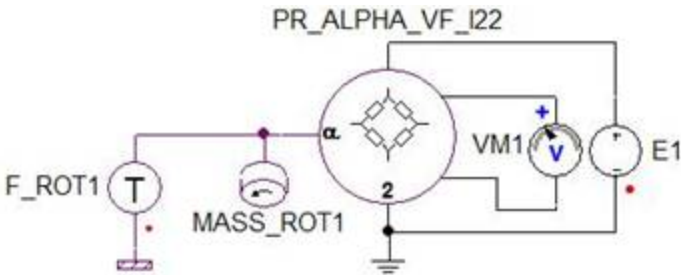


Figure 2. Application example of the Piezoresistive Angular Acceleration (Velocity-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROT1	VALUE	20 * (t/40m) [Nm]
	J	1 [kg m]
	PHI0	0 [rad]
Mass MASS_ROT1	OMEGA0	0 [rad/s]
	offset	0.1 * E1.EMF [V]
	corner_frequency	18 [Hz]
Piezoresistive Angular Acceleration (Velocity-Force) sensor PR_ALPHA_VF_I22		

	temp	27 [°C]
	max_alpha	50 [rad/s ²]
	min_alpha	0 [rad/s ²]
	full_scale_span	0.9 * E1.EMF [V]
	max_non-linearity	0 [%]
	hysteresis	0 [%]
	max_temp	150 [°C]
	min_temp	-50 [°C]
	temp_hys-teresis	0 [%]
	tempco_span	0.2 [%/ (°C)]
	temp_sens_offset	1m [V/(°C)]
	p_resistance	2k [Ohm]
	resistor_tem-pco	0 [%/(°C)]
	nominal_res_temp	25 [°C]
Voltage Source E1	EMF	5 [V]

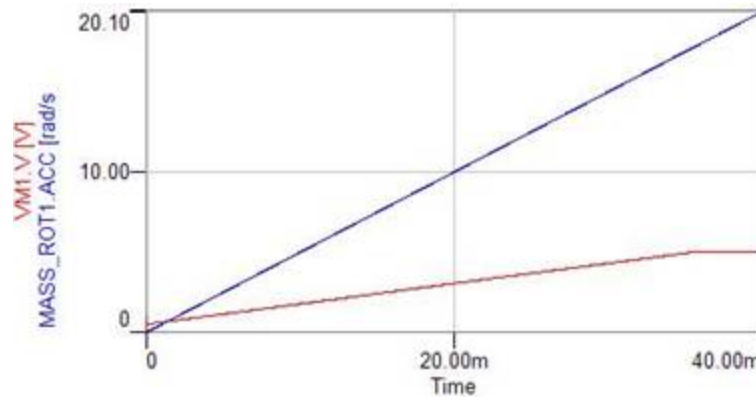


Figure 3. Simulation results-output voltage of PR_ALPHA_VF_I22 and acceleration of MASS_ROT1

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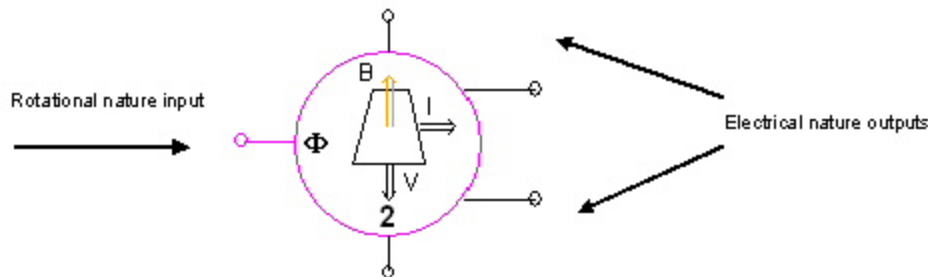
References

Level 2 Angular Position Sensor Models

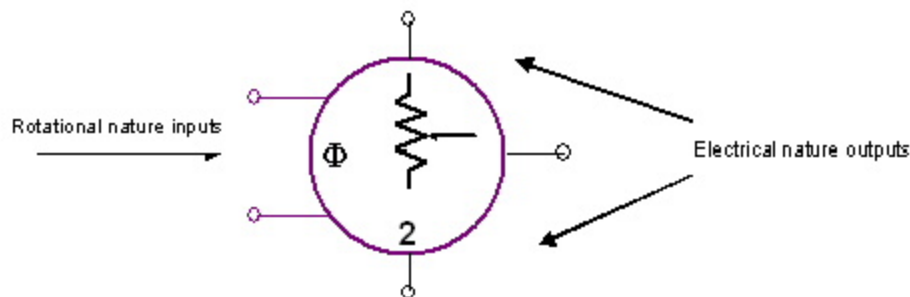
The Level 2 Angular Position Sensor Models simulate realistic non-ideal behavior of eight different types of angle sensors. Models are available for use with the Twin Builder *displacement-force* and *velocity-force* rotational domains.

All of the angle sensor models have conservative input pins that must be connected to a rotational network and conservative output pins that must be connected to an electrical network. The models also feature nonconservative parameters that can be changed in order to tailor the behavior of the model to that of a specific real device.

As shown in the following example, angular position sensor models for the displacement-force rotational domain have pink conservative input pins that must be connected to a displacement-force rotational network. The models also have black conservative pins that must be connected to an electrical network.



Similarly, angular position sensor models for the velocity-force rotational domain have purple rotational nature input pins and black electrical nature pins.



The Level 2 Angular Position Sensor Models feature models for the following angle sensing mechanisms:

- **Absolute Encoder:** Angular position is encoded as a 6 to 16-bit binary number.
Displacement-Force model: ([ABS_ENCODER_DF_I2](#))
Velocity-Force model: ([ABS_ENCODER_VF_I2](#))
- **Microswitch:** The angular displacement past a specified threshold position causes a switch to toggle from its normally closed pin to its normally open pin.

Displacement-Force model: ([AMSWITCH_DF_I2](#))

Velocity-Force model: ([AMSWITCH_VF_I2](#))

- Anisotropic Magnetoresistive (AMR): A change in the angle produces a change in the two AC outputs, which vary as $\sin(2\alpha)$ and $\cos(2\alpha)$.

Displacement-Force model: ([ANG_DISP_AMR_DF_I2](#))

Velocity-Force model: ([ANG_DISP_AMR_VF_I2](#))

- Potentiometric: A change in angle moves a potentiometer wiper, producing a change in the voltage divider output signal.

Displacement-Force model: ([ANG_DISP_DF_I2](#))

Velocity-Force model: ([ANG_DISP_VF_I2](#))

- Hall-Effect: A change in angular position produces a corresponding linear change in the output voltage signal.

Displacement-Force model: ([ANG_DISP_HE_DF_I2](#))

Velocity-Force model: ([ANG_DISP_HE_VF_I2](#))

- Incremental Encoder: When a reference position is passed, an angular displacement produces two output pulse trains in quadrature and a reference pulse.

Displacement-Force model: ([INC_ENCODER_DF_I2](#))

Velocity-Force model: ([INC_ENCODER_VF_I2](#))

- Synchro Resolver: Angular motion causes a two-secondary transformer to produce two output signals that vary as the sine and cosine of the angular position.

Displacement-Force model: ([RESOLVER_DF_I2](#))

Velocity-Force model: ([RESOLVER_VF_I2](#))

- Rotational Variable Differential Transformer (RVDT): Angular motion changes the extent of the coupling between a primary winding and two secondary windings, producing variations in the amplitude and phase of an AC output signal.

Displacement-Force model: ([RVDT_DF_I2](#))

Velocity-Force model: ([RVDT_VF_I2](#))

Level 2 Absolute Encoder Angular Position Sensor (Displacement-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

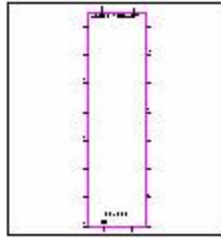


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Description

An absolute encoder angle sensor translates absolute angular position to a natural binary output. The precision of the output, i.e. the number of bits that make up the output, is determined by the number of equally spaced position indicators that are available on the sensor. For example, an angle sensor with sixteen position indicators would have a four-bit output.

The Level 2 Absolute encoder Angular Position (Displacement-Force) sensor model is used to simulate the non-ideal behavior of a 6 to 16-bit absolute encoder angle sensor in the Twin Builder displacement-force rotational domain. The model has a conservative input pin with a rotational nature and nineteen conservative electrical-nature pins. Two of the pins are used to connect the model to a power supply and a ground. One pin is used for the sensor's output-enable signal. The remaining pins are for the sixteen possible binary outputs.

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Netlist Syntax

```
MODEL ABS_ENCODER_DF_I2 ?InstanceName(@InstanceName):(@@Refbase)@(ID)) PHI:=
%0, Vdd:= %1, Vss:= %2, BIT_15:= %3, BIT_14:= %4, BIT_13:= %5, BIT_12:= %6, BIT_11:=
%7, BIT_10:= %8, BIT_9:= %9, BIT_8:= %10, BIT_7:= %11, BIT_6:= %12, BIT_5:= %13, BIT_
4:= %14, BIT_3:= %15, BIT_2:= %16, BIT_1:= %17, BIT_0:= %18, LE:= %19 ( resolution:=
@resolution, max_amplitude:= @max_amplitude, min_amplitude:= @min_amplitude, supply_
current:= @supply_current, latch_threshold:= @latch_threshold, output_resistance:= @output_
resistance, response_time:= @response_time, error:= @error) SRC: DB(Lib:-
:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational
Vdd	Positive power supply terminal Vdd	Electrical
Vss	Negative power supply terminal Vss	Electrical
BIT_0 (See Note)	Output bit zero	Electrical
BIT_1 (See Note)	Output bit one	Electrical
BIT_2 (See Note)	Output bit two	Electrical
BIT_3 (See Note)	Output bit three	Electrical
BIT_4 (See Note)	Output bit four	Electrical

BIT_5 (See Note)	Output bit five	Electrical
BIT_6 (See Note)	Output bit six	Electrical
BIT_7 (See Note)	Output bit seven	Electrical
BIT_8 (See Note)	Output bit eight	Electrical
BIT_9 (See Note)	Output bit nine	Electrical
BIT_10 (See Note)	Output bit ten	Electrical
BIT_11 (See Note)	Output bit eleven	Electrical
BIT_12 (See Note)	Output bit twelve	Electrical
BIT_13 (See Note)	Output bit thirteen	Electrical
BIT_14 (See Note)	Output bit fourteen	Electrical
BIT_15 (See Note)	Output bit fifteen	Electrical
LE	Output enable	Electrical

Note: Terminal set to No Action when unconnected. Terminal may remain unconnected without generating an error.

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
latch_threshold	Output enable threshold voltage	Real	2.5 [V]
output_resistance	Output resistance at each output pin	Real	0 [Ohm]
resolution	Number of bits available at output	Real	16
max_amplitude	Logic 1 output amplitude	Real	5 [V]
min_amplitude	Logic 0 output amplitude	Real	0 [V]
supply_current	Supply current	Real	20m [A]
response_time	Time lapse between rising edge of output enable signal and change in binary output	Real	0 [s]
error	Percent measurement error	Real	0 [%]

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Example

In this example, the Absolute Encoder Angular Position Sensor (Displacement-Force) ABS_ENCODER_DF_I22 measures the angular position of the Mass MASS_ROTb1, and the encoded measurement results are sent out through its output channels. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3-12.

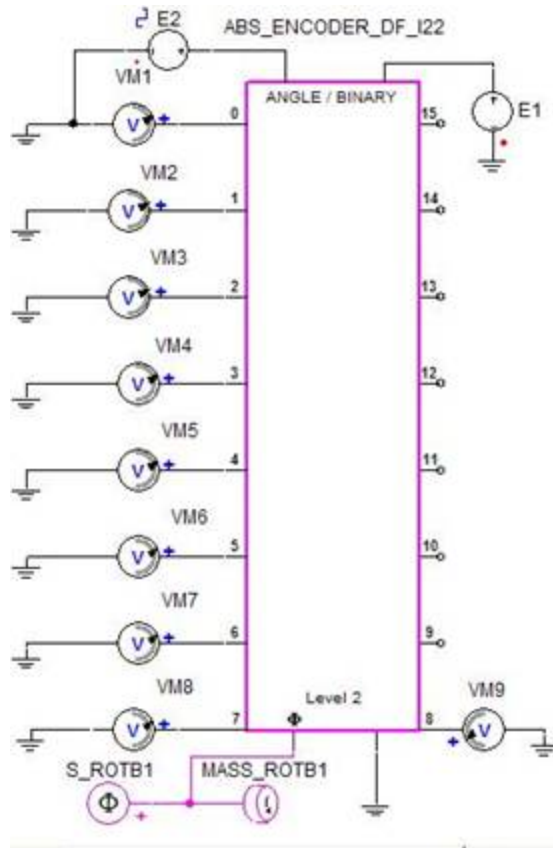


Figure 2. Application example of the Absolute Encoder Angular Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Angle Source S_ROT B1	VALUE	$(2 * \pi) * (t/40m)$ [rad]
Voltage Source E1	EMF	5 [V]
Voltage Source (pulse) E2	AMPL	2.5 [V]
	FREQ	100 [Hz]
	PHASE	0 [degree]

	OFF	2.5 [V]
	TDELAY	0 [s]
	J	1 [kg m ²]
Mass MASS_ROTb1	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Absolute Encoder Angular Position Sensor (Displacement-Force) ABS_ENCODER_DF_I22	latch_threshold	2.4 [V]
	output_resistance	0 [Ohm]
	resolution	9
	max_amplitude	4 [V]
	min_amplitude	1 [V]
	supply_current	30m [A]
	response_time	10u [s]
	error	0 [%]

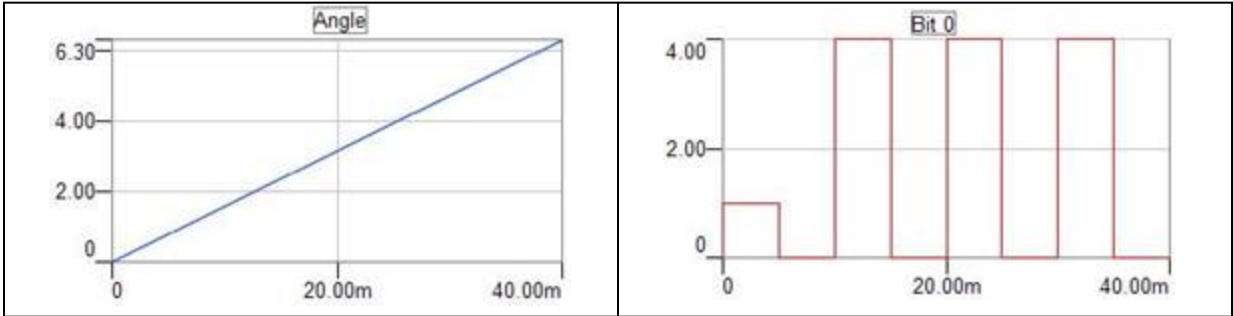
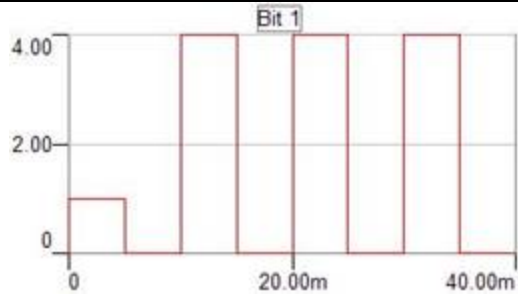
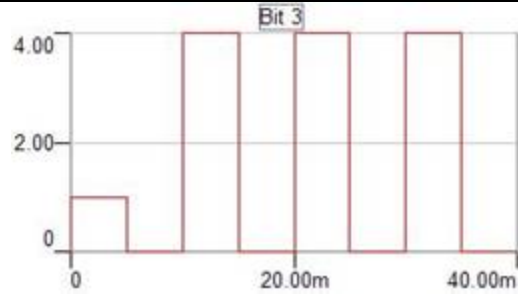
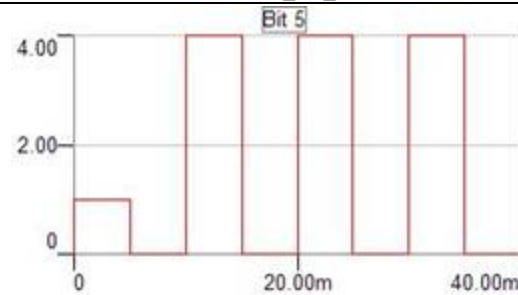
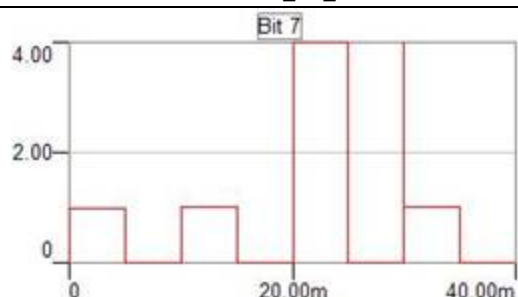
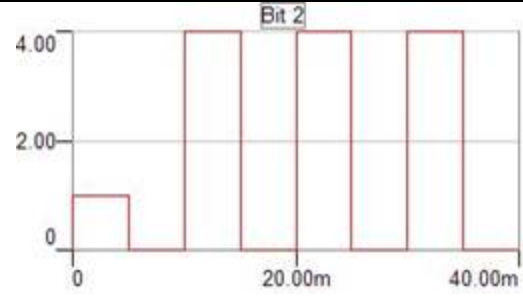
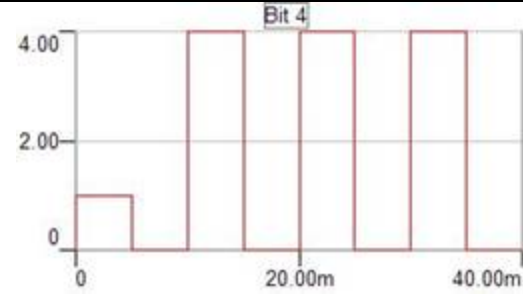
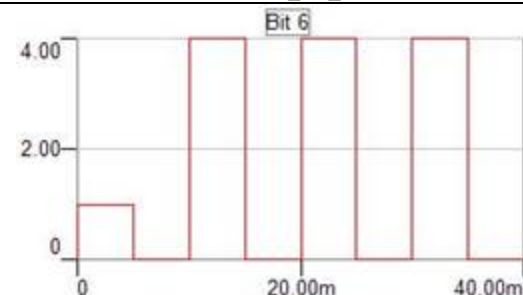
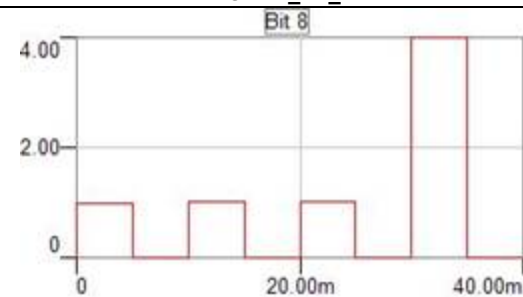


Figure 3. Simulation results-angular position of MASS_ROTBT1**Figure 5. Simulation results-output bit1 of ABS_ENCODER_DF_I22****Figure 7. Simulation results-output bit3 of ABS_ENCODER_DF_I22****Figure 9. Simulation results-output bit5 of ABS_ENCODER_DF_I22****Figure 11. Simulation results-output bit7 of ABS_ENCODER_DF_I22****Figure 4. Simulation results-output bit0 of ABS_ENCODER_DF_I22****Figure 6. Simulation results-output bit2 of ABS_ENCODER_DF_I22****Figure 8. Simulation results-output bit4 of ABS_ENCODER_DF_I22****Figure 10. Simulation results-output bit6 of ABS_ENCODER_DF_I22****Figure 12. Simulation results-output bit8 of ABS_ENCODER_DF_I22**[Top](#)

References

Level 2 Microswitch Angular Position Sensor (Displacement-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

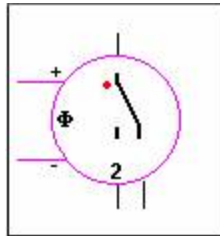


Figure 1. Component symbol

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Description

The Level 2 Microswitch Angular Position (Displacement-Force) sensor model is used to simulate the non-ideal behavior of a microswitch angle sensor in the Twin Builder displacement-force rotational domain. The microswitch model toggles from its normally closed terminal to its normally open terminal when the specified threshold angular position is exceeded by some element in the displacement-force rotational domain.

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Netlist Syntax

```
MODEL AMSWITCH_DF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) PHI:= %0,  
REF:= %1, nmnc:= %2, nmno:= %3, np:= %4 ( threshold:= @threshold, switch_resistance:=  
@switch_resistance, response_time:= @response_time) SRC: DB(Lib:=@ModelLibraryName)  
;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational
REF	Reference angle	Rotational
np	Positive terminal	Electrical
nmnc	Normally-closed negative terminal	Electrical
nmno	Normally-open negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
threshold	Threshold angle	Real	1.5707963267949 [rad]
switch_resistance	Switch on-state resistance	Real	0 [Ohm]
response_time	Switch response time	Real	0 [s]

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Example

In this example, when the angular position of the Mass MASS_ROTB1 is below the threshold of the Microswitch Angular Position Sensor (Displacement-Force) AMSWITCH_DF_I22, the resistor Rnc is connected to the current source via AMSWITCH_DF_I22; AMSWITCH_DF_I22 toggles from its normally closed terminal to its normally open terminal when the angular position of MASS_ROTB1 exceeds the threshold. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 - 5.

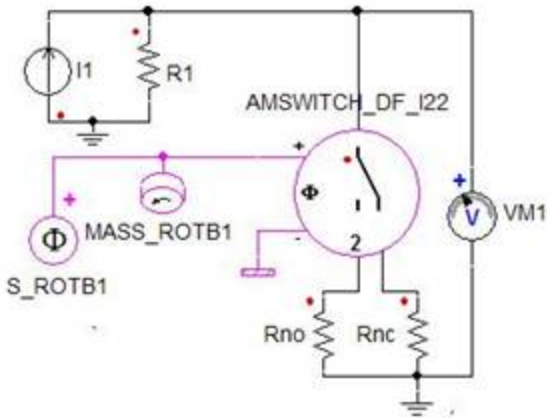


Figure 2. Application example of the Microswitch Angular Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Angle Source S_ROT B1	VALUE	$1 * (t \geq 5m) + -0.5 * (t \geq 25m)$ [rad]
Current Source I1	IS	1 [A]
Resistor Rno/Rnc	R	1k [Ohm]
Resistor R1	R	1k [Ohm]
Mass MASS_ROT B1	J	1 [kg m ²]
	PHI0	0 [rad]

	OMEGA0	0 [rad/s]
Microswitch Angular Position Sensor (Displacement-Force) AMSWITCH_ DF_I22	threshold	1 [rad]
	switch_res- istance	100m [Ohm]
	response_ time	10m [s]

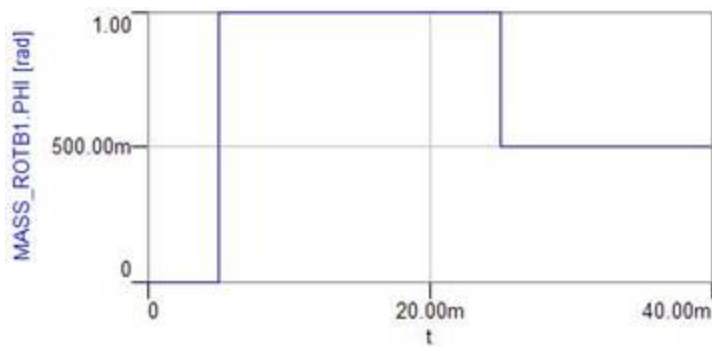


Figure 3. Simulation results- angular position of MASS_ROT B1

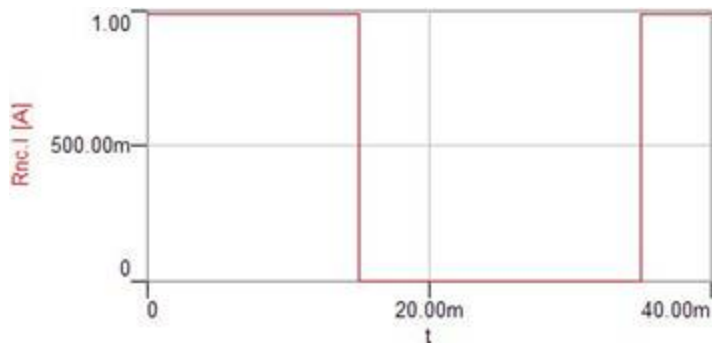


Figure 4. Simulation results- current through Rnc

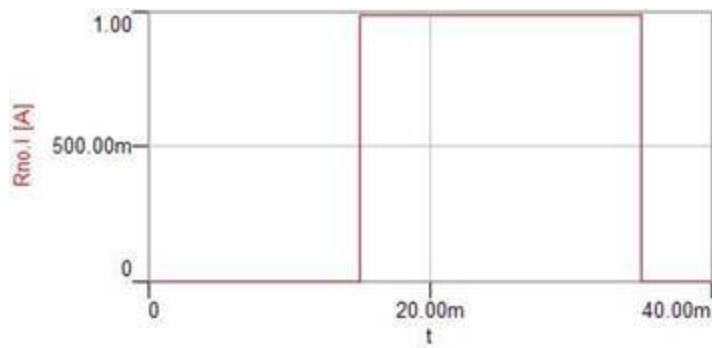


Figure 5. Simulation results- current through Rno

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References

Level 2 Anisotropic Magnetoresistive Angular Position Sensor (Displacement-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

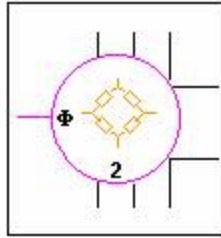


Figure 1. Component symbol

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Description

The Level 2 Anisotropic Magnetoresistive Angular Position (Displacement-Force) sensor model is used to simulate the ideal behavior of an AMR angle sensor in the Twin Builder displacement-force rotational domain. A change in the angular position of an element in the displacement-force rotational domain causes a corresponding change in the sensor model's two differential, sinusoidal voltage output signals.

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Netlist Syntax

MODEL ANG_DISP_AMR_DF_I2 ?InstanceName(@InstanceName):(@@Refbase)@(ID)) Vcc-
s:= %0, Vsss:= %1, out_pluss:= %2, out_minuss:= %3, Vccs:= %4, Vssc:= %5, out_plus:= %6,
out_minusc:= %7, PHI:= %8 (corner_frequency:= @corner_frequency, peak_s:= @peak_s,
peak_c:= @peak_c, offset_s:= @offset_s, offset_c:= @offset_c, nonlinearity:= @nonlinearity,
hysteresis:= @hysteresis, temp:= @temp, max_temp:= @max_temp, min_temp:= @min_temp,
temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span, temp_sens_offset:=
@temp_sens_offset, bridge_s_resistance:= @bridge_s_resistance, bridge_c_resistance:=
@bridge_c_resistance, resistor_tempco:= @resistor_tempco, nominal_res_temp:= @nominal_
res_temp) SRC: DB(Lib:=@ModelLibraryName);

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Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational
Vccs	Supply for the sine-output bridge	Electrical
Vccs	Supply for the cosine-output bridge	Electrical
Vsss	Ground for the sine-output bridge	Electrical
Vssc	Ground for the cosine-output bridge	Electrical
out_pluss	Positive output terminal for the sine-out-put bridge	Electrical
out_minuss	Negative output terminal for the sine-out-put bridge	Electrical
out_plus	Positive output terminal for the cosine-output bridge	Electrical
out_minusc	Negative output terminal for the cosine-output bridge	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
temp	Device temperature	Real	27 [°C]
corner_frequency	Corner frequency of input signal	Real	0 [Hz]
peak_s	Maximum amplitude of the sine output signal	Real	50m [V]
peak_c	Maximum amplitude of the cosine output signal	Real	50m [V]
offset_s	Offset of the sine output signal	Real	0 [V]
offset_c	Offset of the cosine output signal	Real	0 [V]
nonlinearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	150 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]

bridge_s_resistance	Resistance of the magnetoresistive bridge producing sine signal	Real	2k [Ohm]
bridge_c_resistance	Resistance of the magnetoresistive bridge producing cosine signal	Real	2k [Ohm]
resistor_tem_pco	Temperature coefficient of the bridge resistor	Real	0 [%/(°C)]
nominal_res_temp	Temperature at which the bridge resistors have nominal value	Real	25 [°C]

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Example

In this example, the two differential sinusoidal voltage output signals of the Anisotropic Magnetoresistive Angular Position Sensor (Displacement-Force) ANG_DISP_AMR_DF_I21 change in response to the change in angular position of the Mass MASS_ROT1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

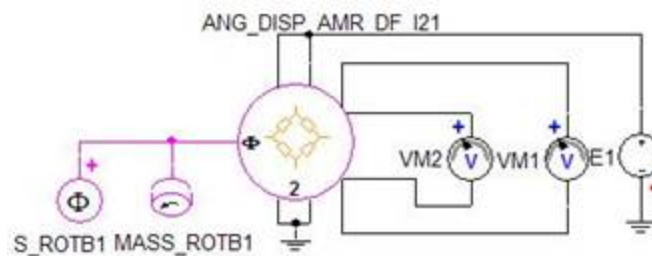


Figure 2. Application example of the Anisotropic Magnetoresistive Angular Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Angle Source S_ROT1	VALUE	$(4 * \pi) * (t/40m)$ [rad]

Voltage Source E1	EMF	5 [V]
Mass MASS_ROT B1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Anisotropic Magnetoresistive Angular Position Sensor (Displacement-Force) ANG_DISP_AMR_DF_I21	temp	27 [°C]
	corner_frequency	0 [Hz]
	peak_s	8m * E1.EMF [V]
	peak_c	8m * E1.EMF [V]
	offset_s	2m * E1.EMF [V]
	offset_c	2m * E1.EMF [V]
	nonlinearity	3k [Ohm]
	hysteresis	0.5 [%]
	max_temp	85 [°C]
	min_temp	-25 [°C]
	temp_hysteresis	0 [%]
	tempco_span	-0.3 [%/ (°C)]

	temp_sens_offset	6E-6 * E1.EMF [V/(°C)]
	bridge_s_resistance	3k [Ohm]
	bridge_c_resistance	3k [Ohm]
	resistor_tem-pco	0.3 [%/ (°C)]
	nominal_res_temp	25 [°C]

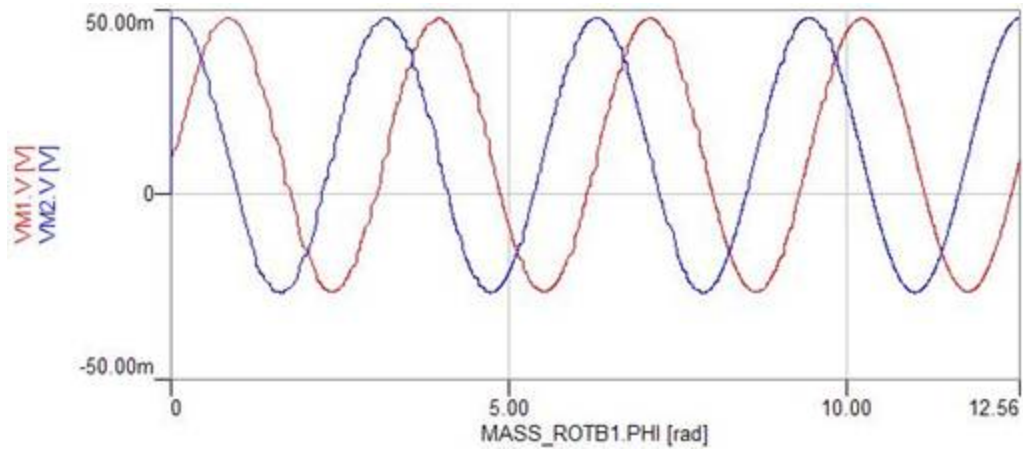


Figure 3. Simulation results- output voltages of ANG_DISP_AMR_DF_I21 as a function of its input angular position

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References

Level 2 Potentiometric Angular Position Sensor (Displacement-Force)

Library: Add Ons/-sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

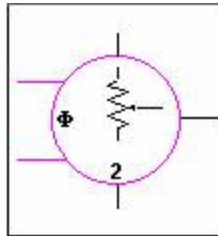


Figure 1. Component symbol

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Description

The Level 2 Potentiometric Angular Position (Displacement-Force) model is used to simulate the non-ideal behavior of a potentiometer angle sensor in the Twin Builder displacement-force rotational domain. A change in angular position of an element in the displacement-force rotational domain causes a corresponding change in the model's voltage divider output signal.

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Netlist Syntax

MODEL ANG_DISP_DF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) RPOS:= %0, Vcc:= %1, Vss:= %2, OUTPUT:= %3, PHI:= %4 (max_angle:= @max_angle, min_angle:= @min_angle, full_scale_span:= @full_scale_span, offset:= @offset, max_nonlinearity:= @max_nonlinearity, max_hysteresis:= @max_hysteresis, temp_hysteresis:= @temp_hysteresis, max_temp:= @max_temp, min_temp:= @min_temp, temp:= @temp, tempco_span:= @tempco_span, temp_sens_offset:= @temp_sens_offset, p_resistance:= @p_resistance, w_resistance:= @w_resistance, time_constant:= @time_constant) SRC: DB(Lib:- :=@ModelLibraryName) ;

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Table 1

Name	Port/Terminal Description	Nature/Data type
THETA	Measured angle	Rotational
RPOS	Reference angle	Rotational
Vcc	Positive supply	Electrical
Vss	Negative supply	Electrical
OUTPUT	Output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
p_resistance	Potentiometer resistance	Real	10k [Ohm]
max_angle	Maximum meas-	Real	6.28318530717959

	urable angle		[Rad]
min_angle	Minimum meas- urable angle	Real	0 [Rad]
full_scale_ span	Difference between the max- imum and min- imum output voltages	Real	10 [V]
time_con- stant	Output time con- stant	Real	0 [s]
temp	Device tem- perature	Real	27 [°C]
wiper_res- istance	Potentiometer wiper resistance	Real	0 [Ohm]
max_non- linearity	Nonlinearity as a percentage of full- scale span	Real	0 [%]
max_hys- teresis	Hysteresis as a percentage of full- scale span	Real	0 [%]
temp_hys- teresis	Temperature hys- teresis as a per- centage of full- scale span	Real	0 [%]
tempco_span	Output voltage tem- perature coef- ficient as a percentage of full- scale span	Real	0 [%/(°C)]
temp_sens_ offset	Offset voltage tem- perature sensitivity	Real	0 [V/(°C)]
max_temp	Maximum oper- ating temperature	Real	125 [°C]

min_temp	Minimum operating temperature	Real	-40 [°C]

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Example

In this example, the output voltage of the Potentiometric Angular Position Sensor (Displacement-Force) ANG_DSP_DF_I22 changes in response to the change in angular position of the Mass MASS_ROT1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

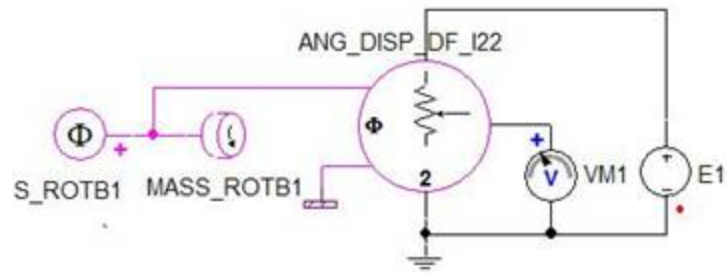


**Figure 2. Application example of the the
Potentiometric Angular Position Sensor (Displacement-Force)**

Table 3

Component	Parameter	Value [Unit]
Angle Source S_ROT B1	VALUE	$(130 * (\pi/180))/39m * t$ [rad]
Voltage Source E1	EMF	5 [V]
Mass MASS_ROT B1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Potentiometric Angular Position Sensor (Displacement-Force) ANG_DSP_DF_I22	offset	0 [V]
	p_resistance	5k [Ohm]
	max_angle	106 [degree]
	min_angle	0 [Rad]
	full_scale_ span	E1.EMF [V]
	time_con- stant	0 [s]
	temp	27 [°C]
	wiper_res- istance	0 [Ohm]
	max_non- linearity	1 [%]

	max_hys- teresis	0 [%]
	temp_hys- teresis	0 [%]
	tempco_span	0.06 [%/(°C)]
	temp_sens_ offset	0 [V/(°C)]
	max_temp	125 [°C]
	min_temp	-40 [°C]

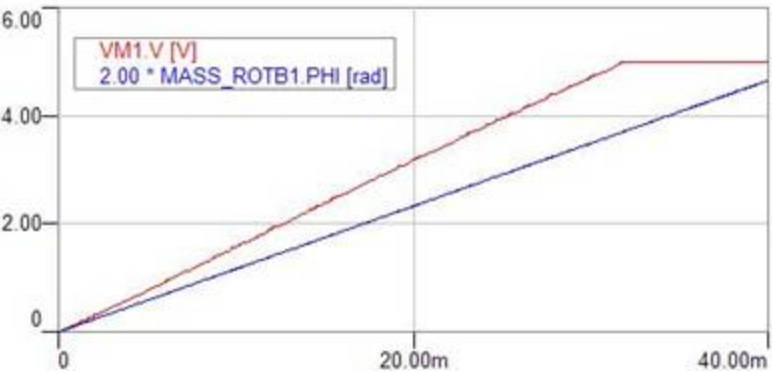


Figure 3. Simulation results-input angular position and output voltage of ANG_DSP_DF_I22

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References

Level 2 Hall Effect Angular Position Sensor (Displacement-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

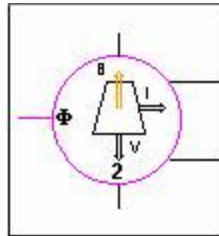


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Description

The Level 2 Hall Effect Angular Position (Displacement-Force) sensor model is used to simulate the non-ideal behavior of a Hall effect angle sensor in the Twin Builder displacement-force rotational domain. A change in angular position of an element in the displacement-force rotational domain causes a corresponding change in the model's voltage output signal. The model has three available output voltage signals: linear, triangular, and sawtooth.

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Netlist Syntax

```
MODEL ANG_DISP_HE_DF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) Vcc:=
%0, Vss:= %1, PHI:= %2, out_plus:= %3, out_minus:= %4 ( input_current:= @input_current,
max_angle:= @max_angle, min_angle:= @min_angle, full_scale_span:= @full_scale_span, off-
set:= @offset, continuous:= @continuous, time_constant:= @time_constant, nonlinearity:=
@nonlinearity, hysteresis:= @hysteresis, temp:= @temp, max_temp:= @max_temp, min_tem-
p:= @min_temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span,
temp_sens_offset:= @temp_sens_offset, output_resistance:= @output_resistance) SRC: DB
(Lib:=@ModelLibraryName);
```

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Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational
Vcc	Positive supply	Electrical
Vss	Negative supply	Electrical
out_plus	Positive Output	Electrical
out_minus	Negative Output	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
input_current	Nominal input current	Real	1m [A]
max_angle	Maximum measurable angle	Real	3.14159265358979 [rad]
min_angle	Minimum measurable angle	Real	0 [Rad]
full_scale_span	Difference between the maximum and minimum output voltages	Real	5 [V]
time_constant	Output time constant	Real	0 [s]
temp	Device temperature	Real	27 [°C]
output_resistance	Output resistance	Real	0 [Ohm]
max_nonlinearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]

tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
max_temp	Maximum operating temperature	Real	150 [°C]
continuous	Output shape	Real	0*
min_temp	Minimum operating temperature	Real	-50 [°C]

* **continuous = 0: clipped linear output; 1: periodic sawtooth output; 2: periodic triangular output**

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Example

In this example, the output voltage of the Hall Effect Angular Position Sensor (Displacement-Force) ANG_DISP_HE_DF_I21 changes in response to the change in angular position of the Mass MASS_ROT_B1. Here, the voltage output signal of ANG_DISP_HE_DF_I21 is set to be a clipped linear output. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

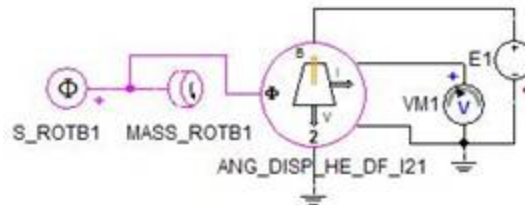


Figure 2. Application example of the Hall Effect Angular Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Angle Source S_ROT_B1	VALUE	$(-\pi/2) + (\pi)^*$

		(t/40m) [rad]
Voltage Source E1	EMF	5 [V]
Mass MASS_ROT B1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Hall Effect Angular Position Sensor (Displacement-Force) ANG_DISP_HE_DF_I21	offset	0.25 [V]
	input_current	15m [A]
	max_angle	45 [degree]
	min_angle	-45 [degree]
	full_scale_span	4.75 [V]
	time_constant	0 [s]
	temp	27 [°C]
	output_resistance	0 [Ohm]
	max_non-linearity	2.5 [%]
	hysteresis	0 [%]
	temp_hysteresis	0 [%]
	tempco_span	0.022 [%/ (°C)]

	temp_sens_offset	0 [V/(°C)]
	max_temp	0.15k [°C]
	continuous	0*
	min_temp	-50 [°C]

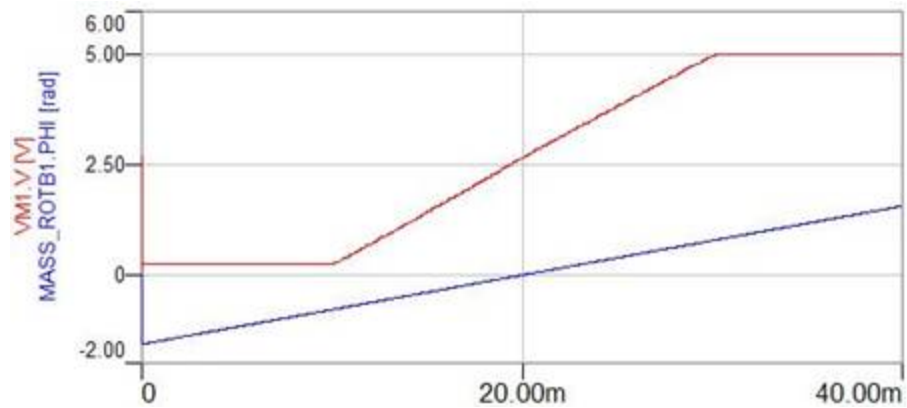


Figure 3. Simulation results- output voltage of ANG_DISP_HE_DF_I21
and angular position of MASS_ROT_B1

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References

Level 2 Incremental Encoder Angular Position Sensor (Displacement-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

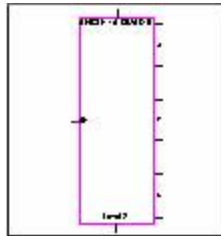


Figure 1. Component symbol

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Description

The Level 2 Incremental encoder Angular Position (Displacement-Force) sensor model is used to simulate the non-ideal behavior of an incremental encoder angle sensor in the Twin Builder displacement-force rotational domain. An incremental encoder has some number of equally spaced sensing elements, all of which will be detected during one revolution of the device. These elements account for two of the device's three outputs: Channel A and Channel B. Channel A is a pulse output that goes to its logic 1 value whenever a sensing element is detected and remains there until the sensor has traveled one-half of the distance to the next element. Channel B is a second pulse output that lags Channel A by a quarter cycle.

The third output of the model is Channel N, which goes to its logic 1 value when the sensor detects the zero point of the sensor and remains high until the sensor has traveled one-quarter of the distance to the next sensing element.

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Netlist Syntax

```
MODEL INC_ENCODER_DF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) PHI:=
%0, A_plus:= %1, A_minus:= %2, B_plus:= %3, B_minus:= %4, N_plus:= %5, N_minus:= %6,
Vdd:= %7, Vss:= %8 ( corner_frequency:= @corner_frequency, north:= @north, num_lines:=
@num_lines, min_amplitude:= @min_amplitude, max_amplitude:= @max_amplitude, pct_
error:= @pct_error, output_resistance:= @output_resistance, supply_current:= @supply_cur-
rent) SRC: DB(Lib:=@ModelLibraryName);
```

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Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational
Vdd	Positive power supply	Electrical
Vss	Negative power supply	Electrical
A_plus (See Note)	Channel A positive output terminal	Electrical
A_minus (See Note)	Channel A negative output terminal	Electrical
B_plus (See Note)	Channel B positive output terminal	Electrical
B_minus (See Note)	Channel B negative output terminal	Electrical
N_plus (See Note)	Channel N positive output terminal	Electrical
N_minus (See Note)	Channel N negative output terminal	Electrical

Note: Terminal set to No Action when unconnected. Terminal may remain unconnected without generating an error.

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
north	Reference angle	Real	0 [rad]

num_lines	Number of sensing elements on the sensor	Real	16
min_amplitude	Logic zero output	Real	0 [V]
max_amplitude	Logic one output	Real	5 [V]
pct_error	Percent measurement error	Real	0 [%]
output_resistance	Resistance at each output	Real	0 [Ohm]
corner_frequency	Corner frequency of the input angle signal	Real	0 [Hz]
supply_current	Supply current	Real	20m [A]

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Example

In this example, the Incremental Encoder Angular Position Sensor (Displacement-Force) INC_ENCODER_DF_I21 measures the angular position of the Mass MASS_ROT1, and the encoded measurement results are sent out through its output channels. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3-6.

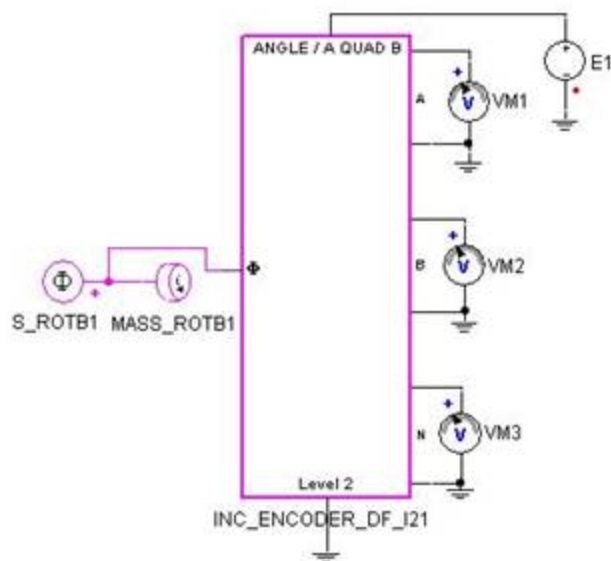


Figure 2. Application example of the Incremental Encoder Angular Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Angle Source S_ROT B1	VALUE	$\pi/8 - (\pi/4) * (t/40m)$ [rad]
Voltage Source E1	EMF	5 [V]
Mass MASS_ROT B1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Incremental Encoder Angular Position Sensor (Displacement-Force) INC_ENCODER_DF_I21	north	0 [rad]
	num_lines	128
	min_amp-	0.3 [V]

	litude	
	max_amp- litude	2.8 [V]
	supply_cur- rent	30m [A]
	pct_error	0 [%]
	output_res- istance	0 [Ohm]
	corner_fre- quency	200k [Hz]

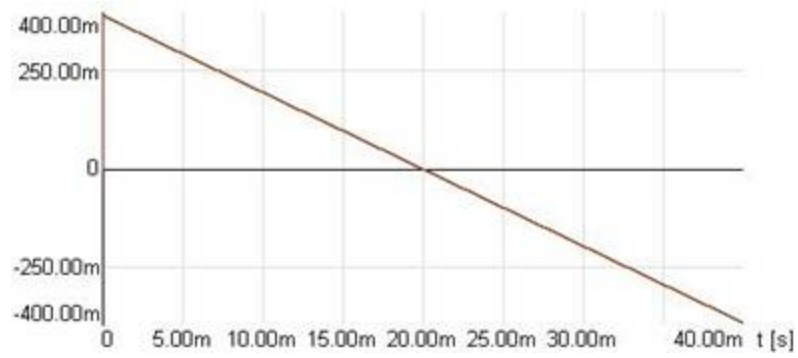
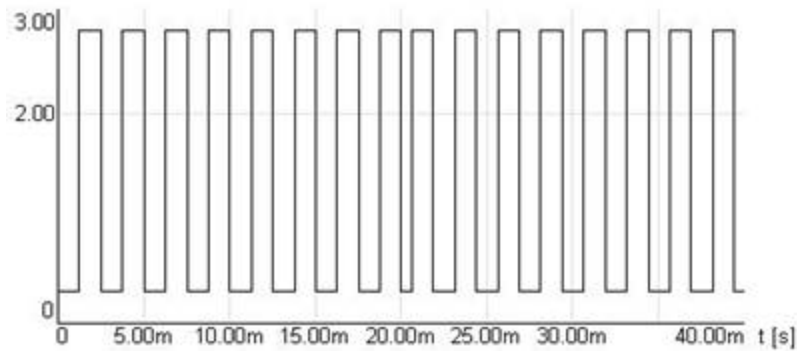
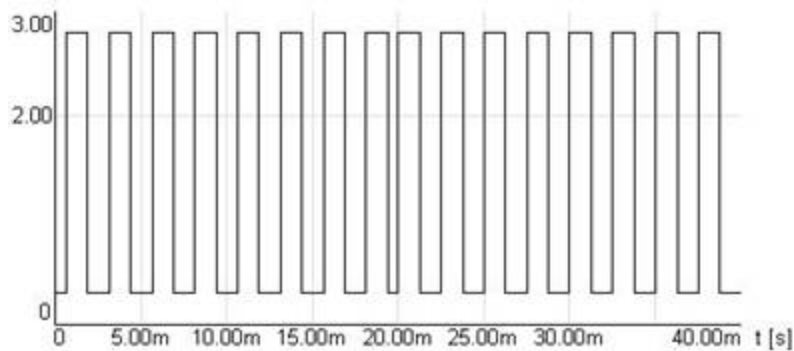
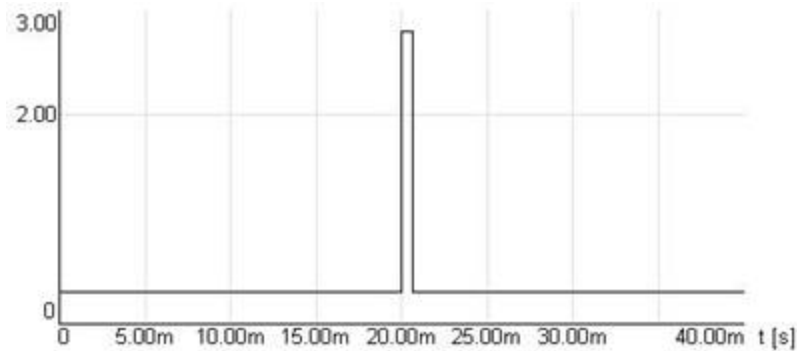


Figure 3. Simulation results- angular position of MASS_ROTB1**Figure 4. Simulation results- Channel A output of INC_ENCODER_DF_I21****Figure 5. Simulation results - Channel B output of INC_ENCODER_DF_I21****Figure 6. Simulation results - Channel N output of INC_ENCODER_DF_I21**[Top](#)

References

Level 2 Resolver Angular Position Sensor (Displacement-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

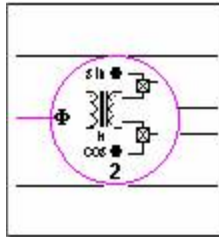


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Description

A synchro resolver angle sensor uses a transformer with one primary winding and two secondary windings that are oriented at 90-degree angles to produce two sinusoidal outputs whose amplitudes vary as the sine and cosine of the current angular position times the current amplitude of the input sinusoid at the primary winding.

The Level 2 Resolver Angular Position (Displacement-Force) sensor model is used to simulate the non-ideal behavior of a synchro resolver angle sensor in the Twin Builder displacement-force rotational domain. The model has a conservative rotational-nature input for the measured angle and six electrical-nature pins, a positive and negative terminal for the sinusoidal input voltage and positive and negative terminals for both sinusoidal output voltages. Note that all negative terminals should be connected to an electrical ground if they are not connected to an electrical network in which at least one element is connected to ground.

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Mathematical Description

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Netlist Syntax

```
MODEL RESOLVER_DF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) REF_
POS:= %0, REF_NEG:= %1, PHI:= %2, OUT_SINE_PLUS:= %3, OUT_SINE_MINUS:= %4,
OUT_COSINE_PLUS:= %5, OUT_COSINE_MINUS:= %6 ( scale_factor:= @scale_factor, null_
voltage:= @null_voltage, primary_inductance:= @primary_inductance, primary_resistance:=
@primary_resistance, secondary_inductance:= @secondary_inductance, secondary_res-
istance:= @secondary_resistance, electrical_error:= @electrical_error) SRC: DB(Lib:-
:=@ModelLibraryName);
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational
REF_POS	Positive terminal for input voltage	Electrical
REF_NEG	Negative terminal for input voltage	Electrical
OUT_SINE_PLUS	Positive terminal for sine out-put	Electrical
OUT_SINE_MINUS	Negative terminal for sine out-put	Electrical
OUT_COSINE_PLUS	Positive terminal for cosine output	Electrical
OUT_COSINE_MINUS	Negative terminal for cosine output	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
scale_factor	Turns ratio of secondaries to primary	Real	1 [V/V]
null_voltage	Amplitude of output voltage at zero measured angle	Real	0 [V]
primary_inductance	Inductance of primary winding	Real	0 [H]
primary_resistance	Resistance of primary winding	Real	0 [Ohm]
secondary_inductance	Inductance of secondary winding	Real	0 [H]
secondary_resistance	Resistance of secondary winding	Real	0 [Ohm]
electrical_error	Percent measurement error	Real	0 [%]

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Example

In this example, the Resolver Angular Position Sensor (Displacement-Force) RESOLVER_DF_I22 measures the angular position of the Mass MASS_ROT1, and the outputs are calculated with the measurement results and the Voltage Source E1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

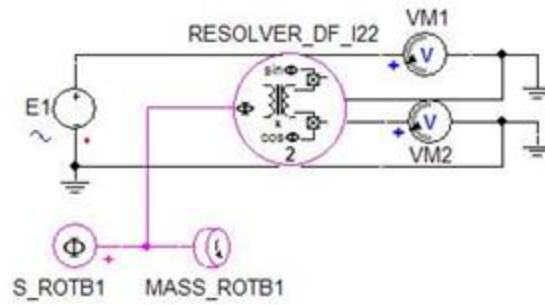


Figure 2. Application example of the Resolver Angular Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Angle Source S_ROT1	VALUE	$(2 * \pi) * (t/5.6m)$ [rad]
Voltage Source (sinusoidal) E1	AMPL	4 [V]
	FREQ	3.4k [Hz]
	PHASE	0 [degree]
	TDELAY	0 [s]
	OFF	0 [V]
Mass MASS_ROT1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Resolver Angular Position Sensor (Displacement-Force) RESOLVER_DF_I22	scale_factor	0.5 [V/V]
	null_voltage	0.265 [V]

	primary_ inductance	2.8m [H]
	primary_ res- istance	5.6 [Ohm]
	secondary_ inductance	1.59m [H]
	secondary_ resistance	10.8 [Ohm]
	electrical_ error	5 [%]

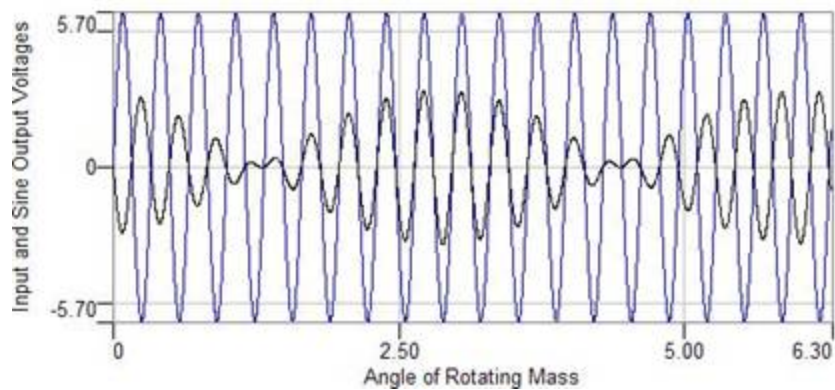


Figure 3. Simulation results-the input and sine output voltage of RESOLVER_DF_I22 vs. the angular position of MASS_ROTb1

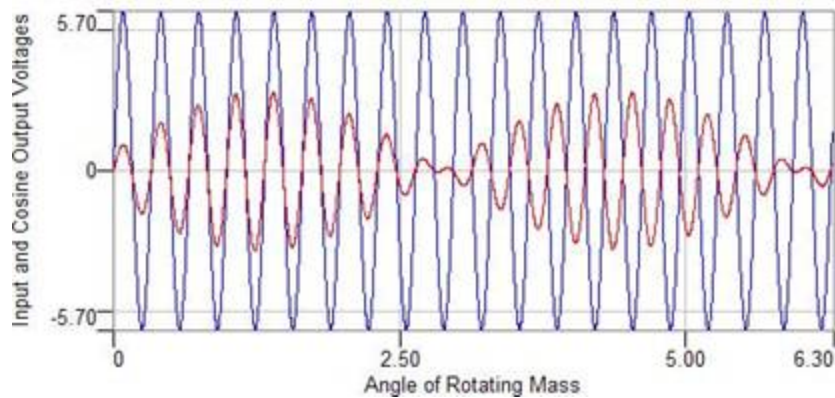


Figure 4. Simulation results-the input and cosine output voltage of RESOLVER_DF_I22 vs. the angular position of MASS_ROTb1

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References

Level 2 RVDT Angular Position Sensor (Displacement-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

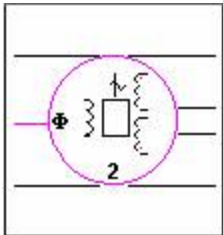


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Description

The Level 2 RVDT Angular position sensor (Displacement-Force) model is used to simulate the non-ideal behavior of a linear variable differential transformer angular position sensor. A change in angular position produces a corresponding change in the AC voltage output signal.

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Mathematical Description

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Netlist Syntax

```
MODEL RVDT_DF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) out_1_plus:=
%0, out_1_minus:= %1, out_2_plus:= %2, out_2_minus:= %3, in_plus:= %4, in_minus:= %5,
PHI:= %6 ( max_angle:= @max_angle, min_angle:= @min_angle, sensitivity:= @sensitivity,
```

max_nonlinearity:= @max_nonlinearity, hysteresis:= @hysteresis, max_temp:= @max_temp, min_temp:= @min_temp, temp:= @temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span, primary_inductance:= @primary_inductance, primary_resistance:= @primary_resistance, secondary_inductance:= @secondary_inductance, secondary_resistance:= @secondary_resistance, null_voltage:= @null_voltage, core_mass_mi:= @core_mass_mi) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational
in_plus	Transformer primary positive terminal	Electrical
in_minus	Transformer primary negative terminal	Electrical
out_1_plus	Transformer secondary 1 positive terminal	Electrical
out_1_minus	Transformer secondary 1 negative terminal	Electrical
out_2_plus	Transformer secondary 2 positive terminal	Electrical
out_2_minus	Transformer secondary 2 negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
sensitivity	RVDT sensitivity	Real	50m [V/V/Rad]

temp	Device temperature	Real	27 [°C]
max_angle	Maximum measurable angle	Real	0.785398163397448 [Rad]
min_angle	Minimum measurable angle	Real	-0.785398163397448 [Rad]
max_non-linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	125 [°C]
min_temp	Minimum operating temperature	Real	-40 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
primary_inductance	Inductance of primary winding	Real	10m [H]
primary_resistance	Resistance of primary winding	Real	0 [Ohm]
secondary_inductance	Inductance of secondary winding	Real	10m [H]

secondary_resistance	Resistance of secondary winding	Real	0 [Ohm]
null_voltage	Amplitude of output voltage at zero angle	Real	0 [%]
core_mass_mi	Mass moment of inertia of transformer core	Real	0 [kg m ²]

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Example

In this example, the RVDT Angular Position Sensor (Displacement-Force) RVDT_DF_I22 measures the angular position of the Mass MASS_ROT1. A change in angular position of MASS_ROT1 produces a corresponding change in the AC voltage output signal of RVDT_DF_I22. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

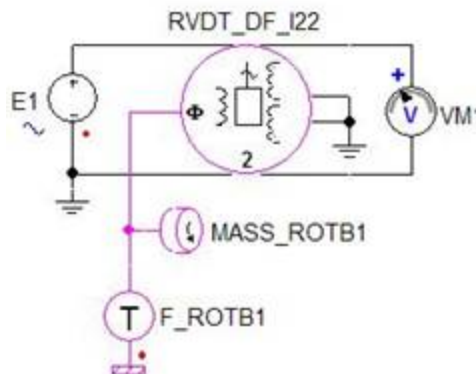


Figure 2. Application example of the RVDT Angular Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROT1	VALUE	100MEG [Nm]
	AMPL	3 [V]
Voltage Source (sinusoidal) E1		

	FREQ	10k [Hz]
	PHASE	0 [degree]
	TDELAY	0 [s]
	OFF	0 [V]
Mass MASS_ROT B1	J	1 [kg m ²]
	PHI0	-70 * (pi/180) [rad]
	OMEGA0	0 [rad/s]
RVDT Angular Position Sensor (Displacement-Force) RVDT_DF_I22	sensitivity	3.6m [V/V/Rad]
	temp	27 [°C]
	max_angle	70 [Rad]
	min_angle	-70 [Rad]
	max_non-linearity	1 [%]
	hysteresis	0 [%]
	max_temp	275 [°C]
	min_temp	-55 [°C]
	temp_hysteresis	0 [%]
	tempco_span	0 [%/(°C)]
	primary_inductance	10m [H]

	primary_resistance	0 [Ohm]
	secondary_inductance	10m [H]
	secondary_resistance	0 [Ohm]
	null_voltage	0.5 [%]
	core_mass_mi	0 [kg m ²]

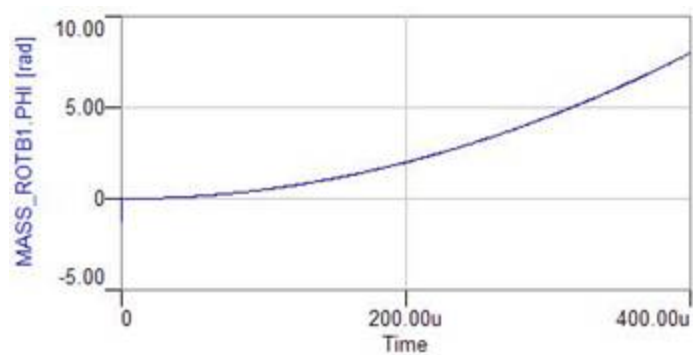


Figure 3. Simulation results-angular positon of MASS_ROT B1

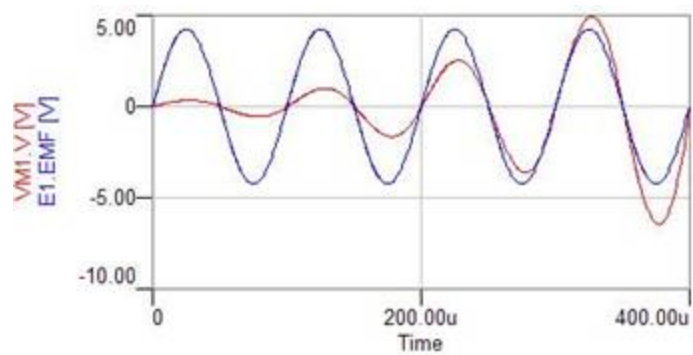


Figure 4. Simulation results-input and output voltages RVDT_DF_I22

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References

Level 2 Absolute Encoder Angular Position Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

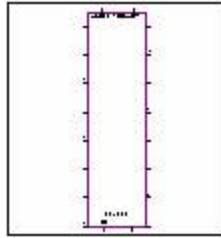


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Description

An absolute encoder angle sensor translates absolute angular position to a natural binary output. The precision of the output, i.e. the number of bits that make up the output, is determined by the number of equally spaced position indicators that are available on the sensor. For example, an angle sensor with sixteen position indicators would have a four-bit output.

The Level 2 Absolute encoder Angular Position (Velocity-Force) sensor model is used to simulate the non-ideal behavior of a 6 to 16-bit absolute encoder angle sensor in the Twin Builder velocity-force rotational domain. The model has a conservative input pin with a rotational nature and nineteen conservative electrical-nature pins. Two of the pins are used to connect the model to a power supply and a ground. One pin is used for the sensor's output-enable signal. The remaining pins are for the sixteen possible binary outputs.

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Mathematical Description

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Netlist Syntax

```
MODEL ABS_ENCODER_VF_I2 ?InstanceName(@InstanceName):(@@Refbase)@(ID)) Vdd:=
%0, Vss:= %1, LE:= %2, BIT_15:= %3, BIT_14:= %4, BIT_13:= %5, BIT_12:= %6, BIT_11:= %7,
BIT_10:= %8, BIT_9:= %9, BIT_8:= %10, BIT_7:= %11, BIT_6:= %12, BIT_5:= %13, BIT_4:=
%14, BIT_3:= %15, BIT_2:= %16, BIT_1:= %17, BIT_0:= %18, PHI:= %19 ( resolution:= @res-
olution, max_amplitude:= @max_amplitude, min_amplitude:= @min_amplitude, response_
time:= @response_time, latch_threshold:= @latch_threshold, output_resistance:= @output_res-
istance, phi_init:= @phi_init, supply_current:= @supply_current, error:= @error) SRC: DB(Lib:-
:=@ModelLibraryName);
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational_V
Vdd	Positive power supply terminal Vdd	Electrical
Vss	Negative power supply terminal Vss	Electrical
BIT_0 (See Note)	Output bit zero	Electrical
BIT_1 (See Note)	Output bit one	Electrical
BIT_2 (See Note)	Output bit two	Electrical
BIT_3 (See Note)	Output bit three	Electrical
BIT_4 (See Note)	Output bit four	Electrical

BIT_5 (See Note)	Output bit five	Electrical
BIT_6 (See Note)	Output bit six	Electrical
BIT_7 (See Note)	Output bit seven	Electrical
BIT_8 (See Note)	Output bit eight	Electrical
BIT_9 (See Note)	Output bit nine	Electrical
BIT_10 (See Note)	Output bit ten	Electrical
BIT_11 (See Note)	Output bit eleven	Electrical
BIT_12 (See Note)	Output bit twelve	Electrical
BIT_13 (See Note)	Output bit thirteen	Electrical
BIT_14 (See Note)	Output bit fourteen	Electrical
BIT_15 (See Note)	Output bit fifteen	Electrical
LE	Output enable	Electrical

Note: Terminal set to No Action when unconnected. Terminal may remain unconnected without generating an error.

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
resolution	Number of bits available at output	Real	16
max_amplitude	Logic 1 output amplitude	Real	5 [V]
min_amplitude	Logic 0 output amplitude	Real	0 [V]
phi_init	Initial sensor angle	Real	0 [Rad]
response_time	Time lapse between rising edge of output enable signal and change in binary output	Real	0 [s]
latch_threshold	Output enable threshold voltage	Real	2.5 [V]
output_resistance	Output resistance at each output pin	Real	0 [Ohm]
supply_current	Supply current	Real	20m [A]
error	Percent measurement error	Real	0 [%]

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Example

In this example, the Absolute Encoder Angular Position Sensor (Velocity-Force) ABS_ENCODER_VF_I22 measures the angular position of the Mass MASS_ROT1, and the encoded measurement results are sent out through its output channels. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3-12.

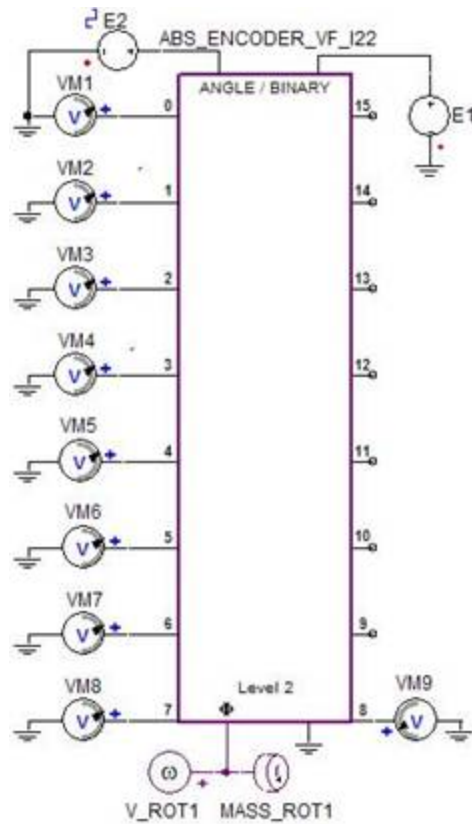
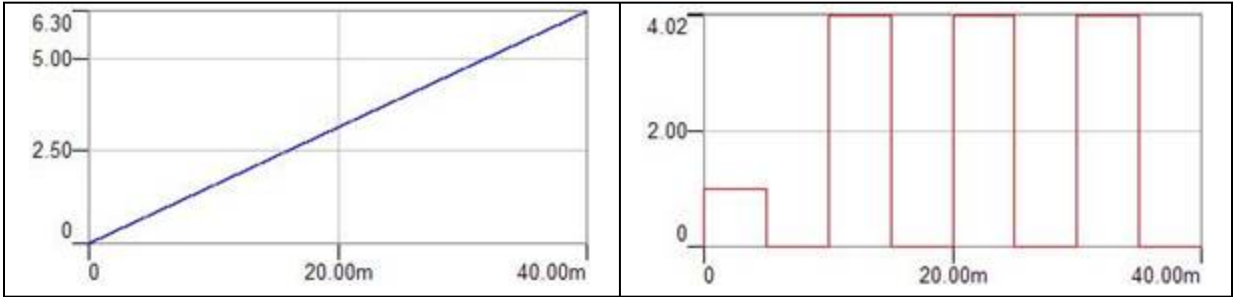


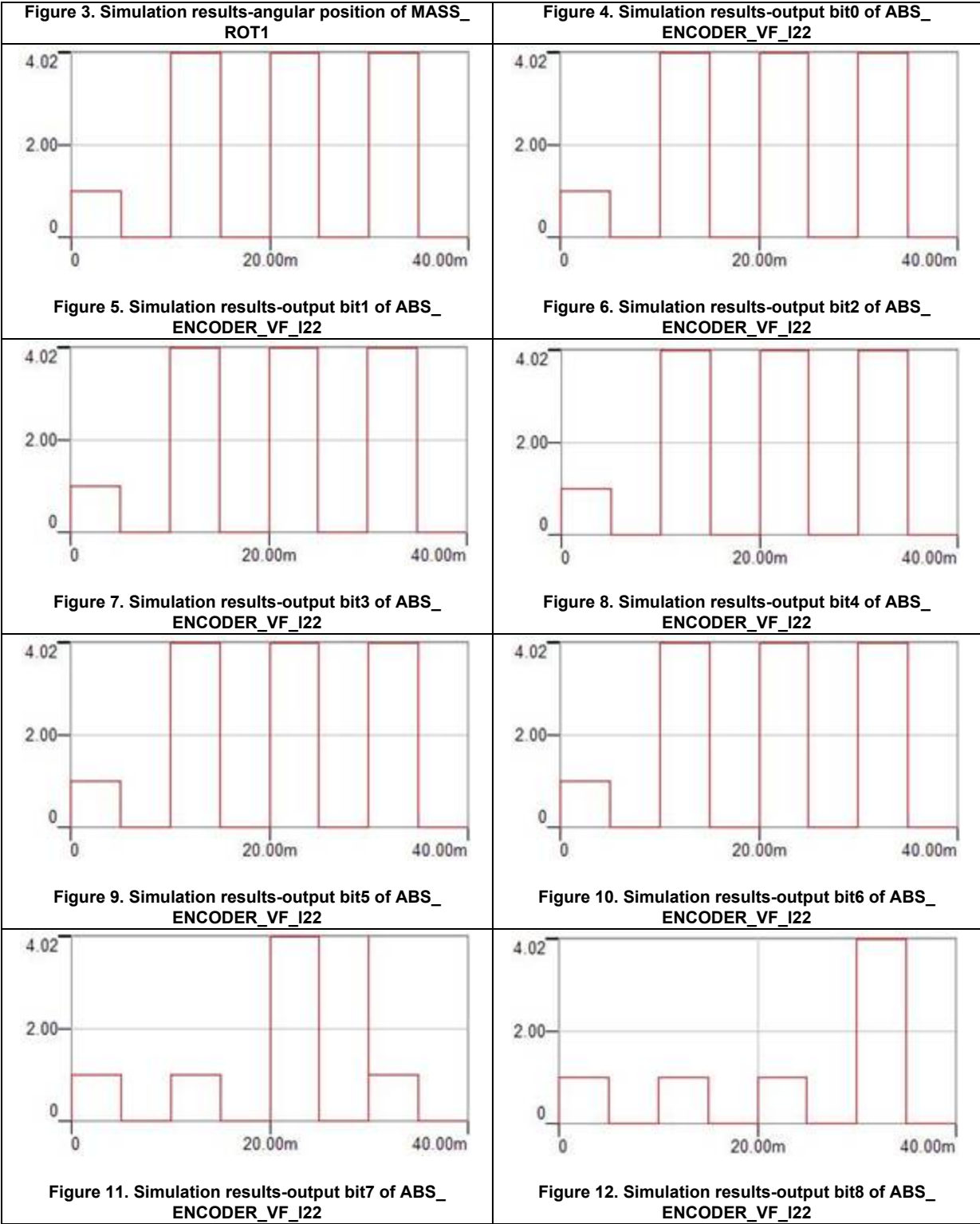
Figure 2. Application example of the Absolute Encoder Angular Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROT1	VALUE	$(2 * \pi) / 40\text{m}$ [rad/s]
Voltage Source E1	EMF	5 [V]
Voltage Source (pulse) E2	AMPL	2.5 [V]
	FREQ	100 [Hz]
	PHASE	0 [degree]
	OFF	2.5 [V]

	TDELAY	0 [s]
Mass MASS_ROT1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Absolute Encoder Angular Position Sensor (Velocity-Force) ABS_ ENCODER_VF_I22	latch_ threshold	2.4 [V]
	output_res- istance	0 [Ohm]
	phi_init	MASS_ ROT1.PHI0 [rad]
	resolution	9
	max_amp- litude	4 [V]
	min_amp- litude	1 [V]
	supply_cur- rent	30m [A]
	response_ time	10u [s]
	error	0 [%]





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References

Level 2 Microswitch Angular Position Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

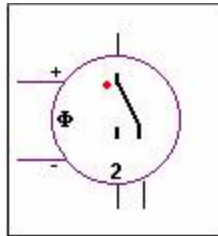


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Description

The Level 2 Microswitch Angular Position (Velocity-Force) sensor model is used to simulate the non-ideal behavior of a microswitch angle sensor in the Twin Builder velocity-force rotational domain. The microswitch model toggles from its normally closed terminal to its normally open terminal when the specified threshold angular position is exceeded by some element in the velocity-force rotational domain.

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Mathematical Description

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Netlist Syntax

MODEL AMSWITCH_VF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) PHI:= %0,
REF:= %1, nmnc:= %2, nmno:= %3, np:= %4 (threshold:= @threshold, switch_resistance:=
@switch_resistance, response_time:= @response_time, phi_init:= @phi_init) SRC: DB(Lib:-
:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational_V
REF	Reference angle	Rotational_V
np	Positive terminal	Electrical
nmnc	Normally-closed negative terminal	Electrical
nmno	Normally-open negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
threshold	Threshold angle	Real	1.5707963267949 [Rad]
switch_resistance	Switch on-state resistance	Real	0 [Ohm]
response_time	Switch response time	Real	0 [s]
phi_init	Initial sensor angle	Real	0 [Rad]

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Example

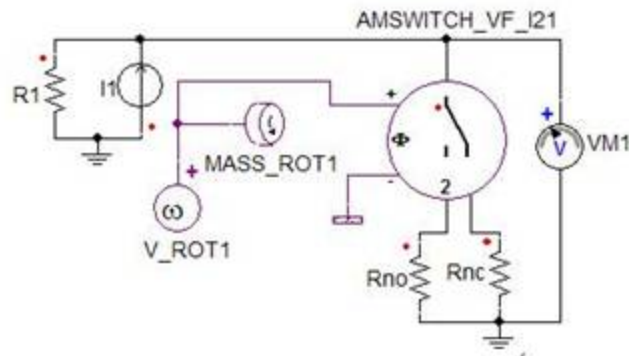


Figure 2. Application example of the Microswitch Angular Position Sensor (Velocity-Force)

Table 3

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROT1	VALUE	$100 * (t \leq 11m) + -100 * (t \geq 25m)$ [rad/s]
Current Source I1	IS	1 [A]
Resistor Rno/Rnc	R	1k [Ohm]
Resistor R1	R	1k [Ohm]
Mass MASS_ROT1	J	1 [kg m ²]
	PHI0	0.25 [rad]
	OMEGA0	0 [rad/s]
Microswitch Angular Position Sensor (Velocity-Force) AMSWITCH_VF_I22	threshold	1 [rad]
	switch_resistance	100m [Ohm]

	response_ time	10m [s]
	phi_init	MASS_ ROT1.PHI0 [rad]

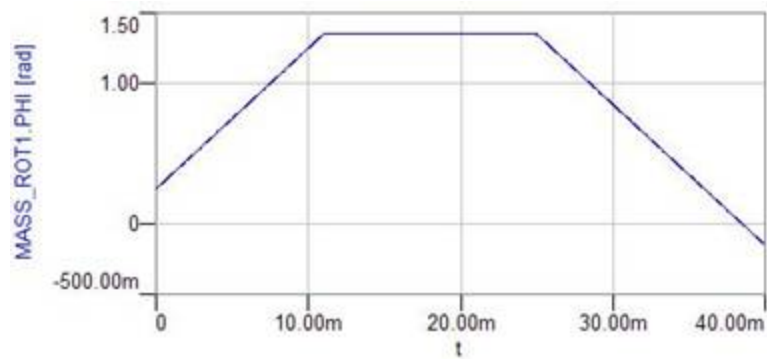


Figure 3. Simulation results- angular position of MASS_ROT1

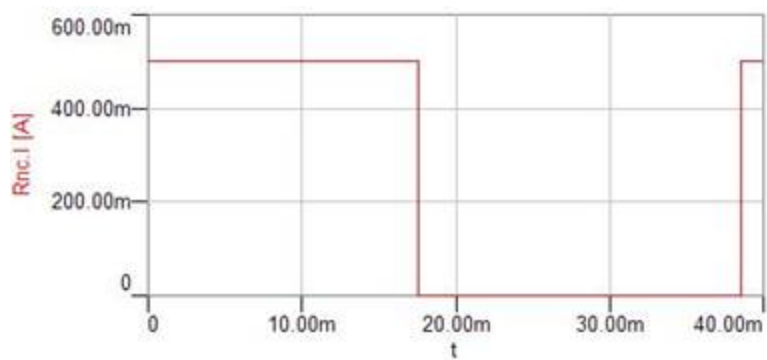


Figure 4. Simulation results- current through Rnc

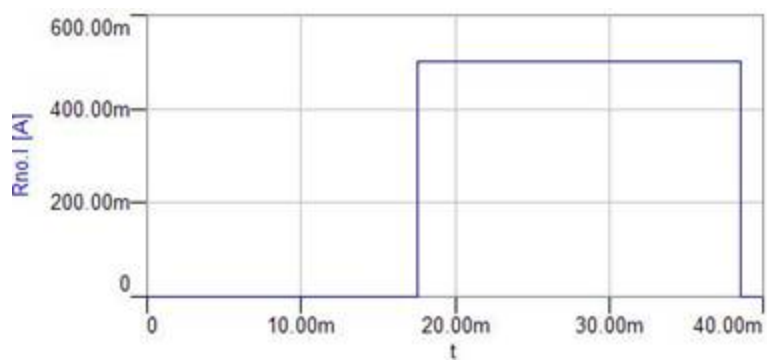


Figure 5. Simulation results- current through Rno

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References

Level 2 Anisotropic Magnetoresistive Angular Position Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

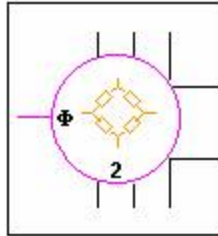


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Description

The Level 2 Anisotropic Magnetoresistive Angular Position (Velocity-Force) sensor model is used to simulate the ideal behavior of an AMR angle sensor in the Twin Builder velocity-force rotational domain. A change in the angular position of an element in the velocity-force rotational domain causes a corresponding change in the sensor model's two differential, sinusoidal voltage output signals.

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Mathematical Description

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Netlist Syntax

```
MODEL ANG_DISP_AMR_VF_I2 ?InstanceName(@InstanceName):(@@Refbase)@(ID)) Vcc-
s:= %0, Vsss:= %1, out_pluss:= %2, out_minuss:= %3, Vccs:= %4, Vssc:= %5, out_plus:= %6,
out_minusc:= %7, PHI:= %8 ( corner_frequency:= @corner_frequency, phi_init:= @phi_init,
peak_s:= @peak_s, peak_c:= @peak_c, offset_s:= @offset_s, offset_c:= @offset_c, non-
linearity:= @nonlinearity, hysteresis:= @hysteresis, temp:= @temp, max_temp:= @max_temp,
min_temp:= @min_temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_
span, temp_sens_offset:= @temp_sens_offset, bridge_s_resistance:= @bridge_s_resistance,
bridge_c_resistance:= @bridge_c_resistance, typical_supply_voltage:= @typical_supply_
voltage, resistor_tempco:= @resistor_tempco, nominal_res_temp:= @nominal_res_temp)
SRC: DB(Lib:=@ModelLibraryName);
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational_V
Vccs	Supply for the sine-output bridge	Electrical
Vccs	Supply for the cosine-output bridge	Electrical
Vsss	Ground for the sine-output bridge	Electrical
Vssc	Ground for the cosine-output bridge	Electrical
out_pluss	Positive output terminal for the sine-out-put bridge	Electrical
out_minuss	Negative output terminal for the sine-out-put bridge	Electrical
out_plus	Positive output terminal for the cosine-output bridge	Electrical
out_minusc	Negative output terminal for the cosine-output bridge	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
temp	Device temperature	Real	27 [°C]
phi_init	initial sensor angle	Real	0 [rad]
corner_frequency	Corner frequency of input signal	Real	0 [Hz]
peak_s	Maximum amplitude of the sine output signal	Real	50m [V]
peak_c	Maximum amplitude of the cosine output signal	Real	50m [V]
offset_s	Offset of the sine output signal	Real	0 [V]
offset_c	Offset of the cosine output signal	Real	0 [V]
nonlinearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	150 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature	Real	0 [%/

	coefficient as a percentage of full-scale span		(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
bridge_s_resistance	Resistance of the magnetoresistive bridge producing sine signal	Real	2k [Ohm]
bridge_c_resistance	Resistance of the magnetoresistive bridge producing cosine signal	Real	2k [Ohm]
typical_supply_voltage	Typical supply voltage	Real	5 [V]
resistor_tem_pco	Temperature coefficient of the bridge resistor	Real	0 [%/(°C)]
nominal_res_temp	Temperature at which the bridge resistors have nominal value	Real	25 [°C]

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Example

In this example, the two differential sinusoidal voltage output signals of the Anisotropic Magnetoresistive Angular Position Sensor (Velocity-Force) ANG_DISP_AMR_VF_I21 change in reponse to the change in angular position of the Mass MASS_ROT1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

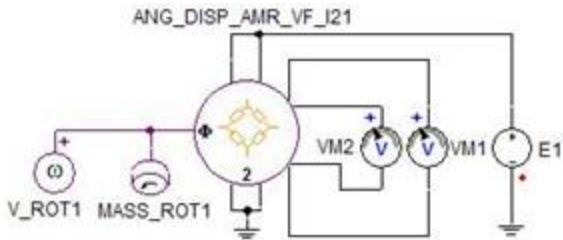


Figure 2. Application example of the Anisotropic Magnetoresistive Angular Position Sensor (Velocity-Force)

Table 3

Component	Parameter	Value [Unit]
Angle Velocity Source V_ROT1	VALUE	$(4 * \pi)/40\text{m}$ [rad]
Voltage Source E1	EMF	5 [V]
Mass MASS_ROT1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Anisotropic Magnetoresistive Angular Position Sensor (Velocity-Force) ANG_DISP_AMR_VF_I21	temp	27 [°C]
	corner_frequency	1M [Hz]
	peak_s	15.6m * E1.EMF [V]
	peak_c	15.6m * E1.EMF [V]
	offset_s	0 [V]
	offset_c	0 [V]
	nonlinearity	3k [Ohm]
	hysteresis	0.01 [%]
	max_temp	0.15k [°C]
	min_temp	-40 [°C]
	temp_hysteresis	0 [%]
	tempco_span	-0.31 [%/(°C)]

	temp_sens_offset	0 [V/(°C)]
	bridge_s_resistance	2.5k [Ohm]
	bridge_c_resistance	2.5k [Ohm]
	resistor_tempco	0.32 [%/(°C)]
	phi_init	MASS_ROT1.PHI0 [degree]
	nominal_res_temp	25 [°C]

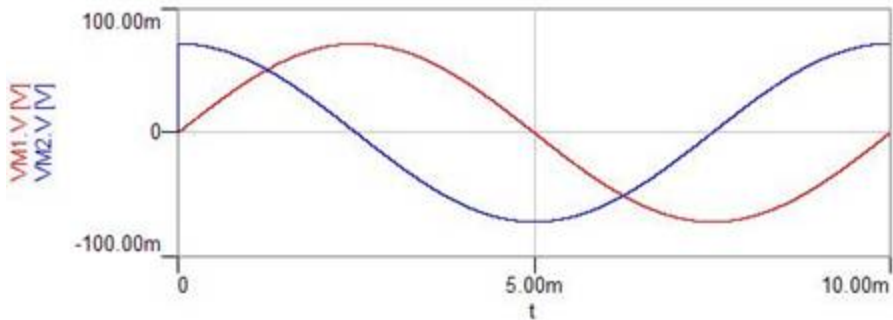


Figure 3. Simulation results- output voltages of ANG_DISP_AMR_VF_I21

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References

Level 2 Hall Effect Angular Position Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

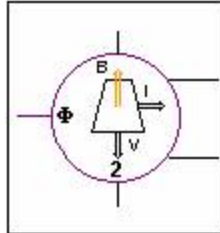


Figure 1. Component symbol

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Description

The Level 2 Hall Effect Angular Position (Velocity-Force) sensor model is used to simulate the non-ideal behavior of a Hall effect angle sensor in the Twin Builder velocity-force rotational domain. A change in angular position of an element in the velocity-force rotational domain causes a corresponding change in the model's voltage output signal. The model has three available output voltage signals: linear, triangular, and sawtooth.

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Netlist Syntax

```
MODEL ANG_DISP_HE_VF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) Vcc:= %0, Vss:= %1, PHI:= %2, out_plus:= %3, out_minus:= %4 ( input_current:= @input_current, max_angle:= @max_angle, min_angle:= @min_angle, full_scale_span:= @full_scale_span, offset:= @offset, continuous:= @continuous, time_constant:= @time_constant, phi_init:= @phi_init, nonlinearity:= @nonlinearity, hysteresis:= @hysteresis, temp:= @temp, max_temp:= @max_temp, min_temp:= @min_temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span, temp_sens_offset:= @temp_sens_offset, output_resistance:= @output_resistance) SRC: DB(Lib:=@ModelLibraryName);
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational_V
Vcc	Positive supply	Electrical
Vss	Negative supply	Electrical
out_plus	Positive output	Electrical
out_minus	Negative output	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
input_current	Nominal input current	Real	1m [A]
max_angle	Maximum measurable angle	Real	3.14159265358979 [Rad]
min_angle	Minimum measurable angle	Real	0 [Rad]
full_scale_span	Difference between the maximum and minimum output voltages	Real	5 [V]
time_constant	Output time constant	Real	0 [s]
temp	Device temperature	Real	27 [°C]
output_resistance	Output resistance	Real	0 [Ohm]
max_nonlinearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]

tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
max_temp	Maximum operating temperature	Real	150 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
phi_init	Initial sensor angle	Real	0 [Rad]

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Example

In this example, the output voltage of the Hall Effect Angular Position Sensor (Velocity-Force) ANG_DISP_HE_VF_I22 changes in response to the change in angular position of the Mass MASS_ROT1. Here, the voltage output signal of ANG_DISP_HE_VF_I22 is set to be a clipped linear output. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

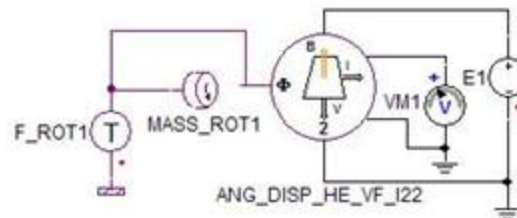


Figure 2. Application example of the Hall Effect Angular Position Sensor (Velocity-Force)

Table 3

Component	Parameter	Value [Unit]
Toque Source F_ROT1	VALUE	20k [rad]
Voltage Source E1	EMF	5 [V]

Mass MASS_ROT1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Hall Effect Angular Position Sensor (Velocity-Force) ANG_DISP_HE_VF_I21	offset	0.05 * E1.EMF [V]
	input_current	100m [A]
	max_angle	360 [degree]
	min_angle	0 [degree]
	full_scale_span	0.9 * E1.EMF [V]
	time_constant	0 [s]
	temp	27 [°C]
	output_resistance	0 [Ohm]
	max_non-linearity	0 [%]
	hysteresis	0 [%]
	temp_hysteresis	0 [%]
	tempco_span	0 [%/(°C)]
	temp_sens_offset	0 [V/(°C)]

	max_temp	0.15k [°C]
	continuous	0*
	min_temp	-50 [°C]

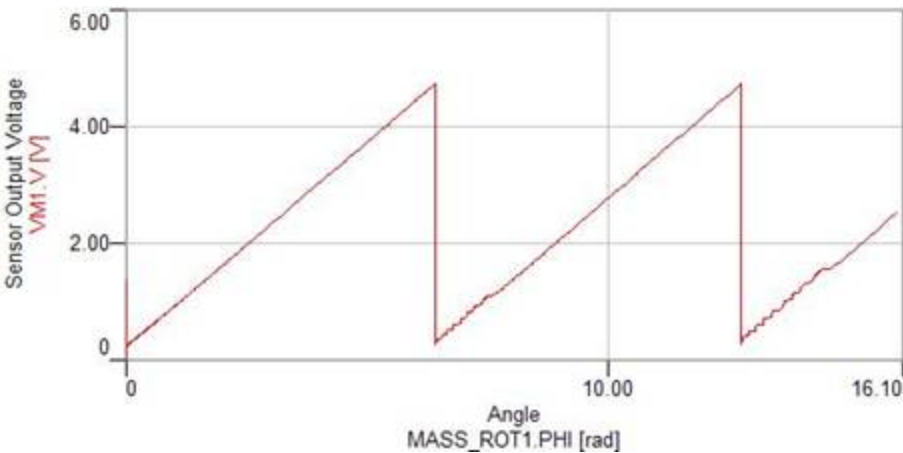


Figure 3. Simulation results- output voltage of ANG_DISP_HE_DF_I21 vs. angular position of MASS_ROT1

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References

Level 2 Potentiometric Angular Position Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

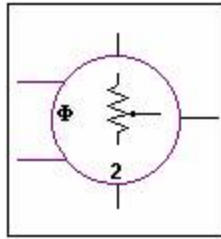


Figure 1. Component symbol

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Description

The Level 2 Potentiometric Angular Position (Velocity-Force) model is used to simulate the non-ideal behavior of a potentiometer angle sensor in the Twin Builder velocity-force rotational domain. A change in angular position of an element in the velocity-force rotational domain causes a corresponding change in the model's voltage divider output signal.

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Mathematical Description

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Netlist Syntax

```
MODEL ANG_DISP_VF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) Vcc:= %0,
Vss:= %1, OUTPUT:= %2, PHI:= %3, RPOS:= %4 ( max_angle:= @max_angle, min_angle:=
@min_angle, full_scale_span:= @full_scale_span, offset:= @offset, max_nonlinearity:=
@max_nonlinearity, max_hysteresis:= @max_hysteresis, temp:= @temp, max_temp:= @max_
temp, min_temp:= @min_temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tem-
pco_span, temp_sens_offset:= @temp_sens_offset, p_resistance:= @p_resistance, w_res-
istance:= @w_resistance, time_constant:= @time_constant, phi_init:= @phi_init) SRC: DB
(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
THETA	Measured angle	Rotational_V
RPOS	Reference angle	Rotational_V
Vcc	Positive supply	Electrical
Vss	Negative supply	Electrical
OUTPUT	Output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
p_resistance	Potentiometer resistance	Real	10k [Ohm]
max_angle	Maximum meas-	Real	6.28318530717959

	urable angle		[Rad]
min_angle	Minimum meas- urable angle	Real	0 [Rad]
full_scale_ span	Difference between the max- imum and min- imum output voltages	Real	10 [V]
time_con- stant	Output time con- stant	Real	0 [s]
temp	Device tem- perature	Real	27 [°C]
w_resistance	Wiper resistance	Real	0 [Ohm]
max_non- linearity	Nonlinearity as a percentage of full- scale span	Real	0 [%]
max_hys- teresis	Hysteresis as a percentage of full- scale span	Real	0 [%]
temp_hys- teresis	Temperature hys- teresis as a per- centage of full- scale span	Real	0 [%]
tempco_span	Output voltage tem- perature coef- ficient as a percentage of full- scale span	Real	0 [%/(°C)]
temp_sens_ offset	Offset voltage tem- perature sensitivity	Real	0 [V/(°C)]
max_temp	Maximum oper- ating temperature	Real	125 [°C]

min_temp	Minimum operating temperature	Real	-40 [°C]
phi_init	Initial sensor angle	Real	0 [Rad]

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Example

In this example, the output voltage of the Potentiometric Angular Position Sensor (Velocity-Force) ANG_DSP_VF_I22 changes in response to the change in angular position of the Mass MASS_ROT1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

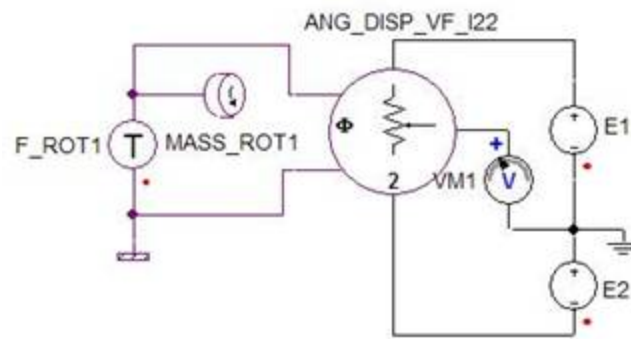


Figure 2. Application example of the Potentiometric Angular Position Sensor (Velocity-Force)**Table 3**

Component	Parameter	Value [Unit]
Torque Source F_ROT1	VALUE	10k [Nm]
Voltage Source E1/E2	EMF	5 [V]
Mass MASS_ROT1	J	1 [kg m2]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Potentiometric Angular Position Sensor (Velocity-Force) ANG_DSP_VF_I22	offset	-E2.EMF [V]
	p_resistance	5k [Ohm]
	max_angle	106 [degree]
	min_angle	0 [Rad]
	full_scale_span	E1.EMF + E2.EMF [V]
	time_constant	0 [s]
	temp	27 [°C]
	w_resistance	0 [Ohm]
	max_non-linearity	2 [%]
	max_hysteresis	0 [%]
	temp_hys-	0 [%]

	teresis	
	tempco_span	0.06 [%/(°C)]
	temp_sens_offset	0 [V/(°C)]
	max_temp	125 [°C]
	min_temp	-40 [°C]
	phi_init	MASS_ROT1.PHI0 [rad]

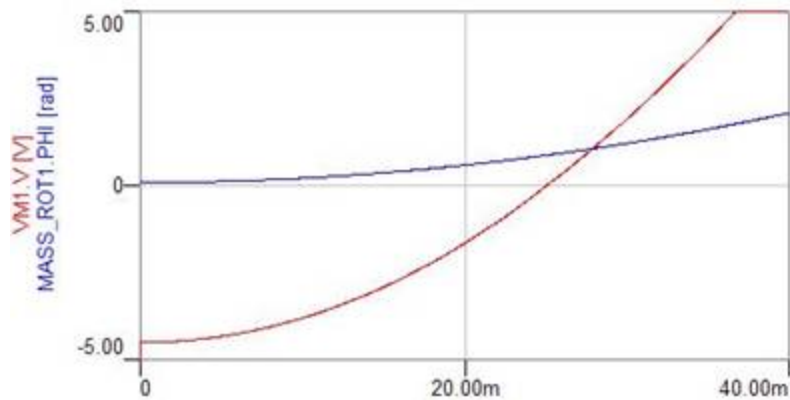


Figure 3. Simulation results-input angular position and output voltage of ANG_DSP_VF_I22

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References

Level 2 Incremental Encoder Angular Position Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

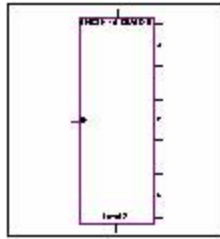


Figure 1. Component symbol

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Description

The Level 2 Incremental encoder Angular Position (Velocity-Force) sensor model is used to simulate the non-ideal behavior of an incremental encoder angle sensor in the Twin Builder velocity-force rotational domain. An incremental encoder has some number of equally spaced sensing elements, all of which will be detected during one revolution of the device. These elements account for two of the device's three outputs: Channel A and Channel B. Channel A is a pulse output that goes to its logic 1 value whenever a sensing element is detected and remains there until the sensor has traveled one-half of the distance to the next element. Channel B is a second pulse output that lags Channel A by a quarter cycle.

The third output of the model is Channel N, which goes to its logic 1 value when the sensor detects the zero point of the sensor and remains high until the sensor has traveled one-quarter of the distance to the next sensing element.

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Mathematical Description

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Netlist Syntax

```
MODEL INC_ENCODER_VF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) PHI:=  
%0, A_plus:= %1, A_minus:= %2, B_plus:= %3, B_minus:= %4, N_plus:= %5, N_minus:= %6,  
Vdd:= %7, Vss:= %8 ( phi_init:= @phi_init, corner_frequency:= @corner_frequency, north:=  
@north, num_lines:= @num_lines, min_amplitude:= @min_amplitude, max_amplitude:=  
@max_amplitude, pct_error:= @pct_error, output_resistance:= @output_resistance, supply_  
current:= @supply_current) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational_V
Vdd	Positive power supply	Electrical
Vss	Negative power supply	Electrical
A_plus (See Note)	Channel A positive output terminal	Electrical
A_minus (See Note)	Channel A negative output terminal	Electrical
B_plus (See Note)	Channel B positive output terminal	Electrical
B_minus (See Note)	Channel B negative output terminal	Electrical
N_plus (See Note)	Channel N positive output terminal	Electrical
N_minus (See Note)	Channel N negative output terminal	Electrical

Note: Terminal set to No Action when unconnected. Terminal may remain unconnected without generating an error.

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
north	Zero position of the encoder	Real	0 [Rad]

num_lines	Number of sensing elements on the sensor	Real	16
min_amplitude	Logic zero output	Real	0 [V]
max_amplitude	Logic one output	Real	5 [V]
pct_error	Percent measurement error	Real	0 [%]
output_resistance	Resistance at each output	Real	0 [Ohm]
corner_frequency	Corner frequency of the input signal	Real	0 [Hz]
supply_current	Supply current	Real	20m [A]
phi_init	Initial sensor angle	Real	0 [Rad]

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Example

In this example, the Incremental Encoder Angular Position Sensor (Velocity-Force) INC_ENCODER_VF_I21 measures the angular position of the Mass MASS_ROT1, and the encoded measurement results are sent out through its output channels. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3-6.

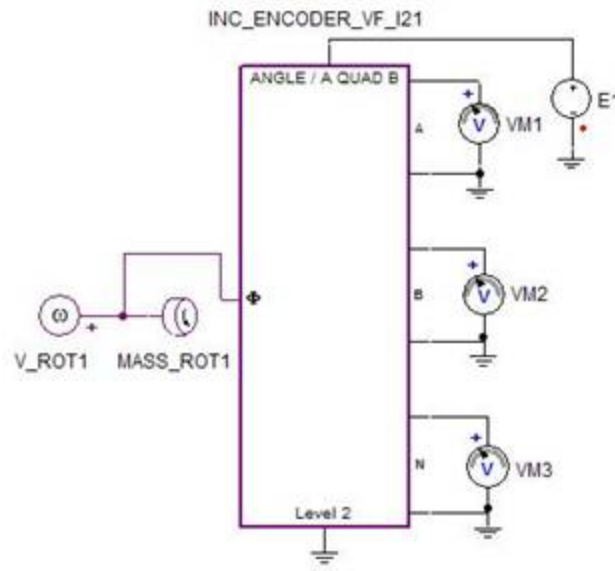


Figure 2. Application example of the Incremental Encoder Angular Position Sensor (Velocity-Force)

Table 3

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROT1	VALUE	$-(\pi/4)/40\text{m}$ [rad/s]
Voltage Source E1	EMF	5 [V]
Mass MASS_ROT1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Incremental Encoder Angular Position Sensor (Velocity-Force) INC_ENCODER_VF_I21	north	0 [rad]
	num_lines	128
	min_amplitude	0.3 [V]
	max_amp-	2.5 [V]

	litude	
	supply_cur- rent	30m [A]
	pct_error	0 [%]
	output_res- istance	0 [Ohm]
	corner_fre- quency	200k [Hz]
	phi_init	MASS_ ROT1.PHI0 [rad]

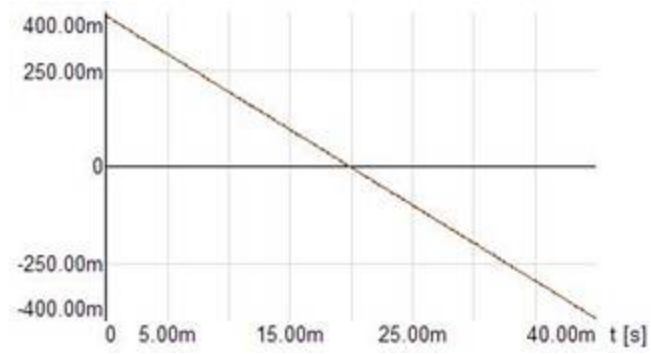


Figure 3. Simulation results- angular position of MASS_ROT1

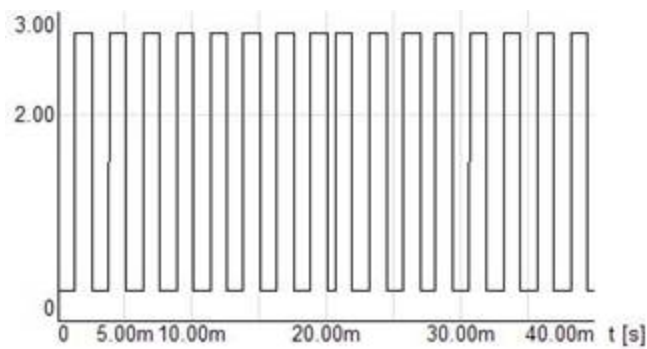


Figure 4. Simulation results- Channel A output of INC_ENCODER_VF_I21

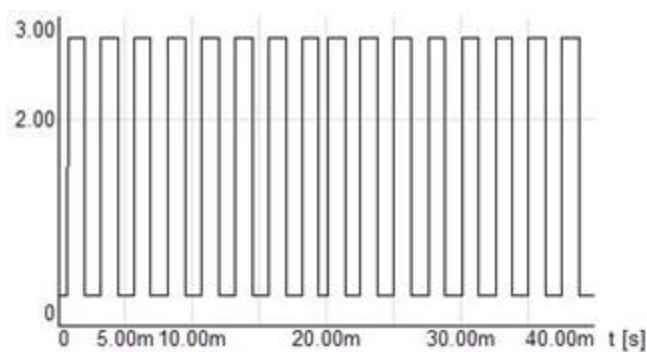


Figure 5. Simulation results- Channel B output of INC_ENCODER_VF_I21

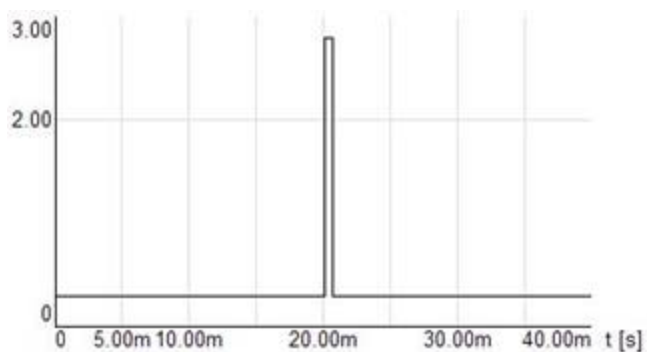


Figure 6. Simulation results- Channel N output of INC_ENCODER_VF_I21

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References

Level 2 Resolver Angular Position Sensor (Velocity-Force)

Library: Add Ons/ sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

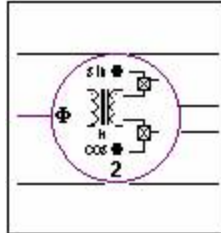


Figure 1. Component symbol

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Description

A synchro resolver angle sensor uses a transformer with one primary winding and two secondary windings that are oriented at 90-degree angles to produce two sinusoidal outputs whose amplitudes vary as the sine and cosine of the current angular position times the current amplitude of the input sinusoid at the primary winding.

The Level 2 Resolver Angular Position (Velocity-Force) sensor model is used to simulate the non-ideal behavior of a synchro resolver angle sensor in the Twin Builder velocity-force rotational domain. The model has a conservative rotational-nature input for the measured angle and six electrical-nature pins, a positive and negative terminal for the sinusoidal input voltage and positive and negative terminals for both sinusoidal output voltages. Note that all negative terminals should be connected to an electrical ground if they are not connected to an electrical network in which at least one element is connected to ground.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

MODEL RESOLVER_VF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) REF_POS:= %0, REF_NEG:= %1, PHI:= %2, OUT_SINE_PLUS:= %3, OUT_SINE_MINUS:= %4, OUT_COSINE_PLUS:= %5, OUT_COSINE_MINUS:= %6 (scale_factor:= @scale_factor, null_voltage:= @null_voltage, primary_inductance:= @primary_inductance, primary_resistance:= @primary_resistance, secondary_inductance:= @secondary_inductance, secondary_resistance:= @secondary_resistance, electrical_error:= @electrical_error, phi_init:= @phi_init) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational_V
REF_POS	Positive terminal for input voltage	Electrical
REF_NEG	Negative terminal for input voltage	Electrical
OUT_SINE_PLUS	Positive terminal for sine output	Electrical
OUT_SINE_MINUS	Negative terminal for sine output	Electrical
OUT_COSINE_PLUS	Positive terminal for cosine output	Electrical
OUT_COSINE_MINUS	Negative terminal for cosine output	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
scale_factor	Turns ratio of secondaries to primary	Real	1 [V/V]
phi_init	Initial sensor angle	Real	0 [Rad]
null_voltage	Amplitude of output voltage at zero measured angle	Real	0 [%]
primary_inductance	Inductance of primary winding	Real	0 [H]
primary_resistance	Resistance of primary winding	Real	0 [Ohm]
secondary_inductance	Inductance of secondary winding	Real	0 [H]
secondary_resistance	Resistance of secondary winding	Real	0 [Ohm]
electrical_error	Percent measurement error	Real	0 [rad]

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Example

In this example, the Resolver Angular Position Sensor (Velocity-Force) RESOLVER_VF_I22 measures the angular position of the Mass MASS_ROT1, and the outputs are calculated with the measurement results and the Voltage Source E1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

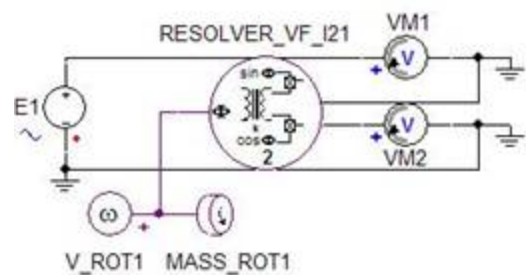


Figure 2. Application example of the Resolver Angular Position Sensor (Velocity-Force)

Table 3

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROT1	VALUE	$(2 * \pi)/5.6\text{m}$ [rad/s]
Voltage Source (sinusoidal) E1	AMPL	4 [V]
	FREQ	3.4k [Hz]
	PHASE	0 [degree]
	TDELAY	0 [s]
	OFF	0 [V]
Mass MASS_ROT1	J	1 [kg m ²]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Resolver Angular Position Sensor (Velocity-Force) RESOLVER_VF_I21	scale_factor	0.5 [V/V]
	null_voltage	0.265 [V]
	primary_inductance	2.8m [H]

	primary_resistance	5.6 [Ohm]
	secondary_inductance	1.59m [H]
	secondary_resistance	10.8 [Ohm]
	phi_init	MASS_ROT1.PHI0 [rad]
	electrical_error	5 [%]

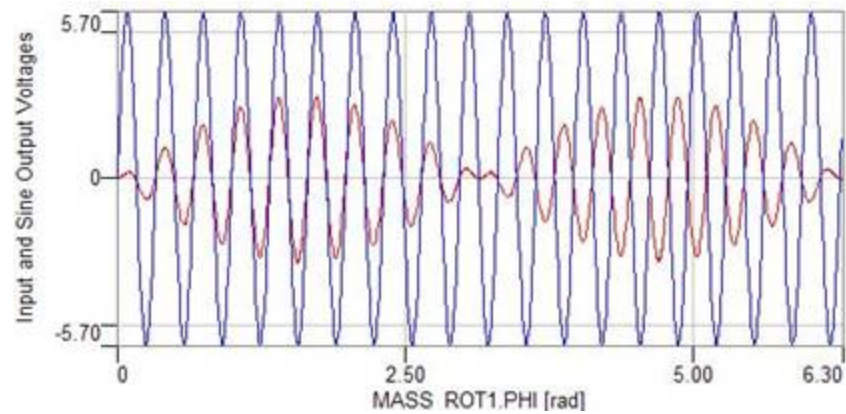


Figure 3. Simulation results-the input and sine output voltage of RESOLVER_VF_I21 vs. the angular position of MASS_ROT1

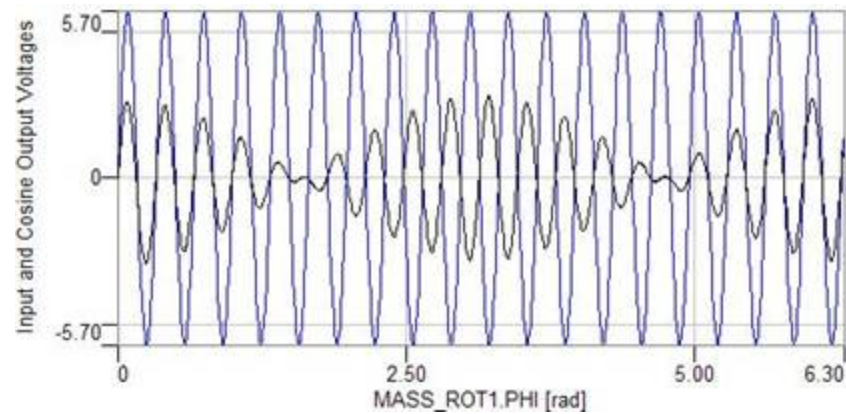


Figure 4. Simulation results-the input and cosine output voltage of RESOLVER_VF_I21 vs. the angular position of MASS_ROT1

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References

Level 2 RVDT Angular Position Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

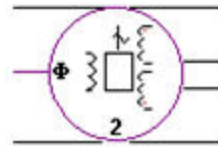


Figure 1. Component symbol

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Description

The Level 2 RVDT Angular position sensor (Velocity-Force) model is used to simulate the non-ideal behavior of a linear variable differential transformer angular position sensor. A change in angular position produces a corresponding change in the AC voltage output signal.

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Netlist Syntax

```
MODEL RVDT_VF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) out_1_plus:=
%0, out_1_minus:= %1, out_2_plus:= %2, out_2_minus:= %3, in_plus:= %4, in_minus:= %5,
```

PHI:= %6 (max_angle:= @max_angle, min_angle:= @min_angle, sensitivity:= @sensitivity, max_nonlinearity:= @max_nonlinearity, hysteresis:= @hysteresis, max_temp:= @max_temp, min_temp:= @min_temp, temp:= @temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span, primary_inductance:= @primary_inductance, primary_resistance:= @primary_resistance, secondary_inductance:= @secondary_inductance, secondary_resistance:= @secondary_resistance, null_voltage:= @null_voltage, core_mass_mi:= @core_mass_mi, phi_init:= @phi_init) SRC: DB(Lib:=@ModelLibraryName) ;

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Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured angle	Rotational_V
in_plus	Transformer primary positive terminal	Electrical
in_minus	Transformer primary negative terminal	Electrical
out_1_plus	Transformer secondary 1 positive terminal	Electrical
out_1_minus	Transformer secondary 1 negative terminal	Electrical
out_2_plus	Transformer secondary 2 positive terminal	Electrical
out_2_minus	Transformer secondary 2 negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]

sensitivity	RVDT sensitivity	Real	50m [V/V/Rad]
temp	Device temperature	Real	27 [°C]
phi_init	Initial sensor angle	Real	0 [Rad]
max_angle	Maximum measurable angle	Real	0.785398163397448 [Rad]
min_angle	Minimum measurable angle	Real	-0.785398163397448 [Rad]
max_non-linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	125 [°C]
min_temp	Minimum operating temperature	Real	-40 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
primary_inductance	Inductance of primary winding	Real	10m [H]

primary_resistance	Resistance of primary winding	Real	0 [Ohm]
secondary_inductance	Inductance of secondary winding	Real	10m [H]
secondary_resistance	Resistance of secondary winding	Real	0 [Ohm]
null_voltage	Amplitude of output voltage at zero angle	Real	0 [%]
core_mass	Mass moment of inertia of transformer core	Real	0 [kg m ²]

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Example

In this example, the RVDT Angular Position Sensor (Velocity-Force) RVDT_VF_I21 measures the angular position of the Mass MASS_ROT1. A change in angular position of MASS_ROT1 produces a corresponding change in the AC voltage output signal of RVDT_VF_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

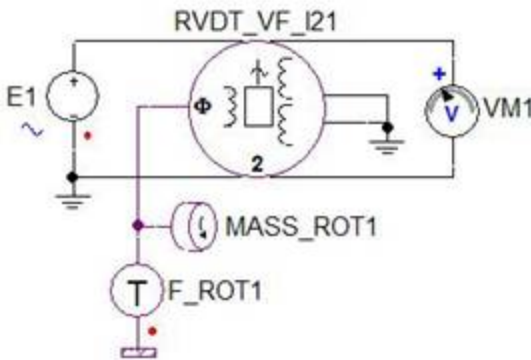


Figure 2. Application example of the RVDT Angular Position Sensor (Velocity-Force)

Table 3

Component	Parameter	Value [Unit]

Torque Source F_ROT1	VALUE	100MEG [Nm]
Voltage Source (sinusoidal) E1	AMPL	3 [V]
	FREQ	10k [Hz]
	PHASE	0 [degree]
	TDELAY	0 [s]
	OFF	0 [V]
Mass MASS_ROT1	J	1 [kg m ²]
	PHI0	-70 * (pi/180) [rad]
	OMEGA0	0 [rad/s]
RVDT Angular Position Sensor (Velocity-Force) RVDT_VF_I21	sensitivity	3.6m * (180/pi) [V/V/Rad]
	temp	27 [°C]
	max_angle	70 [Rad]
	min_angle	-70 [Rad]
	max_non-linearity	1 [%]
	hysteresis	0 [%]
	max_temp	275 [°C]
	min_temp	-55 [°C]
	temp_hys-teresis	0 [%]

	tempco_span	0 [%/(°C)]
	primary_inductance	10m [H]
	primary_resistance	0 [Ohm]
	phi_init	MASS_ROT1.PHI0 [rad]
	secondary_inductance	10m [H]
	secondary_resistance	0 [Ohm]
	null_voltage	0.5 [%]
	core_mass_mi	0 [kg m²]

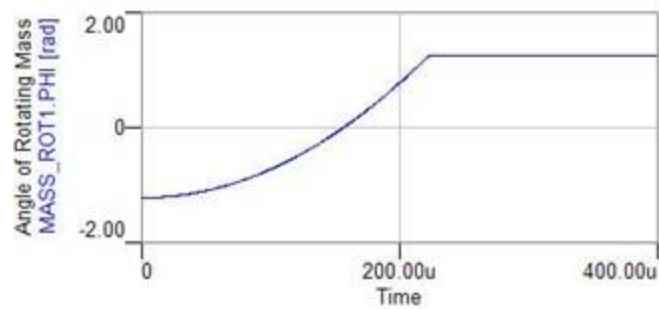


Figure 3. Simulation results-angular positon of MASS_ROT1

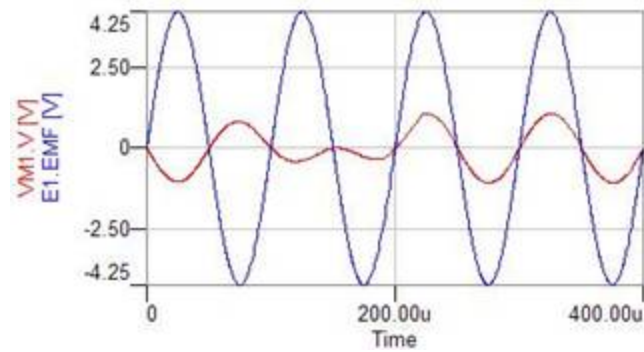


Figure 4. Simulation results-input and output voltages RVDT_VF_I21

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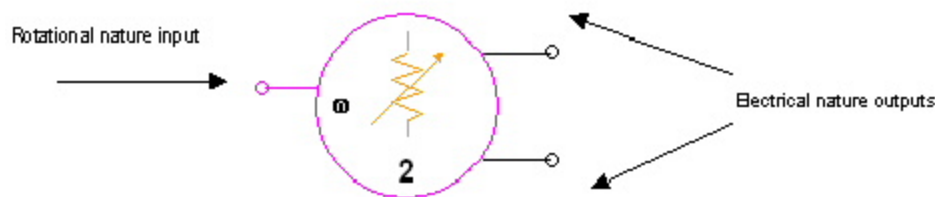
References

Level 2 Angular Velocity Sensor Models

The Level 2 Angular Velocity Sensor Models simulate realistic non-ideal behavior of four different types of angular velocity sensors. Models are available for use with the Twin Builder *displacement-force* and *velocity-force* rotational domains.

All of the angular velocity sensor models have conservative input pins that must be connected to a rotational network and conservative output pins that must be connected to an electrical network. The models also feature nonconservative parameters that can be changed in order to tailor the behavior of the model to that of a specific real device.

As shown in the following example, angular velocity sensor models for the displacement-force rotational domain have pink conservative input pins that must be connected to a displacement-force rotational network. The models also have black conservative pins that must be connected to an electrical network.



Similarly, angular velocity sensor models for the velocity-force rotational domain have purple rotational nature input pins and black electrical nature pins.

The Level 2 Angular Velocity Sensor Models feature models for the following angular velocity sensing mechanisms:

- Hall-Effect: A change in angular velocity produces a corresponding linear change in frequency of a *sinusoidal* or *pulsed* voltage output signal.

Displacement-Force Pulse Output model: ([HE_PULSE_OMEGA_DF_I2](#))

Velocity-Force Pulse Output model: ([HE_PULSE_OMEGA_VF_I2](#))

Displacement-Force Sinusoidal Output model: ([HE_SINE_OMEGA_DF_I2](#))

Velocity-Force Sinusoidal Output model: ([HE_SINE_OMEGA_VF_I2](#))

- Variable Reluctance: A change in angular velocity produces a change in the amplitude and frequency of a *sinusoidal* output voltage or a *linear* change in a conditional output signal.

Displacement-Force Linear Output model: ([VR_OMEGA_DF_I2](#))

Velocity-Force Linear Output model: ([VR_OMEGA_VF_I2](#))

Displacement-Force Sinusoidal Output model: ([VR_OMEGA_SINE_DF_I2](#))

Velocity-Force Sinusoidal Output model: ([VR_OMEGA_SINE_VF_I2](#))

Level 2 Hall-Effect (Pulse Output) Angular Velocity Sensor (Displacement-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

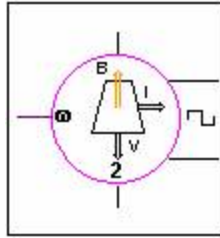


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Description

The Level 2 Hall-Effect (Pulse Output) Angular Velocity (Displacement-Force) sensor model is used to simulate the non-ideal behavior of a pulse-output, Hall-effect angular velocity sensor in the Twin Builder displacement-force rotational domain. A change in the angular velocity of an element in the displacement-force rotational domain that is connected to the model's input causes a corresponding change in the frequency of the model's pulsed voltage output signal.

The model has one conservative input pin in the displacement-force rotational domain for its angular velocity input and four conservative electrical-domain pins, two for power supply connections and two for the sensor output voltage. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is grounded.

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Netlist Syntax

```
MODEL HE_PULSE_OMEGA_DF_I2 ?InstanceName(@InstanceName):(@@Refbase)@(ID))
OMEGA:= %0, OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 ( max_omega:= @max_
omega, min_omega:= @min_omega, frequency_offset:= @frequency_offset, num_gear_
teeth:= @num_gear_teeth, phase:= @phase, offset:= @offset, amplitude:= @amplitude, sup-
ply_current:= @supply_current, corner_frequency:= @corner_frequency, output_resistance:=
@output_resistance, nonlinearity:= @nonlinearity, hysteresis:= @hysteresis, temp:= @temp,
max_temp:= @max_temp, min_temp:= @min_temp, temp_hysteresis:= @temp_hysteresis,
tempco_span:= @tempco_span, rise_time:= @rise_time) SRC: DB(Lib:=@ModelLibraryName)
;
```

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Table 1

Name	Port/Terminal Description	Nature/Data type
OMEGA	Measured angular velocity	Rotational
OUT_P	Positive output	Electrical
OUT_M	Negative output	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
phase	Phase shift of out-put sinusoid	Real	0 [Rad]

offset	DC offset of pulse output	Real	0 [V]
amplitude	Amplitude of pulse output	Real	5 [V]
corner_frequency	Corner frequency of input signal	Real	0 [Hz]
temp	Device temperature	Real	27 [°C]
output_resistance	Output resistance	Real	0 [Ohm]
max_omega	Maximum measurable angular velocity	Real	628.318530717959k [Rad/s]
min_omega	Minimum measurable angular velocity	Real	0 [Rad/s]
frequency_offset	Output frequency at minimum angular velocity	Real	0 [Hz]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	200 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
num_gear_teeth	Number of teeth on sensed gear	Real	20

supply_current	Supply current	Real	500u [A]
nonlinearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
rise_time	10-90% rise time	Real	0 [s]

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Example

In this example, the Hall-Effect (Pulse Output) Angular Velocity (Displacement-Force) sensor HE_PULSE_OMEGA_DF_I21 measures the angular velocity of the Mass MASS_ROT1. The change in the measurement results causes a corresponding change in the frequency of the sinusoidal voltage output of HE_PULSE_OMEGA_DF_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

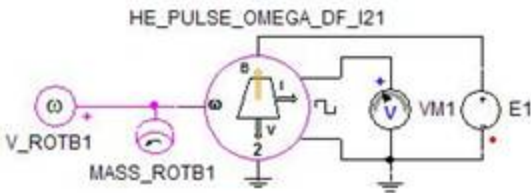


Figure 2. Application example of the Hall-Effect (Pulse Output) Angular Velocity (Displacement-Force) sensor**Table 3**

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROT B1	VALUE	5k * (t/400u) [rad/s]
Mass MASS_ROT B1	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Hall-Effect (Pulse Output) Angular Velocity (Displacement-Force) sensor HE_PULSE_OMEGA_DF_I21	phase	0 [rad]
	offset	2.2 [V]
	amplitude	0.3 [V]
	corner_frequency	0 [Hz]
	temp	27 [°C]
	output_resistance	0 [Ohm]
	max_omega	100k [rad/s]
	min_omega	0 [rad/s]
	frequency_offset	0 [Hz]
	hysteresis	0 [%]
	max_temp	0.15k [°C]

	min_temp	-50 [°C]
	temp_hys- teresis	0 [%]
	num_gear_ teeth	20
	supply_cur- rent	14.5m [A]
	nonlinearity	0.5 [%]
	tempco_span	0 [%/(°C)]
	rise_time	0 [s]
Voltage Source E1	EMF	5 [V]

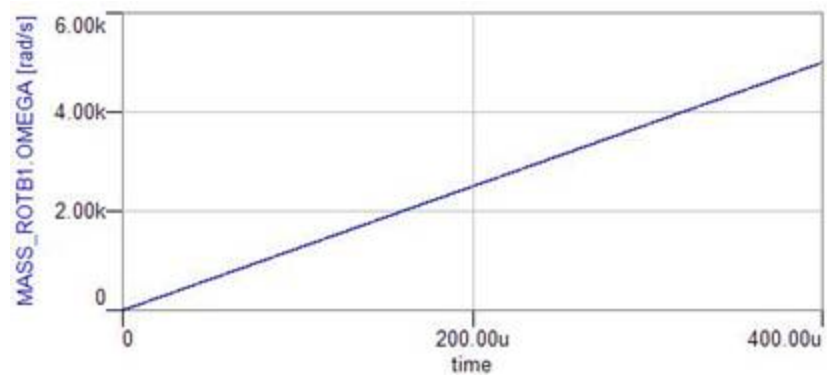


Figure 3. Simulation results-angular velocity of MASS_ROT B1

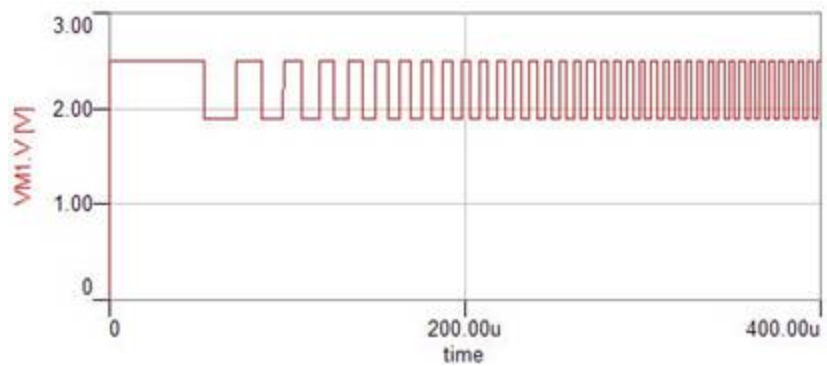


Figure 4. Simulation results-output voltage of HE_PULSE_OMEGA_DF_I21

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References

Level 2 Hall-Effect (Sinusoidal Output) Angular Velocity Sensor (Displacement-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

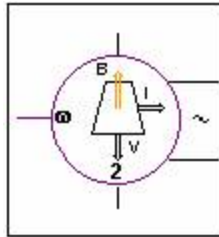


Figure 1. Component symbol

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Description

The Level 2 Hall-Effect (Sinusoidal Output) Angular Velocity (Displacement-Force) sensor model is used to simulate the non-ideal behavior of a sinusoidal-output, Hall-effect angular velocity sensor in the Twin Builder displacement-force rotational domain. A change in the angular velocity of an element in the displacement-force rotational domain that is connected to the model's input causes a corresponding change in the frequency of the model's sinusoidal voltage output signal.

The model has one conservative pin in the displacement-force rotational domain for its angular velocity input and four conservative electrical domain pins: two for power supply connections and two for the sensor output voltage. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is grounded.

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Netlist Syntax

```
MODEL HE_SINE_OMEGA_DF_I2 ?InstanceName(@InstanceName):(@Refbase)@(ID))
OMEGA:= %0, OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 ( corner_frequency:=
@corner_frequency, max_omega:= @max_omega, min_omega:= @min_omega, frequency_
offset:= @frequency_offset, num_gear_teeth:= @num_gear_teeth, nonlinearity:= @non-
linearity, hysteresis:= @hysteresis, temp:= @temp, max_temp:= @max_temp, min_temp:=
@min_temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span, phase:=
@phase, offset:= @offset, amplitude:= @amplitude, supply_current:= @supply_current, out-
put_resistance:= @output_resistance) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Table 1

Name	Port/Terminal Description	Nature/Data type
OMEGA	Measured angular velocity	Rotational
OUT_P	Positive output	Electrical
OUT_M	Negative output	Electrical
Vdd	Positive supply	Electrical
Vss	Negative supply	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
phase	Phase shift of out-	Real	0 [Rad]

	put sinusoid		
offset	DC offset of sinusoidal output	Real	0 [V]
amplitude	Amplitude of sinusoidal output	Real	5 [V]
corner_frequency	Corner frequency of input signal	Real	0 [Hz]
temp	Device temperature	Real	27 [°C]
output_resistance	Output resistance	Real	0 [Ohm]
max_omega	Maximum measurable angular velocity	Real	628.318530717959k [Rad/s]
min_omega	Minimum measurable angular velocity	Real	0 [Rad/s]
frequency_offset	Output frequency at minimum angular velocity	Real	0 [Hz]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	250 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]

tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
num_gear_teeth	Number of teeth on sensed gear	Real	20
nonlinearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
supply_current	Supply current	Real	0.5m [A]

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Example

In this example, the Hall-Effect (Sinusoidal Output) Angular Velocity (Displacement-Force) sensor HE_SINE_OMEGA_DF_I21 measures the angular velocity of the Mass MASS_ROT B1. The change in the measurement results causes a corresponding change in the frequency of the sinusoidal voltage output of HE_SINE_OMEGA_DF_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

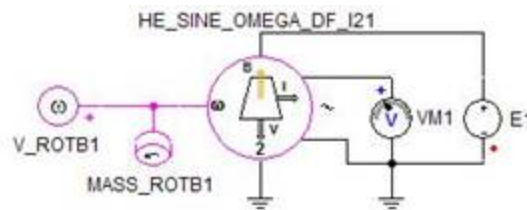


Figure 2. Application example of the Hall-Effect (Sinusoidal Output) Angular Velocity (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROT B1	VALUE	10k + 10k * (t>=200u) [rad/s]
Mass MASS_ROT B1	J	1 [kg m]

	PHI0	0 [rad]
	OMEGA0	10k [rad/s]
Hall-Effect (Sinusoidal Output) Angular Velocity (Displacement-Force) sensor HE_SINE_OMEGA_DF_I21	phase	0 [rad]
	offset	0 [V]
	amplitude	0.9 * E1.EMF [V]
	corner_frequency	0 [Hz]
	temp	27 [°C]
	output_resistance	0 [Ohm]
	max_omega	20k [rad/s]
	min_omega	1k [rad/s]
	frequency_offset	0 [Hz]
	max_temp	250 [°C]
	min_temp	-50 [°C]
	temp_hysteresis	0 [%]
	tempco_span	0 [%/(°C)]
	num_gear_teeth	20
	nonlinearity	0 [%]

	supply_cur- rent	0.5m [A]
Voltage Source E1	EMF	5 [V]

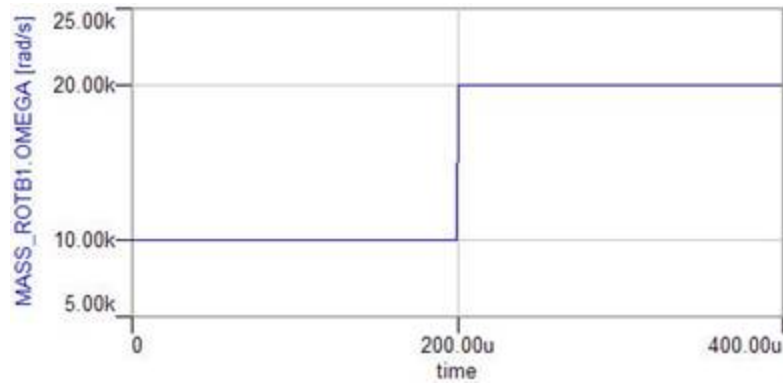


Figure 3. Simulation results-angular velocity of MASS_ROT B1

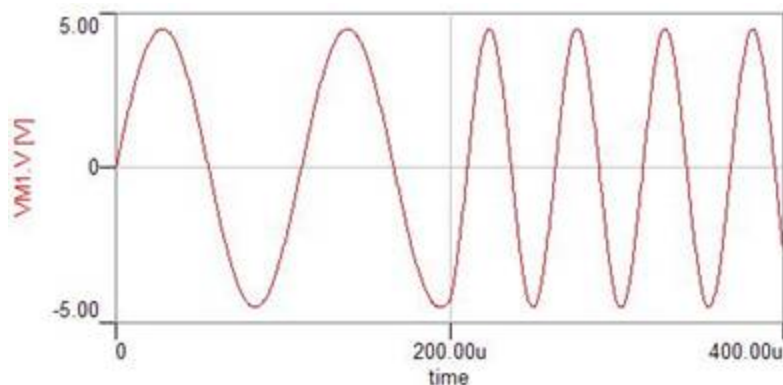


Figure 4. Simulation results-output voltage of HE_SINE_OMEGA_DF_I21

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References

Level 2 Variable Reluctance Angular Velocity Sensor (Displacement-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

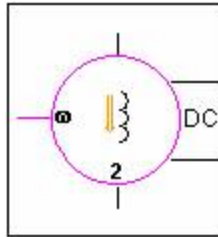


Figure 1. Component symbol

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Description

The Level 2 Variable Reluctance Angular Velocity (Displacement-Force) sensor model is used to simulate the ideal behavior of a conditioned variable reluctance angular velocity sensor in the Twin Builder displacement-force rotational domain. A change in angular velocity of an element in the displacement-force rotational domain that is connected to the model's input causes a corresponding change in the model's linear voltage output signal.

The model has one conservative pin in the displacement-force rotational domain for its angular velocity input and four conservative electrical-domain pins, two for power supply connections and two for the sensor output voltage. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is grounded.

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Netlist Syntax

```
MODEL VR_OMEGA_DF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) OMEGA:=
%0, Vdd:= %1, Vss:= %2, OUT_P:= %3, OUT_M:= %4 ( corner_frequency:= @corner_fre-
quency, full_scale_span:= @full_scale_span, offset:= @offset, max_omega:= @max_omega,
min_omega:= @min_omega, nonlinearity:= @nonlinearity, hysteresis:= @hysteresis, temp:=
@temp, max_temp:= @max_temp, min_temp:= @min_temp, temp_hysteresis:= @temp_hys-
teresis, tempco_span:= @tempco_span, temp_sens_offset:= @temp_sens_offset, output_res-
istance:= @output_resistance, supply_current:= @supply_current) SRC: DB
(Lib:=@ModelLibraryName) ;
```

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Table 1

Name	Port/Terminal Description	Nature/Data type
OMEGA	Measured angular velocity	Rotational
OUT_P	Positive output	Electrical
OUT_M	Negative output	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
corner_fre-	Corner frequency of input sig-	Real	0 [Hz]

quency	nal		
temp	Device temperature	Real	27 [°C]
output_resistance	Output resistance	Real	0 [Ohm]
full_scale_span	Difference of output voltages at maximum and minimum measurable angular velocities	Real	10 [V]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	200 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
max_omega	Maximum measurable angular velocity	Real	10 [Rad/s]
min_omega	Minimum measurable angular velocity	Real	0 [Rad/s]
nonlinearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
supply_current	Supply current	Real	0.5m [A]

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Example

In this example, the Variable Reluctance Angular Velocity (Displacement-Force) sensor VR_OMEGA_DF_I21 measures the angular velocity of the Mass MASS_ROT1. The linear voltage output of VR_OMEGA_DF_I21 changes in response to the measurement results. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

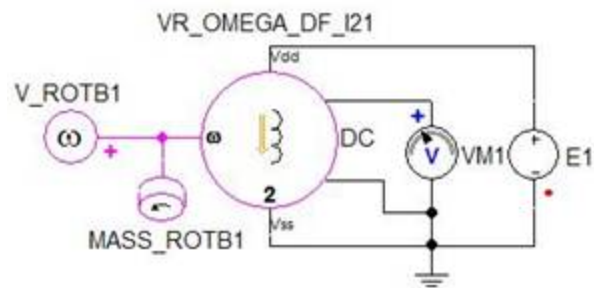


Figure 2. Application example of the Variable Reluctance Angular Velocity (Displacement-Force) Sensor

Table 3

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROTB1	VALUE	110 * (t/40m) [rad/s]
Mass MASS_ROTB1	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Voltage Source E1	EMF	5 [V]
Variable Reluctance Angular Velocity (Displacement-Force) sensor VR_OMEGA_DF_I21	offset	0.1 * E1.EMF [V]
	corner_frequency	0 [Hz]
	temp	27 [°C]
	output_resistance	0 [Ohm]
	full_scale_	0.9 *

	span	E1.EMF [V]
	hysteresis	0 [%]
	max_temp	200 [°C]
	min_temp	-50 [°C]
	temp_hys- teresis	0 [%]
	tempco_span	0 [%/(°C)]
	max_omega	100 [Rad/s]
	min_omega	0 [Rad/s]
	nonlinearity	0 [%]
	temp_sens_ offset	0 [V/(°C)]
	supply_cur- rent	0.5m [A]

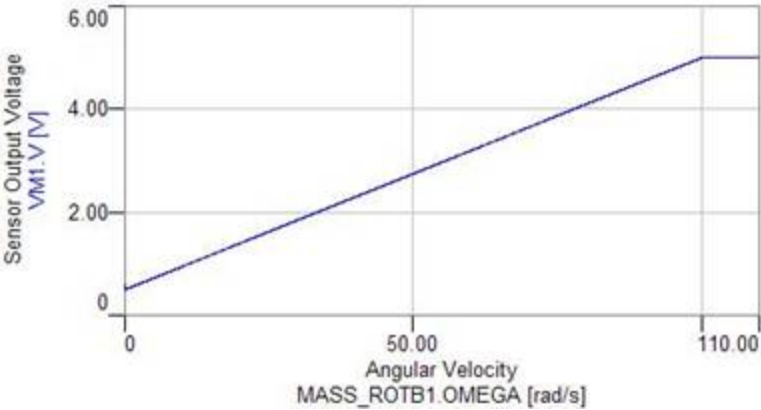


Figure 3. Simulation results-output voltage of VR_OMEGA_DF_I21 vs. its angular velocity input

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References

Level 2 Variable Reluctance (Sinusoidal Output) Angular Velocity Sensor (Displacement-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

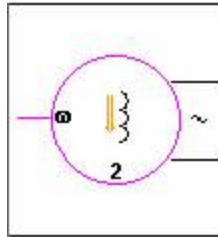


Figure 1. Component symbol

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Description

The Level 2 Variable Reluctance (Sinusoidal Output) Angular Velocity (Displacement-Force) sensor model is used to simulate the non-ideal behavior of a variable reluctance gear angular velocity sensor in the Twin Builder displacement-force rotational domain. The model produces a sinusoidal output whose amplitude and frequency are dependent on the angular velocity of a rotating gear, the diameter of the gear, and the number of teeth on the gear. The Level 2 model differs from the Level 1 ideal model in that the sensor's temperature sensitivity and coil resistance are also taken into account.

The model has one conservative input pin in the displacement-force rotational domain for its angular velocity input and two conservative electrical-domain pins for its sinusoidal voltage output. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is grounded.

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Netlist Syntax

```
MODEL VR_OMEGA_SINE_DF_I2 ?InstanceName(@InstanceName):(@@Refbase)@(ID))
OMEGA:= %0, OUT_P:= %1, OUT_M:= %2 ( max_surface_speed:= @max_surface_speed,
min_surface_speed:= @min_surface_speed, gear_diameter:= @gear_diameter, num_gear_
teeth:= @num_gear_teeth, full_scale_span:= @full_scale_span, temp_sens:= @temp_sens,
temp:= @temp, phase:= @phase, coil_resistance:= @coil_resistance) SRC: DB(Lib:-
:=@ModelLibraryName);
```

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Table 1

Name	Port/Terminal Description	Nature/Data type
OMEGA	Measured angular velocity	Rotational
OUT_P	Positive output	Electrical
OUT_M	Negative output	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
phase	Sensor phase shift	Real	0 [Rad]
temp	Current sensor temperature	Real	27 [°C]
full_scale_span	Difference in peak-to-peak voltages at maximum and min-	Real	30 [V]

	imum measurable angular velocities		
max_surface_speed	Maximum measurable surface speed	Real	100 [m/s]
min_surface_speed	Minimum measurable surface speed	Real	20 [m/s]
gear_diameter	Diameter of sensed gear	Real	50m [m]
num_gear_teeth	Number of teeth on sensed gear	Real	50
temp_sens	Output temperature sensitivity	Real	0 [V/(°C)]
coil_resistance	Coil Resistance	Real	0 [Ohm]

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Example

In this example, the Variable Reluctance (Sinusoidal Output) Angular Velocity (Displacement-Force) sensor VR_OMEGA_SINE_DF_I22 measures the angular velocity of the Mass MASS_ROT2. VR_OMEGA_SINE_DF_I22 produces a sinusoidal output whose amplitude and frequency are dependent on measurement results. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

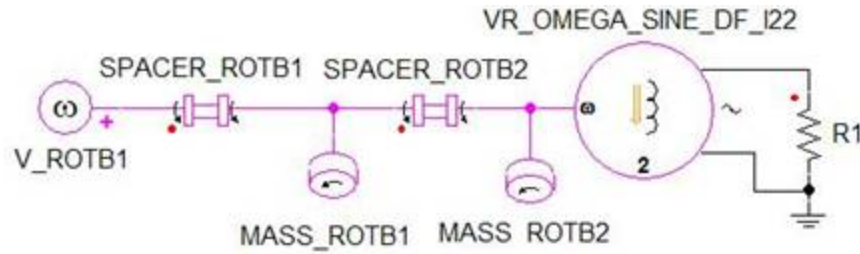


Figure 2. Application example of the Variable Reluctance Angular Velocity (Displacement-Force) Sensor

Table 3

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROTB1	VALUE	$33.3 * (t \geq 200u) + 33.3 * (t \geq 400u) + 14.3 * (t \geq 600u)$ [rad/s]
Spacer $SPACER\_ROTB1/$ $SPACER\_ROTB2$	LEN	0 [rad]
Mass $MASS\_ROTB1$	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Mass $MASS\_ROTB2$	J	2 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Resistor $R1$	R	100k [Ohm]
Variable Reluctance (Sinusoidal Output) Angular Velocity (Displacement-Force) sensor $VR\_OMEGA\_SINE\_DF\_I22$	phase	0 [rad]
	temp	27 [°C]

	full_scale_span	175 [V]
	max_surface_speed	25.4 [m/s]
	min_surface_speed	0.25 [m/s]
	gear_diameter	100m [m]
	num_gear_teeth	100
	temp_sens	0 [V/(°C)]
	coil_resistance	1.2k [Ohm]

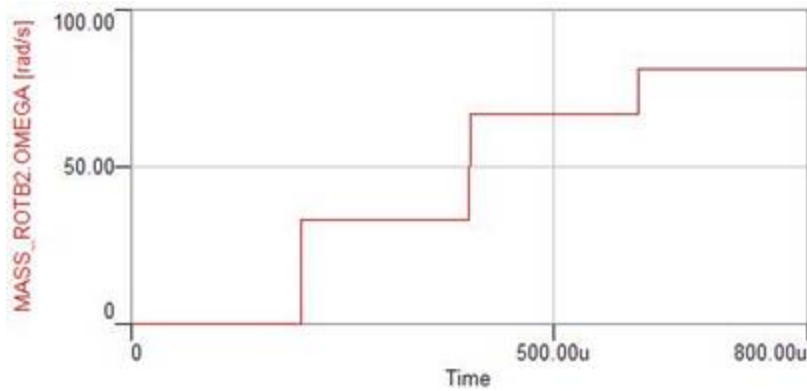


Figure 3. Simulation results-angular velocity of MASS_ROT2

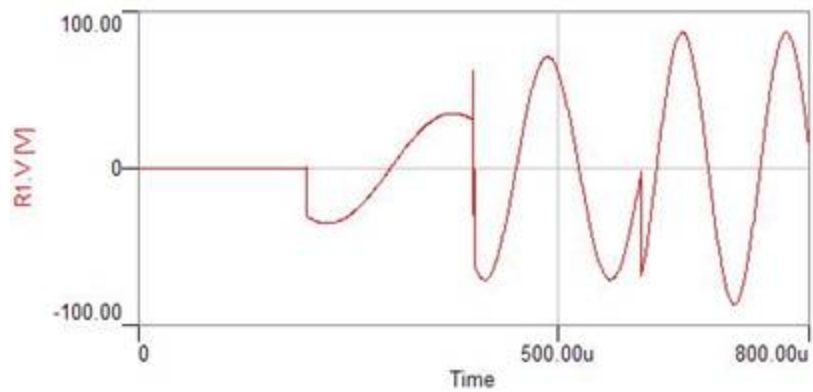


Figure 4. Simulation results-output voltage of VR_OMEGA_SINE_DF_I22

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References

Level 2 Hall-Effect (Pulse Output) Angular Velocity Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

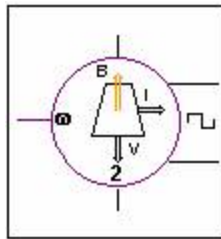


Figure 1. Component symbol

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Description

The Level 2 Hall-Effect (Pulse Output) Angular Velocity (Velocity-Force) sensor model is used to simulate the non-ideal behavior of a pulse-output, Hall-effect angular velocity sensor in the Twin Builder velocity-force rotational domain. A change in the angular velocity of an element in the velocity-force rotational domain that is connected to the model's input causes a corresponding change in the frequency of the model's pulsed voltage output signal.

The model has one conservative input pin in the velocity-force rotational domain for its angular velocity input and four conservative electrical-domain pins, two for power supply connections and two for the sensor output voltage. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is grounded.

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Netlist Syntax

```
MODEL HE_PULSE_OMEGA_VF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
OMEGA:= %0, OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 ( max_omega:= @max_
omega, min_omega:= @min_omega, frequency_offset:= @frequency_offset, num_gear_
teeth:= @num_gear_teeth, phase:= @phase, offset:= @offset, amplitude:= @amplitude, sup-
ply_current:= @supply_current, corner_frequency:= @corner_frequency, output_resistance:=
@output_resistance, nonlinearity:= @nonlinearity, hysteresis:= @hysteresis, temp:= @temp,
max_temp:= @max_temp, min_temp:= @min_temp, temp_hysteresis:= @temp_hysteresis,
tempco_span:= @tempco_span) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Table 1

Name	Port/Terminal Description	Nature/Data type
OMEGA	Measured angular velocity	Rotational_V
OUT_P	Positive output	Electrical
OUT_M	Negative output	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
phase	Phase shift of output sinusoid	Real	0 [Rad]
offset	DC offset of pulse output	Real	0 [V]
amplitude	Amplitude of pulse output	Real	5 [V]
corner_frequency	Corner frequency of input signal	Real	0 [Hz]
temp	Device temperature	Real	27 [°C]
output_resistance	Output resistance	Real	0 [Ohm]
max_omega	Maximum measurable angular velocity	Real	628.318530717959k [Rad/s]
min_omega	Minimum measurable angular velocity	Real	0 [Rad/s]
frequency_offset	Output frequency at minimum angular velocity	Real	0 [Hz]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	200 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]

temp_hys- teresis	Temperature hys- teresis as a per- centage of full- scale span	Real	0 [%]
tempco_span	Output voltage temperature coef- ficient as a per- centage of full- scale span	Real	0 [%/(°C)]
num_gear_ teeth	Number of teeth on sensed gear	Real	20
supply_cur- rent	Supply current	Real	0.5m [A]
nonlinearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]

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Example

In this example, the Hall-Effect (Pulse Output) Angular Velocity (Velocity-Force) sensor HE_PULSE_OMEGA_VF_I21 measures the angular velocity of the Mass MASS_ROT1. The change in the measurement results causes a corresponding change in the frequency of the sinusoidal voltage output of HE_PULSE_OMEGA_VF_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

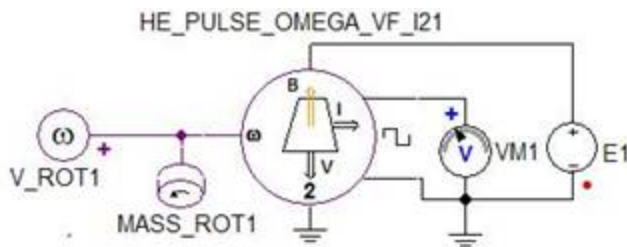


Figure 2. Application example of the Hall-Effect (Pulse Output) Angular Velocity (Velocity-Force) sensor

Table 3

Component	Parameter	Value [Unit]

Angular Velocity Source V_ROT1	VALUE	5k * (t/400u) [rad/s]
Mass MASS_ROT1	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Hall-Effect (Pulse Output) Angular Velocity (Velocity-Force) sensor HE_PULSE_OMEGA_VF_I21	phase	0 [rad]
	offset	2.2 [V]
	amplitude	0.3 [V]
	corner_frequency	0 [Hz]
	temp	27 [°C]
	output_resistance	0 [Ohm]
	max_omega	100k [rad/s]
	min_omega	0 [rad/s]
	frequency_offset	0 [Hz]
	hysteresis	0 [%]
	max_temp	0.15k [°C]
	min_temp	-50 [°C]
	temp_hysteresis	0 [%]

	num_gear_teeth	20
	supply_current	14.5m [A]
	nonlinearity	0.5 [%]
	tempco_span	0 [%/(°C)]
	rise_time	0 [s]
Voltage Source E1	EMF	5 [V]

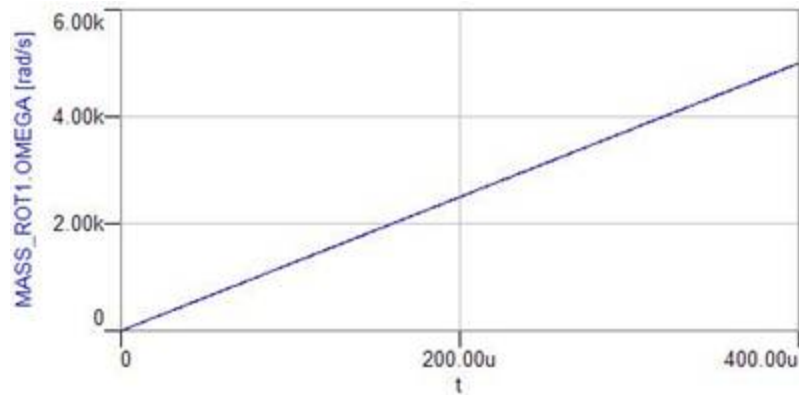


Figure 3. Simulation results-angular velocity of MASS_ROT1

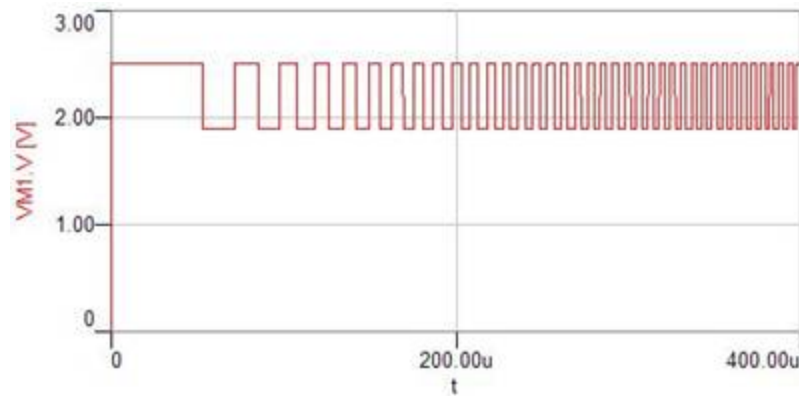


Figure 4. Simulation results-output voltage of HE_PULSE_OMEGA_VF_I21

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References

Level 2 Hall-Effect (Sinusoidal Output) Angular Velocity Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

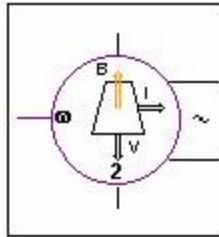


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Description

The Level 2 Hall-Effect (Sinusoidal Output) Angular Velocity (Velocity-Force) sensor model is used to simulate the non-ideal behavior of a sinusoidal-output, Hall-effect angular velocity sensor in the Twin Builder velocity-force rotational domain. A change in the angular velocity of an element in the velocity-force rotational domain that is connected to the model's input causes a corresponding change in the frequency of the model's sinusoidal voltage output signal.

The model has one conservative pin in the velocity-force rotational domain for its angular velocity input and four conservative electrical domain pins: two for power supply connections and two for the sensor output voltage. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is grounded.

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Mathematical Description

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Netlist Syntax

```
MODEL HE_SINE_OMEGA_VF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
OMEGA:= %0, OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 ( corner_frequency:=
@corner_frequency, max_omega:= @max_omega, min_omega:= @min_omega, frequency_
offset:= @frequency_offset, num_gear_teeth:= @num_gear_teeth, nonlinearity:= @non-
linearity, hysteresis:= @hysteresis, temp:= @temp, max_temp:= @max_temp, min_temp:=
@min_temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span, phase:=
@phase, offset:= @offset, amplitude:= @amplitude, supply_current:= @supply_current, out-
put_resistance:= @output_resistance) SRC: DB(Lib:=@ModellibraryName) ;
```

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Table 1

Name	Port/Terminal Description	Nature/Data type
OMEGA	Measured angular velocity	Rotational_V
OUT_P	Positive output	Electrical
OUT_M	Negative output	Electrical
Vdd	Positive supply	Electrical
Vss	Negative supply	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
phase	Phase shift of out-put sinusoid	Real	0 [Rad]
offset	DC offset of sinus-	Real	0 [V]

	oidal output		
amplitude	Amplitude of sinusoidal output	Real	5 [V]
corner_frequency	Corner frequency of input signal	Real	0 [Hz]
temp	Device temperature	Real	27 [°C]
output_resistance	Output resistance	Real	0 [Ohm]
max_omega	Maximum measurable angular velocity	Real	628.318530717959k [Rad/s]
min_omega	Minimum measurable angular velocity	Real	0 [Rad/s]
frequency_offset	Output frequency at minimum angular velocity	Real	0 [Hz]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	250 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a per-	Real	0 [%/(°C)]

	centage of full-scale span		
num_gear_teeth	Number of teeth on sensed gear	Real	20
nonlinearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
supply_current	Supply current	Real	0.5m [A]

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Example

In this example, the Hall-Effect (Sinusoidal Output) Angular Velocity (Velocity-Force) sensor HE_SINE_OMEGA_VF_I21 measures the angular velocity of the Mass MASS_ROT1. The change in the measurement results causes a corresponding change in the frequency of the sinusoidal voltage output of HE_SINE_OMEGA_VF_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

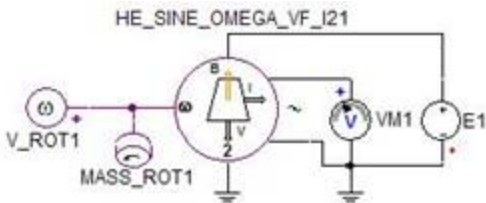


Figure 2. Application example of the Hall-Effect (Sinusoidal Output) Angular Velocity (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROT1	VALUE	10k + 10k * (t>=200u) [rad/s]
Mass MASS_ROT1	J	1 [kg m]
	PHI0	0 [rad]

	OMEGA0	10k [rad/s]
Hall-Effect (Sinusoidal Output) Angular Velocity (Velocity-Force) sensor HE_SINE_OMEGA_VF_I21	phase	0 [rad]
	offset	0 [V]
	amplitude	0.9 * E1.EMF [V]
	corner_frequency	0 [Hz]
	temp	27 [°C]
	output_resistance	0 [Ohm]
	max_omega	20k [rad/s]
	min_omega	1k [rad/s]
	frequency_offset	0 [Hz]
	max_temp	250 [°C]
	min_temp	-50 [°C]
	temp_hysteresis	0 [%]
	tempco_span	0 [%/(°C)]
	num_gear_teeth	20
	nonlinearity	0 [%]
	supply_current	0.5m [A]

Voltage Source E1	EMF	5 [V]

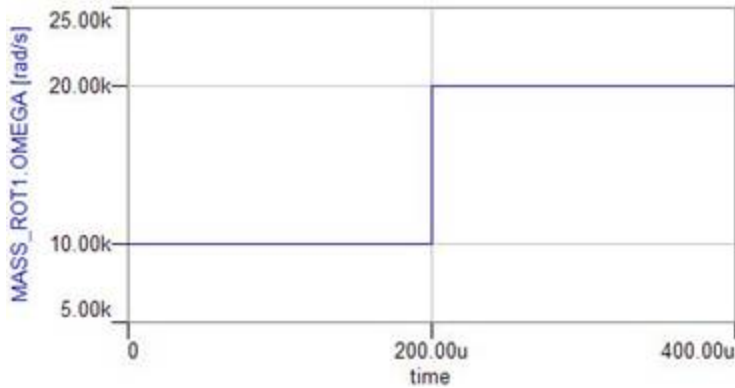


Figure 3. Simulation results-angular velocity of MASS_ROT1

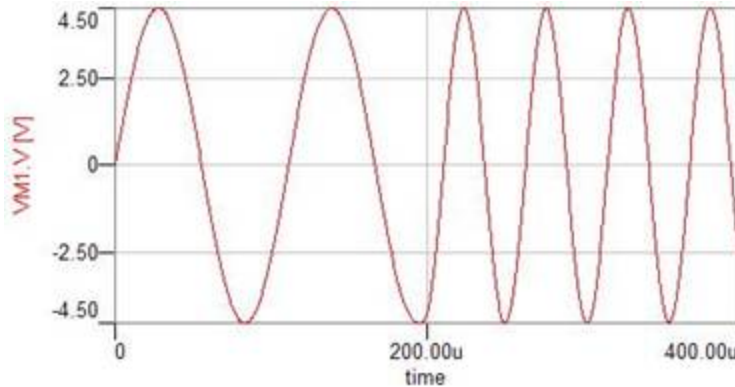


Figure 4. Simulation results-output voltage of HE_SINE_OMEGA_VF_I21

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References

Level 2 Variable Reluctance (Sinusoidal Output) Angular Velocity Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

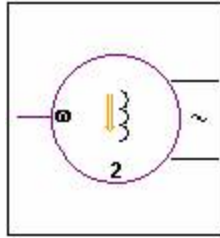


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Description

The Level 2 Variable Reluctance (Sinusoidal Output) Angular Velocity (Displacement-Force) sensor model is used to simulate the non-ideal behavior of a variable reluctance gear angular velocity sensor in the Twin Builder displacement-force rotational domain. The model produces a sinusoidal output whose amplitude and frequency are dependent on the angular velocity of a rotating gear, the diameter of the gear, and the number of teeth on the gear. The Level 2 model differs from the Level 1 ideal model in that the sensor's temperature sensitivity and coil resistance are also taken into account.

The model has one conservative input pin in the displacement-force rotational domain for its angular velocity input and two conservative electrical-domain pins for its sinusoidal voltage output. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is grounded.

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Netlist Syntax

```
MODEL VR_OMEGA_SINE_VF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
OMEGA:= %0, OUT_P:= %1, OUT_M:= %2 ( max_surface_speed:= @max_surface_speed,
min_surface_speed:= @min_surface_speed, gear_diameter:= @gear_diameter, num_gear_
teeth:= @num_gear_teeth, full_scale_span:= @full_scale_span, temp_sens:= @temp_sens,
temp:= @temp, phase:= @phase, coil_resistance:= @coil_resistance) SRC: DB(Lib:-
:=@ModelLibraryName);
```

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Table 1

Name	Port/Terminal Description	Nature/Data type
OMEGA	Measured angular velocity	Rotational
OUT_P	Positive output	Electrical
OUT_M	Negative output	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
phase	Sensor phase shift	Real	0 [Rad]
temp	Current sensor temperature	Real	27 [°C]
full_scale_span	Difference in peak-to-peak voltages at maximum and min-	Real	30 [V]

	imum measurable angular velocities		
max_surface_speed	Maximum measurable surface speed	Real	100 [m/s]
min_surface_speed	Minimum measurable surface speed	Real	20 [m/s]
gear_diameter	Diameter of sensed gear	Real	50m [m]
num_gear_teeth	Number of teeth on sensed gear	Real	50
temp_sens	Output temperature sensitivity	Real	0 [V/(°C)]
coil_resistance	Coil Resistance	Real	0 [Ohm]

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Example

In this example, the Variable Reluctance (Sinusoidal Output) Angular Velocity (Velocity-Force) sensor VR_OMEGA_SINE_VF_I21 measures the angular velocity of the Mass MASS_ROT2. VR_OMEGA_SINE_VF_I21 produces a sinusoidal output whose amplitude and frequency are dependent on measurement results. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

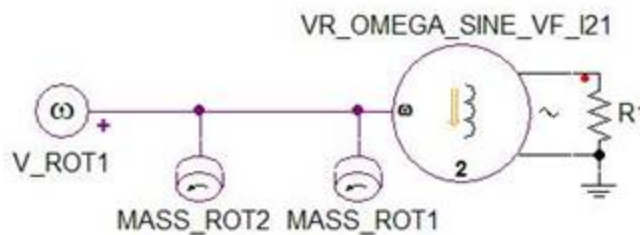


Figure 2. Application example of the Variable Reluctance Angular Velocity (Velocity-Force) Sensor

Table 3

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROT1	VALUE	$33.3 * (t \geq 200\mu) + 33.3 * (t \geq 400\mu) + 14.3 * (t \geq 600\mu)$ [rad/s]
Mass MASS_ROT1/MASS_ROT2	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Resistor R1	R	100k [Ohm]
Variable Reluctance (Sinusoidal Output) Angular Velocity (Velocity-Force) sensor VR_OMEGA_SINE_VF1	phase	0 [rad]
	temp	27 [°C]
	full_scale_span	175 [V]
	max_surface_speed	25.4 [m/s]
	min_surface_speed	0.25 [m/s]

	gear_dia-meter	100m [m]
	num_gear_teeth	100
	temp_sens	0 [V/(°C)]
	coil_res-istance	1.2k [Ohm]

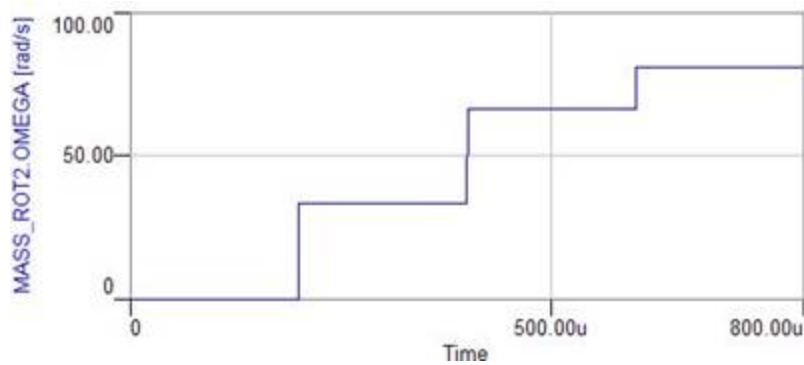


Figure 3. Simulation results-angular velocity of MASS_ROT2

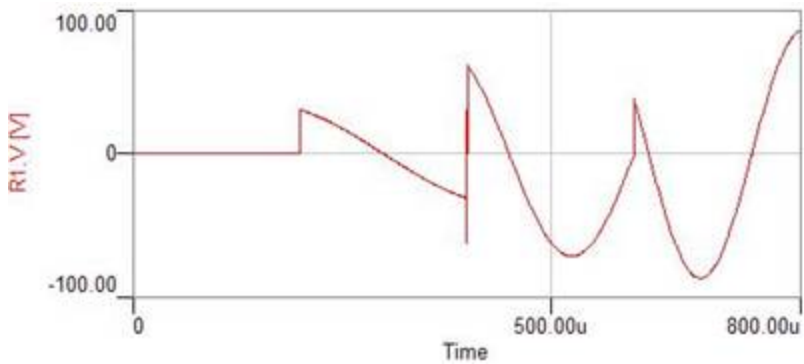


Figure 4. Simulation results-output voltage of VR_OMEGA_SINE_VF_I21

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References

Level 2 Variable Reluctance Angular Velocity Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

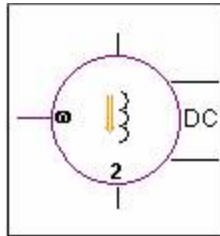


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Description

The Level 2 Variable Reluctance Angular Velocity (Velocity-Force) sensor model is used to simulate the ideal behavior of a conditioned variable reluctance angular velocity sensor in the Twin Builder velocity-force rotational domain. A change in angular velocity of an element in the velocity-force rotational domain that is connected to the model's input causes a corresponding change in the model's linear voltage output signal.

The model has one conservative input pin in the velocity-force rotational domain for its angular velocity input and four conservative electrical-domain pins, two for power supply connections and two for the sensor output voltage. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is grounded.

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Netlist Syntax

```
MODEL VR_OMEGA_VF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) OMEGA:=
%0, Vdd:= %1, Vss:= %2, OUT_P:= %3, OUT_M:= %4 ( corner_frequency:= @corner_fre-
quency, full_scale_span:= @full_scale_span, offset:= @offset, max_omega:= @max_omega,
min_omega:= @min_omega, nonlinearity:= @nonlinearity, hysteresis:= @hysteresis, temp:=
@temp, max_temp:= @max_temp, min_temp:= @min_temp, temp_hysteresis:= @temp_hys-
teresis, tempco_span:= @tempco_span, temp_sens_offset:= @temp_sens_offset, output_res-
istance:= @output_resistance, supply_current:= @supply_current) SRC: DB
(Lib:=@ModelLibraryName) ;
```

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Table 1

Name	Port/Terminal Description	Nature/Data type
OMEGA	Measured angular velocity	Rotational_V
OUT_P	Positive output	Electrical
OUT_M	Negative output	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
corner_fre-	Corner frequency of input sig-	Real	0 [Hz]

quency	nal		
temp	Device temperature	Real	27 [°C]
output_resistance	Output resistance	Real	0 [Ohm]
full_scale_span	Difference of output voltages at maximum and minimum measurable angular velocities	Real	10 [V]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	200 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
max_omega	Maximum measurable angular velocity	Real	10 [Rad/s]
min_omega	Minimum measurable angular velocity	Real	0 [Rad/s]
nonlinearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
supply_current	Supply current	Real	0.5m [A]

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Example

In this example, the Variable Reluctance Angular Velocity (Velocity-Force) sensor VR_OMEGA_VF_I21 measures the angular velocity of the Mass MASS_ROT1. The linear voltage output of VR_OMEGA_VF_I21 changes in response to the measurement results. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

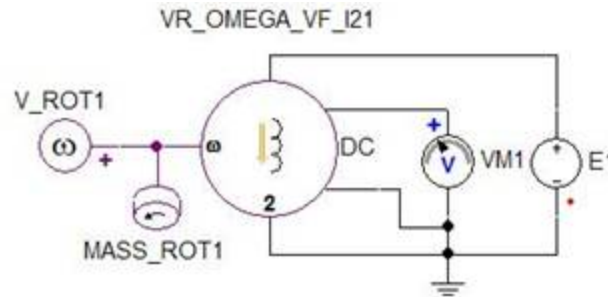


Figure 2. Application example of the Variable Reluctance Angular Velocity (Velocity-Force) Sensor

Table 3

Component	Parameter	Value [Unit]
Angular Velocity Source V_ROT1	VALUE	$110 \cdot (t/40m)$ [rad/s]
Mass MASS_ROT1	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Voltage Source E1	EMF	5 [V]
Variable Reluctance Angular Velocity (Velocity-Force) sensor VR_OMEGA_VF_I21	offset	$0.1 \cdot E1.EMF$ [V]
	corner_frequency	0 [Hz]

temp	27 [°C]
output_resistance	0 [Ohm]
full_scale_span	0.9 * E1.EMF [V]
hysteresis	0 [%]
max_temp	100 [°C]
min_temp	-50 [°C]
temp_hysteresis	0 [%]
tempco_span	0 [%/(°C)]
max_omega	100 [Rad/s]
min_omega	0 [Rad/s]
nonlinearity	0 [%]
temp_sens_offset	0 [V/(°C)]
supply_current	0.5m [A]

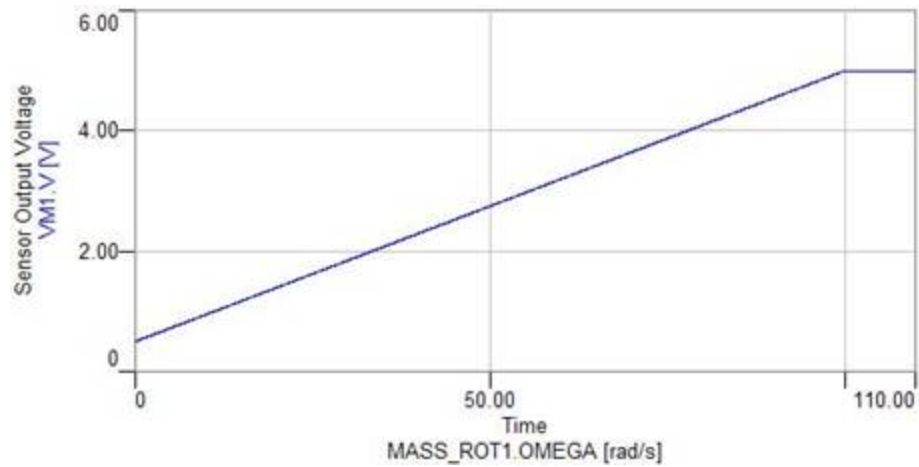


**Figure 3. Simulation results-output voltage of VR_OMEGA_VF_I21
vs. the angular velocity of MASS_ROT1**

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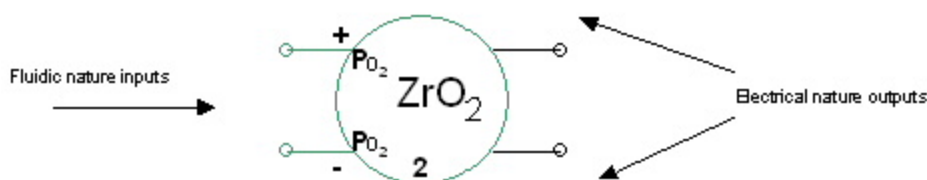
References

Level 2 Exhaust Gas Sensor Models

The Level 2 Exhaust Gas Sensor Models simulate realistic non-ideal behavior of automotive exhaust gas sensors.

All of the exhaust gas sensor models have conservative input pins that must be connected to a fluidic network and conservative output pins that must be connected to an electrical network. The models also feature nonconservative parameters that can be changed in order to tailor the behavior of the model to that of a specific real device.

As shown in the following example, Exhaust Gas sensor models for the fluidic domain have green conservative input pins that must be connected to a fluidic network. The models also have black pins that must be connected to an electrical network.



The Level 2 Exhaust Gas Sensor Models feature models for the following Exhaust Gas-sensing mechanisms:

- Zirconium Oxide ([NERNST_ZrO2_LE1_I2](#)) -- produces a voltage output signal that is proportional to the natural logarithm of the ratio of the partial pressure of oxygen in the surrounding atmosphere to the partial pressure of oxygen in exhaust gas.

Level 2 Zirconium Oxide (Lambda=1) Exhaust Gas Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

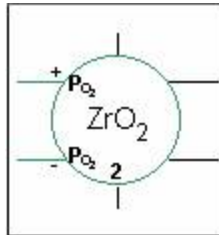


Figure 1. Component symbol

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Description

The Level 2 Zirconium Oxide (Lambda=1) exhaust gas Sensor model simulates the non-ideal behavior of a Zirconium Oxide exhaust gas sensor. The model produces a voltage signal that is proportional to the natural logarithm of the ratio of the partial pressure of oxygen in the surrounding atmosphere to the partial pressure in the oxygen in exhaust gas.

The model has two conservative fluidic-nature pins, one each for the oxygen partial pressures in the atmosphere and in the measured exhaust gas. The model also has four conservative electrical-nature pins, two for the positive and negative power supplies and two for the voltage output. The negative output terminal should be connected to ground if the model is connected to an electrical network in which no other element is grounded.

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Netlist Syntax

MODEL NERNST_ZrO2_LE1_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) AIR:= %0, EXHAUST:= %1, Vdd:= %2, Vss:= %3, OUT_P:= %4, OUT_N:= %5 (temp:= @temp, current_scale_factor:= @current_scale_factor, time_constant:= @time_constant, output_resistance:= @output_resistance) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
AIR	Atmospheric oxygen partial pressure	Fluidic
EXHAUST	Exhaust gas oxygen partial pressure	Fluidic
OUT_P	Positive output terminal	Electrical
OUT_N	Negative output terminal	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
temp	Absolute temperature	Real	300 [K]

output_resistance	Output resistance	Real	0 [Ohm]
time_constant	Output time constant	Real	0 [s]
current_scale_factor	Input conductivity	Real	0.2 [S]

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Example

In this example, the Zirconium Oxide (Lambda=1) Exhaust Gas Sensor NERNST_ZrO2_LE11 measures the oxygen partial pressures in the atmosphere and in the measured exhaust gas. The output voltage of NERNST_ZrO2_LE11 is proportional to the natural logarithm of the ratio of the measurement results. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

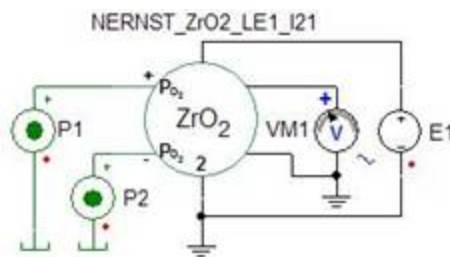


Figure 2. Application example of the Zirconium Oxide (Lambda=1) Exhaust Gas Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	8.47E-32 [Pa]
Pressure Source P2	VALUE	21.778k [Pa]
Zirconium Oxide (Lambda=1) Exhaust Gas Sensor NERNST_ZrO2_LE11	temp	493 [K]
	current_scale_factor	0.104 [S]

Voltage Source (sinusoidal) E1	AMPL	17 [V]
	FREQ	60 [Hz]
	PHASE	0 [degree]
	OFF	0 [V]
	TDELAY	0 [s]

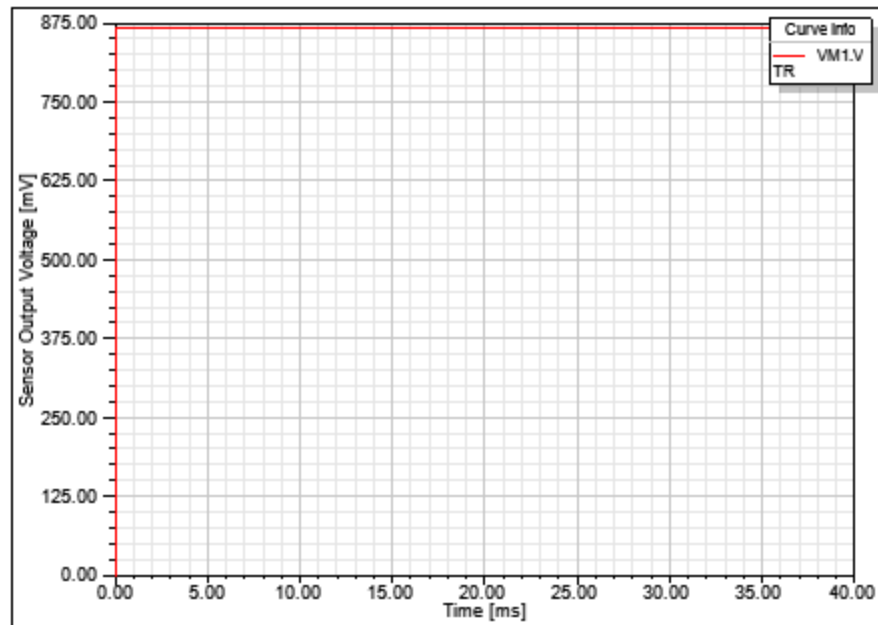


Figure 3. Simulation results-output voltage of NERNST_ZrO2_LE11

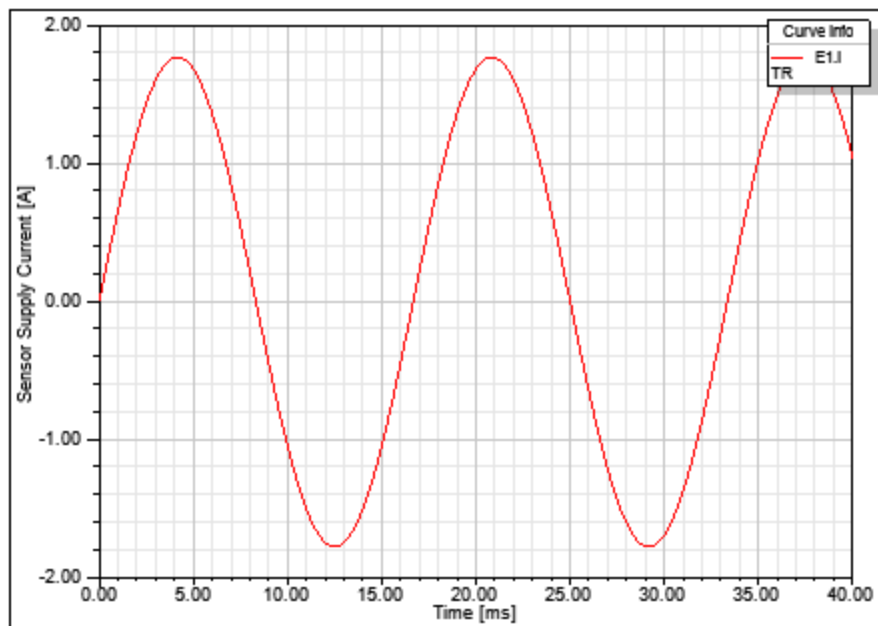


Figure 4. Simulation results-supply current from Voltage Source E1 supplied to the sensor NERNST_ZrO2_LE11

NOTE: Additional examples exist for this component in the Examples sub-directory.

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References

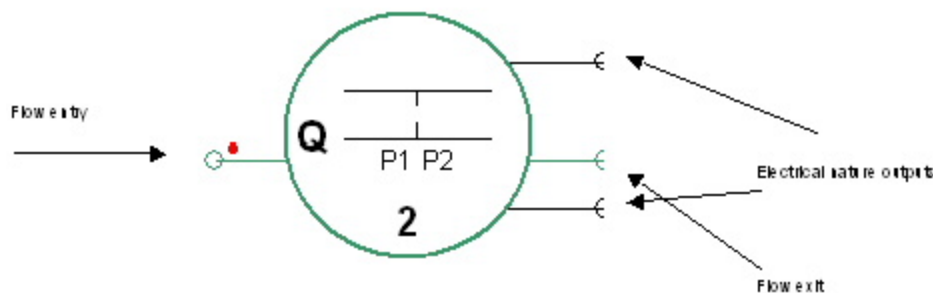
Level 2 Flow Sensor Models

The Level 2 Flow Sensor Models simulate non-ideal behavior of six different types of flow sensors.

All of the flow sensor models have conservative pins that must be connected to a fluidic network. Note that because flow is a through quantity, all flow sensor models have one fluidic pin for flow entry and another pin for flow exit.

Like other sensor models, the flow sensor models also have conservative output pins that must be connected to an electrical network and nonconservative parameters that can be changed in order to tailor the behavior of the model to that of a specific real device.

As shown in the following example, flow sensor green conservative input pins that must be connected to a fluidic network. The pin with the red dot indicates the pin at which the measured flow should enter. The models also have black pins that must be connected to an electrical network.



The Level 2 Flow Sensor Models feature models for the following flow-sensing mechanisms:

- Differential Pressure ([FLOW_DP_I2](#)): The sensor causes a small pressure drop across itself and produces an output voltage that is proportional to the square root of this pressure drop.
- Vane ([FLOW_VANE_I2](#)): Fluid flow deflects a vane, which in turn adjusts the wiper of a potentiometer, producing a voltage output signal. The deflection of the vane, and thus the output signal voltage, is proportional to the amount of flow.
- Karmen Vortex ([KVORTEX_FLOW_I2](#)): Fluid flow generates vortices within the sensor, which generate a pulsed output voltage signal. The frequency of the pulsed output is proportional to the flow through the sensor.
- Strain Gauge ([SG_FLOW_I2](#)): Flow deforms resistors connected in a Wheatstone bridge configuration, producing a differential voltage output.
- Thermal Mass-Flow ([T_M_FLOW_I2](#)): The sensor produces a voltage output that is proportional to the amount of mass moving through the sensor.
- Turbine: Flow turns a turbine within the sensor, producing a DC Output, or a pulse or sinusoidal (AC Output) voltage.
AC Output model: ([TURBINE_FLOW_I2](#))
DC Output model: ([TURBINE_FLOW_DC_I2](#))

Level 2 Differential Pressure Flow Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

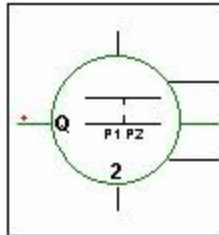


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Description

The Level 2 Differential Pressure Flow Sensor model simulates the non-ideal behavior of a differential pressure flow sensor. The model produces a voltage output signal that varies linearly with the flow moving through it.

The model has two conservative fluidic-nature pins through which flow enters and exits. The model also has four conservative electrical-nature pins, two for its power supply connections and two for its voltage output. The negative output terminal should be connected to ground if the model is connected to an electrical network in which no other element is grounded.

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Netlist Syntax

```
MODEL FLOW_DP_I2 ?InstanceName(@InstanceName):(@Refbase)@(ID)) FLOW_IN:= %0,  
FLOW_OUT:= %1, OUT_P:= %2, OUT_M:= %3, Vdd:= %4, Vss:= %5 ( sensor_conductance:=  
@sensor_conductance, sensitivity:= @sensitivity, offset:= @offset, max_output:= @max_out-  
put, min_output:= @min_output, supply_current:= @supply_current, time_constant:= @time_  
constant, temp_sens:= @temp_sens, temp:= @temp, output_resistance:= @output_resistance)  
SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
FLOW_IN	Flow entry	Fluidic
FLOW_OUT	Flow exit	Fluidic
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive power supply	Electrical
Vss	Negative power supply	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
sensor_conductance	Hydraulic conductance of sensor	Real	1m [m ³ / (Pa s)]
sensitivity	Sensitivity to square root of differential pressure	Real	1 [V/ (Pa) ^{1/2}]

offset	Sensor output voltage at minimum flow	Real	0 [V]
temp_sens	Output temperature sensitivity	Real	0 [V/(°C)]
temp	Device temperature	Real	27 [°C]
output_resistance	Sensor output resistance	Real	0 [Ohm]
time_constant	Output time constant	Real	0 [s]
max_output	Maximum output	Real	5 [V]
min_output	Minimum output	Real	0 [V]
supply_current	Typical supply current	Real	1m [A]

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Example

In this example, the Differential Pressure Flow Sensor FLOW_DP_I22 measures the flow through the Linear Orifice RHYD1, and the output voltage of FLOW_DP_I22 varies linearly with the measurement result. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

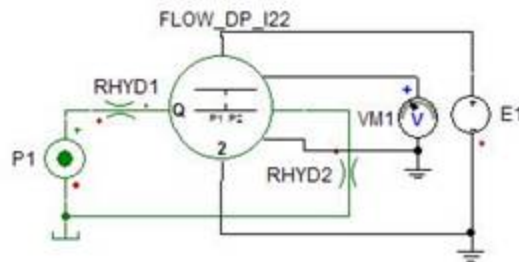


Figure 2. Application example of the Differential Pressure Flow Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	12.5Meg * (t >=100m) [Pa]

Linear Orifice RHYD1	K	1u [k/(Pa s)]
Voltage Source E1	EMF	5 [V]
Differential Pressure Flow Sensor FLOW_DP_I22	sensor_conductance	1m [m ³ /(Pa s)]
	sensitivity	50m [V/(Pa) ^{1/2}]
	offset	0 [V]
	temp_sens	100 [V/(°C)]
	temp	27 [°C]
	output_resistance	0 [Ohm]
	time_constant	500m [s]
	max_output	E1.EMF [V]
	min_output	0 [V]
	supply_current	0.5m [A]

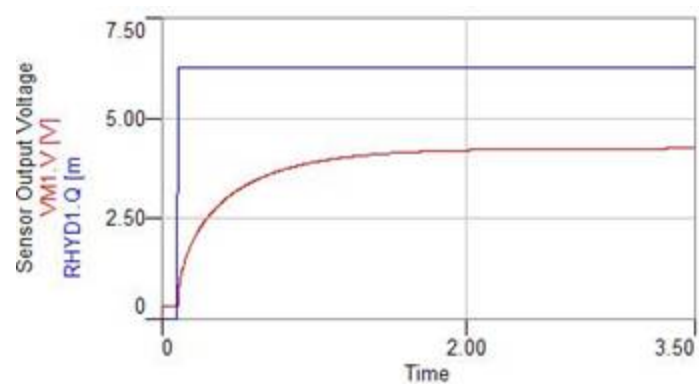


Figure 3. Simulation results-output voltage of FLOW_DP_I22 vs. its flow input

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References

Level 2 Vane Flow Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

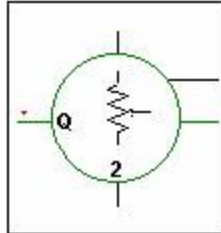


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Description

The Level 2 Vane Flow Sensor model simulates the non-ideal behavior of a potentiometric vane flow sensor. The voltage divider output of the model changes linearly in response to a change in flow.

The model has two conservative fluidic-nature pins through which flow enters and exits. The model also has three conservative electrical-nature pins: two to connect the model to its power supplies and one for the model's output.

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Netlist Syntax

```
MODEL FLOW_VANE_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) FLOW_P:=
%0, FLOW_M:= %1, Vdd:= %2, Vss:= %3, OUT:= %4 ( max_flow:= @max_flow, min_flow:=
@min_flow, full_scale_span:= @full_scale_span, offset:= @offset, p_resistance:= @p_res-
istance, sensor_h_conductance:= @sensor_h_conductance, corner_frequency:= @corner_fre-
quency, temp:= @temp, wiper_resistance:= @wiper_resistance, max_nonlinearity:= @max_
nonlinearity, hysteresis:= @hysteresis, max_temp:= @max_temp, min_temp:= @min_temp,
temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span, temp_sens_offset:=
@temp_sens_offset) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
FLOW_P	Flow entry	Fluidic
FLOW_M	Flow exit	Fluidic
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical
OUT	Output	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor output voltage at minimum flow	Real	0 [V]
p_resistance	Resistance of potentiometer	Real	10k [Ohm]
sensor_h_conductance	Hydraulic conductance of sensor	Real	1k [m ³ / (Pa s)]
corner_frequency	Corner frequency of input signal	Real	0 [Hz]
temp	Device temperature	Real	573.15 [K]
wiper_resistance	Potentiometer wiper resistance	Real	0 [Ohm]
max_flow	Maximum measurable flow	Real	1 [m ³ /s]
min_flow	Minimum measurable flow	Real	0 [m ³ /s]
full_scale_span	Difference of outputs at maximum and minimum flows	Real	10 [V]
max_non-linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	746.15 [K]

min_temp	Minimum operating temperature	Real	496.15 [K]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/K]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/K]

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Example

In this example, the Vane Flow Sensor FLOW_VANE_I22 measures the flow through the Linear Orifice RHYD1, and the output voltage of FLOW_VANE_I22 changes linear in response to the measurement results. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

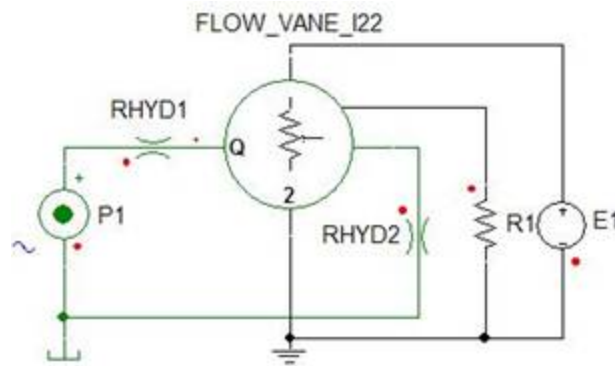


Figure 2. Application example of the Vane Flow Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source (sinusoidal) P1	AMPL	100K [Pa]
	FREQ	1 [Hz]
	PHASE	0 [degree]
	OFF	0 [Pa]
	TDELAY	0 [s]
Linear Orifice RHYD1/ RHYD2	K	1u [k/(Pa s)]
Resistor R1	R	100k [Ohm]
Voltage Source E1	EMF	20 [V]
Vane Flow Sensor FLOW_VANE_I22	offset	0.1 * E1.EMF [V]
	p_resistance	2k [Ohm]
	sensor_h_conductance	100 [m ³ /(Pa s)]

corner_frequency	1 [Hz]
temp	30 [K]
wiper_resistance	100 [Ohm]
max_flow	40m [m ³ /s]
min_flow	10m [m ³ /s]
full_scale_span	0.9 * E1.EMF [V]
max_nonlinearity	1 [%]
hysteresis	1 [%]
max_temp	200 [°C]
min_temp	-50 [°C]
temp_hysteresis	0 [%]
tempco_span	-(7/5) [%/°C]
temp_sens_offset	0 [V/K]

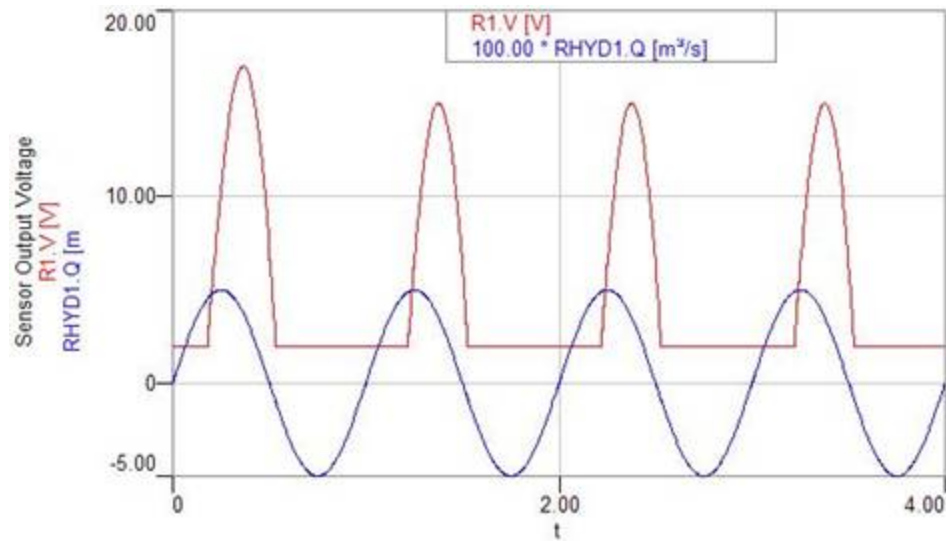


Figure 3. Simulation results-output voltage of FLOW_VANE_I22 vs. its flow input

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References

Level 2 Karmen Vortex Flow Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

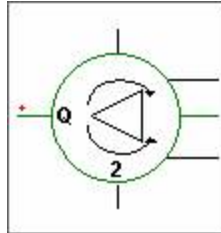


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Description

The Level 2 Karmen Vortex Flow Sensor model simulates the non-ideal behavior of a Karmen vortex flow sensor. The model produces a pulsed voltage output signal with its frequency proportional to the flow through the sensor.

The model has two conservative fluidic-nature pins through which flow enters and exits. The model also has four conservative electrical-nature pins, two for its power supply connections and two for its pulsed voltage output. The negative output terminal should be connected to ground if the model is connected to an electrical network in which no other element is grounded.

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Netlist Syntax

```
MODEL KVORTEX_FLOW_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) FLOW_
IN:= %0, FLOW_OUT:= %1, OUT_P:= %2, OUT_M:= %3, Vdd:= %4, Vss:= %5 ( max_flow:=
@max_flow, min_flow:= @min_flow, full_scale_span:= @full_scale_span, phase:= @phase,
output_amplitude:= @output_amplitude, sensor_h_conductance:= @sensor_h_conductance,
corner_frequency:= @corner_frequency, max_nonlinearity:= @max_nonlinearity, hysteresis:=
@hysteresis, temp:= @temp, max_temp:= @max_temp, min_temp:= @min_temp, temp_hys-
teresis:= @temp_hysteresis, tempco_span:= @tempco_span, output_resistance:= @output_
resistance, supply_current:= @supply_current, rise_time:= @rise_time) SRC: DB(Lib:-
:=@ModelLibraryName);
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
FLOW_IN	Flow entry	Fluidic
FLOW_OUT	Flow exit	Fluidic
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive power supply	Electrical
Vss	Negative power supply	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
phase	Phase shift of output signal	Real	0 [deg]
sensor_h_conductance	Hydraulic conductance of flow sensor	Real	1k [m ³ / (Pa s)]
corner_frequency	Corner frequency of input signal	Real	0 [Hz]
temp	Device temperature	Real	27 [°C]
output_resistance	Output resistance	Real	0 [Ohm]
max_flow	Maximum measurable flow	Real	1 [m ³ /s]
min_flow	Minimum measurable flow	Real	0 [m ³ /s]
full_scale_span	Difference of output frequencies at maximum and minimum flows	Real	10k [Hz]
output_amplitude	Amplitude of output signal	Real	5 [V]
max_non-linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	150 [°C]
min_temp	Minimum operating tem-	Real	-50 [°C]

	perature		
temp_hys-teresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
supply_current	Typical supply current	Real	500u [A]
rise_time	10-90% rise time	Real	0 [s]

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Example

In this example, the Karmen Vortex Flow Sensor KVORTEX_FLOW_I21 measures the flow through the Linear Orifice RHYD1, and the frequency of the pulse output voltage of KVORTEX_FLOW_I21 varies response to the measurement result. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

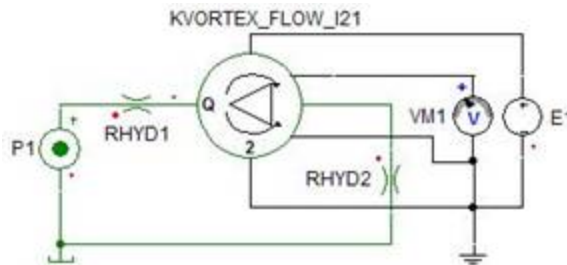


Figure 2. Application example of the Karmen Vortex Flow Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	83.34 * (t/40m) [Pa]
Linear Orifice RHYD1/RHYD2	K	1u [k/(Pa s)]
Voltage Source E1	EMF	20 [V]

Karmen Vortex Flow Sensor KVORTEX_FLOW_I21	phase	0 [deg]
	sensor_h_conductance	1k [m ³ /(Pa s)]
	corner_frequency	0 [Hz]
	temp	27 [°C]
	output_resistance	0 [Ohm]
	max_flow	41.67u [m ³ /s]
	min_flow	5u [m ³ /s]
	full_scale_span	750 [Hz]
	output_amplitude	E1.EMF [V]
	max_non-linearity	0 [%]
	hysteresis	0 [%]
	max_temp	150 [°C]
	min_temp	-50 [°C]
	temp_hysteresis	0 [%]
	tempco_span	0 [%/(°C)]
	supply_current	500 [A]
	rise_time	0 [s]

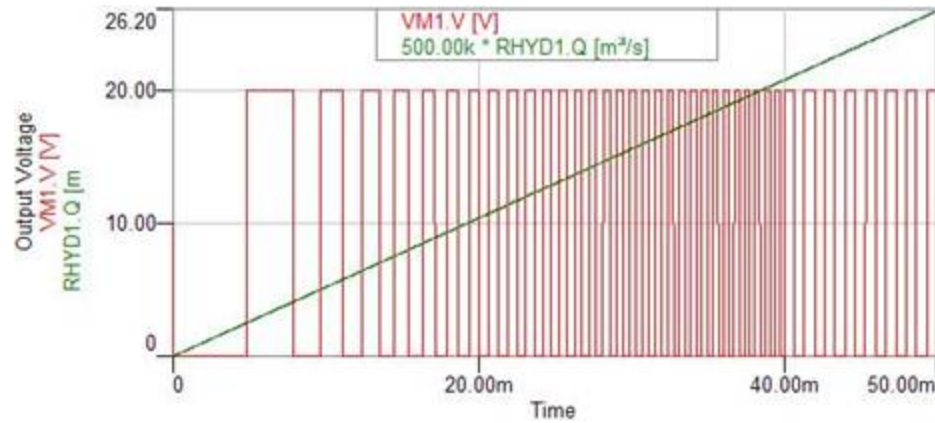


Figure 3. Simulation results-output voltage of KVORTEX_FLOW_I21 and the flow through RHYD1(scaled)

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Level 2 Strain Gauge Flow Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

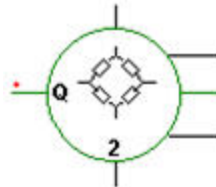


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Description

The Level 2 Strain gauge Absolute Pressure Sensor model is used to simulate the ideal behavior of a strain-gauge flow sensor. A change in the flow through the sensor produces a corresponding change in the differential voltage output signal.

The Level 2 Strain Gauge Flow Sensor model has two conservative fluidic domain pins through which the measured flow enters and exits the sensor and four conservative electrical domain pins: two for the sensor's power supplies and two for the sensor's differential output.

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Netlist Syntax

```
MODEL SG_FLOW_I2 ?InstanceName(@InstanceName):(@Refbase)@(ID)) FLOW_IN:= %0,
FLOW_OUT:= %1, Vdd:= %2, Vss:= %3, OUT_P:= %4, OUT_M:= %5 ( h_conductance:= @h_
conductance, time_constant:= @time_constant, max_flow:= @max_flow, min_flow:= @min_
flow, full_scale_span:= @full_scale_span, offset:= @offset, nonlinearity:= @nonlinearity, hys-
teresis:= @hysteresis, temp:= @temp, max_temp:= @max_temp, min_temp:= @min_temp,
temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span, temp_sens_offset:=
@temp_sens_offset, resistor_tempco:= @resistor_tempco, nominal_res_temp:= @nominal_
res_temp, bridge_resistance:= @bridge_resistance) SRC: DB(Lib:=@ModelLibraryName);
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
FLOW_IN	Flow entry	Fluidic
FLOW_OUT	Flow exit	Fluidic
Vdd	Positive Supply	Electrical
Vss	Negative Supply	Electrical
OUT_P	Positive Output Terminal	Electrical
OUT_M	Negative Output Terminal	Electrical

Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
max_flow	Maximum measurable flow	Real	1 [m ³ /s]
min_flow	Minimum measurable flow	Real	0 [m ³ /s]
full_scale_	Difference of maximum and	Real	5 [V]

span	minimum output voltages		
offset	Sensor offset voltage	Real	0 [V]
bridge_resistance	Bridge resistance	Real	10k [Ohm]
h_conductance	Hydraulic conductance	Real	1m [m ³ / (Pa s)]
time_constant	Time constant	Real	0 [s]
nonlinearity	Nonlinearity	Real	0 [%]
hysteresis	Hysteresis	Real	0 [%]
temp	Current temperature	Real	27 [°C]
max_temp	Maximum operating temperature	Real	200 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Temperature hysteresis	Real	0 [%]
tempco_span	Temperature coefficient of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset temperature sensitivity	Real	0 [V/(°C)]
resistor_tempco	Resistor temperature coefficient	Real	0 [%/(°C)]
nominal_res_temp	Nominal bridge resistance temperature	Real	25 [°C]

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Example

In this example, the Strain gauge Flow Sensor SG_FLOW_I21 measures the flow rate through the Linear Orifice RHYD1, and a change in the flow through the sensor produces a corresponding change in the differential voltage output signal. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

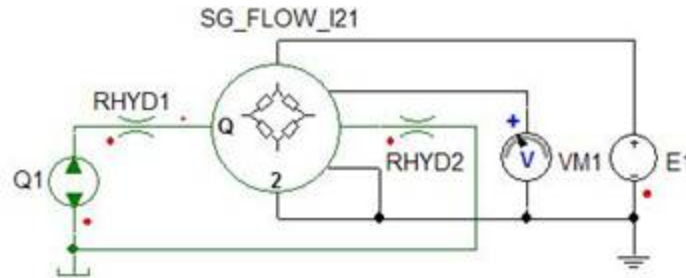


Figure 2. Application example of the Strain gauge Flow Sensor

Table 3

Component	Parameter	Value [Unit]
Flow Source Q1	VALUE	$10u * (t \geq 5m) + 20u * (t \geq 15m) + 20u * (t \geq 25m) + 10u * (t \geq 30m)$ [m/s]
Linear Orifice RHYD1/RHYD2	K	1n [k/(Pa s)]
Voltage Source E1	EMF	10 [V]
Strain gauge Flow Sensor SG_FLOW_I21	offset	$0.1 * E1.EMF$ [V]
	bridge_resistance	5k [Ohm]
	max_flow	50u [m/s]
	min_flow	10u [m/s]
	full_scale_span	$0.9 * E1.EMF$ [V]

h_conductance	1m [m ³ /(Pa s)]
time_constant	500u [s]
nonlinearity	3 [%]
hysteresis	0 [%]
temp	27 [°C]
max_temp	200 [°C]
min_temp	-50 [°C]
temp_hysteresis	0 [%]
tempco_span	1 [%/(°C)]
temp_sens_offset	5m [V/(°C)]
resistor_tempco	0 [%/(°C)]
nominal_res_temp	25 [°C]

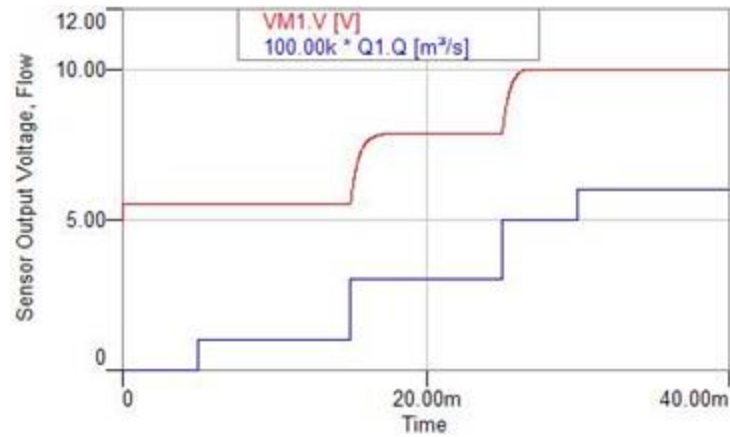


**Figure 3. Simulation results-output voltage of SG_FLOW_I21
vs. the flow rate of Q1**

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References

Level 2 Thermal Mass-Flow Flow Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

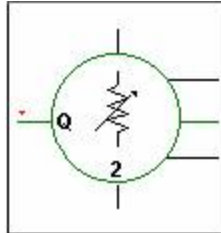


Figure 1. Component symbol

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Description

The Level 2 Thermal Mass-Flow Flow Sensor model simulates the non-ideal behavior of a thermal mass-flow flow sensor. The model produces a voltage signal that varies according to a user-defined characteristic with the mass or volume of fluid that flows through it. Fluid mass is determined in the model by multiplying the flow through the model by the specified density of the flowing fluid. Fluid density is entered into the model as a parameter through a nonconservative input node.

The model has two conservative fluidic-nature pins through which flow enters and exits. The model also has four conservative electrical-nature pins, two for its power supply connections and two for its voltage output. The negative output terminal should be connected to ground if the model is connected to an electrical network in which no other element is grounded.

The model also has a nonconservative input node for the file containing the voltage characteristic of an actual device. The characteristic for the model should be entered via a .mdx file. These can be generated in several ways.

See *Characteristics in Simulation Models* in the main Twin Builder help.

See *Using SheetScan* in the main Twin Builder help.

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Netlist Syntax

Netlist generated by *Special Component Dialog*.

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
FLOW_IN	Flow entry	Fluidic
FLOW_OUT	Flow exit	Fluidic
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive supply terminal	Electrical
Vss	Negative supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
fluid_density	Density of fluid passing through the sensor	Real	1.225 [kg/m ²]

output_resistance	Sensor output resistance	Real	0 [Ohm]
hysteresis	Hysteresis as a percentage of full scale span	Real	0 [%]
temp	Device temperature	Real	27 [°C]
max_temp	Maximum operating temperature	Real	200 [°C]
min_temp	Minimum operating temperature	Real	0 [°C]
temp_hysteresis	Temperature hysteresis	Real	0 [%]
tempco_span	Output temperature coefficient	Real	0 [%]
time_constant	Time constant	Real	0 [s]
voltage_char	Sensor voltage-flow characteristic	file	0
trim_voltage	Trim voltage	Real	5 [V]
null_voltage	Null voltage	Real	0 [V]
nonlinearity	Nonlinearity	Real	0 [%]
null_voltage_tsens	Temperature sensitivity of the null voltage	Real	0 [V/(°C)]
calibrated	Sensor calibration (mass flow, volume flow)	Real	0
supply_current	Sensor supply current	Real	0.5m [A]
h_conductance	Parasitic hydraulic conductance	Real	1m [m ³ /(Pa s)]

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Example

In this example, the Thermal Mass Flow Sensor T_M_FLOW_I21 measures the flow through the Linear Orifice RHYD1, and T_M_FLOW_I21 produces a voltage signal that varies according to a user-defined characteristic with the mass of fluid that flows through it. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

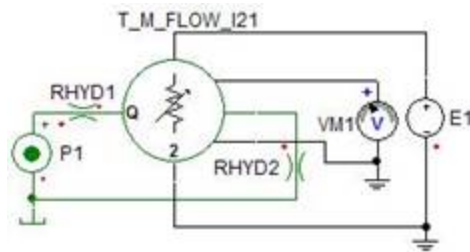


Figure 2. Application example of the Thermal Mass Flow Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	$333 * (t \geq 2m) + 333 * (t \geq 6m)$ [Pa]
Linear Orifice RHYD1/RHYD2	K	1u [k/(Pa s)]
Voltage Source E1	EMF	8 [V]
Thermal Mass Flow Sensor T_M_FLOW_I21	fluid_density	1.225 [kg/m ²]
	output_resistance	0 [Ohm]
	hysteresis	0.5 [%]
	temp	27 [°C]
	max_temp	200 [°C]
	min_temp	-50 [°C]
	temp_hysteresis	0 [%]
	tempco_span	0.067 [%]
	time_constant	1m/2.1967 [s]

	voltage_char	adj_hw.mdx
	trim_voltage	5 [V]
	null_voltage	1 [V]
	nonlinearity	0 [%]
	null_voltage_tsens	416.7 [V/(°C)]
	calibrated	0
	supply_current	0.5m [A]
	h_conductance	1m [m ³ /(Pa s)]

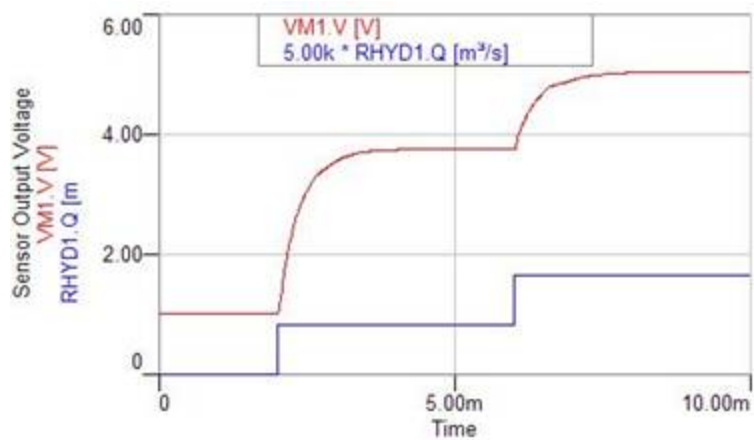


Figure 3. Simulation results-output voltage of T_M_FLOW_I21 and the mass flow through RHYD1 (scaled)

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References

Component Dialog Settings

The following Parameters are set in the Component Dialog for the **Level 2 Sensor Thermal Mass Flow Component**:

Name:

Specify the Name of the component instance. Select the **Show Name** checkbox to display the name on the schematic.

Parameters:

Device Parameters: Enter a numerical value, a variable, or an expression in the text box. Common parameter types. Look their meaning up in the parameter table.

Output Voltage Characteristic Input: The model also has a nonconservative input node for the file containing the voltage characteristic of an actual device. The characteristic for the model should be entered via a .mdx file. See *Characteristics in Simulation Models* in the main Twin Builder help.

Mass or Volume Flow Calibration: Select the calibration type, either **Mass Flow** or **Volume Flow**.

Outputs/Display

For information regarding displaying parameter pins, see *Output/Display Tab* in the main Twin Builder help.

Level 2 Turbine (DC Output) Flow Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

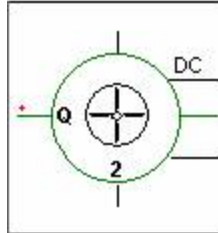


Figure 1. Component symbol

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Description

The Level 2 Turbine (DC Output) Flow Sensor model simulates the ideal behavior of a turbine flow sensor with a conditioned DC output. The model produces a DC output proportional to the flow moving through it.

The model has two conservative fluidic-nature pins through which flow enters and exits. The model also has two conservative electrical-nature pins for its voltage output and two for its positive and negative power supply pins. The negative output terminal for the output voltage should be connected to ground if the model is connected to an electrical network in which no other element is grounded.

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Netlist Syntax

```
MODEL TURBINE_FLOW_DC_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))  
Vdd:= %0, Vss:= %1, OUT_P:= %2, OUT_M:= %3, FLOW_IN:= %4, FLOW_OUT:= %5 ( sup-  
ply_current:= @supply_current, h_conductance:= @h_conductance, time_constant:= @time_  
constant, max_flow:= @max_flow, min_flow:= @min_flow, full_scale_span:= @full_scale_  
span, offset:= @offset, nonlinearity:= @nonlinearity, hysteresis:= @hysteresis, temp:= @temp,  
max_temp:= @max_temp, min_temp:= @min_temp, temp_hysteresis:= @temp_hysteresis,  
tempco_span:= @tempco_span, temp_sens_offset:= @temp_sens_offset, output_resistance:=  
@output_resistance) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
FLOW_IN	Flow entry	Fluidic
FLOW_OUT	Flow exit	Fluidic
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive power supply	Electrical
Vss	Negative power supply	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
supply_current	Sensor supply current	Real	10m [A]
max_flow	Maximum measurable flow rate	Real	1 [m ³ /s]
min_flow	Minimum measurable flow rate	Real	250m [m ³ /s]
full_scale_span	Difference of maximum and minimum output voltages	Real	5 [V]
offset	Zero-flow voltage	Real	0 [V]
h_conductance	Sensor hydraulic conductance	Real	1m [m ³ /(Pa s)]
time_constant	Sensor time constant	Real	0 [s]
nonlinearity	Sensor nonlinearity	Real	0 [%]
hysteresis	Sensor hysteresis	Real	0 [%]
temp	Sensor temperature	Real	27 [°C]
max_temp	Maximum operating temperature	Real	200 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Sensor temperature hysteresis	Real	0 [%]
tempco_span	Temperature sensitivity of	Real	0 [%/(°C)]

	full-scale span		
temp_sens_off-set	Temperature sensitivity of off-set voltage	Real	0 [V/(°C)]
output_res-istance	Sensor output resistance	Real	0 [Ohms]

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Example

In this example, the Turbine (DC Output) Flow Sensor TURBINE_FLOW_DC_I21 measures the flow rate through the Linear Orifice RHYD1, and TURBINE_FLOW_DC_I21 produces a DC output voltage proportional to the measurement result. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

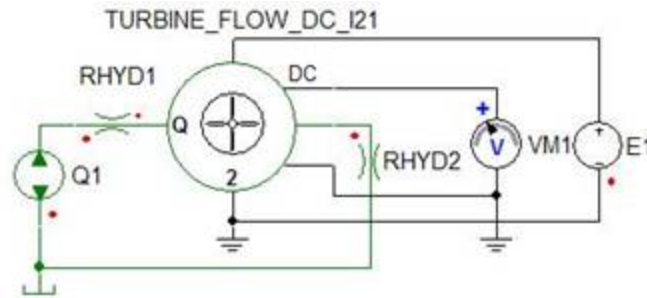


Figure 2. Application example of the Turbine (DC Output) Flow Sensor

Table 3

Component	Parameter	Value [Unit]
Flow Source Q1	VALUE	35u * (t/150m) [m/s]
Linear Orifice RHYD1/RHYD2	K	1n [k/(Pa s)]
Voltage Source E1	EMF	12 [V]
Turbine (DC Output) Flow Sensor TURBINE_FLOW_DC_I21	supply_current	30m [A]
	max_flow	33.333u [m ³ /s]
	min_flow	1.66666u [m ³ /s]
	full_scale_span	5 [V]
	offset	0 [V]
	h_conductance	1m [m ³ /(Pa s)]
	time_constant	0 [s]
	nonlinearity	-3 [%]

	hysteresis	0 [%]
	temp	27 [°C]
	max_temp	50 [°C]
	min_temp	-50 [°C]
	temp_hys- teresis	0 [%]
	tempco_span	0 [%/(°C)]
	temp_sens_off- set	0 [V/(°C)]
	output_res- istance	0 [Ohms]

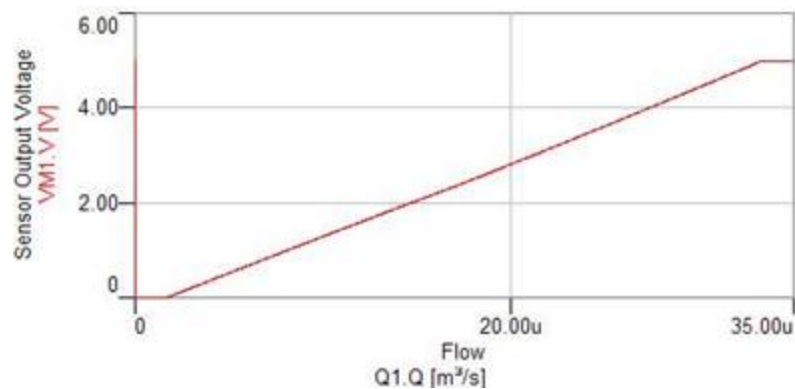


Figure 3. Simulation results-output voltage of TURBINE_FLOW_DC_I21 vs. the flow rate of Q1

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References

Level 2 Turbine (AC Output) Flow Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

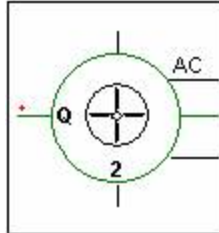


Figure 1. Component symbol

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Description

The Level 2 Turbine (AC Output) Flow Sensor model simulates the non-ideal behavior of a turbine flow sensor with an AC output. The model produces a pulse or sinusoidal output signal whose frequency varies with the flow moving through it.

The model has two conservative fluidic-nature pins through which flow enters and exits. The model also has two conservative electrical-nature pins for its voltage output and two for its positive and negative power supply pins. The negative output terminal for the output voltage should be connected to ground if the model is connected to an electrical network in which no other element is grounded.

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Netlist Syntax

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
FLOW_IN	Flow entry	Fluidic
FLOW_OUT	Flow exit	Fluidic
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive power supply	Electrical
Vss	Negative power supply	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
max_flow	Maximum measurable flow rate	Real	5 [m ³ /s]
min_flow	Minimum measurable flow rate	Real	0 [m ³ /s]
offset_fre- quency	Zero-flow frequency	Real	10k [Hz]
full_scale_ span	Difference of maximum and minimum output frequencies	Real	100k [Hz]

amplitude	Amplitude of output voltage signal		5 [V]
output_type	Shape of output (pulse or sinusoid)	Real	0
phase	Phase shift of output voltage	Real	0 [Rad]
offset	DC offset of output voltage	Real	0 [V]
supply_current	Sensor supply current	Real	10m [A]
hyd_conductance	Sensor hydraulic conductance	Real	0 [m ³ /(Pa s)]
time_constant	Sensor time constant	Real	0 [s]
temp	Sensor temperature	Real	27 [°C]
max_temp	Maximum operating temperature	Real	200 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
tempco_span	Temperature coefficient of sensor full-scale span	Real	0 [%/(°C)]
temp_hysteresis	Sensor temperature hysteresis	Real	0 [%]
nonlinearity	Sensor nonlinearity	Real	0 [%]
hysteresis	Sensor hysteresis	Real	0 [%]
output_resistance	Sensor output resistance	Real	0 [Ohm]

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Example

In this example, the Turbine (AC Output) Flow Sensor TURBINE_FLOW_I21 measures the flow rate through the Linear Orifice RHYD1, and the frequency of the pulse output voltage of TURBINE_FLOW_I21 varies response to the measurement result. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

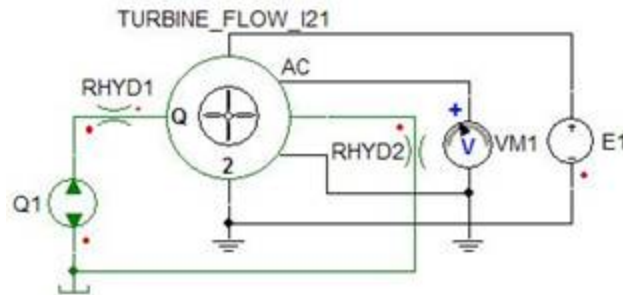


Figure 2. Application example of the Turbine (AC Output) Flow Sensor

Table 3

Component	Parameter	Value [Unit]
Flow Source Q1	VALUE	$50.1u^*(t \geq 5m) + 584u^*(t \geq 80m)$ [m/s]
Linear Orifice RHYD1/RHYD2	K	1n [k/(Pa s)]
Voltage Source E1	EMF	5 [V]
Turbine (AC Output) Flow Sensor TURBINE_FLOW_I21	max_flow	6.34E-4 [m/s]
	min_flow	5.01E-5 [m/s]
	offset_frequency	22.8 [Hz]
	full_scale_span	266 [Hz]
	amplitude	5 [V]

output_type	pulse
phase	0 [rad]
offset	0 [V]
supply_current	1.5 [mA]
hyd_conductance	4.12E-7 [m ³ /(Pa s)]
time_constant	0 [s]
temp	27 [°C]
max_temp	200 [°C]
min_temp	-50 [°C]
tempco_span	0 [%/(°C)]
temp_hysteresis	0 [%]
nonlinearity	0 [%]
hysteresis	0 [%]
output_resistance	0 [Ohm]

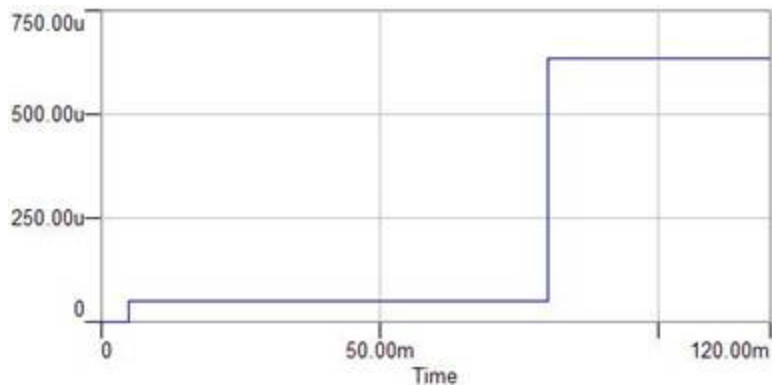


Figure 3. Simulation results-flow rate of Q1

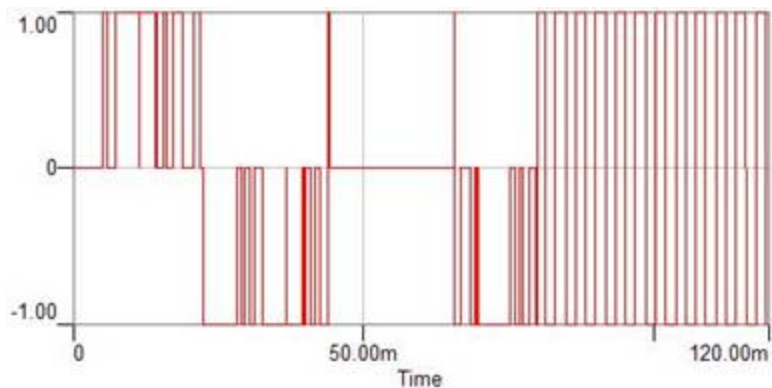


Figure 4. Simulation results-output voltage of TURBINE_FLOW1

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References

Component Dialog Settings

The following Parameters are set in the Component Dialog for the **Level 2 Sensor Turbine Flow Component**:

Name:

Specify the Name of the component instance. Select the **Show Name** checkbox to display the name on the schematic.

Parameters:

Device Parameters: Enter a numerical value, a variable, or an expression in the text box. Common parameter types. Look their meaning up in the parameter table.

Output Signal Type: Select the output signal shape, either **Pulse** or **Sinusoidal**.

Outputs/Display

For information regarding displaying parameter pins, see *Output/Display Tab* in the main Twin Builder help.

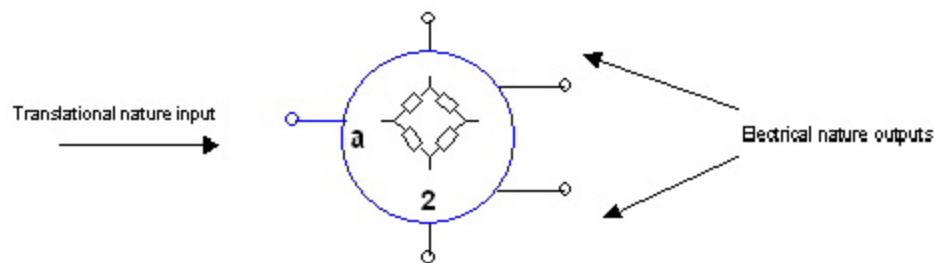
Level 2 Linear Acceleration Sensor Models

The Level 2 Linear Acceleration Sensor Models simulate the non-ideal behavior of four different types of linear acceleration sensors. Models are available for use with the Twin Builder *displacement-force* and *velocity-force* translational domains.

All of the linear acceleration sensor models have conservative input pins that must be connected to a translational network and conservative output pins that must be connected to an electrical network. The models also feature nonconservative parameters that can be changed in order to tailor the behavior of the model to that of a specific real device.

As shown in the following example, linear acceleration sensor models for the displacement-force translational domain have light blue conservative input pins that must be connected to a displacement-force translational network. The models also have black conservative pins that must be connected to an electrical network.

Similarly, linear acceleration sensor models for the velocity-force translational domain have dark blue translational-nature input pins and black electrical-nature pins.



The Level 2 Linear Acceleration Sensor Models feature models for the following linear acceleration sensing mechanisms:

- **Capacitive:** acceleration of the sensor causes the movement of the shared plate in a differential capacitor pair. The sensor responds by producing a change in its linear voltage output signal.
Displacement-Force model: ([C_ACC_DF_I2](#))
Velocity-Force model: ([C_ACC_VF_I2](#))

- **Piezoelectric:** acceleration of the sensor causes the deformation of a piezoelectric element which produces a corresponding voltage output signal.
Displacement-Force model: ([PE_ACC_DF_I2](#))
Velocity-Force model: ([PE_ACC_VF_I2](#))

- **Piezoresistive:** acceleration of the sensor causes the deformation of resistors connected in a Wheatstone bridge configuration, producing a corresponding differential voltage output signal.
Displacement-Force model: ([PR_ACC_DF_I2](#))
Velocity-Force model: ([PR_ACC_VF_I2](#))

- **Inertia Switch:** - a specified threshold acceleration causes a switch contained inside the sensor to change state from open to closed.
Displacement-Force model: ([TINERTIA_SWITCH_DF_I2](#))
Velocity-Force model: ([TINERTIA_SWITCH_VF_I2](#))

Level 2 Capacitive Linear Acceleration Sensor (Displacement-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

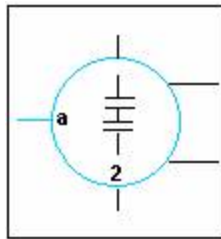


Figure 1. Component symbol

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Description

The Level 2 Capacitive Linear Acceleration (Displacement-Force) sensor model is used to simulate the non-ideal behavior of a conditioned capacitive linear acceleration sensor in the Twin Builder displacement-force translational domain. A change in the model's linear acceleration input produces a corresponding change in the model's linear voltage output.

The model has one conservative input pin in the displacement-force translational domain for its linear acceleration input and four conservative electrical-domain pins. Two of the pins are for the model's power supplies, and two are for its voltage output. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is connected to ground.

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Netlist Syntax

```
MODEL C_ACC_DF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) LINEAR:= %0,
OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 ( max_ACC:= @max_ACC, min_ACC:=
@min_ACC, full_scale_span:= @full_scale_span, offset:= @offset, nonlinearity:= @non-
linearity, hysteresis:= @hysteresis, max_temp:= @max_temp, min_temp:= @min_temp, temp_
hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span, temp_sens_offset:= @temp_
sens_offset, corner_frequency:= @corner_frequency, temp:= @temp, output_resistance:=
@output_resistance, supply_current:= @supply_current) SRC: DB(Lib:=@ModelLibraryName)
;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
LINEAR	Measured linear acceleration	Translational
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive power supply	Electrical
Vss	Negative power supply	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
corner_fre-	Corner frequency of the input	Real	0 [Hz]

quency	signal		
temp	Device temperature	Real	27 [°C]
output_resistance	Output resistance	Real	0 [Ohm]
max_ACC	Maximum measurable linear acceleration	Real	50 [m/s ²]
min_ACC	Minimum measurable linear acceleration	Real	0 [m/s ²]
full_scale_span	Difference of output voltages at maximum and minimum linear accelerations	Real	5 [V]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	200 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
nonlinearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
supply_current	Typical supply current	Real	1m [A]

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Example

In this example, the Capacitive Linear Acceleration (Displacement-Force) sensor C_ACC_DF_I22 measures the linear velocity of the Mass MASS_TRB1. A change in the acceleration of MASS_TRB1 produces a corresponding change in the linear voltage output of C_ACC_DF_I22. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

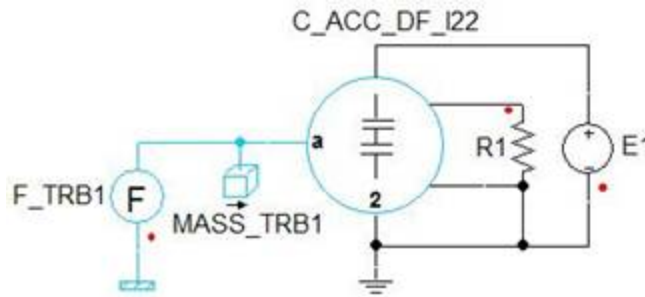


Figure 2. Application example of the Capacitive Linear Acceleration (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Force Source F_TRB1	VALUE	20 * (t/40m) [N]
Mass MASS_TRB1	m	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Capacitive Linear Acceleration (Displacement-Force) sensor C_ACC_DF_I22	offset	0.1 * E1.EMF [V]
	corner_frequency	0 [Hz]
	temp	27 [°C]

	output_resistance	0 [Ohm]
	max_ACC	18 [m/s ²]
	min_ACC	0 [m/s ²]
	full_scale_span	0.8 * E1.EMF [V]
	hysteresis	0 [%]
	max_temp	200 [°C]
	min_temp	-50 [°C]
	temp_hysteresis	0 [%]
	tempco_span	0.2 [%/ (°C)]
	temp_sens_offset	1m [V/(°C)]
	nonlinearity	1 [%]
	supply_current	1m [A]
Voltage Source E1	EMF	5 [V]

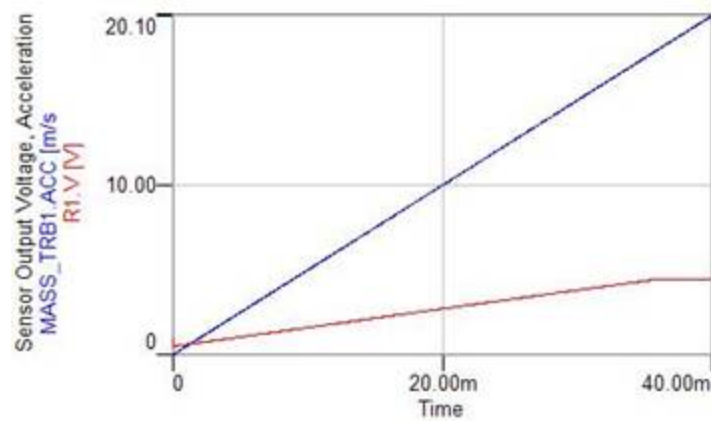


**Figure 3. Simulation results-output voltage of C_ACC_DF_I22
and acceleration of MASS_TRB1**

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References

Level 2 Piezoelectric Linear Acceleration Sensor (Displacement-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

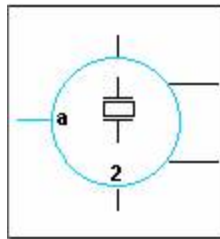


Figure 1. Component symbol

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Description

The Level 2 Piezoelectric Linear Acceleration (Displacement-Force) sensor model is used to simulate the non-ideal behavior of a piezoelectric linear acceleration sensor in the Twin Builder displacement-force translational domain. A change in the model's linear acceleration input produces a corresponding change in the model's linear voltage output.

The model has one conservative input pin in the displacement-force translational domain for its linear acceleration input and four conservative electrical-domain pins, two for its power supply connections and two for its voltage output. The negative output terminal should be connected to an electrical ground if the model is connected to an electrical network in which no other component is grounded.

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Netlist Syntax

```
MODEL PE_ACC_DF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) LINEAR:=
%0, OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 ( max_ACC:= @max_ACC, min_ACC:=
@min_ACC, full_scale_span:= @full_scale_span, offset:= @offset, supply_current:= @supply_
current, nonlinearity:= @nonlinearity, hysteresis:= @hysteresis, max_temp:= @max_temp,
min_temp:= @min_temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_
span, temp_sens_offset:= @temp_sens_offset, corner_frequency:= @corner_frequency, tem-
p:= @temp, output_resistance:= @output_resistance) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
LINEAR	Measured linear acceleration	Translational
OUT_P	Positive terminal	Electrical
OUT_M	Negative terminal	Electrical
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
corner_fre- quency	Corner frequency of the input signal	Real	0 [Hz]

temp	Device temperature	Real	27 [°C]
output_resistance	Output resistance	Real	0 [Ohm]
max_ACC	Maximum measurable linear acceleration	Real	50 [m/s ²]
min_ACC	Minimum measurable linear acceleration	Real	0 [m/s ²]
full_scale_span	Difference of output voltages at maximum and minimum linear accelerations	Real	5 [V]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	150 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
supply_current	Supply current	Real	5m [A]
nonlinearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]

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Example

In this example, the Piezoelectric Linear Acceleration (Displacement-Force) sensor PE_ACC_DF_I21 measures the angular velocity of the Mass MASS_TRB1. A change in the acceleration input of MASS_TRB1 produces a corresponding change in the linear voltage output of PE_ACC_DF_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

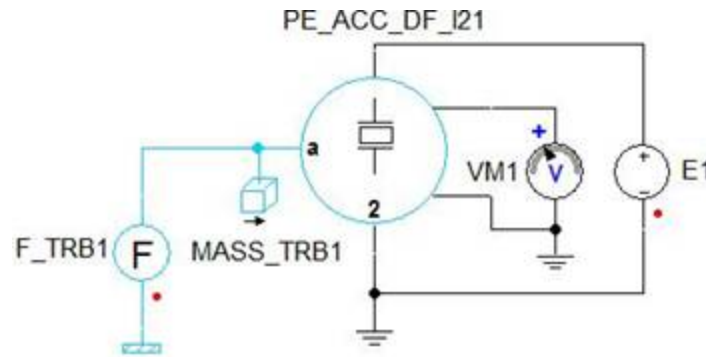


Figure 2. Application example of the Piezoelectric Linear Acceleration (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Force Source F_{TRB1}	VALUE	$20 * t/40m$ [N]
Mass $MASS_{TRB1}$	m	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Piezoelectric Linear Acceleration (Displacement-Force) sensor $PE\_ACC\_DF\_I21$	offset	$0.1 * E1.EMF$ [V]
	corner_frequency	0 [Hz]
	temp	27 [°C]

	output_resistance	0 [Ohm]
	max_ACC	18 [m/s ²]
	min_ACC	0 [m/s ²]
	full_scale_span	0.8 * E1.EMF [V]
	hysteresis	0 [%]
	max_temp	150 [°C]
	min_temp	-50 [°C]
	temp_hysteresis	0 [%]
	tempco_span	0.2 [%/ (°C)]
	temp_sens_offset	1m [V/(°C)]
	nonlinearity	1 [%]
	supply_current	10m [A]
Voltage Source E1	nonlinearity	10 [V]

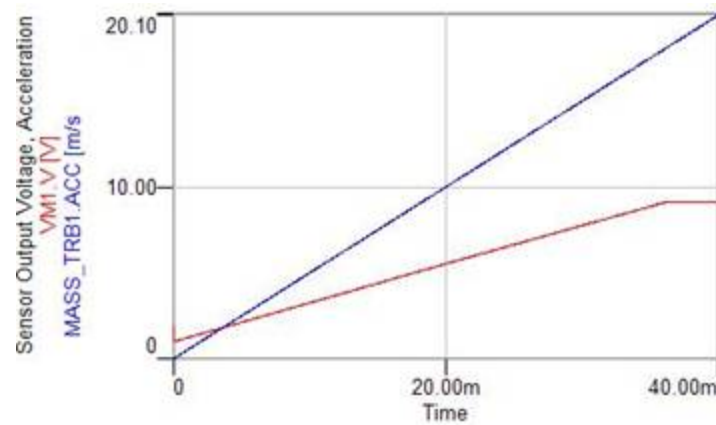


Figure 3. Simulation results-output voltage of PE_ACC_DF_I21 and acceleration of MASS_TRB1

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References

Level 2 Piezoresistive Linear Acceleration Sensor (Displacement-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

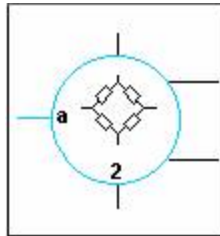


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Description

The Level 2 Piezoresistive Linear Acceleration (Displacement-Force) sensor model is used to simulate the non-ideal behavior of a piezoresistive linear acceleration sensor in the Twin Builder displacement-force translational domain. A change in the model's linear acceleration input produces a corresponding change in the model's Wheatstone bridge, which in turn produces a change in the model's linear voltage output.

The model has one conservative input pin in the displacement-force translational domain for its linear acceleration input and four conservative electrical-domain pins, two for its power supplies and two for its voltage output.

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Netlist Syntax

```
MODEL PR_ACC_DF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) LINEAR:=
%0, OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 ( max_ACC:= @max_ACC, min_ACC:=
@min_ACC, full_scale_span:= @full_scale_span, offset:= @offset, nonlinearity:= @non-
linearity, hysteresis:= @hysteresis, max_temp:= @max_temp, min_temp:= @min_temp, temp_
hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span, temp_sens_offset:= @temp_
sens_offset, corner_frequency:= @corner_frequency, temp:= @temp, resistor_tempco:= @res-
istor_tempco, nominal_res_temp:= @nominal_res_temp, p_resistance:= @p_resistance) SRC:
DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
LINEAR	Measured linear acceleration	Translational
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive power supply	Electrical
Vss	Negative power supply	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
corner_fre-	Corner frequency of the input	Real	0 [Hz]

quency	signal		
temp	Device temperature	Real	27 [°C]
max_ACC	Maximum measurable linear acceleration	Real	50 [m/s ²]
min_ACC	Minimum measurable linear acceleration	Real	0 [m/s ²]
full_scale_span	Difference of output voltages at maximum and minimum linear accelerations	Real	5 [V]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	150 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
p_resistance	Bridge resistance	Real	10k [Ohm]
resistor_tempco	Bridge resistor temperature coefficient	Real	0 [%/(°C)]
nominal_res_temp	Bridge resistor nominal resistance temperature	Real	25 [°C]
nonlinearity	Nonlinearity as a percentage of	Real	0 [%]

	full-scale span		

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Example

In this example, the Piezoresistive Linear Acceleration (Displacement-Force) sensor PR_ACC_DF_I22 measures the linear velocity of the Mass MASS_TRB1. A change in the acceleration of MASS_TRB1 produces a corresponding change in the linear voltage output of PR_ACC_DF_I22. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

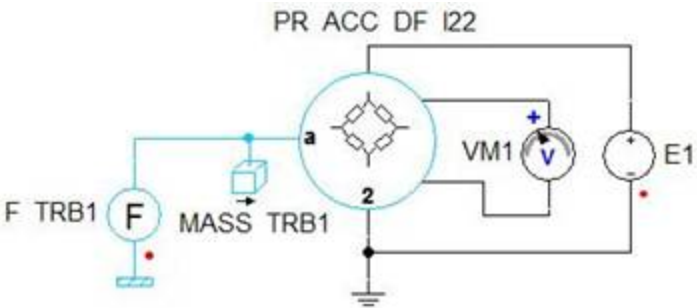


Figure 2. Application example of the Piezoresistive Linear Acceleration (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Force Source F_TRB1	VALUE	20 * t/40m [N]
Mass MASS_TRB1	m	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Piezoresistive Linear Acceleration (Displacement-Force) sensor PR_ACC_DF_I22	offset	0.1 * E1.EMF [V]
	corner_frequency	0 [Hz]

	temp	27 [°C]
	max_ACC	18 [m/s ²]
	min_ACC	0 [m/s ²]
	full_scale_ span	0.8 * E1.EMF [V]
	hysteresis	0 [%]
	max_temp	150 [°C]
	min_temp	-50 [°C]
	temp_hys- teresis	0 [%]
	tempco_span	0.2 [%/ (°C)]
	temp_sens_ offset	1m [V/(°C)]
	p_resistance	10k [Ohm]
	resistor_tem- pco	0.1 [%/(°C)]
	nominal_res_ temp	25 [°C]
	nonlinearity	1 [%]
Voltage Source E1	EMF	10 [V]

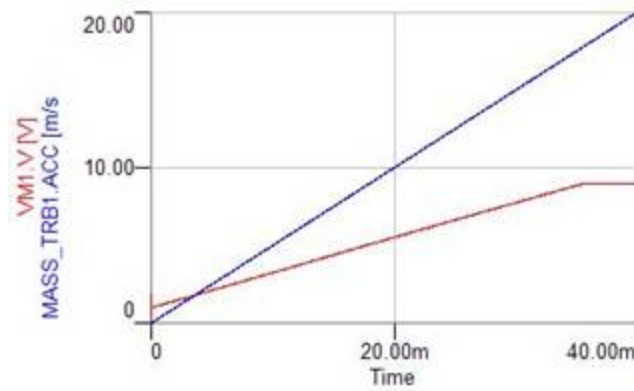


Figure 3. Simulation results-output voltage of PR_ACC_DF_I22 and acceleration of MASS_TRB1

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References

Level 2 Inertia Switch Linear Acceleration Sensor (Displacement-force)

Library: Add Ons/-sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

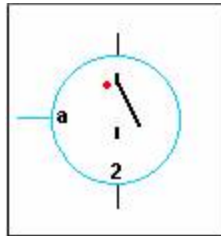


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Description

The Level 2 Inertia Switch Linear Acceleration (Displacement-Force) sensor model is used to simulate the non-ideal behavior of an inertia switch linear acceleration sensor in the Twin Builder displacement-force translational domain. When the linear acceleration applied to the sensor exceeds a specified threshold value, its switch changes state from open to closed.

The model has one conservative input pin in the displacement-force translational domain for its linear acceleration input and two conservative electrical-domain pins for its positive and negative terminals. The positive terminal is the one into which current flows.

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Netlist Syntax

MODEL TINERTIA_SWITCH_DF_I2 ?InstanceName(@InstanceName):(@Refbase)@(ID))
 LINEAR:= %0, np:= %1, nm:= %2 (threshold:= @threshold, switch_resistance:= @switch_resistance, meas_error:= @meas_error) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
LINEAR	Measured linear acceleration	Translational
np	Positive terminal	Electrical
nm	Negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
threshold	Threshold linear acceleration of the switch	Real	50 [m/s ²]
switch_resistance	Switch on-state resistance	Real	0 [Ohm]
meas_error	Percent measurement error	Real	0 [%]

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Example

In this example, the Inertia Switch Linear Acceleration (Displacement-Force) sensor TINERTIA_SWITCH_DF_I21 measures the linear acceleration of the Mass MASS_TRB1. When the acceleration of Mass MASS_TRB1 exceeds a specified threshold value, TINERTIA_SWITCH_DF_I21 switches from open to close. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

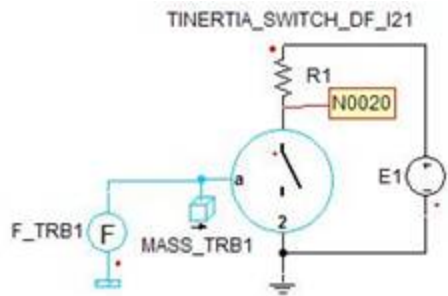


Figure 2. Application example of the Inertia Switch Linear Acceleration (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Force Source F_TRB1	VALUE	40 * (t/40m) [N]
Mass MASS_TRB1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Inertia Switch Linear Acceleration (Displacement-Force) sensor TINERTIA_SWITCH_DF_I21	threshold	20 [m/s ²]
	switch_resistance	10 [Ohm]
	meas_error	-10 [%]
Voltage Source E1	EMF	1 [V]
Resistor R1	R	1k [Ohm]

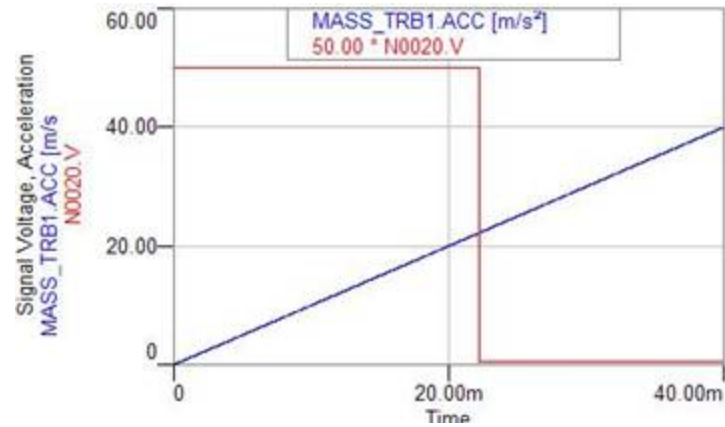


Figure 3. Simulation results-output voltage of TINERTIA_SWITCH_DF_I21 (scaled) and acceleration of MASS_TRB1

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References

Level 2 Capacitive Linear Acceleration Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

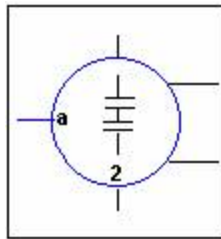


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Description

The Level 2 Capacitive Linear Acceleration (Velocity-Force) sensor model is used to simulate the non-ideal behavior of a conditioned capacitive linear acceleration sensor in the Twin Builder velocity-force translational domain. A change in the model's linear acceleration input produces a corresponding change in the model's linear voltage output.

The model has one conservative input pin in the velocity-force translational domain for its linear acceleration input and four conservative electrical-domain pins. Two of the pins are for the model's power supplies, and two are for its voltage output. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is connected to ground.

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Netlist Syntax

```
MODEL C_ACC_VF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) LINEAR:= %0,
OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 ( max_ACC:= @max_ACC, min_ACC:=
@min_ACC, full_scale_span:= @full_scale_span, offset:= @offset, nonlinearity:= @non-
linearity, hysteresis:= @hysteresis, max_temp:= @max_temp, min_temp:= @min_temp, temp_
hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span, temp_sens_offset:= @temp_
sens_offset, corner_frequency:= @corner_frequency, temp:= @temp, output_resistance:=
@output_resistance, supply_current:= @supply_current) SRC: DB(Lib:=@ModelLibraryName)
;
```

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Table 1

Name	Port/Terminal Description	Nature/Data type
LINEAR	Measured linear acceleration	Translational_V
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive power supply	Electrical
Vss	Negative power supply	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
corner_fre-	Corner frequency of the input	Real	0 [Hz]

quency	signal		
temp	Device temperature	Real	27 [°C]
output_resistance	Output resistance	Real	0 [Ohm]
max_ACC	Maximum measurable linear acceleration	Real	50 [m/s ²]
min_ACC	Minimum measurable linear acceleration	Real	0 [m/s ²]
full_scale_span	Difference of output voltages at maximum and minimum linear accelerations	Real	5 [V]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	200 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
nonlinearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
supply_current	Typical supply current	Real	1m [A]

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Example

In this example, the Capacitive Linear Acceleration (Velocity-Force) sensor C_ACC_VF_I22 measures the linear velocity of the Mass MASS_TR1. A change in the acceleration of MASS_TR1 produces a corresponding change in the linear voltage output of C_ACC_VF_I22. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

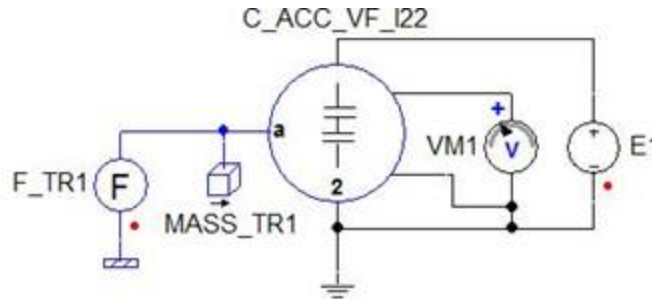


Figure 2. Application example of the Capacitive Linear Acceleration (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Force Source F_TR1	VALUE	20 * (t/40m) [N]
Mass MASS_TR1	m	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Capacitive Linear Acceleration (Velocity-Force) sensor C_ACC_VF_I22	offset	0.1 * E1.EMF [V]
	corner_frequency	0 [Hz]
	temp	27 [°C]

	output_resistance	0 [Ohm]
	max_ACC	18 [m/s ²]
	min_ACC	0 [m/s ²]
	full_scale_span	0.8 * E1.EMF [V]
	hysteresis	0 [%]
	max_temp	200 [°C]
	min_temp	-50 [°C]
	temp_hysteresis	0 [%]
	tempco_span	0.2 [%/ (°C)]
	temp_sens_offset	1m [V/(°C)]
	nonlinearity	1 [%]
	supply_current	1m [A]
Voltage Source E1	EMF	5 [V]

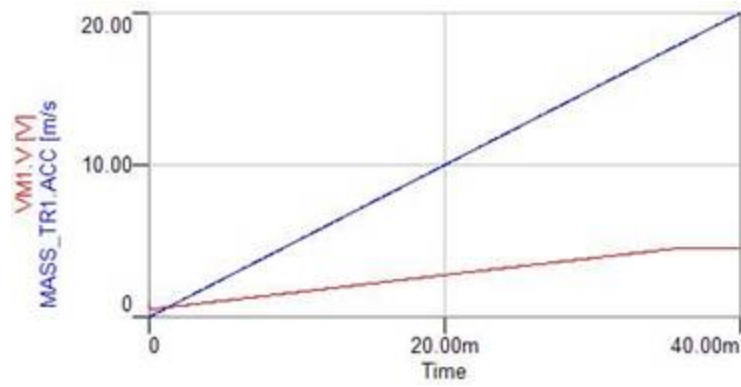


Figure 3. Simulation results-output voltage of C_ACC_VF_I22 and acceleration of MASS_TR1

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References

Level 2 Piezoelectric Linear Acceleration Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

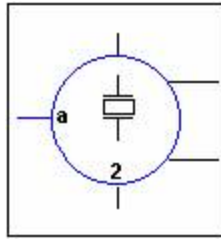


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Description

The Level 2 Piezoelectric Linear Acceleration (Velocity-Force) sensor model is used to simulate the non-ideal behavior of a piezoelectric linear acceleration sensor in the Twin Builder velocity-force translational domain. A change in the model's linear acceleration input produces a corresponding change in the model's linear voltage output.

The model has one conservative input pin in the velocity-force translational domain for its linear acceleration input and four conservative electrical-domain pins, two for its power supplies and two for its voltage output. The negative output terminal should be connected to an electrical ground if the model is connected to an electrical network in which no other component is grounded.

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Netlist Syntax

```
MODEL PE_ACC_VF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) LINEAR:=
%0, OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 ( max_ACC:= @max_ACC, min_ACC:=
@min_ACC, full_scale_span:= @full_scale_span, offset:= @offset, supply_current:= @supply_
current, nonlinearity:= @nonlinearity, hysteresis:= @hysteresis, max_temp:= @max_temp,
min_temp:= @min_temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_
span, temp_sens_offset:= @temp_sens_offset, corner_frequency:= @corner_frequency, tem-
p:= @temp, output_resistance:= @output_resistance) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Table 1

Name	Port/Terminal Description	Nature/Data type
LINEAR	Measured linear acceleration	Translational
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
corner_fre- quency	Corner frequency of the input signal	Real	0 [Hz]

temp	Device temperature	Real	27 [°C]
output_resistance	Output resistance	Real	0 [Ohm]
max_ACC	Maximum measurable linear acceleration	Real	50 [m/s ²]
min_ACC	Minimum measurable linear acceleration	Real	0 [m/s ²]
full_scale_span	Difference of output voltages at maximum and minimum linear accelerations	Real	5 [V]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	150 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
supply_current	Supply current	Real	5m [A]
nonlinearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]

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Example

In this example, the Piezoelectric Linear Acceleration (Velocity-Force) sensor PE_ACC_VF_I22 measures the angular velocity of the Mass MASS_TR1. A change in the acceleration input of MASS_TR1 produces a corresponding change in the linear voltage output of PE_ACC_VF_I22. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

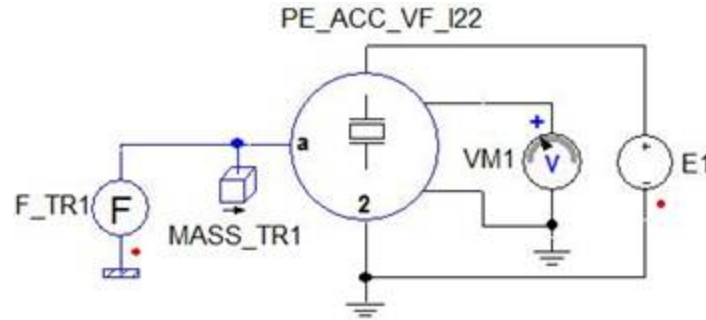


Figure 2. Application example of the Piezoelectric Linear Acceleration (Velocity-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Force Source F_TR1	VALUE	$20 * t/40m$ [N]
Mass MASS_TR1	m	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Piezoelectric Linear Acceleration (Velocity-Force) sensor PE_ACC_VF_I22	offset	$0.1 * E1.EMF$ [V]
	corner_frequency	0 [Hz]
	temp	27 [°C]
	output_res-	0 [Ohm]

	istance	
	max_ACC	18 [m/s ²]
	min_ACC	0 [m/s ²]
	full_scale_ span	0.8 * E1.EMF [V]
	hysteresis	0 [%]
	max_temp	150 [°C]
	min_temp	-50 [°C]
	temp_hys- teresis	0 [%]
	tempco_span	0.2 [%/ (°C)]
	temp_sens_ offset	1m [V/(°C)]
	nonlinearity	1 [%]
	supply_cur- rent	10m [A]
Voltage Source E1	nonlinearity	10 [V]

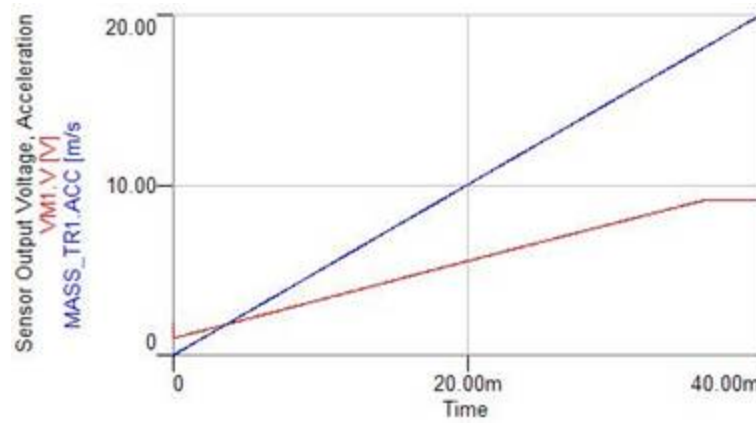


Figure 3. Simulation results-output voltage of PE_ACC_VF_I22 and acceleration of MASS_TR1

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References

Level 2 Piezoresistive Linear Acceleration Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

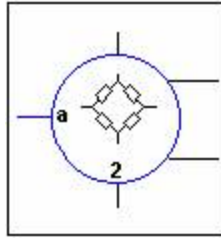


Figure 1. Component symbol

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Description

The Level 2 Piezoresistive Linear Acceleration (Velocity-Force) sensor model is used to simulate the non-ideal behavior of a piezoresistive linear acceleration sensor in the Twin Builder velocity-force translational domain. A change in the model's linear acceleration input produces a corresponding change in the model's Wheatstone bridge, which in turn produces a change in the model's linear voltage output.

The model has one conservative input pin in the velocity-force translational domain for its linear acceleration input and four conservative electrical-domain pins, two for its power supplies and two are for its voltage output.

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Netlist Syntax

```
MODEL PR_ACC_VF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) LINEAR:=
%0, OUT_P:= %1, OUT_M:= %2, Vdd:= %3, Vss:= %4 ( max_ACC:= @max_ACC, min_ACC:=
@min_ACC, full_scale_span:= @full_scale_span, offset:= @offset, nonlinearity:= @non-
linearity, hysteresis:= @hysteresis, max_temp:= @max_temp, min_temp:= @min_temp, temp_
hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span, temp_sens_offset:= @temp_
sens_offset, corner_frequency:= @corner_frequency, temp:= @temp, resistor_tempco:= @res-
istor_tempco, nominal_res_temp:= @nominal_res_temp, p_resistance:= @p_resistance) SRC:
DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
LINEAR	Measured linear acceleration	Translational
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive power supply	Electrical
Vss	Negative power supply	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
corner_fre-	Corner frequency of the input	Real	0 [Hz]

quency	signal		
temp	Device temperature	Real	27 [°C]
max_ACC	Maximum measurable linear acceleration	Real	50 [m/s ²]
min_ACC	Minimum measurable linear acceleration	Real	0 [m/s ²]
full_scale_span	Difference of output voltages at maximum and minimum linear accelerations	Real	5 [V]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	150 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
p_resistance	Bridge resistance	Real	10k [Ohm]
resistor_tempco	Bridge resistor temperature coefficient	Real	0 [%/(°C)]
nominal_res_temp	Bridge resistor nominal resistance temperature	Real	25 [°C]
nonlinearity	Nonlinearity as a percentage of	Real	0 [%]

	full-scale span		

[Top](#)**Example**

In this example, the Piezoresistive Linear Acceleration (Velocity-Force) sensor PR_ACC_VF_I22 measures the linear velocity of the Mass MASS_TR1. A change in the acceleration of MASS_TR1 produces a corresponding change in the linear voltage output of PR_ACC_VF_I22. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

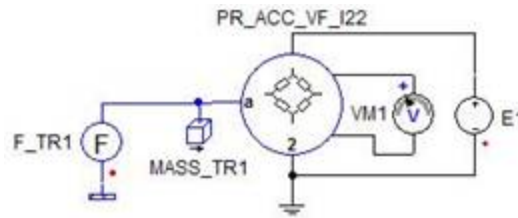


Figure 2. Application example of the Piezoresistive Linear Acceleration (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Force Source F_TR1	VALUE	$20 \cdot t/40\text{m}$ [N]
Mass MASS_TR1	m	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Piezoresistive Linear Acceleration (Velocity-Force) sensor PR_ACC_VF_I22	offset	$0.1 \cdot E1.EMF$ [V]
	corner_frequency	0 [Hz]
	temp	27 [°C]

	max_ACC	18 [m/s ²]
	min_ACC	0 [m/s ²]
	full_scale_span	0.8 * E1.EMF [V]
	hysteresis	0 [%]
	max_temp	150 [°C]
	min_temp	-50 [°C]
	temp_hys- teresis	0 [%]
	tempco_span	0.2 [%/ (°C)]
	temp_sens_ offset	1m [V/(°C)]
	p_resistance	10k [Ohm]
	resistor_tem- pco	0.1 [%/(°C)]
	nominal_res_ temp	25 [°C]
	nonlinearity	1 [%]
Voltage Source E1	EMF	10 [V]

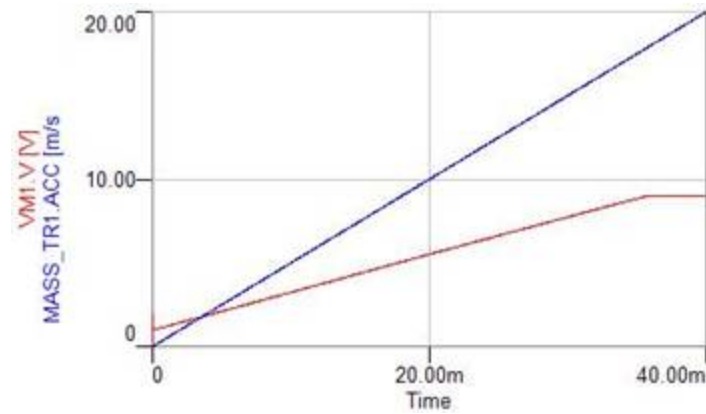


Figure 3. Simulation results-output voltage of PR_ACC_VF_I22 and acceleration of MASS_TR1

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References

Level 2 Inertia Switch Linear Acceleration Sensor (Velocity-force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

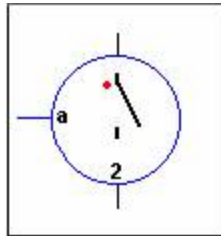


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Description

The Level 2 Inertia Switch Linear Acceleration (Velocity-Force) sensor model is used to simulate the non-ideal behavior of an inertia switch linear acceleration sensor in the Twin Builder velocity-force translational domain. When the linear acceleration applied to the sensor exceeds a specified threshold value, its switch changes state from open to close.

The model has one conservative input pin in the velocity-force translational domain for its linear acceleration input and two conservative electrical-domain pins for its positive and negative terminals. The positive terminal is the one into which current flows.

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Netlist Syntax

MODEL TINERTIA_SWITCH_VF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
 LINEAR:= %0, np:= %1, nm:= %2 (threshold:= @threshold, switch_resistance:= @switch_resistance, meas_error:= @meas_error) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
LINEAR	Measured linear acceleration	Translational_V
np	Positive terminal	Electrical
nm	Negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
threshold	Threshold linear acceleration of the switch	Real	50 [m/s ²]
switch_resistance	Switch on-state resistance	Real	0 [Ohm]
meas_error	Percent measurement error	Real	0 [%]

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Example

In this example, the Inertia Switch Linear Acceleration (Velocity-Force) sensor TINERTIA_SWITCH_VF_I21 measures the linear acceleration of the Mass MASS_TR1. When the acceleration of Mass MASS_TR1 exceeds a specified threshold value, TINERTIA_SWITCH_VF_I21 switches from open to close. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

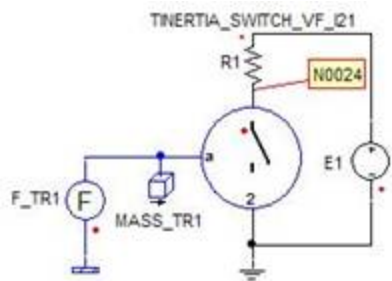


Figure 2. Application example of the Inertia Switch Linear Acceleration (Velocity-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Force Source F_TR1	VALUE	40 * (t/40m) [N]
Mass MASS_TR1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Inertia Switch Linear Acceleration (Velocity-Force) sensor TINERTIA_SWITCH_VF_I21	threshold	20 [m/s ²]
	switch_resistance	10 [Ohm]
	meas_error	-10 [%]
Voltage Source E1	EMF	1 [V]
Resistor R1	R	1k [Ohm]

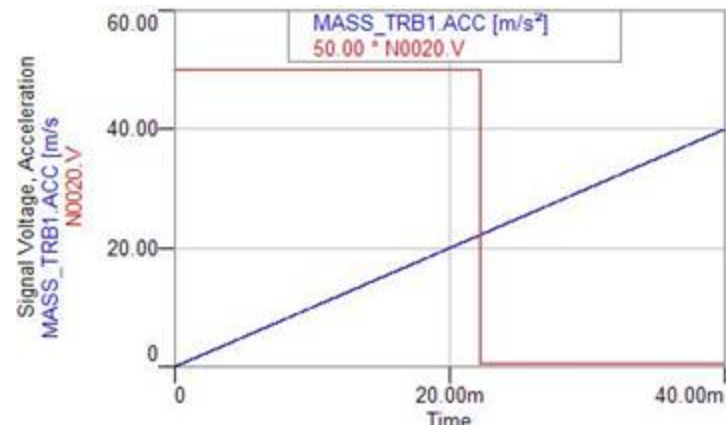


Figure 3. Simulation results-output voltage of TINERTIA_SWITCH_VF_I21 (scaled) and acceleration of MASS_TR1

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Level 2 Linear Position Sensor Models

The Level 2 Linear Position Sensor Models simulate the non-ideal behavior of eight different types of linear position sensors. Models are available for use with the Twin Builder *displacement-force* and *velocity-force* translational domains.

All of the linear position sensor models have conservative input pins that must be connected to a translational network and conservative output pins that must be connected to an electrical network. The models also feature nonconservative parameters that can be changed in order to tailor the behavior of the model to that of a specific real device.

As shown in the following example, linear position sensor models for the displacement-force translational domain have light blue conservative input pins that must be connected to a displacement-force translational network. The models also have black pins that must be connected to an electrical network.

Similarly, linear position sensor models for the velocity-force translational domain have dark blue translational nature input pins and black electrical nature pins.

The Level 2 Linear Position Sensor Models feature models for the following linear position sensing mechanisms:

- Anisotropic Magnetoresistive (AMR): A change in linear position produces a corresponding linear change in the output voltage signal.

Displacement-Force model: ([LIN_DISP_AMR_DF_I2](#))

Velocity-Force model: ([LIN_DISP_AMR_VF_I2](#))

- Potentiometric: A change in linear position moves a potentiometer wiper, producing a change in the voltage divider output signal.

Displacement-Force model: ([LIN_DISP_DF_I2](#))

Velocity-Force model: ([LIN_DISP_VF_I2](#))

- Hall-Effect: A change in linear position produces a corresponding linear change in the output voltage signal.

Displacement-Force model: ([LIN_DISP_HE_DF_I2](#))

Velocity-Force model: ([LIN_DISP_HE_VF_I2](#))

- Linear Variable Differential Transformer (LVDT): Linear motion changes the extent of the coupling between a primary winding and two secondary windings, producing variations in the amplitude and phase of an AC output signal.

Displacement-Force model: ([LVDT_DF_I2](#))

Velocity-Force model: ([LVDT_VF_I2](#))

- SCR: A change in linear position changes the inductance of a variable inductor, causing a corresponding change in the output signal at the junction between the variable inductor and a constant-value reference inductor.

Displacement-Force model: ([SCR_DF_I2](#))

Velocity-Force model: ([SCR_VF_I2](#))

- Absolute Encoder: Linear position is encoded as a 6 to 16-bit binary number.

Displacement-Force model: ([TABS_ENCODER_DF_I2](#))

Velocity-Force model: ([TABS_ENCODER_VF_I2](#))

- Incremental Encoder: Linear displacement produces two output pulse trains in quadrature and a reference pulse when a reference position is passed.

Displacement-Force model: ([TINC_ENCODER_I2](#))

Velocity-Force model: ([TINC_ENCODER_VF_I2](#))

- Microswitch: Linear displacement past a specified threshold position causes a switch to toggle from its normally closed pin to its normally open pin.

Displacement-Force model: ([TMSWITCH_DF_I2](#))

Velocity-Force model: ([TMSWITCH_VF_I2](#))

Level 2 Anisotropic Magnetoresistive Linear Position Sensor (Displacement-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

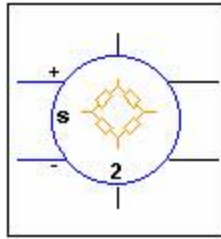


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Description

The Level 2 Anisotropic Magnetoresistive Linear Position (Displacement-Force) sensor model is used to simulate the non-ideal behavior of an AMR linear position sensor in the Twin Builder displacement-force translational domain. A change in the linear position of an element in the displacement-force translational domain causes a corresponding change in the sensor model's linear voltage output signal.

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Netlist Syntax

```
MODEL LIN_DISP_AMR_DF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) Vcc:= %0, Vss:= %1, POSITION:= %2, REF:= %3, out_plus:= %4, out_minus:= %5 ( input_current:= @input_current, time_constant:= @time_constant, max_displacement:= @max_displacement, min_displacement:= @min_displacement, full_scale_span:= @full_scale_span, offset:= @offset, nonlinearity:= @nonlinearity, hysteresis:= @hysteresis, temp:= @temp, max_temp:= @max_temp, min_temp:= @min_temp, temp_hysteresis:= @temp_hysteresis, output_tempco:= @output_tempco, temp_sens_offset:= @temp_sens_offset, output_resistance:= @output_resistance) SRC: DB(Lib:=@ModelLibraryName);
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational
REF	Reference linear position	Translational
Vcc	Positive power supply	Electrical
Vss	Negative power supply	Electrical
out_plus	Positive output terminal	Electrical
out_minus	Negative output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
input_current	Device supply current	Real	1m [A]
temp	Device temperature	Real	27 [°C]

output_resistance	Output resistance	Real	0 [Ohm]
time_constant	Output time constant	Real	0 [s]
max_displacement	Maximum measurable linear displacement	Real	10m [m]
min_displacement	Minimum measurable linear displacement	Real	0 [m]
full_scale_span	Difference of maximum and minimum measurable displacements	Real	10 [V]
offset	Output at minimum measurable displacement	Real	0 [V]
nonlinearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	150 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
output_tempco	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]

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Example

In this example, the Anisotropic Magnetoresistive Linear Position Sensor (Displacement-Force) LIN_DISP_AMR_DF_I22 measures the linear position of the Mass MASS_TRB1. A change in the linear position of MASS_TRB1 produces a corresponding change in the voltage output of LIN_DISP_AMR_DF_I22. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

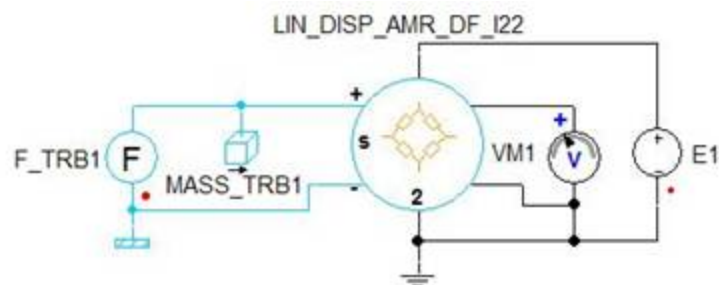


Figure 2. Application example of the Anisotropic Magnetoresistive Linear Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Force Source F_TRB1	VALUE	1k [N]
Voltage Source E1	EMF	5 [V]
Mass MASS_TRB1	M	1 [kg]
	S0	0 [in]
	V0	0 [m/s]
Anisotropic Magnetoresistive Linear Position Sensor (Displacement-Force) LIN_DISP_AMR_DF_I22	input_current	4m [A]
	temp	27 [°C]
	output_res-istance	10 [Ohm]
	time_constant	500u [s]
	max_dis-placement	500m [m]
	min_dis-placement	-500m [m]

full_scale_ span	E1.EMF [V]
offset	0 [V]
nonlinearity	1 [%]
hysteresis	0 [%]
max_temp	150 [°C]
min_temp	-50 [°C]
temp_hys- teresis	0 [%]
output_tempco	-1 [%/ (°C)]
temp_sens_off- set	0 [V/(°C)]

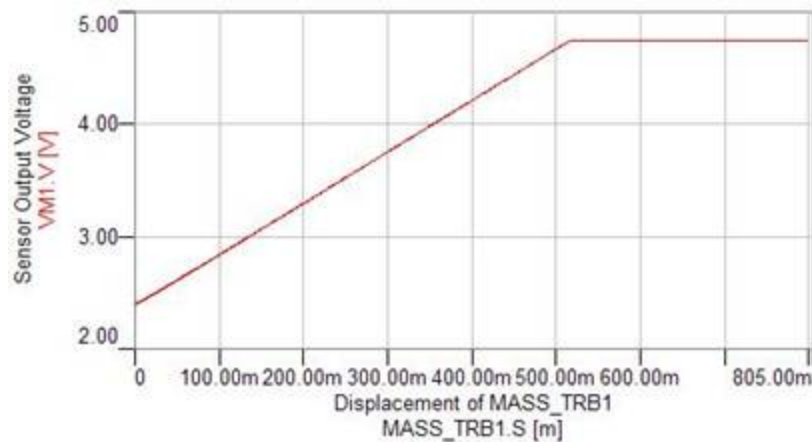


**Figure 3. Simulation results- the output voltages of LIN_DISP_AMR_DF_I22
vs. the displacement of MASS_TRB1**

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References

Level 2 Potentiometric Linear Position Sensor (Displacement-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

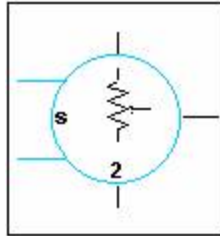


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Description

The Level 2 Potentiometric Linear Position (Displacement-Force) model is used to simulate the non-ideal behavior of a potentiometer linear position sensor in the Twin Builder displacement-force translational domain. A change in linear position of an element in the displacement-force translational domain causes a corresponding change in the model's voltage divider output signal.

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Netlist Syntax

```
MODEL LIN_DISP_DF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) REF:= %0,
Vcc:= %1, Vss:= %2, OUTPUT:= %3, POSITION:= %4 ( max_displacement:= @max_dis-
placement, min_displacement:= @min_displacement, full_scale_span:= @full_scale_span, off-
set:= @offset, max_nonlinearity:= @max_nonlinearity, max_hysteresis:= @max_hysteresis,
temp_hysteresis:= @temp_hysteresis, max_temp:= @max_temp, min_temp:= @min_temp,
temp:= @temp, tempco_span:= @tempco_span, temp_sens_offset:= @temp_sens_offset, p_
resistance:= @p_resistance, w_resistance:= @w_resistance, time_constant:= @time_con-
stant) SRC: DB(Lib:=@ModelLibraryName);
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
THETA	Measured Linear position	Translational
RPOS	Reference Linear position	Translational
Vcc	Positive supply	Electrical
Vss	Negative supply	Electrical
OUTPUT	Output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
p_resistance	Potentiometer resistance	Real	10k [Ohm]
temp	Device temperature	Real	27 [°C]

w_resistance	Potentiometer wiper resistance	Real	0 [Ohm]
max_displacement	Maximum measurable linear position	Real	0.1 [m]
min_displacement	Minimum measurable linear position	Real	0 [m]
full_scale_span	Difference of maximum and minimum output voltages	Real	10 [V]
max_non-linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
max_hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	125 [°C]
min_temp	Minimum operating temperature	Real	-40 [°C]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
time_constant	Output time constant	Real	0 [s]

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Example

In this example, the Potentiometric Linear Position Sensor (Displacement-Force) LIN_DISP_DF_I21 measures the linear position of the Mass MASS_TRB1. A change in the linear position of MASS_TRB1 produces a corresponding change in the voltage output of LIN_DISP_DF_I21. The

schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

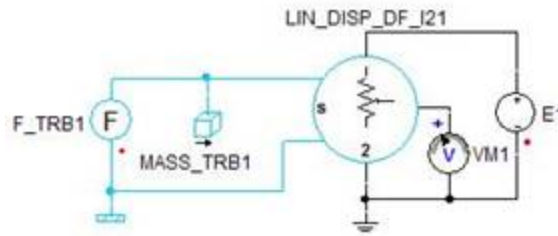


Figure 2. Application example of the Potentiometric Linear Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Force Source F_TRB1	VALUE	1k [N]
Voltage Source E1	EMF	15 [V]
Mass MASS_TRB1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Potentiometric Linear Position Sensor (Displacement-Force) LIN_DISP_DF_I21	offset	0 [V]
	p_resistance	6k [Ohm]
	temp	27 [°C]
	w_resistance	0 [Ohm]
	max_displacement	6 [in]
	min_displacement	0 [m]

	full_scale_span	E1.EMF [V]
	max_non-linearity	1 [%]
	max_hys-teresis	0 [%]
	temp_hys-teresis	0 [%]
	max_temp	80 [°C]
	min_temp	-40 [°C]
	tempco_span	0 [%/(°C)]
	temp_sens_off-set	0 [V/(°C)]
	time_constant	0 [s]

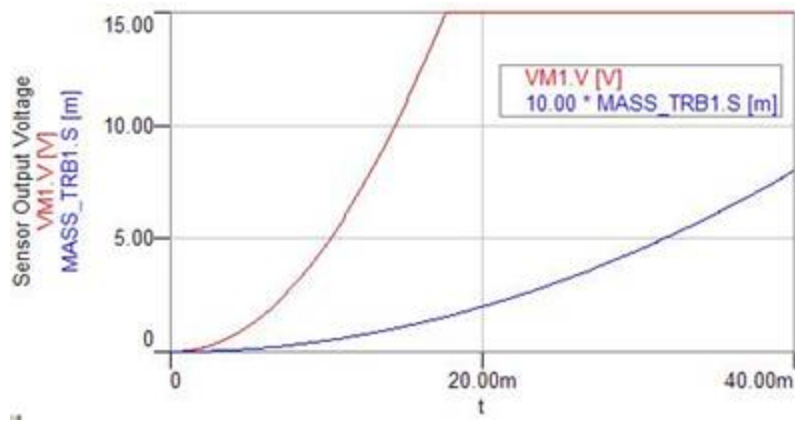


Figure 3. Simulation results-the linear position of MASS_TRB1 (scaled) and the output voltages of LIN_DISP_DF_I21

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References

Level 2 Hall-Effect Linear Position Sensor (Displacement-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

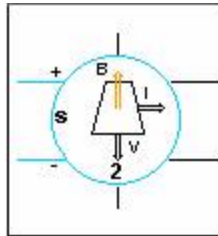


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Description

The Level 2 Hall-Effect Linear Position (Displacement-Force) sensor model is used to simulate the non-ideal behavior of a Hall-effect linear position sensor in the Twin Builder displacement-force translational domain. A change in the linear position of an element in the displacement-force translational domain causes a corresponding change in the model's voltage output signal.

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Netlist Syntax

```
MODEL LIN_DISP_HE_DF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) Vcc:=
%0, Vss:= %1, POSITION:= %2, REF:= %3, out_plus:= %4, out_minus:= %5 ( input_current:=
@input_current, time_constant:= @time_constant, max_displacement:= @max_displacement,
min_displacement:= @min_displacement, full_scale_span:= @full_scale_span, offset:= @off-
set, nonlinearity:= @nonlinearity, hysteresis:= @hysteresis, temp:= @temp, max_temp:=
@max_temp, min_temp:= @min_temp, temp_hysteresis:= @temp_hysteresis, output_tem-
pco:= @output_tempco, temp_sens_offset:= @temp_sens_offset, output_resistance:= @out-
put_resistance) SRC: DB(Lib:=@ModelLibraryName);
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational
REF	Reference linear position	Translational
Vcc	Positive supply	Electrical
Vss	Negative supply	Electrical
out_plus	Positive output	Electrical
out_minus	Negative output	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
input_current	Typical device input current	Real	1m [A]
temp	Device temperature	Real	27 [°C]

output_resistance	Output resistance	Real	0 [Ohm]
time_constant	Output time constant	Real	0 [s]
max_displacement	Maximum measurable displacement	Real	10m [m]
min_displacement	Minimum measurable displacement	Real	0 [m]
full_scale_span	Difference of maximum and minimum output voltages	Real	10 [V]
offset	Output at zero displacement	Real	0 [V]
nonlinearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	150 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
output_tempco	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]

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Example

In this example, the Hall-Effect Linear Position Sensor (Displacement-Force) LIN_DISP_HE_DF_I22 measures the linear position of the Mass MASS_TRB1. A change in the linear position of

MASS_TRB1 produces a corresponding change in the voltage output of LIN_DISP_HE_DF_I22. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

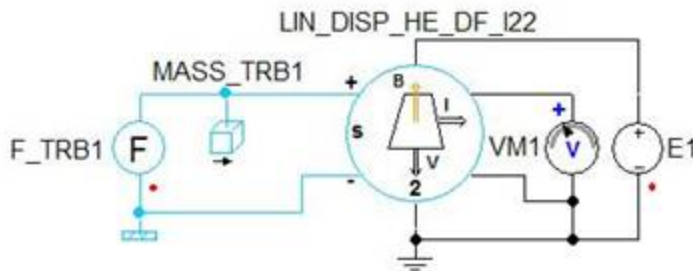


Figure 2. Application example of the Hall-Effect Linear Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Force Source F_TRB1	VALUE	1k [N]
Voltage Source E1	EMF	15 [V]
Mass MASS_TRB1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Hall-Effect Linear Position Sensor (Displacement-Force) LIN_DISP_HE_DF_I22	input_current	5m [A]
	temp	27 [°C]
	output_resistance	0 [Ohm]
	time_constant	100u [s]
	max_displacement	30 [in]

min_displacement	0 [m]
full_scale_span	0.9 * E1.EMF [V]
offset	0.1 * E1.EMF [V]
nonlinearity	5 [%]
hysteresis	0 [%]
max_temp	0.15k [°C]
min_temp	-50 [°C]
temp_hysteresis	0 [%]
output_tempco	-1 [%/ (°C)]
temp_sens_offset	0 [V/(°C)]

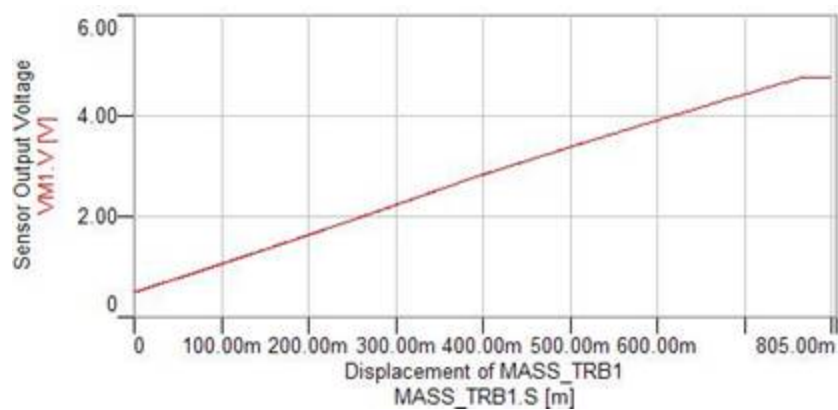


**Figure 3. Simulation results- the output voltages of LIN_DISP_HE_DF_I22
vs. the displacement of MASS_TRB1**

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References

Level 2 LVDT Linear Position Sensor (Displacement-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

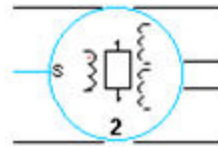


Figure 1. Component symbol

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Description

The Level 2 LVDT Linear position sensor (Displacement-Force) model is used to simulate the non-ideal behavior of a linear variable differential transformer linear position sensor. A change in linear position produces a corresponding change in the AC voltage output signal.

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Netlist Syntax

```
MODEL LVDT_DF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) out_1_plus:= %0,
out_1_minus:= %1, out_2_plus:= %2, out_2_minus:= %3, in_plus:= %4, in_minus:= %5,
```

POSITION:= %6 (max_position:= @max_position, min_position:= @min_position, sensitivity:= @sensitivity, max_nonlinearity:= @max_nonlinearity, hysteresis:= @hysteresis, max_temp:= @max_temp, min_temp:= @min_temp, temp:= @temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span, primary_inductance:= @primary_inductance, primary_resistance:= @primary_resistance, secondary_inductance:= @secondary_inductance, secondary_resistance:= @secondary_resistance, null_voltage:= @null_voltage, core_mass:= @core_mass) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational
in_plus	Transformer primary positive terminal	Electrical
in_minus	Transformer primary negative terminal	Electrical
out_1_plus	Transformer secondary 1 positive terminal	Electrical
out_1_minus	Transformer secondary 1 negative terminal	Electrical
out_2_plus	Transformer secondary 2 positive terminal	Electrical
out_2_minus	Transformer secondary 2 negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]

sensitivity	LVDT sensitivity	Real	1 [V/V/m]
temp	Device temperature	Real	27 [°C]
max_non-linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	125 [°C]
min_temp	Minimum operating temperature	Real	-40 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/ (°C)]
primary_inductance	Inductance of primary winding	Real	10m [H]
primary_resistance	Resistance of primary winding	Real	0 [Ohm]
secondary_inductance	Inductance of secondary winding	Real	10m [H]
secondary_resistance	Resistance of secondary winding	Real	0 [Ohm]
null_voltage	Amplitude of output voltage at zero measured displacement	Real	0 [V]
max_position	Maximum measurable linear position	Real	1m [m]
min_position	Minimum measurable linear	Real	-1m [m]

	position		
core_mass	Mass of transformer core	Real	0 [kg]

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Example

In this example, the LVDT Linear position sensor (Displacement-Force) LVDT_DF_I22 measures the linear position of the Mass MASS_TRB1. A change in the linear position of MASS_TRB1 produces a corresponding change in the output voltage of LVDT_DF_I22. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

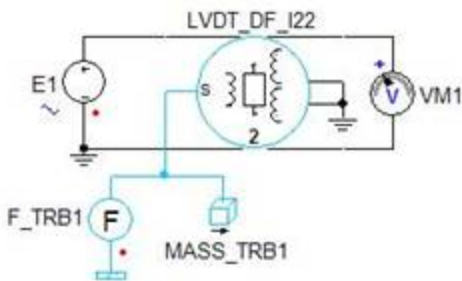


Figure 2. Application example of the SCR Linear Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Force Source F_TRB1	VALUE	-10k [N]
Voltage Source (sinusoidal) E1	AMPL	1 [V]
	FREQ	10k [Hz]
	PHASE	0 [degree]
	OFF	0 [V]
	TDELAY	0 [s]
Mass MASS_TRB1	M	1 [kg]

LVDT Linear position sensor (Displacement-Force) LVDT_DF_I22	S0	0 [m]
	V0	0 [m/s]
	sensitivity	63 [V/V/m]
	temp	27 [°C]
	max_non-linearity	0.25 [%]
	hysteresis	0.01 [%]
	max_temp	105 [°C]
	min_temp	-55 [°C]
	temp_hysteresis	0 [%]
	tempco_span	-0.02 [%/(°C)]
	primary_inductance	21.6 [H]
	primary_resistance	0 [Ohm]
	secondary_inductance	10m [H]
	secondary_resistance	0 [Ohm]
	null_voltage	0 [V]
	max_position	1.25m [m]
	min_position	-1.25m [m]

	core_mass	0.4 [kg]

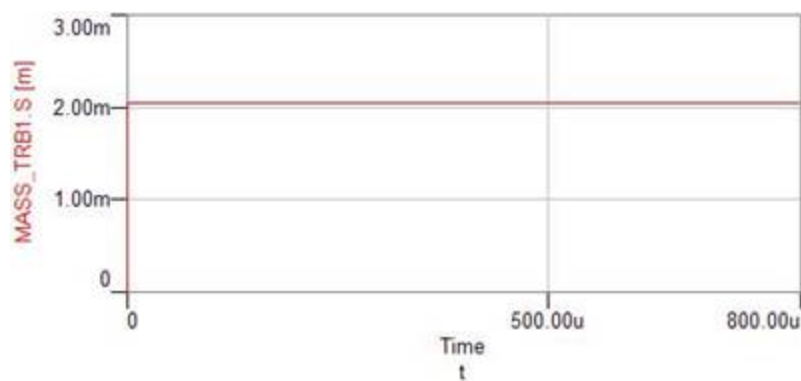


Figure 3. Simulation results-linear displacement of MASS_TRB1

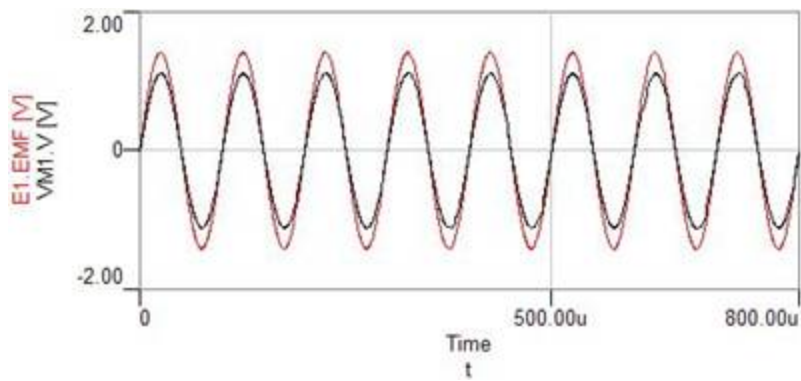


Figure 4. Simulation results- voltage outputs of LVDT_DF_I22 and E1

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References

Level 2 SCR Linear Position Sensor (Displacement-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

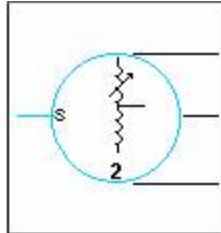


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Description

The Level 2 SCR Linear Position (Displacement-Force) simulates the non-ideal behavior of a short-circuit ring linear position sensor. The model consists of a variable inductance in series with a reference inductance. As the linear position of an element in the Twin Builder displacement-force translational domain is varied, a corresponding change occurs in the value of the variable inductance. The junction between the variable and reference inductances is where the sensor's output signal, such as a variable AC voltage, can be measured.

The model has a conservative translational-nature pin for measured linear position and three conservative electrical nature pins: two for the reference signal input and output and one for the signal output.

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Netlist Syntax

MODEL SCR_DF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) np:= %0, nm:= %1, signal:= %2, POSITION:= %3 (max_position:= @max_position, full_scale_span:= @full_scale_span, reference_inductance:= @reference_inductance, nominal_inductance:= @nominal_inductance, time_constant:= @time_constant, max_nonlinearity:= @max_nonlinearity, hysteresis:= @hysteresis, temp:= @temp, max_temp:= @max_temp, min_temp:= @min_temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span) SRC: DB(Lib:- :=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational
np	Positive input for reference voltage or current	Electrical
nm	Negative input for reference voltage or current	Electrical
signal	Signal output	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
reference_inductance	Inductance of reference inductor	Real	10m [H]
nominal_	Nominal inductance of variable	Real	1m [H]

inductance	inductor		
max_position	Maximum measurable linear position	Real	10m [m]
full_scale_span	Difference of variable inductor values at maximum and zero positions	Real	10m [H]
max_non-linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
temp	Device temperature	Real	27 [°C]
max_temp	Maximum operating temperature	Real	150 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Temperature sensitivity of variable inductance	Real	0 [%/(°C)]
time_constant	Output time constant	Real	0 [s]

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Example

In this example, the SCR Linear Position Sensor (Displacement-Force) SCR_DF_I21 measures the linear position of the Mass MASS_TRB1. A change in the linear position of MASS_TRB1 produces a corresponding change in the variable inductance of SCR_DF_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

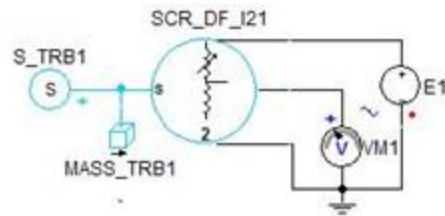


Figure 2. Application example of the SCR Linear Position Sensor(Displacement-Force)**Table 3**

Component	Parameter	Value [Unit]
Position Source S_TRB1	VALUE	5m * (t/80m) [m]
Voltage Source (sinusoidal) E1	AMPL	5 [V]
	FREQ	100 [Hz]
	PHASE	0 [degree]
	OFF	0 [V]
	TDELAY	0 [s]
Mass MASS_TRB1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
SCR Linear Position Sensor (Displacement-Force) SCR_DF_I21	reference_ inductance	10m [H]
	nominal_ inductance	1m [H]
	max_position	5m [m]
	full_scale_ span	9m [H]
	max_non- linearity	5 [%]
	hysteresis	0 [%]

	temp	27 [°C]
	max_temp	150 [°C]
	min_temp	-50 [°C]
	temp_hys-teresis	0 [%]
	tempco_span	5 [%/(°C)]
	time_con-stant	0 [s]

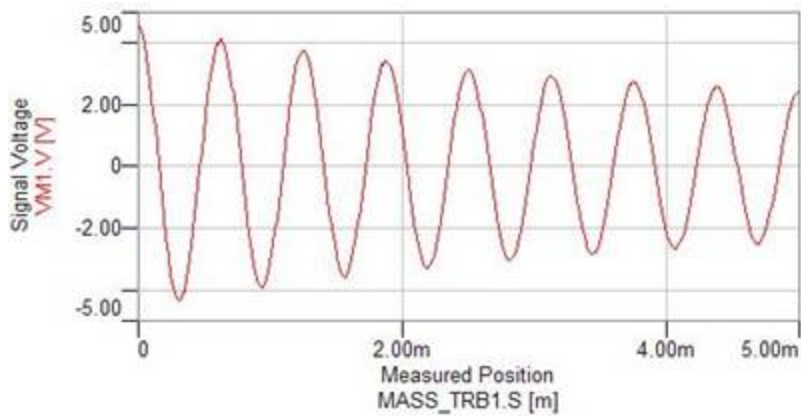


Figure 3. Simulation results-voltage output of SCR_DF_I21 vs. linear displacement of MASS_TRB1

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References

Level 2 Absolute Encoder Linear Position Sensor (Displacement-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

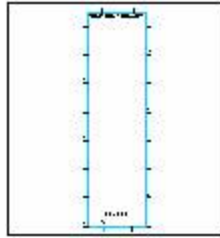


Figure 1. Component symbol

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Description

An absolute encoder linear position sensor translates absolute linear position to a natural binary output. The precision of the output, i.e. the number of bits that make up the output, is determined by the number of equally spaced position indicators that are available on the sensor. For example, an linear position sensor with sixteen position indicators would have a four-bit output.

The Level 2 Absolute encoder Linear Position (Displacement-Force) sensor model is used to simulate the non-ideal behavior of a 6 to 16-bit absolute encoder linear position sensor in the Twin Builder displacement-force translational domain. The model has a conservative input pin with a translational nature and nineteen conservative electrical-nature pins. Two of the pins are used to connect the model to a power supply and a ground. One pin is used for the sensor's output-enable signal. The remaining pins are for the sixteen possible binary outputs.

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Netlist Syntax

MODEL TABS_ENCODER_DF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
Vdd:= %0, Vss:= %1, LE:= %2, BIT_15:= %3, BIT_14:= %4, BIT_13:= %5, BIT_12:= %6, BIT_11:= %7, BIT_10:= %8, BIT_9:= %9, BIT_8:= %10, BIT_7:= %11, BIT_6:= %12, BIT_5:= %13, BIT_4:= %14, BIT_3:= %15, BIT_2:= %16, BIT_1:= %17, BIT_0:= %18, POSITION:= %19 (resolution:= @resolution, max_amplitude:= @max_amplitude, min_amplitude:= @min_amplitude, max_position:= @max_position, supply_current:= @supply_current, latch_threshold:= @latch_threshold, reaction_time:= @reaction_time, output_resistance:= @output_resistance, error:= @error) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical
BIT_0 (See Note)	Output bit zero	Electrical
BIT_1 (See Note)	Output bit one	Electrical
BIT_2 (See Note)	Output bit two	Electrical
BIT_3 (See Note)	Output bit three	Electrical
BIT_4 (See Note)	Output bit four	Electrical
BIT_5 (See Note)	Output bit five	Electrical
BIT_6 (See Note)	Output bit six	Electrical

BIT_7 (See Note)	Output bit seven	Electrical
BIT_8 (See Note)	Output bit eight	Electrical
BIT_9 (See Note)	Output bit nine	Electrical
BIT_10 (See Note)	Output bit ten	Electrical
BIT_11 (See Note)	Output bit eleven	Electrical
BIT_12 (See Note)	Output bit twelve	Electrical
BIT_13 (See Note)	Output bit thirteen	Electrical
BIT_14 (See Note)	Output bit fourteen	Electrical
BIT_15 (See Note)	Output bit fifteen	Electrical
LE	Output enable	Electrical

Note: Terminal set to No Action when unconnected. Terminal may remain unconnected without generating an error.

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
resolution	Number of bits available at the output	Real	16
max_amplitude	Logic 1 output amplitude	Real	5 [V]

min_amp- litude	Logic 0 output amplitude	Real	0 [V]
max_pos- ition	Maximum measurable position	Real	5m [m]
supply_cur- rent	Supply current	Real	20m [A]
latch_ threshold	Output enable threshold voltage	Real	2.5 [V]
reaction_ time	Time lapse between rising edge of output enable signal and change in binary output	Real	0 [s]
output_res- istance	Output resistance at each output pin	Real	0 [Ohm]
error	Percent measurement error	Real	0 [%]

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Example

In this example, the Absolute Encoder Linear Position Sensor (Displacement-Force) TABS_ENCODER_DF_I22 measures the linear displacement of the Mass MASS_TRB1, and the encoded measurement results are sent out through its output channels. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3-12.

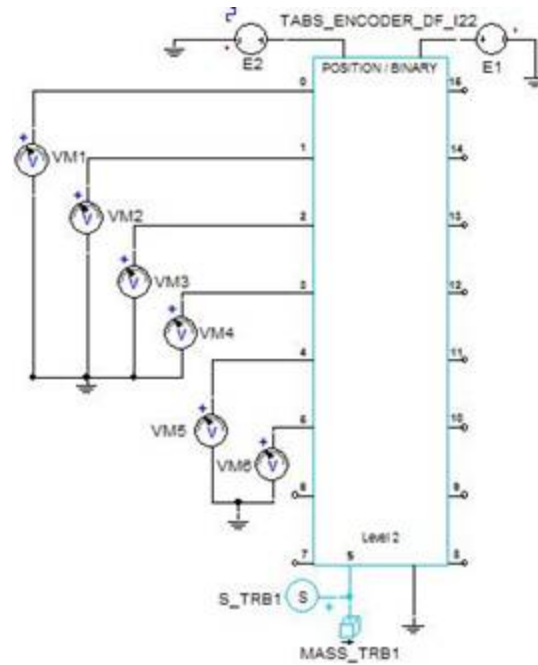


Figure 2. Application example of the Absolute Encoder Linear Position Sensor (Displacement-Force)**Table 3**

Component	Parameter	Value [Unit]
Position Source S_TRB1	VALUE	10m * (t/40m) [m]
Voltage Source E1	EMF	5 [V]
Voltage Source (pulse) E2	AMPL	2.5 [V]
	FREQ	100 [Hz]
	PHASE	0 [degree]
	OFF	2.5 [V]
	TDELAY	0 [s]
Mass MASS_TRB1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Absolute Encoder Linear Position Sensor (Displacement-Force) TABS_ENCODER_DF_I22	resolution	6
	max_amp- litude	4.5 [V]
	min_amp- litude	1 [V]
	max_pos- ition	10m [s]
	supply_cur-	4m [A]

	rent	
	latch_ threshold	2.5 [V]
	reaction_ time	500u [s]
	output_res- istance	0 [Ohm]
	error	0 [m]

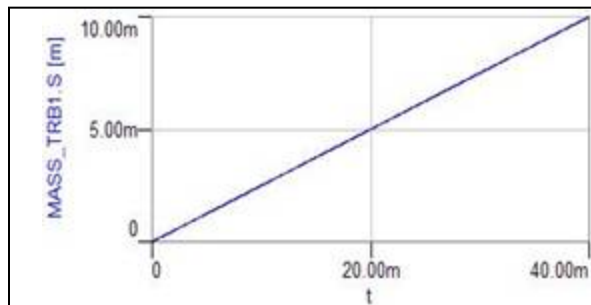


Figure 3. Simulation results-linear displacement of MASS_TRB1

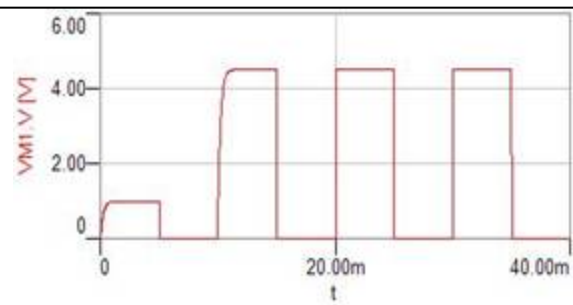


Figure 4. Simulation results- output bit0 of TABS_ENCODER_DF_I22

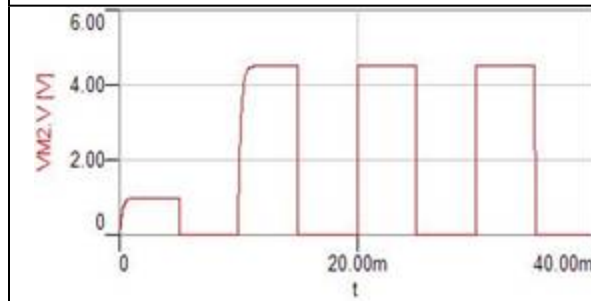


Figure 5. Simulation results- output bit1 of TABS_ENCODER_DF_I22

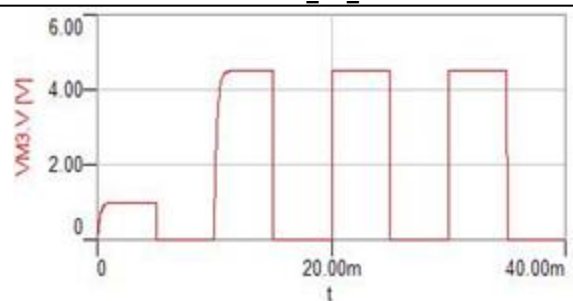


Figure 6. Simulation results- output bit2 of TABS_ENCODER_DF_I22

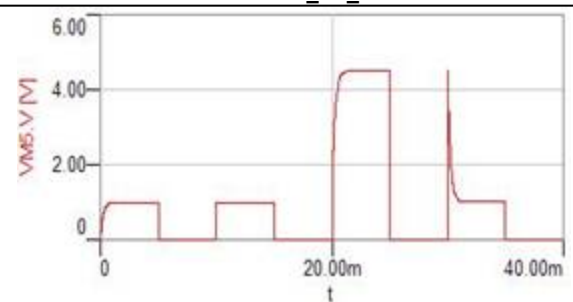
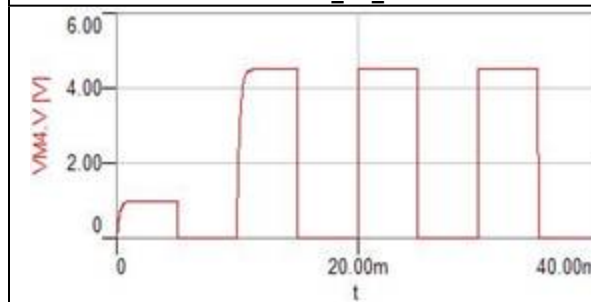
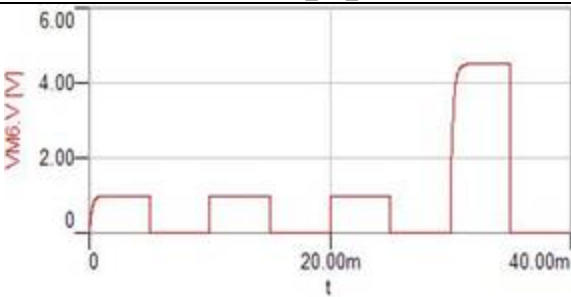


Figure 7. Simulation results- output bit3 of TABS_ENCODER_DF_I22  Figure 9. Simulation results- output bit5 of TABS_ENCODER_DF_I22	Figure 8. Simulation results- output bit4 of TABS_ENCODER_DF_I22

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References

Level 2 Incremental Encoder Linear Position Sensor (Displacement-Force)

Library: Add Ons/-sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

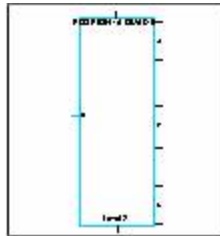


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Description

The Level 2 Incremental encoder Linear Position (Displacement-Force) sensor model is used to simulate the non-ideal behavior of an incremental encoder linear position sensor in the Twin Builder displacement-force translational domain. An incremental encoder has some number of equally spaced sensing elements, all of which will be detected during one motion along the length of the device. These elements account for two of the device's three outputs: Channel A and Channel B. Channel A is a pulse output that goes to its logic 1 value whenever a sensing element is detected and remains there until the sensor has traveled one-half of the distance to the next element. Channel B is a second pulse output that lags Channel A by a quarter cycle.

The third output of the model is Channel N, which goes to its logic 1 value when the sensor detects the zero point of the sensor and remains high until the sensor has traveled one-quarter of the distance to the next sensing element.

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Netlist Syntax

MODEL TINC_ENCODER_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) Vdd:= %0, Vss:= %1, A_plus:= %2, A_minus:= %3, B_plus:= %4, B_minus:= %5, N_plus:= %6, N_minus:= %7, POSITION:= %8 (num_lines:= @num_lines, min_amplitude:= @min_amplitude, max_amplitude:= @max_amplitude, pct_error:= @pct_error, delay:= @delay, output_resistance:= @output_resistance, zero_position:= @zero_position, max_position:= @max_position, min_position:= @min_position, supply_current:= @supply_current) SRC: DB (Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured linear position	Translational
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical
A_plus (See Note)	Channel A positive output terminal	Electrical
A_minus (See Note)	Channel A negative output terminal	Electrical
B_plus (See Note)	Channel B negative output terminal	Electrical
B_minus (See Note)	Channel B positive output terminal	Electrical
N_plus (See	Channel N positive output ter-	Electrical

Note)	minal	
N_minus (See Note)	Channel N negative output terminal	Electrical

Note: Terminal set to No Action when unconnected. Terminal may remain unconnected without generating an error.

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
num_lines	Number of sensing elements on sensor	Real	16
min_amplitude	Logic zero output	Real	0 [V]
max_amplitude	Logic one output	Real	5 [V]
pct_error	Percent measurement error	Real	0 [%]
delay	Rise time of final output value fro 10% to 90%	Real	0 [s]
output_resistance	Resistance at each output	Real	0 [Ohm]
zero_position	Zero position of encoder	Real	0 [m]
max_position	Maximum measurable position	Real	5m [m]
min_position	Minimum measurable position	Real	0 [m]
supply_current	Supply current	Real	50m [A]

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Example

In this example, a Position Source Is measured by an Incremental Encoder Linear Position Sensor (Displacement-Force) TINC_ENCODER_DF_I21, and the encoded measurement result is sent out through the output channels of TINC_ENCODER_DF_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in figures 3-5.

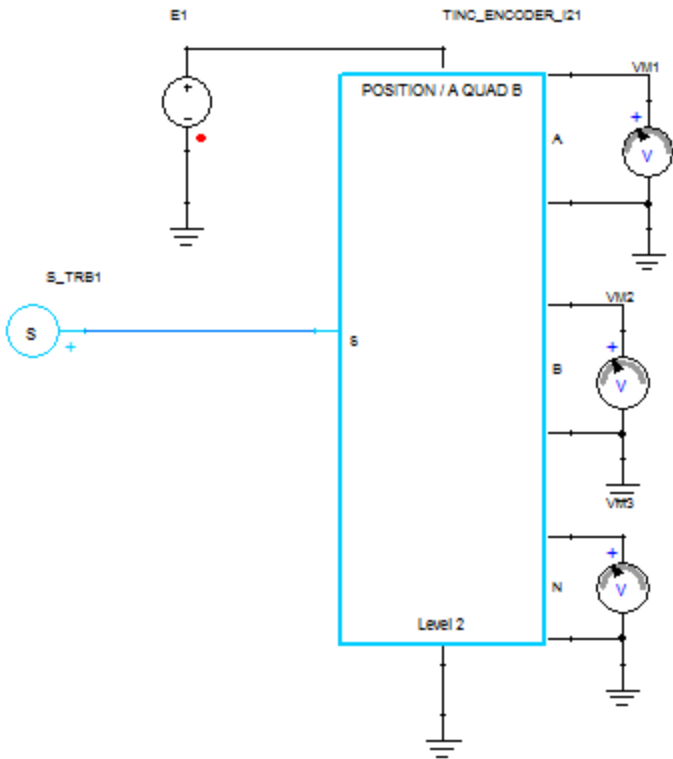


Figure 2. Application example of the Incremental Encoder Linear Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Position Source S_TRB1	VALUE	-50 + 20m * (t/80u) [in]

Voltage Source E1	EMF	20 [V]
Incremental Encoder Linear Position Sensor (Displacement-Force) TINC_ENCODER_DF_I21	num_lines	25k
	min_amplitude	0.5 [V]
	max_amplitude	18.5 [V]
	pct_error	0 [%]
	delay	1u [s]
	output_resistance	0 [Ohm]
	zero_position	-50 [in]
	max_position	0 [in]
	min_position	-50 [in]
	supply_current	80m [A]

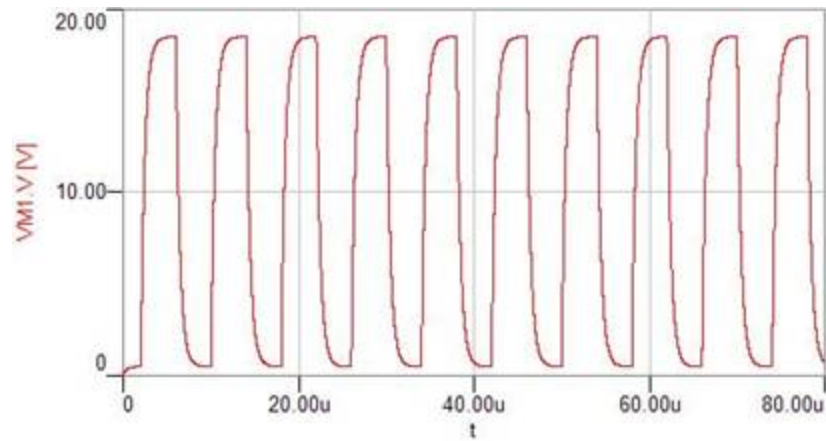


Figure 3. Simulation result-Channel A output of TINC_ENCODER_DF1

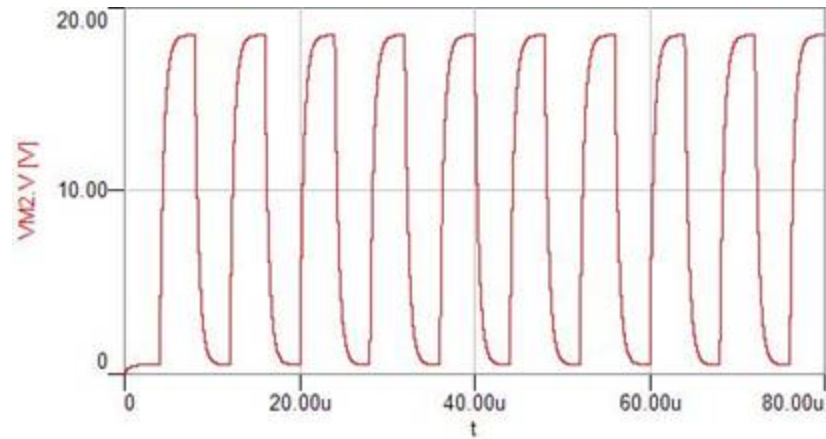


Figure 4. Simulation result-Channel B output of TINC_ENCODER_DF1

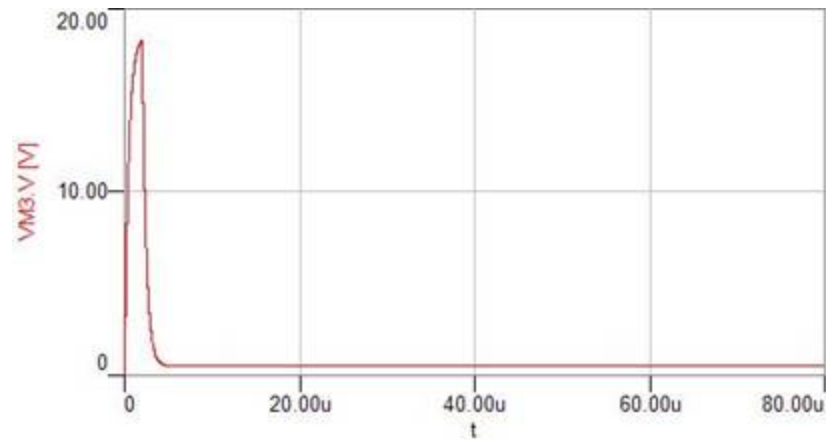


Figure 5. Simulation result-Channel N output of TINC_ENCODER_DF1

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References

Level 2 Microswitch Linear Position Sensor (Displacement-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

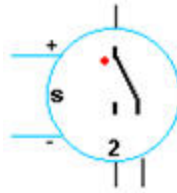


Figure 1. Component symbol

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Description

The Level 2 Microswitch Linear Position (Displacement-Force) sensor model is used to simulate the non-ideal behavior of a microswitch linear position sensor in the Twin Builder displacement-force translational domain. The microswitch model toggles from its normally closed terminal to its normally open terminal when the specified threshold linear position is exceeded by some element in the displacement-force translational domain.

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Mathematical Description

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Netlist Syntax

MODEL TMSWITCH_DF_I2 ?InstanceName(@InstanceName):(@Refbase)@(ID))
POSITION:= %0, REF:= %1, nmnc:= %2, nmno:= %3, np:= %4 (threshold:= @threshold,
switch_resistance:= @switch_resistance, response_time:= @response_time) SRC: DB(Lib:-
:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational
REF	Reference linear position	Translational
np	Positive terminal	Electrical
nmnc	Normally-closed negative terminal	Electrical
nmno	Normally-open negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
threshold	Threshold linear position	Real	1m [m]
switch_resistance	Switch on-state resistance	Real	0 [Ohm]
response_time	Switch response time	Real	0 [s]

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Example

In this example, when the linear displacement of the Mass MASS_TRB1 is below the threshold of the Microswitch Linear Position Sensor (Displacement-Force) TMSWITCH_DF_I21, the resistor Rnc is connected to the current source via TMSWITCH_DF_I21; TMSWITCH_DF_I21 toggles from its normally closed terminal to its normally open terminal when the linear displacement of MASS_TRB1 exceeds the threshold. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3-5.

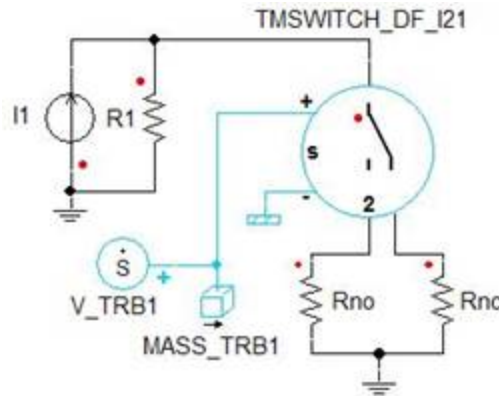


Figure 2. Application example of the Microswitch Linear Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Velocity Source V_TRB1	VALUE	$1 * (t \leq 11\text{m})$ $+ -2 * (t \geq 25\text{m})$ [m/s]
Current Source I1	IS	1 [A]
Resistor Rno/Rnc	R	1k [Ohm]
Resistor R1	R	100k [Ohm]
Mass MASS_TRB1	m	1 [kg]
	S0	0 [m]
	V0	0 [m/s]

Microswitch Angular Position Sensor (Displacement-Force) AMSWITCH_ DF_I21	threshold	10m [m]
	switch_res- istance	50m [Ohm]
	response_ time	10 [ms]

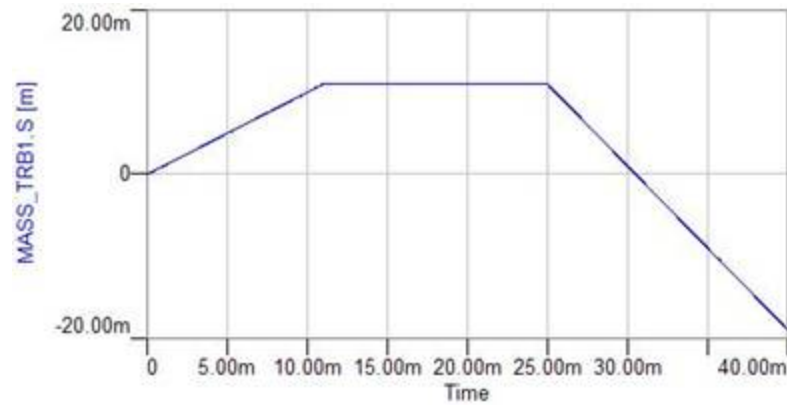


Figure 3. Simulation results - linear displacement of MASS_TRB1

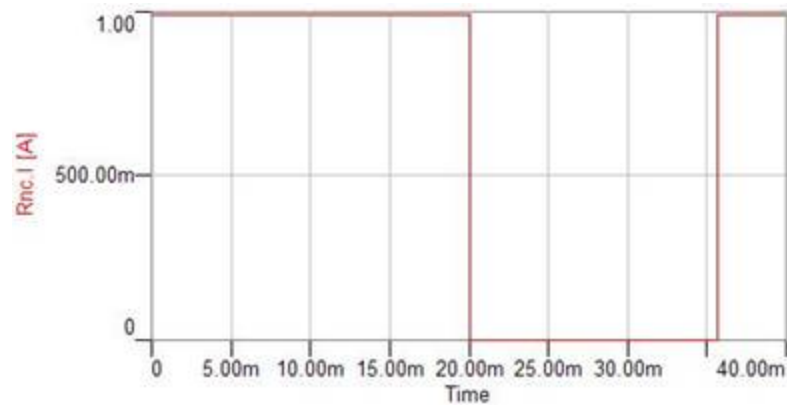


Figure 4. Simulation results- current through Rnc

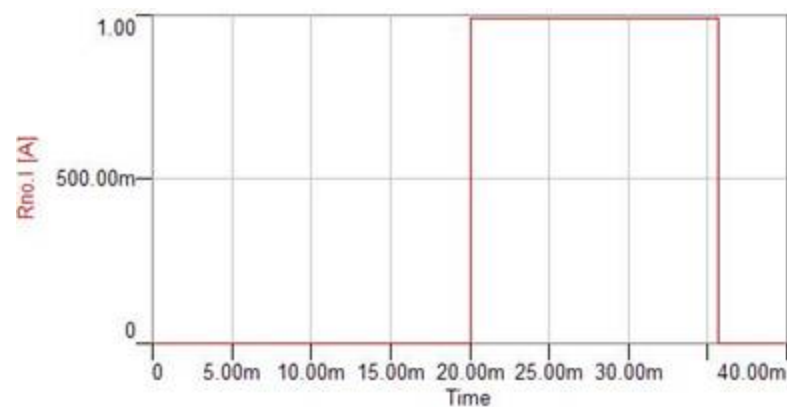


Figure 5. Simulation results- current through Rno

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References

Level 2 Anisotropic Magnetoresistive Linear Position Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

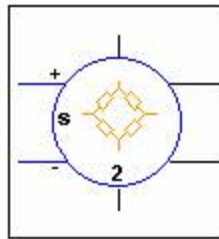


Figure 1. Component symbol

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Description

The Level 2 Anisotropic Magnetoresistive Linear Position (Velocity-Force) sensor model is used to simulate the non-ideal behavior of an AMR linear position sensor in the Twin Builder velocity-force translational domain. A change in the linear position of an element in the velocity-force translational domain causes a corresponding change in the sensor model's linear voltage output signal.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL LIN_DISP_AMR_VF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) Vcc:=
%0, Vss:= %1, POSITION:= %2, REF:= %3, out_plus:= %4, out_minus:= %5 ( input_current:=
@input_current, time_constant:= @time_constant, s_init:= @s_init, max_displacement:=
@max_displacement, min_displacement:= @min_displacement, full_scale_span:= @full_
scale_span, offset:= @offset, nonlinearity:= @nonlinearity, hysteresis:= @hysteresis, temp:=
@temp, max_temp:= @max_temp, min_temp:= @min_temp, temp_hysteresis:= @temp_hys-
teresis, output_tempco:= @output_tempco, temp_sens_offset:= @temp_sens_offset, output_
resistance:= @output_resistance) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational_V
REF	Reference linear position	Translational_V
Vcc	Positive power supply	Electrical
Vss	Negative power supply	Electrical
out_plus	Positive output terminal	Electrical
out_minus	Negative output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
input_current	Device supply current	Real	1m [A]
temp	Device temperature	Real	27 [°C]

output_resistance	Output resistance	Real	0 [Ohm]
s_init	Initial sensor position	Real	0 [m]
time_constant	Output time constant	Real	0 [s]
max_displacement	Maximum measurable linear displacement	Real	10m [m]
min_displacement	Minimum measurable linear displacement	Real	0 [m]
full_scale_span	Difference of maximum and minimum measurable displacements	Real	10 [V]
offset	Output at minimum measurable displacement	Real	0 [V]
nonlinearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	150 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
output_tempco	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]

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Example

In this example, the Anisotropic Magnetoresistive Linear Position Sensor (Velocity-Force) LIN_DISP_AMR_VF_I22 measures the linear position of the Mass MASS_TR1. A change in the linear position of MASS_TR1 produces a corresponding change in the voltage output of LIN_DISP_AMR_VF_I22. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

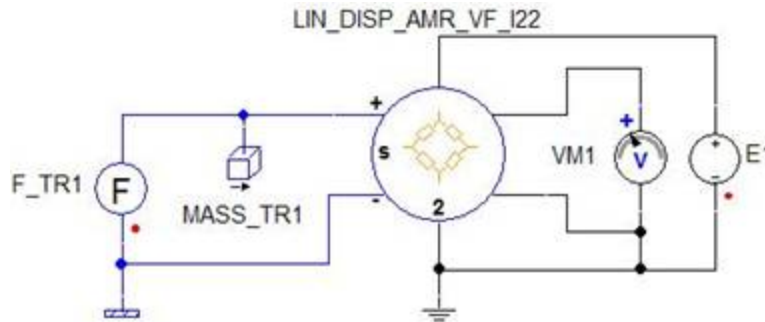


Figure 2. Application example of the Anisotropic Magnetoresistive Linear Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Force Source F_TRB1	VALUE	1k [N]
Voltage Source E1	EMF	5 [V]
Mass MASS_TRB1	M	1 [kg]
	S0	0 [in]
	V0	0 [m/s]
Anisotropic Magnetoresistive Linear Position Sensor (Velocity-Force) LIN_DISP_AMR_VF_I21	input_current	4m [A]
	temp	27 [°C]
	output_resistance	10 [Ohm]

	time_constant	500u [s]
	max_displacement	500m [m]
	min_displacement	-500m [m]
	full_scale_span	E1.EMF [V]
	offset	0 [V]
	nonlinearity	1 [%]
	hysteresis	0 [%]
	max_temp	150 [°C]
	min_temp	-50 [°C]
	temp_hysteresis	0 [%]
	output_tempco	-1 [%/(°C)]
	s_init	0 [m]
	temp_sens_offset	0 [V/(°C)]

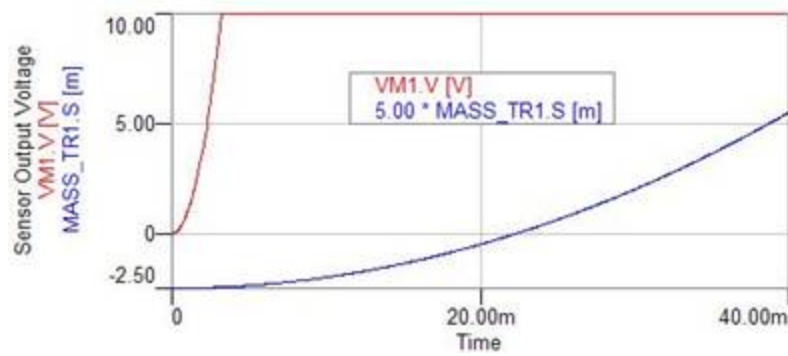


Figure 3. Simulation results- the output voltages of LIN_DISP_AMR_VF_I21 and the displacement of MASS_TR1

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References

Level 2 Potentiometric Linear Position Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

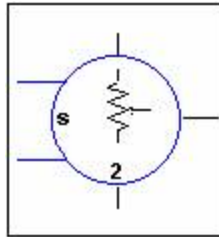


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Description

The Level 2 Potentiometric Linear Position (Velocity-Force) model is used to simulate the non-ideal behavior of a potentiometer linear position sensor in the Twin Builder velocity-force translational domain. A change in linear position of an element in the velocity-force translational domain causes a corresponding change in the model's voltage divider output signal.

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Mathematical Description

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Netlist Syntax

```
MODEL LIN_DISP_VF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) Vcc:= %0,
Vss:= %1, OUTPUT:= %2, POSITION:= %3, REF:= %4 ( max_displacement:= @max_dis-
placement, min_displacement:= @min_displacement, full_scale_span:= @full_scale_span, off-
set:= @offset, max_nonlinearity:= @max_nonlinearity, max_hysteresis:= @max_hysteresis,
temp_hysteresis:= @temp_hysteresis, max_temp:= @max_temp, min_temp:= @min_temp,
temp:= @temp, tempco_span:= @tempco_span, temp_sens_offset:= @temp_sens_offset, p_
resistance:= @p_resistance, w_resistance:= @w_resistance, time_constant:= @time_constant,
s_init:= @s_init) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
THETA	Measured Linear position	Translational_V
RPOS	Reference Linear position	Translational_V
Vcc	Positive supply	Electrical
Vss	Negative supply	Electrical
OUTPUT	Output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
p_resistance	Potentiometer resistance	Real	10k [Ohm]
temp	Device temperature	Real	27 [°C]

w_resistance	Potentiometer wiper resistance	Real	0 [Ohm]
s_init	Initial sensor position	Real	0 [m]
max_displacement	Maximum measurable linear position	Real	0.1 [m]
min_displacement	Minimum measurable linear position	Real	0 [m]
full_scale_span	Difference of maximum and minimum output voltages	Real	10 [V]
max_non-linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
max_hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	125 [°C]
min_temp	Minimum operating temperature	Real	-40 [°C]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
time_constant	Output time constant	Real	[s]

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Example

In this example, the Potentiometric Linear Position Sensor (Velocity-Force) LIN_DISP_VF_I21 measures the linear position of the Mass MASS_TR1. A change in the linear position of MASS_TR1 produces a corresponding change in the voltage output of LIN_DISP_VF_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

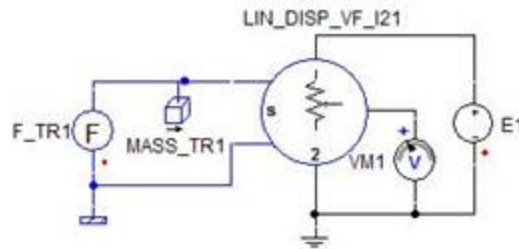


Figure 2. Application example of the Potentiometric Linear Position Sensor (Velocity-Force)

Table 3

Component	Parameter	Value [Unit]
Force Source F_TR1	VALUE	4k [N]
Voltage Source E1	EMF	15 [V]
Mass MASS_TR1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Potentiometric Linear Position Sensor (Velocity-Force) LIN_DISP_VF_I21	offset	0 [V]
	p_resistance	6k [Ohm]
	temp	27 [°C]
	w_resistance	0 [Ohm]
	max_displacement	6 [in]

	min_dis- placement	0 [m]
	full_scale_ span	E1.EMF [V]
	max_non- linearity	1 [%]
	max_hys- teresis	0 [%]
	temp_hys- teresis	0 [%]
	max_temp	80 [°C]
	min_temp	-40 [°C]
	tempco_span	0 [%/(°C)]
	temp_sens_off- set	0 [V/(°C)]
	s_init	MASS_ TR1.S0 [m]
	time_constant	0 [s]

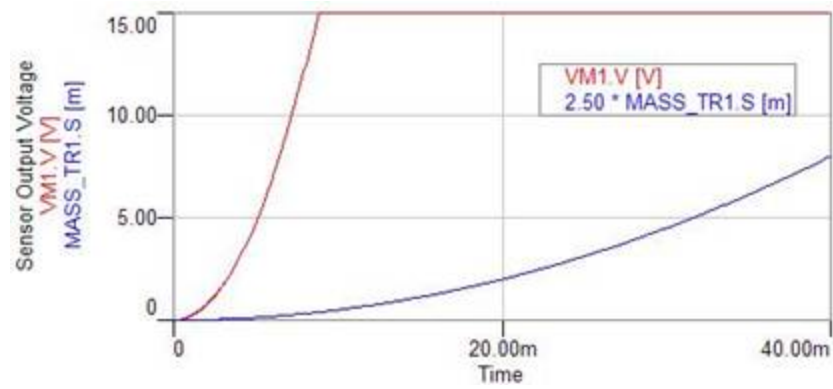


Figure 3. Simulation results-the linear position of MASS_TR1 (scaled) and the output voltages of LIN_DISP_VF_I21

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References

Level 2 Hall-Effect Linear Position Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

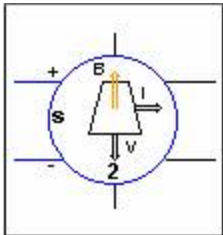


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Description

The Level 2 Hall-Effect Linear Position (Velocity-Force) sensor model is used to simulate the non-ideal behavior of a Hall-effect linear position sensor in the Twin Builder velocity-force translational domain. A change in the linear position of an element in the velocity-force translational domain causes a corresponding change in the model's voltage output signal.

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Mathematical Description

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Netlist Syntax

```
MODEL LIN_DISP_HE_VF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) Vcc:= %0, Vss:= %1, POSITION:= %2, REF:= %3, out_plus:= %4, out_minus:= %5 ( input_current:=
```


@input_current, time_constant:= @time_constant, s_init:= @s_init, max_displacement:= @max_displacement, min_displacement:= @min_displacement, full_scale_span:= @full_scale_span, offset:= @offset, nonlinearity:= @nonlinearity, hysteresis:= @hysteresis, temp:= @temp, max_temp:= @max_temp, min_temp:= @min_temp, temp_hysteresis:= @temp_hysteresis, output_tempco:= @output_tempco, temp_sens_offset:= @temp_sens_offset, output_resistance:= @output_resistance) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational_V
REF	Reference linear position	Translational_V
Vcc	Positive supply	Electrical
Vss	Negative supply	Electrical
out_plus	Positive output	Electrical
out_minus	Negative output	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
input_current	Typical device input current	Real	1m [A]
temp	Device temperature	Real	27 [°C]
output_resistance	Output resistance	Real	0 [Ohm]

s_init	Initial sensor angle	Real	0 [m]
time_constant	Output time constant	Real	0 [s]
max_displacement	Maximum measurable displacement	Real	10m [m]
min_displacement	Minimum measurable displacement	Real	0 [m]
full_scale_span	Difference of maximum and minimum output voltages	Real	10 [V]
offset	Output at minimum displacement	Real	0 [V]
nonlinearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	150 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
output_tempco	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]

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Example

In this example, the Hall-Effect Linear Position Sensor (Velocity-Force) LIN_DISP_HE_VF_I21 measures the linear position of the Mass MASS_TR1. A change in the linear position of MASS_

TR1 produces a corresponding change in the voltage output of LIN_DISP_HE_VF_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

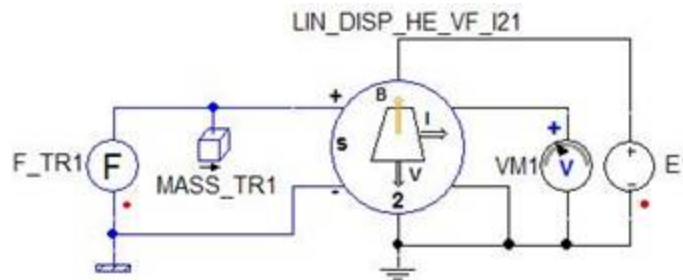


Figure 2. Application example of the Hall-Effect Linear Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Force Source F_TR1	VALUE	1k [N]
Voltage Source E1	EMF	15 [V]
Mass MASS_TR1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Hall-Effect Linear Position Sensor (Velocity-Force) LIN_DISP_HE_VF_I21	input_current	5m [A]
	temp	27 [°C]
	output_resistance	0 [Ohm]
	time_constant	100u [s]
	max_displacement	30 [in]

min_displacement	0 [m]
full_scale_span	0.9 * E1.EMF [V]
offset	0.1 * E1.EMF [V]
nonlinearity	5 [%]
hysteresis	0 [%]
max_temp	0.15k [°C]
min_temp	-50 [°C]
temp_hysteresis	0 [%]
output_tempco	-1 [%/ (°C)]
s_init	MASS_ TR1.S0 [m]
temp_sens_offset	0 [V/(°C)]

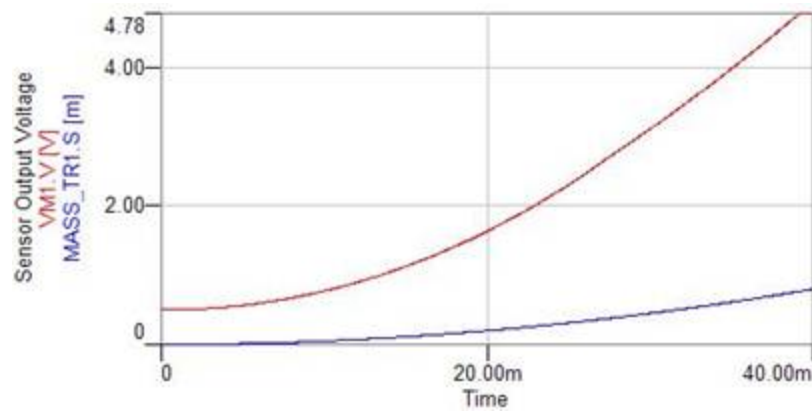


Figure 3. Simulation results- the output voltages of LIN_DISP_HE_VF_I21 and the displacement of MASS_TR1

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References

Level 2 LVDT Linear Position Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

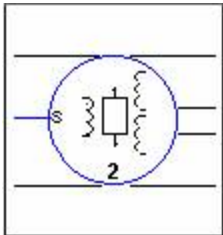


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Description

The Level 2 LVDT Linear position sensor (Velocity-Force) model is used to simulate the non-ideal behavior of a linear variable differential transformer linear position sensor. A change in linear position produces a corresponding change in the AC voltage output signal.

Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL LVDT_VF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) out_1_plus:= %0,  
out_1_minus:= %1, out_2_plus:= %2, out_2_minus:= %3, in_plus:= %4, in_minus:= %5,  
POSITION:= %6 ( max_position:= @max_position, min_position:= @min_position, sensitivity:=  
@sensitivity, max_nonlinearity:= @max_nonlinearity, hysteresis:= @hysteresis, max_temp:=
```

@max_temp, min_temp:= @min_temp, temp:= @temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span, primary_inductance:= @primary_inductance, primary_resistance:= @primary_resistance, secondary_inductance:= @secondary_inductance, secondary_resistance:= @secondary_resistance, null_voltage:= @null_voltage, core_mass:= @core_mass, s_init:= @s_init) SRC: DB(Lib:=@ModelLibraryName);

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational_V
in_plus	Transformer primary positive terminal	Electrical
in_minus	Transformer primary negative terminal	Electrical
out_1_plus	Transformer secondary 1 positive terminal	Electrical
out_1_minus	Transformer secondary 1 negative terminal	Electrical
out_2_plus	Transformer secondary 2 positive terminal	Electrical
out_2_minus	Transformer secondary 2 negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]

sensitivity	LVDT sensitivity	Real	1 [V/V/m]
temp	Device temperature	Real	27 [°C]
max_position	Maximum measurable linear position	Real	1m [m]
min_position	Minimum measurable linear position	Real	-1m [m]
max_non-linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	125 [°C]
min_temp	Minimum operating temperature	Real	-40 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/ (°C)]
primary_inductance	Inductance of primary winding	Real	10m [H]
primary_resistance	Resistance of primary winding	Real	0 [Ohm]
secondary_inductance	Inductance of secondary winding	Real	10m [H]
secondary_resistance	Resistance of secondary winding	Real	0 [Ohm]
null_voltage	Amplitude of output voltage at zero measured displacement	Real	0 [V]

core_mass	Mass of transformer core	Real	0 [kg]
s_init	Initial sensor position	Real	0 [m]

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Example

In this example, the LVDT Linear position sensor (Velocity-Force) LVDT_VF_I21 measures the linear position of the Mass MASS_TR1. A change in the linear position of MASS_TR1 produces a corresponding change in the output voltage of LVDT_VF_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

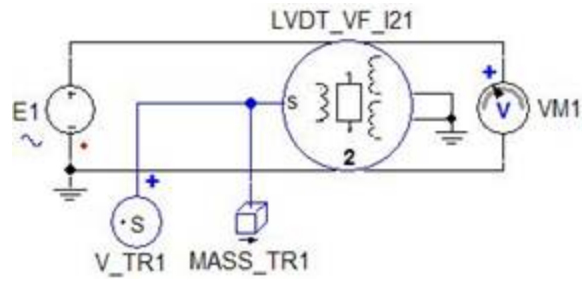


Figure 2. Application example of the SCR Linear Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Velocity Source V_TR1	VALUE	-2.5m/800u [m/s]
Voltage Source (sinusoidal) E1	AMPL	1 [V]
	FREQ	10k [Hz]
	PHASE	0 [degree]
	OFF	0 [V]
	TDELAY	0 [s]
Mass MASS_TR1	M	1 [kg]
	S0	1.25m [m]
	V0	0 [m/s]
LVDT Linear position sensor (Velocity-Force) LVDT_VF_I21	sensitivity	63 [V/V/m]
	temp	27 [°C]
	max_non-linearity	0.25 [%]
	hysteresis	0.01 [%]
	max_temp	105 [°C]
	min_temp	-55 [°C]
	temp_hysteresis	0 [%]
	tempco_span	-0.02 [%/ (°C)]

	primary_ inductance	21.6 [H]
	primary_res- istance	0 [Ohm]
	secondary_ inductance	10m [H]
	secondary_ resistance	0 [Ohm]
	null_voltage	0 [V]
	max_position	1.25m [m]
	min_position	-1.25m [m]
	s_init	MASS_ TR1.S0
	core_mass	0.4 [kg]

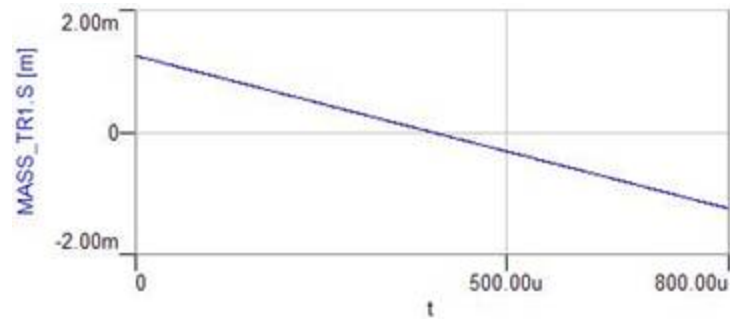


Figure 3. Simulation results-linear displacement of MASS_TR1

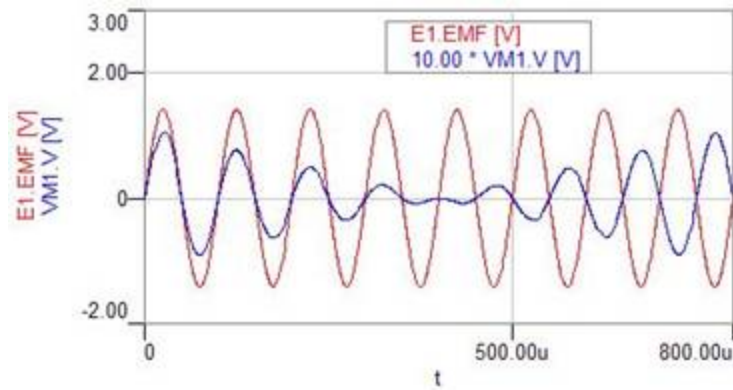


Figure 4. Simulation results- voltage outputs of E1 and LVDT_VF_I21

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References

Level 2 SCR Linear Position Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

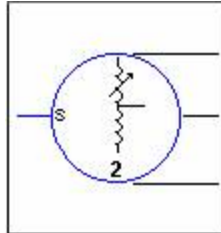


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Description

The Level 2 SCR Linear Position (Velocity-Force) simulates the non-ideal behavior of a short-circuit ring linear position sensor. The model consists of a variable inductance in series with a reference inductance. As the linear position of an element in the Twin Builder velocity-force translational domain is varied, a corresponding change occurs in the value of the variable inductance. The junction between the variable and reference inductances is where the sensor's output signal, such as a variable AC voltage, can be measured.

The model has a conservative translational-nature pin for measured linear position and three conservative electrical nature pins: two for the reference signal input and output and one for the signal output.

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Netlist Syntax

```
MODEL SCR_VF_I2 ?InstanceName(@InstanceName):(@Refbase@ID)) np:= %0, nm:=
%1, signal:= %2, POSITION:= %3 ( max_position:= @max_position, full_scale_span:= @full_
scale_span, reference_inductance:= @reference_inductance, nominal_inductance:= @nom-
inal_inductance, time_constant:= @time_constant, max_nonlinearity:= @max_nonlinearity, hys-
teresis:= @hysteresis, temp:= @temp, max_temp:= @max_temp, min_temp:= @min_temp,
temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span, s_init:= @s_init) SRC:
DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational
np	Positive input for reference voltage or current	Electrical
nm	Negative input for reference voltage or current	Electrical
signal	Signal output	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
reference_inductance	Inductance of reference inductor	Real	10m [H]
s_init	Initial sensor position	Real	0 [m]

nominal_ inductance	Nominal inductance of variable inductor	Real	1m [H]
max_position	Maximum measurable linear position	Real	10m [m]
full_scale_ span	Difference of variable inductor values at maximum and zero positions	Real	10m [H]
max_non- linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
temp	Device temperature	Real	273 [°C]
max_temp	Maximum operating temperature	Real	423 [°C]
min_temp	Minimum operating temperature	Real	223 [°C]
temp_hys- teresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Temperature sensitivity of variable inductance	Real	0 [%/ (°C)]
time_con- stant	Output time constant	Real	0 [s]

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Example

In this example, the SCR Linear Position Sensor (Velocity-Force) SCR_VF_I21 measures the linear position of the Mass MASS_TRB1. A change in the linear position of MASS_TRB1 produces a corresponding change in the variable inductance of SCR_VF_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

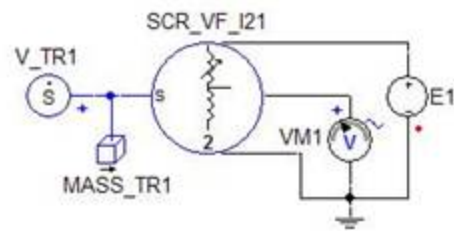


Figure 2. Application example of the SCR Linear Position Sensor (Velocity-Force)**Table 3**

Component	Parameter	Value [Unit]
Velocity Source V_TR1	VALUE	$5\text{m} * (t/80\text{m})$ [m]
Voltage Source (sinusoidal) E1	AMPL	5 [V]
	FREQ	100 [Hz]
	PHASE	90 [degree]
	OFF	0 [V]
	TDELAY	0 [s]
Mass MASS_TR1	M	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
SCR Linear Position Sensor (Velocity-Force) SCR_VF_I21	reference_ inductance	10m [H]
	nominal_ inductance	1m [H]
	max_position	5m [m]
	full_scale_ span	9m [H]
	max_non- linearity	5 [%]
	hysteresis	0 [%]

	temp	27 [°C]
	max_temp	150 [°C]
	min_temp	-50 [°C]
	temp_hys- teresis	0 [%]
	tempco_span	5 [%/(°C)]
	s_init	Mass MASS_ TR1.S0
	Time_con- stant	0 [s]

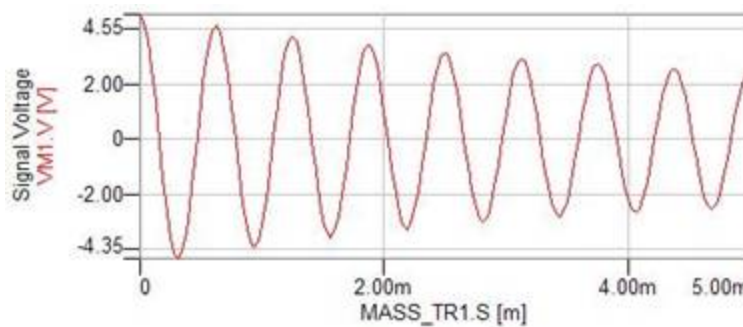


Figure 3. Simulation results-voltage output of SCR_VF_I21 vs. linear displacement of MASS_TR1

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References

Level 2 Absolute Encoder Linear Position Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

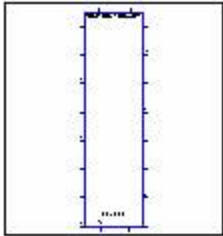


Figure 1. Component symbol

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Description

An absolute encoder linear position sensor translates absolute linear position to a natural binary output. The precision of the output, i.e. the number of bits that make up the output, is determined by the number of equally spaced position indicators that are available on the sensor. For example, an linear position sensor with sixteen position indicators would have a four-bit output.

The Level 2 Absolute encoder Linear Position (Velocity-Force) sensor model is used to simulate the non-ideal behavior of a 6 to 16-bit absolute encoder linear position sensor in the Twin Builder velocity-force translational domain. The model has a conservative input pin with a translational nature and nineteen conservative electrical-nature pins. Two of the pins are used to connect the model to a power supply and a ground. One pin is used for the sensor's output-enable signal. The remaining pins are for the sixteen possible binary outputs.

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Netlist Syntax

```
MODEL TABS_ENCODER_VF_I2 ?InstanceName(@InstanceName):(@@Refbase)@(ID))
Vdd:= %0, Vss:= %1, LE:= %2, BIT_15:= %3, BIT_14:= %4, BIT_13:= %5, BIT_12:= %6, BIT_
11:= %7, BIT_10:= %8, BIT_9:= %9, BIT_8:= %10, BIT_7:= %11, BIT_6:= %12, BIT_5:= %13,
BIT_4:= %14, BIT_3:= %15, BIT_2:= %16, BIT_1:= %17, BIT_0:= %18, POSITION:= %19 ( res-
olution:= @resolution, max_amplitude:= @max_amplitude, min_amplitude:= @min_amplitude,
max_position:= @max_position, s_init:= @s_init, supply_current:= @supply_current, output_
resistance:= @output_resistance, reaction_time:= @reaction_time, latch_threshold:= @latch_
threshold, error:= @error) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational_V
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical
BIT_0 (See Note)	Output bit zero	Electrical
BIT_1 (See Note)	Output bit one	Electrical
BIT_2 (See Note)	Output bit two	Electrical
BIT_3 (See Note)	Output bit three	Electrical
BIT_4 (See Note)	Output bit four	Electrical
BIT_5 (See Note)	Output bit five	Electrical
BIT_6 (See Note)	Output bit six	Electrical

BIT_7 (See Note)	Output bit seven	Electrical
BIT_8 (See Note)	Output bit eight	Electrical
BIT_9 (See Note)	Output bit nine	Electrical
BIT_10 (See Note)	Output bit ten	Electrical
BIT_11 (See Note)	Output bit eleven	Electrical
BIT_12 (See Note)	Output bit twelve	Electrical
BIT_13 (See Note)	Output bit thirteen	Electrical
BIT_14 (See Note)	Output bit fourteen	Electrical
BIT_15 (See Note)	Output bit fifteen	Electrical
LE	Output enable	Electrical

Note: Terminal set to No Action when unconnected. Terminal may remain unconnected without generating an error.

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
resolution	Number of bits available at the output	Real	16
max_amplitude	Logic 1 output amplitude	Real	5 [V]

min_amp- litude	Logic 0 output amplitude	Real	0 [V]
max_pos- ition	Maximum measurable position	Real	5m [m]
s_init	Initial sensor position	Real	0 [m]
supply_cur- rent	Supply current	Real	20m [A]
output_res- istance	Output resistance at each output pin	Real	0 [Ohm]
reaction_ time	Time lapse between rising edge of output enable signal and change in binary output	Real	0 [s]
latch_ threshold	Output enable threshold voltage	Real	2.5 [V]
error	Percent measurement error	Real	0 [%]

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Example

In this example, the Absolute Encoder Linear Position Sensor (Velocity-Force) TABS_ENCODER_VF2 measures the linear displacement of the Mass MASS_TR1, and the encoded measurement results are sent out through its output channels. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3-9.

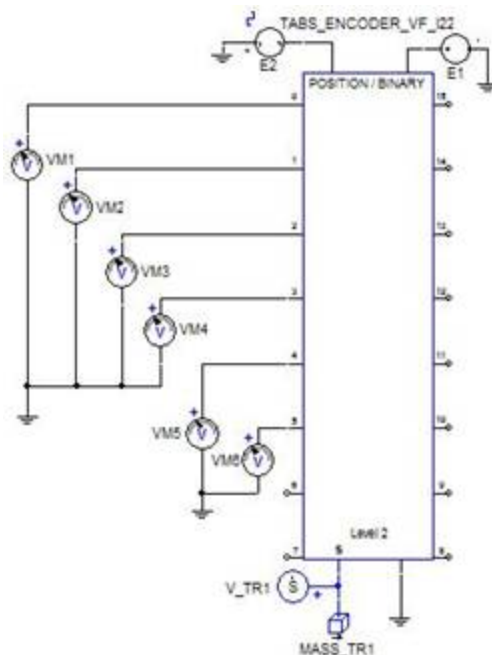


Figure 2. Application example of the Absolute Encoder Linear Position Sensor (Velocity-Force)

Table 3

Component	Parameter	Value [Unit]
Velocity Source V_TR1	VALUE	10m/40m [m]
Voltage Source E1	EMF	5 [V]
Voltage Sorce (pulse) E2	AMPL	2.5 [V]
	FREQ	100 [Hz]
	PHASE	0 [degree]
	OFF	2.5 [V]
	TDELAY	0 [s]
Mass MASS_TR1	M	1 [kg]

Absolute Encoder Linear Position Sensor (Velocity-Force) TABS_ENCODER_VF_I22	S0	0 [m]
	V0	0 [m/s]
	resolution	6
	max_amp- litude	4.5 [V]
	min_amp- litude	1 [V]
	max_pos- ition	10m [s]
	supply_cur- rent	4m [A]
	latch_ threshold	2.5 [V]
	s_init	MASS_ TR1.S0 [m]
	reaction_ time	500u [s]
	output_res- istance	0 [Ohm]
	error	0 [m]

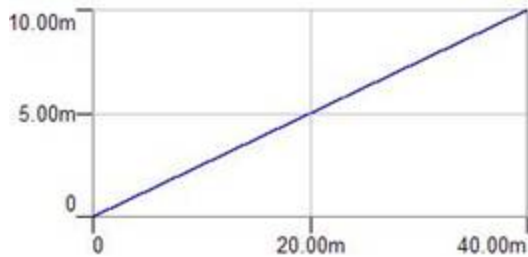


Figure 3. Simulation results-linear displacement of MASS_TR1

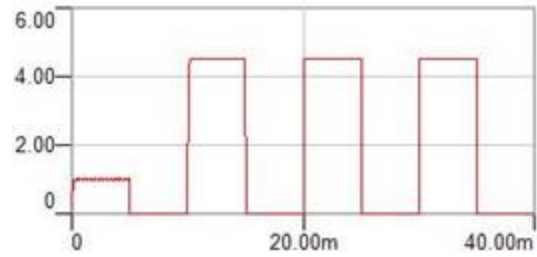


Figure 4. Simulation results- output bit0 of TABS_ENCODER_VF_I22

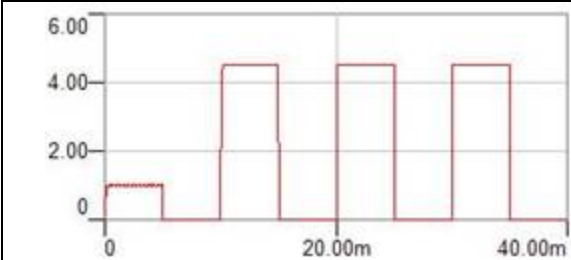


Figure 5. Simulation results- output bit1 of TABS_ENCODER_VF_I22

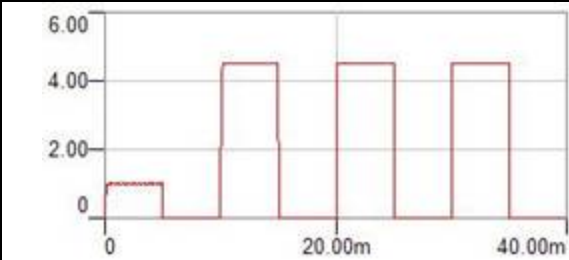


Figure 6. Simulation results- output bit2 of TABS_ENCODER_VF_I22

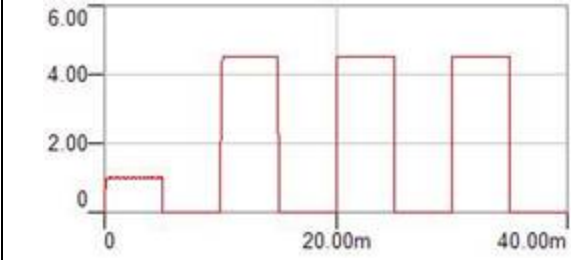


Figure 7. Simulation results- output bit3 of TABS_ENCODER_VF_I22

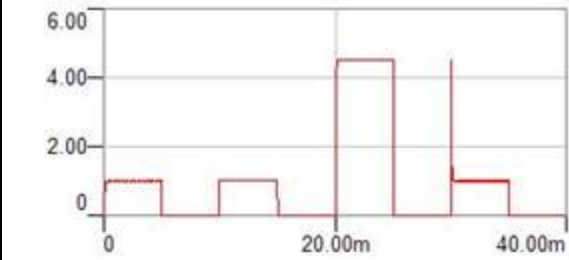


Figure 8. Simulation results- output bit4 of TABS_ENCODER_VF_I22

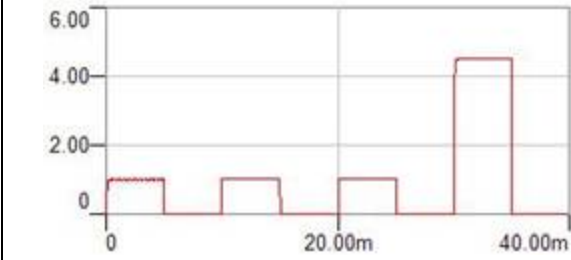


Figure 9. Simulation results- output bit5 of TABS_ENCODER_VF_I22

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References

Level 2 Incremental Encoder Linear Position Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

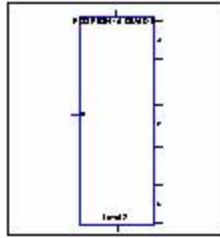


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Description

The Level 2 Incremental encoder Linear Position (Velocity-Force) sensor model is used to simulate the non-ideal behavior of an incremental encoder linear position sensor in the Twin Builder velocity-force translational domain. An incremental encoder has some number of equally spaced sensing elements, all of which will be detected during one motion along the length of the device. These elements account for two of the device's three outputs: Channel A and Channel B. Channel A is a pulse output that goes to its logic 1 value whenever a sensing element is detected and remains there until the sensor has traveled one-half of the distance to the next element. Channel B is a second pulse output that lags Channel A by a quarter cycle.

The third output of the model is Channel N, which goes to its logic 1 value when the sensor detects the zero point of the sensor and remains high until the sensor has traveled one-quarter of the distance to the next sensing element.

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Netlist Syntax

```
MODEL TINC_ENCODER_VF_I2 ?InstanceName(@InstanceName):(@@Refbase)@(ID))
Vdd:= %0, Vss:= %1, A_plus:= %2, A_minus:= %3, B_plus:= %4, B_minus:= %5, N_plus:= %6,
N_minus:= %7, POSITION:= %8 ( num_lines:= @num_lines, min_amplitude:= @min_amp-
litude, max_amplitude:= @max_amplitude, pct_error:= @pct_error, delay:= @delay, output_res-
istance:= @output_resistance, zero_position:= @zero_position, max_position:= @max_
position, min_position:= @min_position, supply_current:= @supply_current, s_init:= @s_init)
SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PHI	Measured linear position	Translational_V
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical
A_plus (See Note)	Channel A positive output terminal	Electrical
A_minus (See Note)	Channel A negative output terminal	Electrical
B_plus (See Note)	Channel B negative output terminal	Electrical
B_minus (See Note)	Channel B positive output terminal	Electrical
N_plus (See	Channel N positive output terminal	Electrical

Note)	minal	
N_minus (See Note)	Channel N negative output terminal	Electrical

Note: Terminal set to No Action when unconnected. Terminal may remain unconnected without generating an error.

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
num_lines	Number of sensing elements on sensor	Real	16
min_amplitude	Logic zero output	Real	0 [V]
max_amplitude	Logic one output	Real	5 [V]
pct_error	Percent measurement error	Real	0 [%]
delay	Rise time of final output value fro 10% to 90%	Real	0 [s]
output_resistance	Resistance at each output	Real	0 [Ohm]
zero_position	Zero position of encoder	Real	0 [m]
max_position	Maximum measurable position	Real	5m [m]
min_position	Minimum measurable position	Real	0 [m]
s_init	Initial sensor position	Real	0 [m]

supply_current	Supply current	Real	50m [A]

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Example

In this example, a Velocity Source V_TR1 is applied to a Mass block MASS_TR1. The displacement of MASS_TR1 is measured by an Incremental Encoder Linear Position Sensor (Velocity-Force) TINC_ENCODER_VF_I21, and the encoded measurement result is sent out through the output channels of TINC_ENCODER_VF_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3-6.

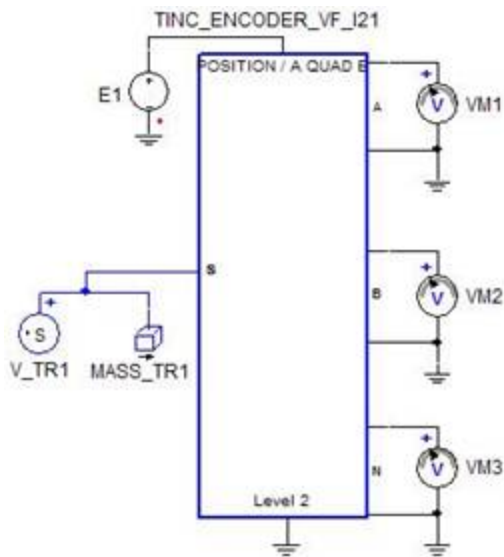


Figure 2. Application example of the Incremental Encoder Linear Position Sensor (Displacement-Force)

Table 3

Component	Parameter	Value [Unit]
Position Source S_TR1	VALUE	-50 + 20m * (t/80u) [in]
Voltage Source E1	EMF	20 [V]

Mass Mass_TR1	M	1 [kg]
	S0	-50.001 [m]
	V0	0 [m/s]
Incremental Encoder Linear Position Sensor (Velocity-Force) TINC_ENCODER_VF_I21	num_lines	25k
	min_amplitude	0.5 [V]
	max_amplitude	18.5 [V]
	pct_error	0 [%]
	delay	1u [s]
	output_resistance	0 [Ohm]
	zero_position	-50 [in]
	max_position	0 [in]
	min_position	-50 [in]
	s_init	MASS_TR1.S0 [m]
	supply_current	80m [A]

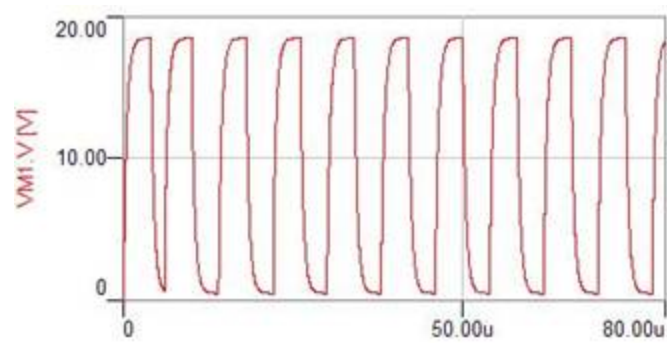


Figure 3. Simulation result-Channel A output of TINC_ENCODER_VF_I21

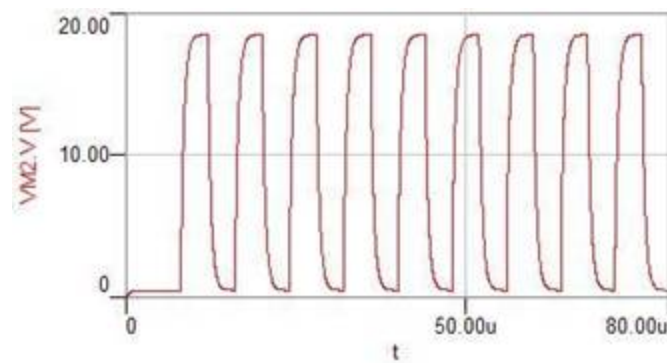


Figure 4. Simulation result-Channel B output of TINC_ENCODER_VF_I21

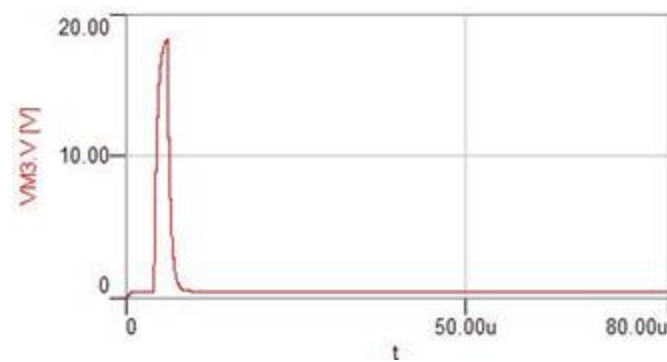


Figure 5. Simulation result-Channel N output of TINC_ENCODER_VF_I21

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References

Level 2 Microswitch Linear Position Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

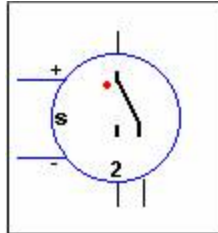


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Description

The Level 2 Microswitch Linear Position (Velocity-Force) sensor model is used to simulate the non-ideal behavior of a microswitch linear position sensor in the Twin Builder velocity-force translational domain. The microswitch model toggles from its normally closed terminal to its normally open terminal when the specified threshold linear position is exceeded by some element in the velocity-force translational domain.

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Netlist Syntax

```
MODEL TMSWITCH_VF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))  
POSITION:= %0, REF:= %1, nmnc:= %2, nmno:= %3, np:= %4 ( threshold:= @threshold,  
switch_resistance:= @switch_resistance, response_time:= @response_time, s_init:= @s_init)  
SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured linear position	Translational_V
REF	Reference linear position	Translational_V
np	Positive terminal	Electrical
nmnc	Normally-closed negative terminal	Electrical
nmno	Normally-open negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
threshold	Threshold linear position	Real	1m [m]
switch_resistance	Switch on-state resistance	Real	0 [Ohm]
response_time	Switch response time	Real	0 [s]
s_init	Initial sensor position	Real	0 [m]

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Example

In this example, when the linear displacement of the Mass MASS_TR1 is below the threshold of the Microswitch Linear Position Sensor (Velocity-Force) TMSWITCH_VF_I22, the resistor Rnc is connected to the current source via TMSWITCH_VF_I22; TMSWITCH_VF_I22 toggles from its normally closed terminal to its normally open terminal when the linear displacement of MASS_TR1 exceeds the threshold. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3-5.

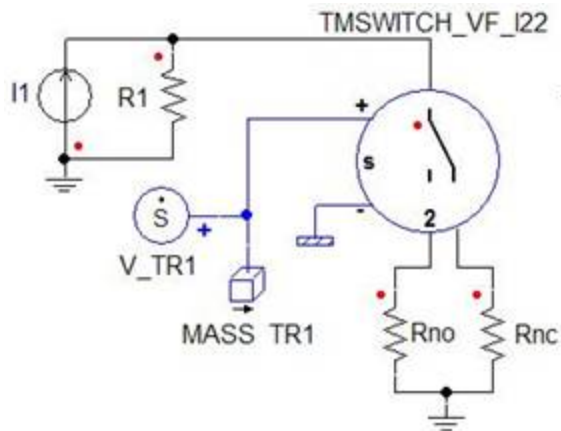


Figure 2. Application example of the Microswitch Linear Position Sensor (Velocity-Force)

Table 3

Component	Parameter	Value [Unit]
Velocity Source V_TR1	VALUE	$1 * (t \leq 11\text{m}) +$ $-2 * (t \geq 25\text{m})$ [m/s]
Current Source I1	IS	1 [A]
Resistor Rno/Rnc	R	1k [Ohm]
Resistor R1	R	100k [Ohm]
Mass MASS_TR1	m	1 [kg]
	S0	1m [m]
	V0	0 [m/s]
Microswitch Linear Position Sensor (Velocity-Force) AMSWITCH_VF_I22	threshold	10m [m]
	switch_resistance	50m [Ohm]
	response_time	10 [ms]

	s_init	MASS_ TR1.S0 [m]

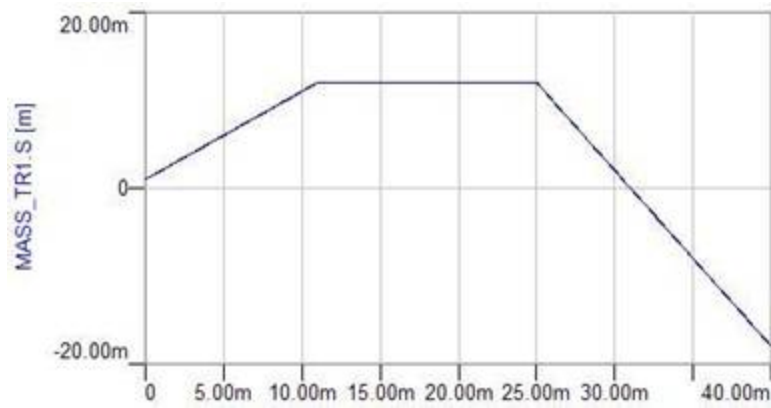


Figure 3. Simulation results - linear displacement of MASS_TRB1

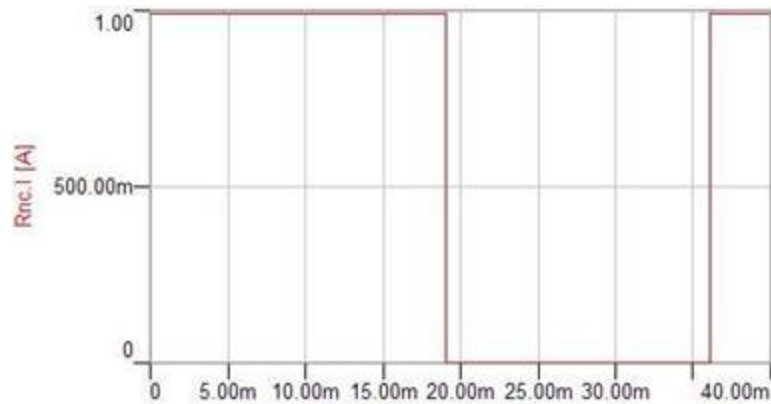


Figure 4. Simulation results- current through Rnc

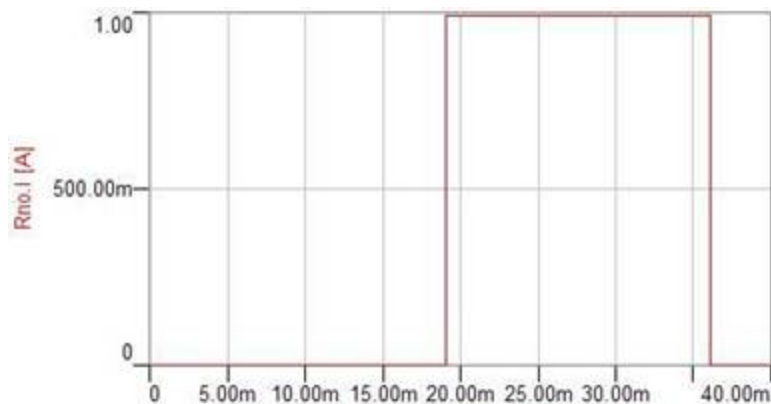


Figure 5. Simulation results- current through Rno

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References

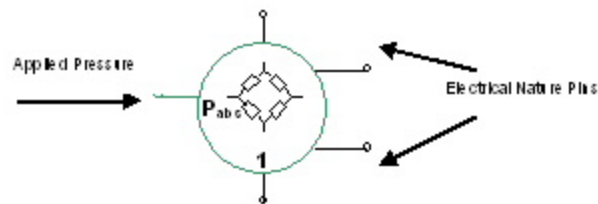
Pressure Sensors

The Level 2 Pressure sensors model the non-ideal behavior of 6 different pressure sensor types. Each type of pressure sensor model is available for sensing *absolute*, *differential*, and *gage* pressure.

The models for the different pressure types differ in the following ways:

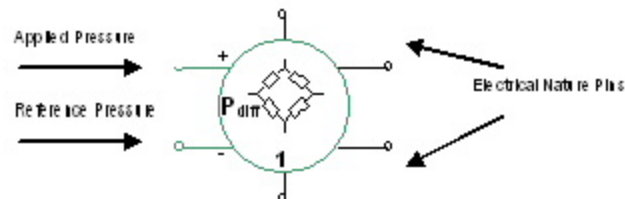
- Absolute pressure sensors measure the applied pressure versus vacuum. The absolute pressure sensor models have one conservative input pin, colored green, which must be connected to a fluidic network. The pressure at the connected fluidic node will be the pressure measured by the sensor model.

The electrical nature pins of the model are colored black.



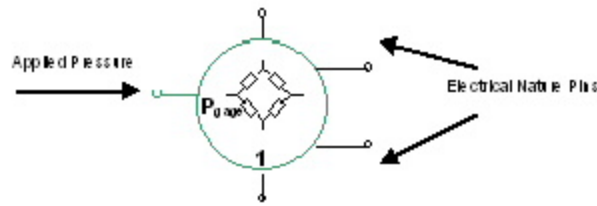
- Differential pressure sensors measure the applied pressure versus a reference pressure. The differential pressure sensor models have two conservative input pins, colored green, that must be connected to a fluidic network. The pressure at the pin labeled with a plus sign (+) is the measured applied pressure, and the pressure at the pin labeled with a minus sign (-) is the reference pressure. The applied pressure minus the reference pressure will be the pressure measured by the sensor model.

The electrical nature pins of the model are colored black.



- Gage pressure sensors measure the applied pressure versus atmospheric pressure. The gage pressure sensor models have one conservative input pin, colored green that must be connected to a fluidic network. The pressure at this pin is the applied pressure. The atmospheric pressure is entered by the user through a nonconservative pin. The applied pressure minus the atmospheric pressure will be the pressure measured by the sensor model.

The electrical nature pins of the model are colored black.



The sensor model library contains models for the following pressure-sensing mechanisms. Each model has three versions, one each for absolute, differential, and gage pressure sensing:

- Piezoresistive: The applied pressure deforms the resistors in a Wheatstone bridge configuration, resulting in a differential voltage output signal.
 Absolute model: ([abs_press_bridge_i2](#))
 Differential model: ([DIFF_PRESS_BRIDGE_I2](#))
 Gage model: ([gage_press_bridge_i2](#))
- Uncompensated Capacitive: The applied pressure brings the plates of a capacitor closer together, providing a variable capacitance output signal.
 Absolute model: ([ABS_PRESS_CAP_I2](#))
 Differential model: ([DIFF_PRESS_CAP_I2](#))
 Gage model: ([GAGE_PRESS_CAP_I2](#))
- LVDT (Linear Variable Differential Transformer): The applied pressure changes the extent of coupling between a primary and two oppositely wound secondaries, producing a differential AC output signal.
 Absolute model: ([ABS_PRESS_LVDT_I2](#))
 Differential model: ([DIFF_PRESS_LVDT_I2](#))
 Gage model: ([GAGE_PRESS_LVDT_I2](#))
- Piezoelectric: The applied pressure deforms a piezoelectric element, resulting in a corresponding change in a voltage output signal.
 Absolute model: ([ABS_PRESS_PE_I2](#))
 Differential model: ([DIFF_PRESS_PE_I2](#))
 Gage model: ([GAGE_PRESS_PE_I2](#))
- Potentiometric: The applied pressure moves the wiper of a potentiometer, resulting in a change in the voltage output signal.
 Absolute model: ([ABS_PRESS_POTEN_I2](#))
 Differential model: ([DIFF_PRESS_POTEN_I2](#))
 Gage model: ([GAGE_PRESS_POTEN_I2](#))
- Pressure switch: The applied pressure toggles an SPDT switch at a defined threshold pressure.
 Absolute model: ([ABS_PRESS_SW_I2](#))
 Differential model: ([DIFF_PRESS_SW_I2](#))
 Gage model: ([GAGE_PRESS_SW_I2](#))

Level 2 Piezoresistive Absolute Pressure Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

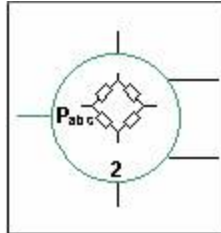


Figure 1. Component symbol

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- [Mathematical Description](#)
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Description

The Level 2 Piezoresistive Absolute Pressure Sensor model is used to simulate the non-ideal behavior of a strain-gauge absolute pressure sensor. A change in the applied pressure produces a corresponding change in the differential voltage output signal.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL abs_press_bridge_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
PRESSURE:= %0, Vcc:= %1, Vcc_m:= %2, out_plus:= %3, out_minus:= %4 ( max_pressure:=
```

@max_pressure, min_pressure:= @min_pressure, full_scale_span:= @full_scale_span, offset:= @offset, max_nonlinearity:= @max_nonlinearity, pressure_hysteresis:= @pressure_hysteresis, temp:= @temp, min_temp:= @min_temp, max_temp:= @max_temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span, temp_sens_offset:= @temp_sens_offset, bridge_resistance:= @bridge_resistance, time_constant:= @time_constant, resistor_tempco:= @resistor_tempco, nominal_res_temp:= @nominal_res_temp) SRC: DB(Lib:-:=@ModelLibraryName);

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PRESSURE	Applied pressure	Fluidic
Vcc	Positive supply	Electrical
Vcc_m	Negative supply	Electrical
out_plus	Positive output terminal	Electrical
out_minus	Negative output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	20m [V]
bridge_resistance	Bridge resistance	Real	10k [Ohm]
max_pressure	Maximum measurable pressure	Real	10k [Pa]
min_pressure	Minimum measurable pressure	Real	0 [Pa]

full_scale_span	Difference between the maximum and minimum output voltages	Real	55m [V]
time_constant	Output time constant	Real	0 [s]
temp	Device temperature	Real	27 [°C]
max_non-linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
pressure_hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
max_temp	Maximum operating temperature	Real	125 [°C]
min_temp	Minimum operating temperature	Real	-40 [°C]
resistor_tempco	Resistor temperature coefficient	Real	0 [%/(°C)]
nominal_res_temp	Nominal bridge resistance temperature	Real	25 [°C]

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Example

In this example, the Piezoresistive Absolute Pressure Sensor abs_press_bridge_l22 measures the pressure across the Linear Orifice RHYD2, and converted it into a voltage signal. This

voltage output is then sent out Analog-Digital Converter adc1 through a voltage follower circuit. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

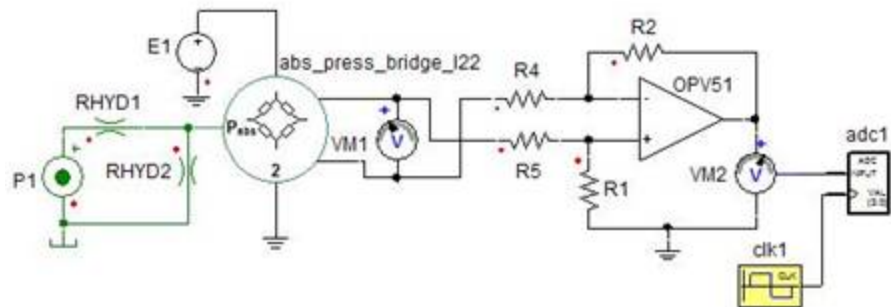


Figure 2. Application example of the Piezoresistive Absolute Pressure Sensor model

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	10k + 20k * (t >= 20m) [Pa]
Linear Orifice RHYD1/RHYD2	K	1n [m ³ /(Pa s)]
Piezoresistive Absolute Pressure Sensor abs_press_bridge_I22	offset	20m [V]
	bridge_resistance	500 [Ohm]
	max_pressure	10k [Pa]
	min_pressure	0 [Pa]
	full_scale_span	55m [Pa]
	time_constant	455u [s]
	temp	27 [°C]

	max_non-linearity	5 [%]
	pressure_hys-teresis	0.1 [%]
	temp_hys-teresis	0.5 [%]
	tempco_span	-0.22 [%/(°C)]
	temp_sens_offset	15e-6 [V/(°C)]
	max_temp	125 [°C]
	min_temp	-40 [°C]
	resistor_tem-pco	0.28 [%/(°C)]
	nominal_res_temp	25 [°C]
Voltage Source E1	EMF	3 [V]
Resistor R1/R2	R	40M [Ohm]
Resistor R4/R5	R	1M [Ohm]
Analog-Digital Converter adc1	min	0.8
	max	3
	clk	clk1.val
	input	VM2.V
Clock Source clk1	ped	10m
	del	0

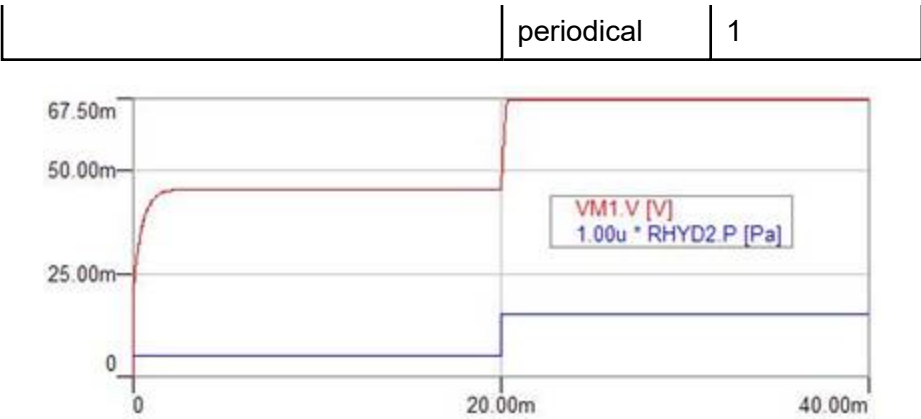


Figure 3. Simulation results-input and output of abs_press_bridge_I22

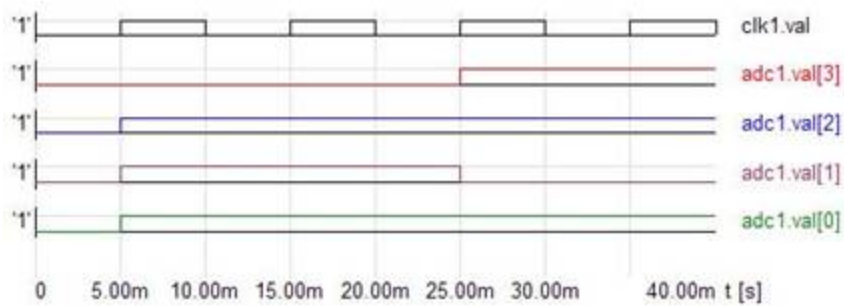


Figure 4. Simulation results- outputs of adc1 and the clock signal

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References

Level 2 Uncompensated Capacitive Absolute Pressure Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

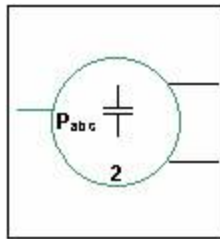


Figure 1. Component symbol

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Description

The Level 2 Uncompensated Capacitive Absolute Pressure Sensor model is used to simulate the non-ideal behavior of a capacitor absolute pressure sensor. A change in the applied pressure produces a corresponding change in the variable capacitance.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL ABS_PRESS_CAP_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) out_
plus:= %0, out_minus:= %1, PRESSURE:= %2 ( nominal_capacitance:= @nominal_capa-
citanace, max_pressure:= @max_pressure, min_pressure:= @min_pressure, full_scale_span:=
@full_scale_span, max_nonlinearity:= @max_nonlinearity, hysteresis:= @hysteresis, temp:=
@temp, max_temp:= @max_temp, min_temp:= @min_temp, temp_hysteresis:= @temp_hys-
teresis, tempco_span:= @tempco_span, temp_sens_offset:= @temp_sens_offset, time_con-
stant:= @time_constant) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PRESSURE	Applied pressure	Fluidic
out_plus	Positive capacitor terminal	Electrical
out_minus	Negative capacitor terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
max_pres- sure	Maximum measurable pres- sure	Real	1k [Pa]
min_pressure	Minimum measurable pressure	Real	0 [Pa]
full_scale_ span	Difference between the max- imum and minimum output capacitances	Real	50p [F]
nominal_capa- citanace	Capacitance of the sensor at the minimum measurable pres- sure	Real	100p [F]

time_constant	Output time constant	Real	0 [s]
temp	Device temperature	Real	27 [°C]
max_non-linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
temp_hys-teresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Nominal capacitance temperature sensitivity	Real	0 [F/(°C)]
max_temp	Maximum operating temperature	Real	125 [°C]
min_temp	Minimum operating temperature	Real	-40 [°C]

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Example

In this example, the output capacitance of the Uncompensated Capacitive Absolute Pressure Sensor ABS_PRESS_CAP2 changes in response to the applied pressure. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

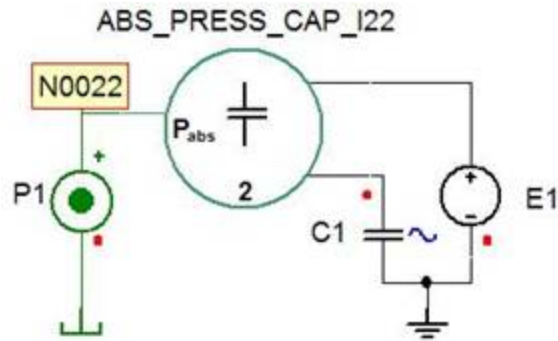


Figure 2. Application example of the Uncompensated Capacitive Absolute Pressure Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	1.2k * (t/70m) [Pa]
Uncompensated Capacitive Absolute Pressure Sensor ABS_PRESS_CAP_I22	max_pres- sure	500MEG [Pa]
	min_pressure	100MEG [Pa]
	full_scale_ span	50p [F]
	nominal_capa- cittance	50p [F]
	time_constant	5m [s]
	temp	27 [°C]
	max_non- linearity	1 [%]
	hysteresis	1 [%]

	temp_hys- teresis	0 [%]
	tempco_span	0.1 [%/ °C]
	temp_sens_ offset	0.1p [F/(°C)]
	max_temp	125 [°C]
	min_temp	-40 [°C]
Voltage Source (sinusoidal) E1	AMPL	5 [V]
	FREQ	100 [Hz]
	OFF	0 [V]
	TDELAY	0 [s]
	PHASE	0 [degree]
Capacitor C1	C	100p [F]
	V0	0 [V]

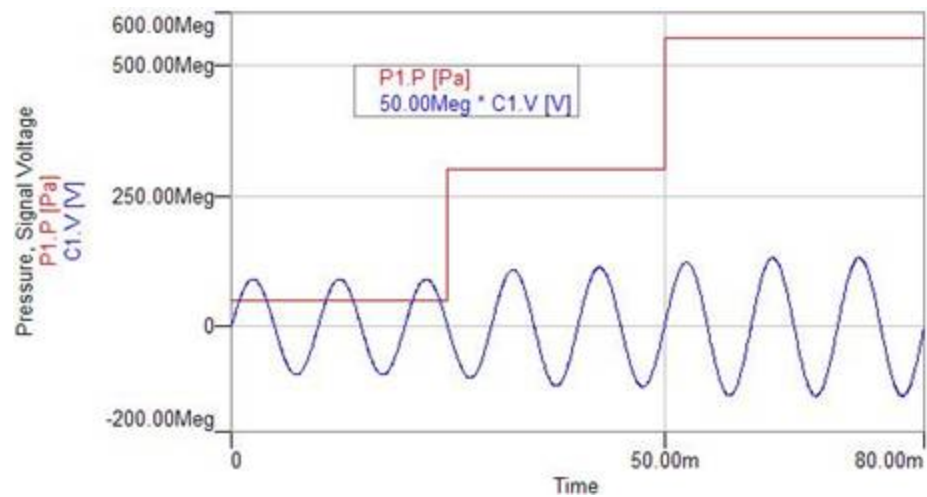


Figure 3. Simulation results-pressure output of P1 and the voltage across C1

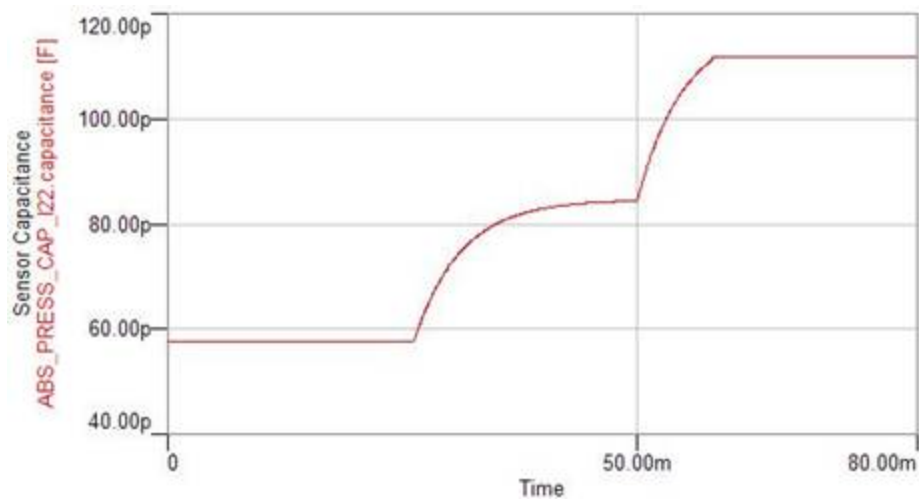


Figure 4. Simulation results-output capacitance of ABS_PRESS_CAP2References

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References

Level 2 LVDT Absolute Pressure Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

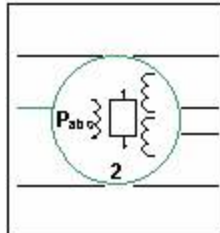


Figure 1. Component symbol

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Description

The Level 2 LVDT Absolute Pressure Sensor model is used to simulate the non-ideal behavior of a linear variable differential transformer absolute pressure sensor. A change in the applied pressure produces a corresponding change in the AC voltage output signal.

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Mathematical Description

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Netlist Syntax

```
MODEL ABS_PRESS_LVDT_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) out_1_
plus:= %0, out_1_minus:= %1, out_2_plus:= %2, out_2_minus:= %3, in_plus:= %4, in_minus:=
```

%5, PRESSURE:= %6 (max_pressure:= @max_pressure, min_pressure:= @min_pressure, sensitivity:= @sensitivity, max_nonlinearity:= @max_nonlinearity, hysteresis:= @hysteresis, max_temp:= @max_temp, min_temp:= @min_temp, temp:= @temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span, primary_inductance:= @primary_inductance, primary_resistance:= @primary_resistance, secondary_inductance:= @secondary_inductance, secondary_resistance:= @secondary_resistance, time_constant:= @time_constant, null_voltage:= @null_voltage) SRC: DB(Lib:=@ModelLibraryName);

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PRESSURE	Applied pressure	Fluidic
in_plus	Transformer primary positive terminal	Electrical
in_minus	Transformer primary negative terminal	Electrical
out_1_plus	Transformer secondary 1 positive terminal	Electrical
out_1_minus	Transformer secondary 1 negative terminal	Electrical
out_2_plus	Transformer secondary 2 positive terminal	Electrical
out_2_minus	Transformer secondary 2 negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]

max_pres- sure	Maximum measurable pres- sure	Real	10k [Pa]
min_pressure	Minimum measurable pres- sure	Real	0 [Pa]
sensitivity	LVDT sensitivity	Real	1 [V/V/Pa]
time_con- stant	Output time constant	Real	0 [s]
temp	Device temperature	Real	27 [°C]
max_non- linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
temp_hys- teresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
max_temp	Maximum operating tem- perature	Real	125 [°C]
min_temp	Minimum operating tem- perature	Real	-40 [°C]
primary_ inductance	Primary winding inductance	Real	10m [H]
primary_res- istance	Primary winding resistance	Real	0 [Ohm]
secondary_ inductance	Secondary winding induct- ance	Real	10m [H]
secondary_	Secondary winding resistance	Real	0 [Ohm]

resistance			
null_voltage	LVDT null voltage	Real	0 [%]

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Example

In this example, the change in the ouptut pressure of the Pressure Source P1 produces a corresponding change in the AC voltage output signal of the LVDT Absolute Pressure Sensor ABS_PRESS_LVDT_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

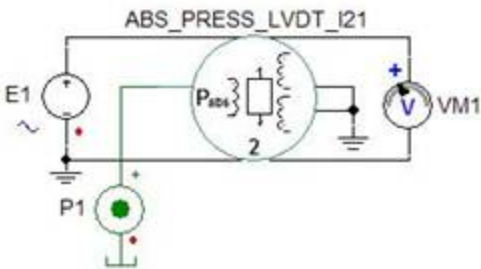


Figure 2. Application example of the LVDT Absolute Pressure Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	$2E8 * (t > 1m) + 2E8 * (t > 2.5m)$ [Pa]
Voltage Source (sinusoidal) E1	AMPL	3 [V]
	FREQ	3k [Hz]
	OFF	0 [V]
	PHASE	0 [degree]
	TDELAY	0 [s]
LVDT Absolute Pressure Sensor ABS_PRESS_LVDT_	max_pres- sure	4E8 [Pa]

I21		
	min_pressure	0 [Pa]
	sensitivity	10n [V/V/Pa]
	time_constant	100u [s]
	temp	dt* [°C]
	max_non-linearity	1 [%]
	hysteresis	0 [%]
	temp_hysteresis	1 [%]
	tempco_span	0 [%/(°C)]
	max_temp	150 [°C]
	min_temp	-50 [°C]
	primary_inductance	10m [H]
	primary_resistance	0 [Ohm]
	secondary_inductance	10m [H]
	secondary_resistance	0 [Ohm]
	null_voltage	1 [%]

*: dt is defined by the Equation Block FML1 as following:

IF (t <= 2m) {dt:=150;} ELSE IF (t > 2m) {dt:=-50;}

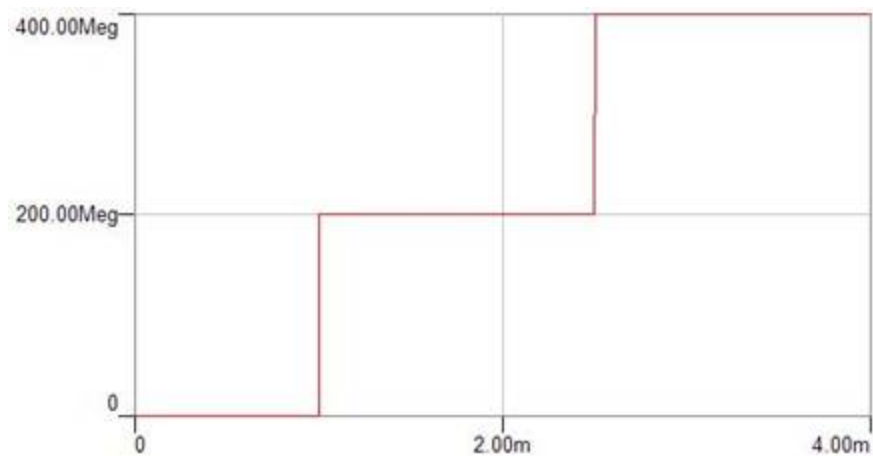


Figure 3. Simulation results-output pressure of P1

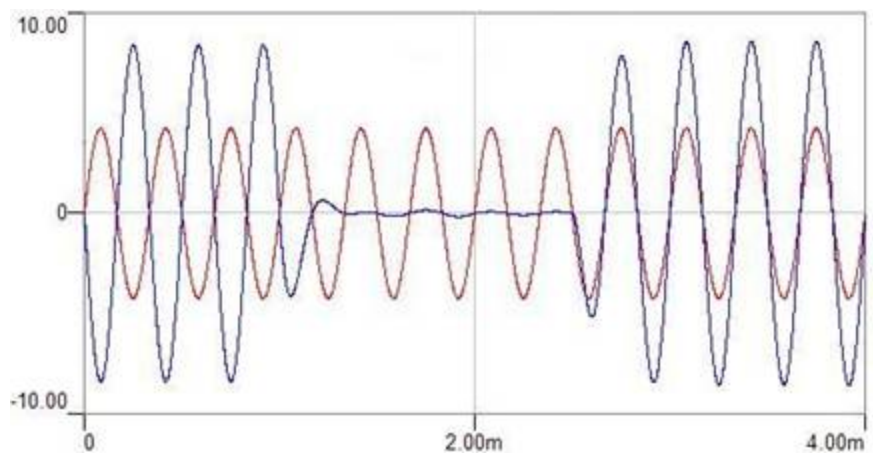


Figure 4. Simulation results-primary and secondary voltage of ABS_PRESS_LVDT_I21

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References

Level 2 Piezoelectric Absolute Pressure Sensor

Library: Add Ons/ sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

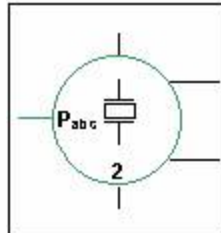


Figure 1. Component symbol

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Description

The Level 2 Piezoelectric Absolute Pressure Sensor model is used to simulate the non-ideal behavior of a piezoelectric crystal absolute pressure sensor. A change in the applied pressure produces a corresponding change in the voltage output signal.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL ABS_PRESS_PE_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
PRESSURE:= %0, out_plus:= %1, out_minus:= %2, Vdd:= %3, Vss:= %4 ( max_pressure:=
```

@max_pressure, min_pressure:= @min_pressure, full_scale_span:= @full_scale_span, offset:= @offset, max_nonlinearity:= @max_nonlinearity, pressure_hysteresis:= @pressure_hysteresis, max_temp:= @max_temp, min_temp:= @min_temp, temp:= @temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span, temp_sens_offset:= @temp_sens_offset, time_constant:= @time_constant, output_resistance:= @output_resistance, nominal_source_current:= @nominal_source_current) SRC: DB(Lib:=@ModelLibraryName);

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PRESSURE	Applied pressure	Fluidic
Vdd	Positive supply	Electrical
Vss	Negative supply	Electrical
out_plus	Positive output terminal	Electrical
out_minus	Negative output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
max_pressure	Maximum measurable pressure	Real	1k [Pa]
min_pressure	Minimum measurable pressure	Real	0 [Pa]
full_scale_span	Difference between the maximum and minimum output voltages	Real	5 [V]

nom_source_current	Typical supply current	Real	1m [A]
time_constant	Output time constant	Real	0 [s]
temp	Device temperature	Real	27 [°C]
output_resistance	Output resistance	Real	0 [Ohm]
max_non-linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
pressure_hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
max_temp	Maximum operating temperature	Real	125 [°C]
min_temp	Minimum operating temperature	Real	-40 [°C]

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Example

In this example, the Piezoelectric Absolute Pressure Sensor ABS_PRESS_PE_I22 measures the pressure output of the Pressure Source P1, and the output voltage of ABS_PRESS_PE_I22 changes in response to the applied pressure. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

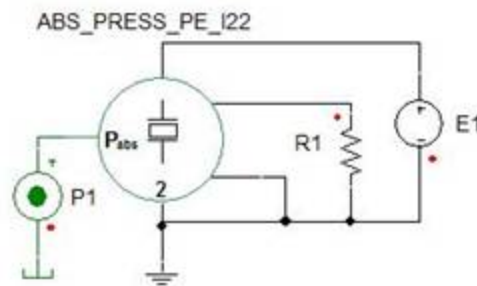


Figure 2. Application example of the Piezoelectric Absolute Pressure Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	2E8 [Pa]
Piezoelectric Absolute Pressure Sensor ABS_PRESS_PE_I22	offset	9 [V]
	max_pressure	2000 [bar]
	min_pressure	0 [bar]
	full_scale_span	5 [V]
	time_constant	455n [s]
	temp	27 [°C]
	max_non-linearity	0 [%]
	pressure_hys-teresis	0 [%]
	temp_hys-teresis	0 [%]

	tempco_span	0.02 [%/(°C)]
	temp_sens_offset	0 [V/(°C)]
	max_temp	125 [°C]
	min_temp	-40 [°C]
	Nominal_source_current	4m [A]
	Output_resistance	100 [Ohm]
Voltage Source E1	EMF	20 [V]
Resistor R1	R	100k [Ohm]

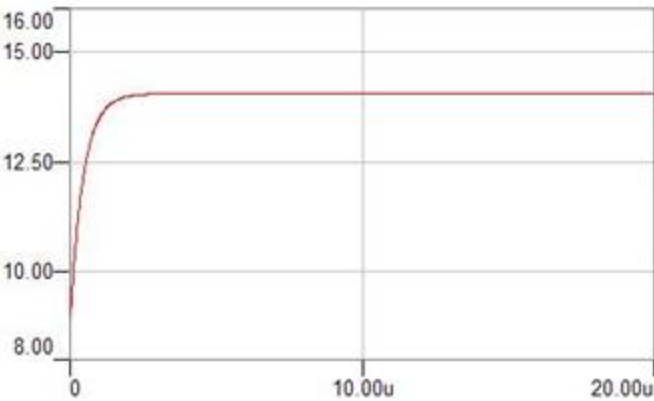


Figure 3. Simulation results- output voltage of ABS_PRESS_PE_I22References

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References

Level 2 Potentiometric Absolute Pressure Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

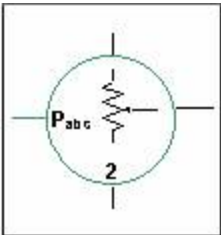


Figure 1. Component symbol

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Description

The Level 2 Potentiometric Absolute Pressure Sensor model is used to simulate the non-ideal behavior of a potentiometer absolute pressure sensor. A change in the applied pressure produces a corresponding change in the voltage divider output signal.

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Mathematical Description

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Netlist Syntax

```
MODEL ABS_PRESS_POTEN_I2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID))
PRESSURE:= %0, OUT:= %1, Vdd:= %2, Vss:= %3 ( max_pressure:= @max_pressure, min_
pressure:= @min_pressure, full_scale_span:= @full_scale_span, offset:= @offset, max_
```

nonlinearity:= @max_nonlinearity, max_hysteresis:= @max_hysteresis, temp_hysteresis:=
@temp_hysteresis, max_temp:= @max_temp, min_temp:= @min_temp, temp:= @temp, tem-
pco_span:= @tempco_span, temp_sens_offset:= @temp_sens_offset, p_resistance:= @p_res-
istance, w_resistance:= @w_resistance, time_constant:= @time_constant) SRC: DB
(Lib:=@ModelLibraryName);

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PRESSURE	Applied pressure	Fluidic
Vdd	Positive supply	Electrical
Vss	Negative supply	Electrical
OUT	Output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
p_resistance	Potentiometer resistance	Real	10k [Ohm]
max_pressure	Maximum measurable pressure	Real	10k [Pa]
min_pressure	Minimum measurable pressure	Real	0 [Pa]
full_scale_span	Difference of maximum and minimum output voltages	Real	10 [V]
w_resistance	Potentiometer wiper resistance	Real	0 [Ohm]
time_constant	Output time constant	Real	0 [s]
temp	Device temperature	Real	27 [°C]
max_non-linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
max_hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
max_temp	Maximum operating temperature	Real	125 [°C]

	perature		
min_temp	Minimum operating temperature	Real	-40 [°C]

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Example

In this example, the output voltage of the Potentiometric Absolute Pressure Sensor ABS_PRESS_POTEN_I22 changes in response to the applied pressure source P1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

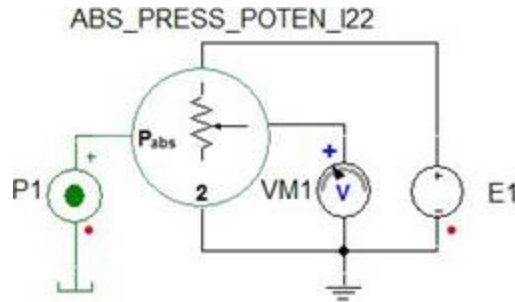


Figure 2. Application example of the Pressure Switch Gage Pressure Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	$(6894.757 * 5k) * (t/40m)$ [Pa]
Voltage Source E1	EMF	10 [V]
Potentiometric Absolute Pressure Sensor ABS_PRESS_POTEN_I22	offset	$0.1 * E1.EMF$ [V]
	p_resistance	5k [Ohm]
	max_pressure	5k [Pa]
	min_pressure	0 [Pa]
	full_scale_span	$0.9 * E1.EMF$ [V]
	w_resistance	0 [Ohm]
	time_constant	0 [s]
	temp	27 [°C]

	max_non-linearity	0 [%]
	max_hys-teresis	0 [%]
	temp_hys-teresis	0 [%]
	tempco_span	0.036 [%/(°C)]
	temp_sens_offset	0 [V/(°C)]
	max_temp	188 [°C]
	min_temp	-21 [°C]

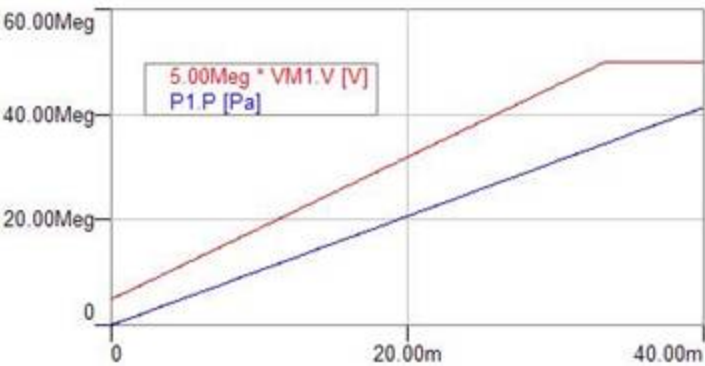


Figure 3. Simulation results-input pressure and output voltage of ABS_PRESS_POTEN_I22

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References

Level 2 Pressure Switch Absolute Pressure Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

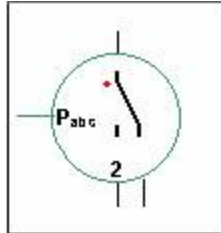


Figure 1. Component symbol

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Description

The Level 2 Pressure Switch Absolute Pressure Sensor model is used to simulate the non-ideal behavior of an absolute pressure-sensing switch. If the pressure applied to the switch exceeds the switch's threshold pressure, the switch changes position from its normally closed terminal to its normally open terminal.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL ABS_PRESS_SW_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
PRESSURE:= %0, nmnc:= %1, nmno:= %2, np:= %3 ( threshold_pressure:= @threshold_
```

pressure, response_time:= @response_time, switch_resistance:= @switch_resistance) SRC:
DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PRESSURE	Applied Pressure	Fluidic
np	Positive Terminal	Electrical
nmnc	Normally Closed Negative Terminal	Electrical
nmno	Normally Open Negative Terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
threshold_pressure	Switch threshold pressure	Real	101.325k [Pa]
switch_resistance	On-state resistance	Real	0 [Ohm]
response_time	Response time	Real	0 [s]

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Example

In this example, when the output pressure of the Pressure Source P1 is below the pressure limit of the Pressure Switch Absolute Pressure Sensor ABS_PRESS_SW_I21, the resistor Rno is connected to the current source via ABS_PRESS_SW_I21; when te output pressure of P1

exceeds the pressure limit of ABS_PRESS_SW_I21, the switch changes position from its normally closed terminal to its normally open terminal, and hence connects Rnc to the current source instead. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 - 5.

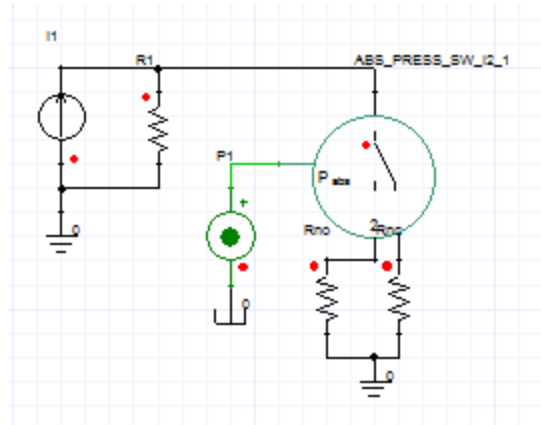


Figure 2. Application example of the Pressure Switch Absolute Pressure Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	$500k \cdot (\text{time} \geq 5m) - 100k \cdot (\text{time} > 25m)$ [Pa]
Current Source I1	IS	1 [A]
Resistor Rno/Rnc	R	1k [Ohm]
Resistor R1	R	1000k [Ohm]
Pressure Switch Absolute Pressure Sensor ABS_PRESS_SW_I21	threshold_pressure	500k [Pa]
	switch_resistance	10 [Ohm]
	response_time	10m [s]

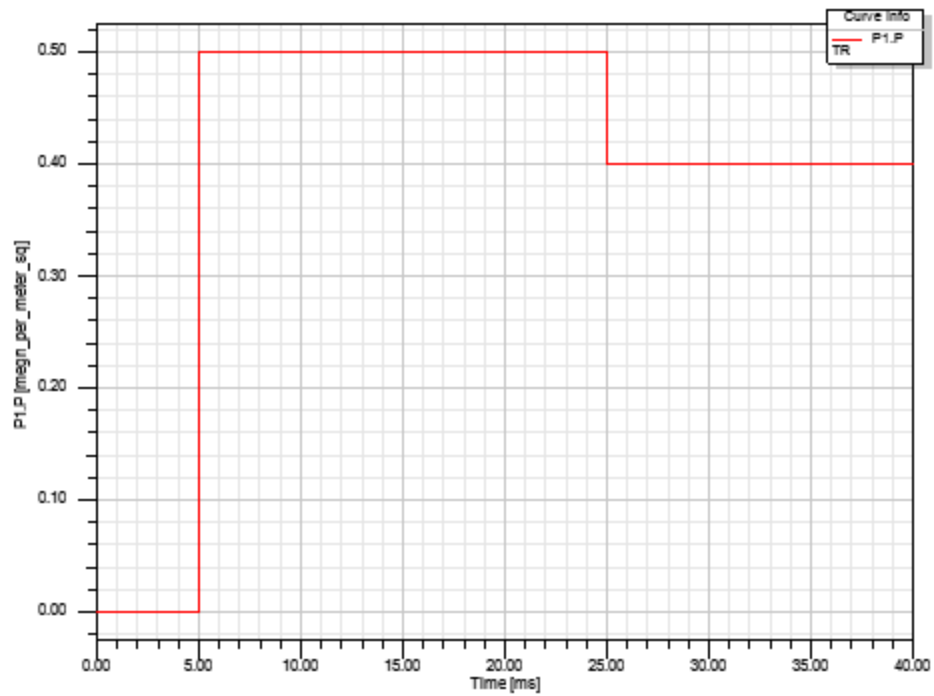


Figure 3. Simulation results-output pressure of P1

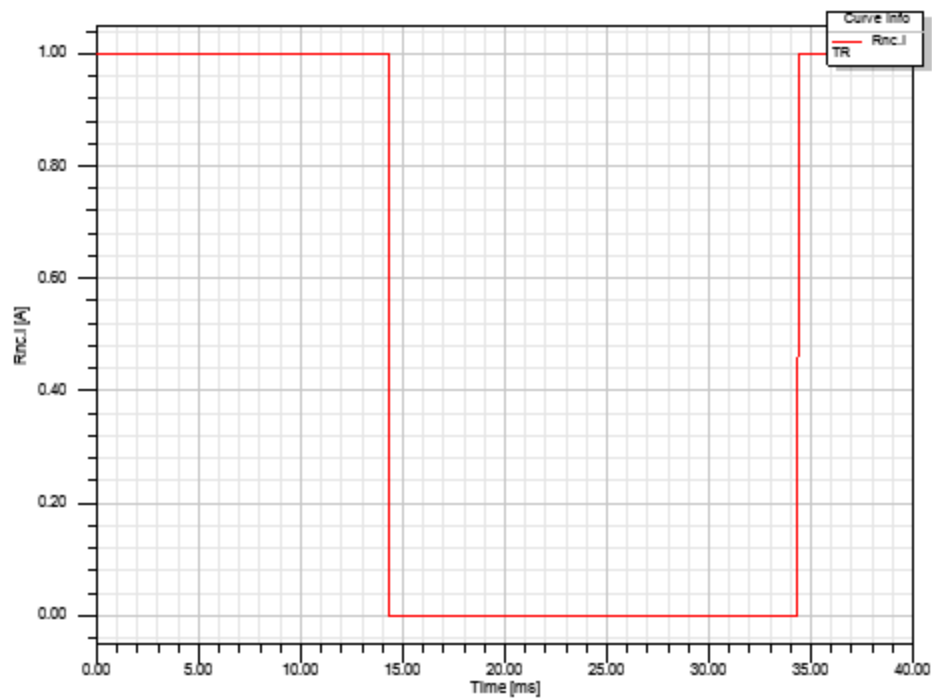


Figure 4. Simulation results-current through Rnc

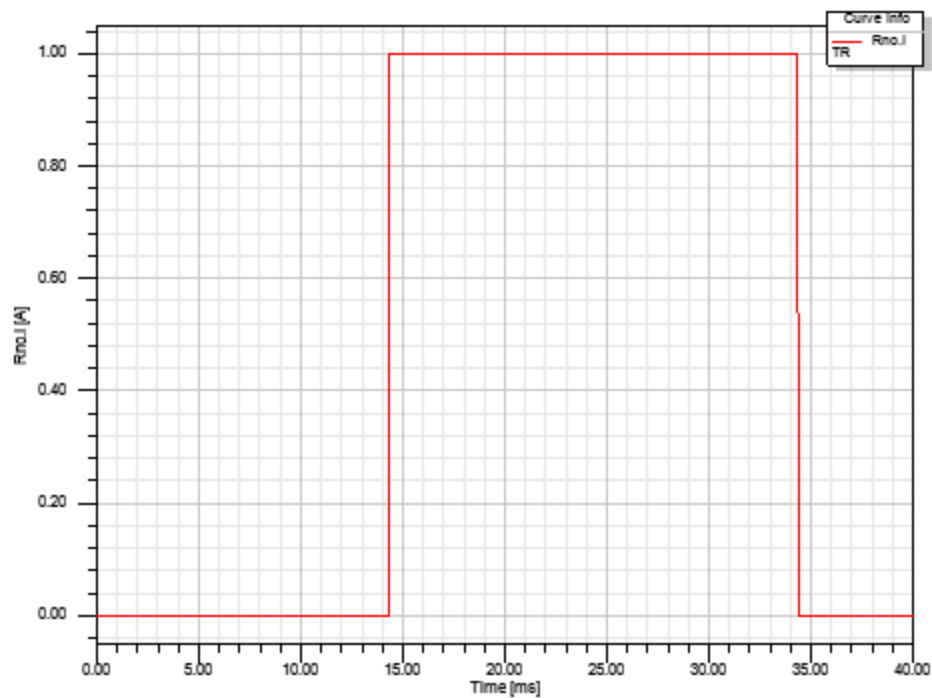


Figure 5. Simulation results-current through Rno

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References

Level 2 Piezoresistive Differential Pressure Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

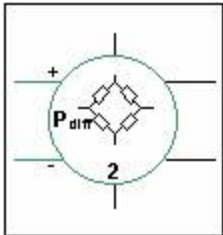


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Description

The Level 2 Piezoresistive Differential Pressure Sensor model is used to simulate the non-ideal behavior of a strain-gauge differential pressure sensor. A change in the measured pressure or the reference pressure produces a corresponding change in the differential voltage output signal.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL DIFF_PRESS_BRIDGE_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
Vcc:= %0, Vcc_m:= %1, out_plus:= %2, out_minus:= %3, PRESSURE2:= %4, PRESSURE1:=
```



```
%5 ( max_pressure:= @max_pressure, min_pressure:= @min_pressure, full_scale_span:=
@full_scale_span, offset:= @offset, max_nonlinearity:= @max_nonlinearity, pressure_hys-
teresis:= @pressure_hysteresis, temp:= @temp, min_temp:= @min_temp, max_temp:=
@max_temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span, temp_
sens_offset:= @temp_sens_offset, bridge_resistance:= @bridge_resistance, time_constant:=
@time_constant, resistor_tempco:= @resistor_tempco, nominal_res_temp:= @nominal_res_
temp) SRC: DB(Lib:=@ModelLibraryName);
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PRESSURE1	Measured pressure	Fluidic
PRESSURE2	Reference pressure	Fluidic
Vcc	Positive supply	Electrical
Vcc_m	Negative supply	Electrical
out_plus	Positive output terminal	Electrical
out_minus	Negative output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	20m [V]
bridge_res-istance	Bridge resistance	Real	10k [Ohm]
max_pres-sure	Maximum measurable pres-sure	Real	10k [Pa]

min_pressure	Minimum measurable pressure	Real	0 [Pa]
full_scale_span	Difference between the maximum and minimum output voltages	Real	55m [V]
time_constant	Output time constant	Real	0 [s]
temp	Device temperature	Real	27 [°C]
max_non-linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
pressure_hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
max_temp	Maximum operating temperature	Real	125 [°C]
min_temp	Minimum operating temperature	Real	-40 [°C]
resistor_tempco	Resistor temperature coefficient	Real	0 [%/(°C)]
nom_res_temp	Nominal bridge resistance temperature	Real	25 [°C]

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Example

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References

Level 2 Uncompensated Capacitive Differential Pressure Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

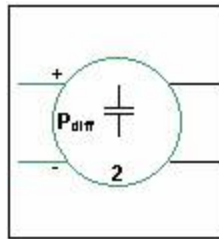


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Description

The Level 2 Uncompensated Capacitive Differential Pressure Sensor model is used to simulate the non-ideal behavior of a capacitor differential pressure sensor. A change in the measured pressure or the reference pressure produces a corresponding change in the variable capacitance output signal.

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Mathematical Description

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Netlist Syntax

```
MODEL DIFF_PRESS_CAP_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) out_
plus:= %0, out_minus:= %1, PRESSURE1:= %2, PRESSURE2:= %3 ( nominal_capacitance:=
@nominal_capacitance, max_pressure:= @max_pressure, min_pressure:= @min_pressure,
full_scale_span:= @full_scale_span, max_nonlinearity:= @max_nonlinearity, hysteresis:=
@hysteresis, temp:= @temp, max_temp:= @max_temp, min_temp:= @min_temp, temp_hys-
teresis:= @temp_hysteresis, tempco_span:= @tempco_span, temp_sens_offset:= @temp_
sens_offset, time_constant:= @time_constant) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PRESSURE1	Measured pressure	Fluidic
PRESSURE2	Reference pressure	Fluidic
out_plus	Positive capacitor terminal	Electrical
out_minus	Negative capacitor terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
max_pressure	Maximum measurable pressure	Real	1k [Pa]
min_pressure	Minimum measurable pressure	Real	0 [Pa]
full_scale_span	Difference between the maximum and minimum output capacitances	Real	50p [F]
nominal_capacitance	Capacitance of the sensor at the minimum measurable pressure	Real	100p [F]
time_constant	Output time constant	Real	0 [s]
temp	Device temperature	Real	27 [°C]
max_non-linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
pressure_hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Nominal capacitance temperature sensitivity	Real	0 [F/(°C)]
max_temp	Maximum operating temperature	Real	125 [°C]

min_temp	Minimum operating temperature	Real	-40 [°C]

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Example

In this example, the Uncompensated Capacitive Differential Pressure Sensor DIFF_PRESS_CAP_I22 measures the pressure output of the Pressure Source P1, and the output capacitance of DIFF_PRESS_CAP_I222 changes in response to the applied pressure. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

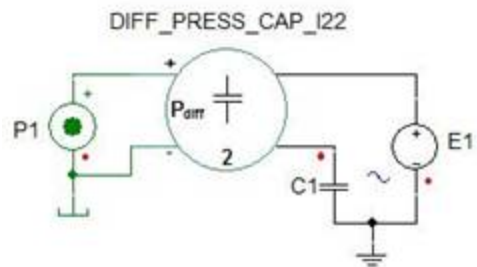


Figure 2. Application example of the Uncompensated Capacitive Differential Pressure Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	$50 + 250 * (t > 10m) + 250 * (t > 40m)$ [Pa]
Uncompensated Capacitive Differential Pressure Sensor DIFF_PRESS_CAP_I22	max_pressure	500 [Pa]
	min_pressure	100 [Pa]
	full_scale_span	75p [F]
	nominal_capacitance	50p [F]
	time_constant	5m [s]
	temp	27 [°C]
	max_non-linearity	1 [%]
	hysteresis	1 [%]
	temp_hysteresis	1 [%]

	tempco_span	0.1 [%/(°C)]
	temp_sens_offset	0.1p [F/(°C)]
	max_temp	125 [°C]
	min_temp	-40 [°C]
Voltage Source (sinusoidal) E1	AMPL	5 [V]
	FREQ	100 [Hz]
	OFF	0 [V]
	TDELAY	0 [s]
	PHASE	0 [degree]
Capacitor C1	C	100p [F]
	V0	0 [V]

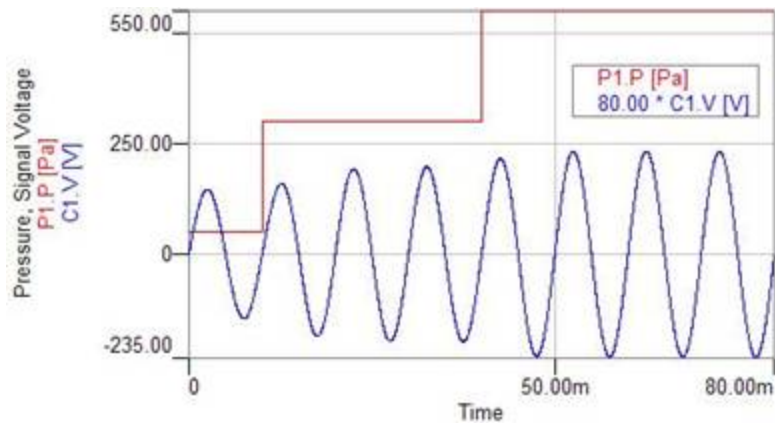


Figure 3. Simulation results- voltage across C1 and output pressure of P1

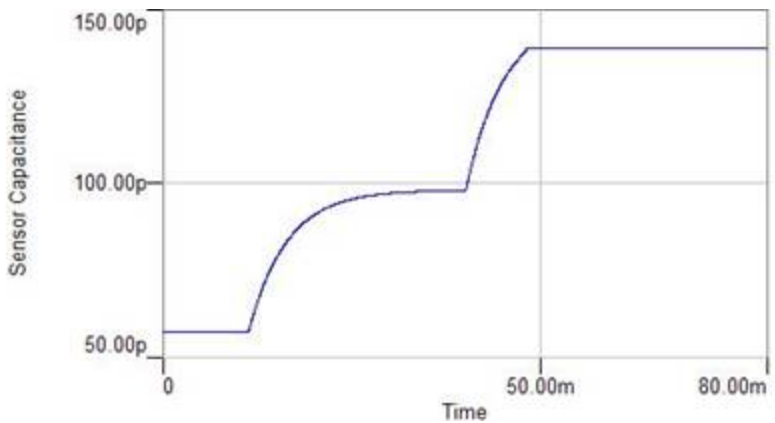


Figure 4. Simulation results-output capacitance of DIFF_PRESS_CAP_I22

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References

Level 2 LVDT Differential Pressure Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

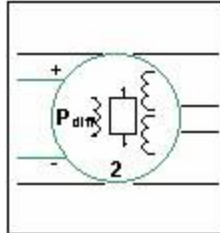


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Description

The Level 2 LVDT Differential Pressure Sensor model is used to simulate the non-ideal behavior of a linear variable differential transformer differential pressure sensor. A change in the applied pressure or the reference pressure produces a corresponding change in the AC voltage output signal.

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Netlist Syntax

```
MODEL DIFF_PRESS_LVDT_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) out_
1_plus:= %0, out_1_minus:= %1, out_2_plus:= %2, out_2_minus:= %3, in_plus:= %4, in_
```

minus:= %5, PRESSURE1:= %6, PRESSURE2:= %7 (max_pressure:= @max_pressure, min_pressure:= @min_pressure, sensitivity:= @sensitivity, max_nonlinearity:= @max_nonlinearity, hysteresis:= @hysteresis, max_temp:= @max_temp, min_temp:= @min_temp, temp:= @temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span, primary_inductance:= @primary_inductance, primary_resistance:= @primary_resistance, secondary_inductance:= @secondary_inductance, secondary_resistance:= @secondary_resistance, null_voltage:= @null_voltage, time_constant:= @time_constant) SRC: DB(Lib:=@ModellibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PRESSURE1	Measured pressure	Fluidic
PRESSURE2	Reference pressure	Fluidic
in_plus	Transformer primary positive terminal	Electrical
in_minus	Transformer primary negative terminal	Electrical
out_1_plus	Transformer secondary 1 positive terminal	Electrical
out_1_minus	Transformer secondary 1 negative terminal	Electrical
out_2_plus	Transformer secondary 2 positive terminal	Electrical
out_2_minus	Transformer secondary 2 negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
max_pressure	Maximum measurable pressure	Real	10k [Pa]
min_pressure	Minimum measurable pressure	Real	0 [Pa]
sensitivity	LVDT sensitivity	Real	1m [V/V/Pa]
time_constant	Output time constant	Real	0 [s]
temp	Device temperature	Real	27 [°C]
max_non-linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
max_temp	Maximum operating temperature	Real	125 [°C]
min_temp	Minimum operating temperature	Real	-40 [°C]
primary_inductance	Primary winding inductance	Real	10m [H]

primary_resistance	Primary winding resistance	Real	0 [Ohm]
secondary_inductance	Secondary winding inductance	Real	10m [H]
secondary_resistance	Secondary winding resistance	Real	0 [Ohm]
null_voltage	LVDT null voltage	Real	0 [%]

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Example

In this example, the change in the ouptput pressure of the Pressure Source P1 produces a corresponding change in the AC voltage output signal of the LVDT Differential Pressure Sensor DIFF_PRESS_LVDT_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

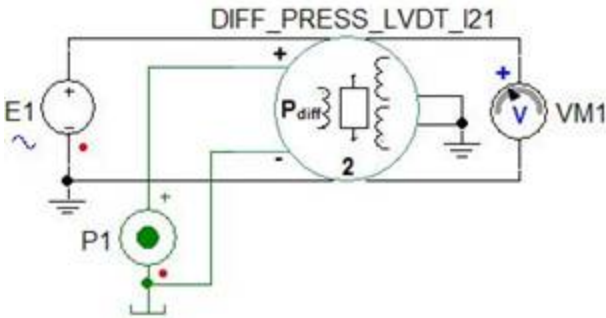


Figure 2. Application example of the LVDT Differential Pressure Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	-10k + 10k * (t > 250u) + 10k * (t > 750u) [Pa]
Voltage Source (sinusoidal) E1	AMPL	3 [V]
	FREQ	3k [Hz]

LVDT Differential Pressure Sensor DIFF_PRESS_ LVDT_I21	OFF	0 [V]
	PHASE	0 [degree]
	TDELAY	0 [s]
	max_pres- sure	10k [Pa]
	min_pressure	-10k [Pa]
	sensitivity	100u [V/V/Pa]
	time_con- stant	100u [s]
	temp	27 [°C]
	max_non- linearity	0 [%]
	hysteresis	0 [%]
	temp_hys- teresis	0 [%]
	tempco_span	0 [%/(°C)]
	max_temp	125 [°C]
	min_temp	-40 [°C]
	primary_ inductance	10m [H]
	primary_res- istance	0 [Ohm]
	secondary_ inductance	10m [H]

	secondary_ resistance	0 [Ohm]
	null_voltage	1 [%]

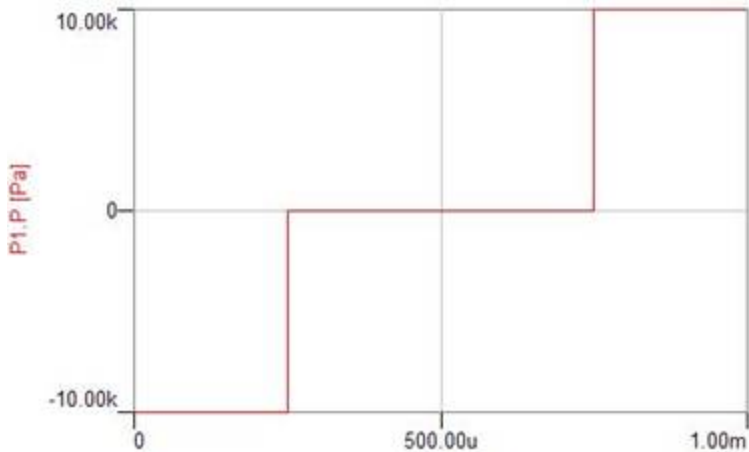


Figure 3. Simulation results-output pressure of P1

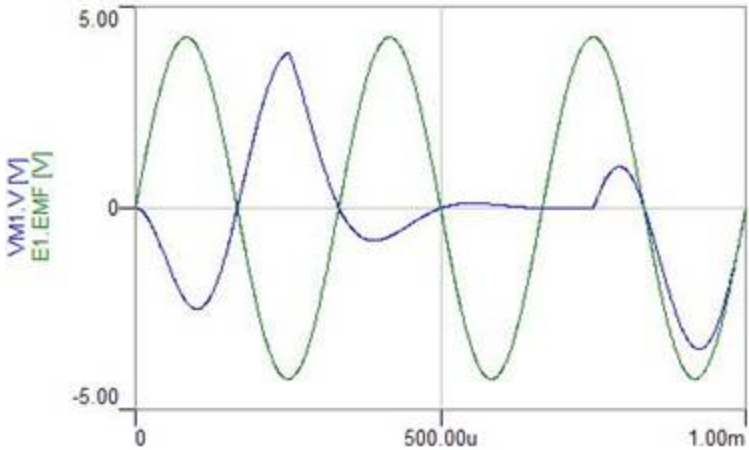


Figure 4. Simulation results-primary and secondary voltage of DIFF_PRESS_LVDT_I21

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References

Level 2 Piezoelectric Differential Pressure Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

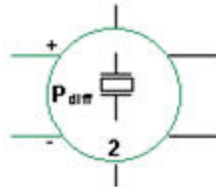


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Description

The Level 2 Piezoelectric Differential Pressure Sensor model is used to simulate the non-ideal behavior of a piezoelectric crystal differential pressure sensor. A change in the measured pressure or the reference pressure produces a corresponding change in the voltage output signal.

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Mathematical Description

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Netlist Syntax

```
MODEL DIFF_PRESS_PE_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) out_
plus:= %0, out_minus:= %1, PRESSURE1:= %2, PRESSURE2:= %3, Vdd:= %4, Vss:= %5 (
```

max_pressure:= @max_pressure, min_pressure:= @min_pressure, full_scale_span:= @full_scale_span, offset:= @offset, max_nonlinearity:= @max_nonlinearity, pressure_hysteresis:= @pressure_hysteresis, max_temp:= @max_temp, min_temp:= @min_temp, temp:= @temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span, temp_sens_offset:= @temp_sens_offset, time_constant:= @time_constant, output_resistance:= @output_resistance, nominal_source_current:= @nominal_source_current) SRC: DB(Lib:- :=@ModelLibraryName);

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PRESSURE1	Measured pressure	Fluidic
PRESSURE2	Reference pressure	Fluidic
Vdd	Positive supply	Electrical
Vss	Negative supply	Electrical
out_plus	Positive output terminal	Electrical
out_minus	Negative output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
max_pressure	Maximum measurable pressure	Real	1k [Pa]
min_pressure	Minimum measurable pressure	Real	0 [Pa]
full_scale_span	Difference between the maximum and minimum output voltages	Real	5 [V]
nom_source_current	Typical supply current	Real	1m [A]
time_constant	Output time constant	Real	0 [s]
temp	Device temperature	Real	27 [°C]
output_resistance	Output resistance	Real	0 [Ohm]
max_non-linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
pressure_hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]

max_temp	Maximum operating temperatu	Real	125 [°C]
min_temp	Minimum operating tem- perature	Real	-40 [°C]

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Example

In this example, the Piezoelectric Differential Pressure Sensor DIFF_PRESS_PE_I22 measures the pressure output of the Pressure Source P1, and the output voltage of DIFF_PRESS_PE_I22 changes in reponse to the applied pressure. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

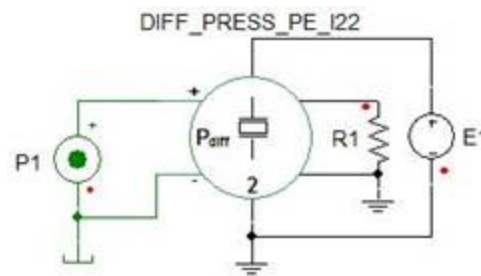


Figure 2. Application example of the Piezoelectric Differential Pressure Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	2E8 [Pa]
Piezoelectric Differential Pressure Sensor DIFF_PRESS_PE_I22	offset	9 [V]
	max_pres- sure	2k [Pa]
	min_pressure	0 [Pa]
	full_scale_ span	5 [V]
	nom_source_	4m [A]

	current	
	time_constant	455n [s]
	temp	27 [°C]
	output_resistance	100 [Ohm]
	max_non-linearity	0 [%]
	pressure_hysteresis	0 [%]
	temp_hysteresis	0 [%]
	tempco_span	0.02 [%/(°C)]
	temp_sens_offset	0 [V/(°C)]
	max_temp	125 [°C]
	min_temp	-40 [°C]
Voltage Source E1	EMF	20 [V]
Resistor R1	R	1k [Ohm]



Figure 3. Simulation results-output voltage of DIFF_PRESS_PE_I22

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References

Level 2 Potentiometric Differential Pressure Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

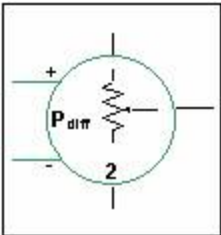


Figure 1. Component symbol

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Description

The Level 2 Potentiometric Differential Pressure Sensor model is used to simulate the non-ideal behavior of a potentiometer differential pressure sensor. A change in the applied pressure or the reference pressure produces a corresponding change in the voltage divider output signal.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL DIFF_PRESS_POTEN_I2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID))
OUT:= %0, Vdd:= %1, Vss:= %2, PRESSURE1:= %3, PRESSURE2:= %4 ( max_pressure:=
@max_pressure, min_pressure:= @min_pressure, full_scale_span:= @full_scale_span,
```


offset:= @offset, max_nonlinearity:= @max_nonlinearity, max_hysteresis:= @max_hysteresis, temp_hysteresis:= @temp_hysteresis, max_temp:= @max_temp, min_temp:= @min_temp, temp:= @temp, tempco_span:= @tempco_span, temp_sens_offset:= @temp_sens_offset, p_resistance:= @p_resistance, w_resistance:= @w_resistance, time_constant:= @time_constant) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PRESSURE1	Applied pressure	Fluidic
PRESSURE2	Reference pressure	Fluidic
Vdd	Positive supply	Electrical
Vss	Negative supply	Electrical
OUT	Output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
p_resistance	Potentiometer resistance	Real	10k [Ohm]
max_pressure	Maximum measurable pressure	Real	10k [Pa]
min_pressure	Minimum measurable pressure	Real	0 [Pa]
full_scale_span	Difference of maximum and minimum output voltages	Real	10 [V]
w_resistance	Potentiometer wiper resistance	Real	0 [Ohm]
time_constant	Output time constant	Real	0 [s]
temp	Device temperature	Real	27 [°C]
max_non-linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
max_hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
max_temp	Maximum operating temperature	Real	125 [°C]

	perature		
min_temp	Minimum operating temperature	Real	-40 [°C]

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Example

In this example, the output voltage of the Potentiometric Differential Pressure Sensor DIFF_PRESS_POTEN_I22 changes in reponse to the applied pressure source P1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

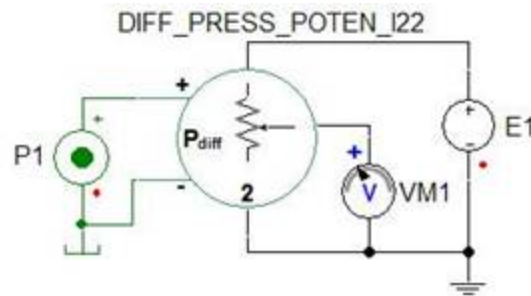


Figure 2. Application example of the Pressure Switch Gage Pressure Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	$(6894.757 * 5k) * (t/40m)$ [Pa]
Voltage Source E1	EMF	10 [V]
Potentiometric Differential Pressure Sensor DIFF_PRESS_POTEN_I22	offset	$0.1 * E1.EMF$ [V]
	p_resistance	5k [Ohm]
	max_pressure	5k [Pa]
	min_pressure	0 [Pa]
	full_scale_span	$0.9 * E1.EMF$ [V]
	w_resistance	0 [Ohm]
	time_constant	0 [s]
	temp	27 [°C]

	max_non-linearity	0 [%]
	max_hys-teresis	0 [%]
	temp_hys-teresis	0 [%]
	tempco_span	0.036 [%/(°C)]
	temp_sens_offset	0 [V/(°C)]
	max_temp	188 [°C]
	min_temp	-21 [°C]

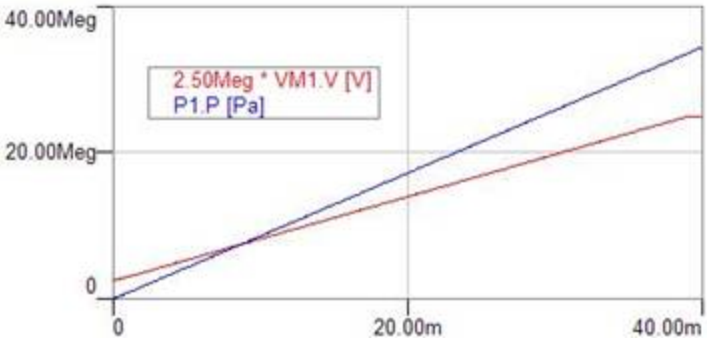


Figure 3. Simulation results-input pressure and output voltage of DIFF_PRESS_POTEN_I22

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References

Level 2 Pressure Switch Differential Pressure Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

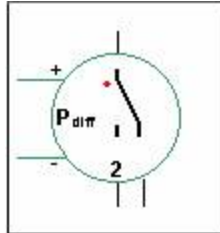


Figure 1. Component symbol

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Description

The Level 2 Pressure Switch Differential Pressure Sensor model is used to simulate the non-ideal behavior of a differential pressure-sensing switch. If the differential pressure applied to the switch exceeds the switch's threshold pressure, the switch changes position from its normally closed terminal to its normally open terminal.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL DIFF_PRESS_SW_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))  
PRESSURE1:= %0, PRESSURE2:= %1, nmnc:= %2, nmno:= %3, np:= %4 ( threshold_pres-  
sure:= @threshold_pressure, response_time:= @response_time, switch_resistance:=  
@switch_resistance) SRC: DB(Lib:=@ModelLibraryName);
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PRESSURE1	Applied pressure	Fluidic
PRESSURE2	Reference pressure	Fluidic
np	Positive terminal	Electrical
nmnc	Normally closed negative terminal	Electrical
nmno	Normally open negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
threshold_pressure	Switch threshold pressure	Real	101.325k [Pa]
switch_resistance	On-state resistance	Real	0 [Ohm]
response_time	Response time	Real	0 [s]

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Example

In this example, when the output pressure of the Pressure Source P1 is below the pressure limit of the Pressure Switch Differential Pressure Sensor DIFF_PRESS_SW_I21, the resistor Rno is connected to the current source via DIFF_PRESS_SW_I21; when the output pressure of P1 exceeds the pressure limit of DIFF_PRESS_SW_I21, the switch changes position from its normally closed terminal to its normally open terminal, and hence connects Rnc to the current source instead. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 - 5.

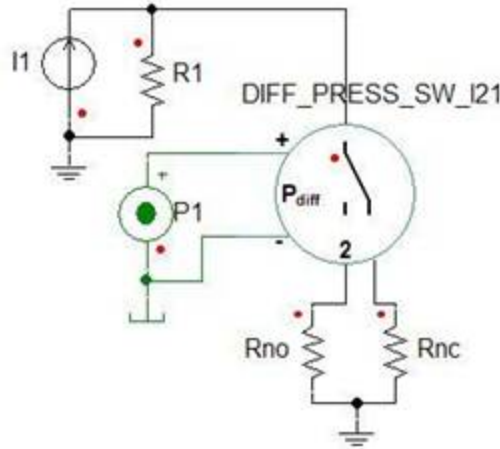


Figure 2. Application example of the Pressure Switch Differential Pressure Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	$500k \cdot (\text{time} > - \geq 5m) - 100k \cdot (\text{time} > 25m)$ [Pa]
Current Source I1	IS	1 [A]
Resistor Rno/Rnc	R	1k [Ohm]
Resistor R1	R	1000k [Ohm]
Pressure Switch Differential Pressure Sensor DIFF_PRESS_SW_I21	threshold_pressure	500k [Pa]
	switch_resistance	10 [Ohm]

	response_ time	10m [s]

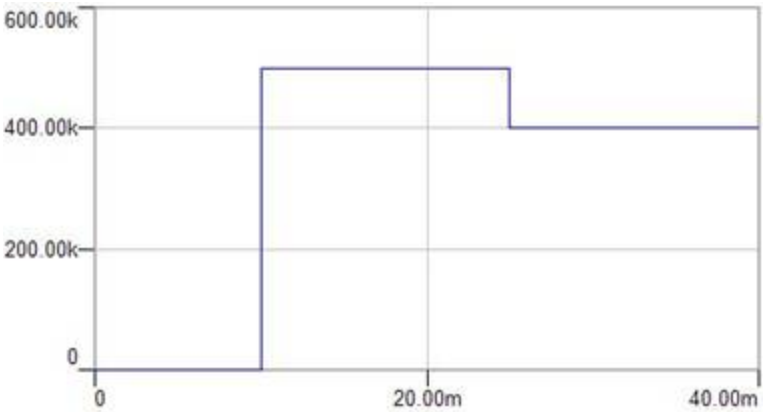


Figure 3. Simulation results-output pressure of P1

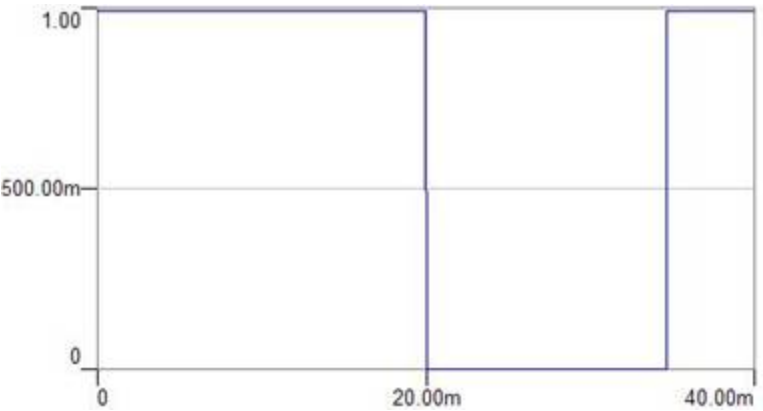


Figure 4. Simulation results-current through Rnc

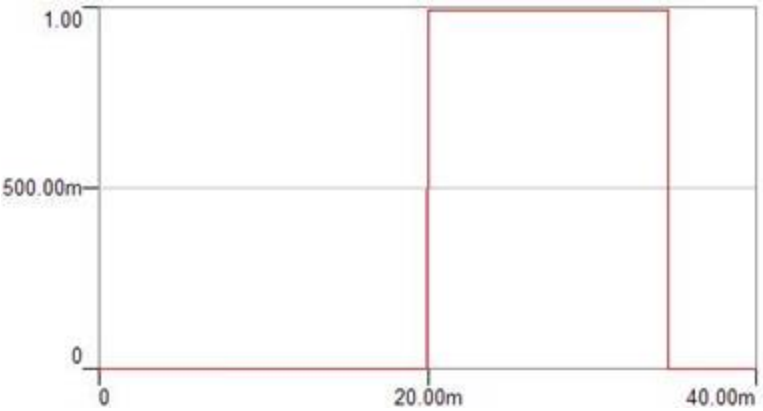


Figure 5. Simulation results-current through Rno

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References

Level 2 Piezoresistive Gage Pressure Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

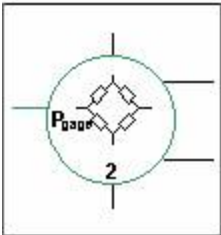


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Description

The Level 2 Piezoresistive Gage Pressure Sensor model is used to simulate the non-ideal behavior of a strain-gauge gage pressure sensor. A change in the measured pressure or the atmospheric pressure produces a corresponding change in the differential voltage output signal.

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Mathematical Description

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Netlist Syntax

```
MODEL gage_press_bridge_I2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID))
PRESSURE:= %0, Vcc:= %1, Vcc_m:= %2, out_plus:= %3, out_minus:= %4 ( max_pressure:=
```

@max_pressure, min_pressure:= @min_pressure, full_scale_span:= @full_scale_span, offset:= @offset, max_nonlinearity:= @max_nonlinearity, pressure_hysteresis:= @pressure_hysteresis, temp:= @temp, min_temp:= @min_temp, max_temp:= @max_temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span, temp_sens_offset:= @temp_sens_offset, bridge_resistance:= @bridge_resistance, time_constant:= @time_constant, resistor_tempco:= @resistor_tempco, nominal_res_temp:= @nominal_res_temp, atmp:= @atmp) SRC: DB(Lib:- :=@ModelLibraryName);

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PRESSURE	Measured pressure	Fluidic
Vcc	Positive supply	Electrical
Vcc_m	Negative supply	Electrical
out_plus	Positive output terminal	Electrical
out_minus	Negative output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	20m [V]
bridge_resistance	Bridge resistance	Real	10k [Ohm]
max_pressure	Maximum measurable pressure	Real	10k [Pa]
min_pressure	Minimum measurable pressure	Real	0 [Pa]

	sure		
full_scale_span	Difference between the maximum and minimum output voltages	Real	55m [V]
atmp	Atmospheric pressure	Real	101.325k [Pa]
time_constant	Output time constant	Real	0 [s]
temp	Device temperature	Real	27 [°C]
max_non-linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
pressure_hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
max_temp	Maximum operating temperature	Real	125 [°C]
min_temp	Minimum operating temperature	Real	-40 [°C]
resistor_tempco	Resistor temperature coefficient	Real	0 [%/(°C)]
nom_res_temp	Nominal bridge resistance temperature	Real	25 [°C]

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Example

In this example, the Piezoresistive Gage Pressure Sensor gage_press_bridge_I21 measures the output pressure applied to the Linear Orifice RHYD2, and converted it into a voltage signal. This voltage output is measured by a Voltage Meter VM1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

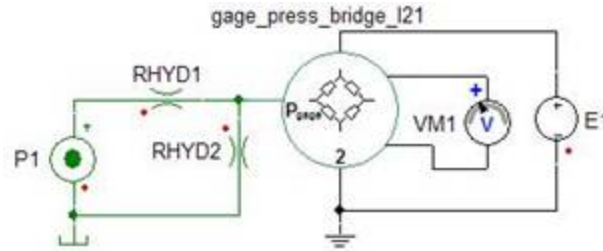


Figure 2. Application example of the Piezoresistive Gage Pressure Sensor model

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	$(10k + 20k * (t \geq 20m)) + 0.101325Meg * 2$ [Pa]
Linear Orifice RHYD1/RHYD2	K	1n [m ³ /(Pa s)]
Piezoresistive Gage Pressure Sensor gage_press_bridge_I21	offset	20m [V]
	bridge_resistance	500 [Ohm]
	max_pressure	10k [Pa]
	min_pressure	0 [Pa]
	full_scale_span	55m [V]
	atmp	101.325k [Pa]

	time_constant	455u [s]
	temp	27 [°C]
	max_non-linearity	5 [%]
	pressure_hysteresis	0.1 [%]
	temp_hysteresis	0.5 [%]
	tempco_span	-0.22 [%/(°C)]
	temp_sens_offset	15u [V/(°C)]
	max_temp	125 [°C]
	min_temp	-40 [°C]
	resistor_tempco	0.28 [%/(°C)]
	nom_res_temp	25 [°C]
	atmp	0.101325Meg [Pa]
Voltage Source E1	EMF	3 [V]

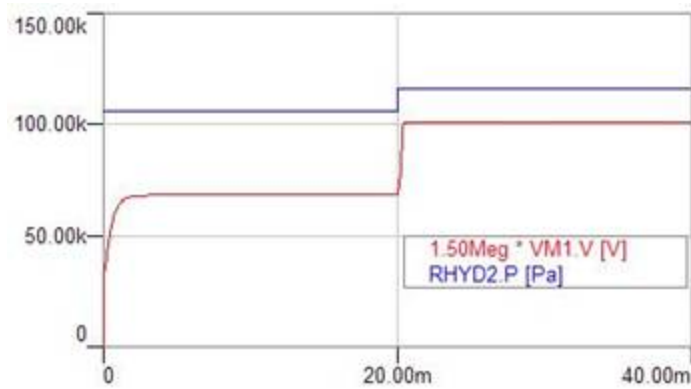


Figure 3. Simulation results-input pressure and output voltage of gage_press_bridge_l21

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References

Level 2 Uncompensated Capacitive Gage Pressure Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

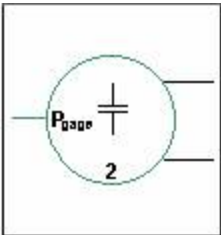


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Description

The Level 2 Uncompensated Capacitive Gage Pressure Sensor model is used to simulate the non-ideal behavior of a capacitor gage pressure sensor. A change in the measured pressure or the atmospheric pressure produces a corresponding change in the variable capacitance output signal.

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Mathematical Description

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Netlist Syntax

```
MODEL GAGE_PRESS_CAP_I2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) out_
plus:= %0, out_minus:= %1, PRESSURE:= %2 ( nominal_capacitance:= @nominal_
```

capacitance, max_pressure:= @max_pressure, min_pressure:= @min_pressure, full_scale_span:= @full_scale_span, max_nonlinearity:= @max_nonlinearity, hysteresis:= @hysteresis, temp:= @temp, max_temp:= @max_temp, min_temp:= @min_temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span, temp_sens_offset:= @temp_sens_offset, time_constant:= @time_constant, atmp:= @atmp) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PRESSURE	Measured pressure	Fluidic
out_plus	Positive capacitor terminal	Electrical
out_minus	Negative capacitor terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
max_pressure	Maximum measurable pressure	Real	1k [Pa]
min_pressure	Minimum measurable pressure	Real	0 [Pa]
full_scale_span	Difference between the maximum and minimum output capacitances	Real	50p [F]
nominal_capacitance	Capacitance of the sensor at the minimum measurable pressure	Real	100p [F]
atmp	Atmospheric pressure	Real	101.325k

			[Pa]
time_constant	Output time constant	Real	0 [s]
temp	Device temperature	Real	27 [°C]
max_non-linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
pressure_hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Nominal capacitance temperature sensitivity	Real	0 [F/(°C)]
max_temp	Maximum operating temperature	Real	125 [°C]
min_temp	Minimum operating temperature	Real	-40 [°C]

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Example

In this example, the output capacitance of the Uncompensated Capacitive Gage Pressure Sensor GAGE_PRESS_CAP_I21 changes in response to the applied pressure. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3-5.

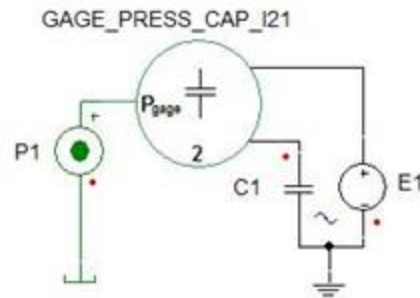


Figure 2. Application example of the Uncompensated Capacitive Gage Pressure Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	101.325k + (500) * (t/60m) [Pa]
Uncompensated Capacitive Gage Pressure Sensor GAGE_PRESS_CAP_I21	max_pressure	500 [Pa]
	min_pressure	100 [Pa]
	full_scale_span	75p [F]
	nominal_capacitance	50p [F]
	atmp	101.325k [Pa]
	time_constant	5m [s]
	temp	27 [°C]
	max_non-linearity	1 [%]
	hysteresis	1 [%]

	temp_hys- teresis	1 [%]
	tempco_span	0.1 [%/(°C)]
	temp_sens_ offset	0.1p [F/(°C)]
	max_temp	125 [°C]
	min_temp	-40 [°C]
Voltage Source (sinusoidal) E1	AMPL	5 [V]
	FREQ	50 [Hz]
	OFF	0 [V]
	TDELAY	0 [s]
	PHASE	0 [degree]
Capacitor C1	C	100p [F]
	V0	0 [V]

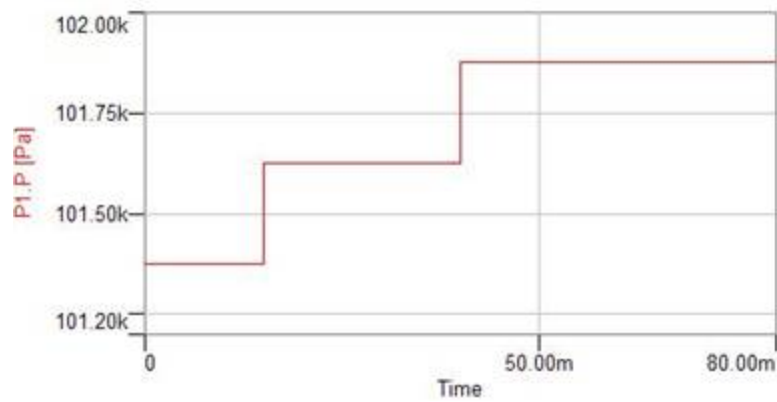


Figure 3. Simulation results-pressure output of P1

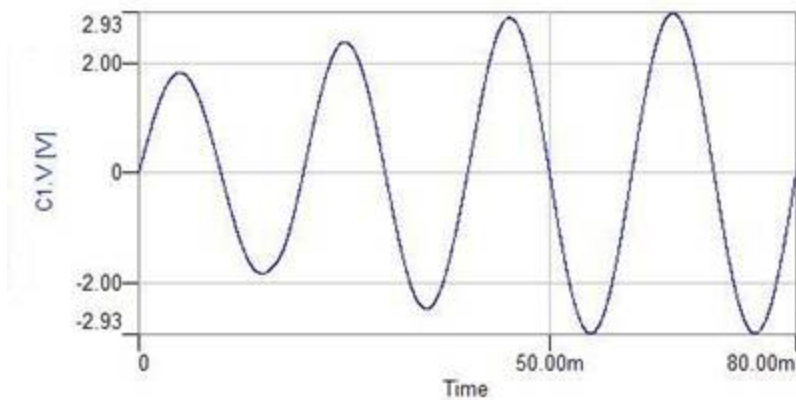


Figure 4. Simulation results-voltage across C1

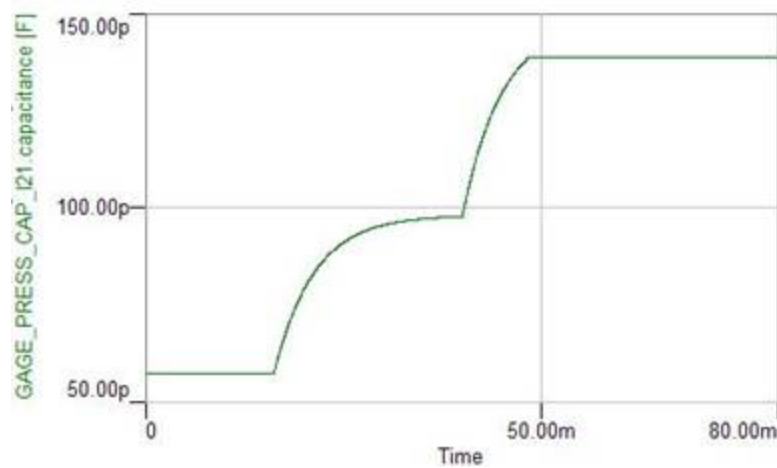


Figure 5. Simulation results-output capacitance of ABS_PRESS_CAP_I21

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References

Level 2 LVDT Gage Pressure Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

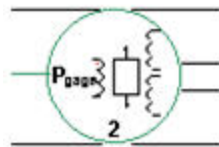


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Description

The Level 2 LVDT Gage Pressure Sensor model is used to simulate the non-ideal behavior of a linear variable differential transformer gage pressure sensor. A change in the applied pressure or the atmospheric pressure produces a corresponding change in the AC voltage output signal.

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Netlist Syntax

```
MODEL GAGE_PRESS_LVDT_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) out_
1_plus:= %0, out_1_minus:= %1, out_2_plus:= %2, out_2_minus:= %3, in_plus:= %4, in_
minus:= %5, PRESSURE:= %6 ( max_pressure:= @max_pressure, min_pressure:= @min_
```


pressure, sensitivity:= @sensitivity, max_nonlinearity:= @max_nonlinearity, hysteresis:= @hysteresis, max_temp:= @max_temp, min_temp:= @min_temp, temp:= @temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span, primary_inductance:= @primary_inductance, primary_resistance:= @primary_resistance, secondary_inductance:= @secondary_inductance, secondary_resistance:= @secondary_resistance, null_voltage:= @null_voltage, atmp:= @atmp, time_constant:= @time_constant) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PRESSURE	Applied pressure	Fluidic
in_plus	Transformer primary positive terminal	Electrical
in_minus	Transformer primary negative terminal	Electrical
out_1_plus	Transformer secondary 1 positive terminal	Electrical
out_1_minus	Transformer secondary 1 negative terminal	Electrical
out_2_plus	Transformer secondary 2 positive terminal	Electrical
out_2_minus	Transformer secondary 2 negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
max_pressure	Maximum measurable pressure	Real	10k [Pa]
min_pressure	Minimum measurable pressure	Real	0 [Pa]
sensitivity	LVDT sensitivity	Real	1 [V/V/Pa]
atmp	Atmospheric pressure	Real	101.325k [Pa]
time_constant	Output time constant	Real	0 [s]
temp	Device temperature	Real	27 [°C]
max_non-linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
max_temp	Maximum operating temperature	Real	125 [°C]
min_temp	Minimum operating temperature	Real	-40 [°C]
primary_inductance	Primary winding inductance	Real	10m [H]

primary_resistance	Primary winding resistance	Real	0 [Ohm]
secondary_inductance	Secondary winding inductance	Real	10m [H]
secondary_resistance	Secondary winding resistance	Real	0 [Ohm]
null_voltage	LVDT null voltage	Real	0 [%]

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Example

In this example, the change in the ouptput pressure of the Pressure Source P1 produces a corresponding change in the AC voltage output signal of the LVDT Gage Pressure Sensor Gage_PRESS_LVDT_I21. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

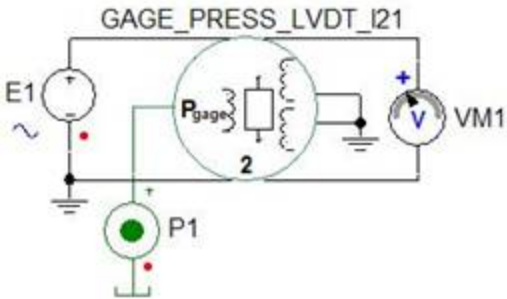


Figure 2. Application example of the LVDT Gage Pressure Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	(10k/1m * t) + 0.101325Meg [Pa]
Voltage Source (sinusoidal) E1	AMPL	3 [V]
	FREQ	3k [Hz]
	OFF	0 [V]

	PHASE	0 [degree]
	TDELAY	0 [s]
LVDT Gage Pressure Sensor GAGE_PRESS_LVDT_I21	max_pres- sure	10k [Pa]
	min_pressure	-10k [Pa]
	sensitivity	100u [V/V/Pa]
	atmp	101.325k [Pa]
	time_con- stant	100u [s]
	temp	27 [°C]
	max_non- linearity	0 [%]
	hysteresis	0 [%]
	temp_hys- teresis	0 [%]
	tempco_span	0 [%/(°C)]
	max_temp	125 [°C]
	min_temp	-40 [°C]
	primary_ inductance	10m [H]
	primary_res- istance	0 [Ohm]
	secondary_ inductance	10m [H]

	secondary_ resistance	0 [Ohm]
	null_voltage	1 [%]

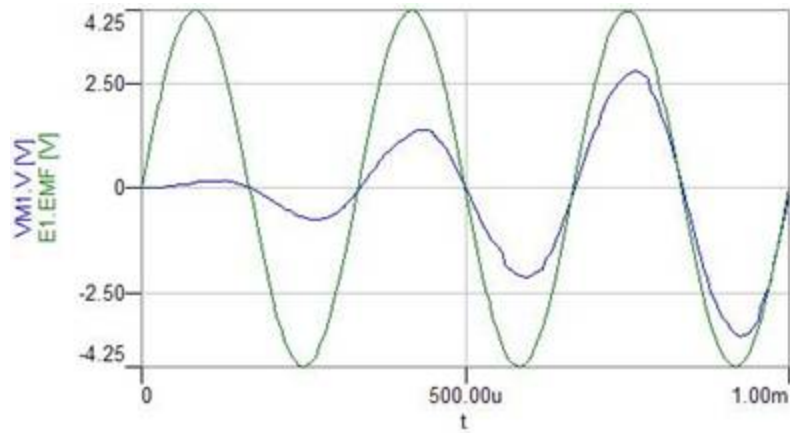


Figure 3. Simulation results-primary and secondary voltage of GAGE_PRESS_LVDT_I21

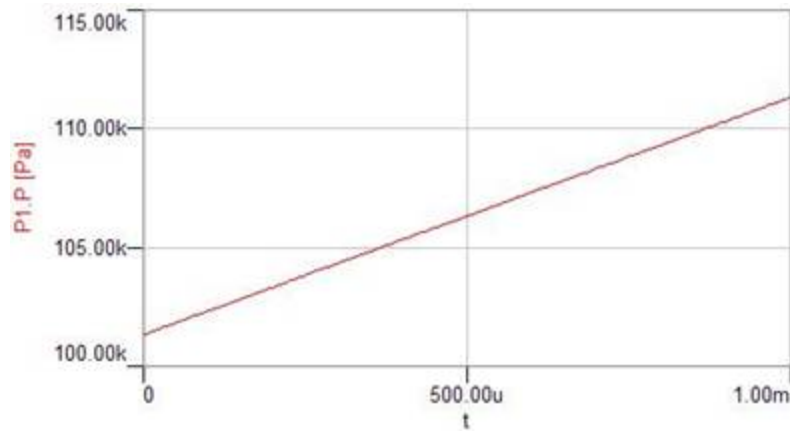


Figure 4. Simulation results-output pressure of P1

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References

Level 2 Piezoelectric Gage Pressure Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

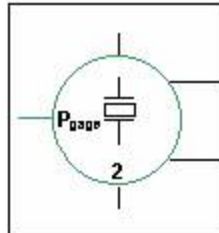


Figure 1. Component symbol

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Description

The Level 2 Piezoelectric Gage Pressure Sensor model is used to simulate the non-ideal behavior of a piezoelectric crystal gage pressure sensor. A change in the applied pressure or the atmospheric pressure produces a corresponding change in the voltage output signal.

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Mathematical Description

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Netlist Syntax

```
MODEL GAGE_PRESS_PE_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
PRESSURE:= %0, out_plus:= %1, out_minus:= %2, Vdd:= %3, Vss:= %4 ( max_pressure:=
```

@max_pressure, min_pressure:= @min_pressure, full_scale_span:= @full_scale_span, offset:= @offset, max_nonlinearity:= @max_nonlinearity, pressure_hysteresis:= @pressure_hysteresis, max_temp:= @max_temp, min_temp:= @min_temp, temp:= @temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tempco_span, temp_sens_offset:= @temp_sens_offset, time_constant:= @time_constant, output_resistance:= @output_resistance, atmp:= @atmp, nominal_supply_current:= @nominal_supply_current) SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PRESSURE	Measured pressure	Fluidic
Vdd	Positive supply	Electrical
Vss	Negative supply	Electrical
out_plus	Positive output terminal	Electrical
out_minus	Negative output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
max_pressure	Maximum measurable pressure	Real	1k [Pa]
min_pressure	Minimum measurable pressure	Real	0 [Pa]
full_scale_span	Difference between the maximum and minimum output	Real	5 [V]

	voltages		
nom_supply_current	Typical supply current	Real	1m [A]
atmp	Atmospheric pressure	Real	101.325k [Pa]
time_constant	Output time constant	Real	0 [s]
temp	Device temperature	Real	27 [°C]
output_resistance	Output resistance	Real	0 [Ohm]
max_non-linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
pressure_hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
max_temp	Maximum operating temperature	Real	125 [°C]
min_temp	Minimum operating temperature	Real	-40 [°C]

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Example

In this example, the Piezoelectric Gage Pressure Sensor Gage_PRESS_PE_I22 measures the output pressure of the Pressure Source P1, and the output voltage of Gage_PRESS_PE_I22

changes in reponse to the applied pressure. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

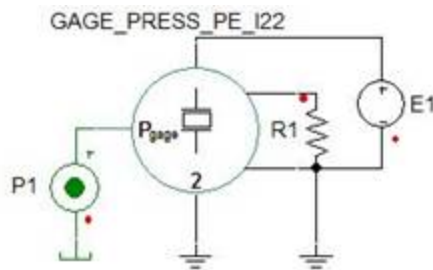


Figure 2. Application example of the Piezoelectric Gage Pressure Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	2E8 + 101.325k [Pa]
Piezoelectric Gage Pressure Sensor GAGE_PRESS_PE_I22	offset	9 [V]
	max_pressure	2k [Pa]
	min_pressure	0 [Pa]
	full_scale_span	5 [V]
	nom_supply_current	1m [A]
	atmp	101.325k [Pa]
	time_constant	455n [s]
	temp	27 [°C]

	output_resistance	200 [Ohm]
	max_non-linearity	1 [%]
	pressure_hysteresis	0 [%]
	temp_hysteresis	0 [%]
	tempco_span	0.02 [%/(°C)]
	temp_sens_offset	0 [V/(°C)]
	max_temp	125 [°C]
	min_temp	-40 [°C]
Voltage Source E1	EMF	20 [V]
Resistor R1	R	1k [Ohm]



Figure 3. Simulation results-output voltage of GAGE_PRESS_PE_I22

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References

Level 2 Potentiometric Gage Pressure Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

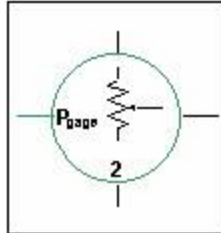


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Description

The Level 2 Potentiometric Gage Pressure Sensor model is used to simulate the non-ideal behavior of a potentiometer gage pressure sensor. A change in the applied pressure or the atmospheric pressure produces a corresponding change in the voltage divider output signal.

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Mathematical Description

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Netlist Syntax

```
MODEL GAGE_PRESS_POTEN_I2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID))
PRESSURE:= %0, OUT:= %1, Vdd:= %2, Vss:= %3 ( max_pressure:= @max_pressure, min_
pressure:= @min_pressure, full_scale_span:= @full_scale_span, offset:= @offset, max_
```

nonlinearity:= @max_nonlinearity, max_hysteresis:= @max_hysteresis, temp_hysteresis:=
@temp_hysteresis, max_temp:= @max_temp, min_temp:= @min_temp, temp:= @temp, tem-
pco_span:= @tempco_span, temp_sens_offset:= @temp_sens_offset, p_resistance:= @p_res-
istance, w_resistance:= @w_resistance, time_constant:= @time_constant, atmp:= @atmp)
SRC: DB(Lib:=@ModelLibraryName) ;

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PRESSURE	Applied pressure	Fluidic
Vdd	Positive supply	Electrical
Vss	Negative supply	Electrical
OUT	Output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
p_resistance	Potentiometer resistance	Real	10k [Ohm]
max_pressure	Maximum measurable pressure	Real	10k [Pa]
min_pressure	Minimum measurable pressure	Real	0 [Pa]
full_scale_span	Difference of maximum and minimum output voltages	Real	10 [V]
atmp	Atmospheric pressure	Real	101.325k [Pa]
w_resistance	Potentiometer wiper resistance	Real	0 [Ohm]
time_constant	Output time constant	Real	0 [s]
temp	Device temperature	Real	27 [°C]
max_non-linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
max_hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature	Real	0 [%/(°C)]

	coefficient as a percentage of full-scale span		
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
max_temp	Maximum operating temperature	Real	125 [°C]
min_temp	Minimum operating temperature	Real	-40 [°C]

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Example

In this example, the output voltage of the Potentiometric Differential Pressure Sensor GAGE_PRESS_POTEN_I22 changes in response to the applied pressure source P1. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

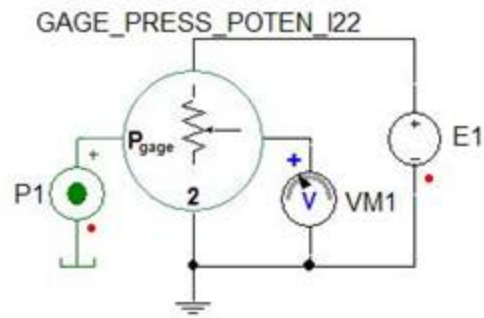


Figure 2. Application example of the Pressure Switch Gage Pressure Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	$(6894.757 * 5k) * (t/40m)$ [Pa]
Voltage Source E1	EMF	10 [V]
Potentiometric Differential Pressure Sensor DIFF_PRESS_POTEN_I22	offset	$0.1 * E1.EMF$ [V]
	p_resistance	5k [Ohm]
	max_pressure	5k [Pa]
	min_pressure	0 [Pa]
	full_scale_span	$0.9 * E1.EMF$ [V]
	w_resistance	0 [Ohm]
	time_constant	0 [s]
	temp	27 [°C]
	max_non-linearity	0 [%]
	max_hysteresis	0 [%]
	temp_hysteresis	0 [%]
	tempco_span	0.036 [%/(°C)]

	temp_sens_offset	0 [V/(°C)]
	max_temp	188 [°C]
	min_temp	-21 [°C]

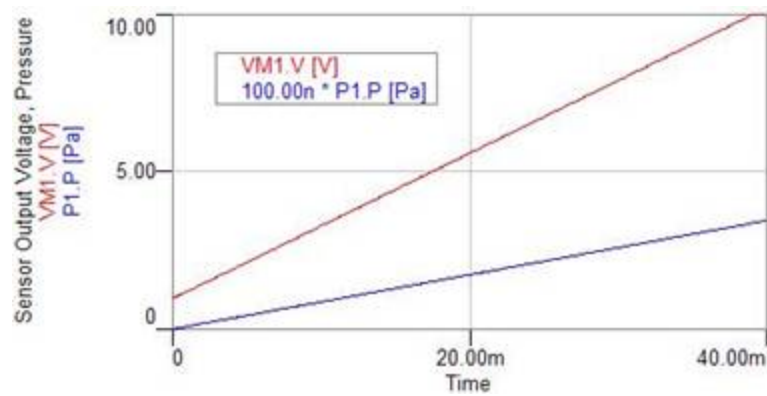


Figure 3. Simulation results-input pressure and output voltage of GAGE_PRESS_POTEN_I22

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References

Level 2 Pressure Switch Gage Pressure Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

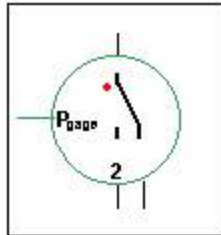


Figure 1. Component symbol

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Description

The Level 2 Pressure Switch Gage Pressure Sensor model is used to simulate the non-ideal behavior of a gage pressure-sensing switch. If the gage pressure applied to the switch exceeds the switch's threshold pressure, the switch changes position from its normally closed terminal to its normally open terminal.

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Netlist Syntax

```
MODEL GAGE_PRESS_SW_I2 ?InstanceName(@InstanceName):(@Refbase)@(ID))  
PRESSURE:= %0, nmnc:= %1, nmno:= %2, np:= %3 ( threshold_pressure:= @threshold_pres-  
sure, response_time:= @response_time, atmp:= @atmp, switch_resistance:= @switch_res-  
istance) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
PRESSURE	Applied pressure	Fluidic
np	Positive terminal	Electrical
nmnc	Normally closed negative terminal	Electrical
nmno	Normally open negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
threshold_pressure	Switch threshold pressure	Real	101.325k [Pa]
atmp	Atmospheric pressure	Real	101.325k [Pa]
switch_resistance	On-state resistance	Real	0 [Ohm]
response_time	Response time	Real	0 [s]

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Example

In this example, when the output pressure of the Pressure Source P1 is below the pressure limit of the Pressure Switch Gage Pressure Sensor GAGE_PRESS_SW_I21, the resistor Rno is connected to the current source via GAGE_PRESS_SW_I21; when the output pressure of P1 exceeds the pressure limit of GAGE_PRESS_SW_I21, the switch changes position from its normally closed terminal to its normally open terminal, and hence connects Rnc to the current source instead. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 - 5.

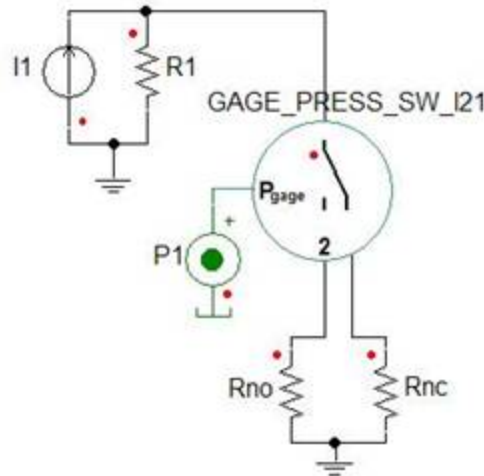


Figure 2. Application example of the Pressure Switch Gage Pressure Sensor

Table 3

Component	Parameter	Value [Unit]
Pressure Source P1	VALUE	$101325 + 500k \cdot (time \geq 5m) - 100k \cdot (time > 25m)$ [Pa]
Current Source I1	IS	1 [A]
Resistor Rno/Rnc	R	1k [Ohm]
Resistor R1	R	1000k [Ohm]
Pressure Switch Gage Pressure Sensor GAGE_PRESS_SW_I21	threshold_pressure	500k [Pa]
	atmp	0.101325Meg [Pa]

	switch_resistance	10 [Ohm]
	response_time	10m [s]

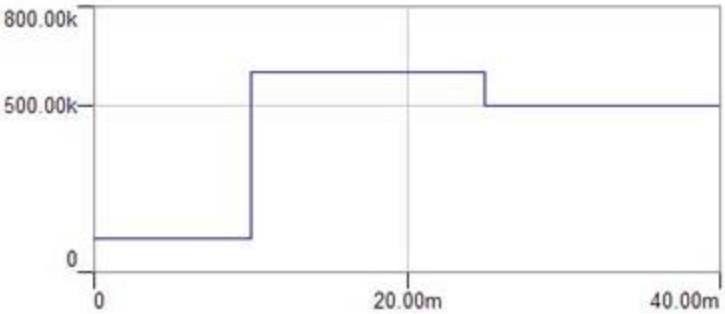


Figure 3. Simulation results-output pressure of P1

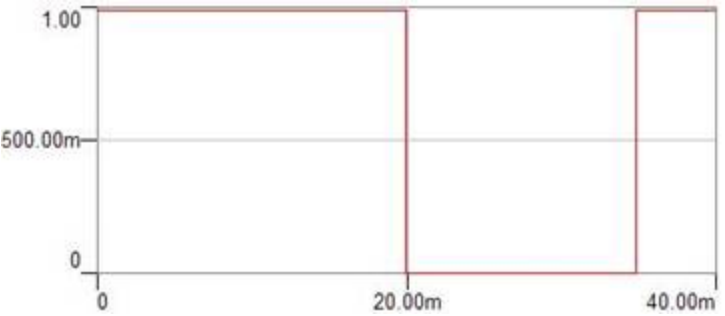


Figure 4. Simulation results-current through Rnc

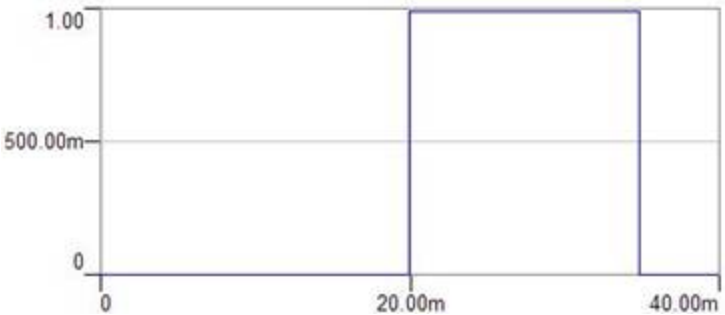


Figure 5. Simulation results-current through Rno

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References

Level 2 Temperature Sensor Models

The Level 2 Temperature Sensor Models simulate the non-ideal behavior of seven different types of temperature sensors.

All of the temperature sensor models have conservative input pins that must be connected to a thermal network and conservative output pins that must be connected to an electrical network. The models also feature nonconservative parameters that can be changed in order to tailor the behavior of the model to that of a specific real device.

As shown in the following example, temperature sensor models for the thermal domain have red conservative input pins that must be connected to a thermal network. The models also have black pins that must be connected to an electrical network.

The Level 2 Temperature Sensor Models feature models for the following temperature-sensing mechanisms:

- Voltage-Output IC ([IC_V_I2](#)): A change in temperature causes a linear change in the output voltage of a temperature-sensing integrated circuit.
- Thermocouple: A temperature differential at two points along a bimetallic wire junction produces an output voltage.
Type K: ([K_THERMOCOUPLE_I2](#))
Types J, T, E, N, B, R, S: ([NON_K_THERMOCOUPLE_I2](#))
- NTC Thermistor ([NTC_THERMISTOR_I2](#)): A change in temperature causes an exponential change in the resistance of a negative temperature coefficient thermistor.
- Potentiometric ([PT_THETA_I2](#)): A change in temperature moves a potentiometer wiper, producing a change in the voltage divider output signal.
- RTD ([RTD_I2](#)): A change in temperature causes a linear change in the resistance of a temperature-dependent resistor.
- Temperature Switch ([TEMP_SWITCH_I2](#)): The absolute temperature at a specified threshold causes a bimetallic switch to change state from closed to open or from open to closed.

Level 2 Voltage-Output IC Temperature Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

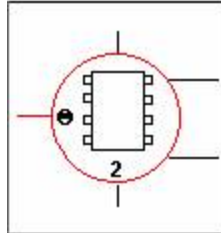


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Description

The Level 2 Voltage-Output IC Temperature Sensor model simulates the non-ideal behavior of an integrated-circuit temperature sensor with a linear voltage output.

The model has one conservative thermal-nature pin for its temperature input and four conservative electrical-nature pins. Two of the electrical pins are to connect the model to its power supply and to ground. The other two nodes are for its voltage output. The negative output node should be connected to ground if the model is connected to an electrical network in which no other element is connected to ground.

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Mathematical Description

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Netlist Syntax

```
MODEL IC_V_I2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) THETA:= %0, Vdd:= %1, Vss:= %2, out_plus:= %3, out_minus:= %4 ( input_current:= @input_current, output_resistance:= @output_resistance, time_constant:= @time_constant, max_temp:= @max_temp, min_temp:= @min_temp, full_scale_span:= @full_scale_span, offset:= @offset, max_nonlinearity:= @max_nonlinearity, hysteresis:= @hysteresis) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
THETA	Measured temperature	Thermal
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical
out_plus	Positive output terminal	Electrical
out_minus	Negative output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
input_current	Typical sensor input current	Real	5m [A]
output_resistance	Output resistance	Real	0 [Ohm]
max_temp	Maximum measurable temperature	Real	473 [K]

min_temp	Minimum measurable temperature	Real	223 [K]
max_non-linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
full_scale_span	Difference of outputs at maximum and minimum temperatures	Real	4.5 [V]
time_constant	Output time constant	Real	0 [s]
offset	Output voltage at minimum measurable temperature	Real	0 [V]

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Example

In this example, the Voltage-Output IC Temperature Sensor IC_V_I21 measures the temperature of the Temperature Source T1, and the voltage output of IC_V_I21 changes accordingly. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

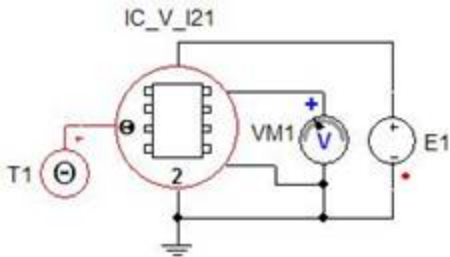


Figure 2. Application example of the Voltage-Output IC Temperature Sensor

Table 3

Component	Parameter	Value [Unit]
Temperature Source T1	VALUE	-50 + 175 * (t>=60) + 175 * (t>=300) [°F]

Voltage-Output IC Temperature Sensor IC_V_I21	input_current	90 [uA]
	output_resistance	0 [Ohm]
	max_temp	300 [°F]
	min_temp	-50 [°F]
	max_non-linearity	0.2 [%]
	hysteresis	0 [%]
	full_scale_span	3.5 [V]
	time_constant	60 [s]
	offset	-0.5 [V]
Voltage Source E1	EMF	5 [V]

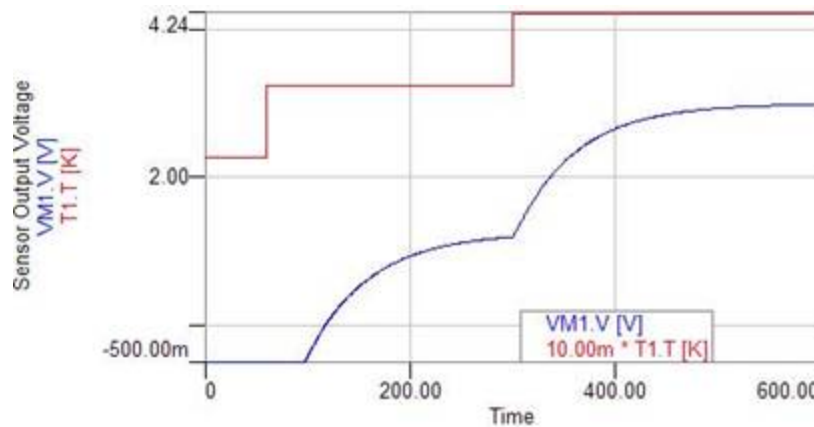


Figure 3. Simulation results-output voltage of IC_V_I21 and temperature of T1

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References

Level 2 Thermocouple (Type K) Temperature Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

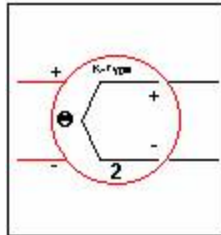


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Description

The Level 2 Thermocouple (Type K) Temperature Sensor model simulates the non-ideal behavior of type K thermocouples in temperatures above zero degrees Celsius.

The model has two conservative thermal-nature pins for its absolute and reference temperature inputs and two conservative electrical-nature pins for its voltage output. The negative output pin of the thermocouple should be connected to an electrical ground if it is connected to an electrical network in which at least one other element is not grounded.

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Netlist Syntax

```
MODEL K_THERMOCOUPLE_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
THETA:= %0, REF:= %1, OUT_p:= %2, OUT_m:= %3 ( a0:= @a0, a1:= @a1, a2:= @a2, a3:=
@a3, a4:= @a4, a5:= @a5, a6:= @a6, a7:= @a7, a8:= @a8, a9:= @a9, a10:= @a10, a11:=
@a11, a12:= @a12, a13:= @a13, a14:= @a14, a15:= @a15, error:= @error, output_res-
istance:= @output_resistance, alpha0:= @alpha0, alpha1:= @alpha1, time_constant:= @time_
constant) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
THETA	Measured temperature	Thermal
REF	Reference temperature	Thermal
OUT_p	Positive output terminal	Electrical
OUT_m	Negative output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
a0	Zero-order coefficient	Real	-17.6004m [V]
a1	First-order coefficient	Real	38.9212m [V/K]
a2	Second-order coefficient	Real	18.5588u [V/K ²]
a3	Third-order coefficient	Real	-99.4576n [V/K ³]
a4	Fourth-order coefficient	Real	318.409p [V/K ⁴]
a5	Fifth-order coefficient	Real	-560.728f [V/K ⁵]
a6	Sixth-order coefficient	Real	5.60751e-016 [V/K ⁶]
a7	Seventh-order coefficient	Real	-3.20207e-019 [V/K ⁷]
a8	Eighth-order coefficient	Real	9.71511e-023 [V/K ⁸]
a9	Ninth-order coefficient	Real	-1.21047e-026 [V/K ⁹]
a10	Tenth-order coefficient	Real	0 [V/K ¹⁰]
a11	Eleventh-order coefficient	Real	0 [V/K ¹¹]
a12	Twelfth-order coefficient	Real	0 [V/K ¹²]
a13	Thirteenth-order coefficient	Real	0 [V/K ¹³]

a14	Fourteenth-order coefficient	Real	0 [V/K ¹⁴]
a15	Fifteenth-order coefficient	Real	0 [V/K ¹⁵]
error	Measurement error	Real	0 [%]
output_resistance	Output resistance	Real	0 [Ohm]
alpha0	Exponential term coefficient	Real	0.118598 [V]
alpha1	Exponential exponent coefficient	Real	-0.118343m [1/K ²]
time_constant	Output time constant	Real	0 [s]

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Example

In this example, the Thermocouple (Type K) Temperature Sensor K_THERMOCOUPLE_I21 measures the temperature of the Thermal Resistor RTH2, and the output voltage of K_THERMOCOUPLE_I21 changes accordingly. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

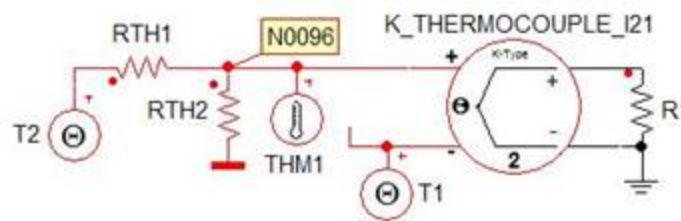


Figure 2. Application example of the Thermocouple (Type K) Temperature Sensor

Table 3

Component	Parameter	Value [Unit]
Temperature Source T2	VALUE	$(273 + (250) * (t \geq 100m) + (500) *$

		$(t \geq 1500\text{m})) * 2 \text{ [K]}$
Temperature Source T1	VALUE	273 [K]
Thermocouple (Type K) Temperature Sensor K_THERMOCOUPLE_I21	a0	-17.6004m [V]
	a1	38.9212m [V/K]
	a2	18.5588u [V/K ²]
	a3	-99.4576n [V/K ³]
	a4	0.318409n [V/K ⁴]
	a5	-0.560728p [V/K ⁵]
	a6	0.560751f [V/K ⁶]
	a7	-3.20207e-019 [V/K ⁷]
	a8	9.71511e-023 [V/K ⁸]
	a9	-1.21047e-026 [V/K ⁹]
	a10	0 [V/K ¹⁰]
	a11	0 [V/K ¹¹]
	a12	0 [V/K ¹²]
	a13	0 [V/K ¹³]
	a14	0 [V/K ¹⁴]
	a15	0 [V/K ¹⁵]
	output_res-	1.25[Ohm]

	istance	
	error	0 [%]
	time_constant	200m [s]
	alpha0	0.118598 [V]
	alpha1	-0.118343m [1/K ²]
Thermal Resistance RTH1/RTH2	K	1 [K/W]

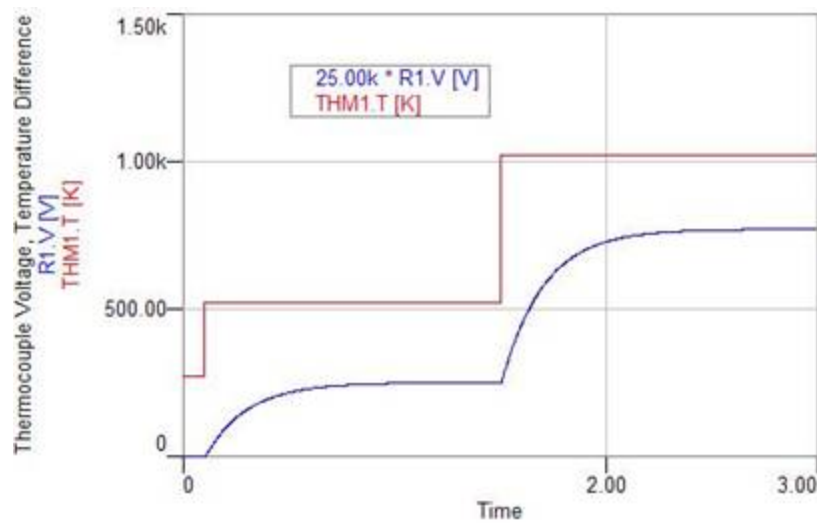


Figure 3. Simulation results-voltage output of K_THERMOCOUPLE_I21 (rescaled) and its differential temperature input

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References

Level 2 Thermocouple (Types J, T, E, N, B, R, S) Temperature Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

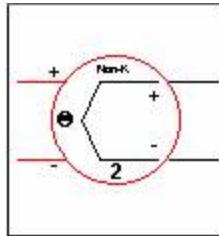


Figure 1. Component symbol

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Description

The Level 2 Thermocouple (Types J, T, E, N, B, R, S) Temperature Sensor model simulates the non-ideal behavior of non-type K thermocouples in any temperature range and type K thermocouples in temperatures below zero degrees Celsius.

The model has two conservative thermal-nature pins for its absolute and reference temperature inputs and two conservative electrical-nature pins for its voltage output. The negative output pin of the thermocouple should be connected to an electrical ground if it is connected to an electrical network in which at least one other element is not grounded.

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Mathematical Description

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Netlist Syntax

```
MODEL NON_K_THERMOCOUPLE_I2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID))
THETA:= %0, REF:= %1, OUT_p:= %2, OUT_m:= %3 ( a0:= @a0, a1:= @a1, a2:= @a2, a3:=
@a3, a4:= @a4, a5:= @a5, a6:= @a6, a7:= @a7, a8:= @a8, a9:= @a9, a10:= @a10, a11:=
@a11, a12:= @a12, a13:= @a13, a14:= @a14, a15:= @a15, time_constant:= @time_constant,
error:= @error, output_resistance:= @output_resistance) SRC: DB(Lib:=@ModelLibraryName)
;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
THETA	Measured temperature	Thermal
REF	Reference temperature	Thermal
OUT_p	Positive output terminal	Electrical
OUT_m	Negative output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
a0	Zero-order coefficient	Real	0 [V]
a1	First-order coefficient	Real	0 [V/K]
a2	Second-order coefficient	Real	0 [V/K ²]
a3	Third-order coefficient	Real	0 [V/K ³]
a4	Fourth-order coefficient	Real	0 [V/K ⁴]

a5	Fifth-order coefficient	Real	0 [V/K ⁵]
a6	Sixth-order coefficient	Real	0 [V/K ⁶]
a7	Seventh-order coefficient	Real	0 [V/K ⁷]
a8	Eighth-order coefficient	Real	0 [V/K ⁸]
a9	Ninth-order coefficient	Real	0 [V/K ⁹]
a10	Tenth-order coefficient	Real	0 [V/K ¹⁰]
a11	Eleventh-order coefficient	Real	0 [V/K ¹¹]
a12	Twelfth-order coefficient	Real	0 [V/K ¹²]
a13	Thirteenth-order coefficient	Real	0 [V/K ¹³]
a14	Fourteenth-order coefficient	Real	0 [V/K ¹⁴]
a15	Fifteenth-order coefficient	Real	0 [V/K ¹⁵]
error	Percent measurement error	Real	0 [%]
output_resistance	Output resistance	Real	0 [Ohm]
time_constant	Output time constant	Real	0 [s]

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Example

In this example, the Thermocouple (Types J, T, E, N, B, R, S) Temperature Sensor NK_THERMOC_I21 measures the temperature of the Thermal Resistor RTH2, and the output voltage of NK_THERMOC_I21 changes accordingly. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

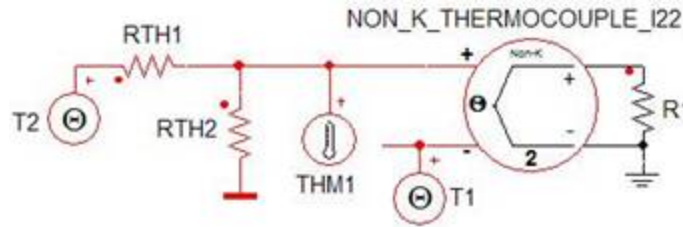


Figure 2. Application example of the Thermocouple (Types J, T, E, N, B, R, S) Temperature Sensor

Table 3

Component	Parameter	Value [Unit]
Temperature Source T1	VALUE	273 [K]
Temperature Source T2	VALUE	$(273 + 250 * (t > 100m)) * 2$ [K]
Thermocouple (Type K) Temperature Sensor NK_THERMOC1	a0	0 [V]
	a1	5.0381187815E-2 [V/K]
	a2	3.0475836930E-5 [V/K ²]
	a3	-8.5681065720E-8 [V/K ³]
	a4	1.3228195295E-10 [V/K ⁴]
	a5	-1.7052958337E-13 [V/K ⁵]

	a6	2.0948090697E-16 [V/K ⁶]
	a7	-1.2538395336E-19 [V/K ⁷]
	a8	1.5631725697E-23 [V/K ⁸]
	a9	0 [V/K ⁹]
	a10	0 [V/K ¹⁰]
	a11	0 [V/K ¹¹]
	a12	0 [V/K ¹²]
	a13	0 [V/K ¹³]
	a14	0 [V/K ¹⁴]
	a15	0 [V/K ¹⁵]
	error	0 [%]
	output_resistance	20 [Ohm]
	time_constant	135m [s]
Thermal Resistance RTH1/RTH2	K	1 [K/W]

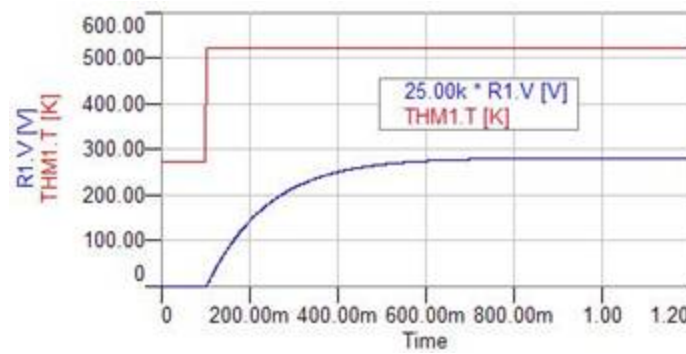


Figure 3. Simulation results-voltage output of NK_THERMOC_I21(rescaled) and its differential temperature input

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References

Level 2 NTC Thermistor Temperature Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

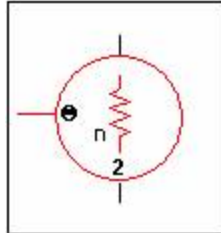


Figure 1. Component symbol

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Description

The Level 2 NTC Thermistor Temperature Sensor model simulates the non-ideal behavior of a negative temperature coefficient thermistor. As the absolute temperature of the thermistor model varies, its resistance varies along an exponential curve described by the Steinhart-Hart equation and three device specific parameters a , b , and c .

The model has a conservative thermal-nature pin for its absolute temperature input and two conservative electrical-nature pins for the thermistor's positive and negative terminals. The positive terminal is the terminal into which current flows.

Nonconservative input nodes can be used to enter a specific thermistor's Steinhart-Hart coefficients a , b , and c as well as its percent deviation from nominal resistance.

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Mathematical Description

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Netlist Syntax

```
MODEL NTC_THERMISTOR_I2 ?InstanceName(@InstanceName):(@Refbase)@(ID))
TEMP:= %0, Rp:= %1, Rm:= %2 ( a:= @a, b:= @b, c:= @c, dev:= @dev, rnom:= @rnom) SRC:
DB(Lib:=@ModelLibraryName);
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
TEMP	Absolute temperature	Thermal
Rp	Positive thermistor terminal	Electrical
Rm	Negative thermistor terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
a	Steinhart-Hart Coefficient "a"	Real	0 [1/K]
b	Steinhart-Hart Coefficient "b"	Real	0 [1/K]
c	Steinhart-Hart Coefficient "c"	Real	0 [1/K]
dev	Percent deviation from nominal resistance	Real	0 [%]
rnom	Thermistor nominal resistance	Real	1k [Ohm]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
R	Thermal resistance [Ohm]	Output	real

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Example

In this example, the NTC Thermistor Temperature Sensor NTC_THERMISTOR_I22 measures the temperature of the Temperature Source T1, and the resistance of NTC_THERMISTOR_I22 changes accordingly. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

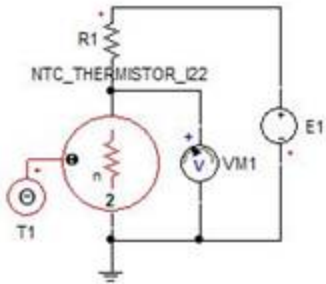


Figure 2. Application example of the NTC Thermistor Temperature Sensor

Table 4

Component	Parameter	Value [Unit]
Temperature Source T1	VALUE	$273 + 200 \cdot (t/40m)$ [K]
NTC Thermistor Temperature Sensor NTC_THERMISTOR_I22	a	1.659880E-03 [1/K]
	b	2.396775E-04 [1/K]
	c	1.168094E-07 [1/K]

	dem	0 [%]
	rnom	1k [Ohm]
Voltage Source E1	EMF	5 [V]

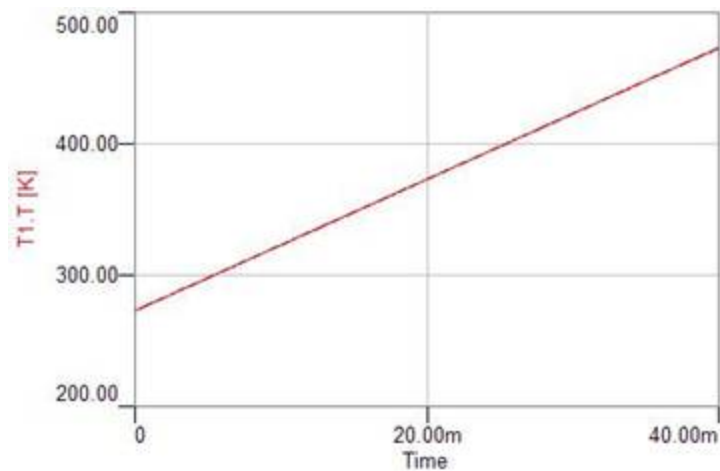


Figure 3. Simulation results-temperature of T1

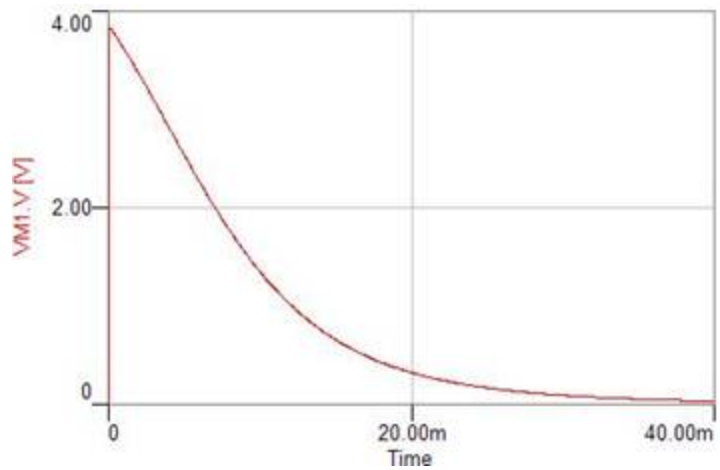


Figure 4. Simulation results-voltage across NTC_THERMISTOR_I22

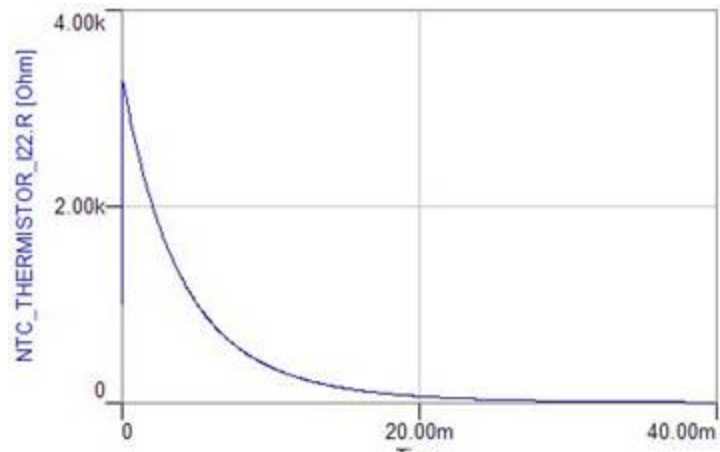


Figure 5. Simulation results-output resistance of NTC_THERMISTOR_I22

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References

Level 2 Potentiometric Temperature Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

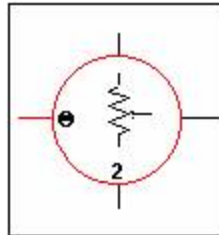


Figure 1. Component symbol

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Description

The Level 2 Potentiometric Temperature Sensor model simulates the non-ideal behavior of a potentiometric temperature sensor. The voltage divider output of the potentiometer model changes linearly in response to a change in temperature.

The model has one conservative thermal-nature pin for its temperature input and three conservative electrical-nature pins. Two of the electrical pins are to connect the model to its power supplies. The remaining node is for the model's output.

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Mathematical Description

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Netlist Syntax

```
MODEL PT_THETA_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) OUT:= %0,  
Vdd:= %1, Vss:= %2, TEMP:= %3 ( max_temp:= @max_temp, min_temp:= @min_temp, full_  
scale_span:= @full_scale_span, offset:= @offset, potentiometer_resistance:= @po-  
tentiometer_resistance, time_constant:= @time_constant, max_nonlinearity:= @max_non-  
linearity, hysteresis:= @hysteresis, wiper_resistance:= @wiper_resistance) SRC: DB  
(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
TEMP	Measured temperature	Thermal
Vdd	Positive power supply terminal	Electrical
Vss	Negative power supply terminal	Electrical
OUT	Output	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor output voltage at minimum temperature	Real	0 [V]
potentiometer_resistance	Resistance of potentiometer	Real	10k [Ohm]
max_temp	Maximum measurable temperature	Real	423 [K]
min_temp	Minimum measurable temperature	Real	223 [K]
full_scale_span	Difference of outputs at maximum and minimum temperatures	Real	10 [V]
max_nonlinearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
wiper_resistance	Potentiometer wiper resistance	Real	0 [Ohm]
time_constant	Output time constant	Real	0 [s]

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Example

In this example, the Potentiometric Temperature Sensor PT_THETA_I21 measures the temperature of the Temperature Source T1, and the output voltage of PT_THETA_I21 changes accordingly. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

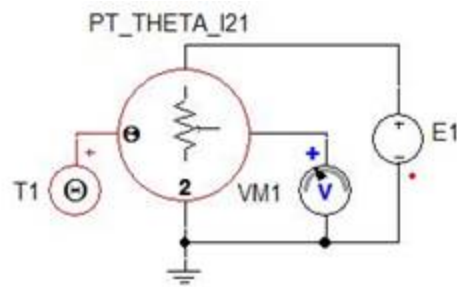


Figure 2. Application example of the Potentiometric Temperature Sensor

Table 3

Component	Parameter	Value [Unit]
Temperature Source T1	VALUE	$-58 + 360 * (t/40m)$ [°C]
Potentiometric Temperature Sensor PT_THETA_I21	offset	$0.1 * E1.EMF$ [V]
	potentiometer_resistance	2k [Ohm]
	max_temp	150 [oC]
	min_temp	-50 [oC]
	time_constant	1m [s]
	max_nonlinearity	5 [%]
	hysteresis	0 [%]
	wiper_resistance	100 [Ohm]
	full_scale_span	$0.9 * E1.EMF$ [V]
Voltage Source E1	EMF	5 [V]

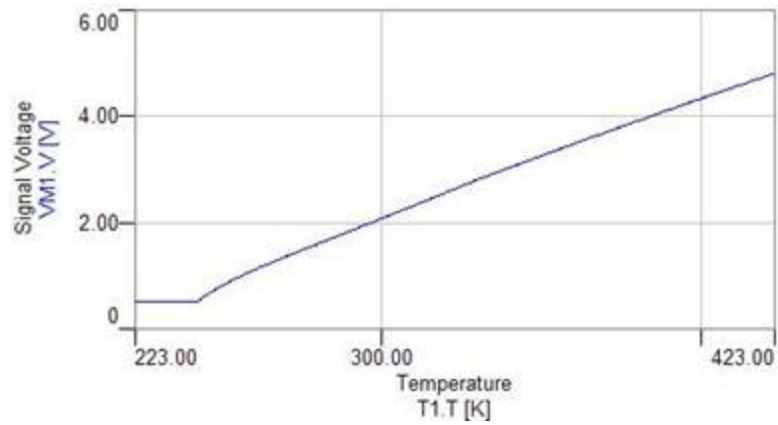


Figure 3. Simulation results-output voltage of PT_THETA_I21 vs. temperature of T1

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References

Level 2 RTD Temperature Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

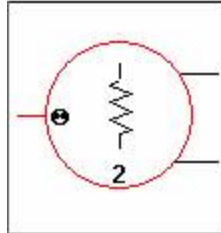


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Description

The Level 2 RTD Temperature Sensor model simulates the non-ideal behavior of a resistance temperature detector (RTD). As the absolute temperature of the RTD model varies, its resistance varies linearly according to its temperature coefficient.

The RTD model has a conservative thermal-nature pin for its absolute temperature input and two conservative electrical-nature pins for its positive and negative terminals. The positive terminal is the terminal into which current flows.

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Mathematical Description

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Netlist Syntax

```
MODEL RTD_I2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) THETA:= %0, np:= %1, nm:= %2 ( ref_resistance:= @ref_resistance, temperature_coefficient:= @temperature_coefficient, error:= @error, ref_res_temp:= @ref_res_temp) SRC: DB(Lib:- :=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
TEMP	Absolute temperature	Thermal
np	Positive RTD terminal	Electrical
nm	Negative RTD terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
temperature_coefficient	RTD temperature coefficient	Real	0.385 [Ohm/ °C]
error	Percent deviation from nominal resistance	Real	0 [%]
ref_resistance	Nominal resistance	Real	100 [Ohm]
ref_res_temp	Temperature at which the RTD assumes nominal resistance	Real	-273.15 [°C]

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Input/Output Quantities

Table 3

Name	Description [Unit]	Direction	Data Type
R	RTD resistance[Ohm]	Output	real

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Example

In this example, the RTD Temperature Sensor RTD_I22 measures the temperature of the Temperature Source T1, and the output resistance of RTD_I22 changes accordingly. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3 and 4.

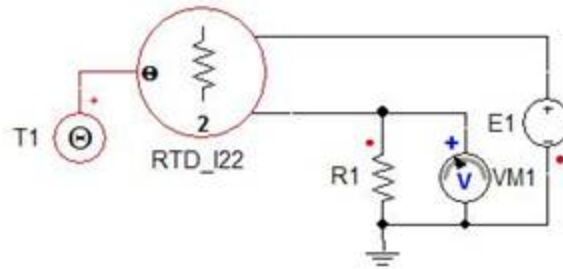


Figure 2. Application example of the RTD Temperature Sensor

Table 4

Component	Parameter	Value [Unit]
Temperature Source T1	VALUE	$-60 + 210 \cdot (t/80m)$ [°F]
RTD Temperature Sensor RTD_I22	temperature_coef-ficient	3.85 [Ohm/°C]
	ref_resistance	1k [Ohm]
	ref_res_temp	0 [K]
	error	5 [%]
Voltage Source E1	EMF	5 [V]

Resistor R1	R	1k [Ohm]

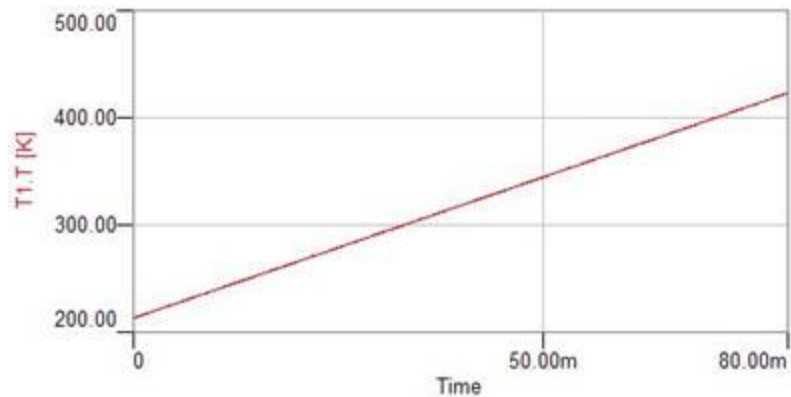


Figure 3. Simulation results- temperature of T1

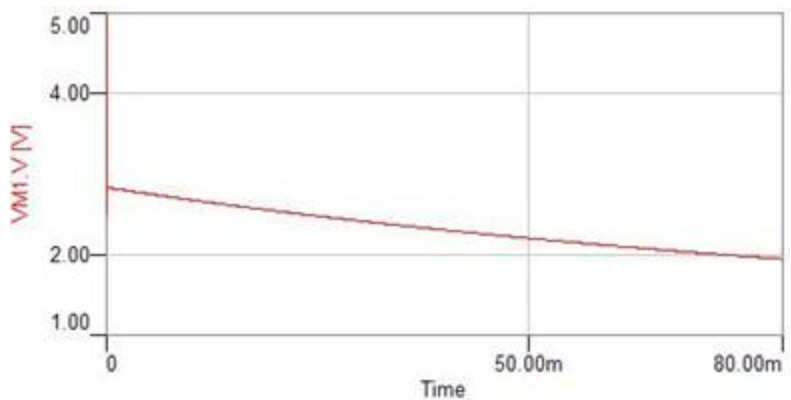


Figure 4. Simulation results-output voltage of RTD_I22

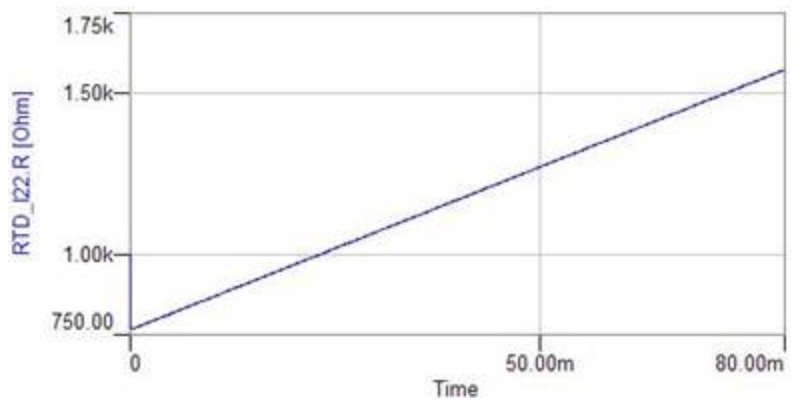


Figure 5. Simulation results-output resistance of RTD_I22

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References

Level 2 Temperature Switch Temperature Sensor

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

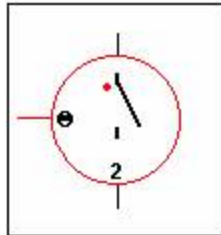


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Description

The Level 2 Temperature Switch Temperature Sensor model simulates the non-ideal behavior of a temperature switch. At a specified threshold temperature, the switch model changes state from closed to open or open to closed.

The model has one conservative thermal-nature pin for its temperature input and two conservative electrical-nature pins for the positive and negative terminals of the switch. The positive terminal is the terminal into which current flows.

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Mathematical Description

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Netlist Syntax

Netlist generated by [Special Component Dialog](#).

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
TEMP	Measured temperature	Thermal
np	Positive terminal	Electrical
nm	Negative terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
switch_resistance	On-state resistance	Real	0 [Ohm]
threshold_temp	Switch threshold temperature	Real	373 [K]
reset_temp	Switch reset temperature	Real	323 [K]
init_state	Switch normal state (0=open, 1-closed)	Real	0
response_time	Switch normal state (open, closed)	Real	0 [s]

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Example

In this example, the temperature of the Temperature Source T1 decides the switching status of the Temperature Switch TEMP_SWITCH_I21. TEMP_SWITCH_I21 is initially closed; when the temperature of T1 is below the switch threshold temperature of TEMP_SWITCH_I21, the switch is open, and Rno is disconnected from the Current Source I1; when the temperature of T1 is over the switch reset temperature of TEMP_SWITCH_I21, the switch resumes its initial status-closed. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

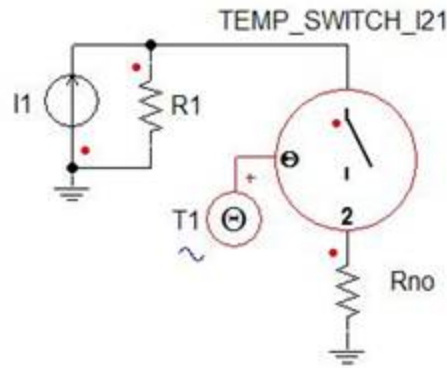


Figure 2. Application example of the Temperature Switch

Table 3

Component	Parameter	Value [Unit]
Temperature Source T1	AMPL	100 [K]
	FREQ	25 [Hz]
	PHASE	0 [degree]
	OFF	300 [K]
	TDELAY	0 [s]
Temperature Switch TEMP_SWITCH_I21	switch_resistance	40m [K]
	threshold_temp	0.373k [K]

	reset_temp	0.323k [K]
	init_state	0
	response_time	500u [s]
Current Source I1	IS	1 [A]
Resistor R1	R	100k [Ohm]
Resistor Rno	R	1k [Ohm]

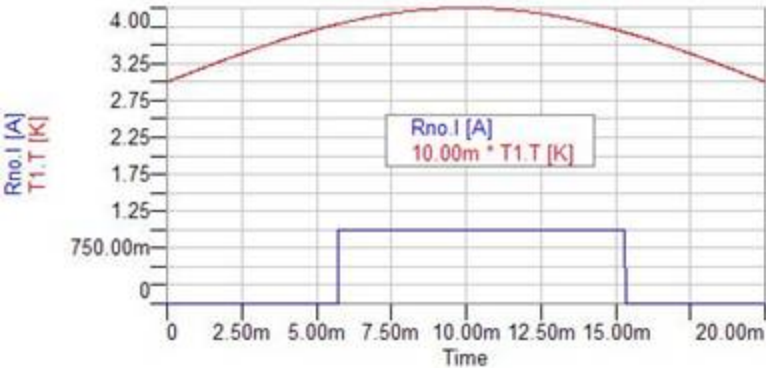


Figure 3. Simulation results-temperature of T1 (scaled) and the current through Rno

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References

Component Dialog Settings

The following Parameters are set in the Component Dialog for the **Level 2 Temperature Switch Component**:

Name:

Specify the Name of the component instance. Select the **Show Name** checkbox to display the name on the schematic.

Parameters:

Device Parameters: Enter a numerical value, a variable, or an expression in the text box. Common parameter types. Look their meaning up in the parameter table.

Switch Initial State: Select the initial state of the switch, either **Open** or **Closed**.

Outputs/Display

For information regarding displaying parameter pins, see *Output/Display Tab* in the main Twin Builder help.

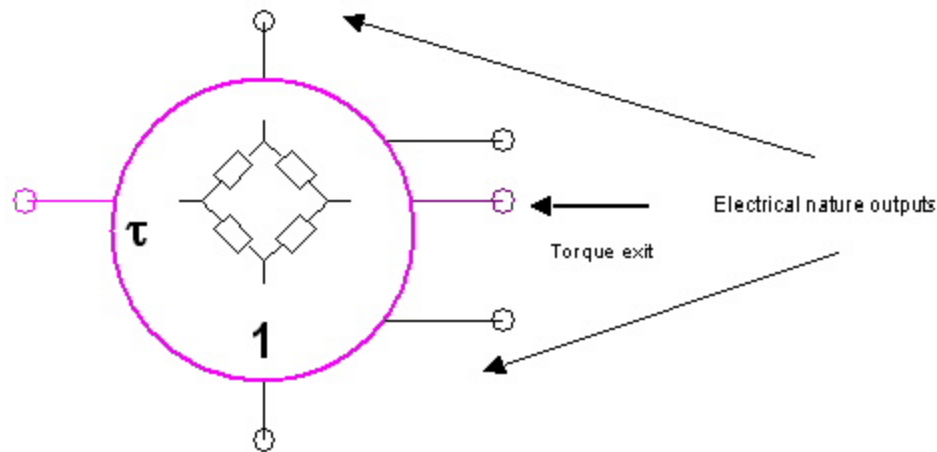
Level 2 Torque Sensor Models

The Level 2 Torque Sensor Models simulate the non-ideal behavior torque sensors.

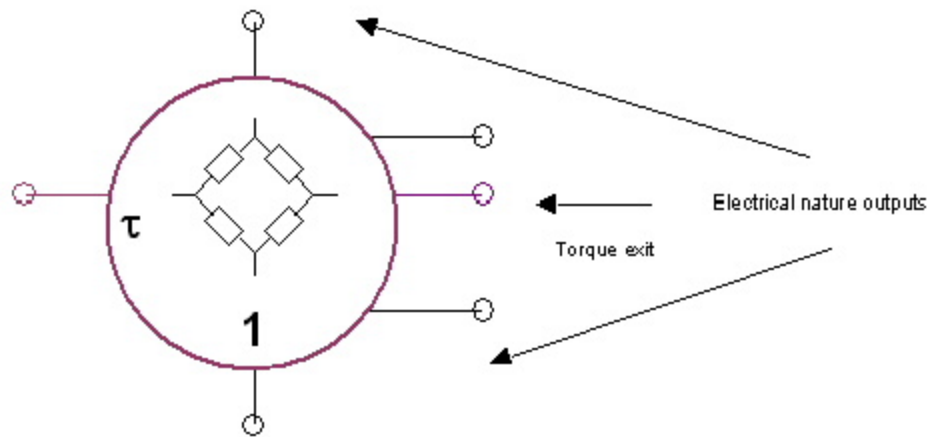
All of the torque sensor models have conservative pins that must be connected to a rotational network. Note that because torque is a through quantity, all torque sensor models have one rotational pin for torque entry and another pin for torque exit.

Like other sensor models, the torque sensor models also have conservative output pins that must be connected to an electrical network and nonconservative parameters that can be changed in order to tailor the behavior of the model to that of a specific real device.

As shown in the following example, torque sensor models for the displacement-force rotational domain have pink conservative input pins that must be connected to a rotational network. The pin on the left side of the model is the pin at which the measured torque should enter. The models also have black pins that must be connected to an electrical network.



Similarly, torque sensor models for the velocity-force rotational domain have purple rotational-nature pins and black electrical nature pins:



The Level 2 Torque Sensor Models feature models for the following torque-sensing mechanisms:

- Strain Gauge: - applied torque deforms the resistors in a Wheatstone bridge, producing a change in the sensor's differential voltage output signal.
- Displacement-Force model: ([SG_TORQUE_DF_I2](#))
Velocity-Force model: ([SG_TORQUE_VF_I2](#))

Level 2 Strain Gauge Torque Sensor (Displacement-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

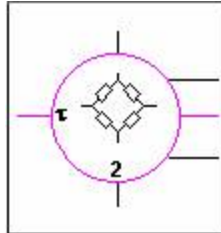


Figure 1. Component symbol

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Description

The Level 2 Strain gauge Torque (Displacement-Force) sensor model is used to simulate the non-ideal behavior of a strain gauge torque sensor in the Twin Builder displacement-force rotational domain. A change in the model's torque input produces a corresponding change in the model's Wheatstone bridge, which in turn produces a change in the model's linear voltage output.

The model has two conservative input pin in the displacement-force rotational domain for its torque input and output and four conservative electrical-domain pins. Two of the electrical-domain pins are for the model's power supplies, and two are for its differential voltage output.

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Netlist Syntax

```
MODEL SG_TORQUE_DF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
TORQUE_IN:= %0, TORQUE_OUT:= %1, OUT_P:= %2, OUT_M:= %3, Vdd:= %4, Vss:= %5 (
moment_inertia:= @moment_inertia, max_torque:= @max_torque, min_torque:= @min_torque,
full_scale_span:= @full_scale_span, offset:= @offset, max_nonlinearity:= @max_nonlinearity,
hysteresis:= @hysteresis, max_temp:= @max_temp, min_temp:= @min_temp, temp_hys-
teresis:= @temp_hysteresis, tempco_span:= @tempco_span, temp_sens_offset:= @temp_
sens_offset, corner_frequency:= @corner_frequency, temp:= @temp, resistor_tempco:= @res-
istor_tempco, nominal_res_temp:= @nominal_res_temp, p_resistance:= @p_resistance) SRC:
DB(Lib:=@ModelLibraryName);
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
TORQUE_IN	Torque entrance	Rotational
TORQUE_OUT	Torque exit	Rotational
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive power supply	Electrical
Vss	Negative power supply	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
corner_frequency	Corner frequency of the input signal	Real	0 [Hz]
temp	Device temperature	Real	27 [°C]
max_torque	Maximum measurable torque	Real	50 [Nm]
min_torque	Minimum measurable torque	Real	0 [Nm]
full_scale_span	Difference of output voltages at maximum and minimum torques	Real	5 [V]
max_non-linearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	150 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]
temp_sens_offset	Offset voltage temperature sensitivity	Real	0 [V/(°C)]

p_resistance	Bridge resistance	Real	10k [Ohm]
resistor_tem-pco	Resistor temperature coef-ficient	Real	0 [%/ (°C)]
nominal_res_temp	Temperature of nominal bridge resistance	Real	25 [°C]
moment_iner-tia	Sensor rotational moment of inertia	Real	1m [kg m ²]

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Example

In this example, the Strain Gauge Torque (Displacement-Force) sensor SG_TORQUE_DF_I22 measures the torque output of the Torque Source F_ROT B1, and produces a corresponding change in its linear voltage output. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

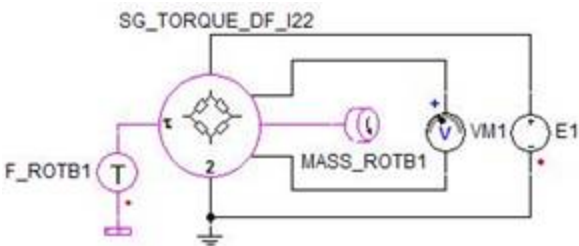


Figure 2. Application example of the Strain Gauge Torque (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROT B1	VALUE	2800 * (t/30m) [N]
	J	1 [kg m]
	PHI0	0 [rad]
Mass MASS_ROT B1	OMEGA0	0 [rad/s]

Voltage Source E1	EMF	10 [V]
Strain Gauge Torque (Displacement-Force) sensor SG_TORQUE_DF_I22	offset	0 [V]
	corner_frequency	0 [Hz]
	temp	27 [°C]
	max_torque	2714 [Nm]
	min_torque	0 [Nm]
	full_scale_span	2m * E1.EMF [V]
	hysteresis	0 [%]
	max_temp	225 [°C]
	min_temp	-65 [°C]
	temp_hysteresis	0 [%]
	p_resistance	350 [Ohm]
	resistor_tempco	0 [%/(°C)]
	nominal_res_temp	25 [°C]
	nonlinearity	0.1 [%]
	offset_temp_sens	56 [V/(°C)]
	tempco_span	0.05 [%/

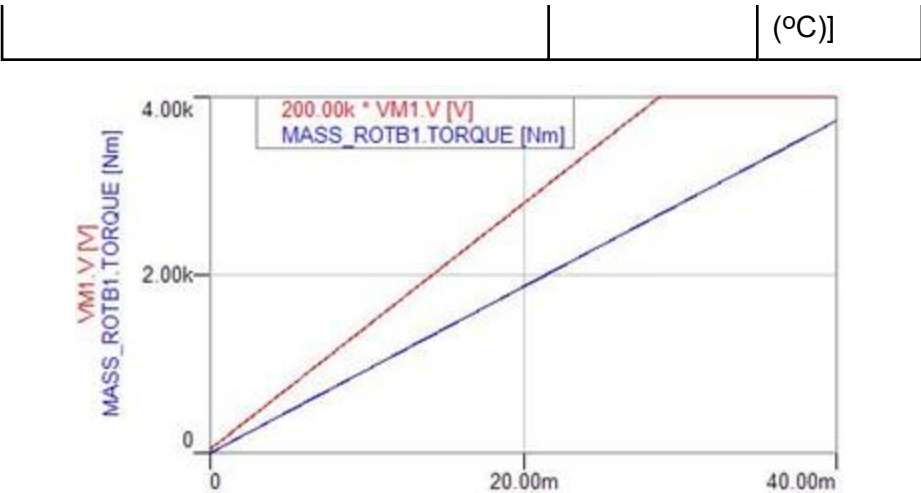


Figure 3. Simulation results-output voltage of SG_TORQUE_DF_I22 (scaled) and torque output of F_ROTb1

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References

Level 2 Strain Gauge Torque Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

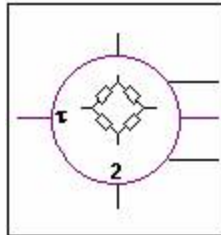


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Description

The Level 2 Strain gauge Torque (Velocity-Force) sensor model is used to simulate the non-ideal behavior of a strain gauge torque sensor in the Twin Builder velocity-force rotational domain. A change in the model's torque input produces a corresponding change in the model's Wheatstone bridge, which in turn produces a change in the model's linear voltage output.

The model has two conservative input pin in the velocity-force rotational domain for its torque input and output and four conservative electrical-domain pins. Two of the electrical-domain pins are for the model's power supplies, and two are for its differential voltage output.

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Netlist Syntax

```
MODEL SG_TORQUE_VF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))
TORQUE_IN:= %0, TORQUE_OUT:= %1, OUT_P:= %2, OUT_M:= %3, Vdd:= %4, Vss:= %5 (
max_torque:= @max_torque, min_torque:= @min_torque, full_scale_span:= @full_scale_span,
offset:= @offset, nonlinearity:= @nonlinearity, hysteresis:= @hysteresis, max_temp:= @max_
temp, min_temp:= @min_temp, temp_hysteresis:= @temp_hysteresis, tempco_span:= @tem-
pco_span, offset_temp_sens:= @offset_temp_sens, corner_frequency:= @corner_frequency,
temp:= @temp, resistor_tempco:= @resistor_tempco, nominal_res_temp:= @nominal_res_
temp, p_resistance:= @p_resistance) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
TORQUE_IN	Torque entrance	Rotational_V
TORQUE_OUT	Torque exit	Rotational_V
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical
Vdd	Positive power supply	Electrical
Vss	Negative power supply	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
offset	Sensor offset voltage	Real	0 [V]
corner_frequency	Corner frequency of the input signal	Real	0 [Hz]
temp	Device temperature	Real	27 [°C]
max_torque	Maximum measurable torque	Real	50 [Nm]
min_torque	Minimum measurable torque	Real	0 [Nm]
full_scale_span	Difference of output voltages at maximum and minimum torques	Real	5 [V]
hysteresis	Hysteresis as a percentage of full-scale span	Real	0 [%]
max_temp	Maximum operating temperature	Real	150 [°C]
min_temp	Minimum operating temperature	Real	-50 [°C]
temp_hysteresis	Temperature hysteresis as a percentage of full-scale span	Real	0 [%]
p_resistance	Bridge resistance	Real	10k [Ohm]
resistor_tempco	Resistor temperature coefficient	Real	0 [%/(°C)]
nominal_res_	Temperature of nominal bridge	Real	25 [°C]

temp	resistance		
nonlinearity	Nonlinearity as a percentage of full-scale span	Real	0 [%]
offset_temp_sens	Offset voltage temperature sensitivity	Real	0 [V/(°C)]
tempco_span	Output voltage temperature coefficient as a percentage of full-scale span	Real	0 [%/(°C)]

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Example

In this example, the Strain Gauge Torque (Velocity-Force) sensor SG_TORQUE_VF_I22 measures the torque output of the Torque Source F_ROT1, and produces a corresponding change in its linear voltage output. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

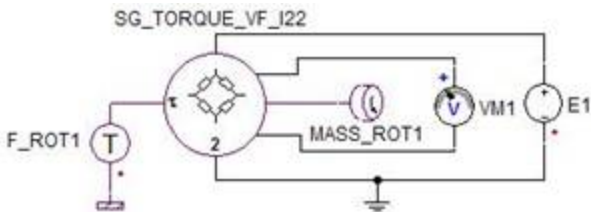


Figure 2. Application example of the Strain Gauge Torque (Velocity-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Torque Source F_ROT1	VALUE	2800 * (t/30m) [N]
Mass MASS_ROT1	J	1 [kg m]
	PHI0	0 [rad]
	OMEGA0	0 [rad/s]
Voltage Source E1	EMF	10 [V]
Strain Gauge Torque (Velocity-Force) sensor SG_TORQUE_VF_I22	offset	0 [V]
	corner_fre- quency	0 [Hz]
	temp	27 [°C]
	max_torque	2714 [Nm]
	min_torque	0 [Nm]
	full_scale_ span	2m * E1.EMF [V]
	hysteresis	0 [%]
	max_temp	225 [°C]
	min_temp	-65 [°C]
	temp_hys-	0 [%]

	teresis	
	p_resistance	350 [Ohm]
	resistor_tem- pco	0 [%/(°C)]
	nominal_res_ temp	25 [°C]
	nonlinearity	0.1 [%]
	offset_temp_ sens	56 [V/(°C)]
	tempco_span	0.05 [%/(°C)]

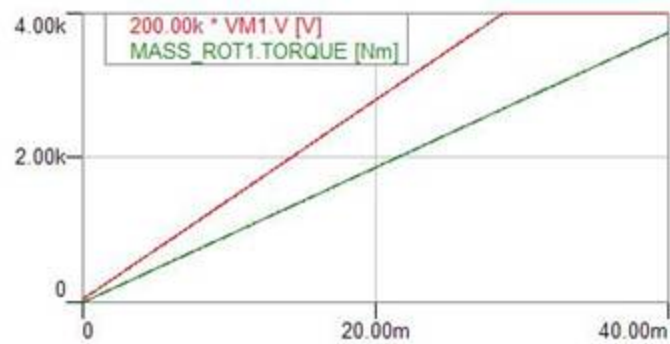


Figure 3. Simulation results-output voltage of SG_TORQUE_VF_I22 (scaled) and torque output of F_ROT1

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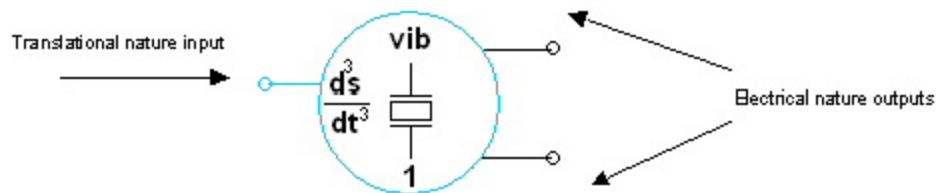
References

Level 2 Vibration Sensor Models

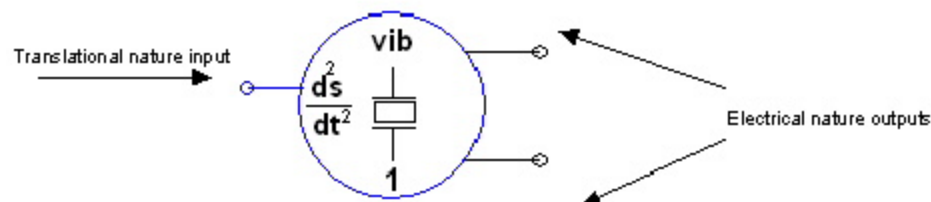
The Level 2 Vibration Sensor Models simulate the non-ideal behavior of two different types of vibration sensors. Models are available for use with the Twin Builder *displacement-force* and *velocity-force* translational domains.

All of the vibration sensor models have conservative input pins that must be connected to a translational network and conservative output pins that must be connected to an electrical network. The models also feature nonconservative parameters that can be changed in order to tailor the behavior of the model to that of a specific real device.

As shown in the following example, vibration sensor models for the displacement-force translational domain have light blue conservative input pins that must be connected to a displacement-force translational network. The models also have black conservative pins that must be connected to an electrical network.



Similarly, vibration sensor models for the velocity-force translational domain have dark blue translational-nature input pins and black electrical-nature pins.



The Level 2 Vibration Sensor Models feature models for the following vibration- sensing mechanisms:

- Acceleration-sensing - a piezoelectric crystal is oriented such that it is sensitive only to the second derivative (acceleration) of a translational displacement within a small range of frequencies. The voltage output of the sensor is proportional to the measured acceleration.
Displacement-Force model: ([ACC_VIB_DF_I2](#))
Velocity-Force model: ([ACC_VIB_VF_I2](#))
- Jerk-sensing - a piezoelectric crystal is oriented such that it is sensitive only to the third derivative (jerk) of a translational displacement within a small range of frequencies. The voltage output of the sensor is proportional to the measured jerk.

Displacement-Force model: ([JERK_VIB_DF_I2](#))

Velocity-Force model: ([JERK_VIB_VF_I2](#))

Level 2 Acceleration-Sensing Vibration Sensor (Displacement-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

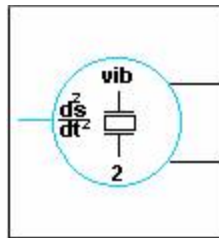


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Description

The Level 2 Acceleration-Sensing Vibration (Displacement-Force) sensor model is used to simulate the non-ideal behavior of an acceleration-sensing vibration sensor in the Twin Builder Displacement-Force translational domain. A change in the second derivative of the model's translational input produces a corresponding change in the model's linear voltage output.

The model has one conservative input pin in the displacement-force translational domain for its vibration input and two conservative electrical-domain pins for its voltage output. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is connected to ground.

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Netlist Syntax

```
MODEL ACC_VIB_DF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID)) POSITION:=
%0, OUT_P:= %1, OUT_M:= %2 ( knock_resonant_frequency:= @knock_resonant_frequency,
q_factor:= @q_factor, peak_sens:= @peak_sens, offset:= @offset, temp_sens:= @temp_sens,
temp:= @temp, output_resistance:= @output_resistance) SRC: DB(Lib:=@ModelLibraryName)
;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured vibration	Translational
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
knock_resonant_fre- quency	Resonant frequency of the target vibration	Real	2k [Hz]
offset	Sensor offset voltage	Real	0 [V]
temp_sens	Output temperature sensitivity	Real	0 [V/(°C)]
temp	Sensor temperature	Real	27 [°C]

output_resistance	Output resistance	Real	0 [Ohm]
Q_factor (must be a positive nonzero value)	Q-factor of the internal filter	Real	2
peak_sensitivity	Sensor sensitivity	Real	0.5m [V/(m/s ³)]

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Example

In this example, a change in the second derivative of the position of MASS_TRB1 produces a corresponding change in the linear voltage output of the Acceleration-Sensing Vibration (Displacement-Force) sensor ACC_VIB_DF_I22. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

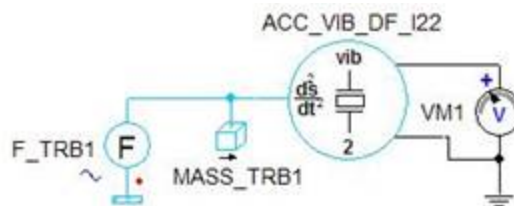


Figure 2. Application example of the Acceleration-Sensing Vibration (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Force Source F_TRB1	AMPL	9.8 [N]
	FREQ	5.2k [Hz]
	PHASE	0 [degree]
	OFF	0 [N]
	TDELAY	0 [s]

Mass MASS_TRB1	M	1 [kg]
	S0	5.2k
	V0	0 [m/s]
Acceleration-Sensing Vibration (Displacement-Force) sensor ACC_VIB_DF_I22	knock_resonant_frequency	5200 [Hz]
	offset	0 [V]
	temp_sens	0 [V/(°C)]
	temp	27 [°C]
	output_resistance	0 [Ohm]
	Q_factor	26
	peak_sensitivity	0.204 [V/(m/s³)]

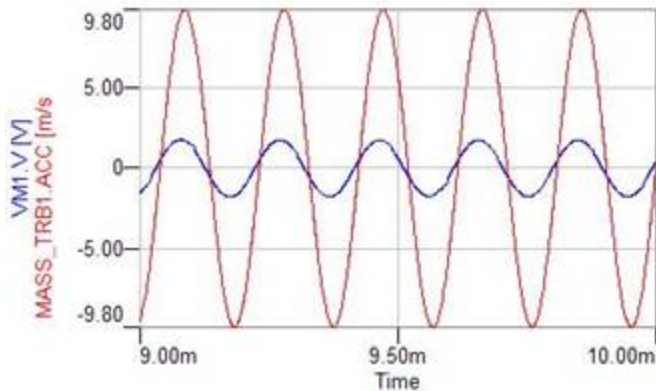


Figure 3. Simulation results-output voltage of ACC_VIB_DF_I22 and acceleration of MASS_TRB1

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References

Level 2 Jerk-Sensing Vibration Sensor (Displacement-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

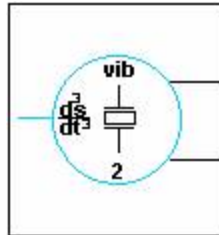


Figure 1. Component symbol

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Description

The Level 2 Jerk-Sensing Vibration (Displacement-Force) sensor model is used to simulate the non-ideal behavior of a jerk-sensing vibration sensor in the Twin Builder Displacement-Force translational domain. A change in the third derivative of the model's translational input produces a corresponding change in the model's linear voltage output.

The model has one conservative input pin in the displacement-force translational domain for its vibration input and two conservative electrical-domain pins for its voltage output. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is connected to ground.

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Netlist Syntax

```
MODEL JERK_VIB_DF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@ (ID))  
POSITION:= %0, OUT_P:= %1, OUT_M:= %2 ( knock_resonant_frequency:= @knock_res-  
onant_frequency, Q_factor:= @Q_factor, peak_sensitivity:= @peak_sensitivity, offset:= @off-  
set, temp_sens:= @temp_sens, temp:= @temp, output_resistance:= @output_resistance)  
SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured vibration	Translational
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
knock_resonant_fre- quency	Resonant frequency of the target vibration	Real	2k [Hz]
Q_factor (must be a positive nonzero value)	Q-factor of the internal filter	Real	2
offset	Sensor offset voltage	Real	0 [V]
temp_sens	Output temperature sensitivity	Real	0 [V/(°C)]
temp	Sensor temperature	Real	27 [°C]

output_resistance	Output resistance	Real	0 [Ohm]
peak_sensitivity	Sensor sensitivity	Real	0.5 [V/(m/s ³)]

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Example

In this example, a change in the third derivative of the position of MASS_TRB1 produces a corresponding change in the linear voltage output of the Jerk-Sensing Vibration (Displacement-Force) sensor JERK_VIB_DF_I22. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

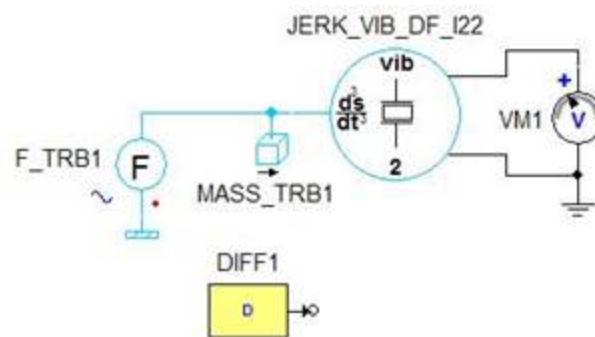


Figure 2. Application example of the Jerk-Sensing Vibration (Displacement-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Force Source F_TRB1	AMPL	1m [N]
	FREQ	2k [Hz]
	PHASE	0 [degree]
	OFF	0 [N]
	TDELAY	0 [s]
Mass MASS_TRB1	m	1 [kg]
	S0	0 [m]

	V0	0 [m/s]
Jerk-Sensing Vibration (Displacement-Force) sensor JERK_VIB_DF_I22	knock_resonant_frequency	2k [Hz]
	Q_factor	2
	offset	0 [V]
	temp_sens	0 [V/(°C)]
	temp	27 [°C]
	output_resistance	0 [Ohm]
	peak_sensitivity	0.2 [V/(m/s ³)]
Derivative DIFF1	INPUT	MASS_TRB1.ACC
	KD	1
	Y0	0
	UL	0
	UU	0
	TS	System*

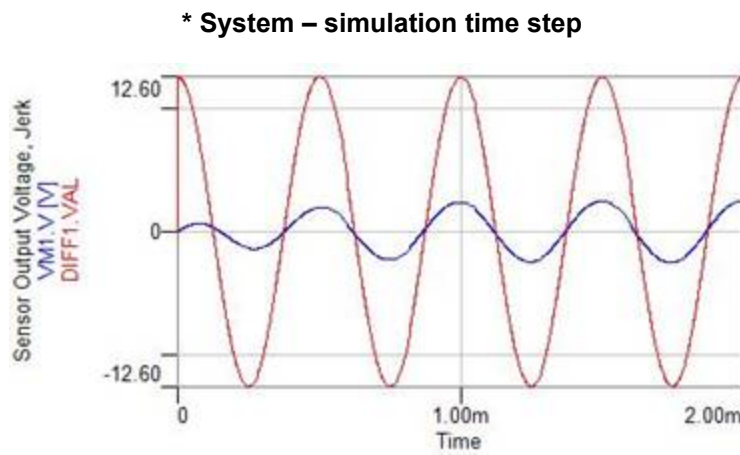


Figure 3. Simulation results-output voltage of JERK_VIB_DF_I22 and Jerk of MASS_TRB1

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References

Level 2 Acceleration-Sensing Vibration Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

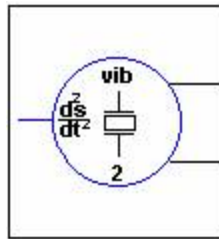


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Description

The Level 2 Acceleration-Sensing Vibration (Velocity-Force) sensor model is used to simulate the non-ideal behavior of a acceleration-sensing vibration sensor in the Twin Builder Velocity-Force translational domain. A change in the second derivative of the model's translational input produces a corresponding change in the model's linear voltage output.

The model has one conservative input pin in the velocity-force translational domain for its vibration input and two conservative electrical-domain pins for its voltage output. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is connected to ground.

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Netlist Syntax

```
MODEL ACC_VIB_VF_I2 ?InstanceName(@InstanceName):(@ (Refbase)@(ID)) POSITION:= %0, OUT_P:= %1, OUT_M:= %2 ( knock_resonant_frequency:= @knock_resonant_frequency, q_factor:= @q_factor, peak_sens:= @peak_sens, offset:= @offset, temp_sens:= @temp_sens, temp:= @temp, output_resistance:= @output_resistance) SRC: DB(Lib:=@ModelLibraryName) ;
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured vibration	Translational_V
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
knock_resonant_frequency	Resonant frequency of the target vibration	Real	2k [Hz]
offset	Sensor offset voltage	Real	0 [V]
temp_sens	Output temperature sensitivity	Real	0 [V/(°C)]
temp	Sensor temperature	Real	27 [°C]
output_resistance	Output resistance	Real	0 [Ohm]
Q_factor (must be a positive nonzero value)	Q-factor of the internal filter	Real	2
peak_sensitivity	Sensor sensitivity	Real	0.5m [V/(m/s ³)]

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Example

In this example, a change in the second derivative of the position of MASS_TR1 produces a corresponding change in the linear voltage output of the Acceleration-Sensing Vibration (Velocity-Force) sensor ACC_VIB_VF_I22. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

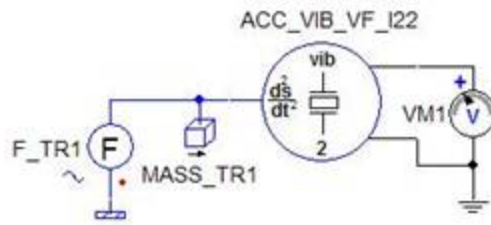


Figure 2. Application example of the Acceleration-Sensing Vibration (Velocity-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Force Source F_TR1	AMPL	9.8 [N]
	FREQ	5.2k [Hz]
	PHASE	0 [degree]
	OFF	0 [N]
	TDELAY	0 [s]
Mass MASS_TR1	M	1 [kg]
	S0	5.2k
	V0	0 [m/s]
Acceleration-Sensing Vibration (Velocity-Force) sensor ACC_VIB_VF_I22	knock_resonant_frequency	5200 [Hz]
	offset	0 [V]
	temp_sens	0 [V/(°C)]
	temp	27 [°C]

	output_res- istance	0 [Ohm]
	Q_factor	26
	peak_sens- itivity	0.204 [V/ (m/s ³)]

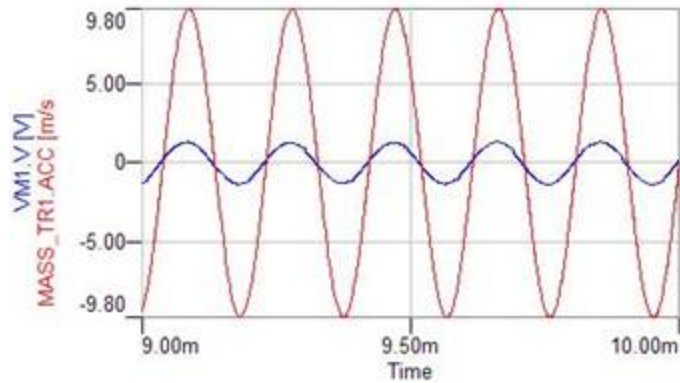


Figure 3. Simulation results-output voltage of ACC_VIB_VF_I22 and acceleration of MASS_TR1

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References

Level 2 Jerk-Sensing Vibration Sensor (Velocity-Force)

Library: Add Ons/- sensors	Modeling Language: SML	Version Number: Twin Builder 2024.2

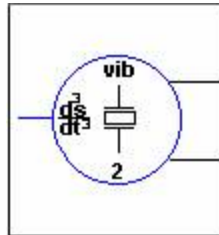


Figure 1. Component symbol

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Description

The Level 2 Jerk-Sensing Vibration (Velocity-Force) sensor model is used to simulate the non-ideal behavior of a jerk-sensing vibration sensor in the Twin Builder Velocity-Force translational domain. A change in the third derivative of the model's translational input produces a corresponding change in the model's linear voltage output.

The model has one conservative input pin in the velocity-force translational domain for its vibration input and two conservative electrical-domain pins for its voltage output. The negative output pin should be connected to an electrical ground if the model is connected to an electrical network in which no other element is connected to ground.

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Assumptions and Limitations

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Mathematical Description

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Netlist Syntax

```
MODEL JERK_VIB_VF_I2 ?InstanceName(@InstanceName):(@Refbase)@(ID)) POSITION:= %0, OUT_P:= %1, OUT_M:= %2 ( knock_resonant_frequency:= @knock_resonant_frequency, Q_factor:= @Q_factor, peak_sensitivity:= @peak_sensitivity, offset:= @offset, temp_sens:= @temp_sens, temp:= @temp, output_resistance:= @output_resistance) SRC: DB(Lib:- :=@ModelLibraryName);
```

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Conservative Pins

Table 1

Name	Port/Terminal Description	Nature/Data type
POSITION	Measured vibration	Translational_V
OUT_P	Positive output terminal	Electrical
OUT_M	Negative output terminal	Electrical

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Parameters

Table 2

Name	Description	Data Type	Default Value [Unit]
knock_resonant_frequency	Resonant frequency of the target vibration	Real	2k [Hz]
Q_factor (must be a positive nonzero value)	Q-factor of the internal filter	Real	2
offset	Sensor offset voltage	Real	0 [V]
temp_sens	Output temperature sensitivity	Real	0 [V/(°C)]
temp	Sensor temperature	Real	27 [°C]

output_resistance	Output resistance	Real	0 [Ohm]
peak_sensitivity	Sensor sensitivity	Real	0.5 [V/ (m/s ³)]

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Example

In this example, a change in the third derivative of the position of MASS_TR1 produces a corresponding change in the linear voltage output of the Jerk-Sensing Vibration (Velocity-Force) sensor JERK_VIB_VF_I22. The schematic of the system is shown in Figure 2, system parameters are listed in Table 3, and the simulation results are shown in Figure 3.

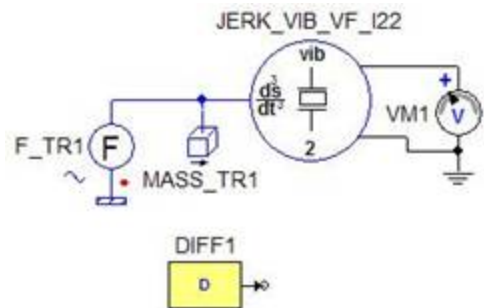


Figure 2. Application example of the Jerk-Sensing Vibration (Velocity-Force) sensor

Table 3

Component	Parameter	Value [Unit]
Force Source F_TR1	AMPL	1m [N]
	FREQ	2k [Hz]
	PHASE	0 [degree]
	OFF	0 [N]
	TDELAY	0 [s]
Mass MASS_TR1	m	1 [kg]
	S0	0 [m]
	V0	0 [m/s]
Jerk-Sensing Vibration (Velocity-Force) sensor JERK_VIB_VF_I22	knock_res- onant_fre- quency	2k [Hz]
	Q_factor	2
	offset	0 [V]
	temp_sens	0 [V/(°C)]

Derivative DIFF1	temp	27 [°C]
	output_resistance	0 [Ohm]
	peak_sensitivity	0.2 [V/(m/s ³)]
	INPUT	MASS_TR1.ACC
	KD	1
	Y0	0
	UL	0
	UU	0
	TS	System*

* System – simulation time step

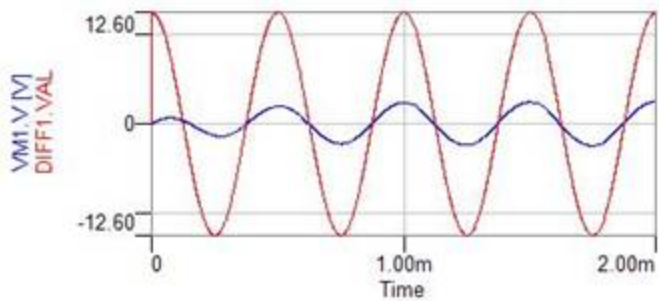


Figure 3. Simulation results-output voltage of JERK_VIB_VF_I22 and Jerk of MASS_TRB1

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