Simscape™

Reference

MATLAB® & SIMULINK®

R2016a

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Simscape™ Reference

Trademarks

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3 Configuration Parameters

4 Model Advisor Checks

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Glossary

Blocks — Alphabetical List

Absolute Reference (2P)

Reference point at zero absolute pressure and specific internal energy

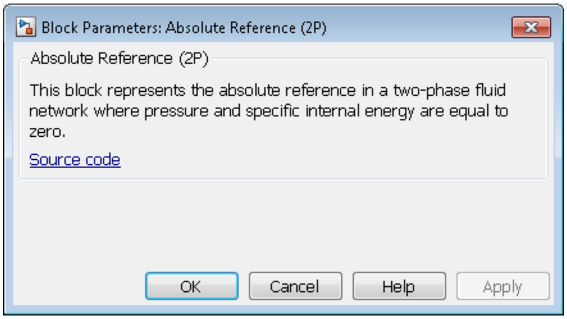
Library

Two-Phase Fluid/Elements

Description

The `Absolute Reference (2P)` block represents a reference point at zero absolute pressure and specific internal energy. Use with the `Pressure & Internal Energy Sensor (2P)` block to measure the absolute pressure and specific internal energy at a two-phase fluid node.

Dialog Box and Parameters



Block Parameters: Absolute Reference (2P)

Absolute Reference (2P)

This block represents the absolute reference in a two-phase fluid network where pressure and specific internal energy are equal to zero.

Source code

The block has no parameters.

Ports

The block has a two-phase fluid conserving port. This port identifies the two-phase fluid node set to zero pressure and specific internal energy.

See Also

`Pressure & Internal Energy Sensor (2P)` | `Reservoir (2P)`

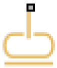
Absolute Reference (TL)

Reference point at zero absolute temperature and pressure

Library

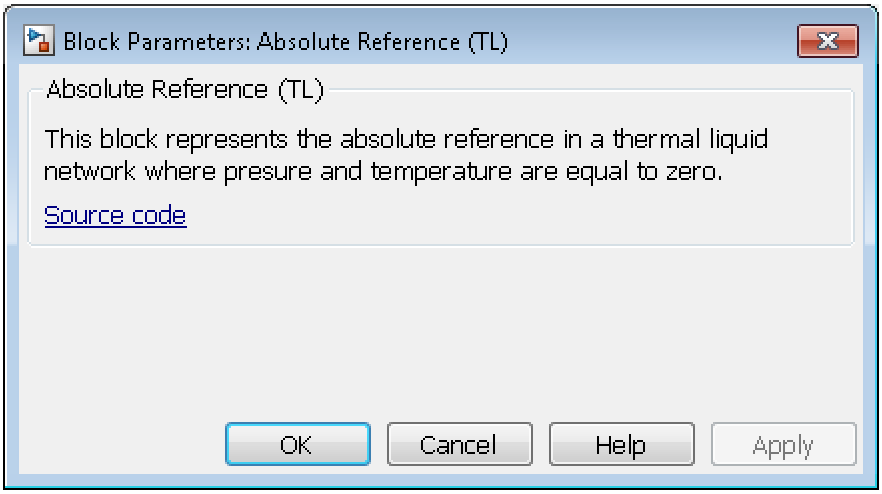
Thermal Liquid/Elements

Description



The `Absolute Reference (TL)` block represents an absolute reference for the pressure and temperature in thermal liquid systems. At port A, the pressure and temperature are both equal to zero.

Dialog Box and Parameters



Block Parameters: Absolute Reference (TL)

Absolute Reference (TL)

This block represents the absolute reference in a thermal liquid network where presure and temperature are equal to zero.

Source code

The block has no parameters.

Ports

The block has one thermal liquid conserving port.

See Also

`Reservoir (TL)`

AC Current Source

Ideal sinusoidal current source

Library

Electrical Sources

Description

The `AC Current Source` block represents an ideal current source that maintains sinusoidal current through it, independent of the voltage across its terminals.

The output current is defined by the following equation:

$$I = I_0 \cdot \sin(2\pi \cdot f \cdot t + \varphi)$$

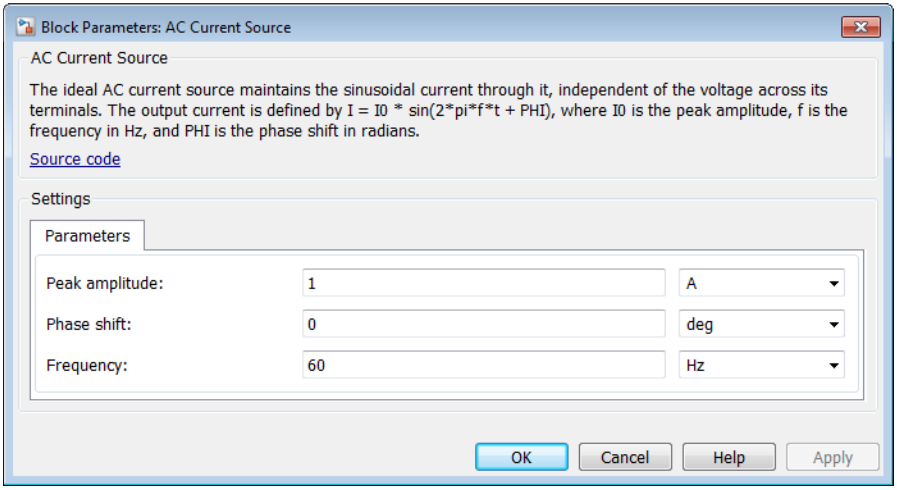
where

I	Current
I_0	Peak amplitude
f	Frequency
φ	Phase shift
t	Time

The positive direction of the current flow is indicated by the arrow.

Note: For Release 2012b and earlier, the unit definition for Hz was `rev/s`, whereas in R2013a it was changed to be `1/s`, in compliance with the SI unit system. For this block it means that you must specify frequency in units of `Hz` or directly convertible to Hz, such as `1/s`, `kHz`, `MHz` and `GHz`. In 2012b and earlier you could also specify frequency in angular units (such as `rad/s` or `rpm`), but this is no longer possible because the internal equation of the block now uses the 2π conversion factor to account for the `1/s` unit definition. If you use this block in a model created prior to R2013a, update it by using the `slupdate` utility. For more information, see the R2013a Release Notes.

Dialog Box and Parameters



The ideal AC current source maintains the sinusoidal current through it, independent of the voltage across its terminals. The output current is defined by I = I0 * sin(2*pi*f*t + PHI), where I0 is the peak amplitude, f is the frequency in Hz, and PHI is the phase shift in radians.

Peak amplitude: 1 A

Phase shift: 0 deg

Frequency: 60 Hz

Peak amplitude

Peak current amplitude. The default value is `1` A.

Phase shift

Phase shift in angular units. The default value is `0`.

Frequency

Current frequency, specified in Hz or units directly convertible to Hz (where Hz is defined as `1/s`). For example, `kHz` and `MHz` are valid units, but `rad/s` is not. The default value is `60` Hz.

Ports

The block has two electrical conserving ports associated with its terminals.

See Also

`AC Voltage Source`

AC Voltage Source

Ideal constant voltage source

Library

Electrical Sources

Description

The `AC Voltage Source` block represents an ideal voltage source that maintains sinusoidal voltage across its output terminals, independent of the current flowing through the source.

The output voltage is defined by the following equation:

$$V = V_0 \cdot \sin(2\pi \cdot f \cdot t + \varphi)$$

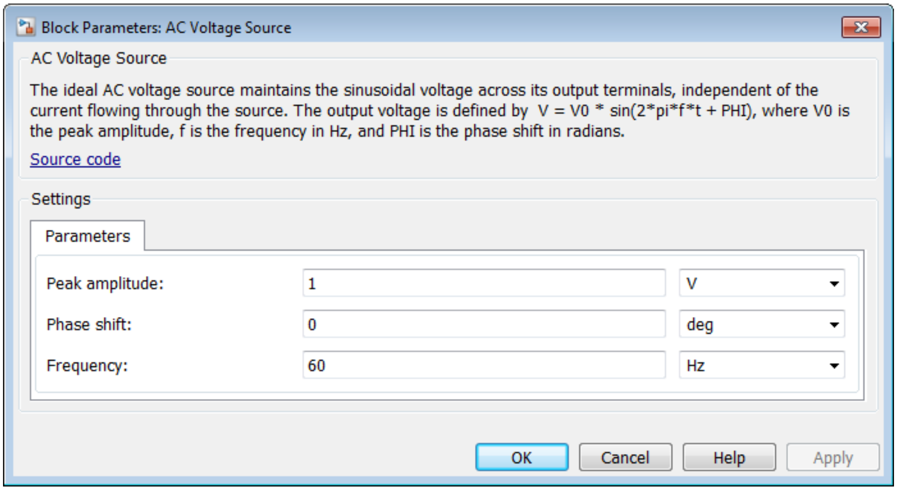
where

V	Voltage
V_0	Peak amplitude
f	Frequency
φ	Phase shift
t	Time

Connections + and – are conserving electrical ports corresponding to the positive and negative terminals of the voltage source, respectively. The current is positive if it flows from positive to negative, and the voltage across the source is equal to the difference between the voltage at the positive and the negative terminal, $V(+) - V(-)$.

Note: For Release 2012b and earlier, the unit definition for Hz was rev/s, whereas in R2013a it was changed to be 1/s, in compliance with the SI unit system. For this block it means that you must specify frequency in units of Hz or directly convertible to Hz, such as 1/s, kHz, MHz and GHz. In 2012b and earlier you could also specify frequency in angular units (such as rad/s or rpm), but this is no longer possible because the internal equation of the block now uses the 2π conversion factor to account for the 1/s unit definition. If you use this block in a model created prior to R2013a, update it by using the `slupdate` utility. For more information, see the R2013a Release Notes.

Dialog Box and Parameters



Block Parameters: AC Voltage Source

AC Voltage Source

The ideal AC voltage source maintains the sinusoidal voltage across its output terminals, independent of the current flowing through the source. The output voltage is defined by V = V0 * sin(2*pi*f*t + PHI), where V0 is the peak amplitude, f is the frequency in Hz, and PHI is the phase shift in radians.

Source code

Settings

Parameters

Peak amplitude:	1	V
Phase shift:	0	deg
Frequency:	60	Hz

Peak amplitude

Peak voltage amplitude. The default value is 1 V.

Phase shift

Phase shift in angular units. The default value is 0.

Frequency

Voltage frequency, specified in Hz or units directly convertible to Hz (where Hz is defined as 1/s). For example, kHz and MHz are valid units, but rad/s is not. The default value is 60 Hz.

Ports

The block has the following ports:

+

Electrical conserving port associated with the source positive terminal.

–

Electrical conserving port associated with the source negative terminal.

See Also

`AC Current Source`

Adiabatic Cup

Thermal element with no thermal mass and perfect insulation

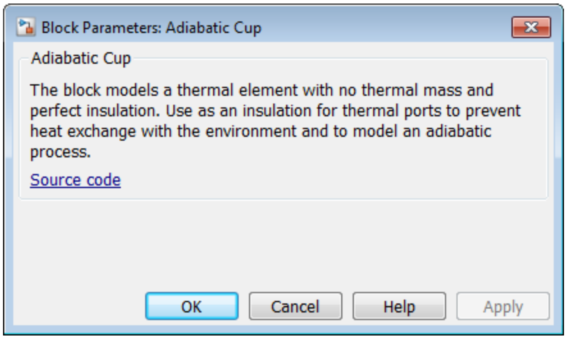
Library

Pneumatic Elements

Description

The `Adiabatic Cup` block models a thermal element with no thermal mass and perfect insulation. Use this block as an insulation for thermal ports to prevent heat exchange with the environment and to model an adiabatic process.

Dialog Box and Parameters



Block Parameters: Adiabatic Cup

Adiabatic Cup

The block models a thermal element with no thermal mass and perfect insulation. Use as an insulation for thermal ports to prevent heat exchange with the environment and to model an adiabatic process.

Source code

The block has no parameters.

Ports

The block has one thermal conserving port.

See Also

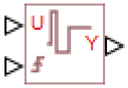
`Cap (TL)` | `Hydraulic Cap` | `Open Circuit` | `Perfect Insulator` | `Rotational Free End` | `Translational Free End`

Asynchronous Sample & Hold

Output sample-and-hold signal with external trigger

Library

Physical Signals/Discrete

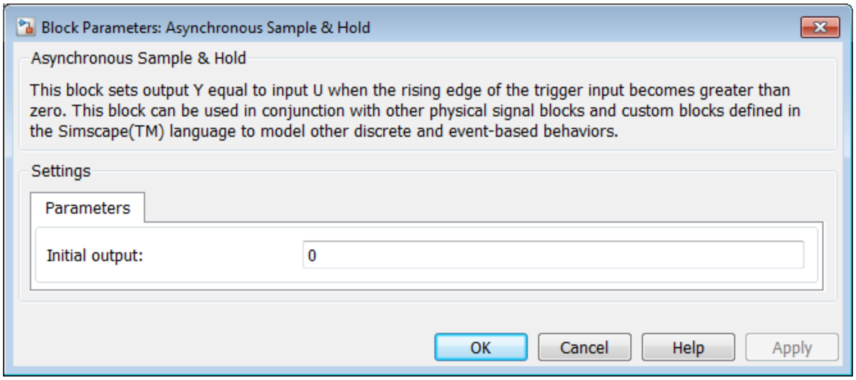


Description

The `Asynchronous Sample & Hold` block sets the output signal, *Y*, equal to the input signal, *U*, when the rising edge of the trigger input becomes greater than zero. Use this block, in conjunction with other physical signal blocks, to model discrete and event-based behaviors.

Both inputs and the output are physical signals.

Dialog Box and Parameters


Block Parameters: Asynchronous Sample & Hold

Asynchronous Sample & Hold

This block sets output Y equal to input U when the rising edge of the trigger input becomes greater than zero. This block can be used in conjunction with other physical signal blocks and custom blocks defined in the Simscape(TM) language to model other discrete and event-based behaviors.

Settings

Parameters

Initial output: 0

Initial output

The value of the output signal at time zero. The output of the block remains at this value until the block is triggered by a rising trigger signal becoming positive. The default value is `0`.

Ports

The block has two physical signal input ports and one physical signal output port.

Examples

The Asynchronous PWM Voltage Source example illustrates how you can use the `Asynchronous Sample & Hold` block to build components with more complex behaviors. For an alternative discrete-time implementation, see the Discrete-Time PWM Voltage Source example. The discrete-time version is better suited to fixed-step solvers and hardware-in-the-loop applications, whereas the asynchronous implementation is better suited to fast desktop simulation using variable-step solvers.

See Also

`Counter`

Cap (2P)

Perfectly insulated stop to fluid flow

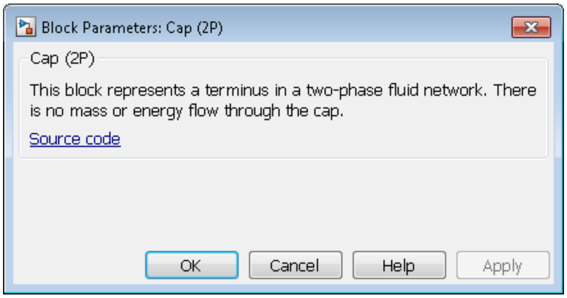
Library

Two-Phase Fluid/Elements

Description

The Cap (2P) block represents a perfectly insulated terminus to a two-phase fluid branch. No fluid flow or heat transfer occur through the cap.

Dialog Box and Parameters



Block Parameters: Cap (2P)

Cap (2P)

This block represents a terminus in a two-phase fluid network. There is no mass or energy flow through the cap.

Source code

The block has no parameters.

Ports

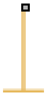
The block has a two-phase fluid conserving port. This port identifies the cap location in a two-phase fluid network.

Cap (TL)

Perfectly insulated stop to fluid flow

Library

Thermal Liquid/Elements

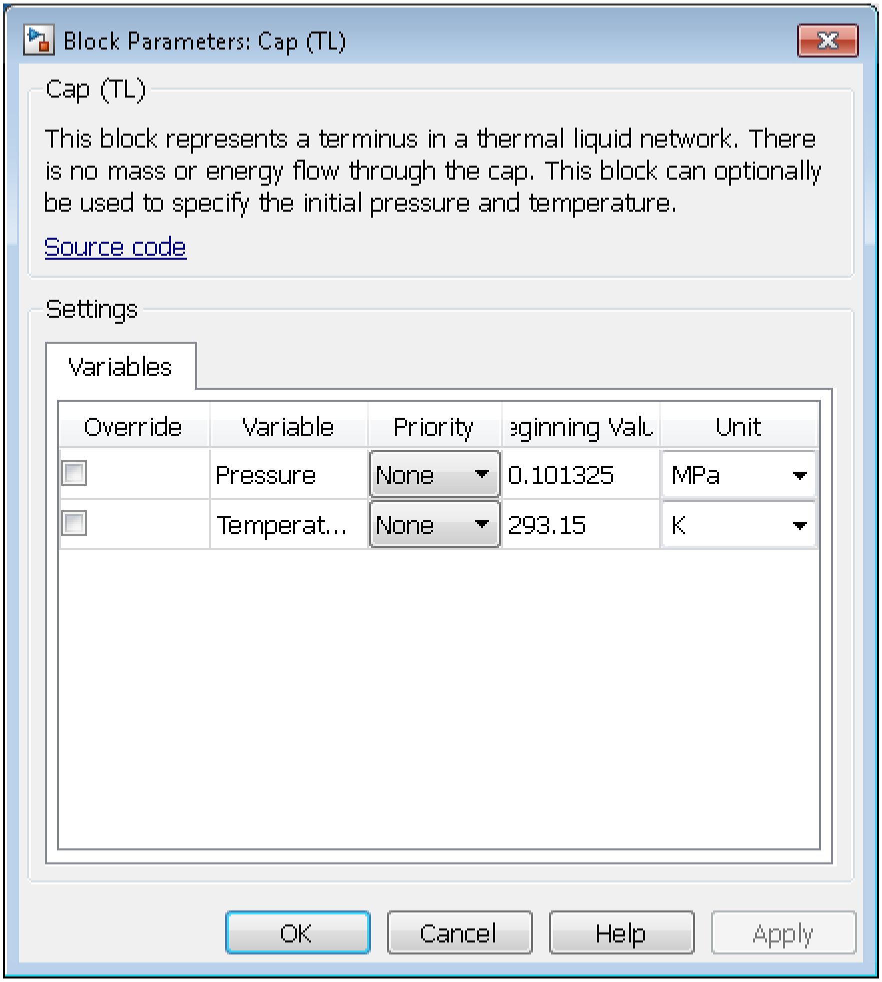


Description

The `Cap (TL)` block represents a physical stop to liquid flow in a pipe network branch. The stop is perfectly insulated, preventing heat transfer with its surroundings.

You can also use this block to set the initial pressure and temperature at a node.

Dialog Box and Parameters



Block Parameters: Cap (TL)

Cap (TL)

This block represents a terminus in a thermal liquid network. There is no mass or energy flow through the cap. This block can optionally be used to specify the initial pressure and temperature.

Source code

Settings

Variables

Override	Variable	Priority	eginning Valu	Unit
□	Pressure	None	0.101325	MPa
□	Temperat...	None	293.15	K

The **Variables** tab lets you set the priority and initial target value for **Pressure** and **Temperature** variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has one thermal liquid conserving port.

Capacitor

Linear capacitor in electrical systems

Library

Electrical Elements

Description

The `Capacitor` block models a linear capacitor, described with the following equation:

$$I = C\frac{dV}{dt}$$

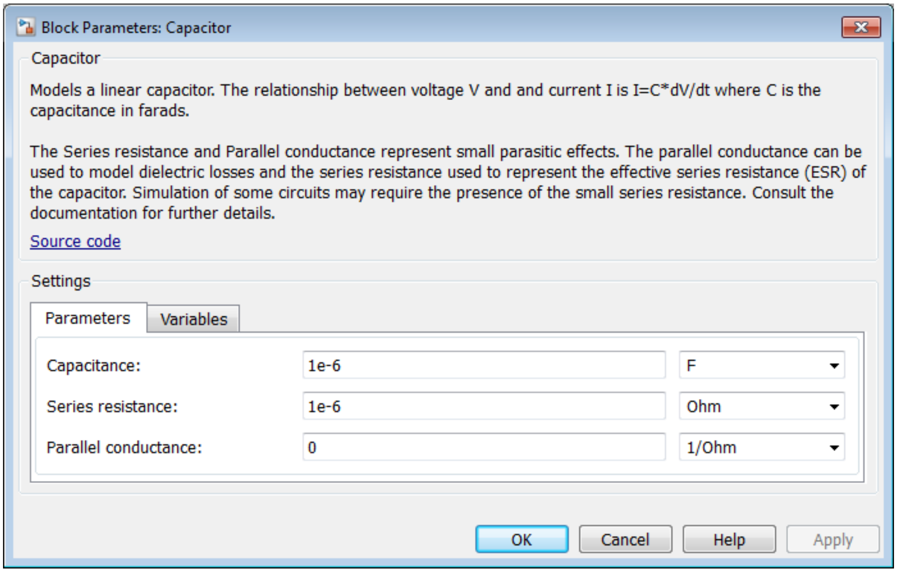
where

I	Current
V	Voltage
C	Capacitance
t	Time

The **Series resistance** and **Parallel conductance** parameters represent small parasitic effects. The parallel conductance directly across the capacitor can be used to model dielectric losses, or equivalently leakage current per volt. The series resistance can be used to represent component effective series resistance (ESR) or connection resistance. Simulation of some circuits may require the presence of the small series resistance. For more information, see "Modeling Best Practices".

Connections + and – are conserving electrical ports corresponding to the positive and negative terminals of the capacitor, respectively. The current is positive if it flows from positive to negative, and the voltage across the capacitor is equal to the difference between the voltage at the positive and the negative terminal, $V(+) - V(-)$.

Dialog Box and Parameters



Capacitor

Models a linear capacitor. The relationship between voltage V and and current I is I=C*dV/dt where C is the capacitance in farads.

The Series resistance and Parallel conductance represent small parasitic effects. The parallel conductance can be used to model dielectric losses and the series resistance used to represent the effective series resistance (ESR) of the capacitor. Simulation of some circuits may require the presence of the small series resistance. Consult the documentation for further details.

Source code

Settings

Capacitance:	1e-6	F
Series resistance:	1e-6	Ohm
Parallel conductance:	0	1/Ohm

- “Parameters Tab” on page 1-21
- “Variables Tab” on page 1-22

Parameters Tab

Capacitance

Capacitance, in farads. The default value is 1 µF.

Series resistance

Represents small parasitic effects. The series resistance can be used to represent component internal resistance. Simulation of some circuits may require the presence of the small series resistance. The default value is 1 µΩ.

Parallel conductance

Represents small parasitic effects. The parallel conductance directly across the capacitor can be used to model leakage current per volt. The default value is 0.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

+

Electrical conserving port associated with the capacitor positive terminal.

-

Electrical conserving port associated with the capacitor negative terminal.

Conductive Heat Transfer

Heat transfer by conduction

Library

Thermal Elements

Description

The `Conductive Heat Transfer` block represents a heat transfer by conduction between two layers of the same material. The transfer is governed by the Fourier law and is described with the following equation:

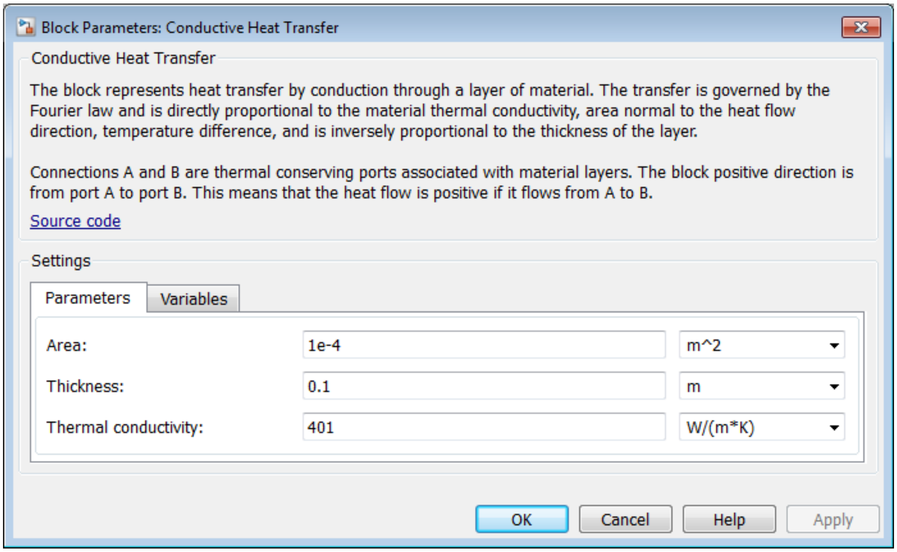
$$Q = k \cdot \frac{A}{D} (T_A - T_B)$$

where

Q	Heat flow
k	Material thermal conductivity
A	Area normal to the heat flow direction
D	Distance between layers
T_A, T_B	Temperatures of the layers

Connections A and B are thermal conserving ports associated with material layers. The block positive direction is from port A to port B. This means that the heat flow is positive if it flows from A to B.

Dialog Box and Parameters



Block Parameters: Conductive Heat Transfer

Conductive Heat Transfer

The block represents heat transfer by conduction through a layer of material. The transfer is governed by the Fourier law and is directly proportional to the material thermal conductivity, area normal to the heat flow direction, temperature difference, and is inversely proportional to the thickness of the layer.

Connections A and B are thermal conserving ports associated with material layers. The block positive direction is from port A to port B. This means that the heat flow is positive if it flows from A to B.

Source code

Settings

Parameters | Variables

Area: 1e-4 m^2

Thickness: 0.1 m

Thermal conductivity: 401 W/(m*K)

- "Parameters Tab" on page 1-24
- "Variables Tab" on page 1-24

Parameters Tab

Area

Area of heat transfer, normal to the heat flow direction. The default value is `0.0001` m^2.

Thickness

Thickness between layers. The default value is `0.1` m.

Thermal conductivity

Thermal conductivity of the material. The default value is `401` W/m/K.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see "Set Priority and Initial Target for Block Variables".

Ports

The block has the following ports:

A

Thermal conserving port associated with layer A.

B

Thermal conserving port associated with layer B.

See Also

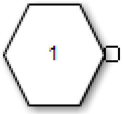
`Convective Heat Transfer` | `Radiative Heat Transfer`

Connection Port

Physical Modeling connector port for subsystem

Library

Utilities



Description

The `Connection Port` block transfers a physical connection or signal across subsystem boundaries. Physical connections include Simscape™ conserving connections and Simscape Multibody™ frame connections, among others. This block is similar in function to the `Inport` and `Outport` blocks in the Simulink® library.

A subsystem needs a `Connection Port` block for each physical connection line that crosses its boundary. You can manually place a `Connection Port` block inside a subsystem, or Simulink can automatically insert a `Connection Port` block when you create a subsystem within an existing network.

Port Appearance on Subsystem Block

The `Connection Port` block adds a port to the parent `Subsystem` block. The port type depends on the connection or signal it transfers. For example, if the port transfers a Simscape conserving connection, then it appears on the `Subsystem` block as a Simscape Conserving port.

As a rule, the port on the `Subsystem` block always matches the port to which the `Connection Port` block connects inside the subsystem. This port can be a Simscape port or a Simscape Multibody port. Simscape ports include:

- Conserving ports ▨
- Physical signal inports and outports ▷
- Two-way connector ports ⊞

Simscape Multibody First Generation ports include:

- Round connector ports ○
- Body coordinate system ports ⊞

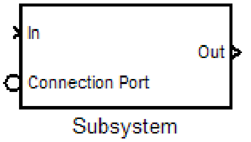
Simscape Multibody Second Generation ports include:

- Frame ports ◧
- Geometry ports ⊡

Port Location and Orientation on Subsystem Block

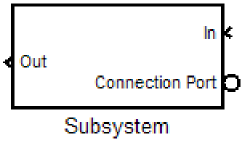
The orientation of the parent subsystem block and your choice of port location determine the `Connection Port` block port location on the parent subsystem block.

- A subsystem is in its fundamental orientation when its Simulink signal inports appear on its left side and its Simulink signal outports appear on its right side.

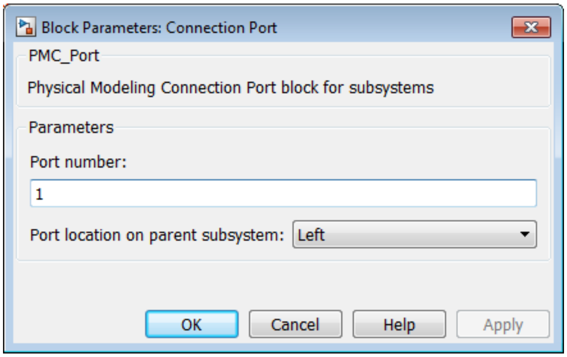
  When a subsystem is oriented in this way, the actual port location on the subsystem block respects your choice of port location (left or right) for the connector port.

- A subsystem orientation is reversed, with left and right interchanged, when its Simulink signal inports occur on its right side and its Simulink signal outports occur on its left side.

  When a subsystem is oriented in this way, the actual port location on the subsystem block reverses your choice of port location. If you choose left, the port appears on the right side. If you choose right, the port appears on the left side.

Dialog Box and Parameters



Block Parameters: Connection Port

PMC_Port

Physical Modeling Connection Port block for subsystems

Parameters

Port number: 1

Port location on parent subsystem: Left

Port number

Labels the subsystem connector port that this block creates. Each connector port requires a unique number as a label. The default value for the first port is `1`.

Port location on parent subsystem

Choose here which side of the parent subsystem block the port is located. The choices are `Left` or `Right`. The default choice is `Left`.

See “Port Location and Orientation on Subsystem Block” on page 1-27.

See Also

In the Simulink documentation, see “Create a Subsystem”.

Constant Area Hydraulic Orifice

Hydraulic orifice with constant cross-sectional area

Library

Hydraulic Elements

Description

The `Constant Area Hydraulic Orifice` block models a sharp-edged constant-area orifice. The flow rate through the orifice is proportional to the pressure differential across the orifice, and is determined according to the following equations:

$$q = C_D \cdot A \sqrt{\frac{2}{\rho}} \cdot \frac{p}{\left(p^2 + p_{cr}^2\right)^{1/4}}$$

$$p = p_A - p_B$$

$$p_{cr} = \frac{\rho}{2}\left(\frac{\mathrm{Re}_{cr} \cdot \nu}{C_D \cdot D_H}\right)^2$$

$$D_H = \sqrt{\frac{4A}{\pi}}$$

where

q	Flow rate
p	Pressure differential
p_A, p_B	Gauge pressures at the block terminals
C_D	Flow discharge coefficient

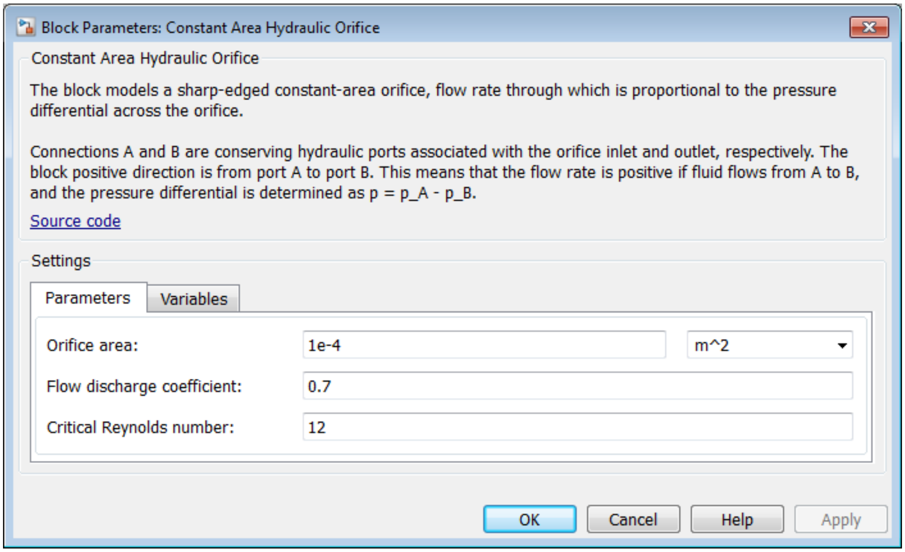
A	Orifice passage area
D_H	Orifice hydraulic diameter
ρ	Fluid density
ν	Fluid kinematic viscosity
p_{cr}	Minimum pressure for turbulent flow
Re_{cr}	Critical Reynolds number

The block positive direction is from port A to port B. This means that the flow rate is positive if it flows from A to B, and the pressure differential is determined as $p = p_A - p_B$.

Basic Assumptions and Limitations

- Fluid inertia is not taken into account.

Dialog Box and Parameters



Block Parameters: Constant Area Hydraulic Orifice

Constant Area Hydraulic Orifice

The block models a sharp-edged constant-area orifice, flow rate through which is proportional to the pressure differential across the orifice.

Connections A and B are conserving hydraulic ports associated with the orifice inlet and outlet, respectively. The block positive direction is from port A to port B. This means that the flow rate is positive if fluid flows from A to B, and the pressure differential is determined as p = p_A - p_B.

Source code

Settings

Orifice area: 1e-4 m^2

Flow discharge coefficient: 0.7

Critical Reynolds number: 12

- “Parameters Tab” on page 1-31

- "Variables Tab" on page 1-31

Parameters Tab

Orifice area

Orifice passage area. The default value is `1e-4` m^2.

Flow discharge coefficient

Semi-empirical parameter for orifice capacity characterization. Its value depends on the geometrical properties of the orifice, and usually is provided in textbooks or manufacturer data sheets. The default value is `0.7`.

Critical Reynolds number

The maximum Reynolds number for laminar flow. The transition from laminar to turbulent regime is assumed to take place when the Reynolds number reaches this value. The value of the parameter depends on the orifice geometrical profile. You can find recommendations on the parameter value in hydraulics textbooks. The default value is `12`, which corresponds to a round orifice in thin material with sharp edges.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see "Set Priority and Initial Target for Block Variables".

Global Parameters

Parameters determined by the type of working fluid:

- **Fluid density**
- **Fluid kinematic viscosity**

Use the `Hydraulic Fluid` block or the `Custom Hydraulic Fluid` block to specify the fluid properties.

Ports

The block has the following ports:

A

Hydraulic conserving port associated with the orifice inlet.

B

Hydraulic conserving port associated with the orifice outlet.

See Also

`Variable Area Hydraulic Orifice`

Constant Area Pneumatic Orifice

Sharp-edged orifice in pneumatic systems

Library

Pneumatic Elements

Description

The `Constant Area Pneumatic Orifice` block models the flow rate of an ideal gas through a sharp-edged orifice.

The flow rate through the orifice is proportional to the orifice area and the pressure differential across the orifice.

$$G = C_d \cdot A \cdot p_i \sqrt{\frac{2\gamma}{\gamma - 1} \cdot \frac{1}{RT_i} \left[\left(\frac{p_o}{p_i} \right)^{\frac{2}{\gamma}} - \left(\frac{p_o}{p_i} \right)^{\frac{\gamma+1}{\gamma}} \right]}$$

where

G	Mass flow rate
C_d	Discharge coefficient, to account for effective loss of area due to orifice shape
A	Orifice cross-sectional area
p_i, p_o	Absolute pressures at the orifice inlet and outlet, respectively. The inlet and outlet change depending on flow direction. For positive flow ($G > 0$), $p_i = p_A$, otherwise $p_i = p_B$.
γ	The ratio of specific heats at constant pressure and constant volume, c_p / c_v
R	Specific gas constant

T	Absolute gas temperature

The choked flow occurs at the critical pressure ratio defined by

$$\beta_{cr} = \frac{p_o}{p_i} = \left(\frac{2}{\gamma + 1} \right)^{\frac{\gamma}{\gamma - 1}}$$

after which the flow rate depends on the inlet pressure only and is computed with the expression

$$G = C_d \bullet A \bullet p_i \sqrt{\frac{\gamma}{RT_i} \bullet \beta_{cr}^{\frac{\gamma+1}{\gamma}}}$$

The square root relationship has infinite gradient at zero flow, which can present numerical solver difficulties. Therefore, for very small pressure differences, defined by $p_o / p_i > 0.999$, the flow equation is replaced by a linear flow-pressure relationship

$$G = kC_d \bullet A \bullet T_i^{-0.5} \left(p_i - p_o \right)$$

where k is a constant such that the flow predicted for p_o / p_i is the same as that predicted by the original flow equation for $p_o / p_i = 0.999$.

The heat flow out of the orifice is assumed equal to the heat flow into the orifice, based on the following considerations:

- The orifice is square-edged or sharp-edged, and as such is characterized by an abrupt change of the downstream area. This means that practically all the dynamic pressure is lost in the expansion.
- The lost energy appears in the form of internal energy that rises the output temperature and makes it very close to the inlet temperature.

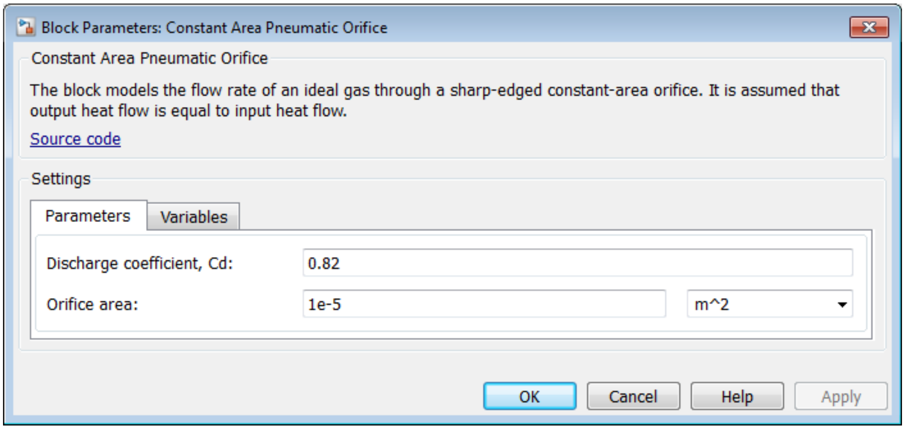
Therefore, $q_i = q_o$, where q_i and q_o are the input and output heat flows, respectively.

The block positive direction is from port A to port B. This means that the flow rate is positive if it flows from A to B.

Basic Assumptions and Limitations

- The gas is ideal.
- Specific heats at constant pressure and constant volume, c_p and c_v, are constant.
- The process is adiabatic, that is, there is no heat transfer with the environment.
- Gravitational effects can be neglected.
- The orifice adds no net heat to the flow.

Dialog Box and Parameters



Block Parameters: Constant Area Pneumatic Orifice

Constant Area Pneumatic Orifice

The block models the flow rate of an ideal gas through a sharp-edged constant-area orifice. It is assumed that output heat flow is equal to input heat flow.

Source code

Settings

Parameters | Variables

Discharge coefficient, Cd: 0.82

Orifice area: 1e-5 m^2

- “Parameters Tab” on page 1-35
- “Variables Tab” on page 1-36

Parameters Tab

Discharge coefficient, Cd

Semi-empirical parameter for orifice capacity characterization. Its value depends on the geometrical properties of the orifice, and usually is provided in textbooks or manufacturer data sheets. The default value is `0.82`.

Orifice area

Specify the orifice cross-sectional area. The default value is `1e-5` m^2.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

A

Pneumatic conserving port associated with the orifice inlet for positive flow.

B

Pneumatic conserving port associated with the orifice outlet for positive flow.

See Also

`Constant Area Pneumatic Orifice (ISO 6358)` | `Variable Area Pneumatic Orifice`

Constant Area Pneumatic Orifice (ISO 6358)

Fixed-area pneumatic orifice complying with ISO 6358 standard

Library

Pneumatic Elements

Description

The `Constant Area Pneumatic Orifice (ISO 6358)` block models the flow rate of an ideal gas through a fixed-area sharp-edged orifice. The model conforms to the ISO 6358 standard and is based on the following flow equations, originally proposed by Sanville [1]:

$$G = \begin{cases} k_1 \bullet p_i \left(1 - \dfrac{p_o}{p_i}\right)\sqrt{\dfrac{T_{ref}}{T_i}} \bullet sign\left(p_i - p_o\right) & \text{if } \dfrac{p_o}{p_i} > \beta_{lam} \text{ (laminar)} \\ p_i \bullet C \bullet \rho_{ref}\sqrt{\dfrac{T_{ref}}{T_i}} \bullet \sqrt{1 - \left(\dfrac{\dfrac{p_o}{p_i} - b}{1 - b}\right)^2} & \text{if } \beta_{lam} > \dfrac{p_o}{p_i} > b \text{ (subsonic)} \\ p_i \bullet C \bullet \rho_{ref}\sqrt{\dfrac{T_{ref}}{T_i}} & \text{if } \dfrac{p_o}{p_i} <= b \text{ (choked)} \end{cases}$$

$$k_1 = \frac{1}{1 - \beta_{lam}} \bullet C \bullet \rho_{ref}\sqrt{1 - \left(\frac{\beta_{lam} - b}{1 - b}\right)^2}$$

where

G	Mass flow rate
β_{lam}	Pressure ratio at laminar flow, a value between 0.999 and 0.995
b	Critical pressure ratio, that is, the ratio between the outlet pressure p_o and inlet pressure p_i at which the gas velocity achieves sonic speed
C	Sonic conductance of the component, that is, the ratio between the mass flow rate and the product of inlet pressure p_1 and the mass density at standard conditions when the flow is choked
ρ_{ref}	Gas density at which the sonic conductance was measured (1.185 kg/m^3 for air)
p_i, p_o	Absolute pressures at the orifice inlet and outlet, respectively. The inlet and outlet change depending on flow direction. For positive flow ($G > 0$), $p_i = p_A$, otherwise $p_i = p_B$.
T_i, T_o	Absolute gas temperatures at the orifice inlet and outlet, respectively
T_{ref}	Gas temperature at which the sonic conductance was measured (T_{ref} = 293.15 K)

The equation itself, parameters b and C, and the heuristic on how to measure these parameters experimentally form the basis for the standard ISO 6358 (1989). The values of the critical pressure ratio b and the sonic conductance C depend on a particular design of a component. Typically, they are determined experimentally and are sometimes given on a manufacturer data sheet.

The block can also be parameterized in terms of orifice effective area or flow coefficient, instead of sonic conductance. When doing so, block parameters are converted into an equivalent value for sonic conductance. When specifying effective area, the following formula proposed by Gidlund and detailed in [2] is used:

$$C = 0.128\, d^{2}$$

where

C	Sonic conductance in dm^3/(s*bar)
d	Inner diameter of restriction in mm

The effective area (whether specified directly, or calculated when the orifice is parameterized in terms of C_v or K_v, as described below) is used to determine the inner diameter d in the Gidlund formula, assuming a circular cross section.

Gidlund also gives an approximate formula for the critical pressure ratio in terms of the pneumatic line diameter D,
$b = 0.41 + 0.272\ d\ /\ D$
This equation is not used by the block and you must specify the critical pressure ratio directly.

If the orifice is parameterized in terms of the C_v [2] coefficient, then the C_v coefficient is turned into an equivalent effective orifice area for use in the Gidlund formula:
$A = 1.6986e - 5\ C_v$
By definition, an opening or restriction has a C_v coefficient of 1 if it passes 1 gpm (gallon per minute) of water at pressure drop of 1 psi.

If the orifice is parameterized in terms of the K_v [2] coefficient, then the K_v coefficient is turned into an equivalent effective orifice area for use in the Gidlund formula:
$A = 1.1785e - 6\ C_v$
K_v is the SI counterpart of C_v. An opening or restriction has a K_v coefficient of 1 if it passes 1 lpm (liter per minute) of water at pressure drop of 1 bar.

The heat flow out of the orifice is assumed equal to the heat flow into the orifice, based on the following considerations:

- The orifice is square-edged or sharp-edged, and as such is characterized by an abrupt change of the downstream area. This means that practically all the dynamic pressure is lost in the expansion.
- The lost energy appears in the form of internal energy that rises the output temperature and makes it very close to the inlet temperature.

Therefore, $q_i = q_o$, where q_i and q_o are the input and output heat flows, respectively.

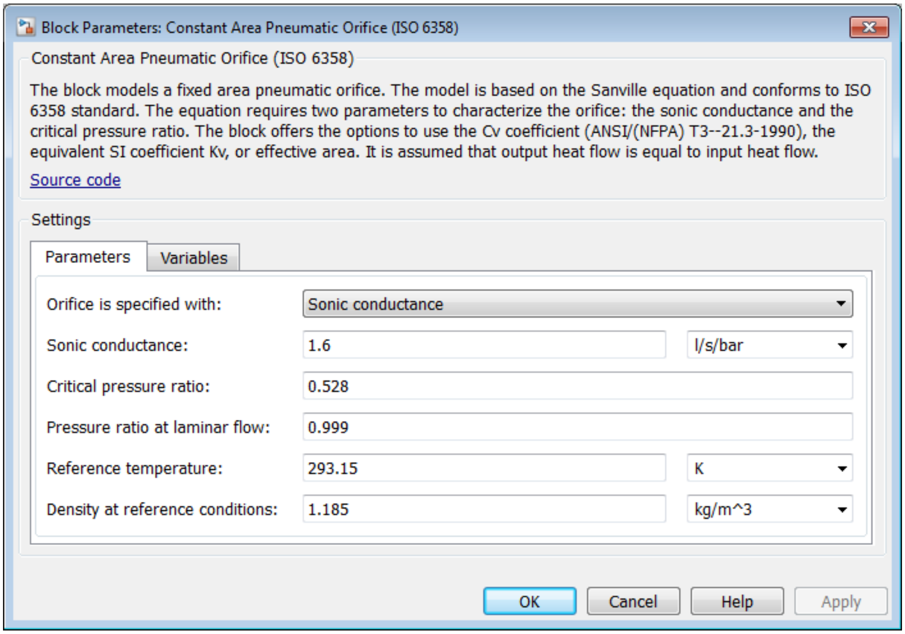
The block positive direction is from port A to port B. This means that the flow rate is positive if it flows from A to B.

Basic Assumptions and Limitations

- The gas is ideal.
- Specific heats at constant pressure and constant volume, c_p and c_v, are constant.
- The process is adiabatic, that is, there is no heat transfer with the environment.
- Gravitational effects can be neglected.

- The orifice adds no net heat to the flow.

Dialog Box and Parameters


Block Parameters: Constant Area Pneumatic Orifice (ISO 6358)

Constant Area Pneumatic Orifice (ISO 6358)

The block models a fixed area pneumatic orifice. The model is based on the Sanville equation and conforms to ISO 6358 standard. The equation requires two parameters to characterize the orifice: the sonic conductance and the critical pressure ratio. The block offers the options to use the Cv coefficient (ANSI/(NFPA) T3--21.3-1990), the equivalent SI coefficient Kv, or effective area. It is assumed that output heat flow is equal to input heat flow.

Source code

Settings

Parameters | Variables

Orifice is specified with: Sonic conductance

Sonic conductance: 1.6 l/s/bar

Critical pressure ratio: 0.528

Pressure ratio at laminar flow: 0.999

Reference temperature: 293.15 K

Density at reference conditions: 1.185 kg/m^3

- "Parameters Tab" on page 1-40
- "Variables Tab" on page 1-42

Parameters Tab

Orifice is specified with

Select one of the following model parameterization methods:

- `Sonic conductance` — Provide value for the sonic conductance of the orifice. The values of the sonic conductance and the critical pressure ratio form the basis for the ISO 6358 compliant flow equations for the orifice. This is the default method.

- `Effective area` — Provide value for the orifice effective area. This value is internally converted by the block into an equivalent value for sonic conductance.
- `Cv coefficient (USCU)` — Provide value for the flow coefficient specified in US units. This value is internally converted by the block into an equivalent value for the orifice effective area.
- `Kv coefficient (SI)` — Provide value for the flow coefficient specified in SI units. This value is internally converted by the block into an equivalent value for the orifice effective area.

Sonic conductance

Specify the sonic conductance of the orifice, that is, the ratio between the mass flow rate and the product of upstream pressure and the mass density at standard conditions when the flow is choked. This value depends on the geometrical properties of the orifice, and usually is provided in textbooks or manufacturer data sheets. The default value is `1.6` l/s/bar. This parameter appears in the dialog box if **Orifice is specified with** parameter is set to `Sonic conductance`.

Effective area

Specify the orifice cross-sectional area. The default value is `1e-5` m^2. This parameter appears in the dialog box if **Orifice is specified with** parameter is set to `Effective area`.

Cv coefficient

Specify the value for the flow coefficient in US units. The default value is `0.6`. This parameter appears in the dialog box if **Orifice is specified with** parameter is set to `Cv coefficient (USCU)`.

Kv coefficient

Specify the value for the flow coefficient in SI units. The default value is `8.5`. This parameter appears in the dialog box if **Orifice is specified with** parameter is set to `Kv coefficient (SI)`.

Critical pressure ratio

Specify the critical pressure ratio, that is, the ratio between the downstream pressure and the upstream pressure at which the gas velocity achieves sonic speed. The default value is `0.528`.

Pressure ratio at laminar flow

Specify the ratio between the downstream pressure and the upstream pressure at laminar flow. This value can be in the range between 0.995 and 0.999. The default value is `0.999`.

Reference temperature

Specify the gas temperature at which the sonic conductance was measured. The default value is `293.15` K.

Density at reference conditions

Specify the gas density at which the sonic conductance was measured. The default value is `1.185` kg/m^3.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see "Set Priority and Initial Target for Block Variables".

Ports

The block has the following ports:

A

Pneumatic conserving port associated with the orifice inlet for positive flow.

B

Pneumatic conserving port associated with the orifice outlet for positive flow.

References

[1] Sanville, F. E. "A New Method of Specifying the Flow Capacity of Pneumatic Fluid Power Valves." Paper D3, p.37-47. BHRA. Second International Fluid Power Symposium, Guildford, England, 1971.

[2] Beater, P. *Pneumatic Drives. System Design, Modeling, and Control.* New York: Springer, 2007.

See Also

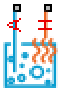
`Constant Area Pneumatic Orifice` | `Variable Area Pneumatic Orifice`

Constant Volume Chamber (2P)

Rigid chamber with constant volume of two-phase fluid

Library

Two-Phase Fluid/Elements



Description

The `Constant Volume Chamber (2P)` block models mass and energy storage in a chamber of fixed volume. The chamber inlet, represented by port A, allows mass and energy exchange with other two-phase fluid components. The chamber wall, represented by port H, allows heat exchange with thermal components.

Fluid pressure and energy rise and fall in the chamber as it exchanges heat with its surroundings and mass with adjacent two-phase fluid components. The changes in pressure and specific internal energy depend on the dynamic compressibility and thermal capacity of the fluid.

The flow resistance between port A and the chamber interior is assumed negligible. The pressure at port A is therefore equal to the pressure inside the chamber:

$$p_A = p_I ,$$

where:

- p_A is the pressure at port A.
- p_I is the pressure in the chamber.

Similarly, the thermal resistance between port H and the chamber interior is assumed negligible. The temperature at port H is therefore equal to the pressure inside the chamber:

$$T_H = T_I ,$$

where:

- T_H is the temperature at port H.
- T_I is the temperature in the chamber.

Energy Balance

The net energy flow rate into the chamber follows from the energy conservation law. Since energy crosses the chamber boundary through ports A and H, the net energy flow rate includes contributions from these two ports:

$$\dot{E} = \phi_A + \phi_H ,$$

where:

- E is the total energy of the fluid in the chamber.
- ϕ_A is the energy flow rate into the chamber through port A.
- ϕ_H is the heat flow rate into the chamber through port H.

Bulk fluid flow, and therefore the kinetic energy associated with it, is assumed negligible in the chamber. As a result, the total energy in the chamber is equal to the internal energy of the fluid:

$$E = Mu_I ,$$

where:

- M is the mass of fluid in the chamber.
- u_I is the specific internal energy of the fluid in the chamber.

Mass Balance

The net mass flow rate into the chamber follows from the mass conservation law. Since mass crosses the chamber boundary only through port A, the net mass flow rate includes only a contribution from this port:

$$\dot{M} = \dot{m}_A ,$$

where:

- $\dot{m}_A$ is the mass flow rate into the chamber through port A.

Accompanying a mass flow rate into the chamber is a change in fluid density, associated with a change in fluid pressure, internal energy, or both. The rate of change of the fluid mass in the chamber follows from the alternate mass conservation equation

$$\left[\left(\frac{\partial\rho}{\partial p}\right)_u \dot{p}_I + \left(\frac{\partial\rho}{\partial u}\right)_p \dot{u}_I\right]V = \dot{m}_A + {}_M.$$

where:

- $\left(\frac{\partial\rho}{\partial p}\right)_u$ is the partial derivative of density with respect to pressure at constant specific internal energy.
- $\left(\frac{\partial\rho}{\partial u}\right)_p$ is the partial derivative of density with respect to specific internal energy at constant pressure.
- V is the chamber volume.
- ϵ_M is a correction term.

The density partial derivatives are computed by the finite difference method using the specific volume lookup tables specified in the `Two-Phase Fluid Properties (2P)` block. The block linearly interpolates the computed values to obtain the partial derivatives in the entire pressure-specific internal energy continuum.

To prevent numerical discontinuities at the phase-transition boundaries, the block blends the density partial derivatives of the various domains using a cubic polynomial function. At a vapor quality of 0–0.1, this function blends the partial derivatives of the subcooled liquid and two-phase mixture domains. At a vapor quality of 0.9–1, it blends the derivatives of the two-phase mixture and superheated vapor domains.

The smoothing applied to the density partial derivatives introduce numerical errors into the alternate mass conservation equation. To correct for these errors, the block adds the correction term

$${}_M = \frac{M - V/v_I}{\tau},$$

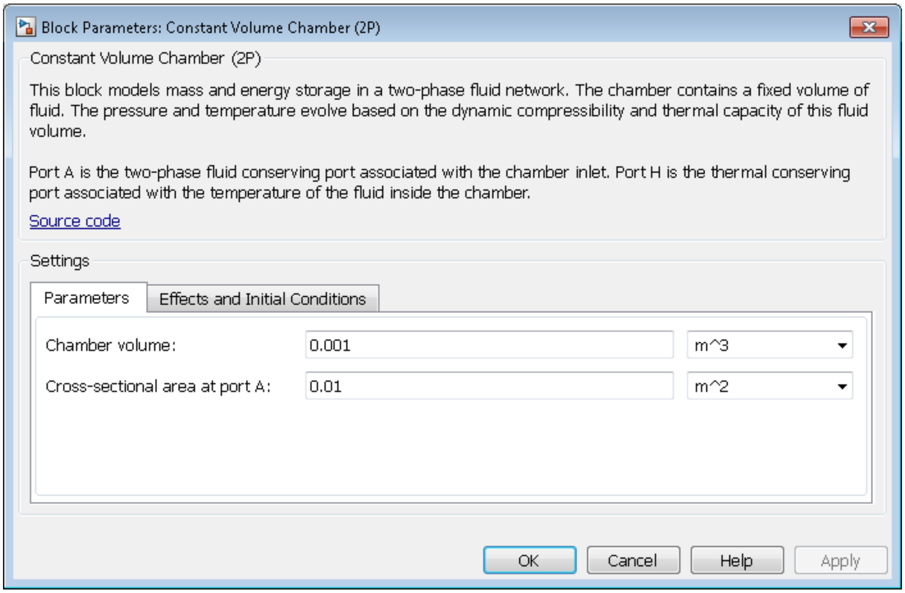
where:

- ϵ_M is the correction term.
- υ_I is the specific volume of the fluid in the chamber.
- τ is the phase-change time constant—a time lag introduced into the transition between phase boundaries.

Assumptions and Limitations

- The chamber walls are rigid. They do not deform due to pressure.
- The flow resistance between port A and the chamber interior is negligible. Pressure is the same at port A and in the chamber interior.
- The thermal resistance between port H and the chamber interior is negligible. Temperature is the same at port H and in the chamber interior.
- The kinetic energy of the fluid in the chamber is negligible.

Dialog Box and Parameters



Block Parameters: Constant Volume Chamber (2P)

Constant Volume Chamber (2P)

This block models mass and energy storage in a two-phase fluid network. The chamber contains a fixed volume of fluid. The pressure and temperature evolve based on the dynamic compressibility and thermal capacity of this fluid volume.

Port A is the two-phase fluid conserving port associated with the chamber inlet. Port H is the thermal conserving port associated with the temperature of the fluid inside the chamber.

Source code

Settings

Chamber volume: 0.001 m^3

Cross-sectional area at port A: 0.01 m^2

Parameters Tab

Chamber volume

Volume of fluid in the chamber. The default value is `0.001` m^3.

Cross-sectional area at port A

Area normal to the direction of flow at the chamber inlet. The default value is `0.01` m^2.

Effects and Initial Conditions Tab

Initial fluid regime

Fluid regime at the start of simulation. The fluid can be a subcooled liquid, a two-phase mixture, or a superheated vapor. The default setting is `Subcooled liquid`.

Initial fluid pressure

Pressure in the chamber at the start of simulation. The default value is `0.101325` MPa.

Initial fluid temperature

Temperature in the chamber at the start of simulation. The default value is `293.15` K.

Phase change time constant

Characteristic duration of a phase-change event. This constant introduces a time lag into the transition between phase boundaries. The default value is `0.1` s.

Ports

The block contains the following ports:

- Port A is a two-phase fluid conserving port representing the chamber inlet.
- Port H is a thermal conserving port representing the chamber surface through which heat exchange occurs.

See Also

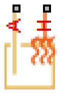
`Reservoir (2P)`

Constant Volume Chamber (TL)

Rigid chamber with constant volume of thermal liquid

Library

Thermal Liquid/Elements



Description

The `Constant Volume Chamber (TL)` block represents a cylindrical enclosure with a fixed volume of liquid. The enclosure can exchange mass and energy with its surroundings, allowing its internal pressure and temperature to evolve over time. Heat transfer occurs via convection, as liquid enters or exits the chamber, and conduction, as thermal energy flows through the chamber walls and the liquid itself.

Port A is a thermal liquid conserving port that corresponds to the chamber inlet. Pressure in the chamber equals the pressure at this port. Port Q is a thermal conserving port associated with the heat flux through the chamber wall. The temperature in the chamber equals the temperature at this port.

Mass Balance

The mass conservation equation in the chamber volume is

$$V\rho\left(\frac{1}{\beta}\frac{dp}{dt}+\alpha\frac{dT}{dt}\right)=\dot{m}_{\mathrm{A}},$$

where:

- V is the volume of liquid in the chamber.

- ρ is the mass density of liquid in the chamber.
- α is the isobaric bulk modulus of the liquid medium.
- β is the isothermal bulk modulus of the liquid medium.
- p is the pressure in the chamber.
- T is the temperature in the chamber.
- $\dot{m}_{\mathrm{A}}$ is the mass flow rate of liquid into the chamber through port A.

Energy Balance

The energy conservation equation in the chamber volume is

$$V\frac{d(\rho u)}{dt} = \phi_{\mathrm{A}} + Q_H ,$$

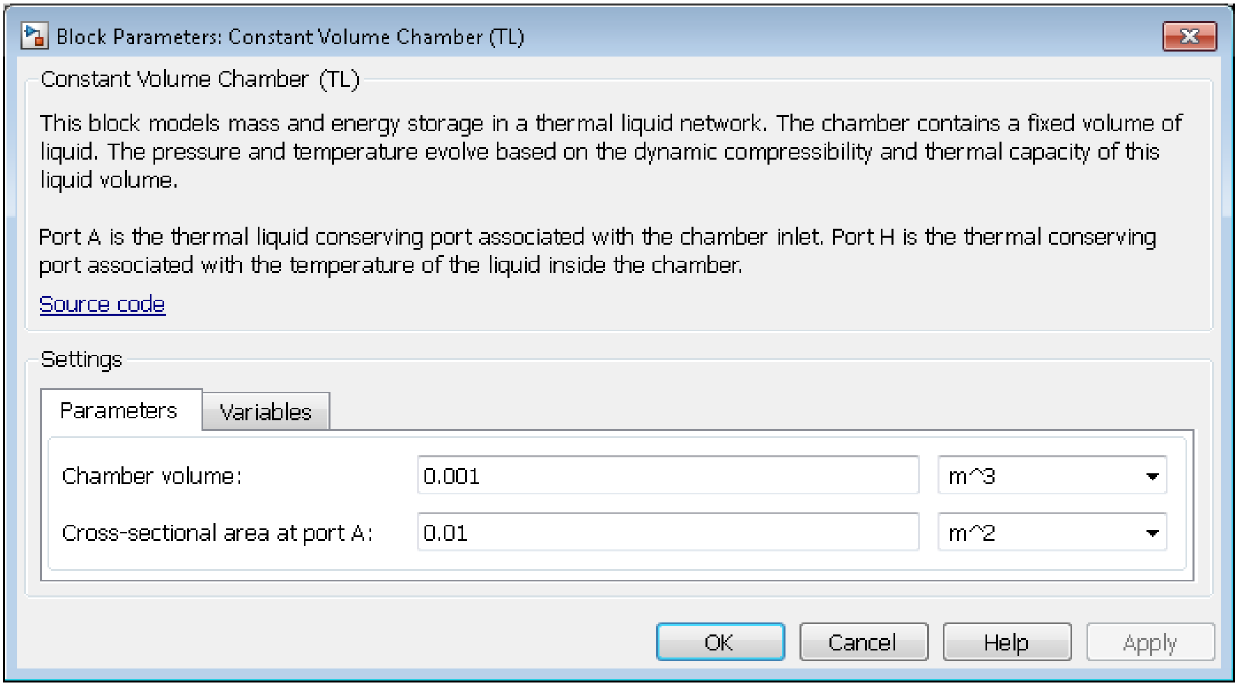
where:

- u is the specific internal energy in the chamber volume.
- φ is the total energy flow rate into the chamber through port A.
- Q_{H} is the thermal energy flow rate into the chamber through the chamber wall.

Assumptions and Limitations

- The chamber is cylindrical and perfectly rigid.

Dialog Box and Parameters



Block Parameters: Constant Volume Chamber (TL)

Constant Volume Chamber (TL)

This block models mass and energy storage in a thermal liquid network. The chamber contains a fixed volume of liquid. The pressure and temperature evolve based on the dynamic compressibility and thermal capacity of this liquid volume.

Port A is the thermal liquid conserving port associated with the chamber inlet. Port H is the thermal conserving port associated with the temperature of the liquid inside the chamber.

Source code

Settings

Parameters | Variables

Chamber volume: 0.001 m^3

Cross-sectional area at port A: 0.01 m^2

Parameters

Chamber volume

Enter the volume of liquid in the chamber. The chamber is rigid and its volume therefore constant during simulation. The chamber is assumed to be completely filled with liquid at all times. The default value is `1e-3` m^3.

Chamber cross-sectional area

Enter the cross-sectional area of the chamber. The chamber cross section is assumed constant. The block uses this parameter to calculate the chamber's characteristic length. The default value is `1e-2` m^2.

Variables

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has one thermal liquid conserving port, A, and one thermal conserving port, H.

See Also

`Reservoir (TL)` | `Controlled Reservoir (TL)`

Constant Volume Hydraulic Chamber

Hydraulic capacity of constant volume

Library

Hydraulic Elements

Description

The `Constant Volume Hydraulic Chamber` block models a fixed-volume chamber with rigid or flexible walls, to be used in hydraulic valves, pumps, manifolds, pipes, hoses, and so on. Use this block in models where you have to account for some form of fluid compressibility. You can select the appropriate representation of fluid compressibility using the block parameters.

Fluid compressibility in its simplest form is simulated according to the following equations:

$$V_f = V_c + \frac{V_c}{E} p$$

$$q = \frac{V_c}{E} \cdot \frac{dp}{dt}$$

where

q	Flow rate into the chamber
V_f	Volume of fluid in the chamber
V_c	Geometrical chamber volume

E	Fluid bulk modulus
p	Gauge pressure of fluid in the chamber

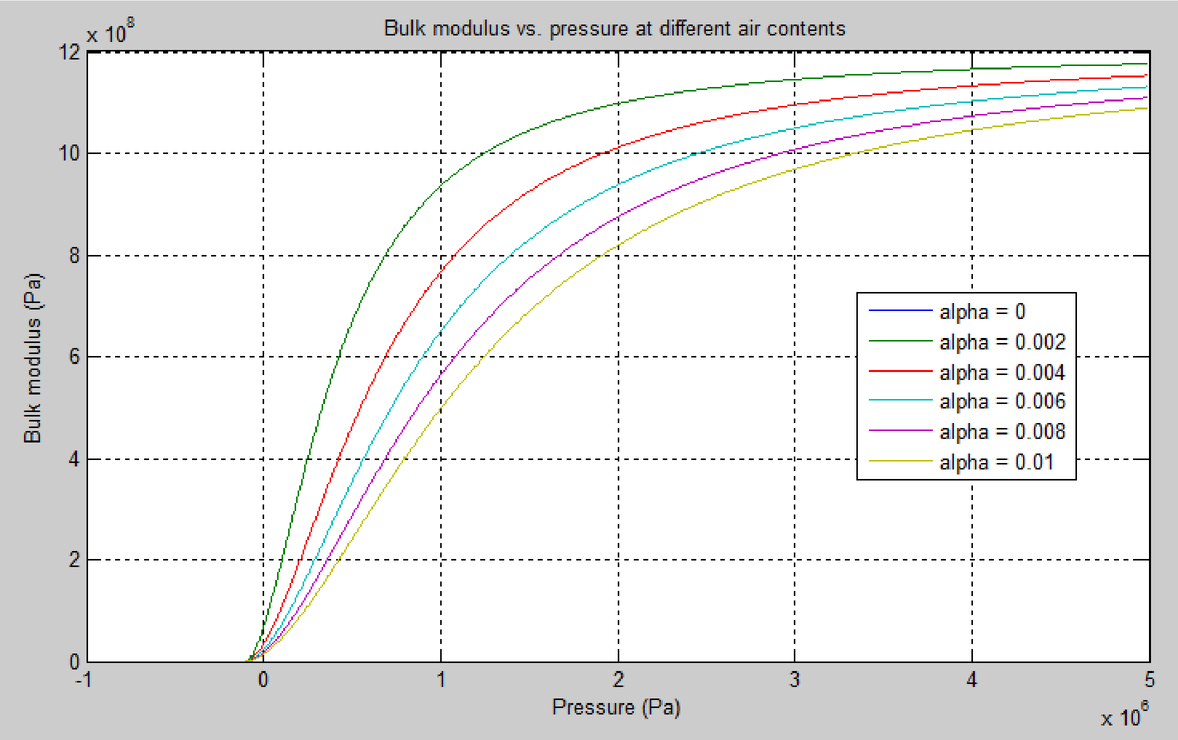
If pressure in the chamber is likely to fall to negative values and approach cavitation limit, the above equations must be enhanced. In this block, it is done by representing the fluid in the chamber as a mixture of liquid and a small amount of entrained, nondissolved gas (see [1, 2]). The mixture bulk modulus is determined as:

$$E = E_l \frac{1 + \alpha \left(\dfrac{p_a}{p_a + p} \right)^{1/n}}{1 + \alpha \dfrac{p_a^{1/n}}{n \bullet \left(p_a + p \right)^{\frac{n+1}{n}}} E_l}$$

where

E_{l}	Pure liquid bulk modulus
p_{a}	Atmospheric pressure
a	Relative gas content at atmospheric pressure, $a = V_{\mathrm{G}}/V_{\mathrm{L}}$
V_{G}	Gas volume at atmospheric pressure
V_{L}	Volume of liquid
n	Gas-specific heat ratio

The main objective of representing fluid as a mixture of liquid and gas is to introduce an approximate model of cavitation, which takes place in a chamber if pressure drops below fluid vapor saturation level. As it is seen in the graph below, the bulk modulus of a mixture decreases at $p \to p_a$, thus considerably slowing down further pressure change. At high pressure, $p >> p_a$, a small amount of nondissolved gas has practically no effect on the system behavior.



Cavitation is an inherently thermodynamic process, requiring consideration of multiple-phase fluids, heat transfers, etc., and as such cannot be accurately simulated with Simscape software. But the simplified version implemented in the block is good enough to signal if pressure falls below dangerous level, and to prevent computation failure that normally occurs at negative pressures.

If pressure falls below absolute vacuum (–101325 Pa), the simulation stops and an error message is displayed.

If chamber walls have noticeable compliance, the above equations must be further enhanced by representing geometrical chamber volume as a function of pressure:

$$V_c = \pi d^2 / 4 \bullet L$$

$$d(s) = \frac{K_p}{1 + \tau s} p(s)$$

where

d	Internal diameter of the cylindrical chamber
L	Length of the cylindrical chamber
K_p	Proportionality coefficient (m/Pa)
τ	Time constant
s	Laplace operator

Coefficient K_p establishes relationship between pressure and the internal diameter at steady-state conditions. For metal tubes, the coefficient can be computed as (see [2]):

$$K_p = \frac{d}{E_M}\left(\frac{D^2 + d^2}{D^2 - d^2} + \nu\right)$$

where

D	Pipe external diameter
E_M	Modulus of elasticity (Young's modulus) for the pipe material
ν	Poisson's ratio for the pipe material

For hoses, the coefficient can be provided by the manufacturer.

The process of expansion and contraction in pipes and especially in hoses is a complex combination of nonlinear elastic and viscoelastic deformations. This process is approximated in the block with the first-order lag, whose time constant is determined empirically (for example, see [3]).

As a result, by selecting appropriate values, you can implement four different models of fluid compressibility with this block:

- Chamber with rigid walls, no entrained gas in the fluid
- Cylindrical chamber with compliant walls, no entrained gas in the fluid
- Chamber with rigid walls, fluid with entrained gas
- Cylindrical chamber with compliant walls, fluid with entrained gas

The block allows two methods of specifying the chamber size:

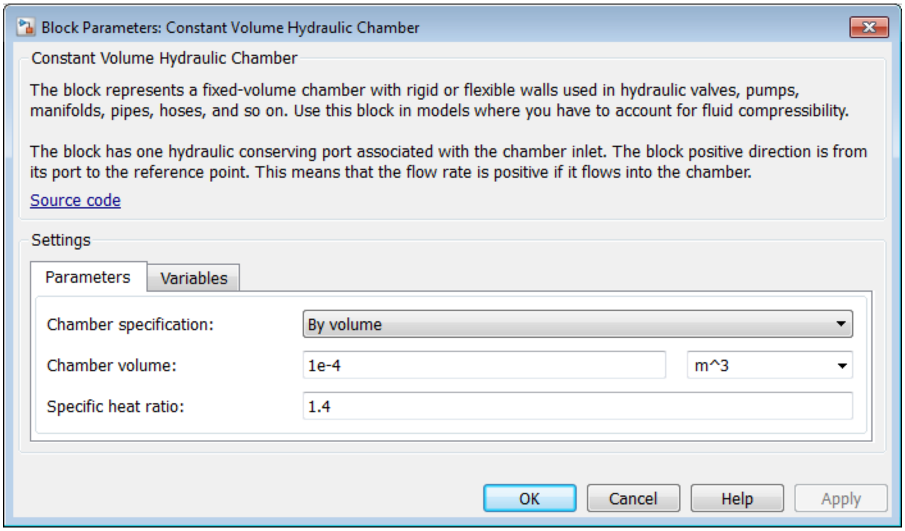
- By volume — Use this option for cylindrical or non-cylindrical chambers with rigid walls. You only need to know the volume of the chamber. This chamber type does not account for wall compliance.
- By length and diameter — Use this option for cylindrical chambers with rigid or compliant walls, such as circular pipes or hoses.

The block has one hydraulic conserving port associated with the chamber inlet. The block positive direction is from its port to the reference point. This means that the flow rate is positive if it flows into the chamber.

Basic Assumptions and Limitations

- No inertia associated with pipe walls is taken into account.
- Chamber with compliant walls is assumed to have a cylindrical shape. Chamber with rigid wall can have any shape.

Dialog Box and Parameters



Block Parameters: Constant Volume Hydraulic Chamber

Constant Volume Hydraulic Chamber

The block represents a fixed-volume chamber with rigid or flexible walls used in hydraulic valves, pumps, manifolds, pipes, hoses, and so on. Use this block in models where you have to account for fluid compressibility.

The block has one hydraulic conserving port associated with the chamber inlet. The block positive direction is from its port to the reference point. This means that the flow rate is positive if it flows into the chamber.

Source code

Settings

Chamber specification: By volume

Chamber volume: 1e-4 m^3

Specific heat ratio: 1.4

Dialog Box and Parameters

- "Parameters Tab" on page 1-57
- "Variables Tab" on page 1-58

Parameters Tab

Chamber specification

The parameter can have one of two values: `By volume` or `By length and diameter`. The value `By length and diameter` is recommended if a chamber is formed by a circular pipe. If the parameter is set to `By volume`, wall compliance is not taken into account. The default value of the parameter is `By volume`.

Chamber wall type

The parameter can have one of two values: `Rigid` or `Compliant`. If the parameter is set to `Rigid`, wall compliance is not taken into account, which can improve computational efficiency. The value `Compliant` is recommended for hoses and metal pipes, where compliance can affect the system behavior. The default value of the parameter is `Rigid`. The parameter is used if the **Chamber specification** parameter is set to `By length and diameter`.

Chamber volume

Volume of fluid in the chamber. The default value is `1e-4` m^3. The parameter is used if the **Chamber specification** parameter is set to `By volume`.

Chamber internal diameter

Internal diameter of the cylindrical chamber. The default value is `0.01` m. The parameter is used if the **Chamber specification** parameter is set to `By length and diameter`.

Cylindrical chamber length

Length of the cylindrical chamber. The default value is `1` m. The parameter is used if the **Chamber specification** parameter is set to `By length and diameter`.

Static pressure-diameter coefficient

Coefficient K_p that establishes relationship between pressure and the internal diameter at steady-state conditions. The parameter can be determined analytically or experimentally. The default value is `1.2e-12` m/Pa. The parameter is used if **Chamber wall type** is set to `Compliant`.

Viscoelastic process time constant

Time constant in the transfer function relating pipe internal diameter to pressure variations. With this parameter, the simulated elastic or viscoelastic process is approximated with the first-order lag. The parameter is determined experimentally or provided by the manufacturer. The default value is `0.01` s. The parameter is used if **Chamber wall type** is set to `Compliant`.

Specific heat ratio

Gas-specific heat ratio. The default value is `1.4`.

Restricted Parameters

When your model is in Restricted editing mode, you cannot modify the following parameters:

- **Chamber specification**
- **Chamber wall type**

All other block parameters are available for modification. The actual set of modifiable block parameters depends on the values of the **Tube cross section type** and **Chamber wall type** parameters at the time the model entered Restricted mode.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Global Parameters

Parameters determined by the type of working fluid:

- **Fluid bulk modulus**
- **Nondissolved gas ratio** — Nondissolved gas relative content determined as a ratio of gas volume to the liquid volume.

Use the `Hydraulic Fluid` block or the `Custom Hydraulic Fluid` block to specify the fluid properties.

Ports

The block has one hydraulic conserving port associated with the chamber inlet.

References

[1] Manring, N.D., *Hydraulic Control Systems*, John Wiley & Sons, New York, 2005

[2] Meritt, H.E., *Hydraulic Control Systems*, John Wiley & Sons, New York, 1967

[3] Holcke, Jan, *Frequency Response of Hydraulic Hoses*, RIT, FTH, Stockholm, 2002

See Also

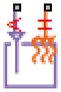
`Variable Hydraulic Chamber`

Constant Volume Pneumatic Chamber

Constant volume pneumatic chamber based on ideal gas law

Library

Pneumatic Elements



Description

The `Constant Volume Pneumatic Chamber` block models a constant volume pneumatic chamber based on the ideal gas law and assuming constant specific heats.

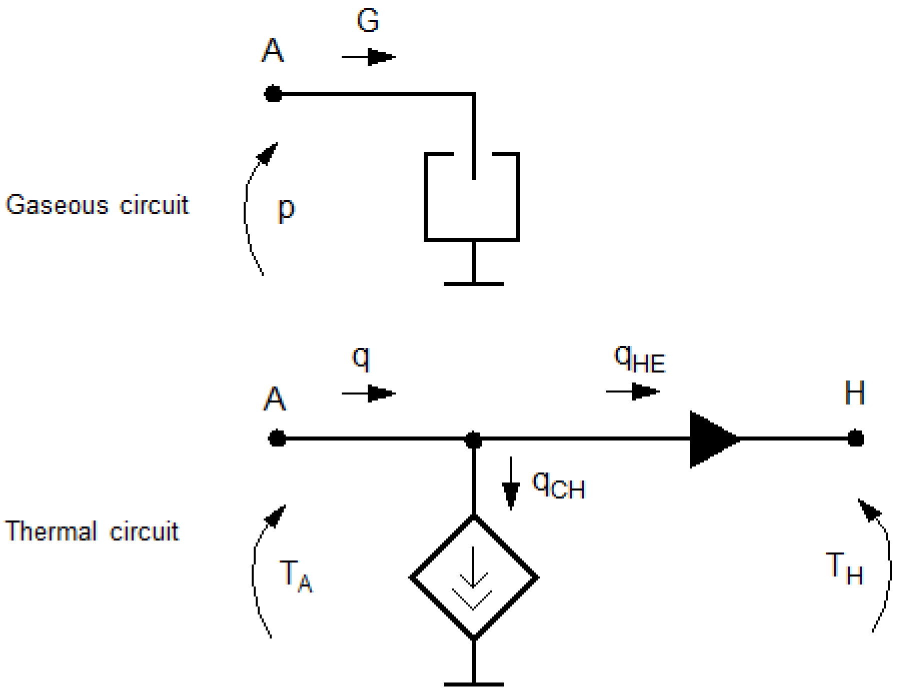
The continuity equation for the network representation of the constant chamber is

$$G = \frac{V}{RT}\left(\frac{dp}{dt} - \frac{p}{T}\frac{dT}{dt}\right)$$

where

G	Mass flow rate at input port
V	Chamber volume
p	Absolute pressure in the chamber
R	Specific gas constant
T	Absolute gas temperature
t	Time

The equivalent circuit of the `Constant Volume Pneumatic Chamber` block model is shown in the following illustration. Port A is the pneumatic conserving port associated with the chamber inlet. Port A connects both to the gaseous and the thermal circuit. Port H is a thermal conserving port through which heat exchange with the environment takes place. Port H connects only to the thermal circuit.



The diagram shows that the heat flow *q* to the chamber consists of two components:

- Heat flow q_{CH}, associated with the gaseous process
- Heat flow q_{HE}, associated with the heat exchange with the environment

The heat flow due to gas inflow is

$$q_{CH} = \frac{c_v V}{R} \bullet \frac{dp}{dt}$$

where c_v is specific heat at constant volume.

The heat exchange with the environment happens through port H, connected to thermal components. To determine the value of the heat exchange flow, the model contains a short-circuit element, resulting in the equation

$T_A = T_H$

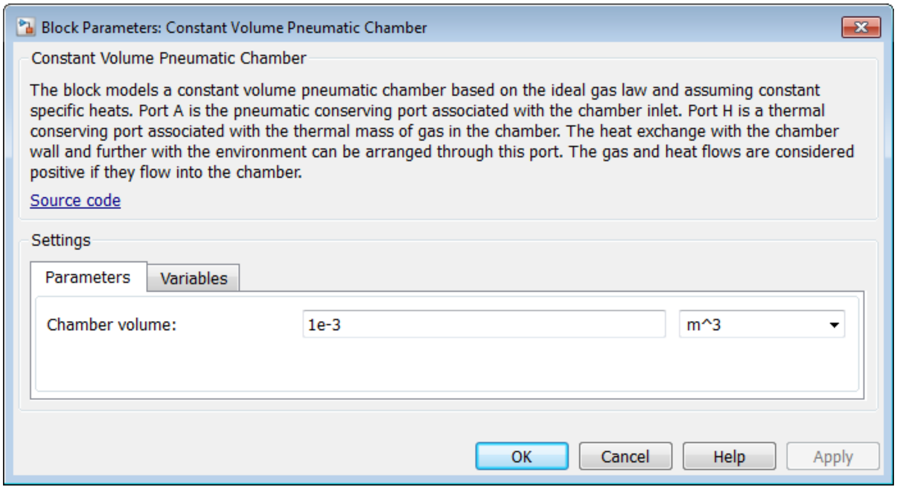
where both T_A and T_H represent the gas temperature.

The gas flow and the heat flow are considered positive if they flow into the chamber.

Basic Assumptions and Limitations

- The gas is ideal.
- Specific heats at constant pressure and constant volume, c_p and c_v, are constant.

Dialog Box and Parameters



Block Parameters: Constant Volume Pneumatic Chamber

Constant Volume Pneumatic Chamber

The block models a constant volume pneumatic chamber based on the ideal gas law and assuming constant specific heats. Port A is the pneumatic conserving port associated with the chamber inlet. Port H is a thermal conserving port associated with the thermal mass of gas in the chamber. The heat exchange with the chamber wall and further with the environment can be arranged through this port. The gas and heat flows are considered positive if they flow into the chamber.

Source code

Settings

Chamber volume: 1e-3 m^3

- “Parameters Tab” on page 1-62
- “Variables Tab” on page 1-63

Parameters Tab

Chamber volume

Specify the volume of the chamber. The default value is `.001` m^3.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

`A`

Pneumatic conserving port associated with the chamber inlet.

`H`

Thermal conserving port through which heat exchange with the environment takes place.

See Also

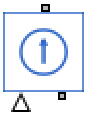
`Pneumatic Piston Chamber` | `Rotary Pneumatic Piston Chamber`

Controlled Current Source

Ideal current source driven by input signal

Library

Electrical Sources



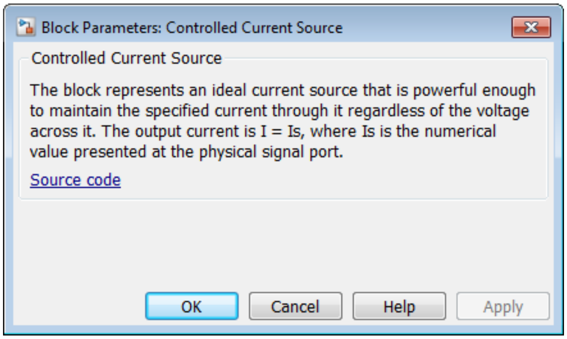
Description

The `Controlled Current Source` block represents an ideal current source that is powerful enough to maintain the specified current through it regardless of the voltage across the source.

The output current is $I = Is$, where Is is the numerical value presented at the physical signal port.

The positive direction of the current flow is indicated by the arrow.

Dialog Box and Parameters



Block Parameters: Controlled Current Source

Controlled Current Source

The block represents an ideal current source that is powerful enough to maintain the specified current through it regardless of the voltage across it. The output current is I = Is, where Is is the numerical value presented at the physical signal port.

Source code

The block has no parameters.

Ports

The block has one physical signal input port and two electrical conserving ports associated with its electrical terminals.

See Also

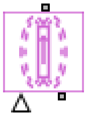
`Controlled Voltage Source`

Controlled Flux Source

Ideal flux source driven by input signal

Library

Magnetic Sources



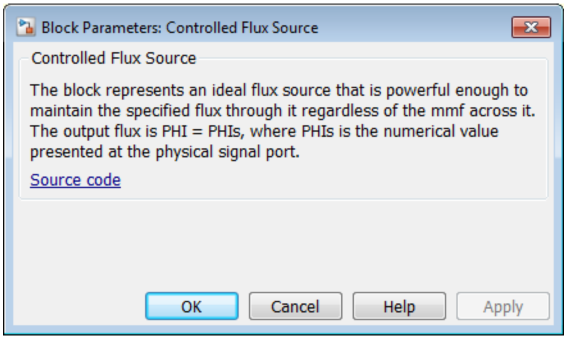
Description

The `Controlled Flux Source` block represents an ideal flux source that is powerful enough to maintain the specified flux through it regardless of the mmf across the source.

The output flux is *PHI* = *PHIs*, where *PHIs* is the numerical value presented at the physical signal port.

The positive direction of the flux flow is indicated by the arrow.

Dialog Box and Parameters



Block Parameters: Controlled Flux Source

Controlled Flux Source

The block represents an ideal flux source that is powerful enough to maintain the specified flux through it regardless of the mmf across it. The output flux is PHI = PHIs, where PHIs is the numerical value presented at the physical signal port.

Source code

The block has no parameters.

Ports

The block has one physical signal input port and two magnetic conserving ports associated with its magnetic terminals.

See Also

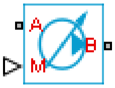
`Flux Source`

Controlled Mass Flow Rate Source (2P)

Generate time-varying mass flow rate

Library

Two-Phase Fluid/Sources



Description

The `Controlled Mass Flow Rate Source (2P)` block generates a time-varying volumetric flow rate through a two-phase fluid branch. The source is ideal. It maintains the specified flow rate regardless of the pressure differential between the inlet and outlet. Losses due to friction are assumed negligible.

Ports A and B represent the source inlet and outlet. The flow is positive if its direction is from port A to port B. Port M is a physical signal input port through which you specify the time-varying mass flow rate. This input controls the mass flow rate through the source. The flow rate is the same at the inlet and outlet.

The energy balance at the source is a function of the energy flow rates through ports A and B and the work done on the fluid:

$$\phi_A + \phi_B + \phi_{work} = 0,$$

where:

- ϕ_{A} is the energy flow rate into the source through port A.
- ϕ_{B} is the energy flow rate into the source through port B.
- ϕ_{work} is the isentropic work done on the fluid.

For a subcooled liquid, the isentropic work term is

$$\phi_{work}^{L} = \dot{m}\left(p_B - p_A\right)v_{avg},$$

where:

- ϕ^{L}_{work} is the isentropic work done on the subcooled liquid.
- $\dot{m}$ is the mass flow rate from port A to port B.
- p_A is the pressure at port A.
- p_B is the pressure at port B.
- v_avg is the average of the specific volumes at ports A and B,

$$v_{avg} = \frac{v_A + v_B}{2}.$$

- v_A is the specific volume at port A.
- v_B is the specific volume at port B.

If the fluid is a superheated vapor, the isentropic work is

$$\phi_{work}^{V} = \dot{m}\left(u_B^{isen} + p_B v_B + \frac{1}{2}\left(\frac{\dot{m}v_B}{S}\right) - u_A^{isen} - p_A v_A - \frac{1}{2}\left(\frac{\dot{m}v_B}{S}\right)\right),$$

where:

- ϕ^{V}_{work} is the isentropic work done on the superheated vapor.
- u_A^{isen} is the isentropic specific internal energy at port A.
- u_B^{isen} is the isentropic specific internal energy at port B.
- S is the source inlet cross-sectional area.

The isentropic specific internal energies at ports A and B follow from the expressions

$$\frac{u_A^{isen} + u_B^{isen}}{2} = \frac{u_A + u_B}{2}$$

and

$$s_{table}\left(\bar{u}_A^{isen}, p_A\right) = s_{table}\left(\bar{u}_B^{isen}, p_B\right),$$

where:

- u_A is the specific internal energy at port A.
- u_B is the specific internal energy at port B.
- $s_{table}(\bar{u}, p)$ is the interpolation of the specific entropy table at the normalized internal energy $\bar{u}$ and pressure p.
- $\bar{u}_A^{isen}$ is the isentropic normalized internal energy at port A.
- $\bar{u}_B^{isen}$ is the isentropic normalized internal energy at port B.

The normalized internal energy at port A is a function of the specific internal energy at that port, as described by the expression

$$\bar{u}_A^{isen} = \begin{cases} \dfrac{u_A^{isen} - u_{min}}{u_{sat}^L(p_A) - u_{min}} - 1, & u_A^{isen} < u_{sat}^L(p_A) \\ \dfrac{u_A^{isen} - u_{sat}^L(p_A)}{u_{sat}^V(p_A) - u_{sat}^L(p_A)}, & u_{sat}^L(p_A) \le u_A^{isen} \le u_{sat}^V(p_A), \\ \dfrac{u_A^{isen} - u_{max}}{u_{max} - u_{sat}^V(p_A)} + 2, & u_{sat}^V(p_A) < u_A^{isen} \end{cases}$$

where:

- u_{min} is the minimum valid specific internal energy.
- u_{max} is the maximum valid specific internal energy.
- $u^L_{sat}(p)$ is the interpolation of the saturated liquid specific internal energy vector at pressure p.
- $u^V_{sat}(p)$ is the interpolation of the saturated vapor specific internal energy vector at pressure p.

Similarly, the normalized internal energy at port B is a function of the specific internal energy at that port, as described by the expression

$$\bar{u}_B^{isen} = \begin{cases} \dfrac{u_B^{isen} - u_{min}}{u_{sat}^L(p_B) - u_{min}} - 1, & u_B^{isen} < u_{sat}^L(p_B) \\ \dfrac{u_B^{isen} - u_{sat}^L(p_B)}{u_{sat}^V(p_B) - u_{sat}^L(p_B)}, & u_{sat}^L(p_B) \le u_B^{isen} \le u_{sat}^V(p_B). \\ \dfrac{u_B^{isen} - u_{max}}{u_{max} - u_{sat}^V(p_B)} + 2, & u_{sat}^V(p_B) < u_B^{isen} \end{cases}$$

The normalized internal energy at either port falls in the range -1 to 0 for a subcooled liquid, 0 to 1 for a two-phase fluid, and 1 to 2 for a superheated vapor. The isentropic work as a function of the average normalized internal energy is

$$\phi_{work} = \begin{cases} \phi_{work}^L, & \bar{u}_{avg} < 0 \\ \left(1 - \bar{u}_{avg}\right)\phi_{work}^L + \bar{u}_{avg}\phi_{work}^V, & 0 \le \bar{u}_{avg} \le 1, \\ \phi_{work}^V, & 1 < \bar{u}_{avg} \end{cases}$$

where:

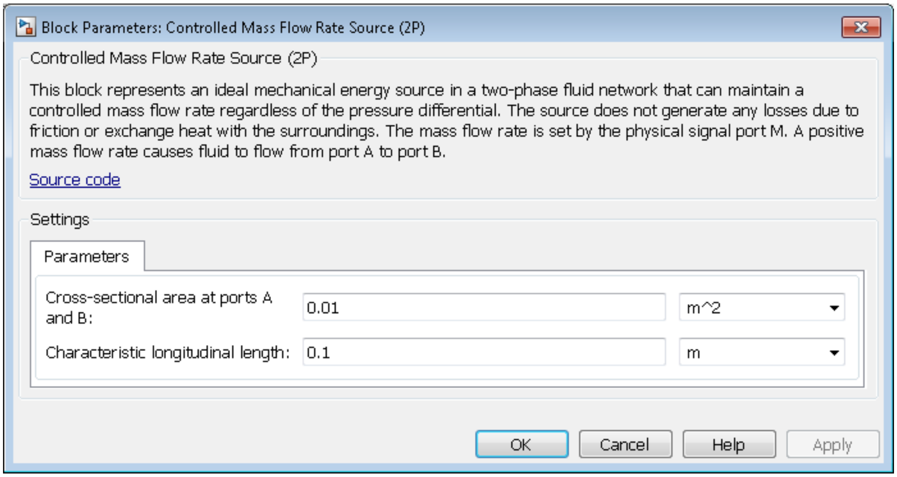
- $\bar{u}_{avg}$ is the average of the normalized internal energies at ports A and B,

$$\bar{u}_{avg} = \frac{\bar{u}_A + \bar{u}_B}{2}.$$

Assumptions and Limitations

- The source is ideal. Losses due to friction are assumed negligible.
- The source is adiabatic. Heat exchange with the surroundings is assumed negligible.
- Work done by the source is isentropic—that is, reversible and adiabatic.

Dialog Box and Parameters



Block Parameters: Controlled Mass Flow Rate Source (2P)

Controlled Mass Flow Rate Source (2P)

This block represents an ideal mechanical energy source in a two-phase fluid network that can maintain a controlled mass flow rate regardless of the pressure differential. The source does not generate any losses due to friction or exchange heat with the surroundings. The mass flow rate is set by the physical signal port M. A positive mass flow rate causes fluid to flow from port A to port B.

Source code

Settings

Parameters

Cross-sectional area at ports A and B: 0.01 m^2

Characteristic longitudinal length: 0.1 m

Cross-sectional area at ports A and B

Area normal to the direction of flow at the source inlet and outlet. The two cross-sectional areas are assumed identical. The default value is `0.01` m^2.

Characteristic longitudinal length

Average distance the fluid traverses in the source before it reaches the outlet. The default value is `0.1`m.

Ports

The block has a pair of two-phase fluid conserving ports, A and B, and a physical signal input port M that provides the time-varying mass flow rate.

See Also

`Controlled Volumetric Flow Rate Source (2P)` | `Mass Flow Rate Source (2P)` | `Volumetric Flow Rate Source (2P)`

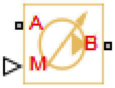
Controlled Mass Flow Rate Source (TL)

Generate time-varying mass flow rate

Library

Thermal Liquid/Sources

Description



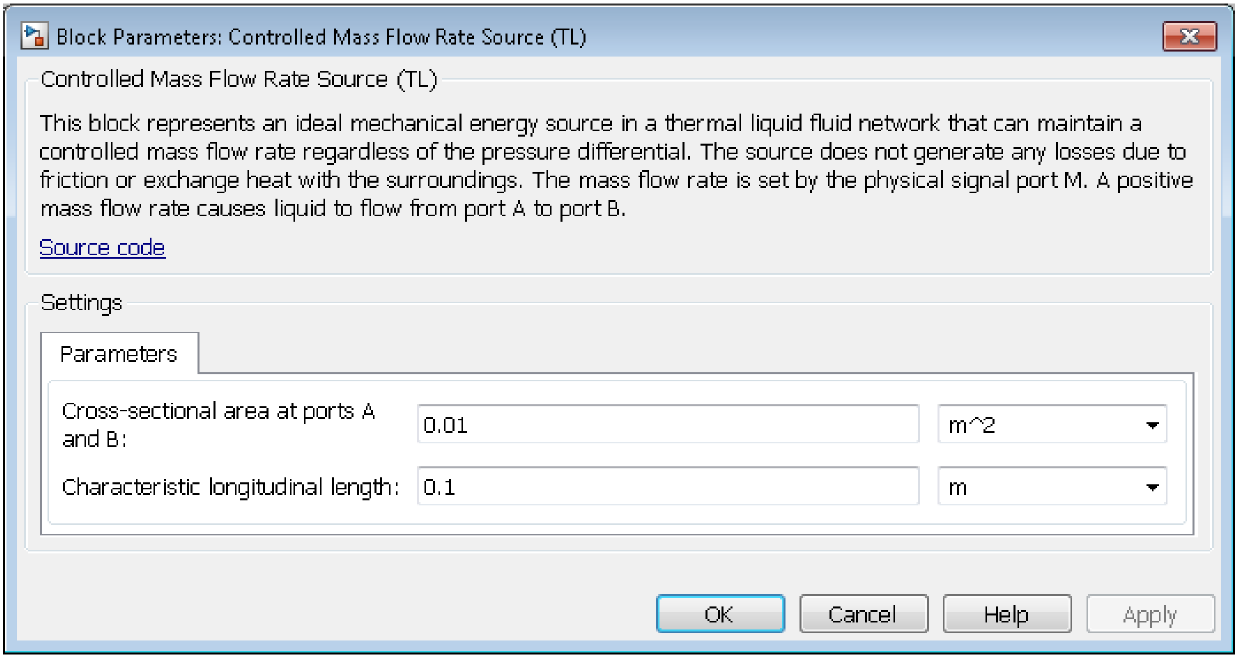
The `Controlled Mass Flow Rate Source (TL)` block represents an ideal compressor generating a variable mass flow rate through its inlets. The compressor can hold the specified mass flow rate regardless of the pressure differential across its inlets. No heat exchange occurs between the compressor and the flowing liquid.

Ports A and B represent the compressor inlets. Both ports are thermal liquid conserving ports. The mass flow rate is positive when liquid flows from inlet A to inlet B. The block provides physical signal port M so that you can specify the mass flow rate through the compressor inlets.

Assumptions and Limitations

- No heat exchange occurs between the compressor and the flowing liquid.
- The pressure differential between the compressor inlets is independent of the mass flow rate through those inlets.

Dialog Box and Parameters



Controlled Mass Flow Rate Source (TL)

This block represents an ideal mechanical energy source in a thermal liquid fluid network that can maintain a controlled mass flow rate regardless of the pressure differential. The source does not generate any losses due to friction or exchange heat with the surroundings. The mass flow rate is set by the physical signal port M. A positive mass flow rate causes liquid to flow from port A to port B.

Cross-sectional area at ports A and B: 0.01 m^2

Characteristic longitudinal length: 0.1 m

Cross-sectional area at ports A and B

Enter the cross-sectional area of the adjoining pipes. The default value is `0.01` m^2.

Characteristic longitudinal length

Enter the mean path length the liquid must flow through to go from inlet A to inlet B. The default value is `0.1` m.

Ports

A	Thermal liquid conserving port associated with compressor inlet A
B	Thermal liquid conserving port associated with compressor inlet B
M	Physical signal port providing the mass flow rate between inlets A and B

See Also

Pressure Source (TL)

Controlled Pressure Source (TL)

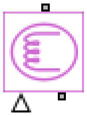
Mass Flow Rate Source (TL)

Controlled MMF Source

Ideal magnetomotive force source driven by input signal

Library

Magnetic Sources

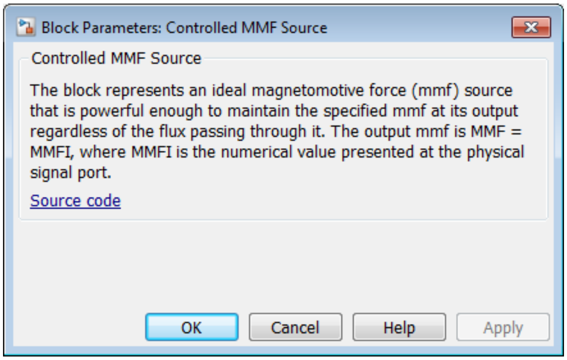


Description

The `Controlled MMF Source` block represents an ideal magnetomotive force (mmf) source that is powerful enough to maintain the specified mmf at its output regardless of the flux passing through it.

The output mmf is $MMF = MMFI$, where $MMFI$ is the numerical value presented at the physical signal port.

Dialog Box and Parameters



Block Parameters: Controlled MMF Source

Controlled MMF Source

The block represents an ideal magnetomotive force (mmf) source that is powerful enough to maintain the specified mmf at its output regardless of the flux passing through it. The output mmf is MMF = MMFI, where MMFI is the numerical value presented at the physical signal port.

Source code

The block has no parameters.

Ports

The block has one physical signal input port and two magnetic conserving ports associated with its magnetic terminals.

See Also

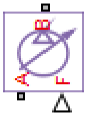
`MMF Source`

Controlled Pneumatic Flow Rate Source

Ideal compressor with signal-controlled mass flow rate

Library

Pneumatic Sources



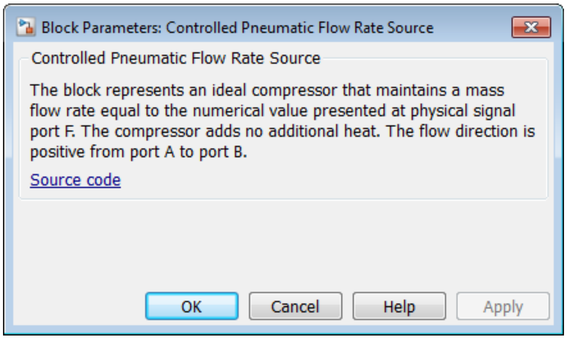
Description

The `Controlled Pneumatic Flow Rate Source` block represents an ideal compressor that maintains a mass flow rate equal to the numerical value presented at physical signal port F. The compressor adds no heat. Block connections A and B correspond to the pneumatic inlet and outlet ports, respectively, and connection F represents a control signal port.

The block positive direction is from port A to port B. This means that the flow rate is positive if it flows from A to B. The pressure differential is determined as $p = p_A - p_B$ and is negative if pressure at the source outlet is greater than pressure at its inlet. The power generated by the source is negative if the source adds energy to the flow.

Warning Be careful when driving an orifice directly from a flow rate source. The choked flow condition limits the flow that is possible through an orifice as a function of upstream pressure and temperature. Hence the flow rate value produced by the flow rate source must be compatible with upstream pressure and temperature. Specifying a flow rate that is too high will result in an unsolvable set of equations.

Dialog Box and Parameters


Block Parameters: Controlled Pneumatic Flow Rate Source
Controlled Pneumatic Flow Rate Source

The block represents an ideal compressor that maintains a mass flow rate equal to the numerical value presented at physical signal port F. The compressor adds no additional heat. The flow direction is positive from port A to port B.

Source code
OK
Cancel
Help
Apply

The block has no parameters.

Ports

The block has the following ports:

A

Pneumatic conserving port associated with the source inlet.

B

Pneumatic conserving port associated with the source outlet.

F

Control signal port.

See Also

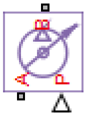
`Pneumatic Flow Rate Source` | `Pneumatic Mass & Heat Flow Sensor`

Controlled Pneumatic Pressure Source

Ideal compressor with signal-controlled pressure difference

Library

Pneumatic Sources

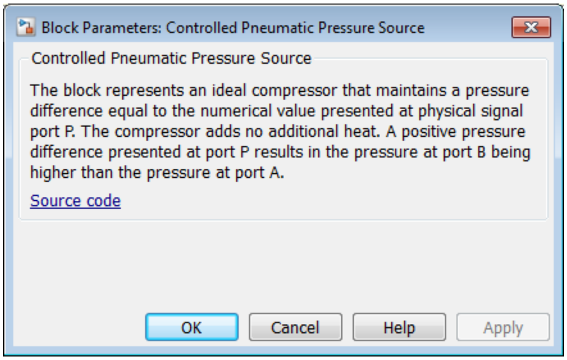


Description

The `Controlled Pneumatic Pressure Source` block represents an ideal compressor that maintains a pressure difference equal to the numerical value presented at physical signal port F. The compressor adds no heat. Block connections A and B correspond to the pneumatic inlet and outlet ports, respectively, and connection F represents a control signal port.

A positive pressure difference results in the pressure at port B being higher than the pressure at port A.

Dialog Box and Parameters



Block Parameters: Controlled Pneumatic Pressure Source

Controlled Pneumatic Pressure Source

The block represents an ideal compressor that maintains a pressure difference equal to the numerical value presented at physical signal port P. The compressor adds no additional heat. A positive pressure difference presented at port P results in the pressure at port B being higher than the pressure at port A.

Source code

The block has no parameters.

Ports

The block has the following ports:

A

Pneumatic conserving port associated with the source inlet.

B

Pneumatic conserving port associated with the source outlet.

F

Control signal port.

See Also

`Pneumatic Pressure & Temperature Sensor` | `Pneumatic Pressure Source`

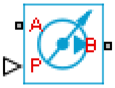
Controlled Pressure Source (2P)

Generate time-varying pressure differential

Library

Two-Phase Fluid/Sources

Description



The `Controlled Pressure Source (2P)` block generates a time-varying pressure differential across a pair of two-phase fluid nodes. The source is ideal. It maintains the specified pressure differential regardless of the mass flow rate between the two-phase fluid nodes. Losses due to friction are assumed negligible.

Ports A and B identify the two-phase fluid nodes across which to apply the pressure differential. Pressure is greater at port B than port A if the pressure differential is positive, and greater at port A than port B if the pressure differential is negative.

The energy balance at the source is a function of the energy flow rates through ports A and B and the work done on the fluid:

$$\phi_A + \phi_B + \phi_{work} = 0,$$

where:

- ϕ_{A} is the energy flow rate into the source through port A.
- ϕ_{B} is the energy flow rate into the source through port B.
- ϕ_{work} is the isentropic work done on the fluid.

For a subcooled liquid, the isentropic work term is

$$\phi_{work}^{L} = \dot{m}\left(p_B - p_A\right)v_{avg},$$

where:

- ϕ^{L}_{work} is the isentropic work done on the subcooled liquid.
- $\dot{m}$ is the mass flow rate from port A to port B.
- p_A is the pressure at port A.
- p_B is the pressure at port B.
- v_{avg} is the average of the specific volumes at ports A and B,

$$v_{avg} = \frac{v_A + v_B}{2}.$$

- v_A is the specific volume at port A.
- v_B is the specific volume at port B.

If the fluid is a superheated vapor, the isentropic work is

$$\phi^{V}_{work} = \dot{m}\left(u^{isen}_{B} + p_B v_B + \frac{1}{2}\left(\frac{\dot{m}v_B}{S}\right) - u^{isen}_{A} - p_A v_A - \frac{1}{2}\left(\frac{\dot{m}v_B}{S}\right)\right),$$

where:

- ϕ^{V}_{work} is the isentropic work done on the superheated vapor.
- u_A^{isen} is the isentropic specific internal energy at port A.
- u_B^{isen} is the isentropic specific internal energy at port B.
- S is the source inlet cross-sectional area.

The isentropic specific internal energies at ports A and B follow from the expressions

$$\frac{u^{isen}_{A} + u^{isen}_{B}}{2} = \frac{u_A + u_B}{2}$$

and

$$s_{table}\left(\bar{u}_A^{isen}, p_A\right) = s_{table}\left(\bar{u}_B^{isen}, p_B\right),$$

where:

- u_A is the specific internal energy at port A.
- u_B is the specific internal energy at port B.
- $s_{table}(\bar{u}, p)$ is the interpolation of the specific entropy table at the normalized internal energy $\bar{u}$ and pressure p.
- $\bar{u}_A^{isen}$ is the isentropic normalized internal energy at port A.
- $\bar{u}_B^{isen}$ is the isentropic normalized internal energy at port B.

The normalized internal energy at port A is a function of the specific internal energy at that port, as described by the expression

$$\bar{u}_A^{isen} = \begin{cases} \dfrac{u_A^{isen} - u_{min}}{u_{sat}^L(p_A) - u_{min}} - 1, & u_A^{isen} < u_{sat}^L(p_A) \\ \dfrac{u_A^{isen} - u_{sat}^L(p_A)}{u_{sat}^V(p_A) - u_{sat}^L(p_A)}, & u_{sat}^L(p_A) \le u_A^{isen} \le u_{sat}^V(p_A), \\ \dfrac{u_A^{isen} - u_{max}}{u_{max} - u_{sat}^V(p_A)} + 2, & u_{sat}^V(p_A) < u_A^{isen} \end{cases}$$

where:

- u_{min} is the minimum valid specific internal energy.
- u_{max} is the maximum valid specific internal energy.
- $u^L_{sat}(p)$ is the interpolation of the saturated liquid specific internal energy vector at pressure p.
- $u^V_{sat}(p)$ is the interpolation of the saturated vapor specific internal energy vector at pressure p.

Similarly, the normalized internal energy at port B is a function of the specific internal energy at that port, as described by the expression

$$\bar{u}_B^{isen} = \begin{cases} \dfrac{u_B^{isen} - u_{min}}{u_{sat}^L(p_B) - u_{min}} - 1, & u_B^{isen} < u_{sat}^L(p_B) \\ \dfrac{u_B^{isen} - u_{sat}^L(p_B)}{u_{sat}^V(p_B) - u_{sat}^L(p_B)}, & u_{sat}^L(p_B) \le u_B^{isen} \le u_{sat}^V(p_B). \\ \dfrac{u_B^{isen} - u_{max}}{u_{max} - u_{sat}^V(p_B)} + 2, & u_{sat}^V(p_B) < u_B^{isen} \end{cases}$$

The normalized internal energy at either port falls in the range -1 to 0 for a subcooled liquid, 0 to 1 for a two-phase fluid, and 1 to 2 for a superheated vapor. The isentropic work as a function of the average normalized internal energy is

$$\phi_{work} = \begin{cases} \phi_{work}^L, & \bar{u}_{avg} < 0 \\ \left(1 - \bar{u}_{avg}\right)\phi_{work}^L + \bar{u}_{avg}\phi_{work}^V, & 0 \le \bar{u}_{avg} \le 1, \\ \phi_{work}^V, & 1 < \bar{u}_{avg} \end{cases}$$

where:

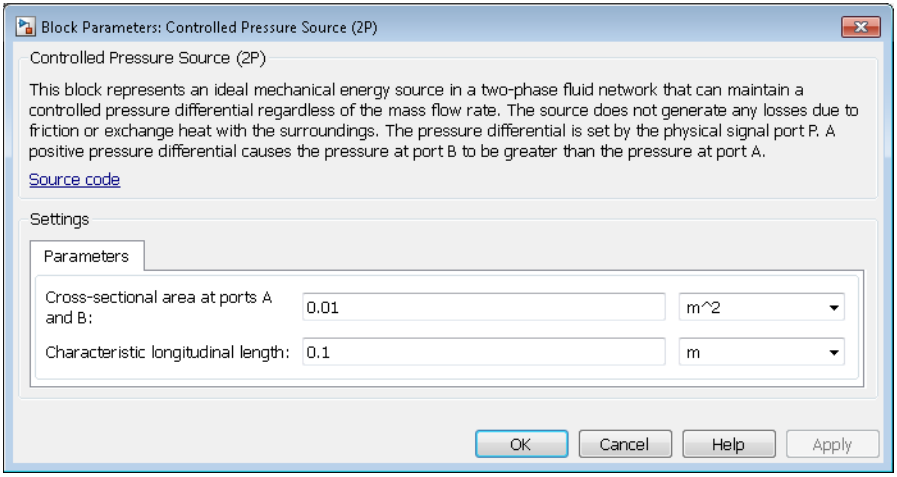
- $\bar{u}_{avg}$ is the average of the normalized internal energies at ports A and B,

$$\bar{u}_{avg} = \frac{\bar{u}_A + \bar{u}_B}{2}.$$

Assumptions and Limitations

- The source is ideal. Losses due to friction are assumed negligible.
- The source is adiabatic. Heat exchange with the surroundings is assumed negligible.
- Work done by the source is isentropic—that is, reversible and adiabatic.

Dialog Box and Parameters



Controlled Pressure Source (2P)

This block represents an ideal mechanical energy source in a two-phase fluid network that can maintain a controlled pressure differential regardless of the mass flow rate. The source does not generate any losses due to friction or exchange heat with the surroundings. The pressure differential is set by the physical signal port P. A positive pressure differential causes the pressure at port B to be greater than the pressure at port A.

Cross-sectional area at ports A and B: 0.01 m^2

Characteristic longitudinal length: 0.1 m

Cross-sectional area at ports A and B

Area normal to the direction of flow at the source inlet and outlet. The two cross-sectional areas are assumed identical. The default value is `0.01` m^2.

Characteristic longitudinal length

Average distance the fluid traverses in the source before it reaches the outlet. The default value is `0.1` m.

Ports

The block has two two-phase fluid conserving ports, A and B, and a physical signal input port P that provides the time-varying pressure.

See Also

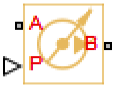
`Pressure Source (2P)`

Controlled Pressure Source (TL)

Generate time-varying pressure differential

Library

Thermal Liquid/Sources



Description

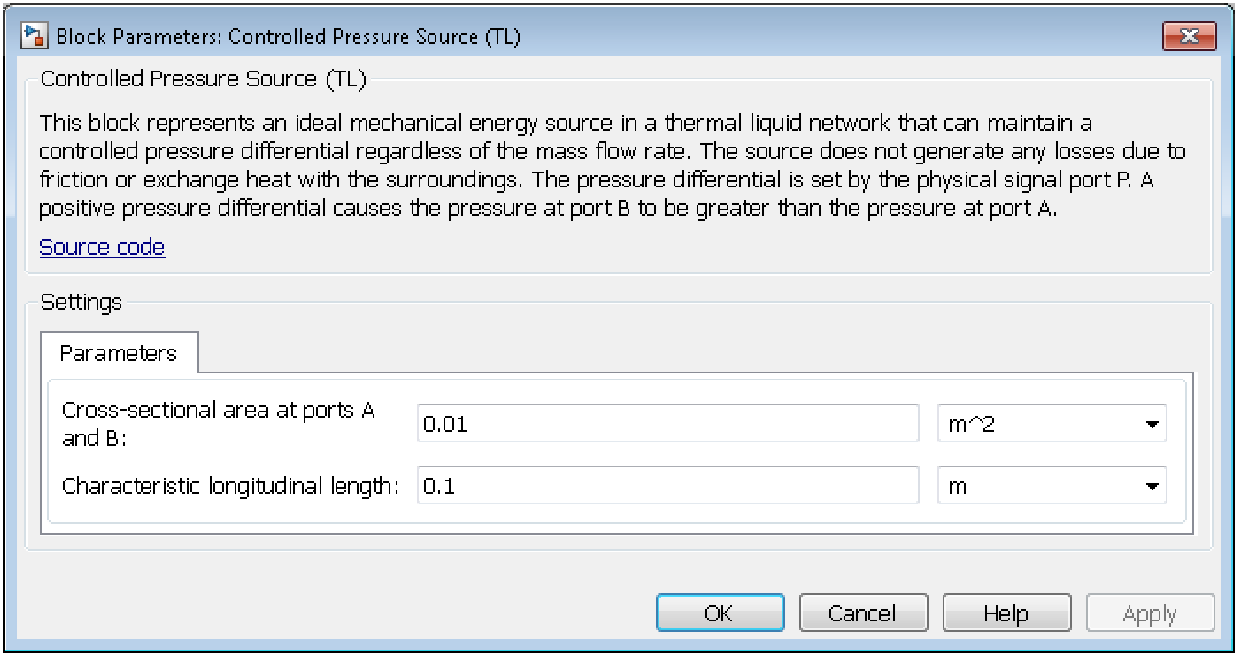
The `Controlled Pressure Source (TL)` block represents an ideal compressor generating a variable pressure differential across its inlets. The compressor can hold the specified pressure differential regardless of its mass flow rate. No heat exchange occurs between the compressor and the flowing liquid.

Ports A and B represent the compressor inlets. Both ports are thermal liquid conserving ports. The pressure differential is positive when the pressure at inlet B is greater than the pressure at inlet A. The block provides physical signal port P so that you can specify the pressure differential across the compressor inlets.

Assumptions and Limitations

- No heat exchange occurs between the compressor and the flowing liquid.
- The pressure differential between the compressor inlets is independent of the mass flow rate through those inlets.

Dialog Box and Parameters



Block Parameters: Controlled Pressure Source (TL)

Controlled Pressure Source (TL)

This block represents an ideal mechanical energy source in a thermal liquid network that can maintain a controlled pressure differential regardless of the mass flow rate. The source does not generate any losses due to friction or exchange heat with the surroundings. The pressure differential is set by the physical signal port P. A positive pressure differential causes the pressure at port B to be greater than the pressure at port A.

Source code

Settings

Parameters

Cross-sectional area at ports A and B: 0.01 m^2

Characteristic longitudinal length: 0.1 m

Cross-sectional area at ports A and B

Enter the cross-sectional area of the adjoining pipes. The default value is `0.01` m^2.

Characteristic longitudinal length

Enter the mean path length the liquid must flow through to go from inlet A to inlet B. The default value is `0.1` m.

Ports

The block has the following ports.

A	Thermal liquid conserving port associated with compressor inlet A
B	Thermal liquid conserving port associated with compressor inlet B
P	Physical signal port providing the pressure differential between inlets A and B

See Also

`Pressure Source (TL)`

`Mass Flow Rate Source (TL)`

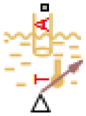
`Controlled Mass Flow Rate Source (TL)`

Controlled Reservoir (TL)

Thermal liquid reservoir at time-varying temperature

Library

Thermal Liquid/Elements



Description

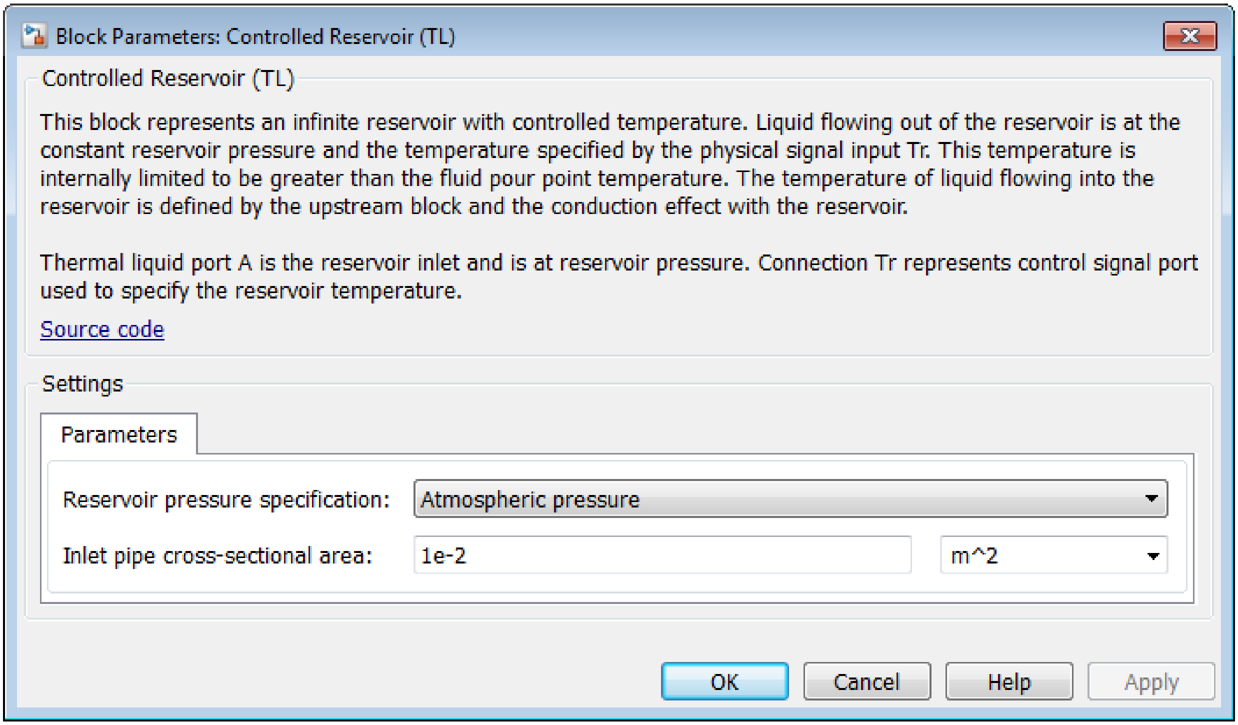
The `Controlled Reservoir (TL)` block represents an infinite reservoir at fixed pressure and variable temperature. The reservoir and its inlet can be at atmospheric pressure or at a specified pressure. Port A, a thermal liquid conserving port, represents the reservoir inlet. Port Tr, a physical signal port, provides the reservoir temperature control signal.

The inlet temperature depends on the direction of liquid flow. If the liquid flows into the reservoir, the inlet temperature equals that of the upstream liquid. The reservoir acts as a heat sink. If liquid flows out of the reservoir, the inlet temperature equals that of the reservoir. The reservoir acts as a heat source.

To ensure a smooth temperature change at the reservoir inlet during liquid flow reversal, the block includes heat conduction along a length equal to the effective diameter of the pipe. This diameter is a function of the specified cross-sectional area of the inlet pipe.

This block also functions as a reference point for pressure and temperature measurements in a pipe network. These measurements are relative to the reservoir pressure and temperature, respectively.

Dialog Box and Parameters



Controlled Reservoir (TL)

This block represents an infinite reservoir with controlled temperature. Liquid flowing out of the reservoir is at the constant reservoir pressure and the temperature specified by the physical signal input Tr. This temperature is internally limited to be greater than the fluid pour point temperature. The temperature of liquid flowing into the reservoir is defined by the upstream block and the conduction effect with the reservoir.

Thermal liquid port A is the reservoir inlet and is at reservoir pressure. Connection Tr represents control signal port used to specify the reservoir temperature.

Source code

Settings

Parameters

Reservoir pressure specification: Atmospheric pressure

Inlet pipe cross-sectional area: 1e-2 m^2

Reservoir pressure specification

Select whether to model the reservoir at atmospheric pressure or at a specified pressure. The default setting is `Atmospheric pressure`.

Reservoir pressure

Enter the desired pressure in the reservoir. This pressure remains constant during simulation. The default value is `1.01325` bar.

Cross-sectional area at port A

Enter the cross-sectional area of the reservoir inlet pipe. The block uses this area to determine the characteristic length of the pipe along which heat conduction occurs. The default value is `1e-2` m^2.

Ports

The block has one thermal liquid conserving port, A, and one physical signal port, T.

See Also

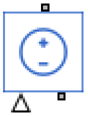
`Reservoir (TL)` | `Constant Volume Chamber (TL)`

Controlled Voltage Source

Ideal voltage source driven by input signal

Library

Electrical Sources

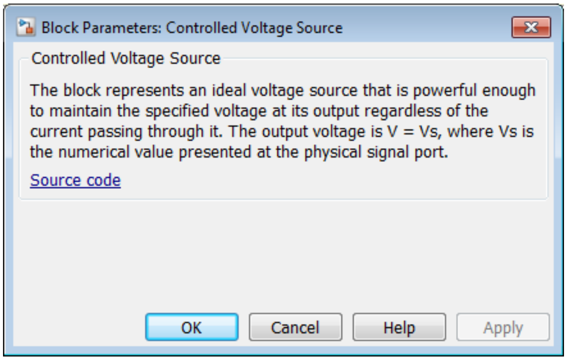


Description

The `Controlled Voltage Source` block represents an ideal voltage source that is powerful enough to maintain the specified voltage at its output regardless of the current flowing through the source.

The output voltage is $V = Vs$, where Vs is the numerical value presented at the physical signal port.

Dialog Box and Parameters



Block Parameters: Controlled Voltage Source
Controlled Voltage Source

The block represents an ideal voltage source that is powerful enough to maintain the specified voltage at its output regardless of the current passing through it. The output voltage is V = Vs, where Vs is the numerical value presented at the physical signal port.

Source code
OK
Cancel
Help
Apply

The block has no parameters.

Ports

The block has one physical signal input port and two electrical conserving ports associated with its electrical terminals.

See Also

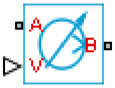
`Controlled Current Source`

Controlled Volumetric Flow Rate Source (2P)

Generate time-varying volumetric flow rate

Library

Thermal Liquid/Sources



Description

The `Controlled Volumetric Flow Rate Source (2P)` block generates a time-varying volumetric flow rate through its outlet. The source is ideal. It maintains the specified flow rate regardless of the pressure differential between the inlet and outlet. Losses due to friction are assumed negligible.

The flow rate input is a physical signal that you connect to port V. This input controls the volumetric flow rate at the outlet. The rate at the inlet can differ from the input signal if the specific volume changes within the source. However, due to mass conservation, the mass flow rates at the inlet and outlet are always identical.

The ports representing the inlet and outlet change with the flow rate sign. If the flow rate is positive, fluid flows from port A to port B and the outlet is at port B. If the flow rate is negative, fluid flows from port B to port A and the outlet is at port A.

The volumetric and mass flow rates at the source outlet are related through the expression

$$\dot{V} = \begin{cases} \dot{m} v_B, & \dot{V} \geq 0 \\ \dot{m} v_A, & \dot{V} < 0 \end{cases},$$

where:

- $\dot{V}$ is the volumetric flow rate.

- $\dot{m}$ is the mass flow rate from port A to port B.
- v_A is the specific volume at port A.
- v_B is the specific volume at port B.

The energy balance at the source is a function of the energy flow rates through ports A and B and the work done on the fluid:

$$\phi_A + \phi_B + \phi_{work} = 0,$$

where:

- ϕ_A is the energy flow rate into the source through port A.
- ϕ_B is the energy flow rate into the source through port B.
- ϕ_{work} is the isentropic work done on the fluid.

For a subcooled liquid, the isentropic work term is

$$\phi_{work}^{L} = \dot{m}\left(p_B - p_A\right)v_{avg},$$

where:

- ϕ^{L}_{work} is the isentropic work done on the subcooled liquid.
- p_A is the pressure at port A.
- p_B is the pressure at port B.
- v_{avg} is the average of the specific volumes at ports A and B,

$$v_{avg} = \frac{v_A + v_B}{2}.$$

If the fluid is a superheated vapor, the isentropic work is

$$\phi_{work}^{V} = \dot{m}\left(u_B^{isen} + p_B v_B + \frac{1}{2}\left(\frac{\dot{m}v_B}{S}\right) - u_A^{isen} - p_A v_A - \frac{1}{2}\left(\frac{\dot{m}v_B}{S}\right)\right),$$

where:

- ϕ^{V}_{work} is the isentropic work done on the superheated vapor.

- u_A^{isen} is the isentropic specific internal energy at port A.
- u_B^{isen} is the isentropic specific internal energy at port B.

The isentropic specific internal energies at ports A and B follow from the expressions

$$\frac{u_A^{isen} + u_B^{isen}}{2} = \frac{u_A + u_B}{2}$$

and

$$s_{table}\left(\bar{u}_A^{isen}, p_A\right) = s_{table}\left(\bar{u}_B^{isen}, p_B\right),$$

where:

- u_A is the specific internal energy at port A.
- u_B is the specific internal energy at port B.
- $S_{table}(\bar{u}, p)$ is the interpolation of the specific entropy table at the normalized internal energy $\bar{u}$ and pressure p.
- $\bar{u}_A^{isen}$ is the isentropic normalized internal energy at port A.
- $\bar{u}_B^{isen}$ is the isentropic normalized internal energy at port B.

The normalized internal energy at port A is a function of the specific internal energy at that port, as described by the expression

$$\bar{u}_A^{isen} = \begin{cases} \dfrac{u_A^{isen} - u_{min}}{u_{sat}^L(p_A) - u_{min}} - 1, & u_A^{isen} < u_{sat}^L(p_A) \\ \dfrac{u_A^{isen} - u_{sat}^L(p_A)}{u_{sat}^V(p_A) - u_{sat}^L(p_A)}, & u_{sat}^L(p_A) \leq u_A^{isen} \leq u_{sat}^V(p_A), \\ \dfrac{u_A^{isen} - u_{max}}{u_{max} - u_{sat}^V(p_A)} + 2, & u_{sat}^V(p_A) < u_A^{isen} \end{cases}$$

where:

- $u_{\min}$ is the minimum valid specific internal energy.
- $u_{\max}$ is the maximum valid specific internal energy.
- $u^{L}{}_{sat}$(p) is the interpolation of the saturated liquid specific internal energy vector at pressure *p*.
- $u^{V}{}_{sat}$(p) is the interpolation of the saturated vapor specific internal energy vector at pressure *p*.

Similarly, the normalized internal energy at port B is a function of the specific internal energy at that port, as described by the expression

$$\bar{u}_B^{isen} = \begin{cases} \dfrac{u_B^{isen} - u_{min}}{u_{sat}^L(p_B) - u_{min}} - 1, & u_B^{isen} < u_{sat}^L(p_B) \\ \dfrac{u_B^{isen} - u_{sat}^L(p_B)}{u_{sat}^V(p_B) - u_{sat}^L(p_B)}, & u_{sat}^L(p_B) \le u_B^{isen} \le u_{sat}^V(p_B). \\ \dfrac{u_B^{isen} - u_{max}}{u_{max} - u_{sat}^V(p_B)} + 2, & u_{sat}^V(p_B) < u_B^{isen} \end{cases}$$

The normalized internal energy at either port falls in the range -1 to 0 for a subcooled liquid, 0 to 1 for a two-phase fluid, and 1 to 2 for a superheated vapor. The isentropic work as a function of the average normalized internal energy is

$$\phi_{work} = \begin{cases} \phi_{work}^L, & \bar{u}_{avg} < 0 \\ \left(1 - \bar{u}_{avg}\right)\phi_{work}^L + \bar{u}_{avg}\phi_{work}^V, & 0 \le \bar{u}_{avg} \le 1, \\ \phi_{work}^V, & 1 < \bar{u}_{avg} \end{cases}$$

where:

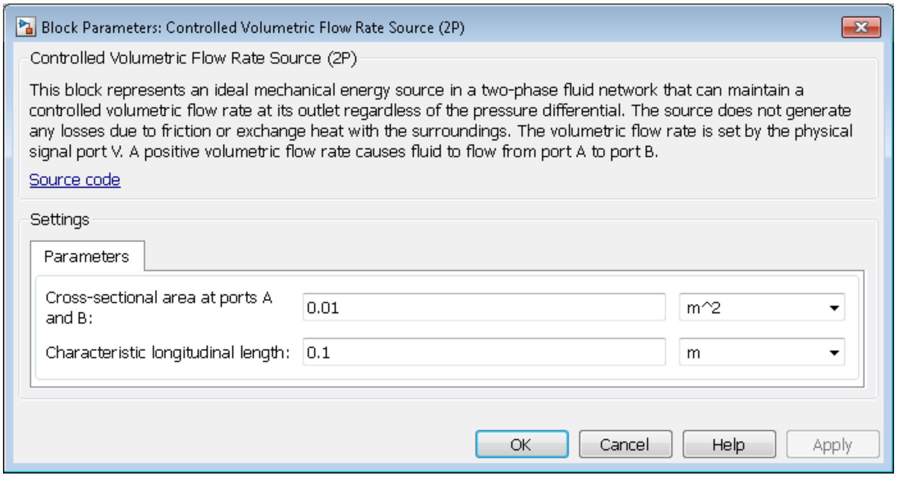
- $\bar{u}_{avg}$ is the average of the normalized internal energies at ports A and B,

$$\bar{u}_{avg} = \frac{\bar{u}_A + \bar{u}_B}{2}.$$

Assumptions and Limitations

- The source is ideal. Losses due to friction are assumed negligible.
- The source is adiabatic. Heat exchange with the surroundings is assumed negligible.
- Work done by the source is isentropic—that is, reversible and adiabatic.

Dialog Box and Parameters



Block Parameters: Controlled Volumetric Flow Rate Source (2P)

Controlled Volumetric Flow Rate Source (2P)

This block represents an ideal mechanical energy source in a two-phase fluid network that can maintain a controlled volumetric flow rate at its outlet regardless of the pressure differential. The source does not generate any losses due to friction or exchange heat with the surroundings. The volumetric flow rate is set by the physical signal port V. A positive volumetric flow rate causes fluid to flow from port A to port B.

Source code

Settings

Parameters

Cross-sectional area at ports A and B: 0.01 m^2

Characteristic longitudinal length: 0.1 m

Cross-sectional area at ports A and B

Area normal to the direction of flow at the source inlet and outlet. The two cross-sectional areas are assumed identical. The default value is `0.01` m^2.

Characteristic longitudinal length

Average distance the fluid traverses in the source before it reaches the outlet. The default value is `0.1`m.

Ports

The block has two two-phase fluid conserving ports, A and B, and a physical signal input port V that provides the time-varying volumetric flow rate.

See Also

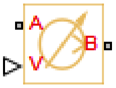
`Controlled Mass Flow Rate Source (2P)` | `Mass Flow Rate Source (2P)` | `Volumetric Flow Rate Source (2P)`

Controlled Volumetric Flow Rate Source (TL)

Generate time-varying volumetric flow rate

Library

Thermal Liquid/Sources



Description

The `Controlled Volumetric Flow Rate Source (TL)` block generates a time-varying volumetric flow rate through its outlet. The source is ideal. It maintains the specified flow rate regardless of the pressure differential between the inlet and outlet. Losses due to friction are assumed negligible.

The flow rate input is a physical signal that you connect to port V. This input controls the volumetric flow rate at the outlet. The rate at the inlet can differ from the input signal if the specific volume changes within the source. However, due to mass conservation, the mass flow rates at the inlet and outlet are always identical.

The ports representing the inlet and outlet change with the flow rate sign. If the flow rate is positive, fluid flows from port A to port B and the outlet is at port B. If the flow rate is negative, fluid flows from port B to port A and the outlet is at port A.

The volumetric and mass flow rates at the source outlet are related through the expression

$$\dot{V} = \begin{cases} \dot{m}v_B, & \dot{V} \geq 0 \\ \dot{m}v_A, & \dot{V} < 0 \end{cases},$$

where:

- $\dot{V}$ is the volumetric flow rate.

- $\dot{m}$ is the mass flow rate from port A to port B.
- v_A is the specific volume at port A.
- v_B is the specific volume at port B.

The energy balance at the source is a function of the energy flow rates through ports A and B and the work done on the fluid:

$$\phi_A + \phi_B + \phi_{work} = 0,$$

where:

- ϕ_A is the energy flow rate into the source through port A.
- ϕ_B is the energy flow rate into the source through port B.
- ϕ_{work} is the isentropic work done on the fluid.

The isentropic work term is

$$\phi_{work} = \dot{m}\left(p_B - p_A\right)v_{avg},$$

where:

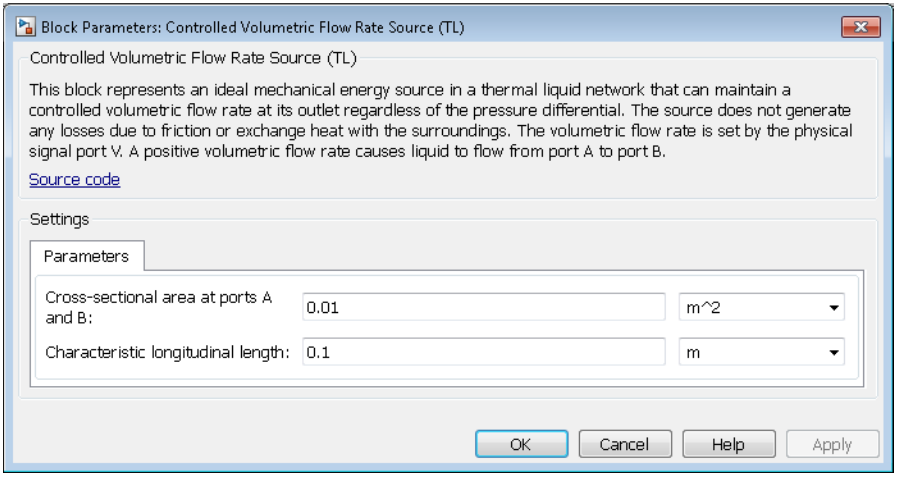
- ϕ_{work} is the isentropic work done on the thermal liquid.
- p_A is the pressure at port A.
- p_B is the pressure at port B.
- v_{avg} is the average of the specific volumes at ports A and B,

$$v_{avg} = \frac{v_A + v_B}{2}.$$

Assumptions and Limitations

- The source is ideal. Losses due to friction are assumed negligible.
- The source is adiabatic. Heat exchange with the surroundings is assumed negligible.
- Work done by the source is isentropic—that is, reversible and adiabatic.

Dialog Box and Parameters



Block Parameters: Controlled Volumetric Flow Rate Source (TL)

Controlled Volumetric Flow Rate Source (TL)

This block represents an ideal mechanical energy source in a thermal liquid network that can maintain a controlled volumetric flow rate at its outlet regardless of the pressure differential. The source does not generate any losses due to friction or exchange heat with the surroundings. The volumetric flow rate is set by the physical signal port V. A positive volumetric flow rate causes liquid to flow from port A to port B.

Source code

Settings

Parameters

Cross-sectional area at ports A and B: 0.01 m^2

Characteristic longitudinal length: 0.1 m

Cross-sectional area at ports A and B

Area normal to the direction of flow at the source inlet and outlet. The two cross-sectional areas are assumed identical. The default value is `0.01` m^2.

Characteristic longitudinal length

Average distance the fluid traverses in the source before it reaches the outlet. The default value is `0.1`m.

Ports

- A — Thermal Liquid conserving port representing source inlet A
- B — Thermal Liquid conserving port representing source inlet B
- V — Physical signal input port for specifying the volumetric flow rate

See Also

`Controlled Mass Flow Rate Source (TL)` | `Mass Flow Rate Source (TL)` | `Volumetric Flow Rate Source (TL)`

Convective Heat Transfer

Heat transfer by convection

Library

Thermal Elements

Description

The `Convective Heat Transfer` block represents a heat transfer by convection between two bodies by means of fluid motion. The transfer is governed by the Newton law of cooling and is described with the following equation:

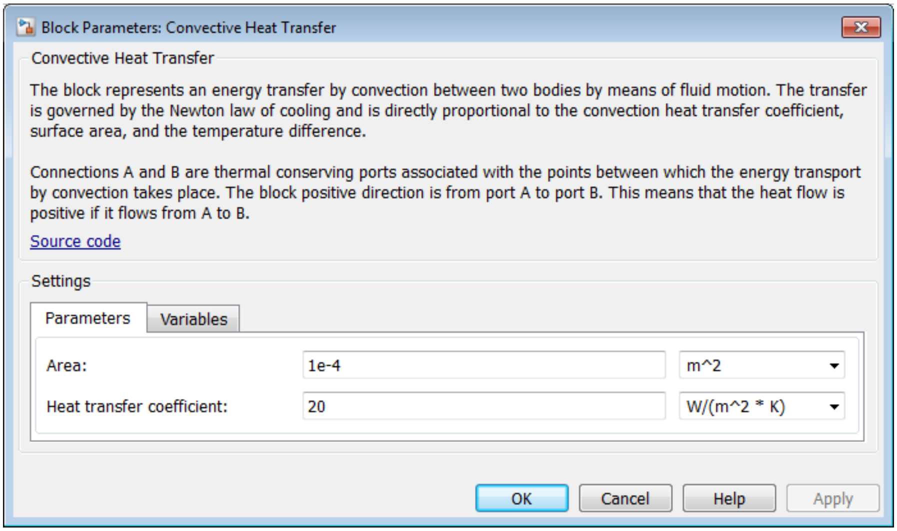
$$Q = k \bullet A \bullet (T_A - T_B)$$

where

Q	Heat flow
k	Convection heat transfer coefficient
A	Surface area
T_A, T_B	Temperatures of the bodies

Connections A and B are thermal conserving ports associated with the points between which the heat transfer by convection takes place. The block positive direction is from port A to port B. This means that the heat flow is positive if it flows from A to B.

Dialog Box and Parameters



Block Parameters: Convective Heat Transfer

Convective Heat Transfer

The block represents an energy transfer by convection between two bodies by means of fluid motion. The transfer is governed by the Newton law of cooling and is directly proportional to the convection heat transfer coefficient, surface area, and the temperature difference.

Connections A and B are thermal conserving ports associated with the points between which the energy transport by convection takes place. The block positive direction is from port A to port B. This means that the heat flow is positive if it flows from A to B.

Source code

Settings

Parameters | Variables

Area:	1e-4	m^2
Heat transfer coefficient:	20	W/(m^2 * K)

- “Parameters Tab” on page 1-105
- “Variables Tab” on page 1-105

Parameters Tab

Area

Surface area of heat transfer. The default value is `0.0001` m^2.

Heat transfer coefficient

Convection heat transfer coefficient. The default value is `20` W/m^2/K.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

A

Thermal conserving port associated with body A.

B

Thermal conserving port associated with body B.

See Also

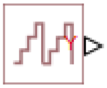
Conductive Heat Transfer | Radiative Heat Transfer

Counter

Increment output signal by 1 with every time step

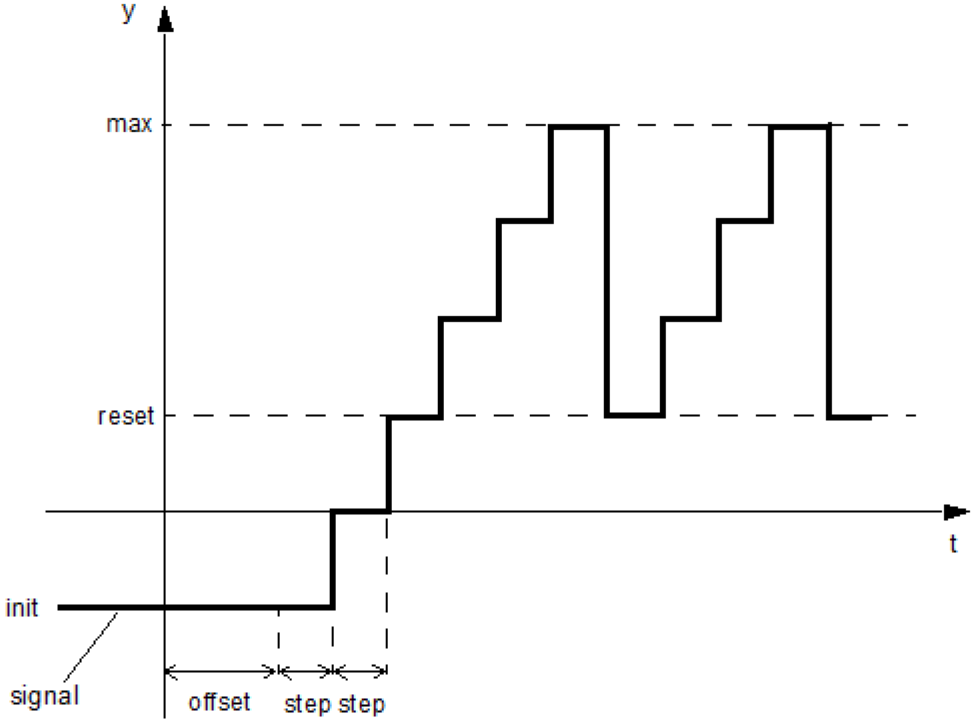
Library

Physical Signals/Sources



Description

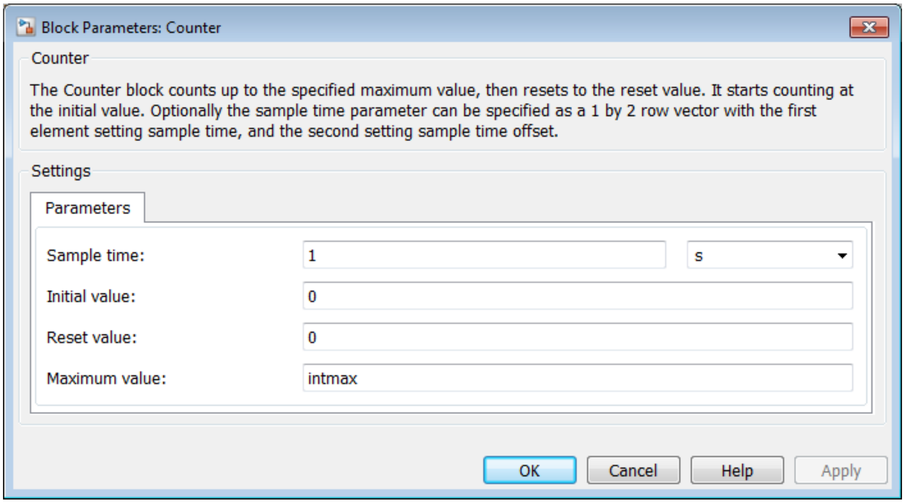
The `Counter` block increments the output signal, *y*, by 1 with every time step repeatedly between the minimum (reset) value and the maximum value. You can optionally specify an initial signal value, different from the reset value, and an initial time offset. The output signal generated by the block is shown in the following diagram.



If the initial time offset is specified, the block outputs the initial signal value `init` until the simulation time reaches the `offset` value, at which point the counting cycle starts. The block outputs the current value for one time step, then repeatedly increments the signal value by 1 and outputs it for one time step, until it reaches the maximum value `max`. The block outputs the `max` value for one time step, then returns to the `reset` value, and the counting cycle starts again.

Use this block, in conjunction with other physical signal blocks, to model discrete behaviors.

Dialog Box and Parameters



Block Parameters: Counter

Counter

The Counter block counts up to the specified maximum value, then resets to the reset value. It starts counting at the initial value. Optionally the sample time parameter can be specified as a 1 by 2 row vector with the first element setting sample time, and the second setting sample time offset.

Settings

Parameters

Sample time: 1 s

Initial value: 0

Reset value: 0

Maximum value: intmax

Sample time

The value of the time *`step`* interval. The default *`step`* value is `1` s. To specify an initial time offset, enter the parameter value as `[` *`step`* `,` *`offset`* `]`, otherwise the *`offset`* value is assumed to be `0`.

Initial value

The value of the output signal at the beginning of the first counting cycle. If you specify an initial time offset by using the **Sample time** parameter, the output of the block remains at this value until the simulation time reaches the *`offset`* value, after which the first counting cycle starts. The value must be an integer. The default value is `0`.

Reset value

The value of the output signal at the beginning of each counting cycle except the first one. The output of the block remains at this value for one time *`step`*, specified by the **Sample time** parameter. The value must be an integer. The default value is `0`.

Maximum value

The value of the output signal at the end of the counting cycle. The output of the block remains at this value for one time *`step`*, specified by the **Sample time** parameter, at which point the signal returns to the **Reset value** and the cycle starts again. The value must be an integer. The default value is `intmax` (2147483647, the largest positive value that can be represented in the MATLAB® software with a 32-bit integer).

Ports

The block has one physical signal output port.

Examples

The Discrete-Time PWM Voltage Source example illustrates how you can use the `Counter` block to build components with more complex behaviors. For an alternative asynchronous implementation, see the Asynchronous PWM Voltage Source example. The discrete-time version is better suited to fixed-step solvers and hardware-in-the-loop applications, whereas the asynchronous implementation is better suited to fast desktop simulation using variable-step solvers.

See Also

`Asynchronous Sample & Hold`

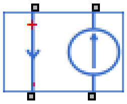
Current-Controlled Current Source

Linear current-controlled current source

Library

Electrical Sources

Description



The `Current-Controlled Current Source` block models a linear current-controlled current source, described with the following equation:

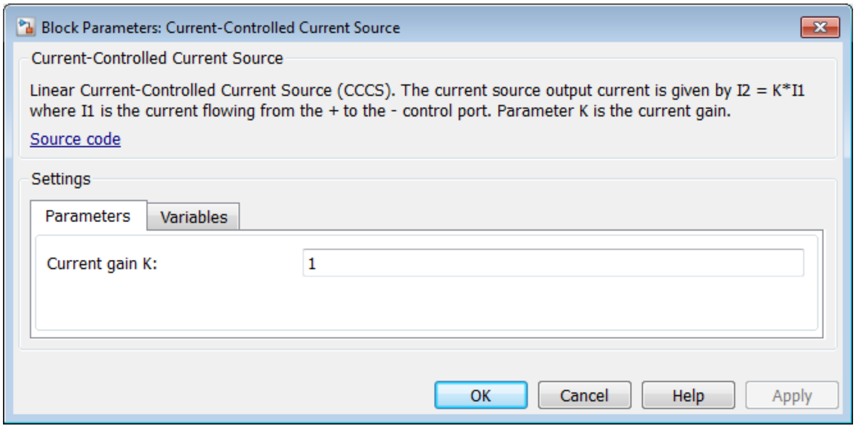
$$I2 = K \bullet I1$$

where

I2	Output current
K	Current gain
I1	Current flowing from the + to the – control port

To use the block, connect the + and – ports on the left side of the block (the control ports) to the control current source. The arrow between these ports indicates the positive direction of the control current flow. The two ports on the right side of the block (the output ports) generate the output current, with the arrow between them indicating the positive direction of the output current flow.

Dialog Box and Parameters



Block Parameters: Current-Controlled Current Source

Current-Controlled Current Source

Linear Current-Controlled Current Source (CCCS). The current source output current is given by I2 = K*I1 where I1 is the current flowing from the + to the - control port. Parameter K is the current gain.

Source code

Settings

Current gain K: 1

- “Parameters Tab” on page 1-112
- “Variables Tab” on page 1-112

Parameters Tab

Current gain K

Ratio of the current between the two output terminals to the current passing between the two control terminals. The default value is 1.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has four electrical conserving ports. Connections + and – on the left side of the block are the control ports. The other two ports are the electrical terminals that provide the output current. The arrows between each pair of ports indicate the positive direction of the current flow.

See Also

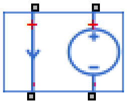
`Current-Controlled Voltage Source` | `Voltage-Controlled Current Source` | `Voltage-Controlled Voltage Source`

Current-Controlled Voltage Source

Linear current-controlled voltage source

Library

Electrical Sources



Description

The `Current-Controlled Voltage Source` block models a linear current-controlled voltage source, described with the following equation:

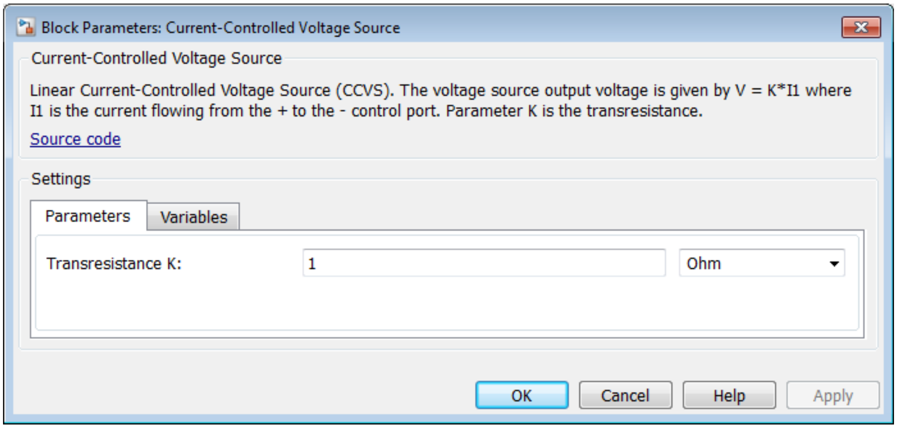
$$V = K \bullet I1$$

where

V	Voltage
K	Transresistance
I1	Current flowing from the + to the – control port

To use the block, connect the + and – ports on the left side of the block (the control ports) to the control current source. The arrow indicates the positive direction of the current flow. The two ports on the right side of the block (the output ports) generate the output voltage. Polarity is indicated by the + and – signs.

Dialog Box and Parameters



Block Parameters: Current-Controlled Voltage Source

Current-Controlled Voltage Source

Linear Current-Controlled Voltage Source (CCVS). The voltage source output voltage is given by V = K*I1 where I1 is the current flowing from the + to the - control port. Parameter K is the transresistance.

Source code

Settings

Transresistance K: 1 Ohm

- “Parameters Tab” on page 1-115
- “Variables Tab” on page 1-115

Parameters Tab

Transresistance K

Ratio of the voltage between the two output terminals to the current passing between the two control terminals. The default value is 1 Ω.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has four electrical conserving ports. Connections + and – on the left side of the block are the control ports. The arrow indicates the positive direction of the current flow. The other two ports are the electrical terminals that provide the output voltage. Polarity is indicated by the + and – signs.

See Also

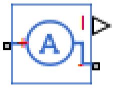
`Current-Controlled Current Source` | `Voltage-Controlled Current Source` | `Voltage-Controlled Voltage Source`

Current Sensor

Current sensor in electrical systems

Library

Electrical Sensors

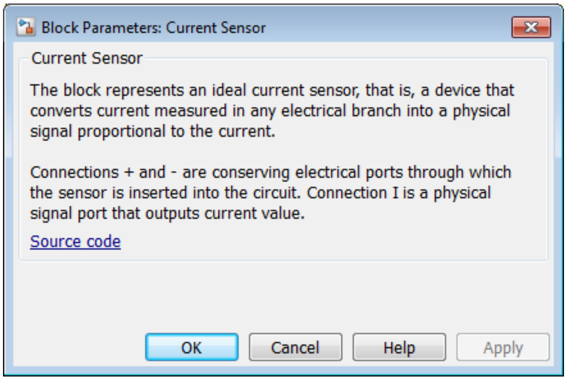


Description

The `Current Sensor` block represents an ideal current sensor, that is, a device that converts current measured in any electrical branch into a physical signal proportional to the current.

Connections + and – are electrical conserving ports through which the sensor is inserted into the circuit. Connection I is a physical signal port that outputs the measurement result.

Dialog Box and Parameters



Block Parameters: Current Sensor

Current Sensor

The block represents an ideal current sensor, that is, a device that converts current measured in any electrical branch into a physical signal proportional to the current.

Connections + and - are conserving electrical ports through which the sensor is inserted into the circuit. Connection I is a physical signal port that outputs current value.

Source code

The block has no parameters.

Ports

The block has the following ports:

`+`

Electrical conserving port associated with the sensor positive terminal.

`-`

Electrical conserving port associated with the sensor negative terminal.

`I`

Physical signal output port for current.

See Also

`PS-Simulink Converter` | `Voltage Sensor`

More About

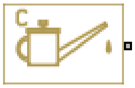
- “Connecting Simscape Diagrams to Simulink Sources and Scopes”

Custom Hydraulic Fluid

Working fluid properties, set by specifying parameter values

Library

Hydraulic Utilities



Description

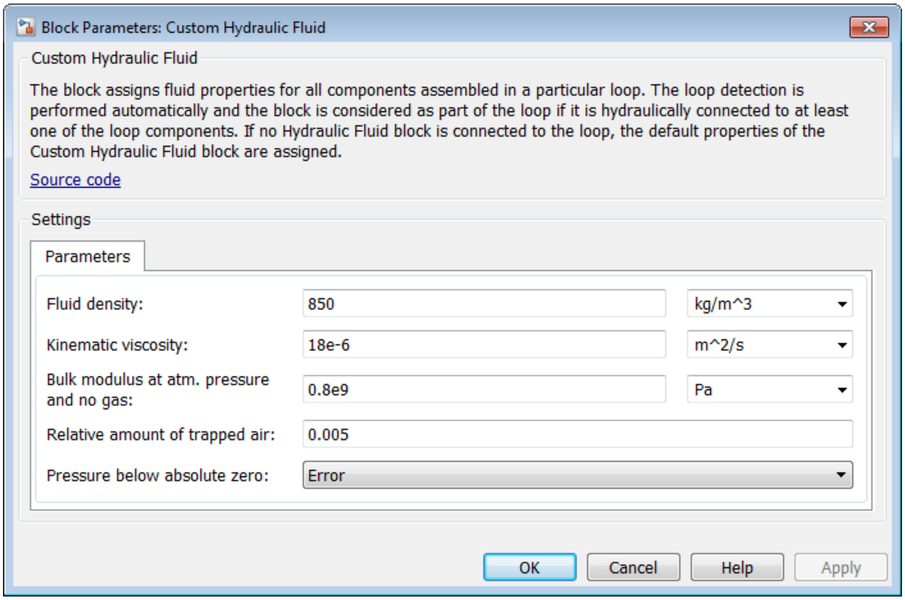
The `Custom Hydraulic Fluid` block lets you specify the type of hydraulic fluid used in a loop of hydraulic blocks. It provides the hydraulic fluid properties, such as kinematic viscosity, density, and bulk modulus, for all the hydraulic blocks in the loop. These fluid properties are assumed to be constant during simulation time.

The `Custom Hydraulic Fluid` block lets you specify the fluid properties, such as kinematic viscosity, density, bulk modulus, and relative amount of entrapped air, as block parameters.

The `Custom Hydraulic Fluid` block has one port. You can connect it to a hydraulic diagram by branching a connection line off the main line and connecting it to the port. When you connect the `Custom Hydraulic Fluid` block to a hydraulic line, the software automatically identifies the hydraulic blocks connected to the particular loop and propagates the hydraulic fluid properties to all the hydraulic blocks in the loop.

Each topologically distinct hydraulic loop in a diagram requires the properties of the working fluid to be specified. You can specify these properties by using either a `Custom Hydraulic Fluid` block or a `Hydraulic Fluid` block, which is available with Simscape Fluids™ libraries. If no `Hydraulic Fluid` block or `Custom Hydraulic Fluid` block is attached to a loop, the hydraulic blocks in this loop use the default fluid, which is equivalent to fluid defined by a `Custom Hydraulic Fluid` block with the default parameter values.

Dialog Box and Parameters



Custom Hydraulic Fluid

The block assigns fluid properties for all components assembled in a particular loop. The loop detection is performed automatically and the block is considered as part of the loop if it is hydraulically connected to at least one of the loop components. If no Hydraulic Fluid block is connected to the loop, the default properties of the Custom Hydraulic Fluid block are assigned.

Fluid density: 850 kg/m^3

Kinematic viscosity: 18e-6 m^2/s

Bulk modulus at atm. pressure and no gas: 0.8e9 Pa

Relative amount of trapped air: 0.005

Pressure below absolute zero: Error

Fluid density

Density of the working fluid. The default value is 850 kg/m^3.

Kinematic viscosity

Kinematic viscosity of the working fluid. The default value is 1.8e-5 m^2/s.

Bulk modulus at atm. pressure and no gas

Bulk modulus of the working fluid, at atmospheric pressure and with no entrapped air. The default value is 8e8 Pa.

Relative amount of trapped air

Amount of entrained, nondissolved gas in the fluid. The amount is specified as the ratio of gas volume at normal conditions to the fluid volume in the chamber. In practice, the relative amount of trapped air is always greater than 0. If set to 0, ideal fluid is assumed, but you will get a warning upon simulation. The default value is 0.005.

Pressure below absolute zero

Determines how the block handles the out-of-range assertion during simulation:

- `Error` — If the pressure falls below absolute zero, the simulation stops and you get an error message. This is the default.
- `Warning` — If the pressure falls below absolute zero, you get a warning but the simulation continues. Use this option when modeling systems where cavitation can occur in extreme cases.

Ports

The block has one hydraulic conserving port.

See Also

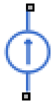
`Hydraulic Fluid`

DC Current Source

Ideal constant current source

Library

Electrical Sources



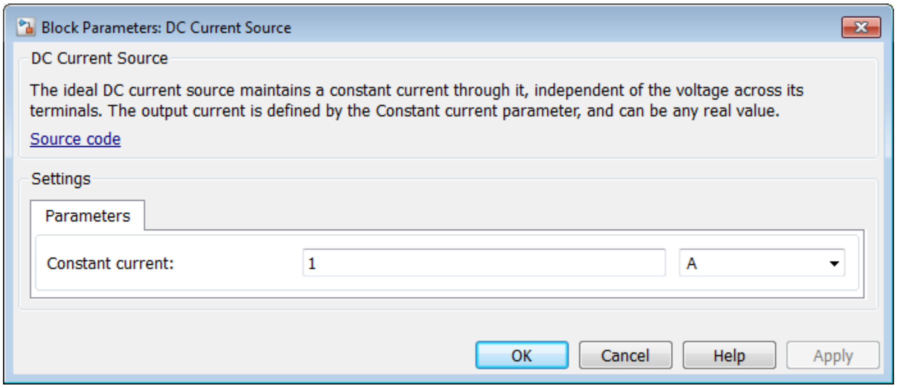
Description

The `DC Current Source` block represents an ideal current source that is powerful enough to maintain specified current through it regardless of the voltage across the source.

You specify the output current by using the **Constant current** parameter, which can be positive or negative.

The positive direction of the current flow is indicated by the arrow.

Dialog Box and Parameters



Block Parameters: DC Current Source

DC Current Source

The ideal DC current source maintains a constant current through it, independent of the voltage across its terminals. The output current is defined by the Constant current parameter, and can be any real value.

Source code

Settings

Parameters

Constant current: 1 A

Constant current

Output current. You can specify positive or negative values. The default value is 1 A.

Ports

The block has two electrical conserving ports associated with its terminals.

See Also

DC Voltage Source

DC Voltage Source

Ideal constant voltage source

Library

Electrical Sources

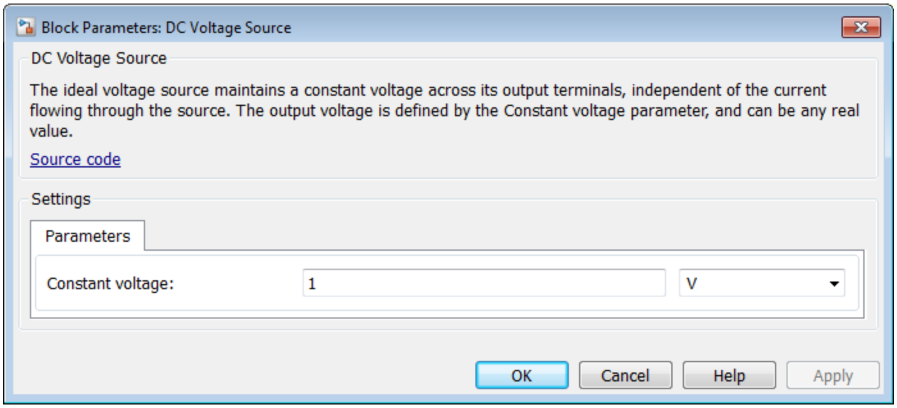
Description

The `DC Voltage Source` block represents an ideal voltage source that is powerful enough to maintain specified voltage at its output regardless of the current flowing through the source.

You specify the output voltage by using the **Constant voltage** parameter, which can be positive or negative.

Connections + and – are conserving electrical ports corresponding to the positive and negative terminals of the voltage source, respectively. The current is positive if it flows from positive to negative, and the voltage across the source is equal to the difference between the voltage at the positive and the negative terminal, *V*(+) – *V*(–).

Dialog Box and Parameters



The ideal voltage source maintains a constant voltage across its output terminals, independent of the current flowing through the source. The output voltage is defined by the Constant voltage parameter, and can be any real value.

Constant voltage: 1 V

Constant voltage

Output voltage. You can specify positive or negative values. The default value is 1 V.

Ports

The block has the following ports:

+

Electrical conserving port associated with the source positive terminal.

-

Electrical conserving port associated with the source negative terminal.

See Also

`DC Current Source`

Diode

Piecewise linear diode in electrical systems

Library

Electrical Elements

Description

The `Diode` block models a piecewise linear diode. If the voltage across the diode is bigger than the **Forward voltage** parameter value, then the diode behaves like a linear resistor with low resistance, given by the **On resistance** parameter value, plus a series voltage source. If the voltage across the diode is less than the forward voltage, then the diode behaves like a linear resistor with low conductance given by the **Off conductance** parameter value.

When forward biased, the series voltage source is described with the following equation:

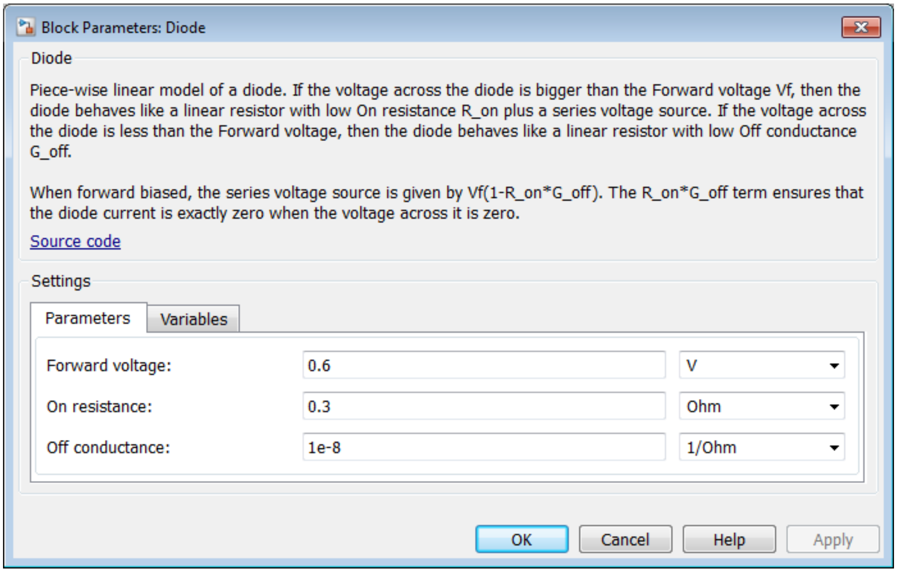
$$V = V_f(1 - R_{on}G_{off}),$$

where

V	Voltage
Vf	Forward voltage
R_{on}	On resistance
G_{off}	Off conductance

The $R_{on} \cdot G_{off}$ term ensures that the diode current is exactly zero when the voltage across it is zero.

Dialog Box and Parameters



Block Parameters: Diode

Diode

Piece-wise linear model of a diode. If the voltage across the diode is bigger than the Forward voltage Vf, then the diode behaves like a linear resistor with low On resistance R_on plus a series voltage source. If the voltage across the diode is less than the Forward voltage, then the diode behaves like a linear resistor with low Off conductance G_off.

When forward biased, the series voltage source is given by Vf(1-R_on*G_off). The R_on*G_off term ensures that the diode current is exactly zero when the voltage across it is zero.

Source code

Settings

Parameters | Variables

Forward voltage: 0.6 V

On resistance: 0.3 Ohm

Off conductance: 1e-8 1/Ohm

- “Parameters Tab” on page 1-127
- “Variables Tab” on page 1-127

Parameters Tab

Forward voltage

Minimum voltage that needs to be applied for the diode to become forward-biased. The default value is `0.6` V.

On resistance

The resistance of a forward-biased diode. The default value is `0.3` Ω.

Off conductance

The conductance of a reverse-biased diode. The default value is `1e-8` 1/Ω.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

+

Electrical conserving port associated with the diode positive terminal.

-

Electrical conserving port associated with the diode negative terminal.

Electrical Reference

Connection to electrical ground

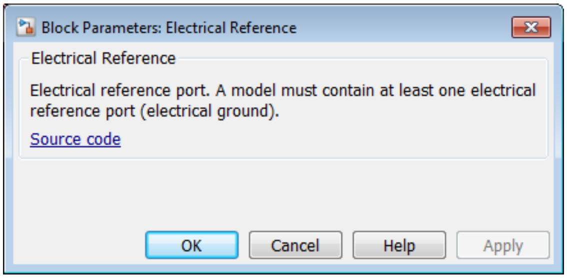
Library

Electrical Elements

Description

The `Electrical Reference` block represents an electrical ground. Electrical conserving ports of all the blocks that are directly connected to ground must be connected to an `Electrical Reference` block. A model with electrical elements must contain at least one `Electrical Reference` block.

Dialog Box and Parameters



Block Parameters: Electrical Reference

Electrical Reference

Electrical reference port. A model must contain at least one electrical reference port (electrical ground).

Source code

The `Electrical Reference` block has no parameters.

Ports

The block has one electrical conserving port.

More About

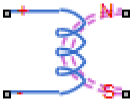
- "Grounding Rules"

Electromagnetic Converter

Lossless electromagnetic energy conversion device

Library

Magnetic Elements



Description

The `Electromagnetic Converter` block provides a generic interface between the electrical and magnetic domains.

The block is based on the following equations:

$$MMF = N \cdot I$$

$$V = -N \cdot \frac{d\Phi}{dt}$$

where

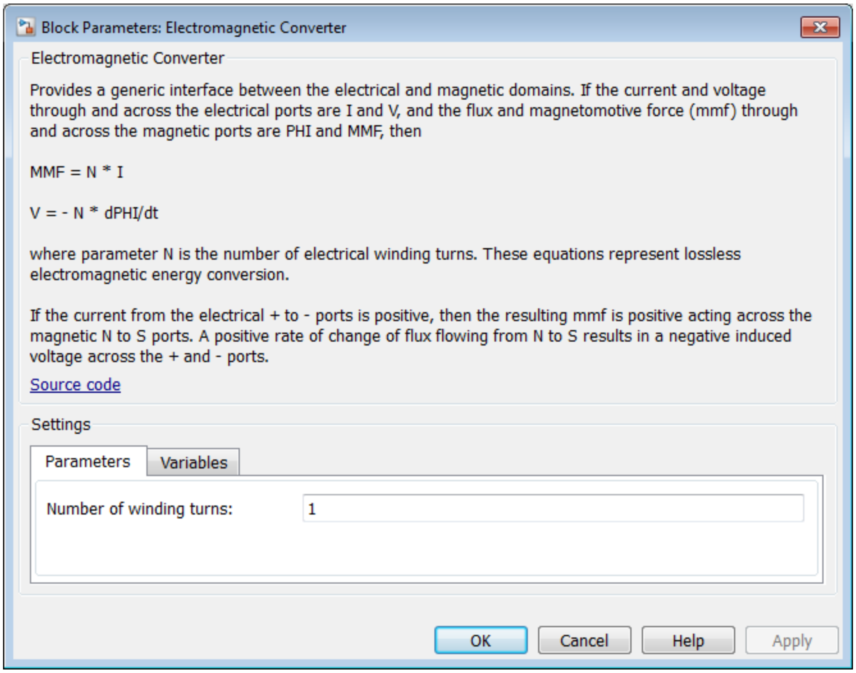
MMF	Magnetomotive force (mmf) across the magnetic ports
Φ	Flux through the magnetic ports
I	Current through the electrical ports
V	Voltage across the electrical ports
N	Number of electrical winding turns
t	Simulation time

Connections N and S are magnetic conserving ports, and connections + and – are electrical conserving ports. If the current from the electrical + to – ports is positive, then the resulting mmf is positive acting across the magnetic N to S ports. A positive rate of change of flux flowing from N to S results in a negative induced voltage across the + and – ports.

Basic Assumptions and Limitations

Electromagnetic energy conversion is lossless.

Dialog Box and Parameters



Block Parameters: Electromagnetic Converter

Electromagnetic Converter

Provides a generic interface between the electrical and magnetic domains. If the current and voltage through and across the electrical ports are I and V, and the flux and magnetomotive force (mmf) through and across the magnetic ports are PHI and MMF, then

MMF = N * I

V = - N * dPHI/dt

where parameter N is the number of electrical winding turns. These equations represent lossless electromagnetic energy conversion.

If the current from the electrical + to - ports is positive, then the resulting mmf is positive acting across the magnetic N to S ports. A positive rate of change of flux flowing from N to S results in a negative induced voltage across the + and - ports.

Source code

Settings

Number of winding turns: 1

- “Parameters Tab” on page 1-133
- “Variables Tab” on page 1-133

Parameters Tab

Number of winding turns

Number of electrical winding turns. The default value is `1`.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

`N`

Magnetic conserving port associated with the block North terminal.

`S`

Magnetic conserving port associated with the block South terminal.

`+`

Positive electrical conserving port.

`-`

Negative electrical conserving port.

See Also

`Reluctance Force Actuator`

Fluid Inertia

Pressure differential across tube or channel due to change in fluid velocity

Library

Hydraulic Elements

Description

The Fluid Inertia block models pressure differential, due to change in fluid velocity, across a fluid passage of constant cross-sectional area. The pressure differential is determined according to the following equation:

$$p = \rho \frac{L}{A} \frac{dq}{dt}$$

where

p	Pressure differential
ρ	Fluid density
L	Passage length
A	Passage area
q	Flow rate
t	Time

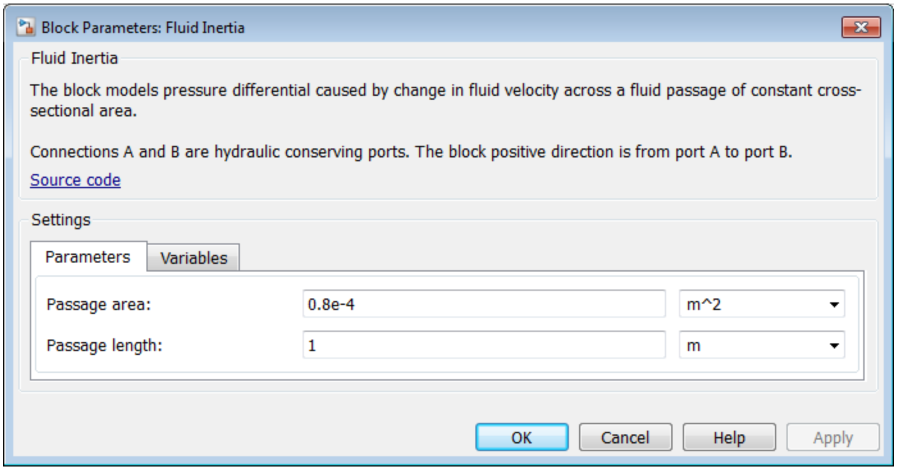
Use this block in various pipe or channel models that require fluid inertia to be accounted for.

The block positive direction is from port A to port B. This means that the flow rate is positive if it flows from A to B.

Assumptions and Limitations

Fluid density remains constant.

Dialog Box and Parameters



Block Parameters: Fluid Inertia

Fluid Inertia

The block models pressure differential caused by change in fluid velocity across a fluid passage of constant cross-sectional area.

Connections A and B are hydraulic conserving ports. The block positive direction is from port A to port B.

Source code

Settings

Parameters | Variables

Passage area: 0.8e-4 m^2

Passage length: 1 m

- “Parameters Tab” on page 1-135
- “Variables Tab” on page 1-136

Parameters Tab

Passage area

Fluid passage cross-sectional area. The default value is `8e-5` m^2.

Passage length

Length of the fluid passage. The default value is `1` m.

Initial flow rate

Initial flow rate through the passage. This parameter specifies the initial condition for use in computing the block's initial state at the beginning of a simulation run. For more information, see “Initial Conditions Computation”. The default value is `0`.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see "Set Priority and Initial Target for Block Variables".

Global Parameters

Parameter determined by the type of working fluid:

- **Fluid density**

Use the `Hydraulic Fluid` block or the `Custom Hydraulic Fluid` block to specify the fluid properties.

Ports

The block has the following ports:

A

Hydraulic conserving port associated with the passage inlet.

B

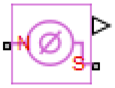
Hydraulic conserving port associated with the passage outlet.

Flux Sensor

Ideal flux sensor

Library

Magnetic Sensors

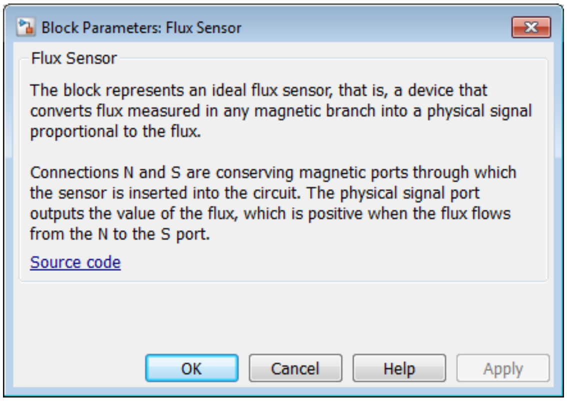


Description

The `Flux Sensor` block represents an ideal flux sensor, that is, a device that converts flux measured in any magnetic branch into a physical signal proportional to the flux.

Connections N and S are conserving magnetic ports through which the sensor is inserted into the circuit. The physical signal port outputs the value of the flux, which is positive when the flux flows from the N to the S port.

Dialog Box and Parameters



Flux Sensor

The block represents an ideal flux sensor, that is, a device that converts flux measured in any magnetic branch into a physical signal proportional to the flux.

Connections N and S are conserving magnetic ports through which the sensor is inserted into the circuit. The physical signal port outputs the value of the flux, which is positive when the flux flows from the N to the S port.

The block has no parameters.

Ports

The block has the following ports:

`N`

Magnetic conserving port associated with the sensor North terminal.

`S`

Magnetic conserving port associated with the sensor South terminal.

The block also has a physical signal output port, which outputs the value of the flux.

See Also

`Controlled Flux Source` | `Flux Source` | `PS-Simulink Converter`

More About

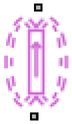
- "Connecting Simscape Diagrams to Simulink Sources and Scopes"

Flux Source

Ideal flux source

Library

Magnetic Sources



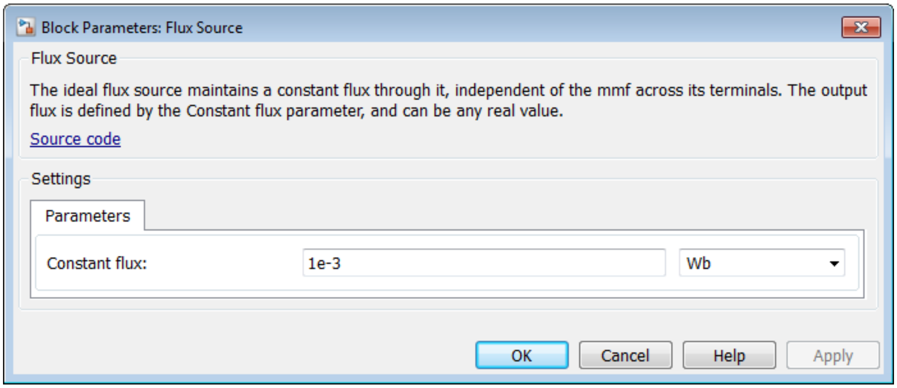
Description

The `Flux Source` block represents an ideal flux source that is powerful enough to maintain specified constant flux through it, regardless of the mmf across its terminals.

You specify the output flux by using the **Constant flux** parameter, which can be positive, negative, or zero.

The positive direction of the flux flow is indicated by the arrow.

Dialog Box and Parameters



Block Parameters: Flux Source

Flux Source

The ideal flux source maintains a constant flux through it, independent of the mmf across its terminals. The output flux is defined by the Constant flux parameter, and can be any real value.

Source code

Settings

Parameters

Constant flux: 1e-3 Wb

Constant flux

Output flux. You can specify any real value. The default value is `0.001` Wb.

Ports

The block has two magnetic conserving ports associated with its terminals.

See Also

`Controlled Flux Source`

Fundamental Reluctance

Simplified implementation of magnetic reluctance

Library

Magnetic Elements

Description

The `Fundamental Reluctance` block provides a simplified model of a magnetic reluctance, that is, a component that resists flux flow. Unlike the `Reluctance` block, which computes reluctance based on the geometry of the section being modeled, the `Fundamental Reluctance` block lets you specify a value of reluctance directly as a block parameter.

The block is based on the following equation:

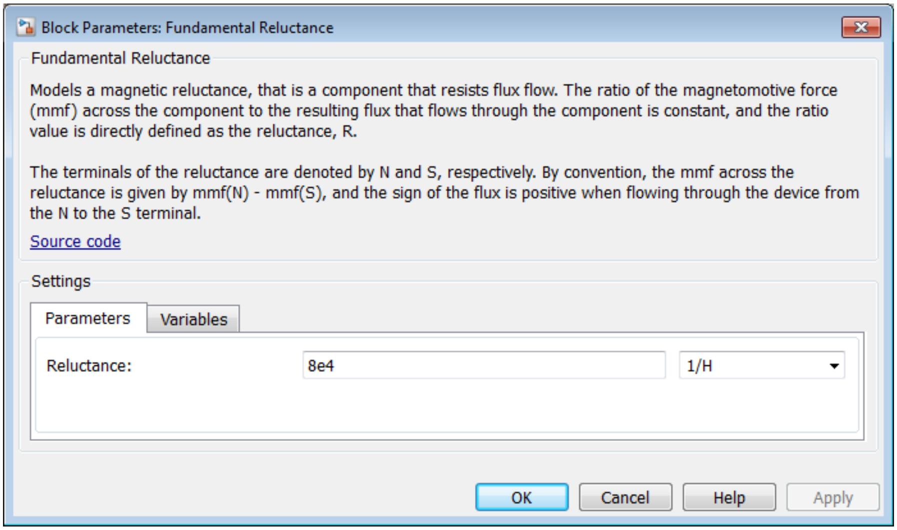
$$MMF = \Phi \cdot \Re$$

where

MMF	Magnetomotive force (mmf) across the component
Φ	Flux through the component
$\Re$	Reluctance

Connections N and S are magnetic conserving ports. The mmf across the reluctance is given by $MMF(N) - MMF(S)$, and the sign of the flux is positive when flowing through the device from N to S.

Dialog Box and Parameters



Block Parameters: Fundamental Reluctance

Fundamental Reluctance

Models a magnetic reluctance, that is a component that resists flux flow. The ratio of the magnetomotive force (mmf) across the component to the resulting flux that flows through the component is constant, and the ratio value is directly defined as the reluctance, R.

The terminals of the reluctance are denoted by N and S, respectively. By convention, the mmf across the reluctance is given by mmf(N) - mmf(S), and the sign of the flux is positive when flowing through the device from the N to the S terminal.

Source code

Settings

Reluctance: 8e4 1/H

- “Parameters Tab” on page 1-142
- “Variables Tab” on page 1-142

Parameters Tab

Reluctance

The ratio of the magnetomotive force (mmf) across the component to the resulting flux that flows through the component. The default value is `8e4` 1/H.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

`N`

Magnetic conserving port associated with the block North terminal.

`S`

Magnetic conserving port associated with the block South terminal.

See Also

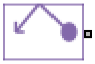
`Reluctance` | `Variable Reluctance`

Gas Properties

Pneumatic domain properties for attached circuit

Library

Pneumatic Utilities



Description

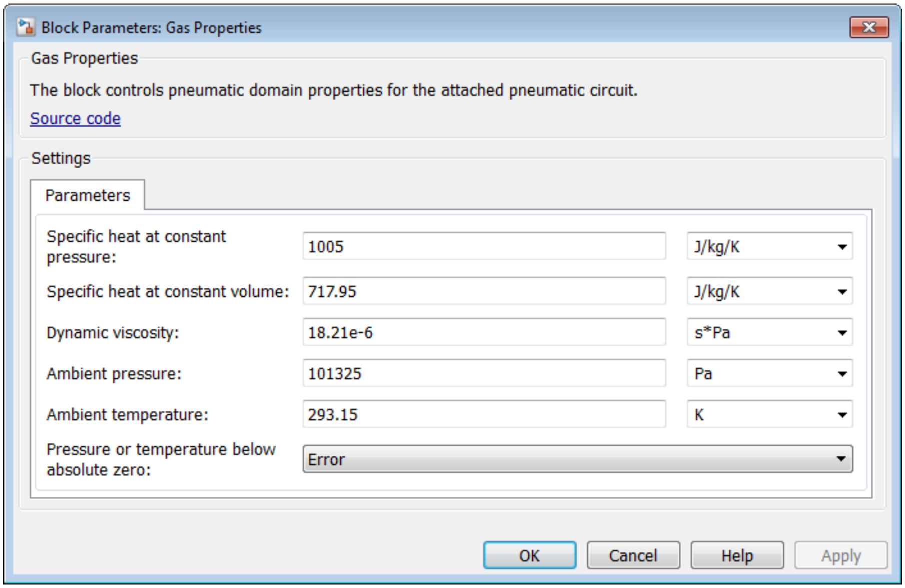
The `Gas Properties` block defines pneumatic domain properties for a circuit, that is, the gas properties that act as global parameters for all the blocks connected to the pneumatic circuit. These gas properties are assumed to be constant during simulation time.

The `Gas Properties` block lets you specify the gas properties, such as specific heat at constant pressure and constant volume, as well as viscosity, as block parameters. It also lets you specify ambient pressure and ambient temperature.

The `Gas Properties` block has one port. You can connect it to a pneumatic diagram by branching a connection line off the main line and connecting it to the port. When you connect the `Gas Properties` block to a pneumatic line, the software automatically identifies the pneumatic blocks connected to the particular circuit and propagates the gas properties to all the pneumatic blocks in the circuit.

Each topologically distinct pneumatic circuit in a diagram requires exactly one `Gas Properties` block to be connected to it. Therefore, there must be as many Gas Properties blocks as there are pneumatic circuits in the system. If no `Gas Properties` block is attached to a circuit, the pneumatic blocks in this circuit use the gas properties corresponding to the default `Gas Properties` block parameter values.

Dialog Box and Parameters



Block Parameters: Gas Properties

Gas Properties

The block controls pneumatic domain properties for the attached pneumatic circuit.

Source code

Settings

Parameters

Specific heat at constant pressure:	1005	J/kg/K
Specific heat at constant volume:	717.95	J/kg/K
Dynamic viscosity:	18.21e-6	s*Pa
Ambient pressure:	101325	Pa
Ambient temperature:	293.15	K
Pressure or temperature below absolute zero:	Error	

Specific heat at constant pressure

Specify the gas specific heat at constant pressure. The default value is `1.005e3` J/kg/K.

Specific heat at constant volume

Specify the gas specific heat at constant volume. The default value is `717.95` J/kg/K.

Dynamic viscosity

Specify the gas dynamic viscosity. The default value is `1.821e-5` s*Pa.

Ambient pressure

Specify the gas ambient pressure. The default value is `101325` Pa.

Ambient temperature

Specify the gas ambient temperature. The default value is `293.15` K.

Pressure or temperature below absolute zero

Determines how the block handles the out-of-range assertion during simulation:

- `Error` — If the pressure or temperature falls below absolute zero, the simulation stops and you get an error message. This is the default.

- `Warning` — If the pressure or temperature falls below absolute zero, you get a warning but the simulation continues.

Ports

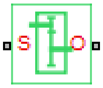
The block has one pneumatic conserving port.

Gear Box

Gear box in mechanical systems

Library

Mechanisms



Description

The `Gear Box` block represents an ideal, nonplanetary, fixed gear ratio gear box. The gear ratio is determined as the ratio of the input shaft angular velocity to that of the output shaft.

The gear box is described with the following equations:

$$\omega_1 = N \cdot \omega_2$$

$$T_2 = N \cdot T_1$$

$$P_1 = \omega_1 \cdot T_1$$

$$P_2 = -\omega_2 \cdot T_2$$

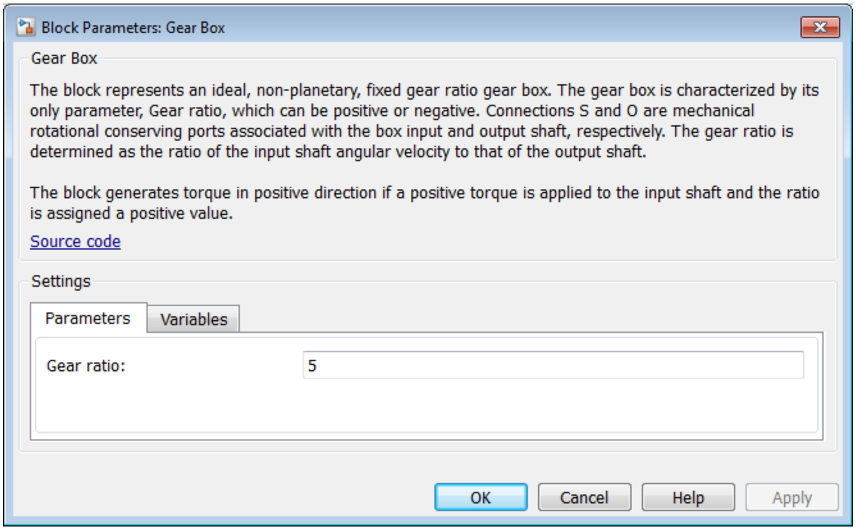
where

ω_1	Input shaft angular velocity
ω_2	Output shaft angular velocity
N	Gear ratio
T_1	Torque on the input shaft

T_2	Torque on the output shaft
P_1	Power on the input shaft
P_2	Power on the output shaft. Notice the minus sign in computing P_2. One of the network rules is that the power flowing through a conserving port is positive if it is removed (dissipated) from the circuit, and is negative if the component generates power into the system.

Connections S and O are mechanical rotational conserving ports associated with the box input and output shaft, respectively. The block positive directions are from S to the reference point and from the reference point to O.

Dialog Box and Parameters



Gear Box

The block represents an ideal, non-planetary, fixed gear ratio gear box. The gear box is characterized by its only parameter, Gear ratio, which can be positive or negative. Connections S and O are mechanical rotational conserving ports associated with the box input and output shaft, respectively. The gear ratio is determined as the ratio of the input shaft angular velocity to that of the output shaft.

The block generates torque in positive direction if a positive torque is applied to the input shaft and the ratio is assigned a positive value.

Gear ratio: 5

- “Parameters Tab” on page 1-148
- “Variables Tab” on page 1-149

Parameters Tab

Gear ratio

The ratio of the input shaft angular velocity to that of the output shaft. You can specify both positive and negative values. The default value is 5.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

S

Mechanical rotational conserving port associated with input shaft.

O

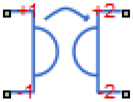
Mechanical rotational conserving port associated with the output shaft.

Gyrator

Ideal gyrator in electrical systems

Library

Electrical Elements



Description

Gyrators can be used to implement an inductor with a capacitor. The main benefit is that an equivalent inductance can be created with a much smaller physically sized capacitance. In practice, a gyrator is implemented with an op-amp plus additional passive components.

The `Gyrator` block models an ideal gyrator with no losses, described with the following equations:

$$I1 = G \bullet V2$$

$$I2 = G \bullet V1$$

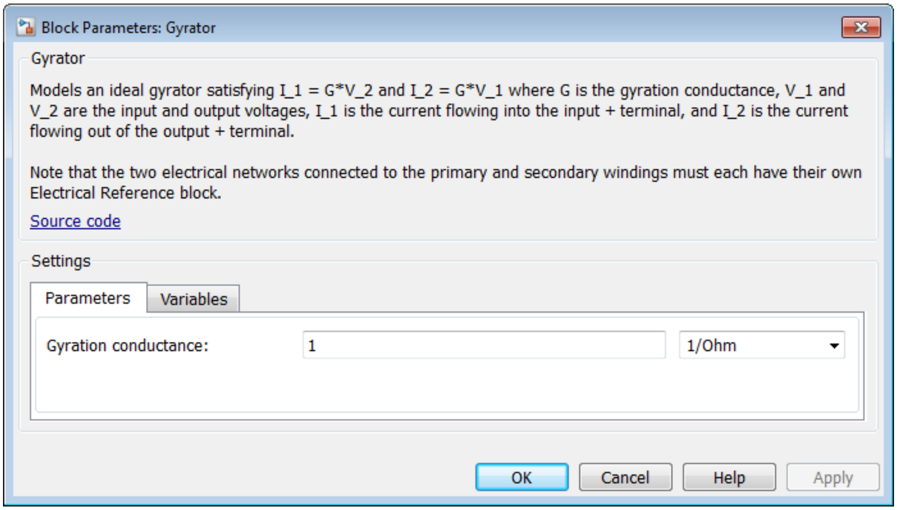
where

V1	Input voltage
V2	Output voltage
I1	Current flowing into the input + terminal
I2	Current flowing out of the output + terminal

G	Gyration conductance

The two electrical networks connected to the primary and secondary windings must each have their own `Electrical Reference` block.

Dialog Box and Parameters



Models an ideal gyrator satisfying I_1 = G*V_2 and I_2 = G*V_1 where G is the gyration conductance, V_1 and V_2 are the input and output voltages, I_1 is the current flowing into the input + terminal, and I_2 is the current flowing out of the output + terminal.

Note that the two electrical networks connected to the primary and secondary windings must each have their own Electrical Reference block.

Gyration conductance: 1 1/Ohm

- “Parameters Tab” on page 1-151
- “Variables Tab” on page 1-151

Parameters Tab

Gyration conductance

The gyration conductance constant *G*. The default value is `1`.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has four electrical conserving ports. Polarity is indicated by the + and – signs. Ports labeled +1 and –1 are connected to the primary winding. Ports labeled +2 and –2 are connected to the secondary winding.

Hydraulic Cap

Hydraulic port terminator with zero flow

Library

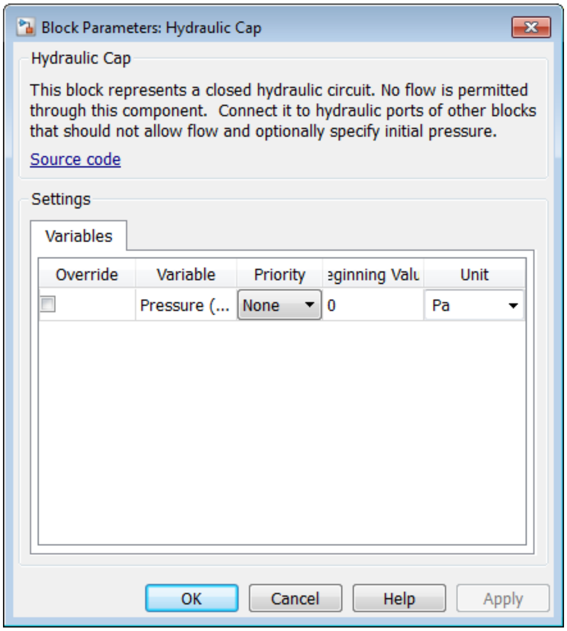
Hydraulic Elements

Description

The `Hydraulic Cap` block represents a hydraulic plug, that is, a hydraulic port with zero flow through it. Physical network block diagrams do not allow unconnected conserving ports. Use this block to terminate hydraulic ports on other blocks that you want to cap.

You can also use this block to set the initial gauge pressure at a node.

Dialog Box and Parameters



Block Parameters: Hydraulic Cap

Hydraulic Cap

This block represents a closed hydraulic circuit. No flow is permitted through this component. Connect it to hydraulic ports of other blocks that should not allow flow and optionally specify initial pressure.

Source code

Settings

Variables

Override	Variable	Priority	eginning Valu	Unit
☐	Pressure (...	None	0	Pa

The Hydraulic Cap block has no parameters.

The **Variables** tab lets you set the priority and initial target value for the **Pressure (gauge)** variable prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has one hydraulic conserving port.

See Also

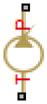
`Adiabatic Cup` | `Cap (TL)` | `Open Circuit` | `Perfect Insulator` | `Rotational Free End` | `Translational Free End`

Hydraulic Constant Flow Rate Source

Ideal source of hydraulic energy, characterized by constant flow rate

Library

Hydraulic Sources

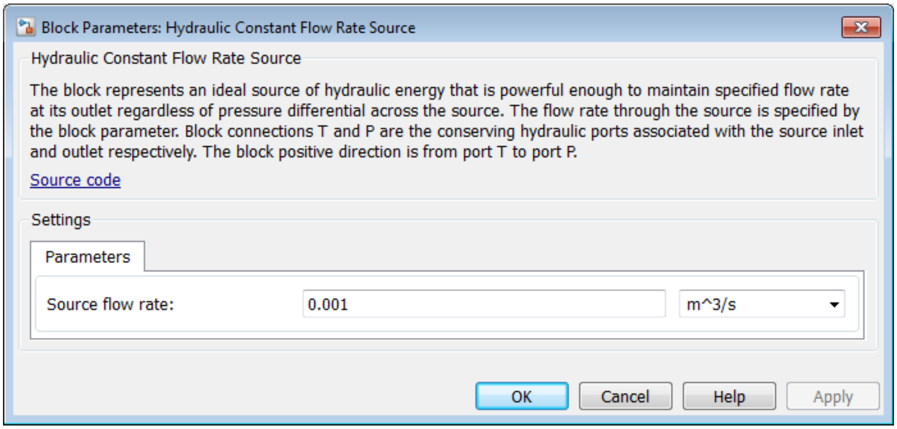


Description

The `Hydraulic Constant Flow Rate Source` block represents an ideal source of hydraulic energy that is powerful enough to maintain specified flow rate at its outlet regardless of the pressure differential across the source. The **Source flow rate** parameter specifies the flow rate through the source.

Block connections T and P correspond to the hydraulic inlet and outlet ports, respectively. The block positive direction is from port T to port P.

Dialog Box and Parameters



Hydraulic Constant Flow Rate Source

The block represents an ideal source of hydraulic energy that is powerful enough to maintain specified flow rate at its outlet regardless of pressure differential across the source. The flow rate through the source is specified by the block parameter. Block connections T and P are the conserving hydraulic ports associated with the source inlet and outlet respectively. The block positive direction is from port T to port P.

Source code

Settings

Parameters

Source flow rate: 0.001 m^3/s

Source flow rate

Specifies the flow rate through the source. The default value is `0.001` m^3/s.

Ports

The block has the following ports:

`T`

Hydraulic conserving port associated with the source inlet.

`P`

Hydraulic conserving port associated with the source outlet.

See Also

`Hydraulic Flow Rate Sensor` | `Hydraulic Flow Rate Source`

Hydraulic Constant Pressure Source

Ideal source of hydraulic energy, characterized by constant pressure

Library

Hydraulic Sources

Description

The `Hydraulic Constant Pressure Source` block represents an ideal source of hydraulic energy that is powerful enough to maintain the specified pressure differential between its inlet and outlet regardless of the flow rate through the source.

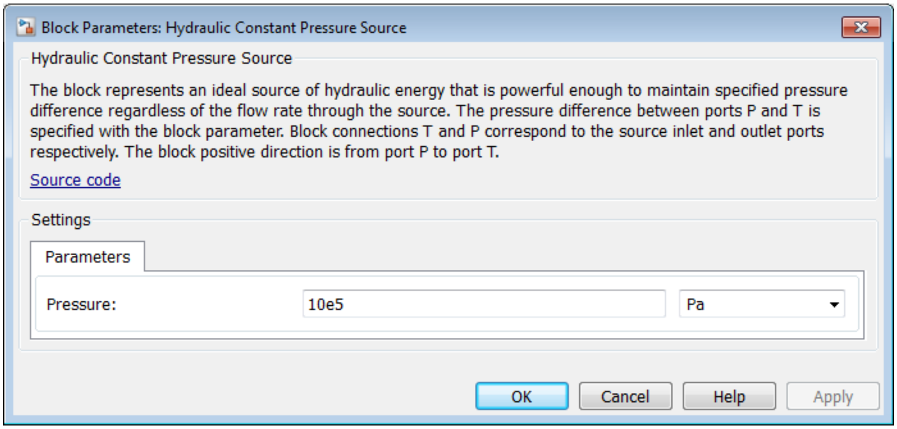
The **Pressure** parameter specifies the pressure differential across the source

$$p = p_P - p_T$$

where p_P, p_T are the gauge pressures at the source ports.

Block connections T and P correspond to the hydraulic inlet and outlet ports, respectively. The block positive direction is from port P to port T.

Dialog Box and Parameters



Hydraulic Constant Pressure Source

The block represents an ideal source of hydraulic energy that is powerful enough to maintain specified pressure difference regardless of the flow rate through the source. The pressure difference between ports P and T is specified with the block parameter. Block connections T and P correspond to the source inlet and outlet ports respectively. The block positive direction is from port P to port T.

Pressure: 10e5 Pa

Pressure

Specifies the pressure difference between the source inlet and outlet. The default value is `1e6` Pa.

Ports

The block has the following ports:

T

Hydraulic conserving port associated with the source inlet.

P

Hydraulic conserving port associated with the source outlet.

See Also

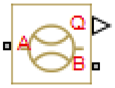
`Hydraulic Pressure Sensor` | `Hydraulic Pressure Source`

Hydraulic Flow Rate Sensor

Ideal flow meter

Library

Hydraulic Sensors

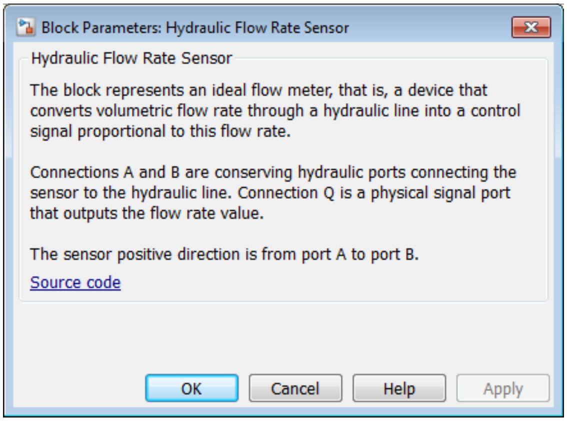


Description

The `Hydraulic Flow Rate Sensor` block represents an ideal flow meter, that is, a device that converts volumetric flow rate through a hydraulic line into a control signal proportional to this flow rate. The sensor is ideal because it does not account for inertia, friction, delays, pressure loss, and so on.

Connections A and B are conserving hydraulic ports connecting the sensor to the hydraulic line. Connection Q is a physical signal port that outputs the flow rate value. The sensor positive direction is from A to B. This means that the flow rate is positive if it flows from A to B.

Dialog Box and Parameters



Block Parameters: Hydraulic Flow Rate Sensor

Hydraulic Flow Rate Sensor

The block represents an ideal flow meter, that is, a device that converts volumetric flow rate through a hydraulic line into a control signal proportional to this flow rate.

Connections A and B are conserving hydraulic ports connecting the sensor to the hydraulic line. Connection Q is a physical signal port that outputs the flow rate value.

The sensor positive direction is from port A to port B.

The block has no parameters.

Ports

The block has the following ports:

A

Hydraulic conserving port associated with the sensor positive probe.

B

Hydraulic conserving port associated with the sensor negative (reference) probe.

Q

Physical signal port that outputs the flow rate value.

See Also

`Hydraulic Constant Flow Rate Source` | `Hydraulic Flow Rate Source` | `PS-Simulink Converter`

More About

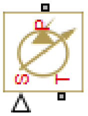
- "Connecting Simscape Diagrams to Simulink Sources and Scopes"

Hydraulic Flow Rate Source

Ideal source of hydraulic energy, characterized by flow rate

Library

Hydraulic Sources

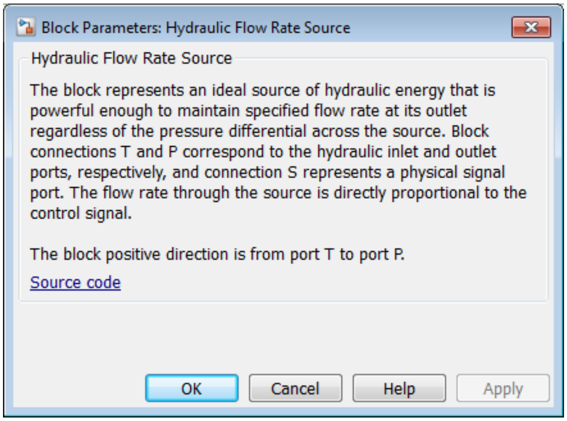


Description

The `Hydraulic Flow Rate Source` block represents an ideal source of hydraulic energy that is powerful enough to maintain specified flow rate at its outlet regardless of the pressure differential across the source. Block connections T and P correspond to the hydraulic inlet and outlet ports, respectively, and connection S represents a control signal port. The flow rate through the source is directly proportional to the signal at the control port S. The entire variety of Simulink signal sources can be used to generate desired flow rate variation profile.

The block positive direction is from port T to port P. This means that the flow rate is positive if it flows from T to P. The pressure differential is determined as $p = p_P - p_T$ and is negative if pressure at the source outlet is greater than pressure at its inlet. The power generated by the source is negative if the source delivers energy to port P.

Dialog Box and Parameters



Block Parameters: Hydraulic Flow Rate Source

Hydraulic Flow Rate Source

The block represents an ideal source of hydraulic energy that is powerful enough to maintain specified flow rate at its outlet regardless of the pressure differential across the source. Block connections T and P correspond to the hydraulic inlet and outlet ports, respectively, and connection S represents a physical signal port. The flow rate through the source is directly proportional to the control signal.

The block positive direction is from port T to port P.

Source code

The block has no parameters.

Ports

The block has the following ports:

T

Hydraulic conserving port associated with the source inlet.

P

Hydraulic conserving port associated with the source outlet.

S

Control signal port.

See Also

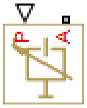
`Hydraulic Constant Flow Rate Source` | `Hydraulic Flow Rate Sensor`

Hydraulic Piston Chamber

Variable volume hydraulic capacity in cylinders

Library

Hydraulic Elements



Description

Note Starting in Release 2014a, you can specify fluid compressibility directly in the `hydro-mechanical converter` blocks. MathWorks recommends that, instead of using the `Hydraulic Piston Chamber` block connected to a converter, you use the **Compressibility** parameter in the converter block dialog box, because the new method provides more accurate results and also because the `Hydraulic Piston Chamber` block may be removed in a future release. For more information, see the R2014a Release Notes.

The `Hydraulic Piston Chamber` block models fluid compressibility in a chamber created by a piston of a cylinder. The fluid is considered to be a mixture of liquid and a small amount of entrained, nondissolved gas. Use this block together with the `Translational Hydro-Mechanical Converter` block. The `Hydraulic Piston Chamber` block takes into account only the flow rate caused by fluid compressibility. The fluid volume consumed to create piston velocity is accounted for in the `Translational Hydro-Mechanical Converter` block.

The chamber is simulated according to the following equations (see [1, 2]):

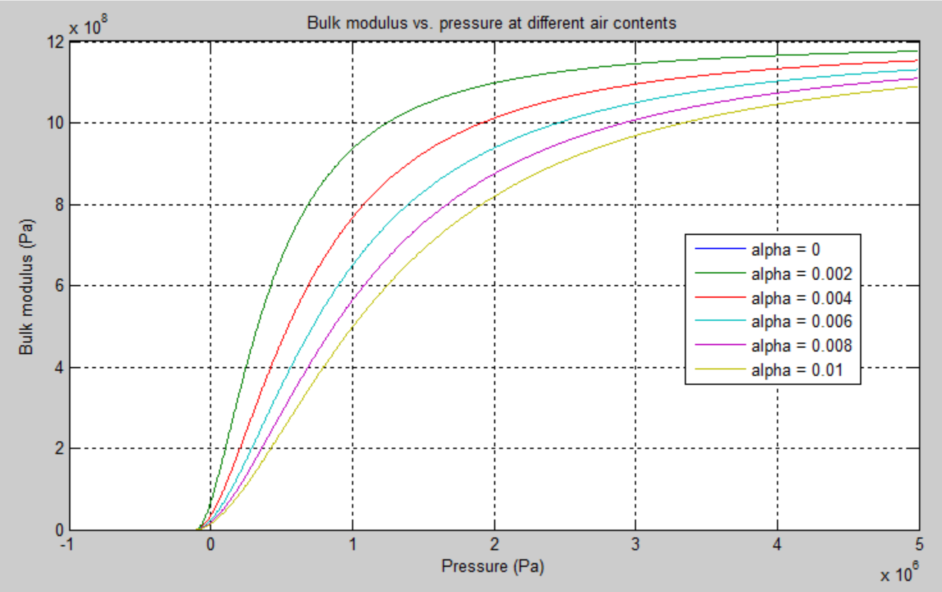
$$q = \frac{V_0 + A(x_0 + x \bullet or)}{E} \bullet \frac{dp}{dt}$$

$$E = E_l \frac{1+\alpha\left(\dfrac{p_a}{p_a+p}\right)^{1/n}}{1+\alpha\dfrac{p_a^{1/n}}{n\bullet(p_a+p)^{\frac{n+1}{n}}}E_l}$$

where

q	Flow rate due to fluid compressibility
V_0	Dead volume
A	Effective piston area
x_0	Piston initial position
x	Piston displacement from initial position
or	Chamber orientation with respect to the globally assigned positive direction. If displacement in positive direction increases the volume of the chamber, *or* equals 1. If displacement in positive direction decreases the volume of the chamber, *or* equals –1.
E	Fluid bulk modulus
E_l	Pure liquid bulk modulus
p	Gauge pressure of fluid in the chamber
p_a	Atmospheric pressure
a	Relative gas content at atmospheric pressure, $a = V_\mathrm{G}/V_\mathrm{L}$
V_G	Gas volume at atmospheric pressure
V_L	Volume of liquid
n	Gas-specific heat ratio

The main objective of representing fluid as a mixture of liquid and gas is to introduce an approximate model of cavitation, which takes place in a chamber if pressure drops below fluid vapor saturation level. As it is seen in the graph below, the bulk modulus of a mixture decreases at $p \to p_a$, thus considerably slowing down further pressure change. At high pressure, $p >> p_a$, a small amount of nondissolved gas has practically no effect on the system behavior.



Cavitation is an inherently thermodynamic process, requiring consideration of multiple-phase fluids, heat transfers, etc., and as such cannot be accurately simulated with Simscape software. But the simplified version implemented in the block is good enough to signal if pressure falls below dangerous level, and to prevent computation failure that normally occurs at negative pressures.

If pressure falls below absolute vacuum (–101325 Pa), the simulation stops and an error message is displayed.

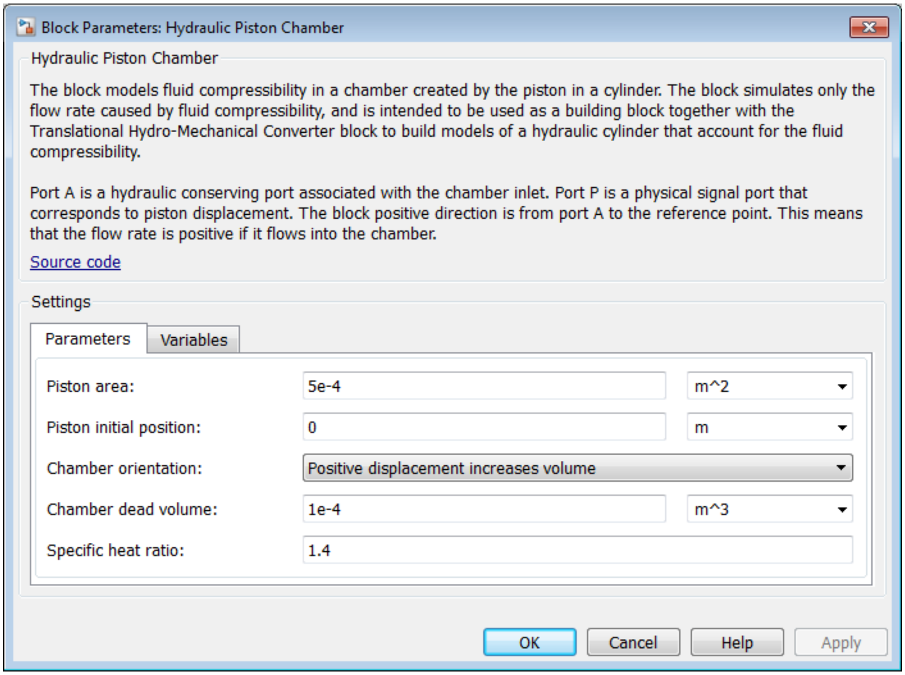
Port A is a hydraulic conserving port associated with the chamber inlet. Port P is a physical signal port that controls piston displacement.

The block positive direction is from port A to the reference point. This means that the flow rate is positive if it flows into the chamber.

Basic Assumptions and Limitations

- Fluid density remains constant.
- Chamber volume can not be less that the dead volume.
- Fluid fills the entire chamber volume.

Dialog Box and Parameters



Hydraulic Piston Chamber

The block models fluid compressibility in a chamber created by the piston in a cylinder. The block simulates only the flow rate caused by fluid compressibility, and is intended to be used as a building block together with the Translational Hydro-Mechanical Converter block to build models of a hydraulic cylinder that account for the fluid compressibility.

Port A is a hydraulic conserving port associated with the chamber inlet. Port P is a physical signal port that corresponds to piston displacement. The block positive direction is from port A to the reference point. This means that the flow rate is positive if it flows into the chamber.

Source code

Settings

Parameters | Variables

Piston area: 5e-4 m^2

Piston initial position: 0 m

Chamber orientation: Positive displacement increases volume

Chamber dead volume: 1e-4 m^3

Specific heat ratio: 1.4

- “Parameters Tab” on page 1-166
- “Variables Tab” on page 1-167

Parameters Tab

Piston area

Effective piston area. The default value is `5e-4` m^2.

Piston initial position

Initial offset of the piston from the cylinder cap. The default value is 0.

Chamber orientation

Specifies chamber orientation with respect to the globally assigned positive direction. The chamber can be installed in two different ways, depending upon whether the piston motion in the positive direction increases or decreases the volume of the chamber. If piston motion in the positive direction decreases the chamber volume, set the parameter to `Positive displacement decreases volume`. The default value is `Positive displacement increases volume`.

Chamber dead volume

Volume of fluid in the chamber at zero piston position. The default value is `1e-4` m^3.

Specific heat ratio

Gas-specific heat ratio. The default value is `1.4`.

Restricted Parameters

When your model is in Restricted editing mode, you cannot modify the following parameter:

- **Chamber orientation**

All other block parameters are available for modification.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Global Parameters

Parameters determined by the type of working fluid:

- **Fluid density**
- **Fluid kinematic viscosity**

Use the `Hydraulic Fluid` block or the `Custom Hydraulic Fluid` block to specify the fluid properties.

Ports

The block has the following ports:

A

Hydraulic conserving port associated with the chamber inlet.

P

Physical signal port that controls piston displacement.

References

[1] Manring, N.D., *Hydraulic Control Systems*, John Wiley & Sons, New York, 2005

[2] Meritt, H.E., *Hydraulic Control Systems*, John Wiley & Sons, New York, 1967

See Also

`Constant Volume Hydraulic Chamber` | `Rotational Hydro-Mechanical Converter` | `Translational Hydro-Mechanical Converter` | `Variable Hydraulic Chamber`

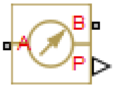
Hydraulic Pressure Sensor

Ideal pressure sensing device

Library

Hydraulic Sensors

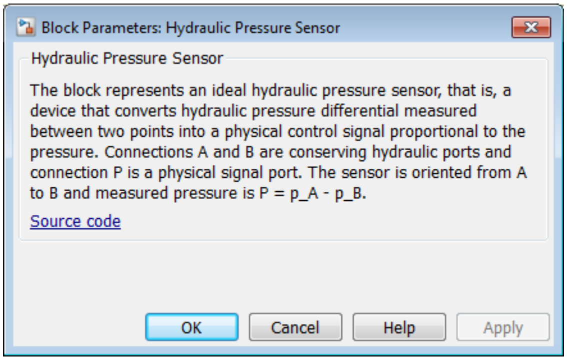
Description



The Hydraulic Pressure Sensor block represents an ideal hydraulic pressure sensor, that is, a device that converts hydraulic pressure differential measured between two points into a control signal proportional to this pressure. The sensor is ideal because it does not account for inertia, friction, delays, pressure loss, and so on.

Connections A and B are conserving hydraulic ports connecting the sensor to the hydraulic line. Connection P is a physical signal port that outputs the pressure value. The sensor positive direction is from A to B. This means that the pressure differential is determined as $p = p_A - p_B$.

Dialog Box and Parameters



Hydraulic Pressure Sensor

The block represents an ideal hydraulic pressure sensor, that is, a device that converts hydraulic pressure differential measured between two points into a physical control signal proportional to the pressure. Connections A and B are conserving hydraulic ports and connection P is a physical signal port. The sensor is oriented from A to B and measured pressure is P = p_A - p_B.

Source code

The block has no parameters.

Ports

The block has the following ports:

`A`

Hydraulic conserving port associated with the sensor positive probe.

`B`

Hydraulic conserving port associated with the sensor negative (reference) probe.

`P`

Physical signal port that outputs the pressure value.

See Also

`Hydraulic Constant Pressure Source` | `Hydraulic Pressure Source` | `PS-Simulink Converter`

More About

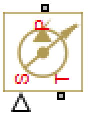
- “Connecting Simscape Diagrams to Simulink Sources and Scopes”

Hydraulic Pressure Source

Ideal source of hydraulic energy, characterized by pressure

Library

Hydraulic Sources



Description

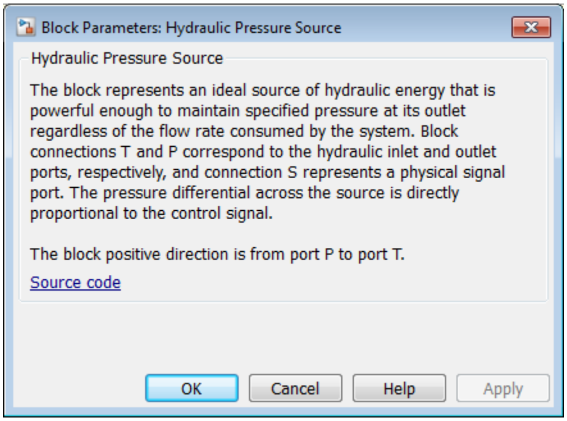
The `Hydraulic Pressure Source` block represents an ideal source of hydraulic energy that is powerful enough to maintain specified pressure at its outlet regardless of the flow rate consumed by the system. Block connections T and P correspond to the hydraulic inlet and outlet ports, respectively, and connection S represents a control signal port. The pressure differential across the source

$$p = p_P - p_T$$

where p_P, p_T are the gauge pressures at the source ports, is directly proportional to the signal at the control port S. The entire variety of Simulink signal sources can be used to generate desired pressure variation profile.

The block positive direction is from port P to port T. This means that the flow rate is positive if it flows from P to T. The power generated by the source is negative if the source delivers energy to port P.

Dialog Box and Parameters



Block Parameters: Hydraulic Pressure Source

Hydraulic Pressure Source

The block represents an ideal source of hydraulic energy that is powerful enough to maintain specified pressure at its outlet regardless of the flow rate consumed by the system. Block connections T and P correspond to the hydraulic inlet and outlet ports, respectively, and connection S represents a physical signal port. The pressure differential across the source is directly proportional to the control signal.

The block positive direction is from port P to port T.

Source code

The block has no parameters.

Ports

The block has the following ports:

`T`

Hydraulic conserving port associated with the source inlet.

`P`

Hydraulic conserving port associated with the source outlet.

`S`

Control signal port.

See Also

`Hydraulic Constant Pressure Source` | `Hydraulic Pressure Sensor`

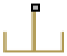
Hydraulic Reference

Connection to atmospheric pressure

Library

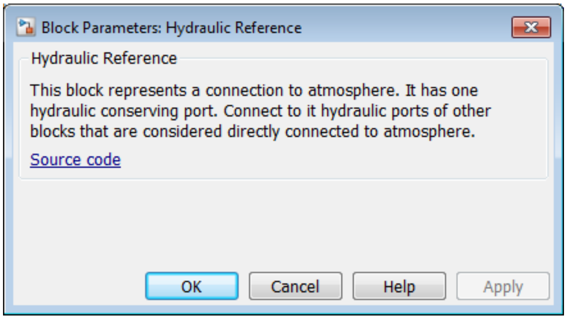
Hydraulic Elements

Description



The `Hydraulic Reference` block represents a connection to atmospheric pressure. Hydraulic conserving ports of all the blocks that are referenced to atmosphere (for example, suction ports of hydraulic pumps, or return ports of valves, cylinders, pipelines, if they are considered directly connected to atmosphere) must be connected to a `Hydraulic Reference` block.

Dialog Box and Parameters



Block Parameters: Hydraulic Reference

Hydraulic Reference

This block represents a connection to atmosphere. It has one hydraulic conserving port. Connect to it hydraulic ports of other blocks that are considered directly connected to atmosphere.

Source code

The `Hydraulic Reference` block has no parameters.

Ports

The block has one hydraulic conserving port.

More About

- “Grounding Rules”

Hydraulic Resistive Tube

Hydraulic pipeline which accounts for friction losses only

Library

Hydraulic Elements

Description

The `Hydraulic Resistive Tube` block models hydraulic pipelines with circular and noncircular cross sections and accounts for resistive property only. In other words, the block is developed with the basic assumption of the steady state fluid momentum conditions. Neither fluid compressibility nor fluid inertia is considered in the model, meaning that features such as water hammer cannot be investigated. If necessary, you can add fluid compressibility, fluid inertia, and other effects to your model using other blocks, thus producing a more comprehensive model.

The end effects are also not considered, assuming that the flow is fully developed along the entire pipe length. To account for local resistances, such as bends, fittings, inlet and outlet losses, and so on, all the resistances are converted into their equivalent lengths, and then the total length of all the resistances is added to the pipe geometrical length.

Pressure loss due to friction is computed with the Darcy equation, in which losses are proportional to the flow regime-dependable friction factor and the square of the flow rate. The friction factor in turbulent regime is determined with the Haaland approximation (see [1]). The friction factor during transition from laminar to turbulent regimes is determined with the linear interpolation between extreme points of the regimes. As a result of these assumptions, the tube is simulated according to the following equations:

$$p = f \frac{\left(L + L_{eq}\right)}{D_H} \frac{\rho}{2A^2} q \cdot |q|$$

$$f = \begin{cases} K_s / Re & \text{for } Re <= Re_L \\ f_L + \dfrac{f_T - f_L}{Re_T - Re_L}(Re - Re_L) & \text{for } Re_L < Re < Re_T \\ \dfrac{1}{\left(-1.8 \log_{10} \left(\dfrac{6.9}{Re} + \left(\dfrac{r / D_H}{3.7} \right)^{1.11} \right) \right)^2} & \text{for } Re >= Re_T \end{cases}$$

$$\mathrm{Re} = \frac{q \cdot D_H}{A \cdot \nu}$$

where

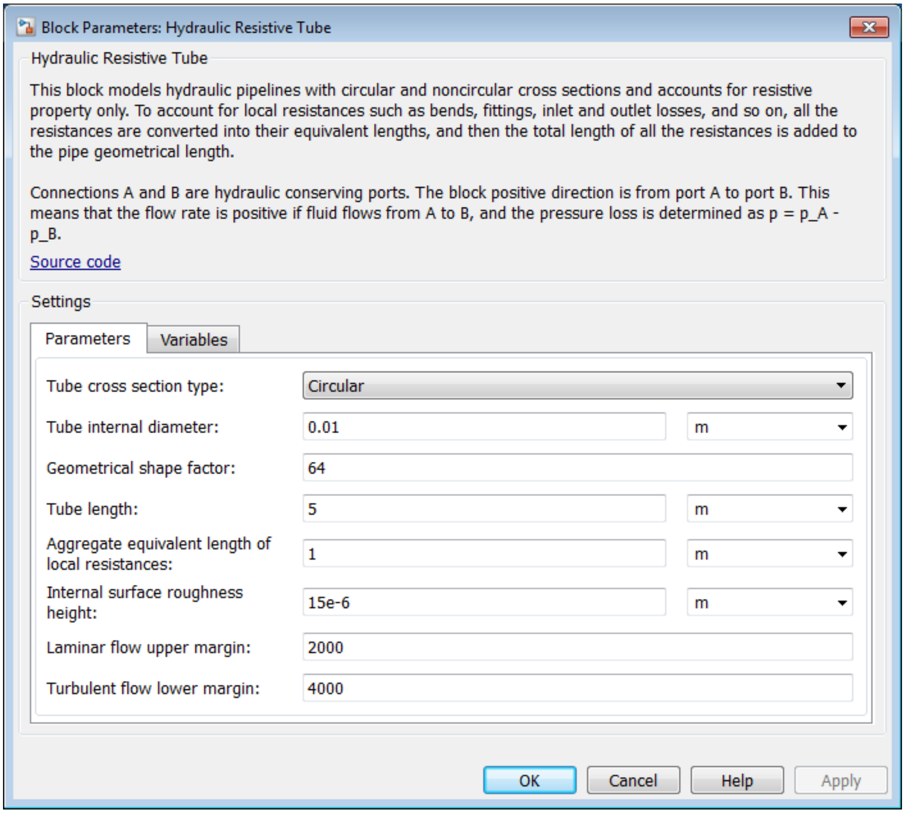
p	Pressure loss along the pipe due to friction
q	Flow rate through the pipe
Re	Reynolds number
Re_L	Maximum Reynolds number at laminar flow
Re_T	Minimum Reynolds number at turbulent flow
K_s	Shape factor that characterizes the pipe cross section
f_L	Friction factor at laminar border
f_T	Friction factor at turbulent border
A	Pipe cross-sectional area
D_H	Pipe hydraulic diameter
L	Pipe geometrical length
L_eq	Aggregate equivalent length of local resistances
r	Height of the roughness on the pipe internal surface
ν	Fluid kinematic viscosity

The block positive direction is from port A to port B. This means that the flow rate is positive if it flows from A to B, and the pressure loss is determined as $p = p_A - p_B$.

Basic Assumptions and Limitations

- Flow is assumed to be fully developed along the pipe length.
- Fluid inertia, fluid compressibility, and wall compliance are not taken into account.

Dialog Box and Parameters



Block Parameters: Hydraulic Resistive Tube

Hydraulic Resistive Tube

This block models hydraulic pipelines with circular and noncircular cross sections and accounts for resistive property only. To account for local resistances such as bends, fittings, inlet and outlet losses, and so on, all the resistances are converted into their equivalent lengths, and then the total length of all the resistances is added to the pipe geometrical length.

Connections A and B are hydraulic conserving ports. The block positive direction is from port A to port B. This means that the flow rate is positive if fluid flows from A to B, and the pressure loss is determined as p = p_A - p_B.

Source code

Settings

Tube cross section type:	Circular	
Tube internal diameter:	0.01	m
Geometrical shape factor:	64	
Tube length:	5	m
Aggregate equivalent length of local resistances:	1	m
Internal surface roughness height:	15e-6	m
Laminar flow upper margin:	2000	
Turbulent flow lower margin:	4000	

- “Parameters Tab” on page 1-178
- “Variables Tab” on page 1-179

Parameters Tab

Tube cross section type

The type of tube cross section: `Circular` or `Noncircular`. For a circular tube, you specify its internal diameter. For a noncircular tube, you specify its hydraulic diameter and tube cross-sectional area. The default value of the parameter is `Circular`.

Tube internal diameter

Tube internal diameter. The parameter is used if **Tube cross section type** is set to `Circular`. The default value is `0.01` m.

Noncircular tube cross-sectional area

Tube cross-sectional area. The parameter is used if **Tube cross section type** is set to `Noncircular`. The default value is `1e-4` m^2.

Noncircular tube hydraulic diameter

Hydraulic diameter of the tube cross section. The parameter is used if **Tube cross section type** is set to `Noncircular`. The default value is `0.0112` m.

Geometrical shape factor

Used for computing friction factor at laminar flow. The shape of the tube cross section determines the value. For a tube with a noncircular cross section, set the factor to an appropriate value, for example, 56 for a square, 96 for concentric annulus, 62 for rectangle (2:1), and so on [1]. The default value is `64`, which corresponds to a tube with a circular cross section.

Tube length

Tube geometrical length. The default value is `5` m.

Aggregate equivalent length of local resistances

This parameter represents total equivalent length of all local resistances associated with the tube. You can account for the pressure loss caused by local resistances, such as bends, fittings, armature, inlet/outlet losses, and so on, by adding to the pipe geometrical length an aggregate equivalent length of all the local resistances. The default value is `1` m.

Internal surface roughness height

Roughness height on the tube internal surface. The parameter is typically provided in data sheets or manufacturer's catalogs. The default value is `1.5e-5` m, which corresponds to drawn tubing.

Laminar flow upper margin

Specifies the Reynolds number at which the laminar flow regime is assumed to start converting into turbulent. Mathematically, this is the maximum Reynolds number at fully developed laminar flow. The default value is `2000`.

Turbulent flow lower margin

Specifies the Reynolds number at which the turbulent flow regime is assumed to be fully developed. Mathematically, this is the minimum Reynolds number at turbulent flow. The default value is `4000`.

Restricted Parameters

When your model is in Restricted editing mode, you cannot modify the following parameter:

- **Tube cross section type**

All other block parameters are available for modification. The actual set of modifiable block parameters depends on the value of the **Tube cross section type** parameter at the time the model entered Restricted mode.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see "Set Priority and Initial Target for Block Variables".

Global Parameters

Parameters determined by the type of working fluid:

- **Fluid density**
- **Fluid kinematic viscosity**

Use the `Hydraulic Fluid` block or the `Custom Hydraulic Fluid` block to specify the fluid properties.

Ports

The block has the following ports:

A

Hydraulic conserving port associated with the tube inlet.

B

Hydraulic conserving port associated with the tube outlet.

References

[1] White, F.M., *Viscous Fluid Flow*, McGraw-Hill, 1991

See Also

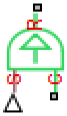
`Linear Hydraulic Resistance`

Ideal Angular Velocity Source

Ideal angular velocity source in mechanical rotational systems

Library

Mechanical Sources



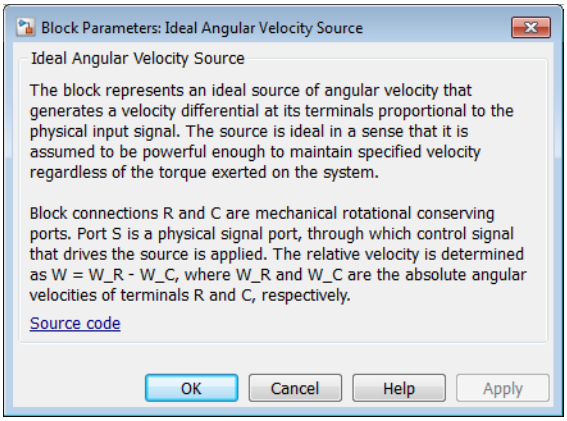
Description

The `Ideal Angular Velocity Source` block represents an ideal source of angular velocity that generates velocity differential at its terminals proportional to the input physical signal. The source is ideal in a sense that it is assumed to be powerful enough to maintain specified velocity regardless of the torque exerted on the system.

Connections R and C are mechanical rotational conserving ports. Port S is a physical signal port, through which the control signal that drives the source is applied. The relative velocity (velocity differential) across the source is directly proportional to the signal at the control port S. The entire variety of Simulink signal sources can be used to generate the desired velocity variation profile.

The block positive direction is from port R to port C. This means that the velocity is measured as $\omega = \omega_R - \omega_C$, where ω_R, ω_C are the absolute angular velocities at ports R and C, respectively, and torque through the source is positive if it is directed from R to C. The power generated by the source is negative if the source delivers energy to port R.

Dialog Box and Parameters



Ideal Angular Velocity Source

The block represents an ideal source of angular velocity that generates a velocity differential at its terminals proportional to the physical input signal. The source is ideal in a sense that it is assumed to be powerful enough to maintain specified velocity regardless of the torque exerted on the system.

Block connections R and C are mechanical rotational conserving ports. Port S is a physical signal port, through which control signal that drives the source is applied. The relative velocity is determined as W = W_R - W_C, where W_R and W_C are the absolute angular velocities of terminals R and C, respectively.

Source code

The block has no parameters.

Ports

The block has the following ports:

R

Mechanical rotational conserving port.

C

Mechanical rotational conserving port associated with the source reference point (case).

S

Physical signal input port, through which the control signal that drives the source is applied.

See Also

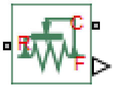
Ideal Rotational Motion Sensor

Ideal Force Sensor

Force sensor in mechanical translational systems

Library

Mechanical Sensors



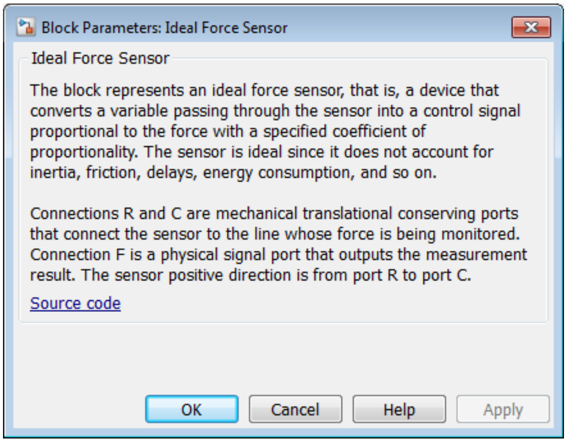
Description

The `Ideal Force Sensor` block represents a device that converts a variable passing through the sensor into a control signal proportional to the force. The sensor is ideal since it does not account for inertia, friction, delays, energy consumption, and so on.

Connections R and C are mechanical translational conserving ports that connect the block to the line where force is being monitored. Connection F is a physical signal port that outputs the measurement result.

The block positive direction is from port R to port C. This means that positive force applied to port R (the sensor positive probe) generates a positive output signal.

Dialog Box and Parameters



Ideal Force Sensor

The block represents an ideal force sensor, that is, a device that converts a variable passing through the sensor into a control signal proportional to the force with a specified coefficient of proportionality. The sensor is ideal since it does not account for inertia, friction, delays, energy consumption, and so on.

Connections R and C are mechanical translational conserving ports that connect the sensor to the line whose force is being monitored. Connection F is a physical signal port that outputs the measurement result. The sensor positive direction is from port R to port C.

Source code

The block has no parameters.

Ports

The block has the following ports:

R

Mechanical translational conserving port associated with the sensor positive probe.

C

Mechanical translational conserving port associated with the sensor negative (reference) probe.

F

Physical signal output port for force.

See Also

Ideal Force Source | PS-Simulink Converter

More About

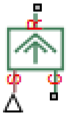
- “Connecting Simscape Diagrams to Simulink Sources and Scopes”

Ideal Force Source

Ideal source of mechanical energy that generates force proportional to the input signal

Library

Mechanical Sources



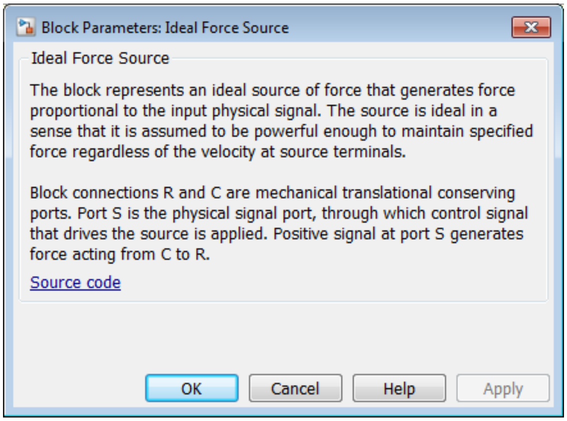
Description

The `Ideal Force Source` block represents an ideal source of mechanical energy that generates force proportional to the input physical signal. The source is ideal in a sense that it is assumed to be powerful enough to maintain specified force at its output regardless of the velocity at source terminals.

Connections R and C are mechanical translational conserving ports. Port S is a physical signal port, through which the control signal that drives the source is applied. You can use the entire variety of Simulink signal sources to generate the desired force variation profile. Positive signal at port S generates force acting from C to R. The force generated by the source is directly proportional to the signal at the control port S.

The block positive direction is from port C to port R. This means that the force is positive if it acts in the direction from C to R. The relative velocity is determined as $v = v_C - v_R$, where v_R, v_C are the absolute velocities at ports R and C, respectively, and it is negative if velocity at port R is greater than that at port C. The power generated by the source is negative if the source delivers energy to port R.

Dialog Box and Parameters



Ideal Force Source

The block represents an ideal source of force that generates force proportional to the input physical signal. The source is ideal in a sense that it is assumed to be powerful enough to maintain specified force regardless of the velocity at source terminals.

Block connections R and C are mechanical translational conserving ports. Port S is the physical signal port, through which control signal that drives the source is applied. Positive signal at port S generates force acting from C to R.

Source code

The block has no parameters.

Ports

The block has the following ports:

`R`

Mechanical translational conserving port.

`C`

Mechanical translational conserving port associated with the source reference point (case).

`S`

Physical signal input port, through which the control signal that drives the source is applied.

See Also

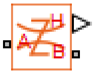
`Ideal Force Sensor`

Ideal Heat Flow Sensor

Ideal heat flow meter

Library

Thermal Sensors



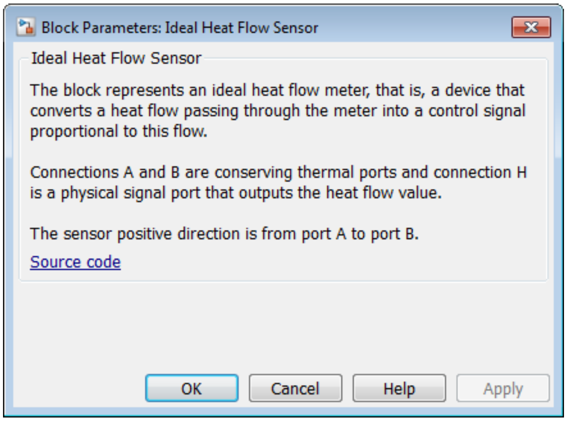
Description

The `Ideal Heat Flow Sensor` block represents an ideal heat flow meter, that is, a device that converts a heat flow passing through the meter into a control signal proportional to this flow. The meter must be connected in series with the component whose heat flow is being monitored.

Connections A and B are thermal conserving ports. Port H is a physical signal port that outputs the heat flow value.

The block positive direction is from port A to port B.

Dialog Box and Parameters



Block Parameters: Ideal Heat Flow Sensor

Ideal Heat Flow Sensor

The block represents an ideal heat flow meter, that is, a device that converts a heat flow passing through the meter into a control signal proportional to this flow.

Connections A and B are conserving thermal ports and connection H is a physical signal port that outputs the heat flow value.

The sensor positive direction is from port A to port B.

Source code

The block has no parameters.

Ports

The block has the following ports:

A

Thermal conserving port associated with the sensor positive probe.

B

Thermal conserving port associated with the sensor negative probe.

H

Physical signal output port for heat flow.

See Also

`Ideal Heat Flow Source` | `PS-Simulink Converter`

More About

- “Connecting Simscape Diagrams to Simulink Sources and Scopes”

Ideal Heat Flow Source

Ideal source of thermal energy, characterized by heat flow

Library

Thermal Sources

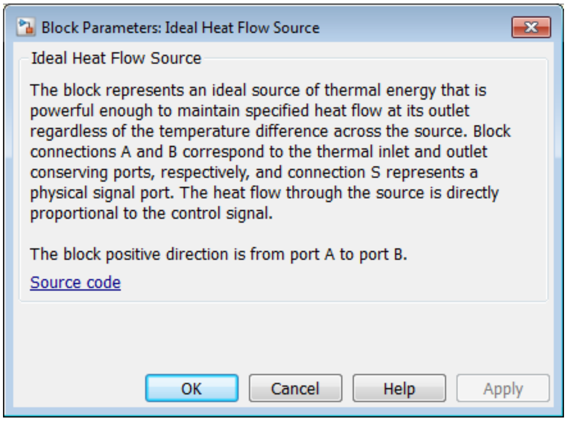
Description

The `Ideal Heat Flow Source` block represents an ideal source of thermal energy that is powerful enough to maintain specified heat flow at its outlet regardless of the temperature difference across the source.

Connections A and B are thermal conserving ports corresponding to the source inlet and outlet, respectively. Port S is a physical signal port, through which the control signal that drives the source is applied. You can use the entire variety of Simulink signal sources to generate the desired heat flow variation profile. The heat flow through the source is directly proportional to the signal at the control port S.

The block positive direction is from port A to port B. This means that positive signal at port S generates heat flow in the direction from A to B.

Dialog Box and Parameters



Ideal Heat Flow Source

The block represents an ideal source of thermal energy that is powerful enough to maintain specified heat flow at its outlet regardless of the temperature difference across the source. Block connections A and B correspond to the thermal inlet and outlet conserving ports, respectively, and connection S represents a physical signal port. The heat flow through the source is directly proportional to the control signal.

The block positive direction is from port A to port B.

Source code

The block has no parameters.

Ports

The block has the following ports:

A

Thermal conserving port associated with the source inlet.

B

Thermal conserving port associated with the source outlet.

S

Physical signal input port, through which the control signal that drives the source is applied.

See Also

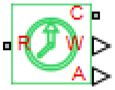
`Ideal Heat Flow Sensor`

Ideal Rotational Motion Sensor

Motion sensor in mechanical rotational systems

Library

Mechanical Sensors



Description

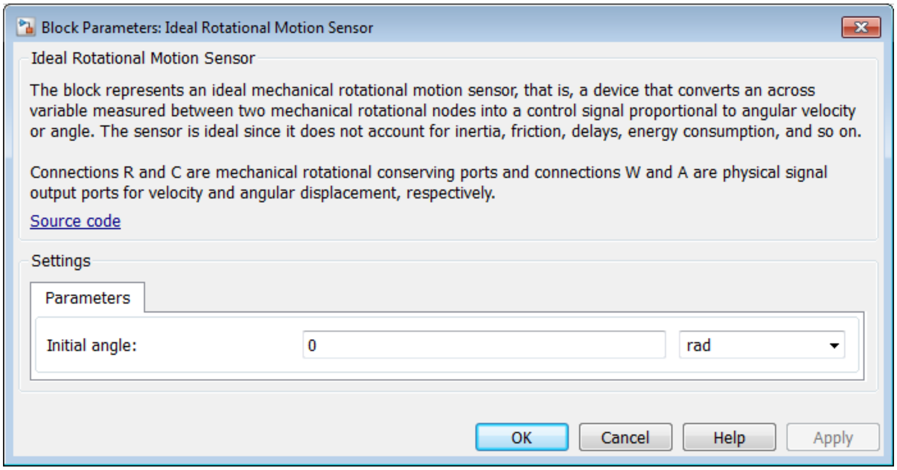
The `Ideal Rotational Motion Sensor` block represents an ideal mechanical rotational motion sensor, that is, a device that converts an across variable measured between two mechanical rotational nodes into a control signal proportional to angular velocity or angle. You can specify the initial angular position (offset) as a block parameter.

The sensor is ideal since it does not account for inertia, friction, delays, energy consumption, and so on.

Connections R and C are mechanical rotational conserving ports that connect the block to the nodes whose motion is being monitored. Connections W and A are physical signal output ports for velocity and angular displacement, respectively.

The block positive direction is from port R to port C. This means that the velocity is measured as $\omega = \omega_R - \omega_C$, where ω_R, ω_C are the absolute angular velocities at ports R and C, respectively.

Dialog Box and Parameters



Block Parameters: Ideal Rotational Motion Sensor

Ideal Rotational Motion Sensor

The block represents an ideal mechanical rotational motion sensor, that is, a device that converts an across variable measured between two mechanical rotational nodes into a control signal proportional to angular velocity or angle. The sensor is ideal since it does not account for inertia, friction, delays, energy consumption, and so on.

Connections R and C are mechanical rotational conserving ports and connections W and A are physical signal output ports for velocity and angular displacement, respectively.

Source code

Settings

Parameters

Initial angle: 0 rad

Initial angle

Sensor initial angle, or offset (rad). The default value is 0.

Ports

The block has the following ports:

R

Mechanical rotational conserving port associated with the sensor positive probe.

C

Mechanical rotational conserving port associated with the sensor negative (reference) probe.

W

Physical signal output port for angular velocity.

A

Physical signal output port for angular displacement.

See Also

`Ideal Angular Velocity Source` | `PS-Simulink Converter`

More About

- “Connecting Simscape Diagrams to Simulink Sources and Scopes”

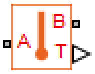
Ideal Temperature Sensor

Ideal temperature sensor

Library

Thermal Sensors

Description

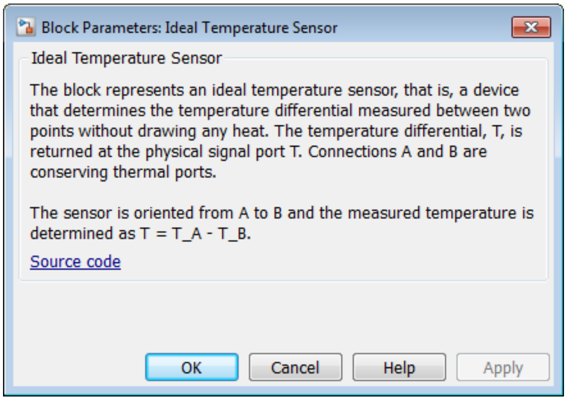


The `Ideal Temperature Sensor` block represents an ideal temperature sensor, that is, a device that determines the temperature differential measured between two points without drawing any heat.

Connections A and B are thermal conserving ports that connect to the two points where temperature is being monitored. Port T is a physical signal port that outputs the temperature differential value.

The block positive direction is from port A to port B. The measured temperature is determined as $T = T_A - T_B$.

Dialog Box and Parameters



Block Parameters: Ideal Temperature Sensor

Ideal Temperature Sensor

The block represents an ideal temperature sensor, that is, a device that determines the temperature differential measured between two points without drawing any heat. The temperature differential, T, is returned at the physical signal port T. Connections A and B are conserving thermal ports.

The sensor is oriented from A to B and the measured temperature is determined as T = T_A - T_B.

Source code

The block has no parameters.

Ports

The block has the following ports:

A

Thermal conserving port associated with the sensor positive probe.

B

Thermal conserving port associated with the sensor negative probe.

T

Physical signal output port for temperature.

See Also

`Ideal Temperature Source` | `PS-Simulink Converter`

More About

- "Connecting Simscape Diagrams to Simulink Sources and Scopes"

Ideal Temperature Source

Ideal source of thermal energy, characterized by temperature

Library

Thermal Sources

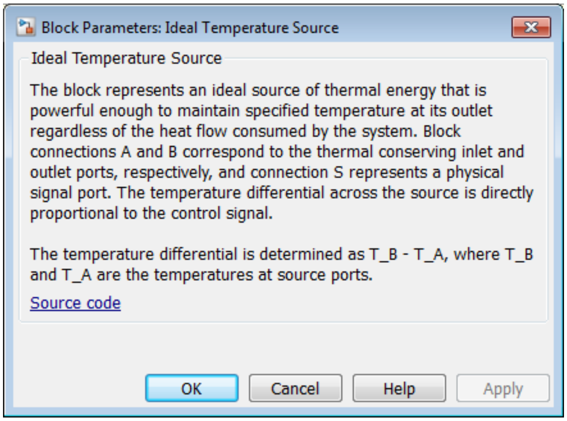
Description

The `Ideal Temperature Source` block represents an ideal source of thermal energy that is powerful enough to maintain specified temperature at its outlet regardless of the heat flow consumed by the system.

Connections A and B are thermal conserving ports corresponding to the source inlet and outlet, respectively. Port S is a physical signal port, through which the control signal that drives the source is applied. You can use the entire variety of Simulink signal sources to generate the desired heat flow variation profile. The temperature differential across the source is directly proportional to the signal at the control port S.

The block positive direction is from port A to port B. This means that the temperature differential is determined as $T_B - T_A$, where T_B and T_A are the temperatures at source ports.

Dialog Box and Parameters



Ideal Temperature Source

The block represents an ideal source of thermal energy that is powerful enough to maintain specified temperature at its outlet regardless of the heat flow consumed by the system. Block connections A and B correspond to the thermal conserving inlet and outlet ports, respectively, and connection S represents a physical signal port. The temperature differential across the source is directly proportional to the control signal.

The temperature differential is determined as T_B - T_A, where T_B and T_A are the temperatures at source ports.

Source code

The block has no parameters.

Ports

The block has the following ports:

A

Thermal conserving port associated with the source inlet.

B

Thermal conserving port associated with the source outlet.

S

Physical signal input port, through which the control signal that drives the source is applied.

See Also

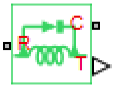
`Ideal Temperature Sensor`

Ideal Torque Sensor

Torque sensor in mechanical rotational systems

Library

Mechanical Sensors



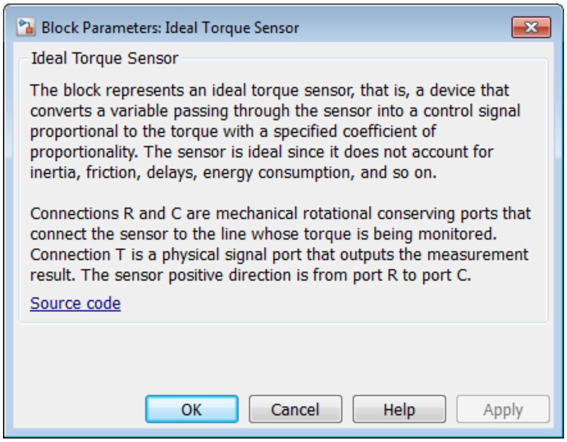
Description

The Ideal Torque Sensor block represents a device that converts a variable passing through the sensor into a control signal proportional to the torque. The sensor is ideal because it does not account for inertia, friction, delays, energy consumption, and so on.

Connections R and C are mechanical rotational conserving ports that connect the block to the line where torque is being monitored. Connection T is a physical signal port that outputs the measurement result.

The block positive direction is from port R to port C.

Dialog Box and Parameters



The block represents an ideal torque sensor, that is, a device that converts a variable passing through the sensor into a control signal proportional to the torque with a specified coefficient of proportionality. The sensor is ideal since it does not account for inertia, friction, delays, energy consumption, and so on.

Connections R and C are mechanical rotational conserving ports that connect the sensor to the line whose torque is being monitored. Connection T is a physical signal port that outputs the measurement result. The sensor positive direction is from port R to port C.

Source code

The block has no parameters.

Ports

The block has the following ports:

`R`

Mechanical rotational conserving port associated with the sensor positive probe.

`C`

Mechanical rotational conserving port associated with the sensor negative (reference) probe.

`T`

Physical signal output port for torque.

See Also

`Ideal Torque Source` | `PS-Simulink Converter`

More About

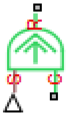
- "Connecting Simscape Diagrams to Simulink Sources and Scopes"

Ideal Torque Source

Ideal source of mechanical energy that generates torque proportional to the input signal

Library

Mechanical Sources



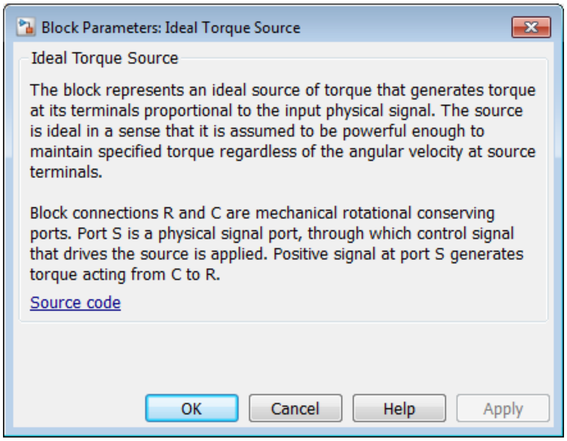
Description

The `Ideal Torque Source` block represents an ideal source of mechanical energy that generates torque proportional to the input physical signal. The source is ideal in a sense that it is assumed to be powerful enough to maintain specified torque regardless of the angular velocity at source terminals.

Connections R and C are mechanical rotational conserving ports. Port S is a physical signal port, through which the control signal that drives the source is applied. You can use the entire variety of Simulink signal sources to generate the desired torque variation profile. Positive signal at port S generates torque acting from C to R. The torque generated by the source is directly proportional to the signal at the control port S.

The block positive direction is from port C to port R. This means that the torque is positive if it acts in the direction from C to R. The relative velocity is determined as $\omega = \omega_R - \omega_C$, where ω_R, ω_C are the absolute angular velocities at ports R and C, respectively, and it is negative if velocity at port R is greater than that at port C. The power generated by the source is negative if the source delivers energy to port R.

Dialog Box and Parameters



Ideal Torque Source

The block represents an ideal source of torque that generates torque at its terminals proportional to the input physical signal. The source is ideal in a sense that it is assumed to be powerful enough to maintain specified torque regardless of the angular velocity at source terminals.

Block connections R and C are mechanical rotational conserving ports. Port S is a physical signal port, through which control signal that drives the source is applied. Positive signal at port S generates torque acting from C to R.

Source code

The block has no parameters.

Ports

The block has the following ports:

`R`

Mechanical rotational conserving port.

`C`

Mechanical rotational conserving port associated with the source reference point (case).

`S`

Physical signal input port, through which the control signal that drives the source is applied.

See Also

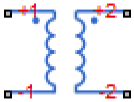
`Ideal Torque Sensor`

Ideal Transformer

Ideal transformer in electrical systems

Library

Electrical Elements



Description

The `Ideal Transformer` block models an ideal power-conserving transformer, described with the following equations:

$$V1 = N \bullet V2$$

$$I2 = N \bullet I1$$

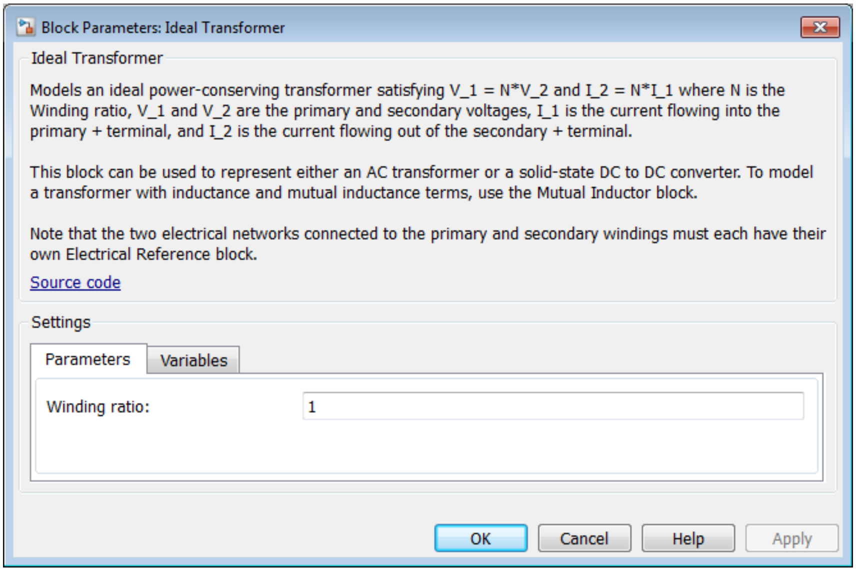
where

V1	Primary voltage
V2	Secondary voltage
I1	Current flowing into the primary + terminal
I2	Current flowing out of the secondary + terminal
N	Winding ratio

This block can be used to represent either an AC transformer or a solid-state DC to DC converter. To model a transformer with inductance and mutual inductance terms, use the Mutual Inductor block.

The two electrical networks connected to the primary and secondary windings must each have their own `Electrical Reference` block.

Dialog Box and Parameters



Ideal Transformer

Models an ideal power-conserving transformer satisfying V_1 = N*V_2 and I_2 = N*I_1 where N is the Winding ratio, V_1 and V_2 are the primary and secondary voltages, I_1 is the current flowing into the primary + terminal, and I_2 is the current flowing out of the secondary + terminal.

This block can be used to represent either an AC transformer or a solid-state DC to DC converter. To model a transformer with inductance and mutual inductance terms, use the Mutual Inductor block.

Note that the two electrical networks connected to the primary and secondary windings must each have their own Electrical Reference block.

Winding ratio: 1

- “Parameters Tab” on page 1-203
- “Variables Tab” on page 1-203

Parameters Tab

Winding ratio

Winding ratio of the transformer, or ratio of primary coil turns to secondary coil turns. The default value is `1`.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has four electrical conserving ports. Polarity is indicated by the + and – signs. Ports labeled +1 and –1 are connected to the primary winding. Ports labeled +2 and –2 are connected to the secondary winding.

See Also

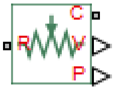
`Mutual Inductor`

Ideal Translational Motion Sensor

Motion sensor in mechanical translational systems

Library

Mechanical Sensors



Description

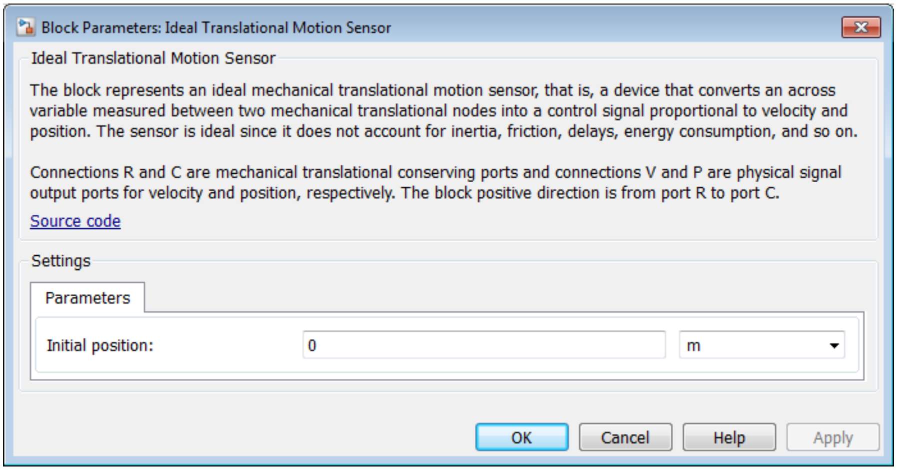
The `Ideal Translational Motion Sensor` block represents a device that converts an across variable measured between two mechanical translational nodes into a control signal proportional to velocity or position. You can specify the initial position (offset) as a block parameter.

The sensor is ideal since it does not account for inertia, friction, delays, energy consumption, and so on.

Connections R and C are mechanical translational conserving ports that connect the block to the nodes whose motion is being monitored. Connections V and P are physical signal output ports for velocity and position, respectively.

The block positive direction is from port R to port C. This means that the velocity is measured as $v = v_R - v_C$, where v_R,v_C are the absolute velocities at ports R and C, respectively.

Dialog Box and Parameters



Block Parameters: Ideal Translational Motion Sensor

Ideal Translational Motion Sensor

The block represents an ideal mechanical translational motion sensor, that is, a device that converts an across variable measured between two mechanical translational nodes into a control signal proportional to velocity and position. The sensor is ideal since it does not account for inertia, friction, delays, energy consumption, and so on.

Connections R and C are mechanical translational conserving ports and connections V and P are physical signal output ports for velocity and position, respectively. The block positive direction is from port R to port C.

Source code

Settings

Parameters

Initial position: 0 m

Initial position

Sensor initial position, or offset (m). The default value is 0.

Ports

The block has the following ports:

R

Mechanical translational conserving port associated with the sensor positive probe.

C

Mechanical translational conserving port associated with the sensor negative (reference) probe.

V

Physical signal output port for velocity.

P

Physical signal output port for position.

See Also

Ideal Translational Velocity Source | PS-Simulink Converter

More About

- “Connecting Simscape Diagrams to Simulink Sources and Scopes”

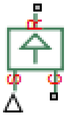
Ideal Translational Velocity Source

Ideal velocity source in mechanical translational systems

Library

Mechanical Sources

Description

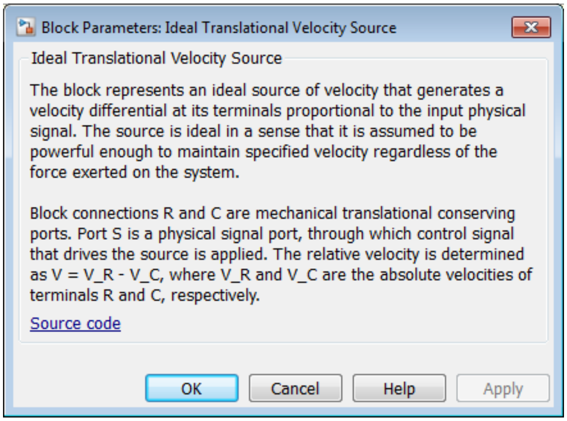


The `Ideal Translational Velocity Source` block represents an ideal source of velocity that generates velocity differential at its terminals proportional to the input physical signal. The source is ideal in a sense that it is assumed to be powerful enough to maintain specified velocity regardless of the force exerted on the system.

Connections R and C are mechanical translational conserving ports. Port S is a physical signal port, through which the control signal that drives the source is applied. The relative velocity (velocity differential) across the source is directly proportional to the signal at the control port S. The entire variety of Simulink signal sources can be used to generate the desired velocity variation profile.

The block positive direction is from port R to port C. This means that the velocity is measured as $v = v_R - v_C$, where v_R, v_C are the absolute velocities at ports R and C, respectively, and force through the source is negative if it is acts from C to R. The power generated by the source is negative if the source delivers energy to port R.

Dialog Box and Parameters



Ideal Translational Velocity Source

The block represents an ideal source of velocity that generates a velocity differential at its terminals proportional to the input physical signal. The source is ideal in a sense that it is assumed to be powerful enough to maintain specified velocity regardless of the force exerted on the system.

Block connections R and C are mechanical translational conserving ports. Port S is a physical signal port, through which control signal that drives the source is applied. The relative velocity is determined as V = V_R - V_C, where V_R and V_C are the absolute velocities of terminals R and C, respectively.

Source code

The block has no parameters.

Ports

The block has the following ports:

R

Mechanical translational conserving port.

C

Mechanical translational conserving port associated with the source reference point (case).

S

Physical signal input port, through which the control signal that drives the source is applied.

See Also

`Ideal Translational Motion Sensor`

Inductor

Linear inductor in electrical systems

Library

Electrical Elements

Description

The `Inductor` block models a linear inductor, described with the following equation:

$$V = L\frac{dI}{dt}$$

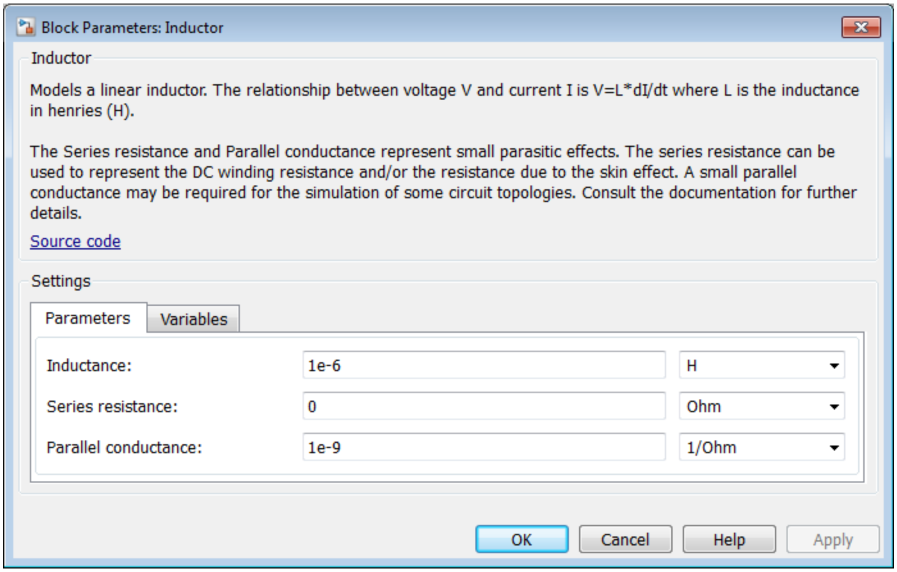
where

I	Current
V	Voltage
L	Inductance
t	Time

The **Series resistance** and **Parallel conductance** parameters represent small parasitic effects. The series resistance can be used to represent the DC winding resistance or the resistance due to the skin effect. Simulation of some circuits may require the presence of a small parallel conductance. For more information, see “Modeling Best Practices”.

Connections + and – are conserving electrical ports corresponding to the positive and negative terminals of the inductor, respectively. The current is positive if it flows from positive to negative, and the voltage across the inductor is equal to the difference between the voltage at the positive and the negative terminal, $V(+) - V(–)$.

Dialog Box and Parameters



Block Parameters: Inductor

Inductor

Models a linear inductor. The relationship between voltage V and current I is V=L*dI/dt where L is the inductance in henries (H).

The Series resistance and Parallel conductance represent small parasitic effects. The series resistance can be used to represent the DC winding resistance and/or the resistance due to the skin effect. A small parallel conductance may be required for the simulation of some circuit topologies. Consult the documentation for further details.

Source code

Settings

Parameters | Variables

Inductance:	1e-6	H
Series resistance:	0	Ohm
Parallel conductance:	1e-9	1/Ohm

- “Parameters Tab” on page 1-211
- “Variables Tab” on page 1-212

Parameters Tab

Inductance

Inductance, in henries. The default value is 1 μH.

Series resistance

Represents small parasitic effects. The series resistance can be used to represent the DC winding resistance. The default value is 0.

Parallel conductance

Represents small parasitic effects. The parallel conductance across the inductor can be used to model insulation conductance. Simulation of some circuits may require the presence of a small parallel conductance. The default value is 1e-9 1/Ω.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

+

Electrical conserving port associated with the inductor positive terminal.

-

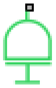
Electrical conserving port associated with the inductor negative terminal.

Inertia

Ideal mechanical rotational inertia

Library

Mechanical Rotational Elements



Description

The `Inertia` block represents an ideal mechanical rotational inertia, described with the following equation:

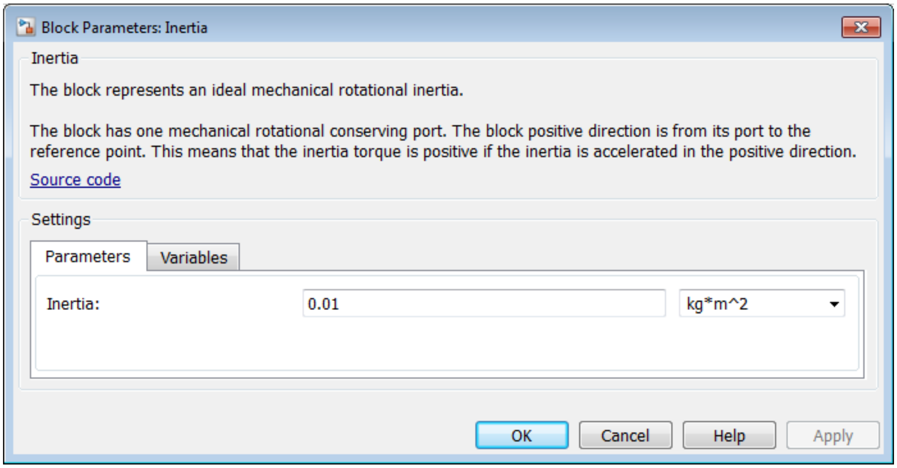
$$T = J\frac{d\omega}{dt}$$

where

T	Inertia torque
J	Inertia
ω	Angular velocity
t	Time

The block has one mechanical rotational conserving port. The block positive direction is from its port to the reference point. This means that the inertia torque is positive if inertia is accelerated in positive direction.

Dialog Box and Parameters



Inertia

The block represents an ideal mechanical rotational inertia.

The block has one mechanical rotational conserving port. The block positive direction is from its port to the reference point. This means that the inertia torque is positive if the inertia is accelerated in the positive direction.

Inertia: 0.01 kg*m^2

- “Parameters Tab” on page 1-214
- “Variables Tab” on page 1-214

Parameters Tab

Inertia

Inertia. The default value is `0.001` kg*m^2.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has one mechanical rotational conserving port, associated with the inertia connection to the system.

See Also

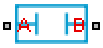
`Mass`

Infinite Flow Resistance (2P)

Perfectly insulated barrier between two-phase fluid networks

Library

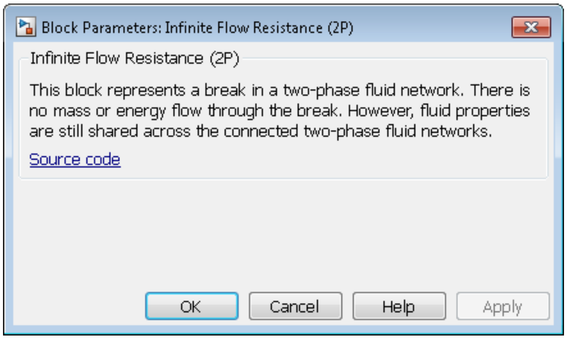
Two-Phase Fluid/Elements



Description

The `Infinite Flow Resistance (2P)` block represents a perfectly insulated barrier between otherwise distinct two-phase fluid networks. The block joins the networks, enabling you to specify their fluid properties using a single Two-Phase Fluid Properties (2P) block. No fluid flow or heat transfer occur across the barrier.

Dialog Box and Parameters



Block Parameters: Infinite Flow Resistance (2P)

Infinite Flow Resistance (2P)

This block represents a break in a two-phase fluid network. There is no mass or energy flow through the break. However, fluid properties are still shared across the connected two-phase fluid networks.

Source code

The block has no parameters.

Ports

The block has a pair of two-phase fluid conserving ports, A and B, representing branches of adjacent two-phase fluid networks.

See Also

`Infinite Thermal Resistance` | `Infinite Flow Resistance (TL)` | `Infinite Hydraulic Resistance` | `Infinite Pneumatic Resistance` | `Infinite Resistance`

Infinite Flow Resistance (TL)

Perfectly insulated barrier between thermal liquid networks

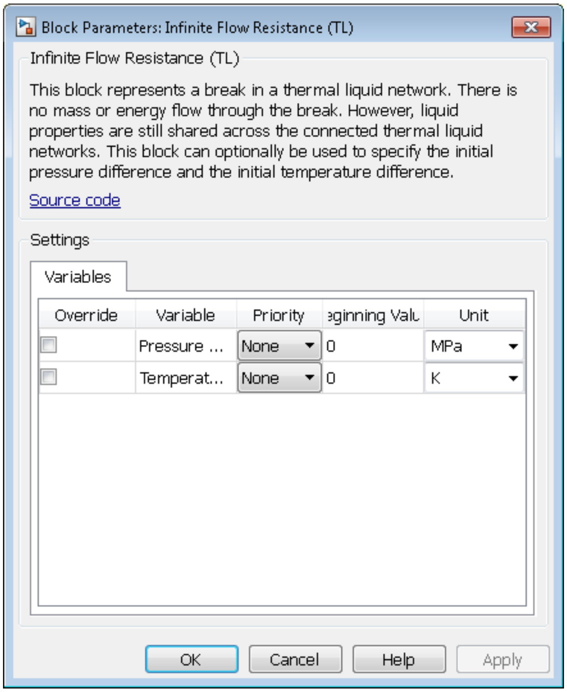
Library

Thermal Liquid/Elements

Description

The `Infinite Flow Resistance (TL)` block represents an infinite resistance, with no fluid or heat flow through it. Use this block to set the initial pressure and temperature difference between two thermal liquid nodes without affecting model equations.

Dialog Box and Parameters



Infinite Flow Resistance (TL)

This block represents a break in a thermal liquid network. There is no mass or energy flow through the break. However, liquid properties are still shared across the connected thermal liquid networks. This block can optionally be used to specify the initial pressure difference and the initial temperature difference.

Source code

Override	Variable	Priority	eginning Valu	Unit
□	Pressure ...	None	0	MPa
□	Temperat...	None	0	K

The **Variables** tab lets you set the priority and initial target value for the **Pressure difference** and **Temperature difference** variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has two thermal liquid conserving ports.

See Also

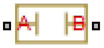
`Infinite Thermal Resistance` | `Infinite Hydraulic Resistance` | `Infinite Pneumatic Resistance` | `Infinite Resistance`

Infinite Hydraulic Resistance

Hydraulic element for setting initial pressure difference between two nodes

Library

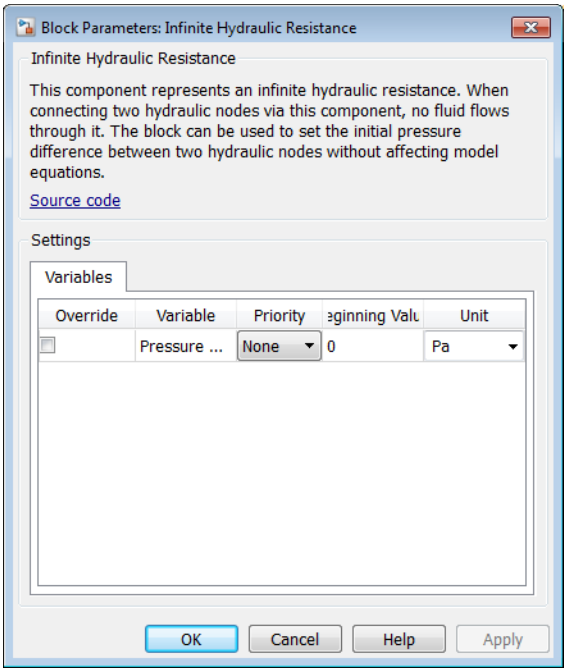
Hydraulic Elements



Description

The `Infinite Hydraulic Resistance` block represents an infinite resistance, with no fluid flow through it. Use this block to set the initial pressure difference between two hydraulic nodes without affecting model equations.

Dialog Box and Parameters



Block Parameters: Infinite Hydraulic Resistance

Infinite Hydraulic Resistance

This component represents an infinite hydraulic resistance. When connecting two hydraulic nodes via this component, no fluid flows through it. The block can be used to set the initial pressure difference between two hydraulic nodes without affecting model equations.

Source code

Settings

Variables

Override	Variable	Priority	ɘginning Valu	Unit
□	Pressure ...	None	0	Pa

The `Infinite Hydraulic Resistance` block has no parameters.

The **Variables** tab lets you set the priority and initial target value for the **Pressure difference** variable prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has two hydraulic conserving ports.

See Also

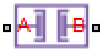
`Infinite Thermal Resistance` | `Infinite Flow Resistance (TL)` | `Infinite Pneumatic Resistance` | `Infinite Resistance`

Infinite Pneumatic Resistance

Pneumatic element for setting initial pressure and temperature difference between two nodes

Library

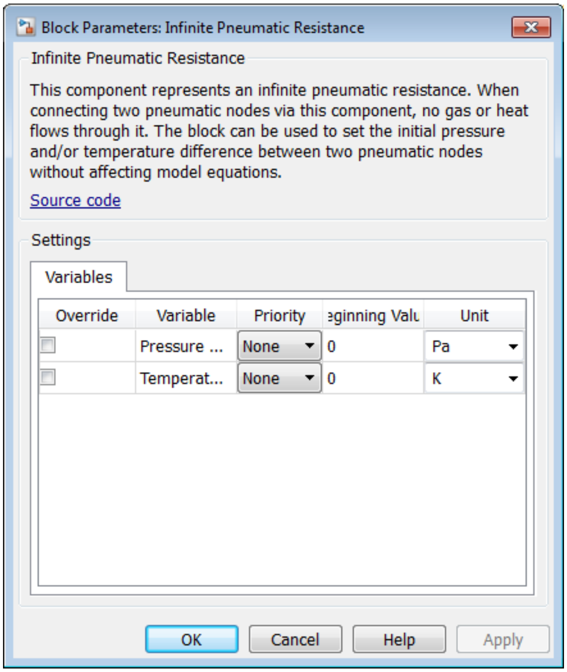
Pneumatic Elements



Description

The `Infinite Pneumatic Resistance` block represents an infinite resistance, with no gas or heat flow through it. Use this block to set the initial pressure and temperature difference between two pneumatic nodes without affecting model equations.

Dialog Box and Parameters



Infinite Pneumatic Resistance

This component represents an infinite pneumatic resistance. When connecting two pneumatic nodes via this component, no gas or heat flows through it. The block can be used to set the initial pressure and/or temperature difference between two pneumatic nodes without affecting model equations.

Source code

Settings

Variables

Override	Variable	Priority	eginning Valu	Unit
□	Pressure ...	None	0	Pa
□	Temperat...	None	0	K

The `Infinite Pneumatic Resistance` block has no parameters.

The **Variables** tab lets you set the priority and initial target value for the **Pressure difference** and **Temperature difference** variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has two pneumatic conserving ports.

See Also

`Infinite Thermal Resistance` | `Infinite Flow Resistance (TL)` | `Infinite Hydraulic Resistance` | `Infinite Resistance`

Infinite Resistance

Electrical element for setting initial voltage difference between two nodes

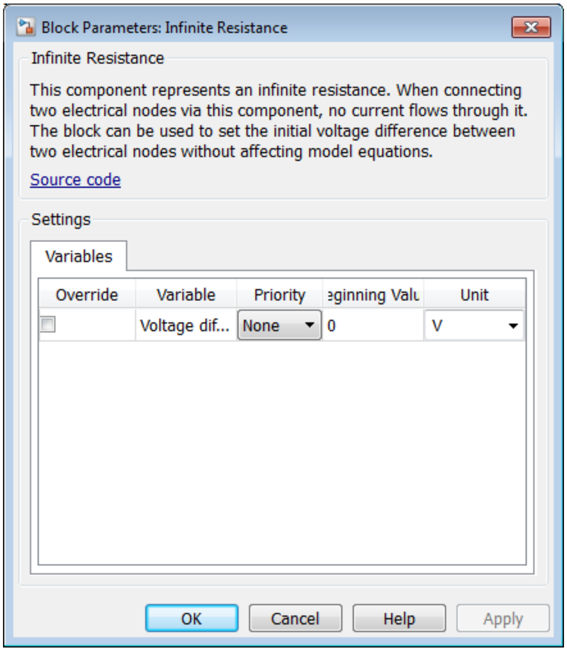
Library

Electrical Elements

Description

The `Infinite Resistance` block represents an infinite electrical resistance that draws no current. Use this block to set the initial voltage difference between two electrical nodes without affecting model equations.

Dialog Box and Parameters



Block Parameters: Infinite Resistance

Infinite Resistance

This component represents an infinite resistance. When connecting two electrical nodes via this component, no current flows through it. The block can be used to set the initial voltage difference between two electrical nodes without affecting model equations.

Source code

Settings

Variables

Override	Variable	Priority	ɘginning Valu	Unit
□	Voltage dif...	None	0	V

The `Infinite Resistance` block has no parameters.

The **Variables** tab lets you set the priority and initial target value for the **Voltage difference** variable prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has two electrical conserving ports.

See Also

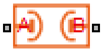
`Infinite Flow Resistance (TL)` | `Infinite Hydraulic Resistance` | `Infinite Pneumatic Resistance` | `Infinite Thermal Resistance`

Infinite Thermal Resistance

Thermal element for setting initial temperature difference between two nodes

Library

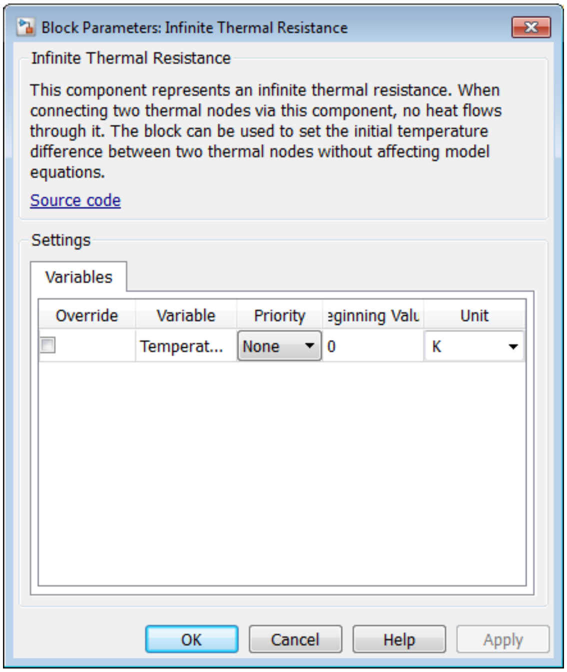
Thermal Elements



Description

The `Infinite Thermal Resistance` block represents an infinite resistance, with no heat flow through it. Use this block to set the initial temperature difference between two thermal nodes without affecting model equations.

Dialog Box and Parameters



Block Parameters: Infinite Thermal Resistance

Infinite Thermal Resistance

This component represents an infinite thermal resistance. When connecting two thermal nodes via this component, no heat flows through it. The block can be used to set the initial temperature difference between two thermal nodes without affecting model equations.

Source code

Settings

Variables

Override	Variable	Priority	›ginning Valu	Unit
□	Temperat...	None	0	K

The `Infinite Thermal Resistance` block has no parameters.

The **Variables** tab lets you set the priority and initial target value for the **Temperature difference** variable prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has two thermal conserving ports.

See Also

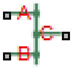
`Infinite Flow Resistance (TL)` | `Infinite Hydraulic Resistance` | `Infinite Pneumatic Resistance` | `Infinite Resistance`

Lever

Generic mechanical lever

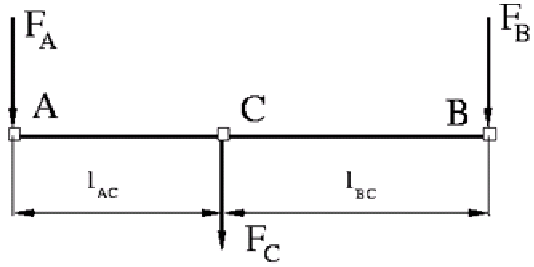
Library

Mechanisms



Description

The `Lever` block represents a mechanical lever in its generic form, known as a free or summing lever, shown in the following schematic.



The summing lever equations are derived with the assumption of small angle deviation from initial position:

$$v_C = K_{AC} \cdot v_A + K_{BC} \cdot v_B$$

$$F_A = K_{AC} \cdot F_C$$

$$F_B = K_{BC} \cdot F_C$$

$$K_{AC} = \frac{l_{BC}}{l_{AC} + l_{BC}}$$

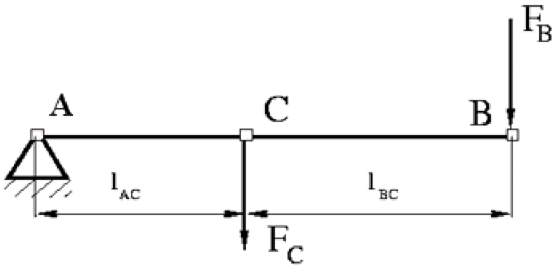
$$K_{BC} = \frac{l_{AC}}{l_{AC} + l_{BC}}$$

where

v_A,v_B,v_C	Lever joints velocities
F_A,F_B,F_C	Lever joints forces
l_{AC},l_{BC}	Arm lengths

The above equations were derived with the assumption that the lever sums forces and motions at node C. The assumption was arbitrary and does not impose any limitations on how the forces or motions are applied to the lever. In other words, any of the lever nodes can be “input” or “output” nodes, depending on the value of the force. Moreover, any of the block nodes can be connected to the reference point, thus converting a three-node lever into a first-class lever, with the fulcrum at the end, or a second-class lever, with the fulcrum in the middle.

The following illustration shows a schematic of a two-node first-class lever, with the fulcrum at node A.

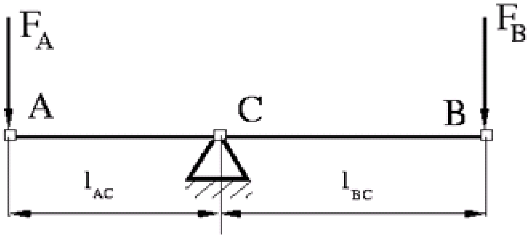


It is described with the following equations:

$$v_C = K_{BC} \cdot v_B$$

$$F_B = K_{BC} \cdot F_C$$

The next illustration shows a schematic of a second-class lever, with the fulcrum in the middle.



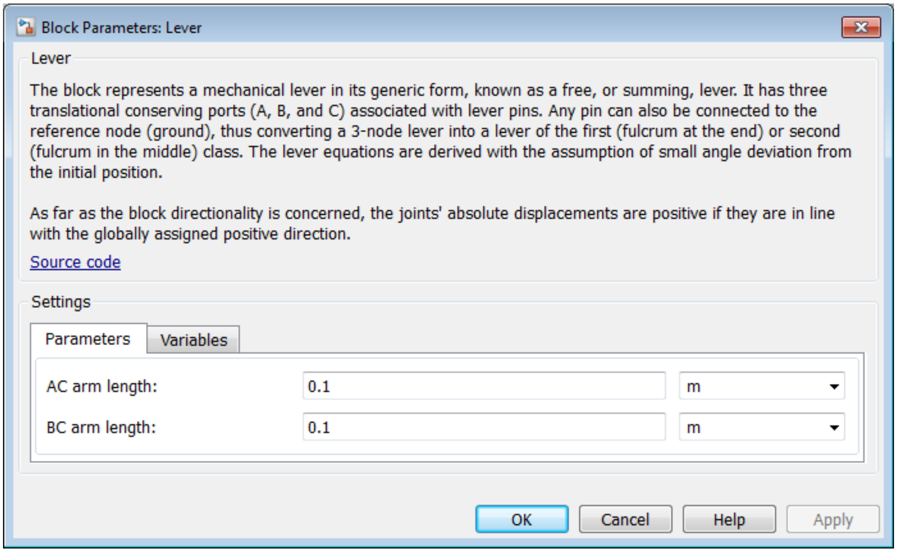
It is described with the following equations:

$$v_A = -\frac{l_{AC}}{l_{BC}} \cdot v_B$$

$$F_B = -\frac{l_{AC}}{l_{BC}} \cdot F_A$$

As far as the block directionality is concerned, the joints' absolute displacements are positive if they are in line with the globally assigned positive direction.

Dialog Box and Parameters



Lever

The block represents a mechanical lever in its generic form, known as a free, or summing, lever. It has three translational conserving ports (A, B, and C) associated with lever pins. Any pin can also be connected to the reference node (ground), thus converting a 3-node lever into a lever of the first (fulcrum at the end) or second (fulcrum in the middle) class. The lever equations are derived with the assumption of small angle deviation from the initial position.

As far as the block directionality is concerned, the joints' absolute displacements are positive if they are in line with the globally assigned positive direction.

Source code

Settings

Parameters | Variables

AC arm length: 0.1 m

BC arm length: 0.1 m

- “Parameters Tab” on page 1-231
- “Variables Tab” on page 1-231

Parameters Tab

AC arm length

Arm length between nodes A and C. The default value is `0.1` m.

BC arm length

Arm length between nodes B and C. The default value is `0.1` m.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

A

Mechanical translational conserving port associated with the node A of the lever.

B

Mechanical translational conserving port associated with the node B of the lever.

C

Mechanical translational conserving port associated with the node C of the lever.

Examples

The Linkage Mechanism example illustrates the use of the `Lever` block in three different modes. Linkages L_1 and L_4 simulate first-class levers with the fulcrum at the end. Linkage L_2 represents a summing lever. Linkage L_3 simulates a second-class lever with the fulcrum in the middle.

Linear Hydraulic Resistance

Hydraulic pipeline with linear resistance losses

Library

Hydraulic Elements

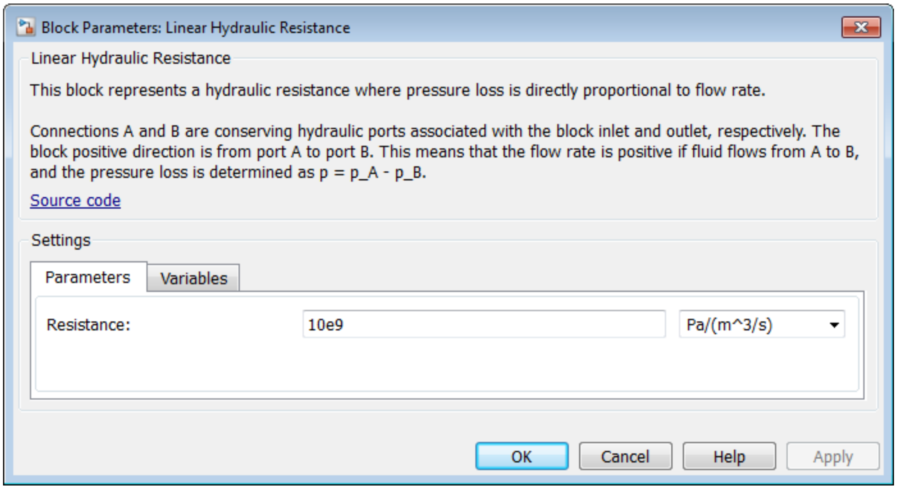
Description

The `Linear Hydraulic Resistance` block represents a hydraulic resistance where pressure loss is directly proportional to flow rate. This block can be useful at preliminary stages of development, or as a powerful means to speed up the simulation, especially if the flow rate varies insignificantly with respect to the operating point.

Connections A and B are conserving hydraulic ports associated with the block inlet and outlet, respectively.

The block positive direction is from port A to port B. This means that the flow rate is positive if fluid flows from A to B, and the pressure loss is determined as $p = p_A - p_B$.

Dialog Box and Parameters



Block Parameters: Linear Hydraulic Resistance

Linear Hydraulic Resistance

This block represents a hydraulic resistance where pressure loss is directly proportional to flow rate.

Connections A and B are conserving hydraulic ports associated with the block inlet and outlet, respectively. The block positive direction is from port A to port B. This means that the flow rate is positive if fluid flows from A to B, and the pressure loss is determined as p = p_A - p_B.

Source code

Settings

Resistance: 10e9 Pa/(m^3/s)

- “Parameters Tab” on page 1-234
- “Variables Tab” on page 1-234

Parameters Tab

Resistance

The linear resistance coefficient. The default value is `10e9` Pa/(m^3/s).

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

A

Hydraulic conserving port associated with the resistance inlet.

B

Hydraulic conserving port associated with the resistance outlet.

See Also

Hydraulic Resistive Tube

Local Restriction (2P)

Fixed flow resistance

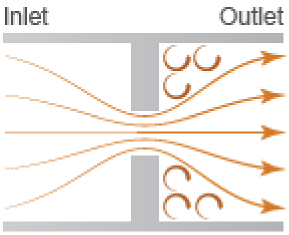
Library

Two-Phase Fluid/Elements

Description

The `Local Restriction (2P)` block models the pressure drop due to a fixed flow resistance such as an orifice. Ports A and B represent the restriction inlet and outlet. The restriction area, specified in the block dialog box, remains constant during simulation.

The restriction consists of a contraction followed by a sudden expansion in flow area. The contraction causes the fluid to accelerate and its pressure to drop. The expansion recovers the lost pressure though only in part, as the flow separates from the wall, losing momentum in the process.



Local Restriction Schematic

The restriction is adiabatic. It does not exchange heat with its surroundings. The net energy flow rate into the restriction follows from the energy conservation equation

$$\phi_I + \phi_O = 0,$$

where:

- ϕ_I is the energy flow rate into the restriction through the inlet.
- ϕ_O is the energy flow rate into the restriction through the outlet.

Momentum Balance in the Contraction Zone

The momentum balance in the contraction zone, located between the inlet and aperture, is

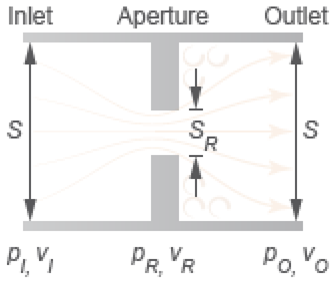
$$p_I S - p_R S_{VC} - p_{avg}\left(S - S_{VC}\right) = \dot{m}\Delta\vec{v}_{IR},$$

where:

- p_I is the pressure at the inlet.
- p_R is the pressure at the restriction aperture.
- p_{avg} is the area-averaged pressure at the wall containing the aperture:

$$p_{avg} = \frac{p_I S + p_R S_{VC}}{S + S_{VC}}$$

- S is the flow cross-sectional area at the inlet and outlet.
- S_{VC} is the vena contracta flow area.
- $\dot{m}$ is the mass flow rate from the inlet to the outlet.
- $\Delta\vec{v}_{IR}$ is the velocity change from the inlet to the aperture.



Local Restriction Variables

Inserting p_{avg} and rearranging terms yields the pressure difference between the inlet and aperture as a function of the ideal mass flow rate:

$$\left(p_I - p_R\right) S_{eqv} = \dot{m} \Delta \vec{v}_{IR},$$

where:

- S_{eqv} is an equivalent cross-sectional area given by

$$S_{eqv} = \frac{2 S S_{VC}}{S + S_{VC}}.$$

Momentum Balance in the Expansion Zone

The flow exits the aperture as a jet. In the exit plane, the average pressure outside the jet is approximately equal to that inside the jet. The momentum balance in the expansion zone, located between the aperture and outlet, is then

$$p_R S_{VC} + p_R \left(S - S_{VC}\right) - p_O S = -\dot{m} \Delta \vec{v}_{OR},$$

where:

- p_{O} is the pressure at the outlet.
- $\Delta \vec{v}_{OR}$ is the velocity change from the outlet to the restriction aperture.

Rearranging terms yields the pressure difference between the outlet and aperture as a function of the ideal mass flow rate:

$$\left(p_O - p_R\right) S = \dot{m} \Delta \vec{v}_{OR}.$$

Vena Contracta Flow Area

The vena contracta is the point in the fluid stream where the flow area is at a minimum. Due to the sharp restriction angle, this flow area is generally smaller than the specified restriction area. The block defines the vena contracta flow area as

$$S_{VC} = \frac{C_d S S_R}{\sqrt{S^2 - \left(1 - C_d^2\right) S_R^2}},$$

where:

- C_d is the discharge coefficient relating the ideal mass flow rate to the actual flow rate.
- S_R is the specified restriction area.

Change in Velocity

The changes in velocity across the contraction and expansion zones vary with the flow regime—laminar or turbulent. The transition between the two occurs when the mass flow rate reaches a critical value:

$$\dot{m}_{crit} = \frac{Re_{crit} \nu_{avg}}{v_{avg}} \sqrt{\frac{\pi S_R}{4}},$$

where:

- $\dot{m}_{crit}$ is the critical mass flow rate separating the laminar and turbulent flow regimes.
- Re_crit is the critical Reynolds number separating the laminar and turbulent flow regimes.
- ν_avg is the average kinematic viscosity in the restriction, defined as

$$\nu_{avg} = \frac{\nu_I + \nu_O}{2}.$$

- ν_I is the kinematic viscosity at the inlet.
- ν_O is the kinematic viscosity at the outlet.
- v_avg is the average specific volume in the restriction, defined as

$$v_{avg} = \frac{v_I + v_O}{2}.$$

- v_I is the specific volume at the inlet.
- v_O is the specific volume at the outlet.

In the turbulent regime, the change in velocity varies linearly with the ideal mass flow rate:

$$\Delta\vec{v}_{IR}^{turb} = \dot{m}\left(\frac{v_R}{S_{VC}} - \frac{v_I}{S}\right),$$

while in the expansion zone it is

$$\Delta\vec{v}_{OR}^{turb} = \dot{m}\left(\frac{v_R}{S_{VC}} - \frac{v_O}{S}\right),$$

where:

- $\Delta\vec{v}_{IR}{}^{turb}$ is the change in velocity from the inlet to the restriction aperture in the turbulent regime.
- $\Delta\vec{v}_{OR}{}^{turb}$ is the change in velocity from the outlet to the restriction aperture in the turbulent regime.

In the laminar regime, the change in velocity is independent of the ideal mass flow rate. In the contraction zone, this change is

$$\Delta\vec{v}_{IR}^{lam} = \dot{m}_{crit}\left(\frac{v_R + v_I}{2}\right)\left(\frac{1}{S_{VC}} - \frac{1}{S}\right),$$

while in the expansion zone it is

$$\Delta\vec{v}_{OR}^{lam} = \dot{m}_{crit}\left(\frac{v_R + v_O}{2}\right)\left(\frac{1}{S_{VC}} - \frac{1}{S}\right),$$

where:

- ${\Delta\vec{v}_{IR}}^{lam}$ is the change in velocity from the inlet to the restriction aperture in the laminar regime.
- ${\Delta\vec{v}_{OR}}^{lam}$ is the change in velocity from the outlet to the restriction aperture in the laminar regime.

Quadratic functions blend the laminar- and turbulent-flow expressions, preventing numerical discontinuities due to transitions in flow regime. In the contraction zone, the general velocity change is

$$\Delta\vec{v}_{IR} = \sqrt{\left(\Delta\vec{v}_{IR}^{turb}\right)^2 + \left(\Delta\vec{v}_{IR}^{lam}\right)^2},$$

while in the contraction zone it is

$$\Delta\vec{v}_{OR} = \sqrt{\left(\Delta\vec{v}_{OR}^{turb}\right)^2 + \left(\Delta\vec{v}_{OR}^{lam}\right)^2}.$$

In the laminar regime, the turbulent-flow terms become negligible, reducing the velocity changes in the expansion and contraction zones to ${\Delta\vec{v}_{IR}}^{lam}$ and ${\Delta\vec{v}_{OR}}^{lam}$. Substituting these terms into the momentum balance equations reveals a linear relationship between the pressure drop and the mass flow rate:

$$\Delta P \propto \dot{m}$$

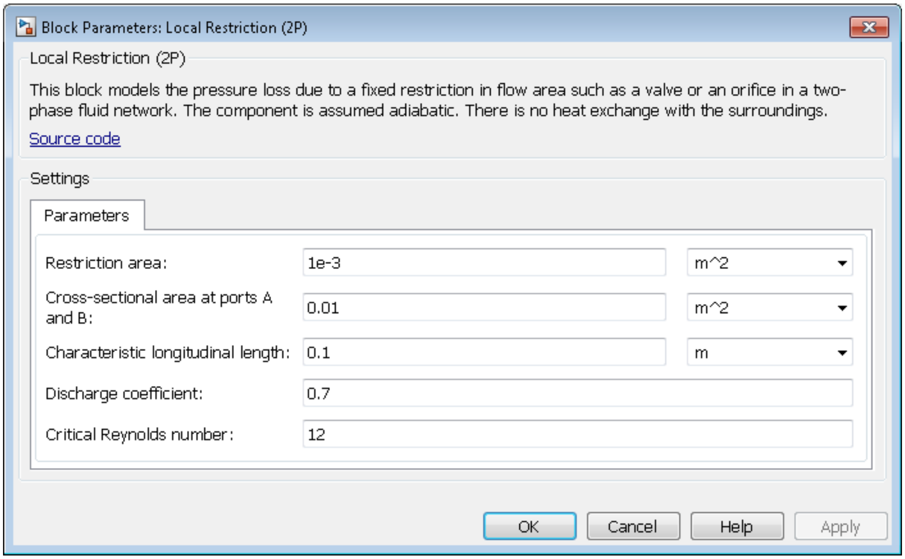
In the turbulent regime, the laminar-flow terms become negligible, reducing the velocity changes in the expansion and contraction zones to ${\Delta\vec{v}_{IR}}^{turb}$ and ${\Delta\vec{v}_{OR}}^{turb}$. Substituting these terms into the momentum balance equations reveals a quadratic relationship between the pressure drop and the mass flow rate:

$$\Delta P \propto \dot{m}^2$$

Assumptions and Limitations

The restriction is adiabatic. It does not exchange heat with its surroundings.

Dialog Box and Parameters



Block Parameters: Local Restriction (2P)

Local Restriction (2P)

This block models the pressure loss due to a fixed restriction in flow area such as a valve or an orifice in a two-phase fluid network. The component is assumed adiabatic. There is no heat exchange with the surroundings.

Source code

Settings

Parameters

Restriction area:	1e-3	m^2
Cross-sectional area at ports A and B:	0.01	m^2
Characteristic longitudinal length:	0.1	m
Discharge coefficient:	0.7	
Critical Reynolds number:	12	

Parameters Tab

Restriction area

Area normal to the direction of flow at the restriction aperture, the narrowest opening in the restriction. The default value is `0.01` m^2.

Cross-sectional area at ports A and B

Area normal to the direction of flow at the inlet and outlet. The two cross-sectional areas are assumed identical. The default value is `0.01` m^2.

Characteristic longitudinal length

Average distance the flow traverses between the inlet and outlet. The default value is `0.1` m.

Flow discharge coefficient

Ratio of the actual mass flow rate through the restriction to its ideal, or theoretical, value. The discharge coefficient helps to account for restriction geometry and non-ideal effects. The default value is `0.7`.

Critical Reynolds number based on restriction diameter

Reynolds number at which flow transitions between laminar and turbulent regimes. The default value is `12`.

Ports

The block has two two-phase fluid conserving ports, A and B, representing the restriction inlet and outlet.

See Also

`Variable Local Restriction (2P)`

Local Restriction (TL)

Time-invariant reduction in flow area

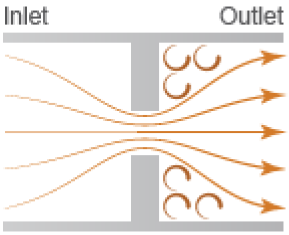
Library

Thermal Liquid/Elements

Description

The `Local Restriction (TL)` block models the pressure drop due to a time-invariant reduction in flow area such as an orifice. Ports A and B represent the restriction inlets. The restriction area, specified in the block dialog box, remains constant during simulation.

The restriction consists of a contraction followed by a sudden expansion in flow area. The contraction causes the fluid to accelerate and its pressure to drop. The pressure drop is assumed to persist in the expansion zone—an approximation suitable for narrow restrictions.



Local Restriction Schematic

Mass Balance

The mass balance in the restriction is

$$0 = \dot{m}_{\mathrm{A}} + \dot{m}_{\mathrm{B}},$$

where:

- $\dot{m}_{\mathrm{A}}$ is the mass flow rate into the restriction through port A.
- $\dot{m}_{\mathrm{B}}$ is the mass flow rate into the restriction through port B.

Momentum Balance

The pressure difference between ports A and B follows from the momentum balance in the restriction:

$$p_{\mathrm{A}} - p_{\mathrm{B}} = \frac{\dot{m}_A \left(\dot{m}_A{}^8 + \dot{m}_{Ac}{}^8\right)^{1/8}}{2 C_{\mathrm{d}}^2 S_R \rho_{\mathrm{u}}},$$

where:

- p_{A} is the pressure at port A.
- p_{B} is the pressure at port B.
- C_{d} is the discharge coefficient of the restriction aperture.
- S_{R} is the cross-sectional area of the restriction aperture.
- ρ_{u} is the liquid density upstream of the restriction aperture.
- $\dot{m}_{\mathrm{Ac}}$ is the critical mass flow rate at port A.

The critical mass flow rate at port A is

$$\dot{m}_{\mathrm{Ac}} = \mathrm{Re}_{\mathrm{c}} \sqrt{\pi S_R} \frac{\mu_{\mathrm{u}}}{2},$$

where:

- Re_{c} is the critical Reynolds number,

$$\mathrm{Re}_c = \frac{\left|\dot{m}_{\mathrm{Ac}}\right| D}{S_{\mathrm{R}} \mu_{\mathrm{u}}},$$

D is the hydraulic diameter of the restriction aperture.

- μ_{u} is the liquid dynamic viscosity upstream of the restriction aperture.

The discharge coefficient is the ratio of the actual mass flow rate through the local restriction to the ideal mass flow rate,

$$C_d = \frac{\dot{m}_{ideal}}{\dot{m}},$$

where:

- $\dot{m}$ is the actual mass flow rate through the local restriction.
- $\dot{m}_{ideal}$ is the ideal mass flow rate through the local restriction:

$$\dot{m}_{ideal} = S_R \sqrt{\frac{2\rho_u \left(p_A - p_B\right)}{1 - \left(S_R / S\right)^2}}.$$

where S is the inlet cross-sectional area.

Energy Balance

The energy balance in the restriction is

$$\phi_{\mathrm{A}} + \phi_{\mathrm{B}} = 0,$$

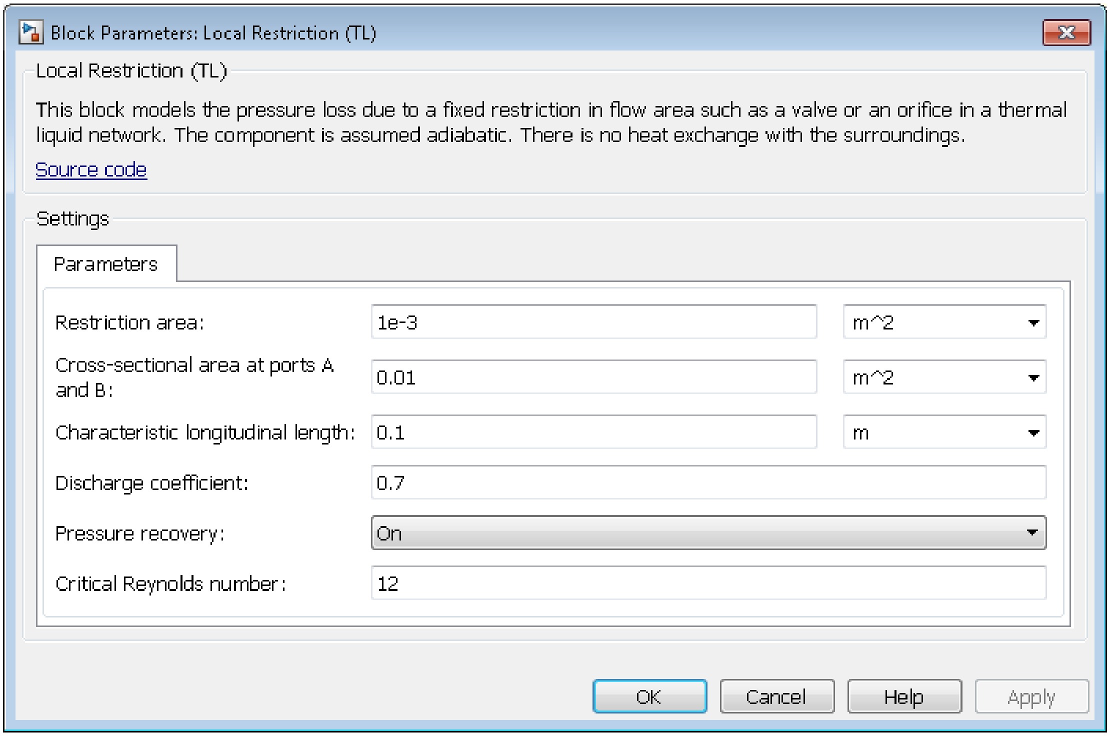
where:

- ϕ_{A} is the energy flow rate into the restriction through port A.
- ϕ_{B} is the energy flow rate into the restriction through port B.

Assumptions and Limitations

- The restriction is adiabatic. It does not exchange heat with its surroundings.
- The dynamic compressibility and thermal capacity of the liquid in the restriction are negligible.

Dialog Box and Parameters



Local Restriction (TL)

This block models the pressure loss due to a fixed restriction in flow area such as a valve or an orifice in a thermal liquid network. The component is assumed adiabatic. There is no heat exchange with the surroundings.

Source code

Settings

Parameters

Restriction area:	1e-3	m^2
Cross-sectional area at ports A and B:	0.01	m^2
Characteristic longitudinal length:	0.1	m
Discharge coefficient:	0.7	
Pressure recovery:	On	
Critical Reynolds number:	12	

Parameters

Restriction Area

Enter the flow cross-sectional area of the local restriction. The default value is `1e-5` m^2.

Cross-sectional area at ports A and B

Enter the flow cross-sectional area of the local restriction ports. This area is assumed the same for the two ports. The default value is `1e-2` m^2 .

Characteristic longitudinal length

Enter the approximate longitudinal length of the local restriction. This length provides a measure of the longitudinal scale of the restriction. The default value is `1e-1` m.

Discharge coefficient

Enter the discharge coefficient of the local restriction. The discharge coefficient is a semi-empirical parameter commonly used to characterize the flow capacity of an orifice. This parameter is defined as the ratio of the actual mass flow rate through the orifice to the ideal mass flow rate:

$$C_d = \frac{\dot{m}_{ideal}}{\dot{m}},$$

where C_d is the discharge coefficient, $\dot{m}$ is the actual mass flow rate through the orifice, and $\dot{m}_{ideal}$ is the ideal mass flow rate:

$$\dot{m}_{ideal} = S_r \sqrt{\frac{2\rho\left(p_A - p_B\right)}{1-\left(S_r / S\right)^2}}.$$

The default value is `0.7`, corresponding to a sharp-edged orifice.

Pressure recovery

Specify whether to account for pressure recovery at the local restriction outlet. Options include `On` and `Off`. The default setting is `On`.

Critical Reynolds number

Enter the Reynolds number for the transition between laminar and turbulent flow regimes. The default value is `12`, corresponding to a sharp-edged orifice.

Ports

The block has two thermal liquid conserving ports, A and B. These ports represent the inlets of the local restriction.

See Also

`Variable Local Restriction (TL)` | `Pipe (TL)`

Magnetic Reference

Reference connection for magnetic ports

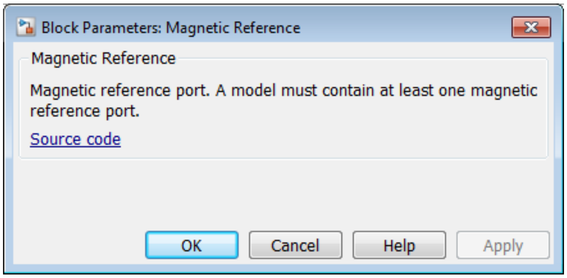
Library

Magnetic Elements

Description

The `Magnetic Reference` block represents a reference point for all magnetic conserving ports. A model with magnetic elements must contain at least one `Magnetic Reference` block.

Dialog Box and Parameters



Block Parameters: Magnetic Reference

Magnetic Reference

Magnetic reference port. A model must contain at least one magnetic reference port.

Source code

The `Magnetic Reference` block has no parameters.

Ports

The block has one magnetic conserving port.

More About

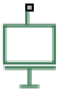
- "Grounding Rules"

Mass

Ideal mechanical translational mass

Library

Mechanical Translational Elements



Description

The `Mass` block represents an ideal mechanical translational mass, described with the following equation:

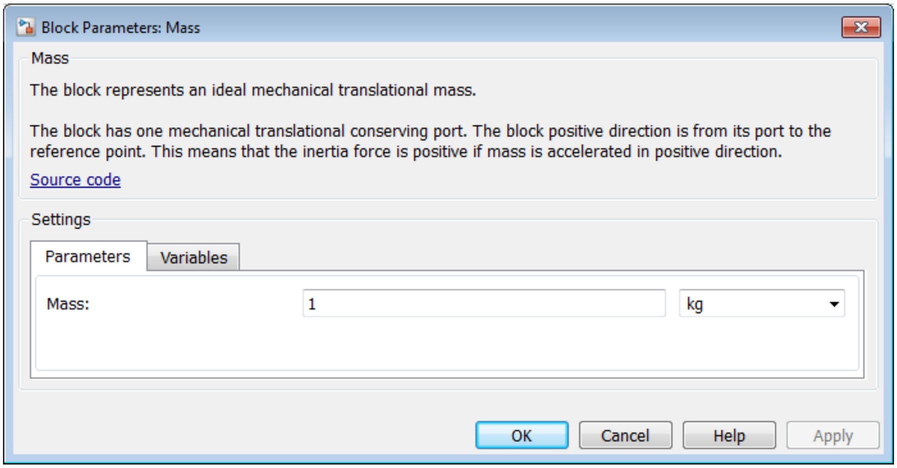
$$F = m\frac{dv}{dt}$$

where

F	Inertia force
m	Mass
v	Velocity
t	Time

The block has one mechanical translational conserving port. The block positive direction is from its port to the reference point. This means that the inertia force is positive if mass is accelerated in positive direction.

Dialog Box and Parameters



Mass

The block represents an ideal mechanical translational mass.

The block has one mechanical translational conserving port. The block positive direction is from its port to the reference point. This means that the inertia force is positive if mass is accelerated in positive direction.

Source code

Settings

Mass: 1 kg

- “Parameters Tab” on page 1-253
- “Variables Tab” on page 1-253

Parameters Tab

Mass

Mass. The default value is 1 kg.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has one mechanical translational conserving port, associated with the mass connection to the system.

See Also

`Inertia`

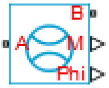
Mass & Energy Flow Sensor (2P)

Measure mass and energy flow rates

Library

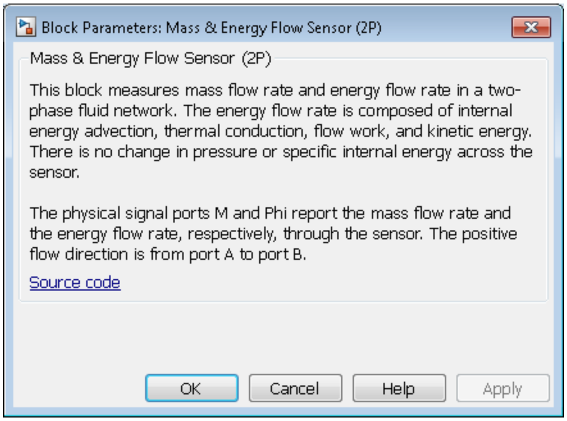
Two-Phase Fluid/Sensors

Description



The `Mass & Energy Flow Sensor (2P)` block measures mass and energy flow rates through the two-phase fluid branch defined by ports A and B. The energy flow rate includes contributions from internal energy advection, thermal conduction, pressure work, and kinetic energy. The flow rates are positive if mass and energy flow from port A to port B.

Dialog Box and Parameters



Mass & Energy Flow Sensor (2P)

This block measures mass flow rate and energy flow rate in a two-phase fluid network. The energy flow rate is composed of internal energy advection, thermal conduction, flow work, and kinetic energy. There is no change in pressure or specific internal energy across the sensor.

The physical signal ports M and Phi report the mass flow rate and the energy flow rate, respectively, through the sensor. The positive flow direction is from port A to port B.

Source code

The block has no parameters.

Ports

The block has two two-phase fluid conserving ports, A and B. Physical signal port M outputs the mass flow rate value. Physical signal port Phi outputs the energy flow rate value.

See Also

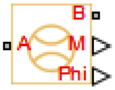
`Controlled Mass Flow Rate Source (2P)` | `Mass Flow Rate Source (2P)` | `Volumetric Flow Sensor (2P)`

Mass & Energy Flow Rate Sensor (TL)

Measure mass and energy flow rates

Library

Thermal Liquid/Sensors



Description

The `Mass & Energy Flow Rate Sensor (TL)` block represents an ideal sensor that measures mass and energy flow rates through a thermal liquid node. Because the flow rates are Through variables, the block must connect in series with the component being measured.

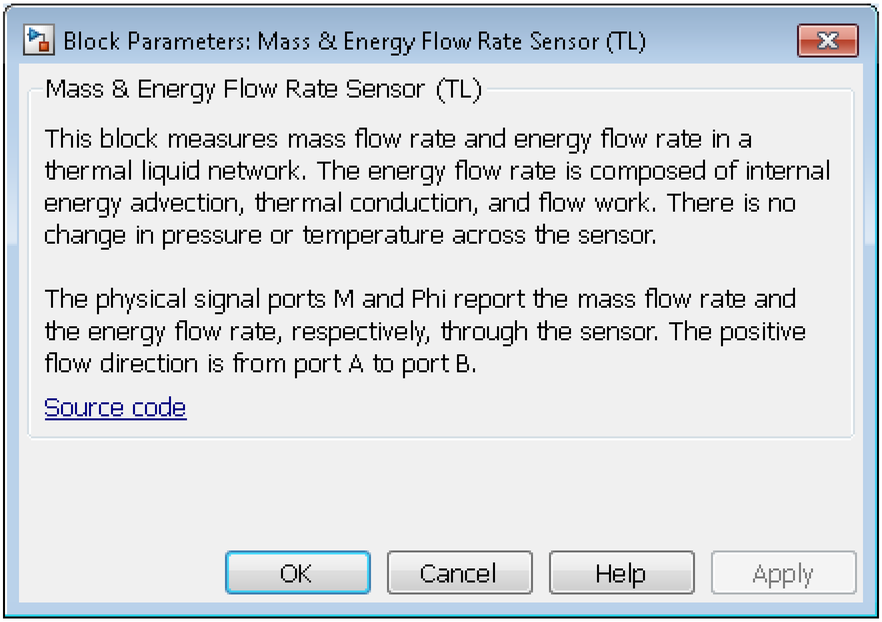
The relative orientation of ports A and B establishes the measurement sign. The sign is positive if flow occurs from port A to port B. Switching port connections reverses the measurement sign.

Two physical signal ports output the measurement data. Port M outputs the mass flow rate. Port Phi outputs the thermal energy flow rate. Connect the ports to `PS-Simulink Converter` blocks to transform the output physical signals into Simulink signals, e.g., for plotting or additional data processing.

Assumptions and Limitations

- Sensor inertia is negligible.

Dialog Box and Parameters



Block Parameters: Mass & Energy Flow Rate Sensor (TL)

Mass & Energy Flow Rate Sensor (TL)

This block measures mass flow rate and energy flow rate in a thermal liquid network. The energy flow rate is composed of internal energy advection, thermal conduction, and flow work. There is no change in pressure or temperature across the sensor.

The physical signal ports M and Phi report the mass flow rate and the energy flow rate, respectively, through the sensor. The positive flow direction is from port A to port B.

The block has no parameters.

Ports

The block has the following ports.

A, B	Thermal liquid conserving ports
M	Physical signal output port for mass flow rate measurement
Phi	Physical signal output port for energy flow rate measurement

See Also

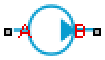
`Pressure & Temperature Sensor (TL)`

Mass Flow Rate Source (2P)

Generate constant mass flow rate

Library

Two-Phase Fluid/Sources



Description

The `Mass Flow Rate Source (2P)` block generates a constant mass flow rate through a two-phase fluid branch. The source is ideal. It maintains the specified flow rate regardless of the pressure differential between the inlet and outlet. Losses due to friction are assumed negligible.

The energy balance at the source is a function of the energy flow rates through ports A and B and the work done on the fluid:

$$\phi_A + \phi_B + \phi_{work} = 0,$$

where:

- ϕ_A is the energy flow rate into the source through port A.
- ϕ_B is the energy flow rate into the source through port B.
- ϕ_{work} is the isentropic work done on the fluid.

For a subcooled liquid, the isentropic work term is

$$\phi_{work}^{L} = \dot{m}\left(p_B - p_A\right)v_{avg},$$

where:

- $\phi^{\mathrm{L}}{}_{\mathrm{work}}$ is the isentropic work done on the subcooled liquid.
- $\dot{m}$ is the mass flow rate from port A to port B.
- p_{A} is the pressure at port A.
- p_{B} is the pressure at port B.
- v_{avg} is the average of the specific volumes at ports A and B,

$$v_{avg} = \frac{v_A + v_B}{2}.$$

- v_{A} is the specific volume at port A.
- v_{B} is the specific volume at port B.

If the fluid is a superheated vapor, the isentropic work is

$$\phi_{work}^{V} = \dot{m}\left(u_B^{isen} + p_B v_B + \frac{1}{2}\left(\frac{\dot{m} v_B}{S} \right) - u_A^{isen} - p_A v_A - \frac{1}{2}\left(\frac{\dot{m} v_B}{S} \right) \right),$$

where:

- $\phi^{\mathrm{V}}{}_{\mathrm{work}}$ is the isentropic work done on the superheated vapor.
- $u_{\mathrm{A}}{}^{\mathrm{isen}}$ is the isentropic specific internal energy at port A.
- $u_{\mathrm{B}}{}^{\mathrm{isen}}$ is the isentropic specific internal energy at port B.
- S is the source inlet cross-sectional area.

The isentropic specific internal energies at ports A and B follow from the expressions

$$\frac{u_A^{isen} + u_B^{isen}}{2} = \frac{u_A + u_B}{2}$$

and

$$s_{table}\left(\bar{u}_A^{isen}, p_A\right) = s_{table}\left(\bar{u}_B^{isen}, p_B\right),$$

where:

- u_A is the specific internal energy at port A.
- u_B is the specific internal energy at port B.
- $s_{table}(\bar{u}, p)$ is the interpolation of the specific entropy table at the normalized internal energy $\bar{u}$ and pressure p.
- $\bar{u}_A^{isen}$ is the isentropic normalized internal energy at port A.
- $\bar{u}_B^{isen}$ is the isentropic normalized internal energy at port B.

The normalized internal energy at port A is a function of the specific internal energy at that port, as described by the expression

$$\bar{u}_A^{isen} = \begin{cases} \dfrac{u_A^{isen} - u_{min}}{u_{sat}^L(p_A) - u_{min}} - 1, & u_A^{isen} < u_{sat}^L(p_A) \\ \dfrac{u_A^{isen} - u_{sat}^L(p_A)}{u_{sat}^V(p_A) - u_{sat}^L(p_A)}, & u_{sat}^L(p_A) \le u_A^{isen} \le u_{sat}^V(p_A), \\ \dfrac{u_A^{isen} - u_{max}}{u_{max} - u_{sat}^V(p_A)} + 2, & u_{sat}^V(p_A) < u_A^{isen} \end{cases}$$

where:

- u_{min} is the minimum valid specific internal energy.
- u_{max} is the maximum valid specific internal energy.
- $u^L_{sat}(p)$ is the interpolation of the saturated liquid specific internal energy vector at pressure p.
- $u^V_{sat}(p)$ is the interpolation of the saturated vapor specific internal energy vector at pressure p.

Similarly, the normalized internal energy at port B is a function of the specific internal energy at that port, as described by the expression

$$\bar{u}_B^{isen} = \begin{cases} \dfrac{u_B^{isen} - u_{min}}{u_{sat}^L(p_B) - u_{min}} - 1, & u_B^{isen} < u_{sat}^L(p_B) \\ \dfrac{u_B^{isen} - u_{sat}^L(p_B)}{u_{sat}^V(p_B) - u_{sat}^L(p_B)}, & u_{sat}^L(p_B) \le u_B^{isen} \le u_{sat}^V(p_B). \\ \dfrac{u_B^{isen} - u_{max}}{u_{max} - u_{sat}^V(p_B)} + 2, & u_{sat}^V(p_B) < u_B^{isen} \end{cases}$$

The normalized internal energy at either port falls in the range -1 to 0 for a subcooled liquid, 0 to 1 for a two-phase fluid, and 1 to 2 for a superheated vapor. The isentropic work as a function of the average normalized internal energy is

$$\phi_{work} = \begin{cases} \phi_{work}^L, & \bar{u}_{avg} < 0 \\ \left(1 - \bar{u}_{avg}\right)\phi_{work}^L + \bar{u}_{avg}\phi_{work}^V, & 0 \le \bar{u}_{avg} \le 1, \\ \phi_{work}^V, & 1 < \bar{u}_{avg} \end{cases}$$

where:

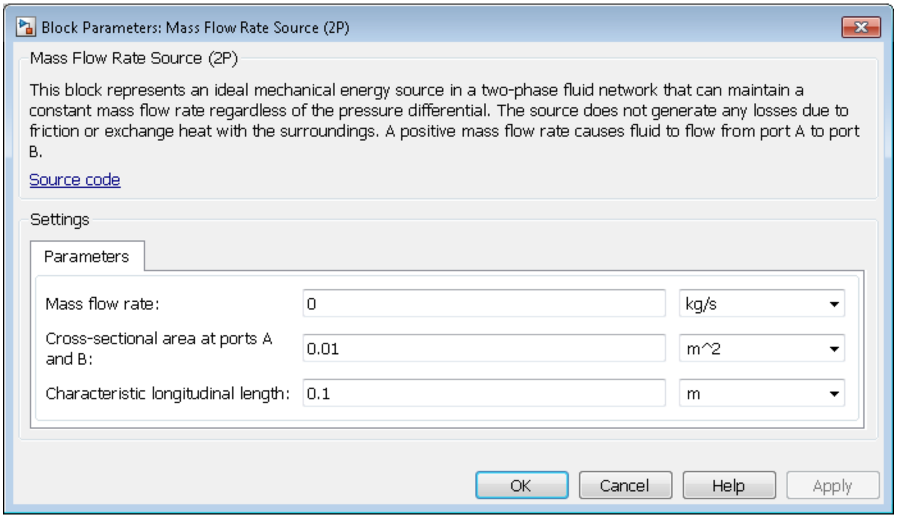
- $\bar{u}_{avg}$ is the average of the normalized internal energies at ports A and B,

$$\bar{u}_{avg} = \frac{\bar{u}_A + \bar{u}_B}{2}.$$

Assumptions and Limitations

- The source is ideal. Losses due to friction are assumed negligible.
- The source is adiabatic. Heat exchange with the surroundings is assumed negligible.
- Work done by the source is isentropic—that is, reversible and adiabatic.

Dialog Box and Parameters



Mass Flow Rate Source (2P)

This block represents an ideal mechanical energy source in a two-phase fluid network that can maintain a constant mass flow rate regardless of the pressure differential. The source does not generate any losses due to friction or exchange heat with the surroundings. A positive mass flow rate causes fluid to flow from port A to port B.

Source code

Settings

Parameters

Mass flow rate: 0 kg/s

Cross-sectional area at ports A and B: 0.01 m^2

Characteristic longitudinal length: 0.1 m

Mass flow rate

Mass flow rate from port A to port B. The default value is `0` kg/s.

Cross-sectional area at ports A and B

Area normal to the direction of flow at the source inlet and outlet. The two cross-sectional areas are assumed identical. The default value is `0.01` m^2.

Characteristic longitudinal length

Average distance the fluid traverses in the source before it reaches the outlet. The default value is `0.1`m.

Ports

The block has two two-phase fluid conserving ports, A and B.

See Also

`Controlled Mass Flow Rate Source (2P)` | `Controlled Volumetric Flow Rate Source (2P)` | `Volumetric Flow Rate Source (2P)`

Mass Flow Rate Source (TL)

Generate constant mass flow rate

Library

Thermal Liquid/Sources

Description

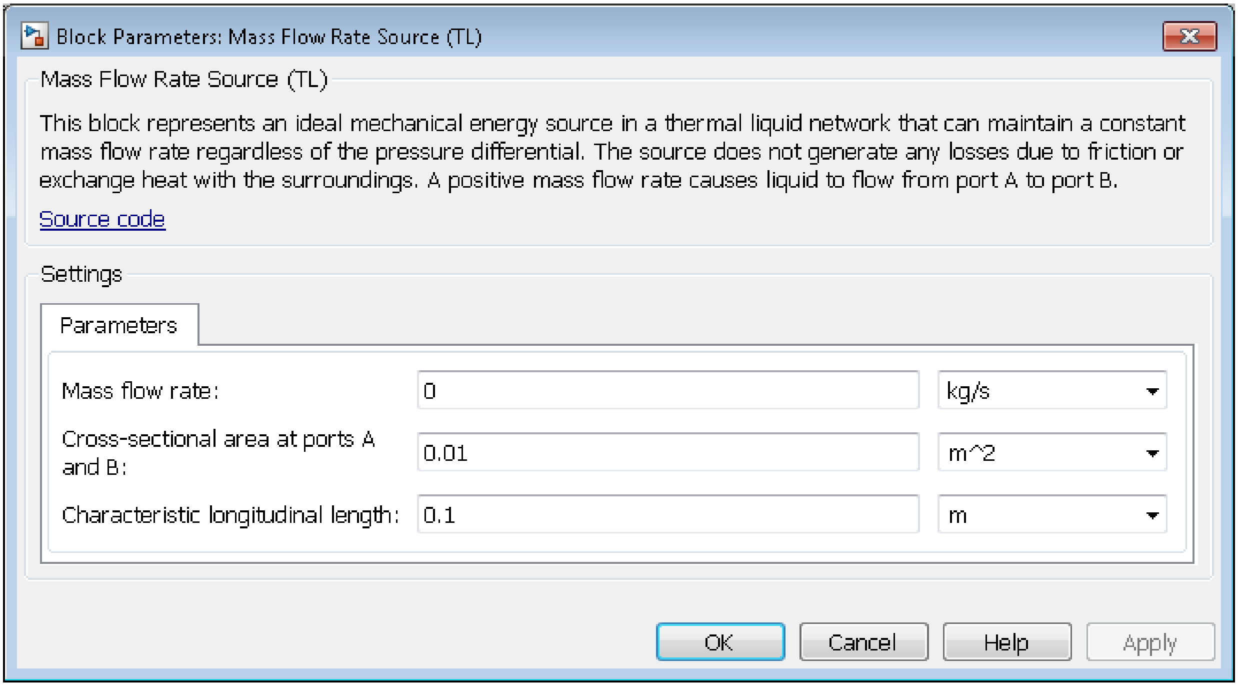
The `Mass Flow Rate Source (TL)` block represents an ideal compressor generating a constant mass flow rate through its inlets. The compressor can hold the specified mass flow rate regardless of the pressure differential between its inlets. No heat exchange occurs between the compressor and the flowing liquid.

Ports A and B represent the compressor inlets. Both ports are thermal liquid conserving ports. The mass flow rate is positive when liquid flows from inlet A to inlet B.

Assumptions and Limitations

- No heat exchange occurs between the compressor and the flowing liquid.
- The mass flow rate through the compressor inlets is independent of the pressure differential between those inlets.

Dialog Box and Parameters



Block Parameters: Mass Flow Rate Source (TL)

Mass Flow Rate Source (TL)

This block represents an ideal mechanical energy source in a thermal liquid network that can maintain a constant mass flow rate regardless of the pressure differential. The source does not generate any losses due to friction or exchange heat with the surroundings. A positive mass flow rate causes liquid to flow from port A to port B.

Source code

Settings

Parameters

Mass flow rate:	0	kg/s
Cross-sectional area at ports A and B:	0.01	m^2
Characteristic longitudinal length:	0.1	m

Mass flow rate

Enter the rate at which mass flows through the compressor inlets. The default value is `0` kg/s.

Cross-sectional area at ports A and B

Enter the cross-sectional area of the adjoining pipes. The default value is `1e-2` m^2.

Characteristic longitudinal length

Enter the mean path length the liquid must flow through to go from inlet A to inlet B. The default value is `1e-1` m.

Ports

This block has two thermal liquid conserving ports, A and B.

See Also

`Controlled Mass Flow Rate Source (TL)`

`Pressure Source (TL)`

`Controlled Pressure Source (TL)`

Mechanical Rotational Reference

Reference connection for mechanical rotational ports

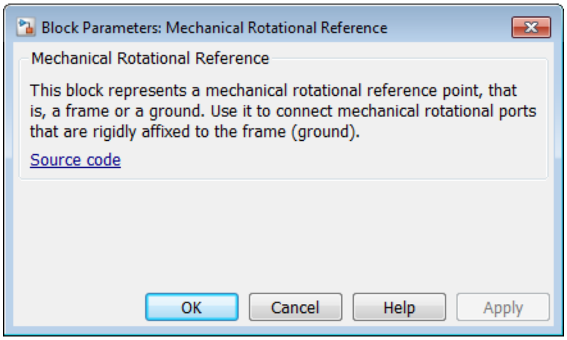
Library

Mechanical Rotational Elements

Description

The `Mechanical Rotational Reference` block represents a reference point, or frame, for all mechanical rotational ports. All rotational ports that are rigidly clamped to the frame (ground) must be connected to a Mechanical Rotational Reference block.

Dialog Box and Parameters



Block Parameters: Mechanical Rotational Reference

Mechanical Rotational Reference

This block represents a mechanical rotational reference point, that is, a frame or a ground. Use it to connect mechanical rotational ports that are rigidly affixed to the frame (ground).

Source code

The `Mechanical Rotational Reference` block has no parameters.

Ports

The block has one mechanical rotational port.

See Also

`Mechanical Translational Reference`

More About

- "Grounding Rules"

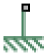
Mechanical Translational Reference

Reference connection for mechanical translational ports

Library

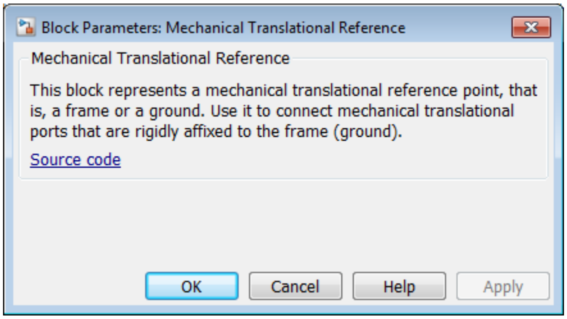
Mechanical Translational Elements

Description



The `Mechanical Translational Reference` block represents a reference point, or frame, for all mechanical translational ports. All translational ports that are rigidly clamped to the frame (ground) must be connected to a `Mechanical Translational Reference` block.

Dialog Box and Parameters



Block Parameters: Mechanical Translational Reference

Mechanical Translational Reference

This block represents a mechanical translational reference point, that is, a frame or a ground. Use it to connect mechanical translational ports that are rigidly affixed to the frame (ground).

Source code

The `Mechanical Translational Reference` block has no parameters.

Ports

The block has one mechanical translational port.

See Also

`Mechanical Rotational Reference`

More About

- "Grounding Rules"

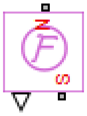
MMF Sensor

Ideal magnetomotive force sensor

Library

Magnetic Sensors

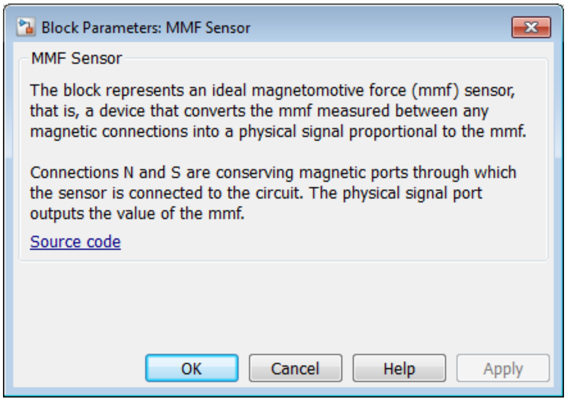
Description



The `MMF Sensor` block represents an ideal magnetomotive force (mmf) sensor, that is, a device that converts the mmf measured between any magnetic connections into a physical signal proportional to the mmf.

Connections N and S are conserving magnetic ports through which the sensor is connected to the circuit. The physical signal port outputs the value of the mmf.

Dialog Box and Parameters



Block Parameters: MMF Sensor

MMF Sensor

The block represents an ideal magnetomotive force (mmf) sensor, that is, a device that converts the mmf measured between any magnetic connections into a physical signal proportional to the mmf.

Connections N and S are conserving magnetic ports through which the sensor is connected to the circuit. The physical signal port outputs the value of the mmf.

Source code

The block has no parameters.

Ports

The block has the following ports:

`N`

Magnetic conserving port associated with the sensor North terminal.

`S`

Magnetic conserving port associated with the sensor South terminal.

The block also has a physical signal output port, which outputs the value of the mmf.

See Also

`Controlled MMF Source` | `MMF Source` | `PS-Simulink Converter`

More About

- "Connecting Simscape Diagrams to Simulink Sources and Scopes"

MMF Source

Ideal magnetomotive force source

Library

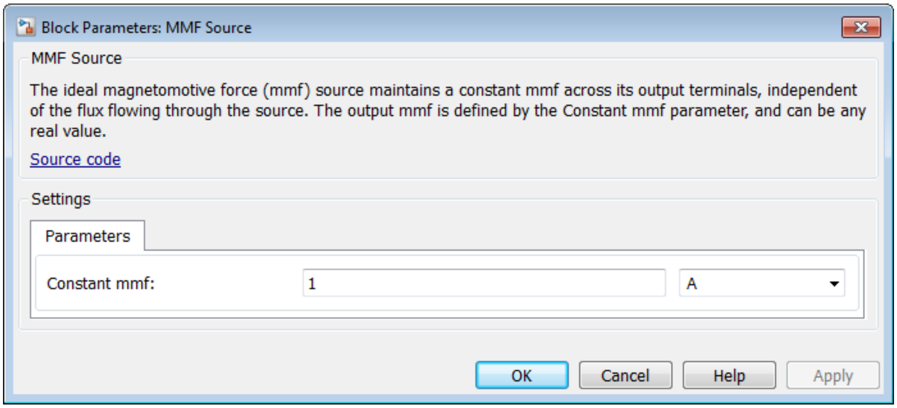
Magnetic Sources

Description

The `MMF Source` block represents an ideal magnetomotive force (mmf) source that is powerful enough to maintain specified constant mmf across its output terminals, regardless of the flux flowing through the source.

You specify the output mmf by using the **Constant mmf** parameter, which can be positive, negative, or zero.

Dialog Box and Parameters



Block Parameters: MMF Source

MMF Source

The ideal magnetomotive force (mmf) source maintains a constant mmf across its output terminals, independent of the flux flowing through the source. The output mmf is defined by the Constant mmf parameter, and can be any real value.

Source code

Settings

Parameters

Constant mmf: 1 A

Constant mmf

Output mmf. You can specify any real value. The default value is 1 A.

Ports

The block has two magnetic conserving ports associated with its terminals.

See Also

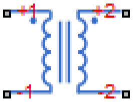
`Controlled Flux Source`

Mutual Inductor

Mutual inductor in electrical systems

Library

Electrical Elements



Description

The `Mutual Inductor` block models a mutual inductor, described with the following equations:

$$V1 = L1\frac{dI1}{dt} + M\frac{dI2}{dt}$$

$$V2 = L2\frac{dI2}{dt} + M\frac{dI1}{dt}$$

$$M = k\sqrt{L1 \bullet L2}$$

where

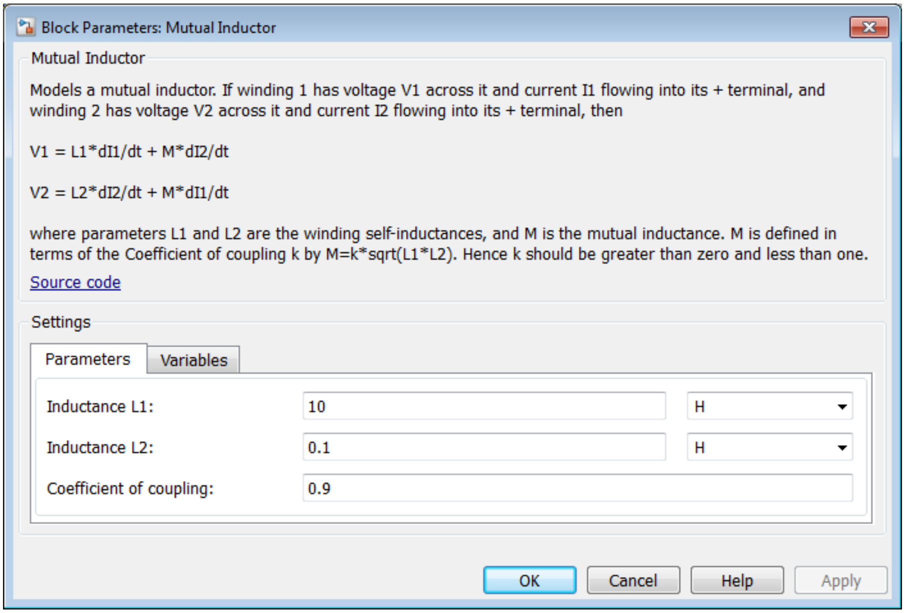
V1	Voltage across winding 1
V2	Voltage across winding 2
I1	Current flowing into the + terminal of winding 1
I2	Current flowing into the + terminal of winding 2
L1, *L2*	Winding self-inductances
M	Mutual inductance

k	Coefficient of coupling, 0 < *k* < 1
t	Time

This block can be used to represent an AC transformer. If inductance and mutual inductance terms are not important in a model, or are unknown, you can use the Ideal Transformer block instead.

The two electrical networks connected to the primary and secondary windings must each have their own `Electrical Reference` block.

Dialog Box and Parameters



Models a mutual inductor. If winding 1 has voltage V1 across it and current I1 flowing into its + terminal, and winding 2 has voltage V2 across it and current I2 flowing into its + terminal, then

V1 = L1*dI1/dt + M*dI2/dt

V2 = L2*dI2/dt + M*dI1/dt

where parameters L1 and L2 are the winding self-inductances, and M is the mutual inductance. M is defined in terms of the Coefficient of coupling k by M=k*sqrt(L1*L2). Hence k should be greater than zero and less than one.

Inductance L1: 10 H

Inductance L2: 0.1 H

Coefficient of coupling: 0.9

- “Parameters Tab” on page 1-276
- “Variables Tab” on page 1-277

Parameters Tab

Inductance L1

Self-inductance of the first winding. The default value is `10` H.

Inductance L2

Self-inductance of the second winding. The default value is `0.1` H.

Coefficient of coupling

Coefficient of coupling, which defines the mutual inductance. The parameter value should be greater than zero and less than 1. The default value is `0.9`.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has four electrical conserving ports. Polarity is indicated by the + and – signs. Ports labeled +1 and –1 are connected to the primary winding. Ports labeled +2 and –2 are connected to the secondary winding.

See Also

`Ideal Transformer`

Op-Amp

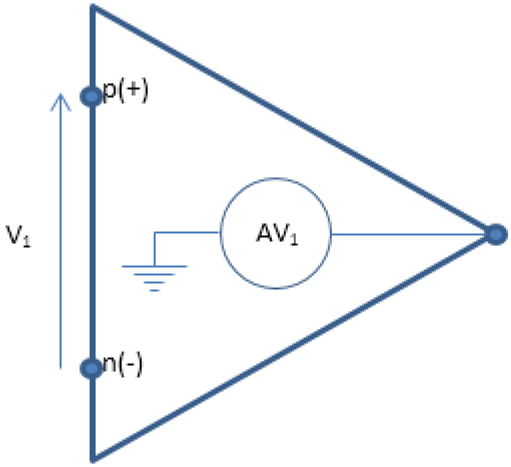
Ideal operational amplifier

Library

Electrical Elements

Description

The `Op-Amp` block models an ideal operational amplifier (op-amp). The figure shows the implementation schematic.



The block implementation is based on the following assumptions:

- The ideal op-amp gain *A* is assumed to be infinite
- Then, for finite output, must have *V1* = 0

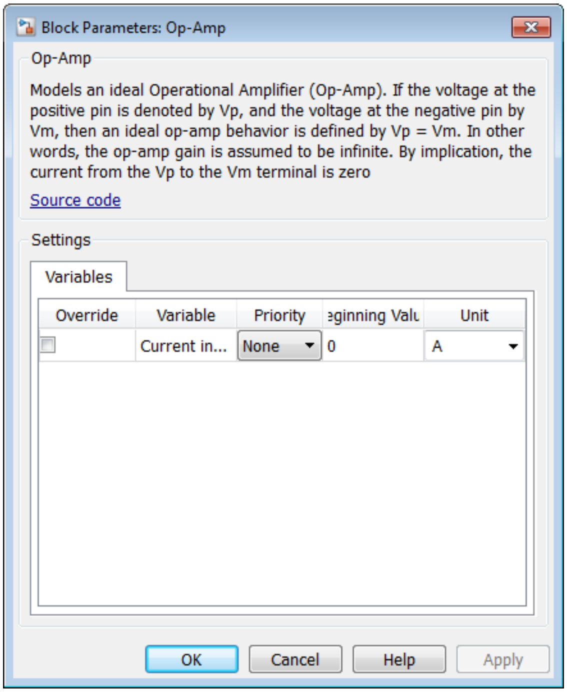
- Ideal op-amp also implies current from p to n is zero (*i1* = 0)

These assumptions result in the following equations for the block:

```
equations
    v1 == p.v - n.v;
    v1 == 0;
    i1 == 0;
end
```

For more information, click the **Source code** link in the block dialog box.

Dialog Box and Parameters



Op-Amp

Models an ideal Operational Amplifier (Op-Amp). If the voltage at the positive pin is denoted by Vp, and the voltage at the negative pin by Vm, then an ideal op-amp behavior is defined by Vp = Vm. In other words, the op-amp gain is assumed to be infinite. By implication, the current from the Vp to the Vm terminal is zero

Source code

Settings

Variables

Override	Variable	Priority	≥ginning Valu	Unit
□	Current in...	None	0	A

The `Op-Amp` block has no parameters.

You can initialize the **Current into output node** variable prior to simulation. For more information, see “About Variable Initialization”.

Ports

The block has three electrical conserving ports.

Open Circuit

Electrical port terminator that draws no current

Library

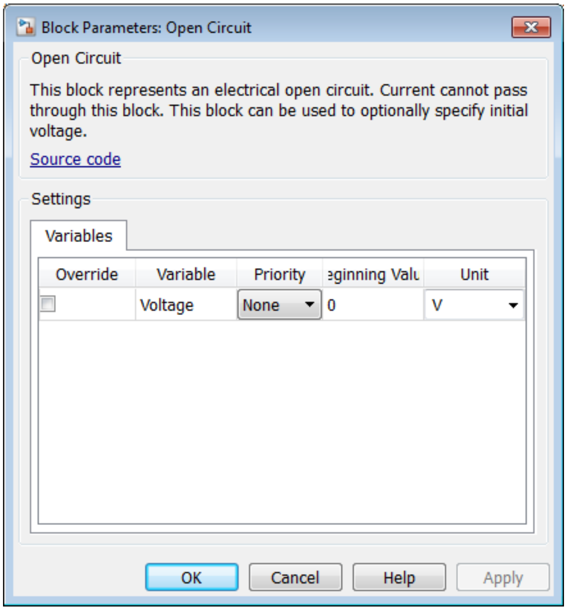
Electrical Elements

Description

The `Open Circuit` block represents an electrical terminal that draws no current. Physical network block diagrams do not allow unconnected conserving ports. Use this block to terminate electrical ports on other blocks that you want to leave open circuit.

You can also use this block to set the initial absolute voltage at a node.

Dialog Box and Parameters



Block Parameters: Open Circuit

Open Circuit

This block represents an electrical open circuit. Current cannot pass through this block. This block can be used to optionally specify initial voltage.

Source code

Settings

Variables

Override	Variable	Priority	eginning Valu	Unit
□	Voltage	None	0	V

The `Open Circuit` block has no parameters.

The **Variables** tab lets you set the priority and initial target value for the **Voltage** variable prior to simulation. For more information, see "Set Priority and Initial Target for Block Variables".

Ports

The block has one electrical conserving port.

See Also

`Adiabatic Cup` | `Cap (TL)` | `Hydraulic Cap` | `Perfect Insulator` | `Rotational Free End` | `Translational Free End`

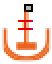
Perfect Insulator

Thermal element with perfect insulation and no thermal mass

Library

Thermal Elements

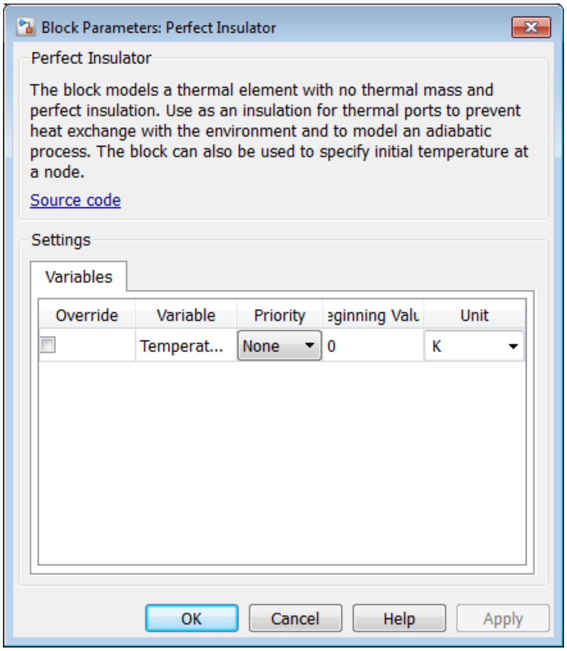
Description



The `Perfect Insulator` block models a thermal element with perfect insulation and no thermal mass. Physical network block diagrams do not allow unconnected conserving ports. Use this block as an insulation for thermal ports to prevent heat exchange with the environment and to model an adiabatic process.

You can also use this block to set the initial temperature at a node.

Dialog Box and Parameters



Block Parameters: Perfect Insulator

Perfect Insulator

The block models a thermal element with no thermal mass and perfect insulation. Use as an insulation for thermal ports to prevent heat exchange with the environment and to model an adiabatic process. The block can also be used to specify initial temperature at a node.

Source code

Settings

Variables

Override	Variable	Priority	eginning Valu	Unit
□	Temperat...	None	0	K

The `Perfect Insulator` block has no parameters.

The **Variables** tab lets you set the priority and initial target value for the **Temperature** variable prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has one thermal conserving port.

See Also

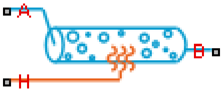
`Adiabatic Cup` | `Cap (TL)` | `Hydraulic Cap` | `Open Circuit` | `Rotational Free End` | `Translational Free End`

Pipe (2P)

Rigid conduit for fluid flow in two-phase fluid systems

Library

Two-Phase Fluid/Elements



Description

The `Pipe (2P)` block models the flow dynamics of a two-phase fluid inside a rigid pipe. The dynamic compressibility and thermal capacity of the fluid are assumed non-negligible.

Two-phase fluid conserving ports A and B represent the pipe inlet and outlet, through which fluid enters and exits the pipe. Thermal conserving port H represents the pipe wall, through which heat transfer with the pipe surroundings occurs.

Fluid Inertia

The block provides an option to model fluid inertia, the resistance to sudden changes in mass flow rate. By default, fluid inertia modeling is turned off. This setting is appropriate when the pressure forces driving the flow far exceed the inertial forces acting on the flow.

The default setting reduces computational costs and is recommended for most models. However, fluid inertia can become important if the mass flow rate changes rapidly. In such cases, turning fluid inertia modeling on can help improve simulation accuracy.

Energy Balance

Energy can flow into the pipe through ports A and B. Heat can flow into the pipe through port H. The energy conservation equation in the pipe volume is

$$\dot{E} = \phi_A + \phi_B + \phi_H,$$

where:

- E is the total energy of the fluid in the pipe.
- ϕ_A is the energy flow rate into the pipe through port A.
- ϕ_B is the energy flow rate into the pipe through port B.
- ϕ_H is the heat flow rate into the pipe through port H.

The total energy of the fluid is the sum of internal and kinetic energy terms:

$$E = M\left(u_I + \frac{1}{2}\left[\frac{\dot{m}_I L}{M}\right]^2\right),$$

where:

- M is the total mass of the fluid in the pipe.
- u_I is the specific internal energy of the fluid in the pipe.
- $\dot{m}_I$ is the average of the mass flow rates into the pipe through ports A and B.
- L is the pipe length.

Mass Balance

Mass can flow into the pipe through ports A and B. The mass conservation equation in the pipe is then

$$\dot{M} = \dot{m}_A + \dot{m}_B,$$

where:

- $\dot{m}_A$ is the mass flow rate into the pipe through port A.
- $\dot{m}_B$ is the mass flow rate into the pipe through port B.

A net mass flow rate into the pipe implies a time-varying mass density, due to changes in pressure or specific internal energy. The mass rate of change in the pipe is then

$$\dot{M} = \left[\left(\frac{\partial \rho}{\partial p} \right)_u \dot{p}_I + \left(\frac{\partial \rho}{\partial u} \right)_p \dot{u}_I \right] V,$$

where:

- $\left(\frac{\partial \rho}{\partial p} \right)_u$ is the partial derivative of density with respect to pressure at constant specific internal energy.
- $\left(\frac{\partial \rho}{\partial u} \right)_p$ is the partial derivative of density with respect to specific internal energy at constant pressure.
- p_I is the fluid pressure in the pipe.
- V is the fluid volume in the pipe.

The block blends the density partial derivatives of the various domains using a cubic polynomial function. At a vapor quality of 0--0.1, this function blends the derivatives of the subcooled liquid and two-phase mixture domains. At a vapor quality of 0.9--1, it blends those of the two-phase mixture and superheated vapor domains.

The smoothed density partial derivatives introduce into the original mass conservation equation numerical errors. To correct for these errors, the block adds the correction term

$${}_{M} = \frac{M - V / v_I}{\tau},$$

where:

- ϵ_M is the correction term.
- v_I is the specific volume of the fluid in the pipe.
- τ is the phase-change time constant—the characteristic duration of a phase-change event. This constant ensures that phase changes do not occur instantaneously, effectively introducing a time lag whenever they occur.

The final form of the mass conservation equation is

$$\dot{M} = \left[\left(\frac{\partial \rho}{\partial p} \right)_u \dot{p}_I + \left(\frac{\partial \rho}{\partial u} \right)_p \dot{u}_I \right] V = \dot{m}_A + \dot{m}_B + {}_{M} .$$

Momentum Balance

The momentum balance in the pipe depends on the fluid inertia setting. If the **Fluid inertia** parameter is set to `Off`, the momentum conservation equation in the half pipe adjacent to port A is

$$\left(p_A - p_I \right) S = F_{visc,A} + \dot{m}_A \Delta v_{BI},$$

while in the half pipe adjacent to port B it is

$$\left(p_B - p_I \right) S = F_{visc,B} + \dot{m}_B \Delta v_{BI} .$$

In the equations:

- p_A is the pressure at port A.
- p_B is the pressure at port B.
- S is the cross-sectional area of the pipe.
- $F_{visc, A}$ is the viscous friction force in the half pipe adjacent to port A.
- $F_{visc, B}$ is the viscous friction force in the half pipe adjacent to port B.
- Δv_{AI} is the flow velocity change in the half pipe adjacent to port A:

$$\Delta v_{AI} = \begin{cases} \dfrac{\dot{m}_A}{S} \max\left(v_I - v_A, 0 \right), & \dot{m}_A \geq 0 \\ \dfrac{\dot{m}_A}{S} \max\left(v_I - v_A, 0 \right), & \dot{m}_A < 0 \end{cases}$$

- Δv_{BI} is the flow velocity change in the half pipe adjacent to port B:

$$\Delta v_{BI} = \begin{cases} \dfrac{\dot{m}_B}{S} \max\left(v_I - v_B, 0 \right), & \dot{m}_B \geq 0 \\ \dfrac{\dot{m}_B}{S} \max\left(v_I - v_B, 0 \right), & \dot{m}_B < 0 \end{cases}$$

If the **Fluid inertia** parameter is set to `On`, the momentum conservation equation in the half pipe adjacent to port A becomes

$$\left(p_A - p_I\right)S = F_{visc,A} + \dot{m}_A \Delta v_{AI} + I_A,$$

while in the half pipe adjacent to port B it becomes

$$\left(p_B - p_I\right)S = F_{visc,B} + \dot{m}_B \Delta v_{BI} + I_B.$$

In the equations:

- I_A is the fluid inertia at port A, defined as

  $$I_A = \ddot{m}_A \frac{L}{2}.$$

- I_B is the fluid inertia at port B, defined as

  $$I_B = \ddot{m}_B \frac{L}{2}.$$

Viscous Friction in Laminar Flows

The viscous friction force depends on the flow regime. In the laminar regime—that is, when the Reynolds number is smaller than the **Laminar flow upper Reynolds number limit** value specified in the block dialog box—the viscous friction force in the half pipe adjacent to port A is

$$F_{visc,A}^{laminar} = \frac{f_{shape} L_{eff} \nu_A \dot{m}_A}{4 D_h^2},$$

while in the half pipe adjacent to port B it is

$$F_{visc,B}^{laminar} = \frac{f_{shape} L_{eff} \nu_B \dot{m}_B}{4 D_h^2}.$$

In the equations:

- f_{shape} is the pipe shape factor.
- L_{eff} is the effective pipe length—the sum of the pipe length and the aggregate equivalent length of local resistances.
- ν_{A} is the kinematic viscosity in the half pipe adjacent to port A.
- ν_{B} is the kinematic viscosity in the half pipe adjacent to port B.
- D_{h} is the hydraulic diameter of the pipe.

Viscous Friction in Turbulent Flows

In the turbulent regime—that is, when the Reynolds number is greater than the **Turbulent flow lower Reynolds number limit** value specified in the block dialog box —the viscous friction force in the half pipe adjacent to port A is

$$F_{visc,A}^{turbulent} = \frac{\dot{m}_A \left|\dot{m}_A\right|}{S}\left(\frac{v_A + v_I}{2}\right)\left(\frac{f_A L_{eff}}{4D_h}\right),$$

while in the half pipe adjacent to port B it is

$$F_{visc,B}^{turbulent} = \frac{\dot{m}_B \left|\dot{m}_B\right|}{S}\left(\frac{v_B + v_I}{2}\right)\left(\frac{f_B L_{eff}}{4D_h}\right).$$

In the equations:

- v_{A} is the specific volume at port A.
- v_{B} is the specific volume at port B.
- f_{A} is the Darcy friction factor for turbulent flow in the half pipe adjacent to port A.
- f_{B} is the Darcy friction factor for turbulent flow in the half pipe adjacent to port B.

The Darcy friction factor for turbulent flow in the half pipe adjacent to port A follows from the Haaland equation as

$$f_A = \frac{1}{\left\{-1.8\log_{10}\left[\frac{6.9}{Re_A} + \left(\frac{r}{3.7}\right)^{1.11}\right]\right\}^2},$$

and in the half pipe adjacent to port B as

$$f_B = \frac{1}{\left\{-1.8\log_{10}\left[\frac{6.9}{Re_B} + \left(\frac{r}{3.7}\right)^{1.11}\right]\right\}^2}.$$

In the equations:

- $\in_{\mathrm{r}}$ is the relative roughness of the pipe.
- Re_{A} is the Reynolds number in the half pipe adjacent to port A,

$$Re_A = \frac{\dot{m}_A D_h v_A}{S \nu_A}.$$

- Re_{B} is the Reynolds number in the half pipe adjacent to port B,

$$Re_B = \frac{\dot{m}_B D_h v_B}{S \nu_B}.$$

Heat Transfer Coefficient

Heat flow through port H occurs by convection. The heat flow rate is

$$\phi_H = \frac{h_A^{coef} + h_B^{coef} S_{surf}}{2}\left(T_H - T_I\right),$$

where:

- $h_{\mathrm{A}}^{\mathrm{coef}}$ is the heat transfer coefficient for the half pipe adjacent to port A.
- $h_{\mathrm{B}}^{\mathrm{coef}}$ is the heat transfer coefficient for the half pipe adjacent to port B.
- S_{Surf} is the pipe surface area.
- T_{H} is the pipe wall temperature.
- T_{I} is the temperature of the fluid in the pipe.

The heat transfer coefficient in the half pipe adjacent to port A is

$$h_A^{coef} = \frac{Nu_A k_A}{D_h},$$

while the heat transfer coefficient in the half pipe adjacent to port B is

$$h_B^{coef} = \frac{Nu_B k_B}{D_h},$$

where:

- Nu_A is the Nusselt number in the half pipe adjacent to port A.
- Nu_B is the Nusselt number in the half pipe adjacent to port B.
- k_A is the thermal conductivity of the fluid at port A.
- k_B is the thermal conductivity of the fluid at port B.

In laminar flows, the Nusselt number is assumed constant and equal to the value specified in the block dialog box. The laminar flow Nusselt number applies when the Reynolds number is smaller than the value entered for the **Laminar flow upper Reynolds number limit** parameter.

The turbulent flow Nusselt number applies when the Reynolds number is greater than the value entered for the **Laminar flow upper Reynolds number limit**parameter. In the transitional region between laminar and turbulent flow, a cubic polynomial function blends the two Nusselt numbers. This blending ensures a smooth transition between flow regimes.

In turbulent flows, the Nusselt number in the half pipe adjacent to port A is

$$Nu_A^{turbulent} = \frac{\frac{f_A}{8}\left(Re_A - 1000\right)Pr_A}{1 + 12.7\sqrt{\frac{f_A}{8}}\left(Pr_A^{2/3} - 1\right)},$$

while in the half pipe adjacent to port B it is

$$Nu_B^{turbulent} = \frac{\frac{f_A}{8}\left(Re_B - 1000\right)Pr_B}{1 + 12.7\sqrt{\frac{f_B}{8}}\left(Pr_B^{2/3} - 1\right)},$$

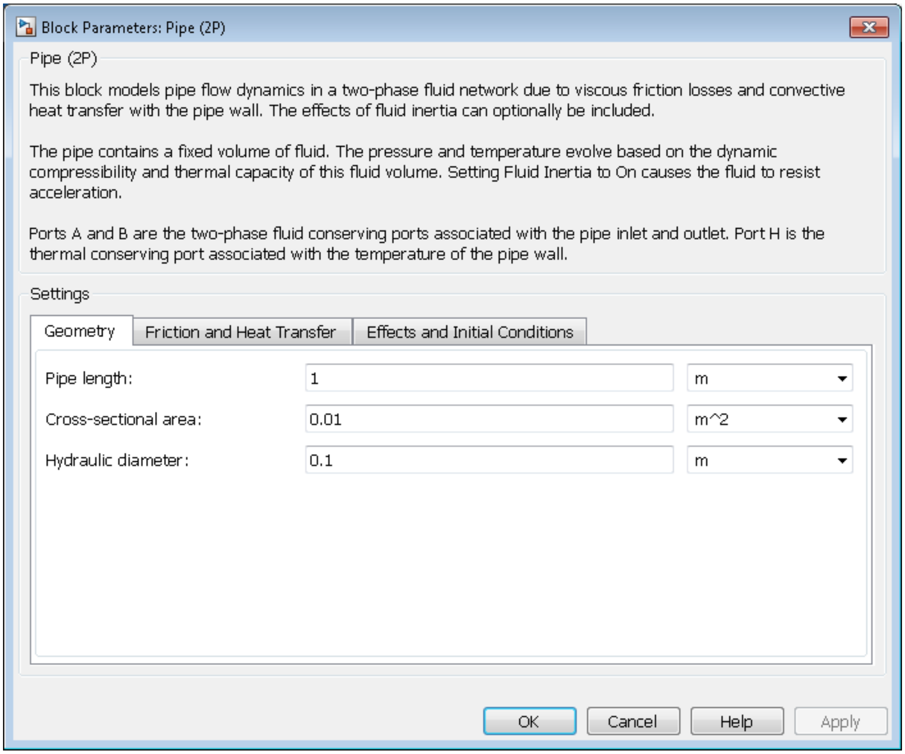
In the equations:

- Pr_A is the Prandtl number in the half pipe adjacent to port A.
- Pr_B is the Prandtl number in the half pipe adjacent to port B.

Assumptions and Limitations

- The pipe wall is rigid.
- The flow is fully developed.
- The effect of gravity is negligible.

Dialog Box and Parameters



Block Parameters: Pipe (2P)

Pipe (2P)

This block models pipe flow dynamics in a two-phase fluid network due to viscous friction losses and convective heat transfer with the pipe wall. The effects of fluid inertia can optionally be included.

The pipe contains a fixed volume of fluid. The pressure and temperature evolve based on the dynamic compressibility and thermal capacity of this fluid volume. Setting Fluid Inertia to On causes the fluid to resist acceleration.

Ports A and B are the two-phase fluid conserving ports associated with the pipe inlet and outlet. Port H is the thermal conserving port associated with the temperature of the pipe wall.

Settings

Geometry | Friction and Heat Transfer | Effects and Initial Conditions

Pipe length:	1	m
Cross-sectional area:	0.01	m^2
Hydraulic diameter:	0.1	m

Geometry Tab

Pipe length

Distance between the pipe inlet and outlet. The default value is `0.1` m.

Cross-sectional area

Internal pipe area normal to the direction of flow. This area is constant along the length of the pipe. The default value is `0.01` m^2.

Hydraulic diameter

Diameter of an equivalent pipe with a circular cross section. In a cylindrical pipe, the hydraulic diameter is the same as its actual diameter. The default value is `0.1` m.

Friction and Heat Transfer Tab

Aggregate equivalent length of local resistances

Pressure loss due to local resistances such as bends, inlets, and fittings, expressed as the equivalent length of these resistances. The default value is `0.1` m.

Internal surface absolute roughness

Average height of all surface defects on the internal surface of the pipe. This parameter enables the calculation of the friction factor in the turbulent flow regime. The default value is `1.5e-5`m.

Laminar flow upper Reynolds number limit

Largest value of the Reynolds number corresponding to fully developed laminar flow. As the Reynolds number rises above this limit, the flow gradually transitions from laminar to turbulent. The default value is `2000`.

Turbulent flow lower Reynolds number limit

Smallest value of the Reynolds number corresponding to fully developed turbulent flow. As the Reynolds number falls below this limit, flow gradually transitions from turbulent to laminar. The default value is `4000`.

Shape factor for laminar flow viscous friction

Semi-empirical parameter encoding the effect of pipe geometry on the viscous friction losses incurred in the laminar regime. The appropriate value to use depends on the cross-sectional shape of the pipe.

Typical values include `56` for a square cross section, `62` for a rectangular cross section, and `96` for a concentric annulus cross section [1]. The default value, corresponding to a circular cross section, is `64`.

Nusselt number for laminar flow heat transfer

Proportionality constant between convective and conductive heat transfer in the laminar regime. This parameter enables the calculation of convective heat transfer in laminar flows. Its value changes with the pipe cross-sectional area and thermal boundary conditions, e.g., constant temperature or constant heat flux at the pipe wall. The default value, corresponding to a circular pipe cross section, is `3.66`.

Effects and Initial Conditions Tab

Fluid inertia

Option to model fluid inertia, the resistance of the fluid to rapid acceleration. The default is `Off`.

Initial fluid regime

Fluid regime at the start of simulation. The fluid can be a subcooled liquid, a two-phase mixture, or a superheated vapor. The default setting is `Subcooled liquid`.

Initial fluid pressure

Pressure in the pipe at the start of simulation. The default value is `0.101325` MPa.

Initial fluid temperature

Temperature in the pipe at the start of simulation. This parameter appears only when **Initial fluid regime** is set to `Subcooled liquid` or `Superheated vapor`. The default value is `293.15` K.

Phase change time constant

Characteristic duration of a phase-change event. This constant introduces a time lag into the transition between phases. The default value is `0.1` s.

Ports

The block has two two-phase fluid conserving ports, A and B. Port H is a thermal conserving port representing the pipe wall through which heat exchange occurs.

References

[1] White, F.M., *Viscous Fluid Flow*, McGraw-Hill, 1991

See Also

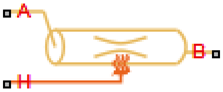
`Local Restriction (2P)` | `Variable Local Restriction (2P)`

Pipe (TL)

Rigid conduit for fluid flow in thermal liquid systems

Library

Thermal Liquid/Elements



Description

The `Pipe (TL)` block represents a pipeline segment with a fixed volume of liquid. The liquid experiences pressure losses and heating due to viscous friction and conductive heat transfer through the pipe wall. Viscous friction follows from the Darcy-Weisbach law, while the heat exchange coefficient follows from Nusselt number correlations. Heat transfer can occur in an unsteady manner.

Pipe Effects

The block includes parameters to account for the dynamic compressibility and inertia of liquid in a pipe. However, by default the block treats liquid flow through the pipe as steady and liquid mass within the pipe as constant. In this mode, the momentum and mass equations of this block are in their steady states. The liquid behaves as if it were incompressible. Pressure waves due to liquid inertia are absent in the pipe.

Depending on the effects you include, the block can function in three configurations: resistive tube, resistive tube with dynamic compressibility, and pipeline segment. The table summarizes the effects present in each configuration.

Configuration	Dynamic Compressibility	Flow Inertia	Thermal Dynamics
Resistive tube	Off	Off	On

Configuration	Dynamic Compressibility	Flow Inertia	Thermal Dynamics
Resistive tube with dynamic compressibility	On	Off	On
Pipeline segment	On	On	On

The configuration to use depends on the relevant effects the model must capture. The pipeline segment configuration provides the greatest accuracy. However, this configuration also increases model complexity, raising the simulation computational cost and challenging the convergence to a numerical solution in rapid transient processes. As the simplest in the list, the resistive tube configuration provides a good starting point in a model. This is the default configuration of the block.

To view the source code for the various block configurations, first navigate to the folder with the configuration source files—for example, by entering this code at the MATLAB command prompt:

```
filePath = fullfile(matlabroot, 'toolbox', 'physmod', 'simscape', 'library',...
'm', '+foundation', '+thermal_liquid', '+elements');
cd(filePath);
```

Then, open the appropriate configuration file. This file can be one of the following:

- pipe_resistive.ssc
- pipe_resistive_compressibility.ssc
- pipe_resistive_compressibility_inertia.ssc

For example, to open the source file for the resistive tube configuration, at the MATLAB command prompt enter:

```
fileName = 'pipe_resistive.ssc';
open(fileName);
```

Use the Pipe block in the resistive tube configuration when:

- Thermal dynamic effects are important but flow dynamic effects, which have a smaller time scale, are not.
- Liquid mass in the pipe is a negligible fraction of the total liquid mass in the system.

The resistive tube configuration is the recommended starting point for this block, even if fluid dynamic compressibility and flow inertia are important in your model. The simulation results using this configuration provides reasonable initial conditions for more advanced configurations in which fluid dynamic compressibility and flow inertia are important—e.g. resistive tube with dynamic compressibility and pipeline segment configurations.

Use this block in the resistive tube with dynamic compressibility configuration when:

- Thermal dynamic effects are important but flow dynamic effects, which have a smaller time scale, are not.
- Liquid mass in the pipe is not negligible with respect to the total liquid mass in the system

Use this block in the pipeline segment configuration when the characteristic time of the thermal liquid system is close to the liquid compressibility time scale:

$$\tau = \frac{L}{a},$$

where:

- τ is the characteristic time of the thermal liquid system
- L is the characteristic pipe length
- a is the speed of sound in the liquid.

Mass Balance

The mass conservation equation for the pipe is

$$\dot{m}_{\mathrm{A}} + \dot{m}_{\mathrm{B}} = \begin{cases} 0, & \text{if fluid dynamic compressibility is 'off'} \\ V\rho\left(\dfrac{1}{\beta}\dfrac{dp}{dt} + \alpha\dfrac{dT}{dt}\right), & \text{if fluid dynamic compressibility is 'on'} \end{cases}$$

where:

- $\dot{m}_{\mathrm{A}}$ and $\dot{m}_{\mathrm{B}}$ are the mass flow rates through ports A and B.
- V is the pipe fluid volume.
- ρ is the thermal liquid density in the pipe.

- β is the isothermal bulk modulus in the pipe.
- α is the isobaric thermal expansion coefficient in the pipe.
- p is the thermal liquid pressure in the pipe.
- T is the thermal liquid temperature in the pipe.

Momentum Balance

The momentum conservation equation for the half pipe adjacent to port A is

$$A\left(p_A - p\right) + F_{\mathrm{v,A}} = \begin{cases} 0, & \text{if flowinertia is'off'} \\ \dfrac{L}{2}\ddot{m}_{\mathrm{A}}, & \text{if flow inertia is'on'} \end{cases}$$

while for the half pipe adjacent to port B it is

$$A\left(p_B - p\right) + F_{\mathrm{v,B}} = \begin{cases} 0, & \text{if flow inertia is'off'} \\ \dfrac{L}{2}\ddot{m}_{\mathrm{B}}, & \text{if flow inertia is'on'} \end{cases}$$

In the equations:

- A is the pipe cross-sectional area.
- p, p_{A}, and p_{B} are the liquid pressures in the pipe, at port A, and port B.
- $F_{\mathrm{v,A}}$ and $F_{\mathrm{v,B}}$ are the viscous dissipation forces between the pipe volume center and ports A and B.

Viscous Friction Forces

The viscous friction force for the half pipe adjacent to port A is

$$F_{\mathrm{v,A}} = \begin{cases} -\lambda\, \nu_{\mathrm{A,u}} \left(\dfrac{L + L_{\mathrm{Eq}}}{2}\right) \dfrac{\dot{m}_{\mathrm{A}}}{2D^2}, & \text{if } \mathrm{Re}_{\mathrm{A}} < \mathrm{Re}_{\mathrm{l}} \\ -f_{\mathrm{A}} \left(\dfrac{L + L_{\mathrm{Eq}}}{2}\right) \dfrac{\dot{m}_{\mathrm{A}} \left|\dot{m}_{\mathrm{A}}\right|}{2\rho_{\mathrm{A,u}} D A}, & \text{if } \mathrm{Re}_{\mathrm{A}} \geq \mathrm{Re}_{\mathrm{t}} \end{cases}$$

while for the half pipe adjacent to port B it is

$$F_{\mathrm{v,B}} = \begin{cases} -\lambda v_{\mathrm{B,u}} \left(\dfrac{L + L_{\mathrm{Eq}}}{2} \right) \dfrac{\dot{m}_{\mathrm{B}}}{2D^2}, & \text{if } \mathrm{Re}_{\mathrm{B}} < \mathrm{Re}_{\mathrm{l}} \\ -f_{\mathrm{B}} \left(\dfrac{L + L_{\mathrm{Eq}}}{2} \right) \dfrac{\dot{m}_{\mathrm{B}} \left| \dot{m}_{\mathrm{B}} \right|}{2\rho_{\mathrm{B,u}} D A}, & \text{if } \mathrm{Re}_{\mathrm{B}} \geq \mathrm{Re}_{\mathrm{t}} \end{cases}$$

In the equations:

- $\rho_{\mathrm{A,u}}$ and $\rho_{\mathrm{B,u}}$ are the upwind liquid densities at ports A and B.
- λ is the pipe shape factor.
- $v_{\mathrm{A,u}}$, $v_{\mathrm{B,u}}$ are the upwind dynamic viscosities at inlets A and B.
- L_{Eq} is the aggregate equivalent length of the local pipe resistances.
- D is the hydraulic diameter of the pipe.
- f_{A} and f_{B} are the Darcy friction factors in the pipe halves adjacent to inlets A and B.
- Re_{A} and Re_{B} are the Reynolds numbers at ports A and B.
- Re_{l} is the largest Reynolds number at which laminar flow can occur.
- Re_{t} is the smallest Reynolds number at which turbulent flow can occur.

The block smooths the transition between laminar and turbulent flow regimes ($\mathrm{Re}_{\mathrm{l}} < \mathrm{Re} < \mathrm{Re}_{\mathrm{t}}$) based on the Reynolds numbers

$$\mathrm{Re}_{\mathrm{A}} = \frac{D\dot{m}_{\mathrm{A}}}{A\mathrm{\mu}_{\mathrm{A,u}}},$$

and

$$\mathrm{Re}_{\mathrm{B}} = \frac{D\dot{m}_{\mathrm{B}}}{A\mu_{\mathrm{B,u}}},$$

where:

- $\mu_{\mathrm{A,u}}$ and $\mu_{\mathrm{B,u}}$ are the upwind dynamic viscosities at inlets A and B.

The Darcy friction factors follow from the Haaland approximation for the turbulent regime:

$$f = \frac{1}{\left[-1.8\log_{10}\left(\frac{6.9}{\mathrm{Re}} + \left(\frac{1}{3.7}\frac{r}{D}\right)^{1.11}\right)\right]^2},$$

where:

- f is the Darcy friction factor.
- r is the pipe surface roughness.

Energy Balance

The energy conservation equation for the pipe is

$$V\frac{d(\rho u)}{dt} = \phi_{\mathrm{A}} + \phi_{\mathrm{B}} + Q_H,$$

where:

- Φ_{A} and Φ_{B} are the total energy flow rates into the pipe through ports A and B.
- Q_{H} is the heat flow rate into the pipe through the pipe wall.

Wall Heat Flow Rate

The heat flow rate into the pipe through the pipe wall is

$$Q_H = h(T_{\mathrm{W}} - T)PL,$$

where:

- Q_{H} is the heat flow rate.
- h is the convective heat transfer coefficient.
- T, T_{W} are the liquid and pipe wall temperatures.
- P is the pipe cross-section perimeter, defined in terms of the hydraulic diameter:

$$P = \frac{4A}{D}.$$

The heat transfer coefficient follows from the definition of the Nusselt number:

$$\mathrm{Nu} = \frac{hD}{k},$$

where *Nu* is the Nusselt number and *k* is the thermal conductivity. For laminar flows, the Nusselt number is a constant that you specify based on the pipe geometry and thermal boundary conditions. A number of `3.66` is commonly used for circular pipes with constant wall temperature. For turbulent flows, the Nusselt number is computed from the Gnielinski equation:

$$Nu = \frac{(f/8)\left(\mathrm{Re}_D - 1000\right)\mathrm{Pr}}{1 + 12.7(f/8)^{1/2}\left(\mathrm{Pr}^{2/3} - 1\right)},$$

where f is the Darcy friction factor, *Re* the Reynolds number, and *Pr* the Prandtl number. The Prandtl number is computed from the fluid properties specified in the Thermal Liquid Settings (TL) block:

$$\mathrm{Pr} = \frac{c_p \mu}{k},$$

where:

- c_p is the specific heat
- μ is the dynamic viscosity
- k is the thermal conductivity

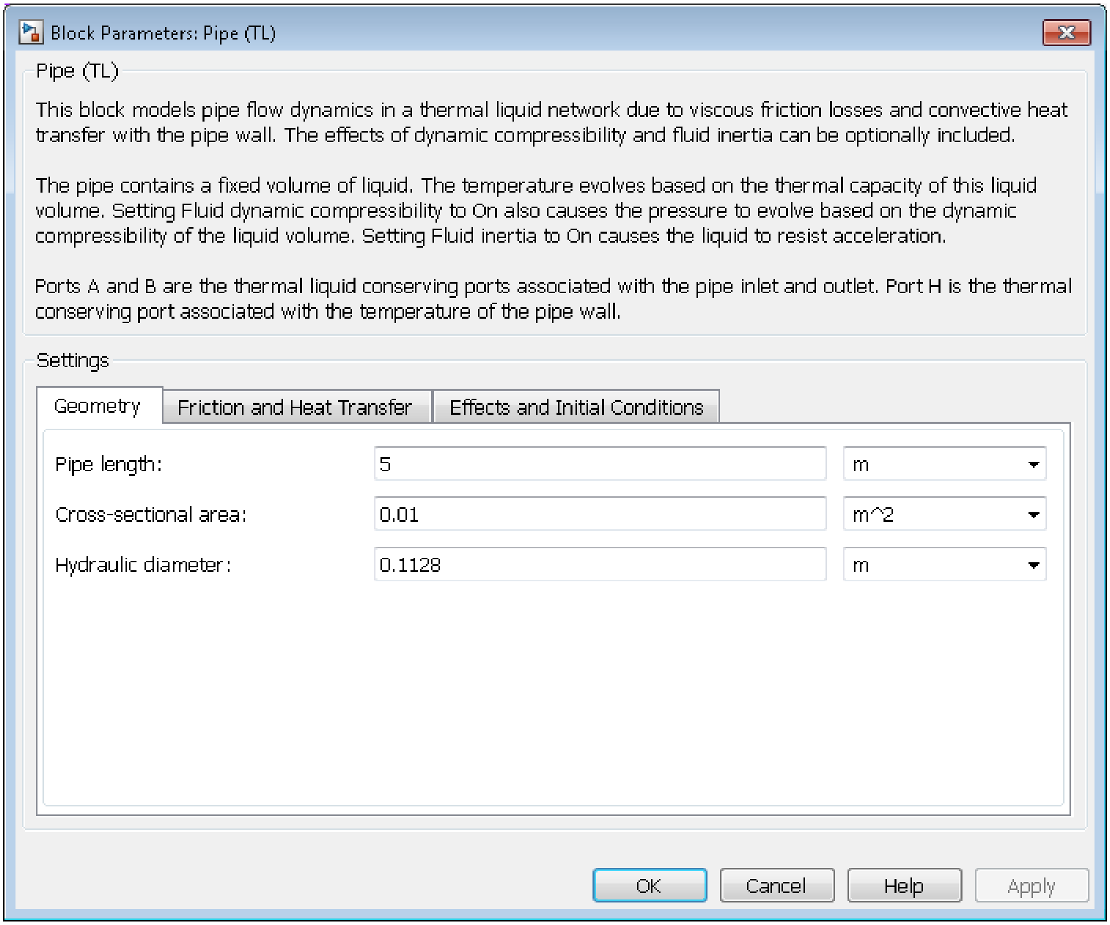
For the transitional region between laminar and turbulent flow regimes, the block computes the Nusselt number using the expression:

$$Nu = Nu_L + \left(Nu_T - Nu_L\right)\frac{Re - Re_L}{\mathrm{Re}_T - Re_L}.$$

Assumptions and Limitations

- The pipe wall is rigid.
- The flow is fully developed.
- The effect of gravity is negligible.

Dialog Box and Parameters



Block Parameters: Pipe (TL)

Pipe (TL)

This block models pipe flow dynamics in a thermal liquid network due to viscous friction losses and convective heat transfer with the pipe wall. The effects of dynamic compressibility and fluid inertia can be optionally included.

The pipe contains a fixed volume of liquid. The temperature evolves based on the thermal capacity of this liquid volume. Setting Fluid dynamic compressibility to On also causes the pressure to evolve based on the dynamic compressibility of the liquid volume. Setting Fluid inertia to On causes the liquid to resist acceleration.

Ports A and B are the thermal liquid conserving ports associated with the pipe inlet and outlet. Port H is the thermal conserving port associated with the temperature of the pipe wall.

Settings

Pipe length: 5 m

Cross-sectional area: 0.01 m^2

Hydraulic diameter: 0.1128 m

Geometry

Pipe length

Enter the longitudinal length of the pipe. This is the length of the pipe along the direction of flow. The default value is `5` m.

Cross-sectional area

Enter the cross-sectional area of the pipe. This is the area of the pipe normal to the direction of flow. The default value is `0.01` m^2.

Hydraulic diameter

Enter the hydraulic diameter of the pipe. This is the diameter of a cylindrical pipe with the same cross-sectional area. The default value is `0.1128` m.

Friction and Heat Transfer

Aggregate equivalent length of local resistances

Enter the combined length of all local resistances present in the pipe. Local resistances include bends, fittings, armatures, and pipe inlets and outlets. The effect of the local resistances is to increase the effective length of the pipe segment. The default value is `1` m.

Internal surface absolute roughness

Enter the absolute roughness of the internal surface of the pipe. This roughness equals the average height of surface defects inside the pipe. The block uses the absolute roughness to determine pressure losses in the turbulent flow regime. The default value is `1.5e-5` m, corresponding to drawn tubing.

Laminar flow upper Reynolds number limit

Enter the Reynolds number above which flow begins to transition from laminar to turbulent. This number equals the maximum Reynolds number corresponding to fully developed laminar flow. The default value is `2000`.

Turbulent flow lower Reynolds number limit

Enter the Reynolds number below which flow begins to transition from turbulent to laminar. This number equals to the minimum Reynolds number corresponding to fully developed turbulent flow. The default value is `4000`.

Shape factor for laminar flow viscous friction

Enter the shape factor of the pipe. This parameter encodes the effect of pipe geometry on the viscous friction losses incurred in the laminar regime. The appropriate value to use depends on the cross-sectional shape of the pipe.

Typical values include 56 for a square cross section, 62 for a rectangular cross section, and 96 for a concentric annulus cross section [1]. The default value, corresponding to a circular cross section, is 64.

Nusselt number for laminar flow heat transfer

Enter the Nusselt number for heat transfer in the laminar regime. The appropriate value to use depends on the pipe geometry and thermal boundary conditions. The default value is 3.66, corresponding to a circular pipe cross section and constant wall temperature.

Effects and Initial Conditions

Fluid dynamic compressibility

Select whether to account for the dynamic compressibility of the liquid. Dynamic compressibility gives the liquid density a dependence on pressure and temperature, impacting the transient response of the system at small time scales. Selecting On displays the additional parameter **Initial fluid pressure in the pipe**. The default setting is Off.

Fluid inertia

Select whether to account for the flow inertia of the liquid. Flow inertia gives the liquid a resistance to changes in mass flow rate. Selecting On displays the additional parameter **Initial mass flow rate oriented from A to B**. The default setting is Off.

Initial liquid temperature

Enter the liquid temperature in the pipe at time zero. The default value is 293.15 K.

Initial liquid pressure

Enter the liquid pressure in the pipe at time zero. This parameter appears only when **Fluid dynamic compressibility** is On. The default value is 1 atm.

Initial mass flow rate oriented from A to B

Enter the mass flow rate from port A to port B at time zero. This parameter is visible only when **Flow inertia** is On. The default value is 0.1 kg/s.

Ports

The block has two thermal liquid conserving ports, A and B, and one thermal conserving port, W.

References

[1] White, F.M., *Viscous Fluid Flow*, McGraw-Hill, 1991

See Also

`Local Restriction (TL)`

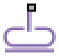
`Variable Local Restriction (TL)`

Pneumatic Absolute Reference

Reference connection to zero absolute pressure and temperature for pneumatic ports

Library

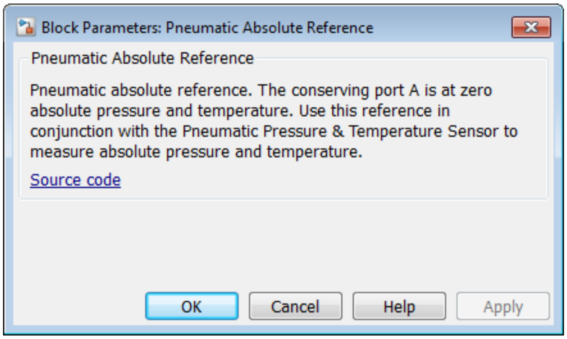
Pneumatic Elements



Description

The `Pneumatic Absolute Reference` block provides a pneumatic reference port at zero absolute pressure and temperature. Use this block with the `Pneumatic Pressure & Temperature Sensor` block to create Physical Signals corresponding to absolute pressure and temperature.

Dialog Box and Parameters



Block Parameters: Pneumatic Absolute Reference

Pneumatic Absolute Reference

Pneumatic absolute reference. The conserving port A is at zero absolute pressure and temperature. Use this reference in conjunction with the Pneumatic Pressure & Temperature Sensor to measure absolute pressure and temperature.

Source code

The block has no parameters.

Ports

The block has one pneumatic conserving port, which is at zero absolute pressure and temperature.

See Also

`Pneumatic Atmospheric Reference` | `Pneumatic Pressure & Temperature Sensor`

More About

- "Grounding Rules"

Pneumatic Atmospheric Reference

Reference connection to ambient pressure and temperature for pneumatic ports

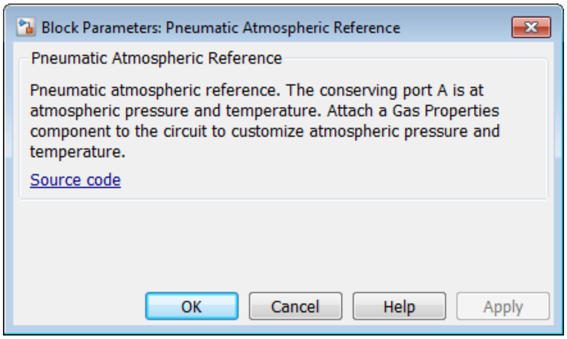
Library

Pneumatic Elements

Description

The `Pneumatic Atmospheric Reference` block provides a pneumatic reference port with pressure and temperature values set to the ambient temperature and pressure. The `Gas Properties` block, if present, specifies the values for ambient temperature and pressure for all pneumatic blocks in the circuit. If a pneumatic circuit does not contain a `Gas Properties` block, ambient temperature and pressure are set to default values of 293.15 K and 101,325 Pa. Use the `Pneumatic Atmospheric Reference` block with the `Pneumatic Pressure Source` block to model an ideal pressure source that takes atmospheric air and increases the pressure by a constant amount.

Dialog Box and Parameters



Block Parameters: Pneumatic Atmospheric Reference

Pneumatic Atmospheric Reference

Pneumatic atmospheric reference. The conserving port A is at atmospheric pressure and temperature. Attach a Gas Properties component to the circuit to customize atmospheric pressure and temperature.

Source code

The block has no parameters.

Ports

The block has one pneumatic conserving port.

See Also

`Gas Properties` | `Pneumatic Absolute Reference` | `Pneumatic Pressure Source`

More About

- "Grounding Rules"

Pneumatic Flow Rate Source

Ideal compressor with constant mass flow rate

Library

Pneumatic Sources

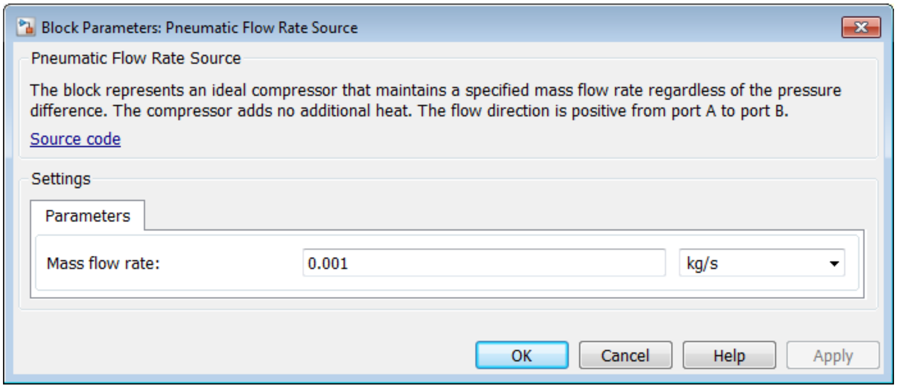
Description

The `Pneumatic Flow Rate Source` block represents an ideal compressor that maintains a specified mass flow rate regardless of the pressure difference. Use this block when delivery of an actual device is practically independent of the source pressure, for example, in positive displacement compressors. The compressor adds no heat. Block connections A and B correspond to the pneumatic inlet and outlet ports, respectively.

The block positive direction is from port A to port B. This means that the flow rate is positive if it flows from A to B. The pressure differential is determined as $p = p_A - p_B$ and is negative if pressure at the source outlet is greater than pressure at its inlet. The power generated by the source is negative if the source adds energy to the flow.

Warning Be careful when driving an orifice directly from a flow rate source. The choked flow condition limits the flow that is possible through an orifice as a function of upstream pressure and temperature. Hence the flow rate value produced by the flow rate source must be compatible with upstream pressure and temperature. Specifying a flow rate that is too high will result in an unsolvable set of equations.

Dialog Box and Parameters


Block Parameters: Pneumatic Flow Rate Source
Pneumatic Flow Rate Source

The block represents an ideal compressor that maintains a specified mass flow rate regardless of the pressure difference. The compressor adds no additional heat. The flow direction is positive from port A to port B.

Source code
Settings
Parameters

Mass flow rate: 0.001 kg/s

Mass flow rate

Specify the mass flow rate of the source. The default value is `0.001` kg/s.

Ports

The block has the following ports:

A

Pneumatic conserving port associated with the source inlet.

B

Pneumatic conserving port associated with the source outlet.

See Also

`Controlled Pneumatic Flow Rate Source` | `Pneumatic Mass & Heat Flow Sensor`

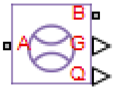
Pneumatic Mass & Heat Flow Sensor

Ideal mass flow and heat flow sensor

Library

Pneumatic Sensors

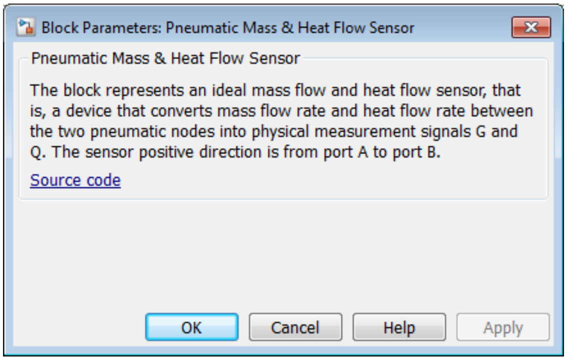
Description



The `Pneumatic Mass & Heat Flow Sensor` block represents an ideal mass flow and heat flow sensor, that is, a device that converts mass flow rate and heat flow rate between the two pneumatic nodes into physical measurement signals G and Q, respectively.

The sensor positive direction is from port A to port B.

Dialog Box and Parameters


Block Parameters: Pneumatic Mass & Heat Flow Sensor

Pneumatic Mass & Heat Flow Sensor

The block represents an ideal mass flow and heat flow sensor, that is, a device that converts mass flow rate and heat flow rate between the two pneumatic nodes into physical measurement signals G and Q. The sensor positive direction is from port A to port B.

Source code

The block has no parameters.

Ports

The block has the following ports:

A

Pneumatic conserving port associated with the sensor inlet.

B

Pneumatic conserving port associated with the sensor outlet.

See Also

`Controlled Pneumatic Flow Rate Source` | `Pneumatic Flow Rate Source` | `PS-Simulink Converter`

More About

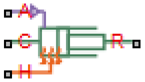
- "Connecting Simscape Diagrams to Simulink Sources and Scopes"

Pneumatic Piston Chamber

Translational pneumatic piston chamber based on ideal gas law

Library

Pneumatic Elements



Description

The `Pneumatic Piston Chamber` block models a pneumatic piston chamber based on the ideal gas law and assuming constant specific heats. Use this model as a building block for pneumatic translational actuators. The piston can exert force in one direction only, and the direction is set by the **Chamber orientation** parameter.

The continuity equation for the network representation of the piston chamber is

$$G = \frac{V_0 + A \bullet x}{RT}\left(\frac{dp}{dt} - \frac{p}{T}\frac{dT}{dt}\right) + \frac{A}{RT} \bullet p \bullet \frac{dx}{dt}$$

where

G	Mass flow rate at input port
V_0	Initial chamber volume
A	Piston effective area
x	Piston displacement
p	Absolute pressure in the chamber
R	Specific gas constant
T	Absolute gas temperature

t	Time

The energy equation is

$$q = \frac{c_v}{R}\left(V_0 + A \bullet x\right)\frac{dp}{dt} + \frac{c_p \bullet A}{R} p \frac{dx}{dt} - q_w$$

where

q	Heat flow due to gas inflow in the chamber (through the pneumatic port)
q_w	Heat flow through the chamber walls (through the thermal port)
c_v	Specific heat at constant volume
c_p	Specific heat at constant pressure

The force equation is

$$F = \left(p - p_a \right) \bullet A$$

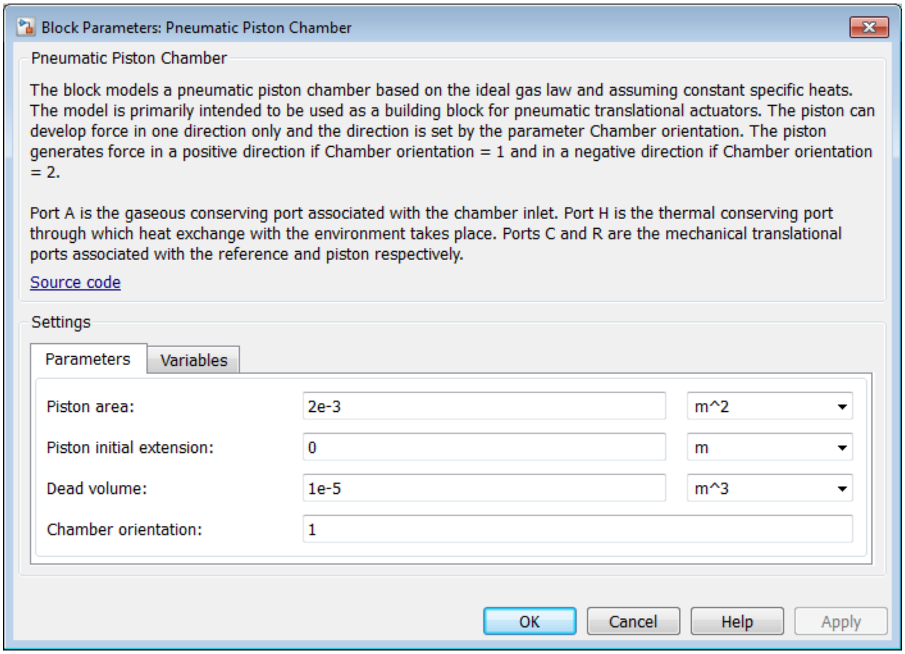
where p_a is the atmospheric pressure acting on the outside of the piston.

Port A is the pneumatic conserving port associated with the chamber inlet. Port H is a thermal conserving port through which heat exchange with the environment takes place. Ports C and R are mechanical translational conserving ports associated with the piston case and rod, respectively. The gas flow and the heat flow are considered positive if they flow into the chamber.

Basic Assumptions and Limitations

- The gas is ideal.
- Specific heats at constant pressure and constant volume, c_p and c_v, are constant.

Dialog Box and Parameters



Block Parameters: Pneumatic Piston Chamber

Pneumatic Piston Chamber

The block models a pneumatic piston chamber based on the ideal gas law and assuming constant specific heats. The model is primarily intended to be used as a building block for pneumatic translational actuators. The piston can develop force in one direction only and the direction is set by the parameter Chamber orientation. The piston generates force in a positive direction if Chamber orientation = 1 and in a negative direction if Chamber orientation = 2.

Port A is the gaseous conserving port associated with the chamber inlet. Port H is the thermal conserving port through which heat exchange with the environment takes place. Ports C and R are the mechanical translational ports associated with the reference and piston respectively.

Source code

Settings

Piston area:	2e-3	m^2
Piston initial extension:	0	m
Dead volume:	1e-5	m^3
Chamber orientation:	1	

- “Parameters Tab” on page 1-318
- “Variables Tab” on page 1-319

Parameters Tab

Piston area

Specify the effective piston area. The default value is `.002` m^2.

Piston initial extension

Specify the initial offset of the piston from the cylinder cap. The default value is `0`.

Dead volume

Specify the volume of gas in the chamber at zero piston position. The default value is `1e-5` m^3.

Chamber orientation

Specify the direction of force generation. The piston generates force in a positive direction if this parameter is set to `1` (the default). If you set this parameter to `2`, the piston generates force in a negative direction.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

`A`

Pneumatic conserving port associated with the chamber inlet.

`H`

Thermal conserving port through which heat exchange with the environment takes place.

`R`

Mechanical translational conserving port associated with the piston (rod).

`C`

Mechanical translational conserving port associated with the reference (case).

See Also

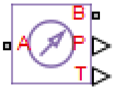
`Constant Volume Pneumatic Chamber` | `Rotary Pneumatic Piston Chamber`

Pneumatic Pressure & Temperature Sensor

Ideal pressure and temperature sensor

Library

Pneumatic Sensors

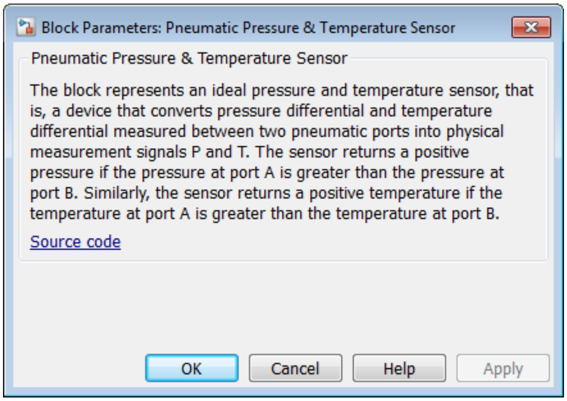


Description

The `Pneumatic Pressure & Temperature Sensor` block represents an ideal pressure and temperature sensor, that is, a device that converts pressure differential and temperature differential measured between two pneumatic ports into physical measurement signals P and T, respectively.

The sensor positive direction is from port A to port B. This means that the sensor returns a positive pressure if the pressure at port A is greater than the pressure at port B. Similarly, the sensor returns a positive temperature if the temperature at port A is greater than the temperature at port B.

Dialog Box and Parameters



Pneumatic Pressure & Temperature Sensor

The block represents an ideal pressure and temperature sensor, that is, a device that converts pressure differential and temperature differential measured between two pneumatic ports into physical measurement signals P and T. The sensor returns a positive pressure if the pressure at port A is greater than the pressure at port B. Similarly, the sensor returns a positive temperature if the temperature at port A is greater than the temperature at port B.

Source code

The block has no parameters.

Ports

The block has the following ports:

A

Pneumatic conserving port associated with the sensor inlet.

B

Pneumatic conserving port associated with the sensor outlet.

See Also

`Controlled Pneumatic Pressure Source` | `Pneumatic Pressure Source` | `PS-Simulink Converter`

More About

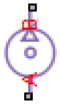
- "Connecting Simscape Diagrams to Simulink Sources and Scopes"

Pneumatic Pressure Source

Ideal compressor with constant pressure difference

Library

Pneumatic Sources

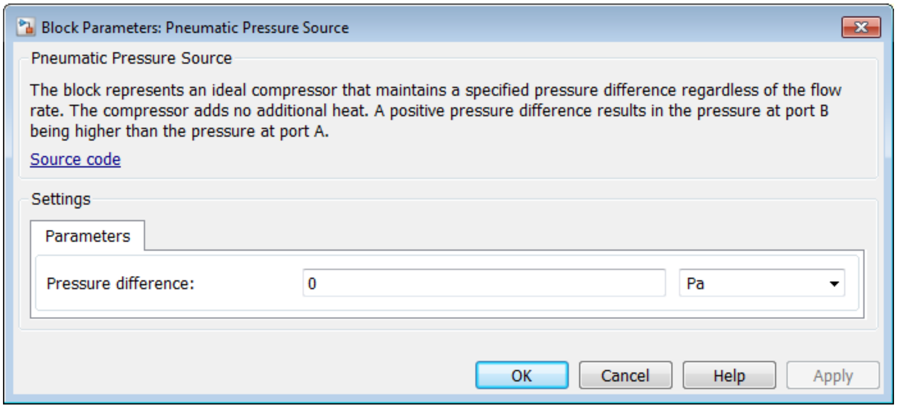


Description

The `Pneumatic Pressure Source` block represents an ideal compressor that maintains a specified pressure difference regardless of the flow rate. Use this block when pressure of an actual device is practically independent of the source flow rate, for example, in factory network outlets or large capacity receivers. The compressor adds no heat. Block connections A and B correspond to the pneumatic inlet and outlet ports, respectively.

A positive pressure difference results in the pressure at port B being higher than the pressure at port A.

Dialog Box and Parameters



Block Parameters: Pneumatic Pressure Source

Pneumatic Pressure Source

The block represents an ideal compressor that maintains a specified pressure difference regardless of the flow rate. The compressor adds no additional heat. A positive pressure difference results in the pressure at port B being higher than the pressure at port A.

Source code

Settings

Parameters

Pressure difference: 0 Pa

Pressure difference

Specify the pressure difference across the source. The default value is 0.

Ports

The block has the following ports:

A

Pneumatic conserving port associated with the source inlet.

B

Pneumatic conserving port associated with the source outlet.

See Also

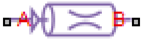
`Controlled Pneumatic Pressure Source` | `Pneumatic Pressure & Temperature Sensor`

Pneumatic Resistive Tube

Pneumatic pipe accounting for pressure loss and added heat due to flow resistance

Library

Pneumatic Elements



Description

The `Pneumatic Resistive Tube` block models the loss in pressure and heating due to viscous friction along a short stretch of pipe with circular cross section. Use this block with the `Constant Volume Pneumatic Chamber` block to build a model of a pneumatic transmission line.

The tube is simulated according to the following equations:

$$p_i - p_o = \begin{cases} \dfrac{RT_i}{p_i} \cdot \dfrac{32\mu L}{AD^2} \cdot G & \text{for } Re < Re_{lam} \text{(laminar flow)} \\ f \cdot \dfrac{RT_i}{p_i} \cdot \dfrac{L}{D} \cdot \dfrac{G^2}{2A^2} & \text{for } Re > Re_{turb} \text{(turbulent flow)} \end{cases}$$

where

p_i, p_o	Absolute pressures at the tube inlet and outlet, respectively. The inlet and outlet change depending on flow direction. For positive flow ($G > 0$), $p_i = p_A$, otherwise $p_i = p_B$.
T_i, T_o	Absolute gas temperatures at the tube inlet and outlet, respectively
G	Mass flow rate
μ	Gas viscosity
f	Friction factor for turbulent flow

D	Tube internal diameter
A	Tube cross-sectional area
L	Tube length
Re	Reynolds number

The friction factor for turbulent flow is approximated by the Haaland function

$$f = \left(-1.8 \log_{10} \left(\frac{6.9}{\mathrm{Re}} + \left(\frac{e}{3.7D} \right)^{1.11} \right) \right)^{-2}$$

where e is the surface roughness for the pipe material.

The Reynolds number is defined as:

$$\mathrm{Re} = \rho v D / \mu$$

where ρ is the gas density and v is the gas velocity. Gas velocity is related to mass flow rate by

$$G = \rho v A$$

For flows between Re_{lam} and Re_{turb}, a linear blend is implemented between the flow predicted by the two equations.

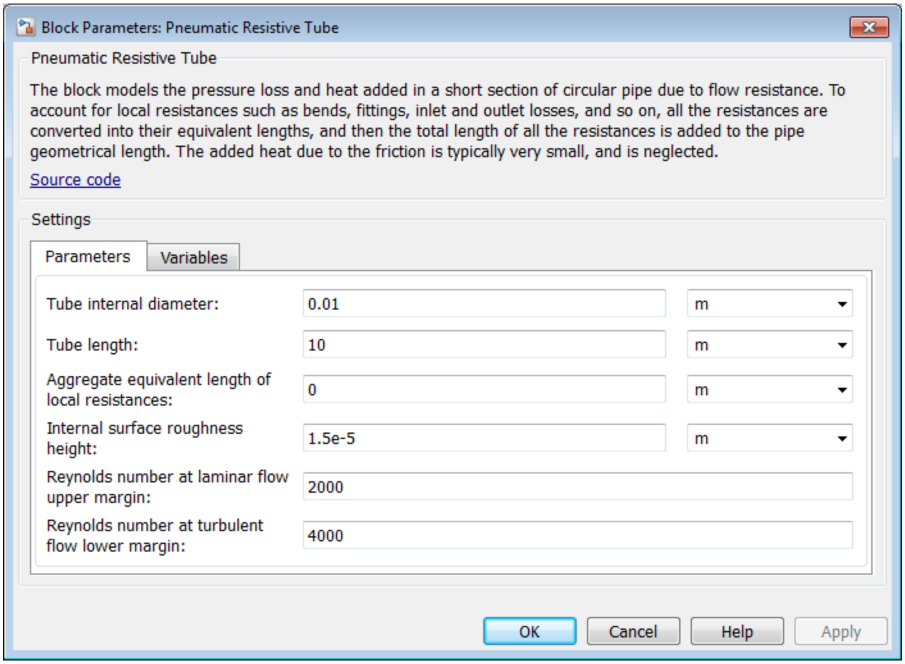
In a real pipe, loss in kinetic energy due to friction is turned into added heat energy. However, the amount of heat is very small, and is neglected in the `Pneumatic Resistive Tube` block. Therefore, $q_i = q_o$, where q_i and q_o are the input and output heat flows, respectively.

Basic Assumptions and Limitations

- The gas is ideal.
- The pipe has a circular cross section.
- The process is adiabatic, that is, there is no heat transfer with the environment.

- Gravitational effects can be neglected.
- The flow resistance adds no net heat to the flow.

Dialog Box and Parameters



Block Parameters: Pneumatic Resistive Tube

Pneumatic Resistive Tube

The block models the pressure loss and heat added in a short section of circular pipe due to flow resistance. To account for local resistances such as bends, fittings, inlet and outlet losses, and so on, all the resistances are converted into their equivalent lengths, and then the total length of all the resistances is added to the pipe geometrical length. The added heat due to the friction is typically very small, and is neglected.

Source code

Settings

Parameters | Variables

Tube internal diameter:	0.01	m
Tube length:	10	m
Aggregate equivalent length of local resistances:	0	m
Internal surface roughness height:	1.5e-5	m
Reynolds number at laminar flow upper margin:	2000	
Reynolds number at turbulent flow lower margin:	4000	

- “Parameters Tab” on page 1-326
- “Variables Tab” on page 1-327

Parameters Tab

Tube internal diameter

Internal diameter of the tube. The default value is `0.01` m.

Tube length

Tube geometrical length. The default value is `10` m.

Aggregate equivalent length of local resistances

This parameter represents total equivalent length of all local resistances associated with the tube. You can account for the pressure loss caused by local resistances, such as bends, fittings, armature, inlet/outlet losses, and so on, by adding to the pipe geometrical length an aggregate equivalent length of all the local resistances. The default value is `0`.

Internal surface roughness height

Roughness height on the tube internal surface. The parameter is typically provided in data sheets or manufacturer catalogs. The default value is `1.5e-5` m, which corresponds to drawn tubing.

Reynolds number at laminar flow upper margin

Specifies the Reynolds number at which the laminar flow regime is assumed to start converting into turbulent flow. Mathematically, this value is the maximum Reynolds number at fully developed laminar flow. The default value is `2000`.

Reynolds number at turbulent flow lower margin

Specifies the Reynolds number at which the turbulent flow regime is assumed to be fully developed. Mathematically, this value is the minimum Reynolds number at turbulent flow. The default value is `4000`.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

A

Pneumatic conserving port associated with the tube inlet for positive flow.

B

Pneumatic conserving port associated with the tube outlet for positive flow.

See Also

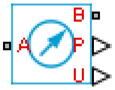
`Constant Volume Pneumatic Chamber`

Pressure & Internal Energy Sensor (2P)

Measure pressure and specific internal energy differences

Library

Two-Phase Fluid/Sensors

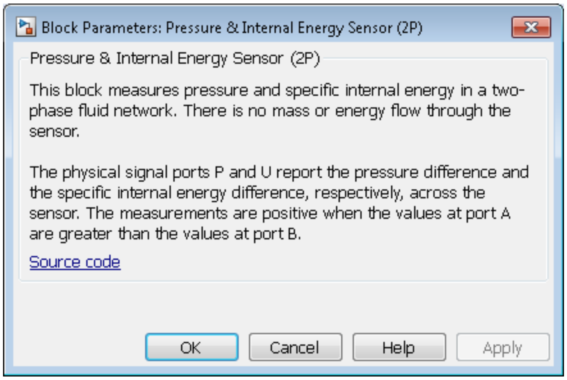


Description

The `Pressure & Internal Energy Sensor (2P)` block measures pressure and specific internal energy differences between two-phase fluid nodes. Ports A and B identify the nodes between which the measurement is taken.

The measured differences are positive if pressure and specific internal energy are greater at port A than at port B. Connect port B to an Absolute Reference (2P) block to measure absolute values instead—the differences with respect to absolute zero reference points.

Dialog Box and Parameters


Block Parameters: Pressure & Internal Energy Sensor (2P)

Pressure & Internal Energy Sensor (2P)

This block measures pressure and specific internal energy in a two-phase fluid network. There is no mass or energy flow through the sensor.

The physical signal ports P and U report the pressure difference and the specific internal energy difference, respectively, across the sensor. The measurements are positive when the values at port A are greater than the values at port B.

Source code

The block has no parameters.

Ports

The block has two two-phase fluid conserving ports, A and B. Physical signal port P outputs the pressure value. Physical signal port U outputs the specific internal energy value.

See Also

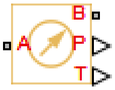
`Absolute Reference (2P)` | `Controlled Pressure Source (2P)` | `Pressure Source (2P)`

Pressure & Temperature Sensor (TL)

Measure pressure and temperature differences

Library

Thermal Liquid/Sensors



Description

The `Pressure & Temperature Sensor (TL)` block represents an ideal sensor that measures pressure and temperature differences between two thermal liquid nodes. Because pressure and temperature are Across variables, the sensor block must connect in parallel with the component being measured.

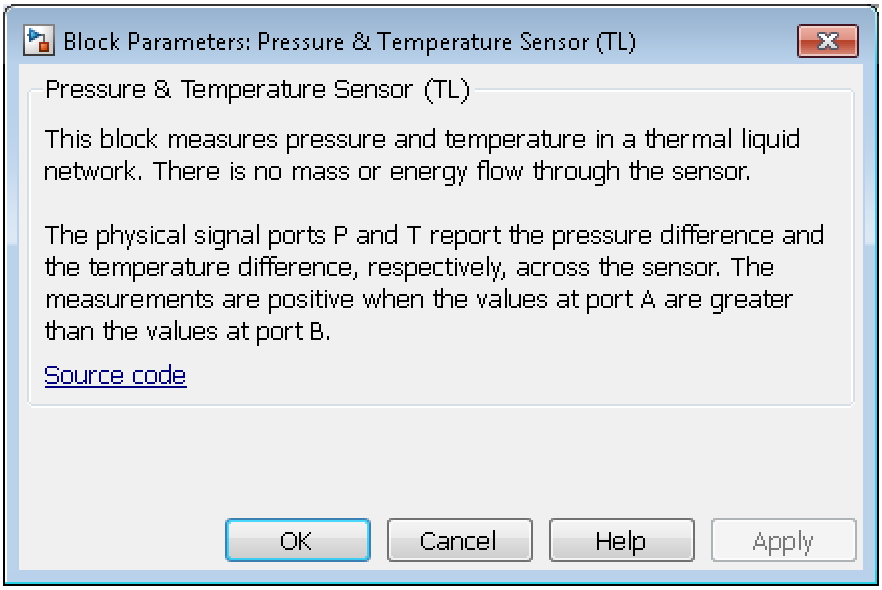
The relative orientation of ports A and B determines the measurement sign. The sign is positive if the measured quantity is greater at port B than it is at port A. Switching port connections reverses the measurement sign.

Ports P and T output the pressure and temperature measurements as physical signals. Connect the ports to `PS-Simulink Converter` blocks to transform the output physical signals into Simulink signals, e.g., for plotting or additional data processing.

Assumptions and Limitations

- Sensor inertia is negligible

Dialog Box and Parameters



Pressure & Temperature Sensor (TL)

This block measures pressure and temperature in a thermal liquid network. There is no mass or energy flow through the sensor.

The physical signal ports P and T report the pressure difference and the temperature difference, respectively, across the sensor. The measurements are positive when the values at port A are greater than the values at port B.

The block has no parameters.

Ports

The block has the following ports.

A, B	Thermal liquid conserving ports
P	Physical signal output port for pressure measurement
T	Physical signal output port for temperature measurement

See Also

`Mass & Energy Flow Rate Sensor (TL)`

Pressure Source (2P)

Generate constant pressure differential

Library

Two-Phase Fluid/Sources

Description

The `Pressure Source (2P)` block generates a constant pressure differential across a pair of two-phase fluid nodes. The source is ideal. It maintains the specified pressure differential regardless of the mass flow rate through the two-phase fluid nodes. Losses due to friction are assumed negligible.

Ports A and B identify the two-phase fluid nodes across which to apply the pressure differential. Pressure is greater at port B than port A if the pressure differential is positive, and greater at port A than port B if the pressure differential is negative.

The energy balance at the source is a function of the energy flow rates through ports A and B and the work done on the fluid:

$$\phi_A + \phi_B + \phi_{work} = 0,$$

where:

- ϕ_{A} is the energy flow rate into the source through port A.
- ϕ_{B} is the energy flow rate into the source through port B.
- ϕ_{work} is the isentropic work done on the fluid.

For a subcooled liquid, the isentropic work term is

$$\phi_{work}^{L} = \dot{m}\left(p_B - p_A\right)v_{avg},$$

where:

- ϕ^{L}_{work} is the isentropic work done on the subcooled liquid.
- $\dot{m}$ is the mass flow rate from port A to port B.
- p_{A} is the pressure at port A.
- p_{B} is the pressure at port B.
- v_{avg} is the average of the specific volumes at ports A and B,

$$v_{avg} = \frac{v_A + v_B}{2}.$$

- v_{A} is the specific volume at port A.
- v_{B} is the specific volume at port B.

If the fluid is a superheated vapor, the isentropic work is

$$\phi^{V}_{work} = \dot{m}\left(u_B^{isen} + p_B v_B + \frac{1}{2}\left(\frac{\dot{m}v_B}{S}\right) - u_A^{isen} - p_A v_A - \frac{1}{2}\left(\frac{\dot{m}v_B}{S}\right)\right),$$

where:

- ϕ^{V}_{work} is the isentropic work done on the superheated vapor.
- $u_{\text{A}}^{\text{isen}}$ is the isentropic specific internal energy at port A.
- $u_{\text{B}}^{\text{isen}}$ is the isentropic specific internal energy at port B.
- S is the source inlet cross-sectional area.

The isentropic specific internal energies at ports A and B follow from the expressions

$$\frac{u_A^{isen} + u_B^{isen}}{2} = \frac{u_A + u_B}{2}$$

and

$$s_{table}\left(\bar{u}_{A}^{isen}, p_{A}\right) = s_{table}\left(\bar{u}_{B}^{isen}, p_{B}\right),$$

where:

- u_A is the specific internal energy at port A.
- u_B is the specific internal energy at port B.
- $s_{table}(\bar{u}, p)$ is the interpolation of the specific entropy table at the normalized internal energy $\bar{u}$ and pressure p.
- $\bar{u}_{A}^{isen}$ is the isentropic normalized internal energy at port A.
- $\bar{u}_{B}^{isen}$ is the isentropic normalized internal energy at port B.

The normalized internal energy at port A is a function of the specific internal energy at that port, as described by the expression

$$\bar{u}_{A}^{isen} = \begin{cases} \dfrac{u_{A}^{isen} - u_{min}}{u_{sat}^{L}(p_{A}) - u_{min}} - 1, & u_{A}^{isen} < u_{sat}^{L}(p_{A}) \\ \dfrac{u_{A}^{isen} - u_{sat}^{L}(p_{A})}{u_{sat}^{V}(p_{A}) - u_{sat}^{L}(p_{A})}, & u_{sat}^{L}(p_{A}) \le u_{A}^{isen} \le u_{sat}^{V}(p_{A}), \\ \dfrac{u_{A}^{isen} - u_{max}}{u_{max} - u_{sat}^{V}(p_{A})} + 2, & u_{sat}^{V}(p_{A}) < u_{A}^{isen} \end{cases}$$

where:

- u_{min} is the minimum valid specific internal energy.
- u_{max} is the maximum valid specific internal energy.
- $u^{L}_{sat}(p)$ is the interpolation of the saturated liquid specific internal energy vector at pressure p.
- $u^{V}_{sat}(p)$ is the interpolation of the saturated vapor specific internal energy vector at pressure p.

Similarly, the normalized internal energy at port B is a function of the specific internal energy at that port, as described by the expression

$$\bar{u}_B^{isen} = \begin{cases} \dfrac{u_B^{isen} - u_{min}}{u_{sat}^L(p_B) - u_{min}} - 1, & u_B^{isen} < u_{sat}^L(p_B) \\ \dfrac{u_B^{isen} - u_{sat}^L(p_B)}{u_{sat}^V(p_B) - u_{sat}^L(p_B)}, & u_{sat}^L(p_B) \le u_B^{isen} \le u_{sat}^V(p_B). \\ \dfrac{u_B^{isen} - u_{max}}{u_{max} - u_{sat}^V(p_B)} + 2, & u_{sat}^V(p_B) < u_B^{isen} \end{cases}$$

The normalized internal energy at either port falls in the range -1 to 0 for a subcooled liquid, 0 to 1 for a two-phase fluid, and 1 to 2 for a superheated vapor. The isentropic work as a function of the average normalized internal energy is

$$\phi_{work} = \begin{cases} \phi_{work}^L, & \bar{u}_{avg} < 0 \\ \left(1 - \bar{u}_{avg}\right)\phi_{work}^L + \bar{u}_{avg}\phi_{work}^V, & 0 \le \bar{u}_{avg} \le 1, \\ \phi_{work}^V, & 1 < \bar{u}_{avg} \end{cases}$$

where:

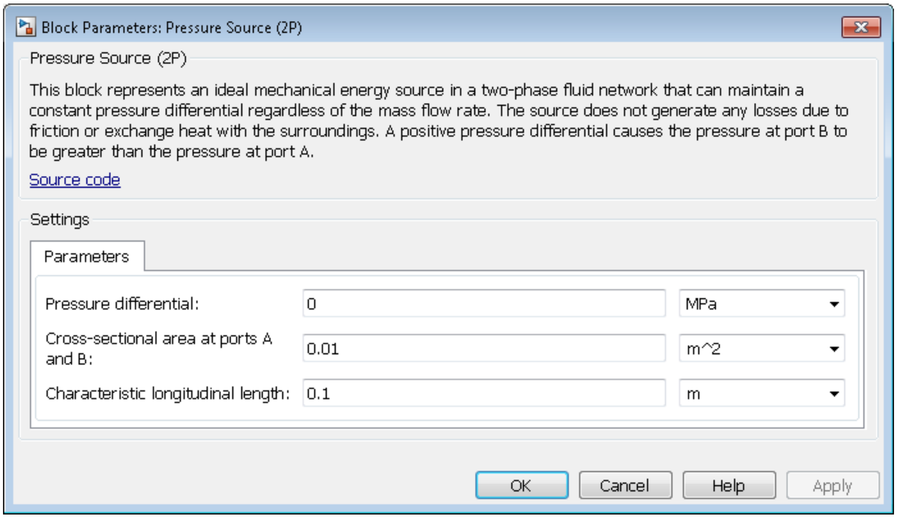
- $\bar{u}_{avg}$ is the average of the normalized internal energies at ports A and B,

$$\bar{u}_{avg} = \frac{\bar{u}_A + \bar{u}_B}{2}.$$

Assumptions and Limitations

- The source is ideal. Losses due to friction are assumed negligible.
- The source is adiabatic. Heat exchange with the surroundings is assumed negligible.
- Work done by the source is isentropic—that is, reversible and adiabatic.

Dialog Box and Parameters



Pressure Source (2P)

This block represents an ideal mechanical energy source in a two-phase fluid network that can maintain a constant pressure differential regardless of the mass flow rate. The source does not generate any losses due to friction or exchange heat with the surroundings. A positive pressure differential causes the pressure at port B to be greater than the pressure at port A.

Source code

Settings

Parameters

Pressure differential: 0 MPa

Cross-sectional area at ports A and B: 0.01 m^2

Characteristic longitudinal length: 0.1 m

Pressure differential

Pressure difference between ports A and B. A positive pressure difference means the pressure is higher at port B than at port A. The default value is `0` MPa.

Cross-sectional area at ports A and B

Area normal to the direction of flow at the source inlet and outlet. The two cross-sectional areas are assumed identical. The default value is `0.01` m^2.

Characteristic longitudinal length

Average distance the fluid traverses in the source before it reaches the outlet. The default value is `0.1` m.

Ports

The block has two two-phase fluid conserving ports, A and B.

See Also

`Controlled Pressure Source (2P)`

Pressure Source (TL)

Generate constant pressure differential

Library

Thermal Liquid/Sources

Description

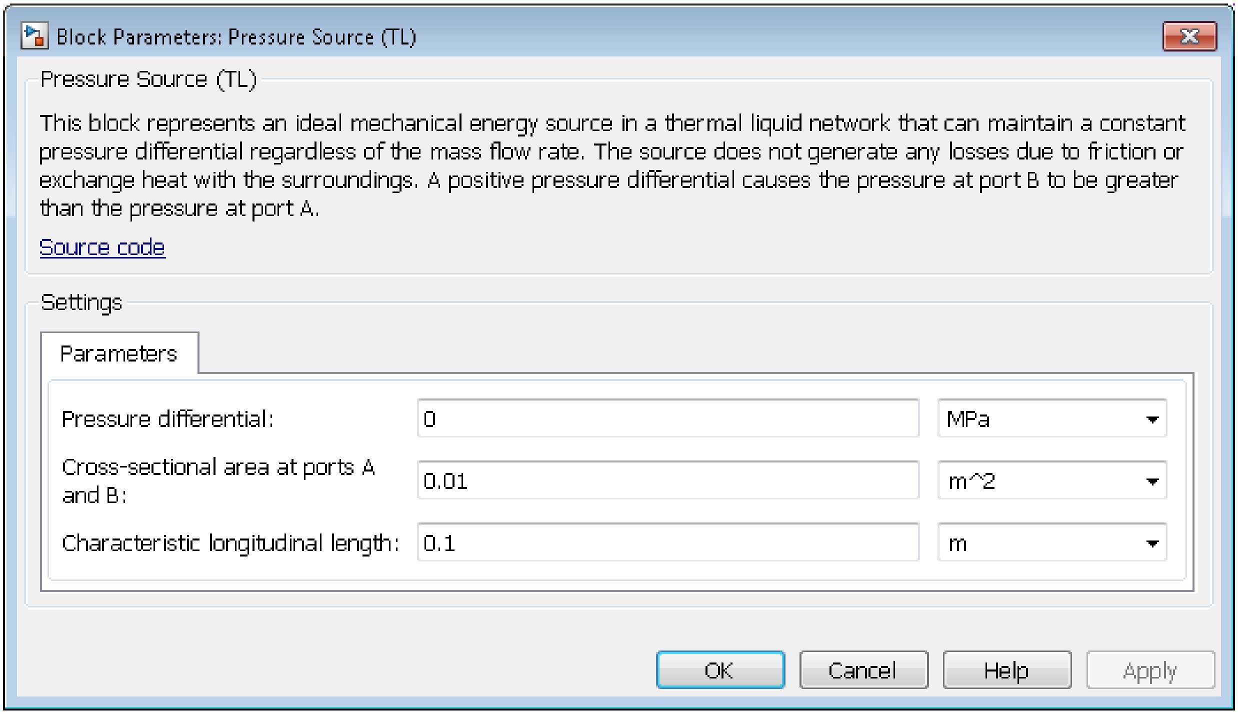
The `Pressure Source (TL)` block represents an ideal compressor generating a constant pressure differential across its inlets. The compressor can hold the specified pressure differential regardless of its mass flow rate. No heat exchange occurs between the compressor and the flowing liquid.

Ports A and B represent the compressor inlets. Both ports are thermal liquid conserving ports. The pressure differential is positive when the pressure at inlet B is greater than the pressure at inlet A.

Assumptions and Limitations

- No heat exchange occurs between the compressor and the flowing liquid.
- The pressure differential between the compressor inlets is independent of the mass flow rate through those inlets.

Dialog Box and Parameters



Block Parameters: Pressure Source (TL)

Pressure Source (TL)

This block represents an ideal mechanical energy source in a thermal liquid network that can maintain a constant pressure differential regardless of the mass flow rate. The source does not generate any losses due to friction or exchange heat with the surroundings. A positive pressure differential causes the pressure at port B to be greater than the pressure at port A.

Source code

Settings

Parameters

Pressure differential: 0 MPa

Cross-sectional area at ports A and B: 0.01 m^2

Characteristic longitudinal length: 0.1 m

Pressure differential

Enter the pressure difference between compressor inlets A and B. The default value is `0` Pa.

Cross-sectional area at ports A and B

Enter the cross-sectional area of the adjoining pipes. The default value is `1e-2` m^2.

Characteristic longitudinal length

Enter the mean path length the liquid must flow through to go from inlet A to inlet B. The default value is `1e-1` m.

Ports

The block has two thermal liquid conserving ports, A and B.

See Also

`Controlled Pressure Source (TL)`

`Mass Flow Rate Source (TL)`

`Controlled Mass Flow Rate Source (TL)`

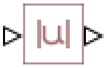
PS Abs

Output absolute value of input physical signal

Library

Physical Signals/Nonlinear Operators

Description



The `PS Abs` block returns the absolute value of the input physical signal:

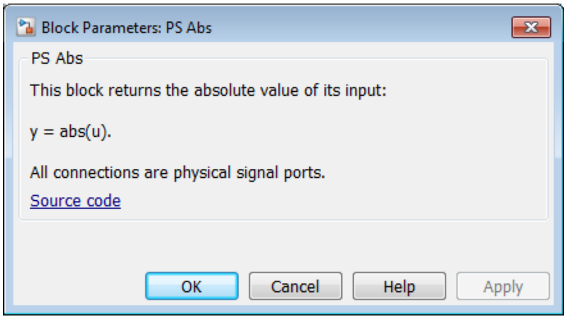
$$y = | u |$$

where

u	Physical signal at the input port
y	Physical signal at the output port

Both the input and the output are physical signals.

Dialog Box and Parameters



This block returns the absolute value of its input:

y = abs(u).

All connections are physical signal ports.

The PS Abs block has no parameters.

Ports

The block has one physical signal input port and one physical signal output port.

See Also

`PS Sign`

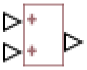
PS Add

Add two physical signal inputs

Library

Physical Signals/Functions

Description



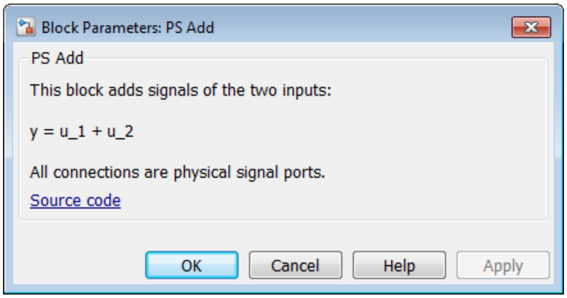
The PS Add block outputs the sum of two input physical signals:

$$y = u_1 + u_2$$

where

u_1	Physical signal at the first input port
u_2	Physical signal at the second input port
y	Physical signal at the output port

Dialog Box and Parameters



PS Add

This block adds signals of the two inputs:

y = u_1 + u_2

All connections are physical signal ports.

Source code

The PS Add block has no parameters.

Ports

The block has two physical signal input ports and one physical signal output port.

See Also

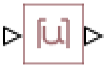
`PS Divide` | `PS Gain` | `PS Math Function` | `PS Product` | `PS Subtract`

PS Ceil

Output the smallest integer larger than or equal to input physical signal

Library

Physical Signals/Nonlinear Operators



Description

The `PS Ceil` block rounds the input physical signal toward positive infinity, that is, to the nearest integer larger than or equal to the input value:

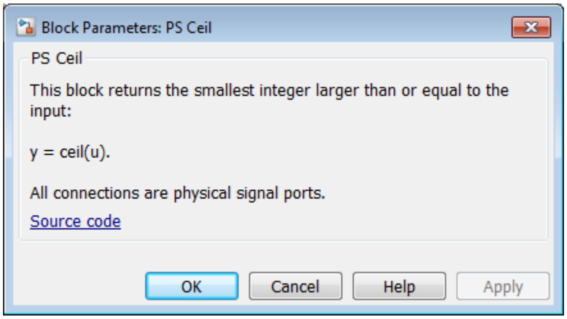
$$y = ceil(u)$$

where

u	Physical signal at the input port
y	Physical signal at the output port

Both the input and the output are physical signals.

Dialog Box and Parameters



Block Parameters: PS Ceil

PS Ceil

This block returns the smallest integer larger than or equal to the input:

y = ceil(u).

All connections are physical signal ports.

Source code

The `PS Ceil` block has no parameters.

Ports

The block has one physical signal input port and one physical signal output port.

See Also

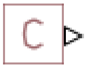
`ceil` | `PS Fix` | `PS Floor` | `PS Round`

PS Constant

Generate constant physical signal

Library

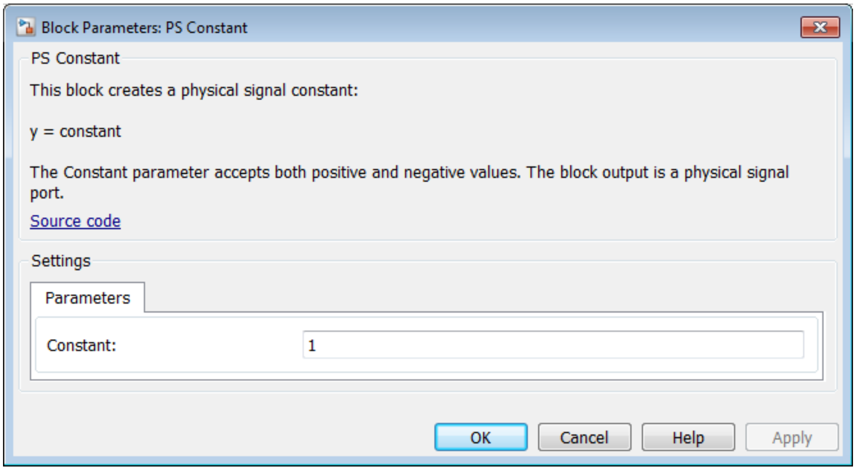
Physical Signals/Sources



Description

The `PS Constant` block generates a physical signal of a constant value. You specify the value of the signal as the **Constant** parameter.

Dialog Box and Parameters



This block creates a physical signal constant:

y = constant

The Constant parameter accepts both positive and negative values. The block output is a physical signal port.

Source code

Constant: 1

Constant

The signal value. You can specify both positive and negative values.

Ports

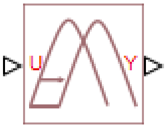
The block has one physical signal output port.

PS Constant Delay

Delay input physical signal by specified time

Library

Physical Signals/Delays



Description

The `PS Constant Delay` block generates the output physical signal, `y`, by delaying the input physical signal, `u`:

$y = u\,(\,t - \tau\,)$

where τ is the delay time.

The delay time is constant throughout the simulation. You specify the value of the delay time as the **Delay time** parameter.

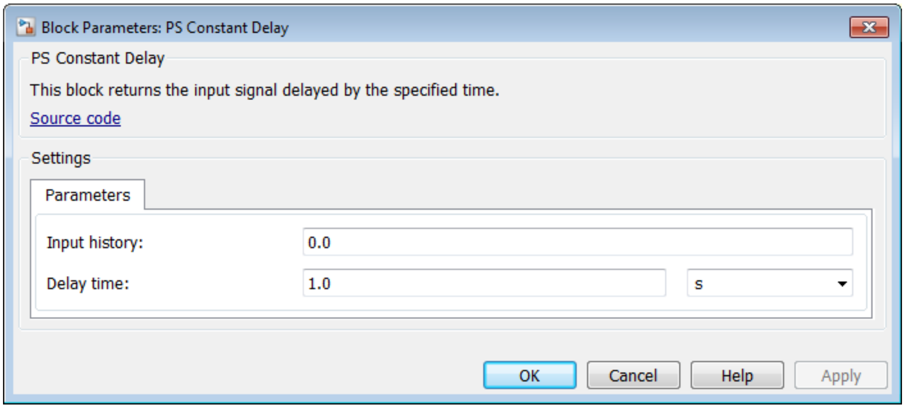
For the initial time interval, when $t <=$ StartTime + τ, the block outputs the **Input history** parameter value.

Note

- When simulating a model that contains blocks with delays, memory allocation for storing the data history is controlled by the **Delay memory budget [kB]** parameter

  in the `Solver Configuration` block. If this budget is exceeded, simulation errors out. You can adjust this parameter value based on your available memory resources.
- For recommendation on how to linearize a model that contains blocks with delays, see "Linearizing with Simulink Linearization Blocks".

Dialog Box and Parameters



Block Parameters: PS Constant Delay

PS Constant Delay

This block returns the input signal delayed by the specified time.

Source code

Settings

Parameters

Input history: 0.0

Delay time: 1.0 s

Input history

The output signal value during the initial time interval, until the specified delay time elapses after the start of simulation. The default value is 0.

Delay time

The delay time for the signal. The parameter value must be positive. The default value is 1 s.

Ports

The block has one physical signal input port and one physical signal output port.

See Also

`PS Variable Delay`

PS Constant Offset Estimator

Measure constant offset value of periodic signal

Library

Physical Signals/Periodic Operators

Description

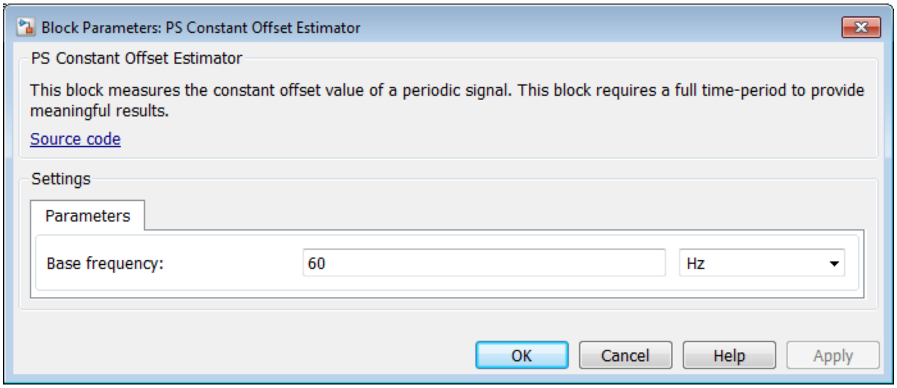
The `PS Constant Offset Estimator` block measures the constant offset value of a periodic signal.

A signal is periodic if it completes a pattern within a measurable time frame, called a period, and repeats that pattern over identical subsequent periods. The signal base frequency is the number of periods per second.

The constant offset is the amount by which the average value of the periodic signal is not centered around the t-axis.

To obtain meaningful results, run the simulation for at least one full time period of the signal.

Dialog Box and Parameters



PS Constant Offset Estimator

This block measures the constant offset value of a periodic signal. This block requires a full time-period to provide meaningful results.

Source code

Settings

Parameters

Base frequency: 60 Hz

Base frequency

Specify the periodic signal frequency. The default value is 60 Hz.

Ports

The block has one physical signal input port and one physical signal output port.

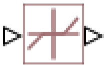
Introduced in R2015b

PS Dead Zone

Provide region of zero output for physical signals

Library

Physical Signals/Nonlinear Operators



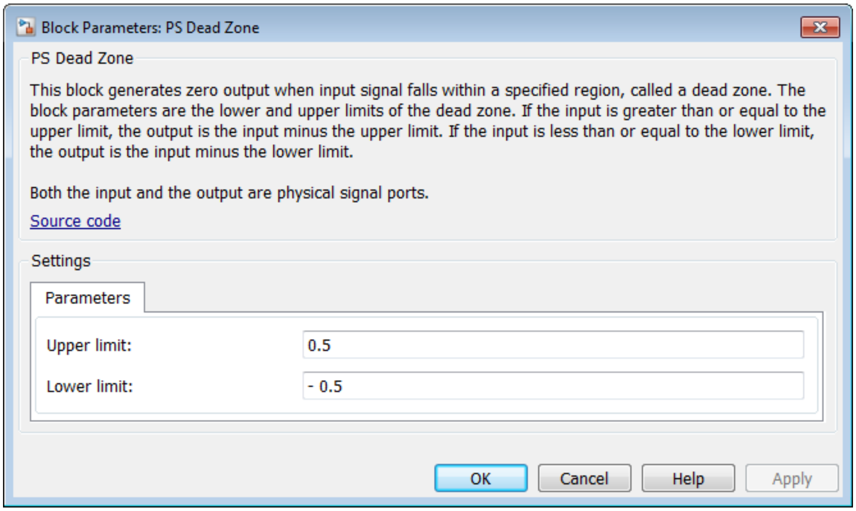
Description

The `PS Dead Zone` block generates zero output when input signal falls within a specified region, called a dead zone. You can specify the lower and upper limits of the dead zone as block parameters. The block output depends on the input and dead zone:

- If the input is within the dead zone (greater than the lower limit and less than the upper limit), the output is zero.
- If the input is greater than or equal to the upper limit, the output is the input minus the upper limit.
- If the input is less than or equal to the lower limit, the output is the input minus the lower limit.

Both the input and the output are physical signals.

Dialog Box and Parameters



PS Dead Zone

This block generates zero output when input signal falls within a specified region, called a dead zone. The block parameters are the lower and upper limits of the dead zone. If the input is greater than or equal to the upper limit, the output is the input minus the upper limit. If the input is less than or equal to the lower limit, the output is the input minus the lower limit.

Both the input and the output are physical signal ports.

Source code

Settings

Parameters

Upper limit: 0.5

Lower limit: - 0.5

Upper limit

The upper limit, or end, of the dead zone. The default value is `0.5`.

Lower limit

The lower limit, or start, of the dead zone. The default value is `-0.5`.

Ports

The block has one physical signal input port and one physical signal output port.

See Also

`PS Saturation`

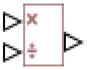
PS Divide

Compute simple division of two input physical signals

Library

Physical Signals/Functions

Description



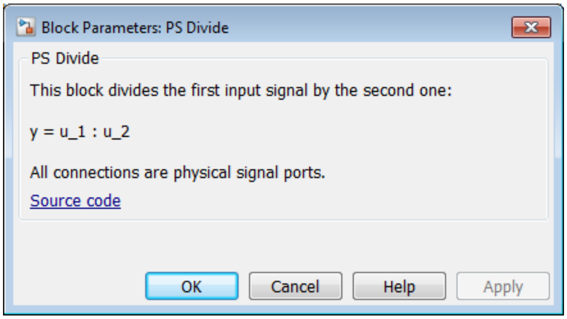
The PS Divide block divides one physical signal input by another and outputs the difference:

$$y = u_1 \div u_2$$

where

u_1	Physical signal at the first input port (marked with the x sign)
u_2	Physical signal at the second input port (marked with the ÷ sign)
y	Physical signal at the output port

Dialog Box and Parameters



Block Parameters: PS Divide

PS Divide

This block divides the first input signal by the second one:

y = u_1 : u_2

All connections are physical signal ports.

Source code

The `PS Divide` block has no parameters.

Ports

The block has two physical signal input ports and one physical signal output port.

See Also

`PS Add` | `PS Gain` | `PS Math Function` | `PS Product` | `PS Subtract`

PS Fix

Round input physical signal toward zero

Library

Physical Signals/Nonlinear Operators

Description

The `PS Fix` block rounds the input physical signal toward zero, that is, for a positive signal returns the nearest integer smaller than or equal to the input value, and for a negative signal returns the nearest integer larger than or equal to the input value:

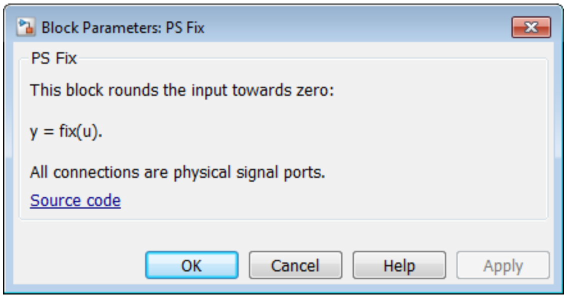
$$y = fix(u)$$

where

u	Physical signal at the input port
y	Physical signal at the output port

Both the input and the output are physical signals.

Dialog Box and Parameters



This block rounds the input towards zero:

y = fix(u).

All connections are physical signal ports.

Source code

The `PS Fix` block has no parameters.

Ports

The block has one physical signal input port and one physical signal output port.

See Also

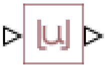
`fix` | `PS Ceil` | `PS Floor` | `PS Round`

PS Floor

Output the largest integer smaller than or equal to input physical signal

Library

Physical Signals/Nonlinear Operators



Description

The `PS Floor` block rounds the input physical signal toward negative infinity, that is, to the nearest integer smaller than or equal to the input value:

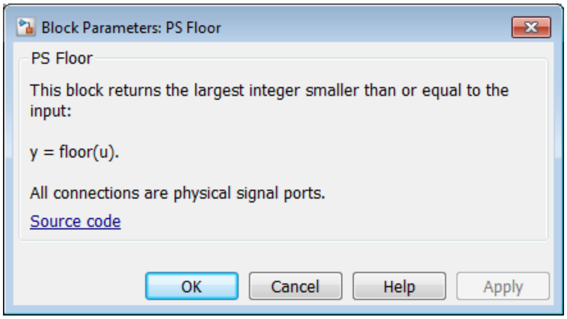
$$y = floor(u)$$

where

u	Physical signal at the input port
y	Physical signal at the output port

Both the input and the output are physical signals.

Dialog Box and Parameters


Block Parameters: PS Floor

PS Floor

This block returns the largest integer smaller than or equal to the input:

y = floor(u).

All connections are physical signal ports.

Source code

The `PS Floor` block has no parameters.

Ports

The block has one physical signal input port and one physical signal output port.

See Also

`floor` | `PS Ceil` | `PS Fix` | `PS Round`

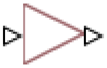
PS Gain

Multiply input physical signal by constant

Library

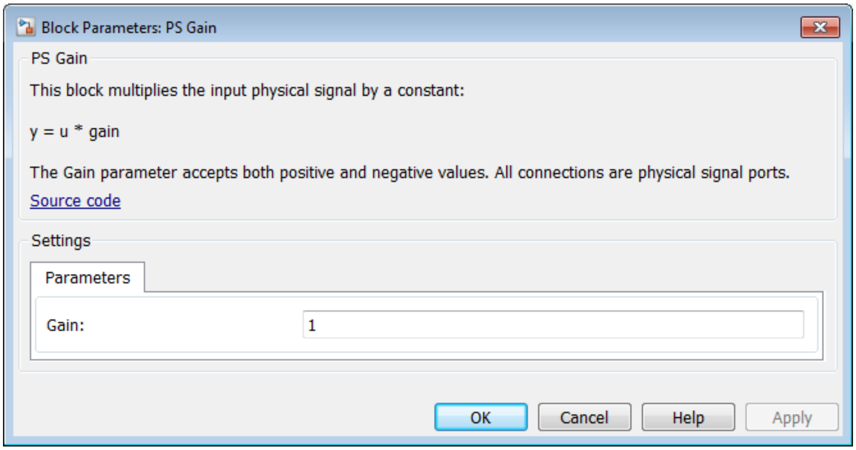
Physical Signals/Functions

Description



The PS Gain block multiplies the input physical signal by a constant value (gain). You specify the value of the gain as the **Gain** parameter.

Dialog Box and Parameters



Block Parameters: PS Gain

PS Gain

This block multiplies the input physical signal by a constant:

y = u * gain

The Gain parameter accepts both positive and negative values. All connections are physical signal ports.

Source code

Settings

Parameters

Gain: 1

Gain

The multiplication coefficient. You can specify both positive and negative values.

Ports

The block has one physical signal input port and one physical signal output port.

See Also

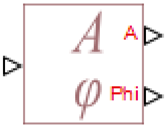
`PS Math Function` | `PS Add` | `PS Divide` | `PS Product` | `PS Subtract`

PS Harmonic Estimator (Amplitude, Phase)

Measure harmonic amplitude and phase of periodic signal

Library

Physical Signals/Periodic Operators



Description

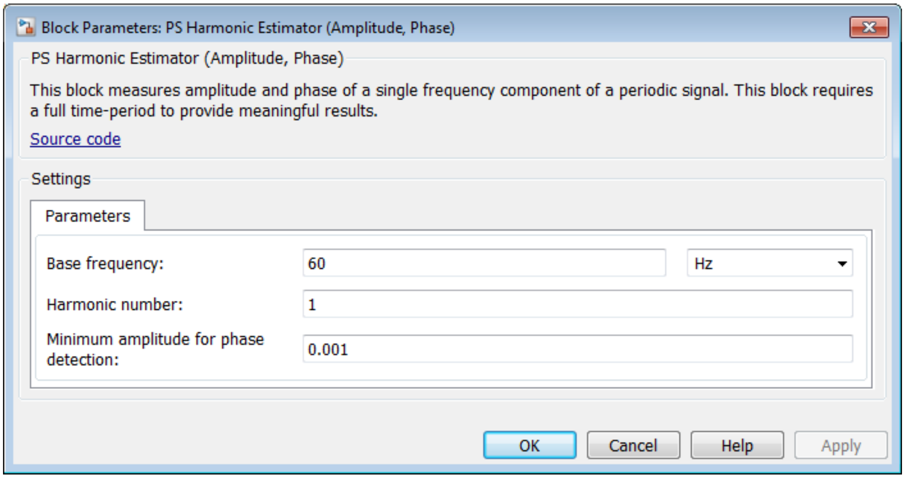
The `PS Harmonic Estimator (Amplitude, Phase)` block measures amplitude and phase of a single frequency component (harmonic) of a periodic signal.

A signal is periodic if it completes a pattern within a measurable time frame, called a period, and repeats that pattern over identical subsequent periods. The signal base frequency is the number of periods per second.

The block accepts a physical signal with one or more harmonics present. It outputs the phase and amplitude for the selected harmonic.

To obtain meaningful results, run the simulation for at least one full time period of the signal.

Dialog Box and Parameters



Block Parameters: PS Harmonic Estimator (Amplitude, Phase)

PS Harmonic Estimator (Amplitude, Phase)

This block measures amplitude and phase of a single frequency component of a periodic signal. This block requires a full time-period to provide meaningful results.

Source code

Settings

Parameters

Base frequency: 60 Hz

Harmonic number: 1

Minimum amplitude for phase detection: 0.001

Base frequency

Specify the periodic signal frequency. The default value is 60 Hz.

Harmonic number

Specify the number of harmonic within the periodic signal. The value must be a positive integer. The default value is 1.

Minimum amplitude for phase detection

Specify the minimum amplitude necessary for measuring the harmonic phase. If the harmonic amplitude is less than this number, the output at port Phi is 0. The default value is 0.001.

Ports

The block has one physical signal input port and two physical signal output ports:

- A — Outputs the harmonic amplitude.
- Phi — Outputs the harmonic phase.

See Also

PS Harmonic Estimator (Real, Imaginary)

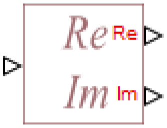
Introduced in R2015b

PS Harmonic Estimator (Real, Imaginary)

Measure real and imaginary parts of periodic signal harmonic

Library

Physical Signals/Periodic Operators



Description

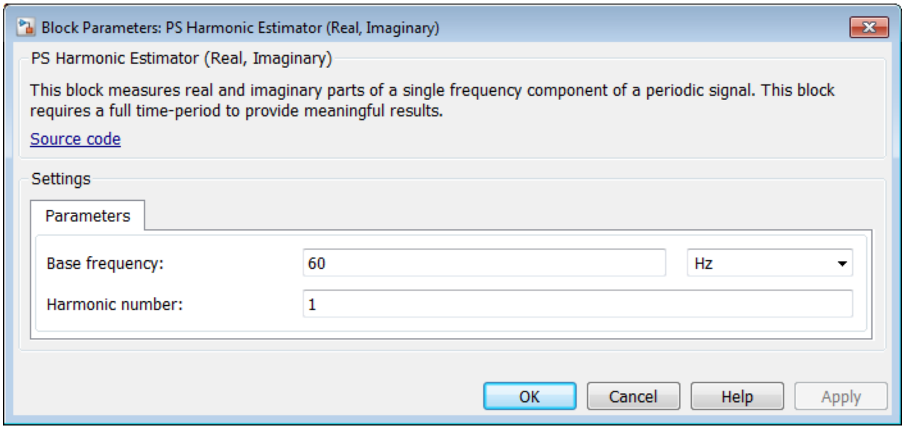
The `PS Harmonic Estimator (Real, Imaginary)` block measures real and imaginary parts of a single frequency component (harmonic) of a periodic signal.

A signal is periodic if it completes a pattern within a measurable time frame, called a period, and repeats that pattern over identical subsequent periods. The signal base frequency is the number of periods per second.

The block accepts a physical signal with one or more harmonics present. It outputs the real and imaginary parts of the signal for the selected harmonic.

To obtain meaningful results, run the simulation for at least one full time period of the signal.

Dialog Box and Parameters



Block Parameters: PS Harmonic Estimator (Real, Imaginary)

PS Harmonic Estimator (Real, Imaginary)

This block measures real and imaginary parts of a single frequency component of a periodic signal. This block requires a full time-period to provide meaningful results.

Source code

Settings

Parameters

Base frequency: 60 Hz

Harmonic number: 1

Base frequency

Specify the periodic signal frequency. The default value is 60 Hz.

Harmonic number

Specify the number of harmonic within the periodic signal. The value must be a positive integer. The default value is 1.

Ports

The block has one physical signal input port and two physical signal output ports:

- Re — Outputs the real part of the harmonic signal.
- Im — Outputs the imaginary part of the harmonic signal.

See Also

PS Harmonic Estimator (Amplitude, Phase)

Introduced in R2015b

PS Integrator

Integrate physical signal

Library

Physical Signals/Linear Operators

Description

The `PS Integrator` block outputs the integral of its input at the current time step. The following equation represents the output of the block:

$$y(t) = \int_{t_0}^{t} u(t)dt + y_0$$

where

u	Physical signal at the input port
y_0	Initial condition
y	Physical signal at the output port
t	Time

The `PS Integrator` block is a dynamic system with one state, its output. The `PS Integrator` block's input is the state's time derivative:

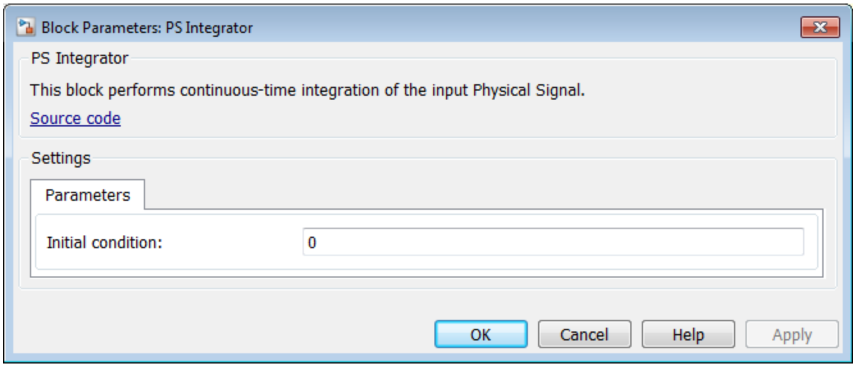
$$x = y(t)$$

$$x_0 = y_0$$

$$\dot{x} = u(t)$$

The solver computes the output of the PS Integrator block at the current time step, using the current input value and the value of the state at the previous time step. To support this computational model, the PS Integrator block saves its output at the current time step for use by the solver to compute its output at the next time step. The block also provides the solver with an initial condition for use in computing the block's initial state at the beginning of a simulation run. The default value of the initial condition is 0. You can specify another value for the initial condition as a parameter on the block dialog box.

Dialog Box and Parameters



Block Parameters: PS Integrator

PS Integrator

This block performs continuous-time integration of the input Physical Signal.

Source code

Settings

Parameters

Initial condition: 0

Initial Condition

Specify the initial condition for use in computing the block's initial state at the beginning of a simulation run. The default value is 0.

Ports

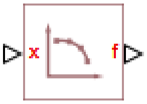
The block has one physical signal input port and one physical signal output port.

PS Lookup Table (1D)

Approximate one-dimensional function using specified lookup method

Library

Physical Signals/Lookup Tables



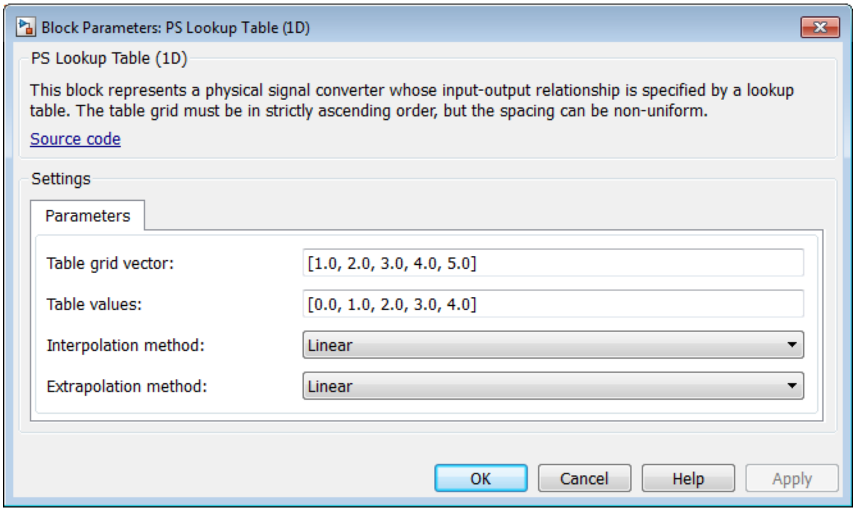
Description

The `PS Lookup Table (1D)` block computes an approximation to some function `f=f(x)` given data vectors `x` and `f`. Both the input and the output are physical signals.

The length of the `x` and `f` data vectors provided to this block must match. Also, the `x` data vector must be strictly monotonic, either increasing or decreasing.

You define the lookup table by specifying the **Table grid vector** parameter as a 1-by-`n` vector (`x` data vector) and the **Table values** parameter as a 1-by-`n` vector (`f` data vector). The block generates output based on the input values using the selected interpolation and extrapolation methods. You have a choice of two interpolation methods and two extrapolation methods.

Dialog Box and Parameters



This block represents a physical signal converter whose input-output relationship is specified by a lookup table. The table grid must be in strictly ascending order, but the spacing can be non-uniform.

Table grid vector: [1.0, 2.0, 3.0, 4.0, 5.0]

Table values: [0.0, 1.0, 2.0, 3.0, 4.0]

Interpolation method: Linear

Extrapolation method: Linear

Table grid vector

Specify the vector of input values as a one-dimensional array. The input values vector must be strictly monotonic, either increasing or decreasing. The values can be nonuniformly spaced. For smooth interpolation, the vector must contain at least three values. For linear interpolation, two values are sufficient.

Table values

Specify the vector of output values as a one-dimensional array. The output values vector must be of the same size as the input values vector.

Interpolation method

Select one of the following interpolation methods for approximating the output value when the input value is between two consecutive grid points:

- `Linear` — Uses a linear function. Select this option to get the best performance.
- `Smooth` — Uses a modified Akima interpolation algorithm. For details, see `tablelookup`. Select this option to produce a continuous curve with continuous first-order derivatives.

Extrapolation method

Select one of the following extrapolation methods for determining the output value when the input value is outside the range specified in the argument list:

- `Linear` — Extends from the edge of the interpolation region linearly. The slope of the linear extrapolation is equal to the slope of the interpolated curve at the edge of the interpolation region.
- `Nearest` — Extends from the edge of the interpolation region as a constant. The value of the nearest extrapolation is equal to the value of the interpolated curve at the edge of the interpolation region. Select this option to produce an extrapolation that does not go above the highest point in the data or below the lowest point in the data.

Restricted Parameters

When your model is in Restricted editing mode, you cannot modify the following parameters:

- **Interpolation method**
- **Extrapolation method**

All other block parameters are available for modification.

Ports

The block has one physical signal input port and one physical signal output port.

See Also

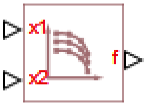
`PS Lookup Table (2D)` | `PS Lookup Table (3D)`

PS Lookup Table (2D)

Approximate two-dimensional function using specified lookup method

Library

Physical Signals/Lookup Tables



Description

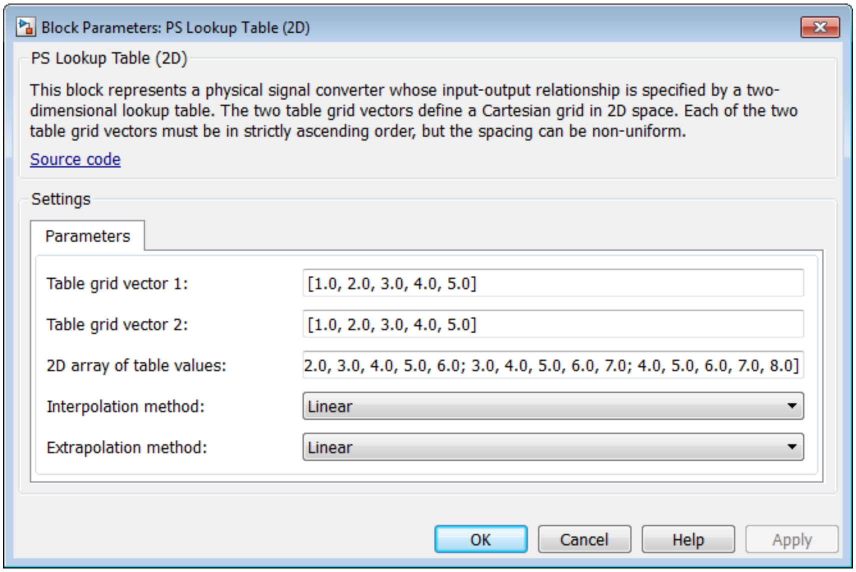
The `PS Lookup Table (2D)` block computes an approximation to some function `f=f(x1,x2)` given the `x1`, `x2`, `f` data points. The two inputs and the output are physical signals.

You define the lookup table by specifying the **Table grid vector 1** parameter (vector of data points along the first axis), the **Table grid vector 2** parameter (vector of data points along the second axis), and the **2D array of table values** (array of output values). The block works on Cartesian mesh, i.e., function values must be specified at vertices of a rectangular array.

The `x1` and `x2` data vectors must be strictly monotonic, either increasing or decreasing. The array size of the tabulated function values must match the dimensions defined by the input vectors. That is, if the inputs are a 1-by-`m` vector and a 1-by-`n` vector, supply an `m`-by-`n` matrix of output values.

The block generates output based on the input grid lookup using the selected interpolation and extrapolation methods. You have a choice of two interpolation methods and two extrapolation methods.

Dialog Box and Parameters



Block Parameters: PS Lookup Table (2D)

PS Lookup Table (2D)

This block represents a physical signal converter whose input-output relationship is specified by a two-dimensional lookup table. The two table grid vectors define a Cartesian grid in 2D space. Each of the two table grid vectors must be in strictly ascending order, but the spacing can be non-uniform.

Source code

Settings

Parameters

Table grid vector 1: [1.0, 2.0, 3.0, 4.0, 5.0]

Table grid vector 2: [1.0, 2.0, 3.0, 4.0, 5.0]

2D array of table values: 2.0, 3.0, 4.0, 5.0, 6.0; 3.0, 4.0, 5.0, 6.0, 7.0; 4.0, 5.0, 6.0, 7.0, 8.0]

Interpolation method: Linear

Extrapolation method: Linear

Table grid vector 1

Specify the vector of input values along the first axis as a 1-by-`m` array. The input values vector must be strictly monotonic, either increasing or decreasing. The values can be nonuniformly spaced. For smooth interpolation, the vector must contain at least three values. For linear interpolation, two values are sufficient.

Table grid vector 2

Specify the vector of input values along the second axis as a 1-by-`n` array. The input values vector must be strictly monotonic, either increasing or decreasing. The values can be nonuniformly spaced. For smooth interpolation, the vector must contain at least three values. For linear interpolation, two values are sufficient.

2D array of table values

Specify the output values as an `m`-by-`n` matrix, defining the function values at the input grid vertices. The matrix size must match the dimensions defined by the input vectors.

Interpolation method

Select one of the following interpolation methods for approximating the output value when the input value is between two consecutive grid points:

- Linear — Uses an extension of linear algorithm for multidimensional interpolation. The method performs linear interpolation first in *x1*-direction and then in *x2*-direction. Select this option to get the best performance.
- Smooth — Uses a modified Akima interpolation algorithm. For details, see tablelookup. Select this option to produce a continuous surface with continuous first-order derivatives.

Extrapolation method

Select one of the following extrapolation methods for determining the output value when the input value is outside the range specified in the argument list:

- Linear — Extends from the edge of the interpolation region linearly. The slope of the linear extrapolation is equal to the slope of the interpolated surface at the edge of the interpolation region.
- Nearest — Extends from the edge of the interpolation region as a constant. The value of the nearest extrapolation is equal to the value of the interpolated surface at the edge of the interpolation region. Select this option to produce an extrapolation that does not go above the highest point in the data or below the lowest point in the data.

Restricted Parameters

When your model is in Restricted editing mode, you cannot modify the following parameters:

- **Interpolation method**
- **Extrapolation method**

All other block parameters are available for modification.

Ports

The block has two physical signal input ports and one physical signal output port.

See Also

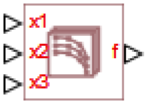
PS Lookup Table (1D) | PS Lookup Table (3D)

PS Lookup Table (3D)

Approximate three-dimensional function using specified lookup method

Library

Physical Signals/Lookup Tables



Description

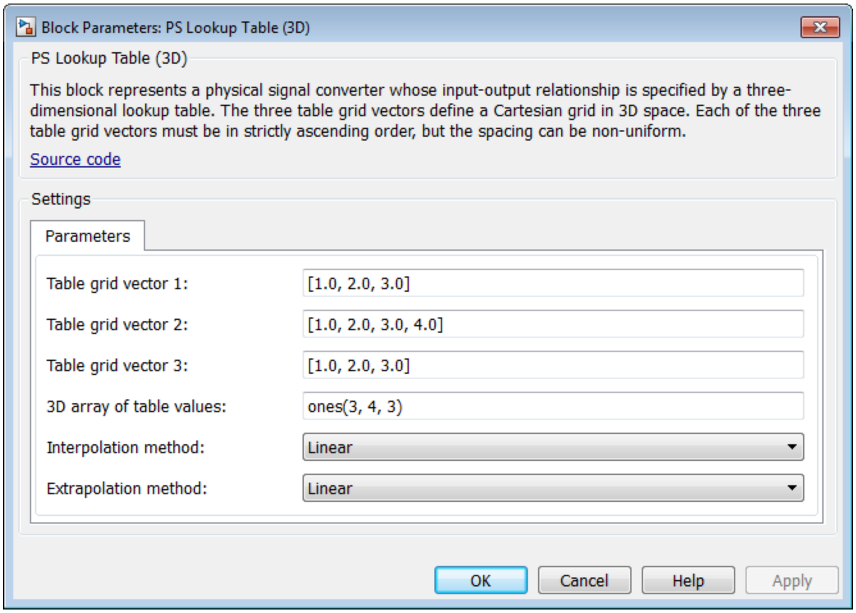
The `PS Lookup Table (3D)` block computes an approximation to some function `f=f(x1,x2,x3)` given the `x1`, `x2`, `x3`, `f` data points. The three inputs and the output are physical signals.

You define the lookup table by specifying the **Table grid vector 1** parameter (vector of data points along the first axis), the **Table grid vector 2** parameter (vector of data points along the second axis), the **Table grid vector 3** parameter (vector of data points along the third axis), and the **3D array of table values** parameter (array of output values).

The `x1`, `x2`, and `x3` data vectors must be strictly monotonic, either increasing or decreasing. The array size of the tabulated function values must match the dimensions defined by the input vectors. That is, if the three input vectors have sizes 1-by-`m`, 1-by-`n`, and 1-by-`k`, respectively, supply an `m`-by-`n`-by-`k` array of output values.

The block generates output based on the input grid lookup using the selected interpolation and extrapolation methods. You have a choice of two interpolation methods and two extrapolation methods.

Dialog Box and Parameters



PS Lookup Table (3D)

This block represents a physical signal converter whose input-output relationship is specified by a three-dimensional lookup table. The three table grid vectors define a Cartesian grid in 3D space. Each of the three table grid vectors must be in strictly ascending order, but the spacing can be non-uniform.

Source code

Settings

Parameters

Table grid vector 1: [1.0, 2.0, 3.0]

Table grid vector 2: [1.0, 2.0, 3.0, 4.0]

Table grid vector 3: [1.0, 2.0, 3.0]

3D array of table values: ones(3, 4, 3)

Interpolation method: Linear

Extrapolation method: Linear

Table grid vector 1

Specify the vector of input values along the first axis as a 1-by-m array. The input values vector must be strictly monotonic, either increasing or decreasing. The values can be nonuniformly spaced. For smooth interpolation, the vector must contain at least three values. For linear interpolation, two values are sufficient.

Table grid vector 2

Specify the vector of input values along the second axis as a 1-by-n array. The input values vector must be strictly monotonic, either increasing or decreasing. The values can be nonuniformly spaced. For smooth interpolation, the vector must contain at least three values. For linear interpolation, two values are sufficient.

Table grid vector 3

Specify the vector of input values along the third axis as a 1-by-k array. The input values vector must be strictly monotonic, either increasing or decreasing. The values can be nonuniformly spaced. For smooth interpolation, the vector must contain at least three values. For linear interpolation, two values are sufficient.

3D array of table values

Specify the output values as an `m`-by-`n`-by-`k` array, defining the function values at the input grid vertices. The output array size must match the dimensions defined by the input vectors.

Interpolation method

Select one of the following interpolation methods for approximating the output value when the input value is between two consecutive grid points:

- `Linear` — Uses an extension of linear algorithm for multidimensional interpolation. The method performs linear interpolation first in *x1*-direction, then in *x2*-direction, and then in *x3*-direction. Select this option to get the best performance.
- `Smooth` — Uses a modified Akima interpolation algorithm. For details, see `tablelookup`. Select this option to produce a continuous surface with continuous first-order derivatives.

Extrapolation method

Select one of the following extrapolation methods for determining the output value when the input value is outside the range specified in the argument list:

- `Linear` — Extends from the edge of the interpolation region linearly. The slope of the linear extrapolation is equal to the slope of the interpolated surface at the edge of the interpolation region.
- `Nearest` — Extends from the edge of the interpolation region as a constant. The value of the nearest extrapolation is equal to the value of the interpolated surface at the edge of the interpolation region. Select this option to produce an extrapolation that does not go above the highest point in the data or below the lowest point in the data.

Restricted Parameters

When your model is in Restricted editing mode, you cannot modify the following parameters:

- **Interpolation method**
- **Extrapolation method**

All other block parameters are available for modification.

Ports

The block has three physical signal input ports and one physical signal output port.

See Also

`PS Lookup Table (1D)` | `PS Lookup Table (2D)`

Introduced in R2016a

PS Math Function

Apply mathematical function to input physical signal

Library

Physical Signals/Functions

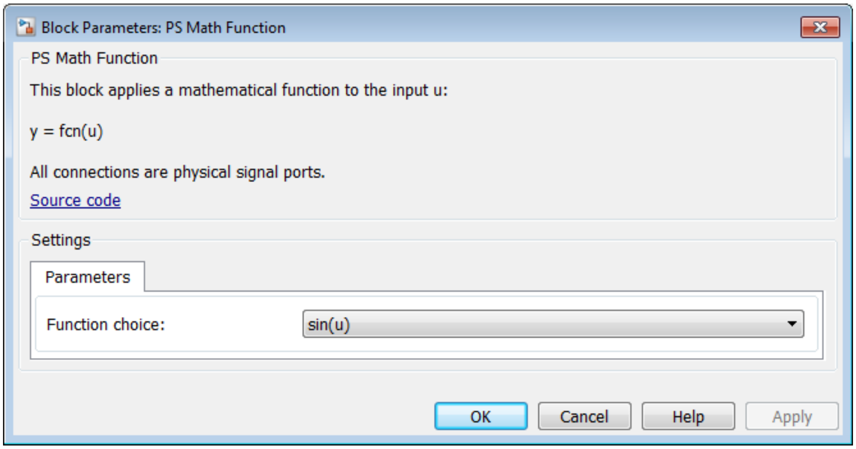
Description

The `PS Math Function` block applies a mathematical function to the input physical signal, u. The block output is the result of the operation of the function on the input. You can select one of the following functions from the **Function choice** parameter list.

Function	Description	Mathematical Expression
`sin(u)`	Sinus	$\sin(u)$
`cos(u)`	Cosinus	$\cos(u)$
`exp(u)`	Exponential	e^u
`log(u)`	Natural logarithm	$\ln(u)$
`10^u`	Power of base 10	10^u
`log10(u)`	Common (base 10) logarithm	$\log(u)$
`u^2`	Power 2	u^2
`sqrt(u)`	Square root	$u^{0.5}$
`1/u`	Reciprocal	$1/u$

The `PS Math Function` block issues a simulation-time error when the input falls out of the expected domain for the particular function used. For example, if set to `sqrt`, the PS Math Function block issues an error if it receives negative input during simulation.

Dialog Box and Parameters



Block Parameters: PS Math Function

PS Math Function

This block applies a mathematical function to the input u:

y = fcn(u)

All connections are physical signal ports.

Source code

Settings

Parameters

Function choice: sin(u)

Function choice

Select the function to perform. The block output is the result of the operation of the function on the input.

Ports

The block has one physical signal input port and one physical signal output port.

See Also

`PS Gain` | `PS Add` | `PS Divide` | `PS Product` | `PS Subtract`

PS Max

Output maximum of two input physical signals

Library

Physical Signals/Nonlinear Operators

Description

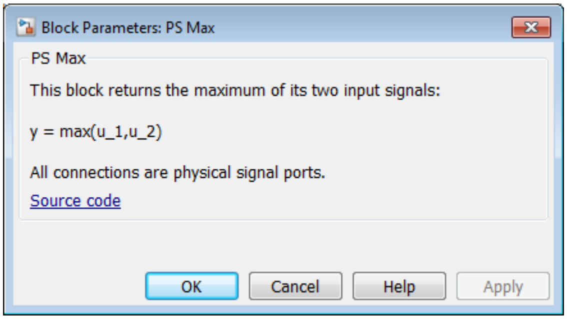
The `PS Max` block outputs the maximum of its two input physical signals:

$$y = \max(u_1, u_2)$$

where

u_1	Physical signal at the first input port
u_2	Physical signal at the second input port
y	Physical signal at the output port

Dialog Box and Parameters



PS Max

This block returns the maximum of its two input signals:

y = max(u_1,u_2)

All connections are physical signal ports.

Source code

The `PS Max` block has no parameters.

Ports

The block has two physical signal input ports and one physical signal output port.

See Also

`PS Min`

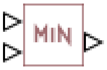
PS Min

Output minimum of two input physical signals

Library

Physical Signals/Nonlinear Operators

Description



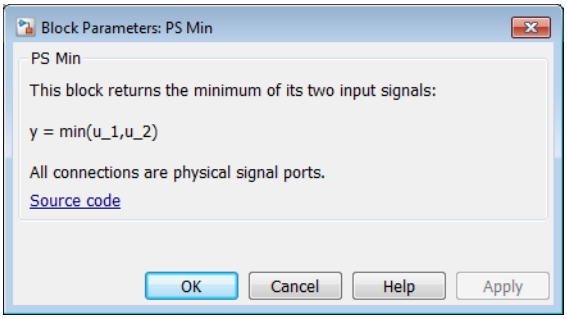
The `PS Min` block outputs the minimum of its two input physical signals:

$$y = \min(u_1, u_2)$$

where

u_1	Physical signal at the first input port
u_2	Physical signal at the second input port
y	Physical signal at the output port

Dialog Box and Parameters



PS Min

This block returns the minimum of its two input signals:

y = min(u_1,u_2)

All connections are physical signal ports.

Source code

The `PS Min` block has no parameters.

Ports

The block has two physical signal input ports and one physical signal output port.

See Also

`PS Max`

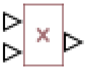
PS Product

Multiply two physical signal inputs

Library

Physical Signals/Functions

Description



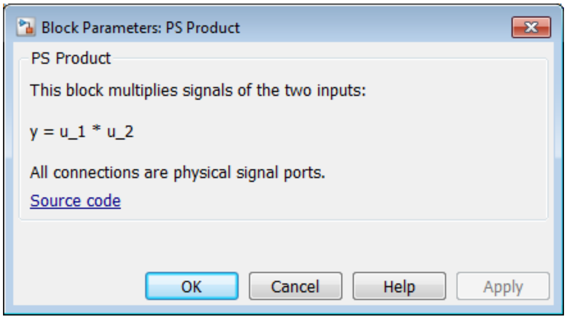
The `PS Product` block outputs the product of two input physical signals:

$$y = u_1 \cdot u_2$$

where

u_1	Physical signal at the first input port
u_2	Physical signal at the second input port
y	Physical signal at the output port

Dialog Box and Parameters



Block Parameters: PS Product

PS Product

This block multiplies signals of the two inputs:

y = u_1 * u_2

All connections are physical signal ports.

Source code

The `PS Product` block has no parameters.

Ports

The block has two physical signal input ports and one physical signal output port.

See Also

`PS Gain` | `PS Add` | `PS Divide` | `PS Math Function` | `PS Subtract`

PS RMS Estimator

Measure RMS value of periodic signal

Library

Physical Signals/Periodic Operators

Description

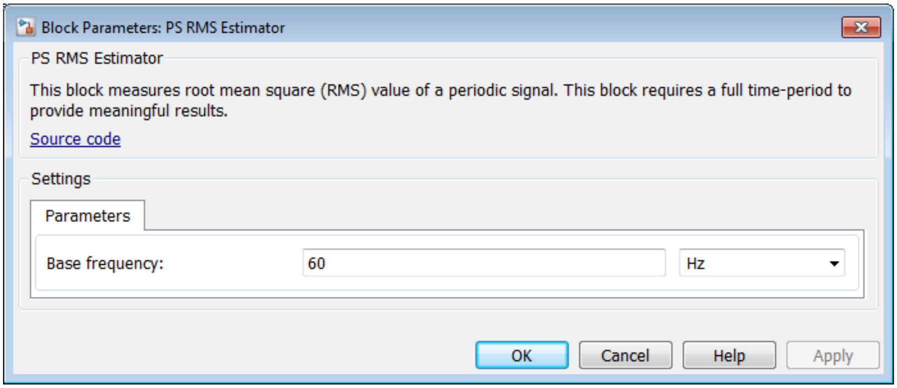
The PS RMS Estimator block measures the root mean square (RMS) value of a periodic signal.

A signal is periodic if it completes a pattern within a measurable time frame, called a period, and repeats that pattern over identical subsequent periods. The signal base frequency is the number of periods per second.

The block accepts a physical signal with one or more AC components present. It outputs an RMS value, where each frequency component is averaged over its time period.

To obtain meaningful results, run the simulation for at least one full time period of the signal.

Dialog Box and Parameters



Block Parameters: PS RMS Estimator

PS RMS Estimator

This block measures root mean square (RMS) value of a periodic signal. This block requires a full time-period to provide meaningful results.

Source code

Settings

Parameters

Base frequency: 60 Hz

Base frequency

Specify the periodic signal frequency. The default value is 60 Hz.

Ports

The block has one physical signal input port and one physical signal output port.

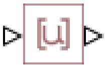
Introduced in R2015b

PS Round

Round input physical signal toward nearest integer

Library

Physical Signals/Nonlinear Operators



Description

The `PS Round` block rounds the input physical signal toward the nearest integer:
$y = \text{round}(\ u\ )$

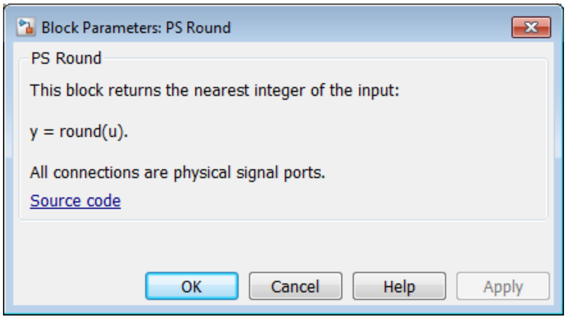
where

u	Physical signal at the input port
y	Physical signal at the output port

Positive signals with a fractional part of 0.5 round up to the nearest positive integer. Negative signals with a fractional part of -0.5 round down to the nearest negative integer.

Both the input and the output are physical signals.

Dialog Box and Parameters



PS Round

This block returns the nearest integer of the input:

y = round(u).

All connections are physical signal ports.

Source code

The `PS Round` block has no parameters.

Ports

The block has one physical signal input port and one physical signal output port.

See Also

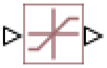
`PS Ceil` | `PS Fix` | `PS Floor` | `round`

PS Saturation

Limit range of physical signal

Library

Physical Signals/Nonlinear Operators



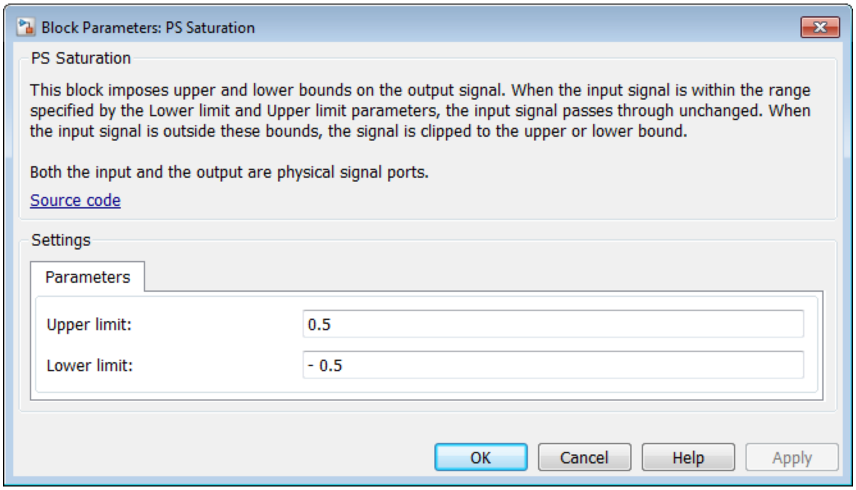
Description

The `PS Saturation` block imposes upper and lower bounds on a physical signal. When the input signal is within the range specified by the **Lower limit** and **Upper limit** parameters, the input signal passes through unchanged. When the input signal is outside these bounds, the signal is clipped to the upper or lower bound.

When the **Lower limit** and **Upper limit** parameters are set to the same value, the block outputs that value.

Both the input and the output are physical signals.

Dialog Box and Parameters



Block Parameters: PS Saturation

PS Saturation

This block imposes upper and lower bounds on the output signal. When the input signal is within the range specified by the Lower limit and Upper limit parameters, the input signal passes through unchanged. When the input signal is outside these bounds, the signal is clipped to the upper or lower bound.

Both the input and the output are physical signal ports.

Source code

Settings

Parameters

Upper limit: 0.5

Lower limit: - 0.5

Upper limit

The upper bound on the input signal. When the input signal to the `PS Saturation` block is above this value, the output of the block is clipped to this value. The default is `0.5`.

Lower limit

The lower bound on the input signal. When the input signal to the `PS Saturation` block is below this value, the output of the block is clipped to this value. The default is `-0.5`.

Ports

The block has one physical signal input port and one physical signal output port.

See Also

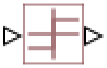
`PS Dead Zone`

PS Sign

Output sign of input physical signal

Library

Physical Signals/Nonlinear Operators



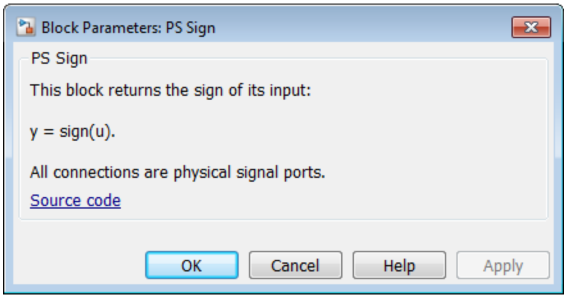
Description

The PS Sign block returns the sign of the input physical signal:

- The output is 1 when the input is greater than zero.
- The output is 0 when the input is equal to zero.
- The output is –1 when the input is less than zero.

Both the input and the output are physical signals.

Dialog Box and Parameters



Block Parameters: PS Sign

PS Sign

This block returns the sign of its input:

y = sign(u).

All connections are physical signal ports.

Source code

The PS Sign block has no parameters.

Ports

The block has one physical signal input port and one physical signal output port.

See Also

`PS Abs`

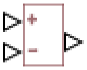
PS Subtract

Compute simple subtraction of two input physical signals

Library

Physical Signals/Functions

Description



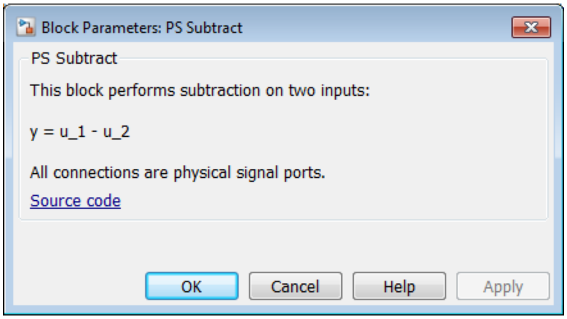
The `PS Subtract` block subtracts one physical signal input from another and outputs the difference:

$$y = u_1 - u_2$$

where

u_1	Physical signal at the first input port (marked with the plus sign)
u_2	Physical signal at the second input port (marked with the minus sign)
y	Physical signal at the output port

Dialog Box and Parameters



PS Subtract

This block performs subtraction on two inputs:

y = u_1 - u_2

All connections are physical signal ports.

Source code

The PS Subtract block has no parameters.

Ports

The block has two physical signal input ports and one physical signal output port.

See Also

PS Gain | PS Add | PS Divide | PS Math Function | PS Product

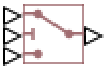
PS Switch

Single-pole double-throw switch controlled by external physical signal

Library

Physical Signals/Nonlinear Operators

Description

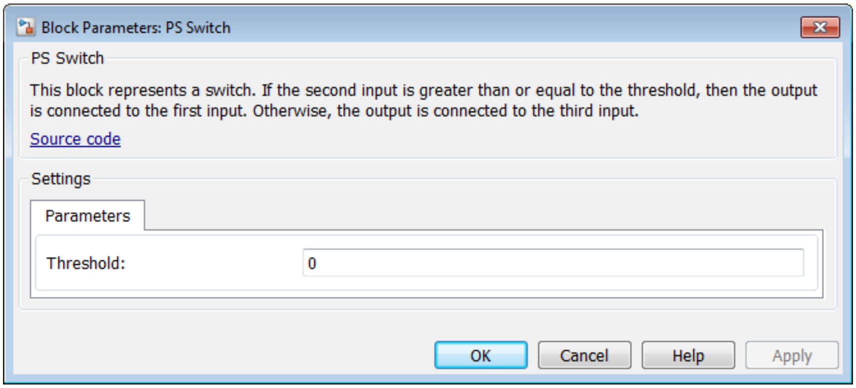


The `PS Switch` block compares the value of the physical signal presented at the second (middle) input port to the threshold value:

- If the control input value is greater than or equal to the threshold, the output is connected to the first input. This is the default connection shown in the block icon.
- If the control input value is less than the threshold, the output is connected to the third input.

The second (middle) input port is the control port and it never connects to the output. All the inputs and the output are physical signals.

Dialog Box and Parameters



Block Parameters: PS Switch

PS Switch

This block represents a switch. If the second input is greater than or equal to the threshold, then the output is connected to the first input. Otherwise, the output is connected to the third input.

Source code

Settings

Parameters

Threshold: 0

Threshold

The threshold value for opening and closing the switch. If the control physical signal, presented at the second (middle) input port, is greater than or equal to this value, then the output is connected to the first input. Otherwise, the output is connected to the third input. The default value is `0`.

Ports

The block has three physical signal input ports and one physical signal output port.

See Also

`Switch`

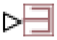
PS Terminator

Terminator for unconnected physical signal outputs

Library

Physical Signals/Sinks

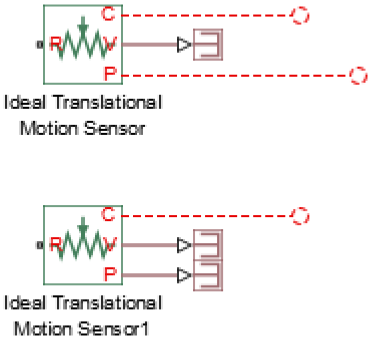
Description



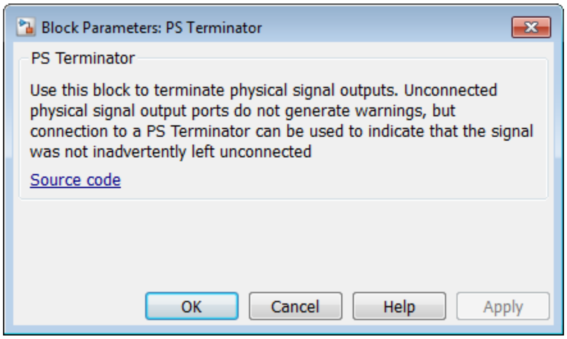
Use the PS Terminator block to cap physical signal output ports that do not connect to other blocks.

Unlike conserving ports in physical modeling, or Simulink output ports, unconnected physical signal output ports do not generate warnings. However, you can use a PS Terminator block for clarity, to indicate that the signal was not inadvertently left unconnected.

The block icon size allows you to connect the PS Terminator block to an open port without rerouting the adjacent lines:


C
R
V
P
Ideal Translational Motion Sensor
C
R
V
P
Ideal Translational Motion Sensor1

Dialog Box and Parameters



PS Terminator

Use this block to terminate physical signal outputs. Unconnected physical signal output ports do not generate warnings, but connection to a PS Terminator can be used to indicate that the signal was not inadvertently left unconnected

Source code

The `PS Terminator` block has no parameters.

Ports

The block has one physical signal input port.

See Also

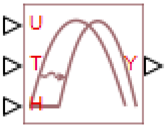
`Adiabatic Cup` | `Cap (TL)` | `Hydraulic Cap` | `Open Circuit` | `Perfect Insulator` | `Rotational Free End` | `Terminator` | `Translational Free End`

PS Variable Delay

Delay input physical signal by variable time

Library

Physical Signals/Delays



Description

The `PS Variable Delay` block generates the output physical signal, `y`, by delaying the input physical signal, `u`:
$y = u\ (\ t - \tau\ )$

where τ is the delay time, which can vary throughout the simulation. You supply the delay time as a signal through the input port `T`.

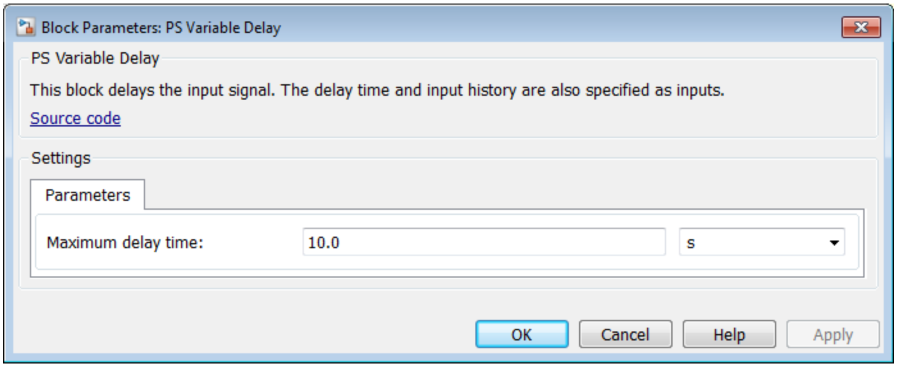
For the initial time interval, when t <= StartTime + τ, the block outputs the value of the signal supplied through the input port `H`.

Note

- When simulating a model that contains blocks with delays, memory allocation for storing the data history is controlled by the **Delay memory budget [kB]** parameter

  in the `Solver Configuration` block. If this budget is exceeded, simulation errors out. You can adjust this parameter value based on your available memory resources.
- For recommendation on how to linearize a model that contains blocks with delays, see "Linearizing with Simulink Linearization Blocks".

Dialog Box and Parameters



Block Parameters: PS Variable Delay

PS Variable Delay

This block delays the input signal. The delay time and input history are also specified as inputs.

Source code

Settings

Parameters

Maximum delay time: 10.0 s

Maximum delay time

> The upper limit for the delay time. Exceeding the maximum delay time during simulation results in a runtime error. The parameter value must be positive. The default value is 10 s.

Ports

The block has the following ports:

U

> Physical signal input port for the original signal.

T

> Physical signal input port that supplies the delay time.

H

> Physical signal input port that supplies the output signal for the initial time interval, when time since the start of simulation is less than or equal to the delay time.

Y

> Physical signal output port for the delayed signal.

Examples

The Variable Transport Delay example shows how you can model a variable transport delay using Simscape language. The Transport Delay subsystem models signal propagation through media moving between the Input and the Output terminals. The media velocity may vary, thus it is specified through the block port. The distance between the terminals is constant and it is specified as a block parameter. To see the implementation details, look under mask of the Transport Delay subsystem, then right-click the Variable Transport Delay block and select **Simscape** > **View source code**.

See Also

`PS Constant Delay`

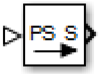
PS-Simulink Converter

Convert physical signal into Simulink output signal

Library

Utilities

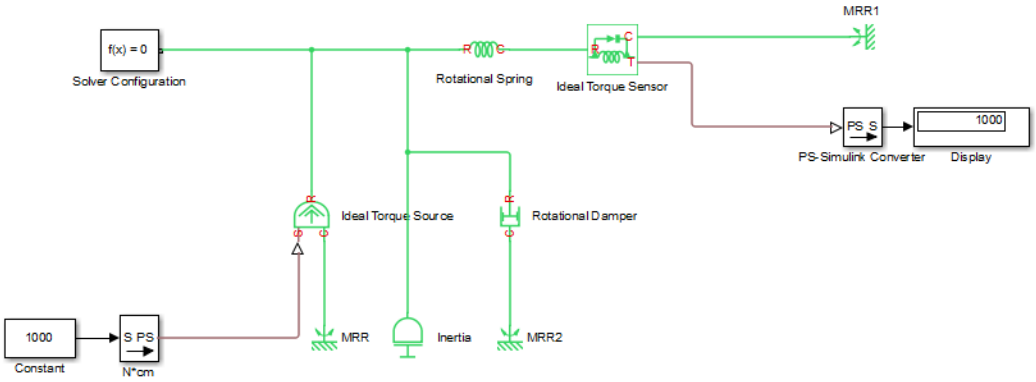
Description



The `PS-Simulink Converter` block converts a physical signal into a Simulink output signal. Use this block to connect outputs of a Physical Network diagram to Simulink scopes or other Simulink blocks.

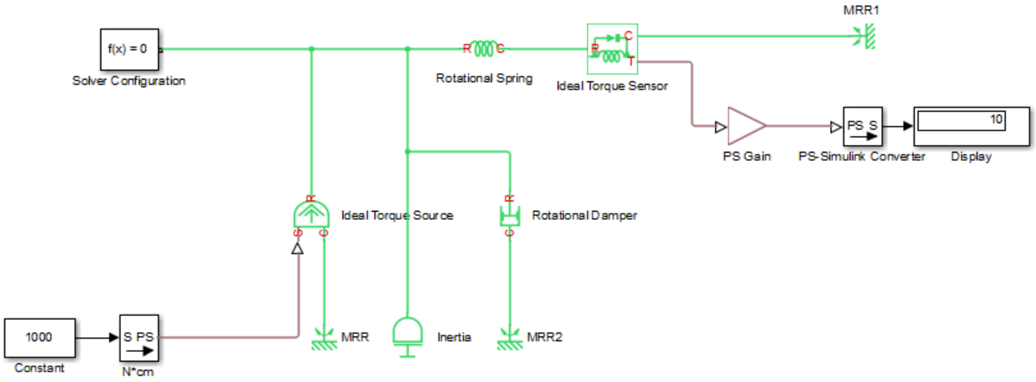
The **Output signal unit** parameter lets you specify the desired units for the output signal. These units must be commensurate with the units of the input physical signal coming into the block. If you specify a desired output unit, the block applies a gain equal to the conversion factor before outputting the Simulink signal. For example, if the input physical signal coming into the block is displacement, in meters, and you set **Output signal unit** to `mm`, the block multiplies the value of the input signal by 10e3 before outputting it.

In the diagram below, the input signal for the `PS-Simulink Converter` block is torque in N*m, and if you do not specify the output signal unit, the `Display` block shows the value of 10. If you change the **Output signal unit** parameter value in the `PS-Simulink Converter` block to `N*cm`, the torque value in the `Display` block changes to 1000, as shown in the diagram.



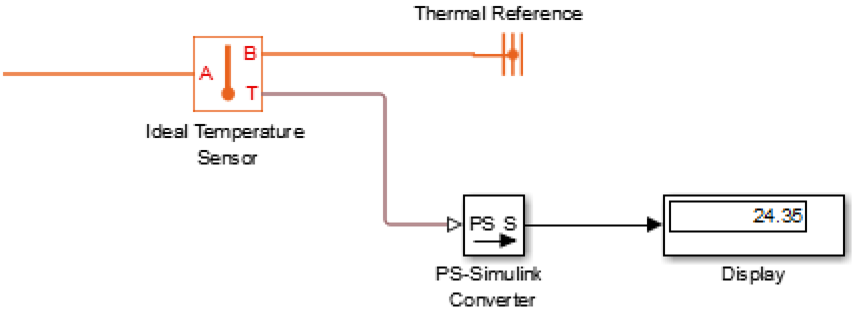
Note Currently, physical units are not propagated through the blocks in the Physical Signals library, such as `PS Add`, `PS Gain`, and so on. If your diagram contains a Physical Signals block before a `PS-Simulink Converter` block, the unit specification in the `PS-Simulink Converter` block is ignored.

In the following example, the `PS-Simulink Converter` block is installed after the `PS Gain1` block. The display reading will remain the same regardless of the **Output signal unit** parameter setting in the `PS-Simulink Converter` block.

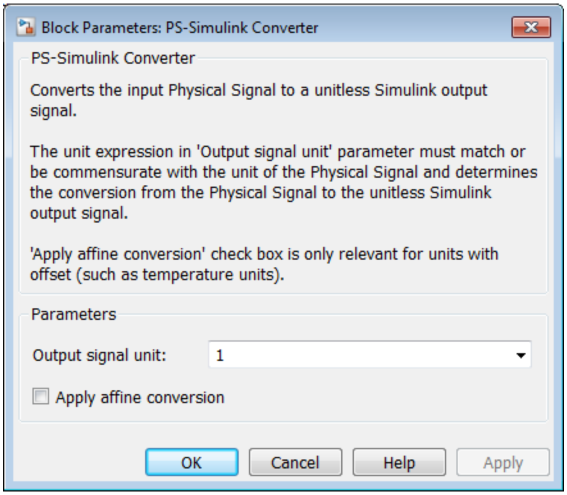


When the output signal is related to thermodynamic variables and contains units of temperature, you must decide whether affine conversion needs to be applied. For more information, see “When to Apply Affine Conversion”. Usually, if the output signal represents a relative temperature, that is, a change in temperature, you need to apply linear conversion, $\Delta T_{new} = L * \Delta T_{old}$ (the default method). However, if the output signal represents an absolute temperature, you need to apply affine conversion, $T_{new} = L * T_{old} + O$.

In the following diagram, the Display block shows the room temperature. If you want to display it in degrees Celsius, open the `PS-Simulink Converter` block, type `C` in the **Output signal unit** field, and select the **Apply affine conversion** check box. The display reading is 24.35. However, if you leave the **Apply affine conversion** check box clear, the `Display` block would show 297.5.



Dialog Box and Parameters



PS-Simulink Converter

Converts the input Physical Signal to a unitless Simulink output signal.

The unit expression in 'Output signal unit' parameter must match or be commensurate with the unit of the Physical Signal and determines the conversion from the Physical Signal to the unitless Simulink output signal.

'Apply affine conversion' check box is only relevant for units with offset (such as temperature units).

Parameters

Output signal unit: 1

□ Apply affine conversion

Output signal unit

> Specify the desired units for the output signal. These units must be commensurate with the units of the input physical signal coming into the block. The system compares the units you specified with the actual units of the input physical signal and applies a gain equal to the conversion factor before outputting the Simulink signal. You can select a unit from the drop-down list, or type the desired unit name, such as `rpm`, or a valid expression, such as `rad/s`. For more information and a list of unit abbreviations, see “How to Specify Units in Block Dialogs” and “Unit Definitions”. The default value is `1`, which means that the unit is not specified. If you do not specify a unit, or if the unit matches the actual units of the input physical signal, no gain is applied.

Apply affine conversion

> This check box is applicable only for units that can be converted either with or without an affine offset, such as thermal units. For more information, see “Thermal Unit Conversions”.

Restricted Parameters

When your model is in Restricted editing mode, you cannot modify any of the block parameters.

Ports

The block has a physical signal input port, located on its left side, and a Simulink output port, located on its right side (in the block default orientation).

See Also

`Simulink-PS Converter`

More About

- “Working with Simulink Units”

Radiative Heat Transfer

Heat transfer by radiation

Library

Thermal Elements

Description

The `Radiative Heat Transfer` block represents a heat transfer by radiation between two bodies. The transfer is governed by the Stefan-Boltzmann law and is described with the following equation:

$$Q = k \bullet A \bullet (T_A^4 - T_B^4)$$

where

Q	Heat flow
k	Radiation coefficient
A	Emitting body surface area
T_A, T_B	Temperatures of the bodies

The radiation coefficient is determined by geometrical shapes, dimensions, and surface emissivity. For example, the radiation constant for the heat transfer between two parallel plates is computed as

$$k = \frac{\sigma}{\frac{1}{\varepsilon_1} + \frac{1}{\varepsilon_2} - 1}$$

where

σ	Stefan-Boltzmann constant
ε_1, ε_2	Surface emissivity for the emitting and receiving plate, respectively

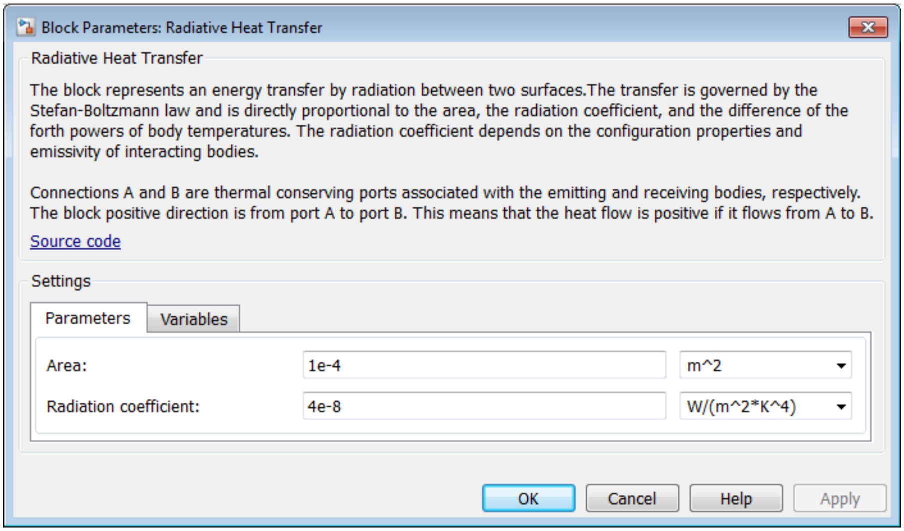
Similarly, the radiation coefficient for concentric cylinders is determined with the formula

$$k = \frac{\sigma}{\frac{1}{\varepsilon_1} + \frac{1-\varepsilon_2}{\varepsilon_2}\frac{r_1}{r_2}}$$

where r_1 and r_2 are the emitting and receiving cylinder radii, respectively. Reference [1] contains formulas for a wide variety of shapes.

Connections A and B are thermal conserving ports associated with the emitting and receiving bodies, respectively. The block positive direction is from port A to port B. This means that the heat flow is positive if it flows from A to B.

Dialog Box and Parameters



Block Parameters: Radiative Heat Transfer

Radiative Heat Transfer

The block represents an energy transfer by radiation between two surfaces.The transfer is governed by the Stefan-Boltzmann law and is directly proportional to the area, the radiation coefficient, and the difference of the forth powers of body temperatures. The radiation coefficient depends on the configuration properties and emissivity of interacting bodies.

Connections A and B are thermal conserving ports associated with the emitting and receiving bodies, respectively. The block positive direction is from port A to port B. This means that the heat flow is positive if it flows from A to B.

Source code

Settings

Area: 1e-4 m^2

Radiation coefficient: 4e-8 W/(m^2*K^4)

- “Parameters Tab” on page 1-411

- “Variables Tab” on page 1-411

Parameters Tab

Area

Radiating body area of heat transfer. The default value is `0.0001` m^2.

Radiation coefficient

Radiation coefficient of the two bodies, based on their geometrical shapes, dimensions, and surface emissivity. See [1] for more information. The default value is `4e-8` W/m^2/K^4.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

`A`

Thermal conserving port associated with body A.

`B`

Thermal conserving port associated with body B.

References

[1] Siegel, R. and J.R. Howell. *Thermal Radiation Heat Transfer*. New York: Taylor and Francis, 2002.

See Also

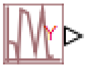
`Conductive Heat Transfer` | `Convective Heat Transfer`

Random Number

Generate normally distributed random numbers for physical modeling

Library

Physical Signals/Sources



Description

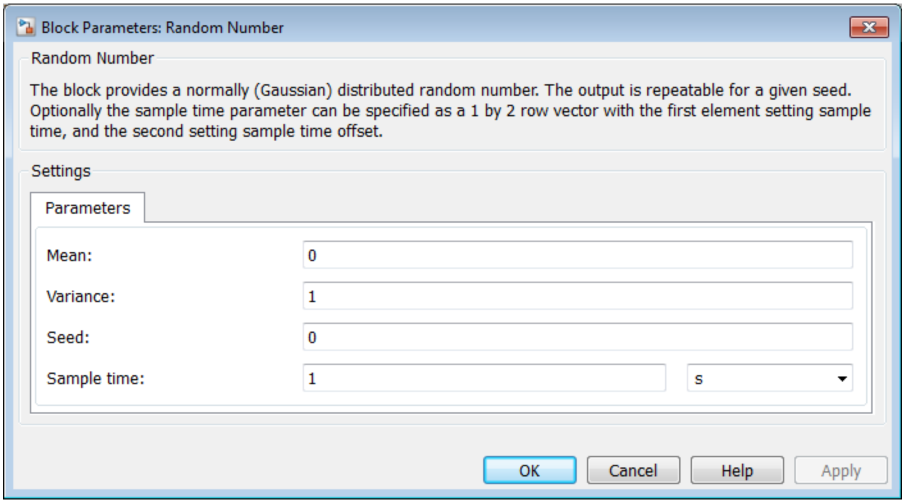
The `Random Number` block generates normally (Gaussian) distributed random numbers. To generate uniformly distributed random numbers, use the `Uniform Random Number` block.

The block behavior is the same as the Simulink `Random Number` block (except that it generates a physical signal rather than a Simulink signal) and is based on the polar rejection method [1, 2].

You have an option to specify an initial time offset as part of the **Sample time** parameter. In this case, the block outputs 0 until the simulation time reaches the *`offset`* value, at which point the random sequence starts.

`Random Number` blocks that use the same seed and parameters generate a repeatable sequence. The seed resets to the specified value each time a simulation starts. By default, the block produces a sequence that has a mean of 0 and a variance of 1.

Dialog Box and Parameters



Block Parameters: Random Number

Random Number

The block provides a normally (Gaussian) distributed random number. The output is repeatable for a given seed. Optionally the sample time parameter can be specified as a 1 by 2 row vector with the first element setting sample time, and the second setting sample time offset.

Settings

Parameters

Mean: 0

Variance: 1

Seed: 0

Sample time: 1 s

Mean

Specify the mean of the random numbers. The default is `0`.

Variance

Specify the variance of the random numbers. The default is `1`.

Seed

Specify the starting seed for the random number generator. Output is repeatable for a given seed. The seed must be an integer in the range of 0 to (2^32 – 1). The default is `0`.

Sample time

The value of the time *`step`* interval. The default *`step`* value is `1` s. To specify an initial time offset, enter the parameter value as `[`*`step, offset`*`]`, otherwise the *`offset`* value is assumed to be `0`. The offset must be less than the step size.

Ports

The block has one physical signal output port.

References

[1] Bell, J. R. “Algorithm 334: Normal random deviates.” *Communications of the ACM*. Vol. 11, Number 7, 1968, p. 498.

[2] Knop, R. “Remark on Algorithm 334 [G5]: normal random deviates.” *Communications of the ACM*. Vol. 12, Number 5, 1969, p. 281.

See Also

`Uniform Random Number`

Reluctance

Magnetic reluctance

Library

Magnetic Elements

Description

The `Reluctance` block models a magnetic reluctance, that is, a component that resists flux flow. The ratio of the magnetomotive force (mmf) across the component to the resulting flux that flows through the component is constant, and the ratio value is defined as the reluctance. Reluctance depends on the geometry of the section being modeled.

The block is based on the following equations:

$$MMF = \Phi \cdot \Re$$

$$\Re = \frac{g}{\mu_0 \cdot \mu_r \cdot A}$$

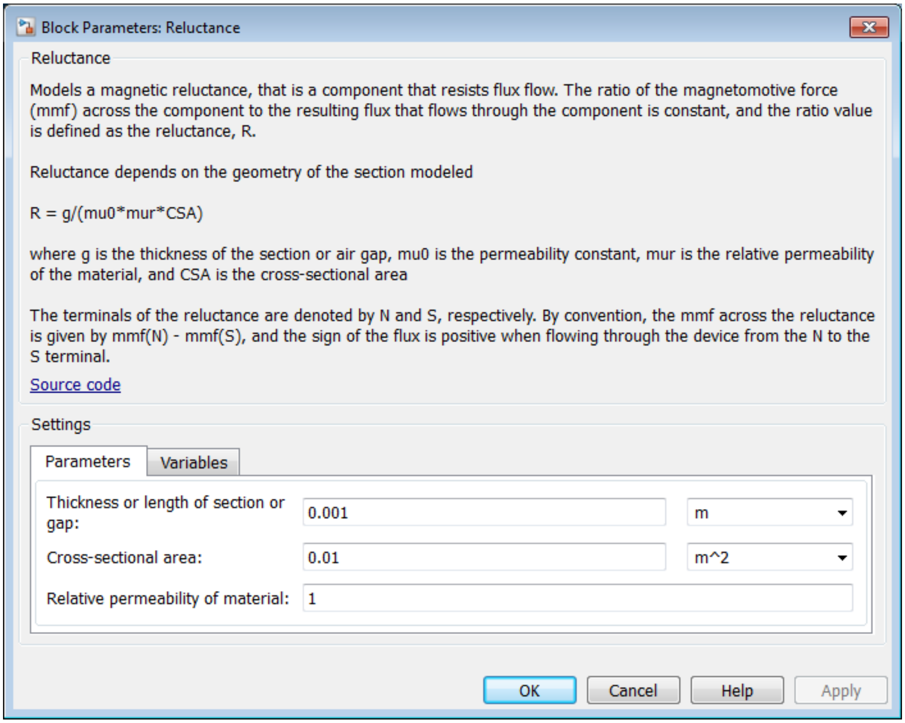
where

MMF	Magnetomotive force (mmf) across the component
Φ	Flux through the component
$\Re$	Reluctance
g	Thickness of the section being modeled, or length of air gap
μ_0	Permeability constant
μ_r	Relative permeability of the material

A	Cross-sectional area of the section being modeled

Connections N and S are magnetic conserving ports. The mmf across the reluctance is given by $MMF(N) - MMF(S)$, and the sign of the flux is positive when flowing through the device from N to S.

Dialog Box and Parameters



Reluctance

Models a magnetic reluctance, that is a component that resists flux flow. The ratio of the magnetomotive force (mmf) across the component to the resulting flux that flows through the component is constant, and the ratio value is defined as the reluctance, R.

Reluctance depends on the geometry of the section modeled

R = g/(mu0*mur*CSA)

where g is the thickness of the section or air gap, mu0 is the permeability constant, mur is the relative permeability of the material, and CSA is the cross-sectional area

The terminals of the reluctance are denoted by N and S, respectively. By convention, the mmf across the reluctance is given by mmf(N) - mmf(S), and the sign of the flux is positive when flowing through the device from the N to the S terminal.

Source code

Settings

Thickness or length of section or gap: 0.001 m

Cross-sectional area: 0.01 m^2

Relative permeability of material: 1

- “Parameters Tab” on page 1-416
- “Variables Tab” on page 1-417

Parameters Tab

Thickness or length of section or gap

Thickness of the section being modeled, or length of air gap. The default value is `0.001` m.

Cross-sectional area

Area of the section being modeled. The default value is `0.01` m^2.

Relative permeability of material

Relative permeability of the section material. The default value is `1`.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

`N`

Magnetic conserving port associated with the block North terminal.

`S`

Magnetic conserving port associated with the block South terminal.

See Also

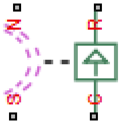
`Fundamental Reluctance` | `Variable Reluctance`

Reluctance Force Actuator

Magnetomotive device based on reluctance force

Library

Magnetic Elements



Description

The `Reluctance Force Actuator` block models a generic magnetomotive device based on reluctance force.

The block is based on the following equations:

$$F = -0.5 \cdot \Phi^2 \cdot \frac{d\Re}{dx}$$

$$\Re(x) = \frac{x}{\mu_0 \cdot \mu_r \cdot A}$$

$$u = dx$$

where

F	Reluctance force
Φ	Flux in the magnetic circuit
$\Re$	Reluctance
x	Thickness or length of the air gap
μ_0	Permeability constant
μ_r	Relative permeability of the material

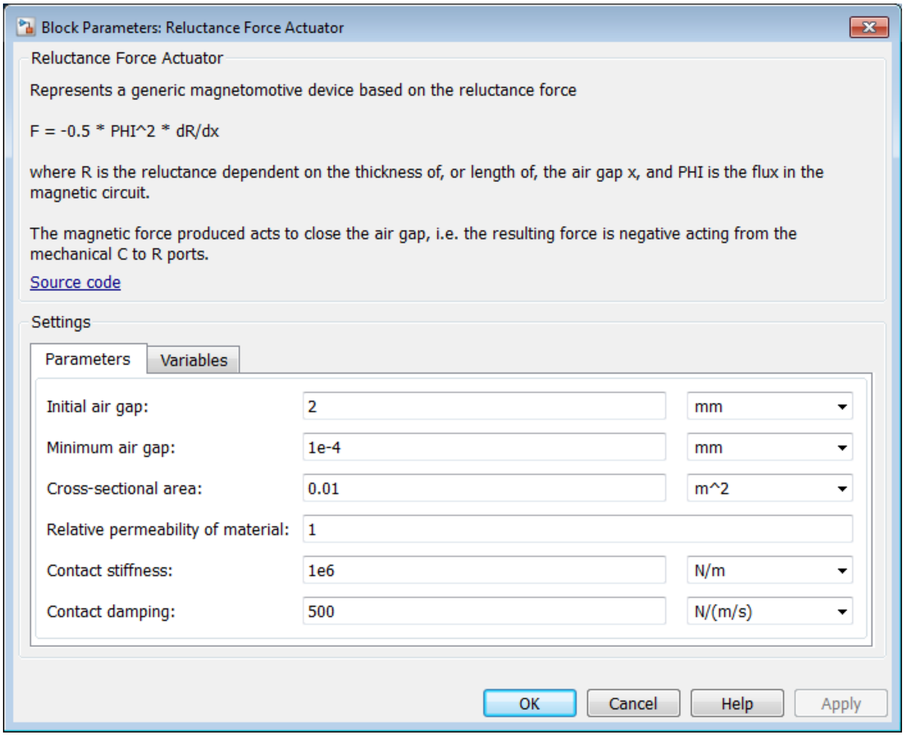
A	Cross-sectional area of the section being modeled
u	Velocity

Connections N and S are magnetic conserving ports, and connections C and R are mechanical translational conserving ports. The magnetic force produced by the actuator acts to close the gap, therefore the resulting force is negative when it acts from C to R.

Basic Assumptions and Limitations

- The current excitation in the system is constant.
- Only axial reluctance is modeled.

Dialog Box and Parameters



Block Parameters: Reluctance Force Actuator

Reluctance Force Actuator

Represents a generic magnetomotive device based on the reluctance force

F = -0.5 * PHI^2 * dR/dx

where R is the reluctance dependent on the thickness of, or length of, the air gap x, and PHI is the flux in the magnetic circuit.

The magnetic force produced acts to close the air gap, i.e. the resulting force is negative acting from the mechanical C to R ports.

Source code

Settings

Initial air gap:	2	mm
Minimum air gap:	1e-4	mm
Cross-sectional area:	0.01	m^2
Relative permeability of material:	1	
Contact stiffness:	1e6	N/m
Contact damping:	500	N/(m/s)

- “Parameters Tab” on page 1-420
- “Variables Tab” on page 1-420

Parameters Tab

Initial air gap

Thickness or length of air gap at the beginning of simulation. The default value is `2` mm.

Minimum air gap

Minimal value of air gap, with the reluctance force acting to close the air gap. The parameter value has to be greater than 0. The default value is `1e-4` mm.

Cross-sectional area

Area of the section being modeled. The default value is `0.01` m^2.

Relative permeability of material

Relative permeability of the section material. The default value is `1`.

Contact stiffness

Stiffness that models the hard stop at the minimum air gap position. The default value is `10e6` N/m.

Contact damping

Damping that models the hard stop at the minimum air gap position. The default value is 500 N/(m/s).

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

`N`

Magnetic conserving port associated with the block North terminal.

`S`

Magnetic conserving port associated with the block South terminal.

`R`

Mechanical translational conserving port associated with the rod.

`C`

Mechanical translational conserving port associated with the case.

See Also

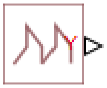
`Fundamental Reluctance` | `Reluctance` | `Variable Reluctance`

Repeating Sequence

Output periodic piecewise linear signal

Library

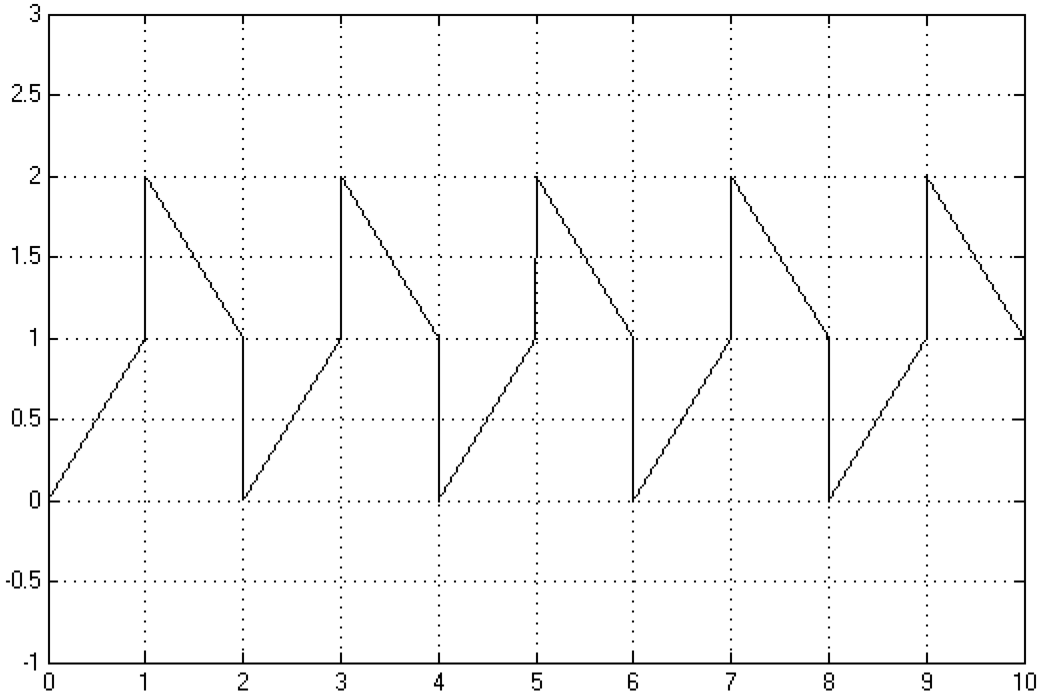
Physical Signals/Sources



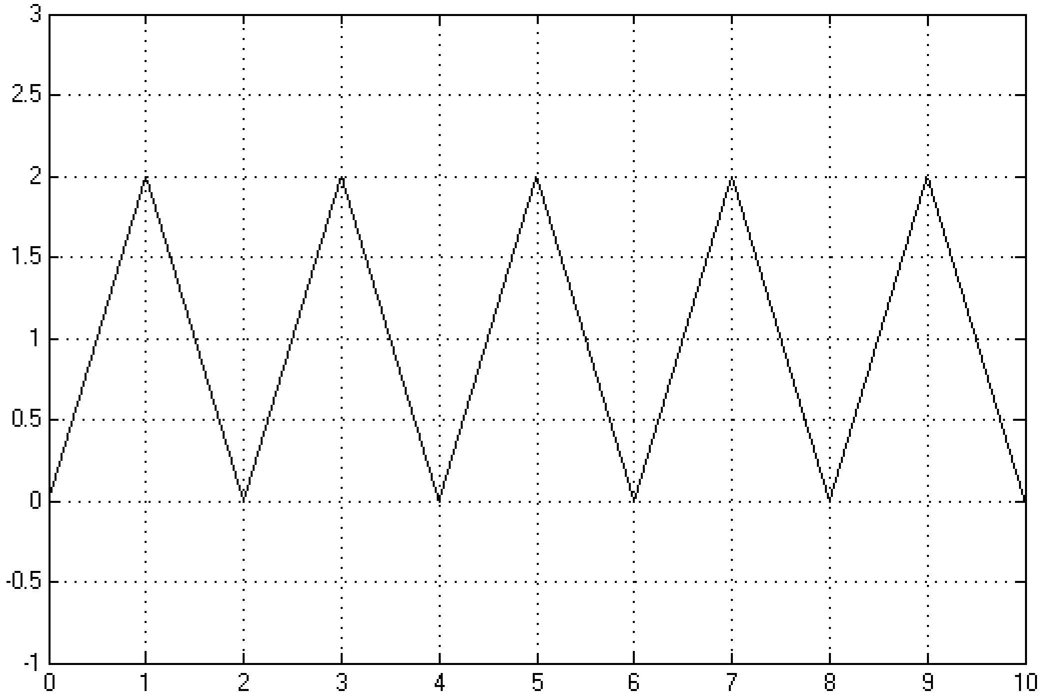
Description

The `Repeating Sequence` block outputs a periodic piecewise linear signal, *y*. You can optionally specify an initial signal value and an initial time offset. The repeating sequence consists of a number of linear segments, connected to each other. The number of segments must be no greater than 20. You specify how to connect the segments by choosing a signal type. For the same set of block parameter values, the resulting output signal will be different depending on the signal type:

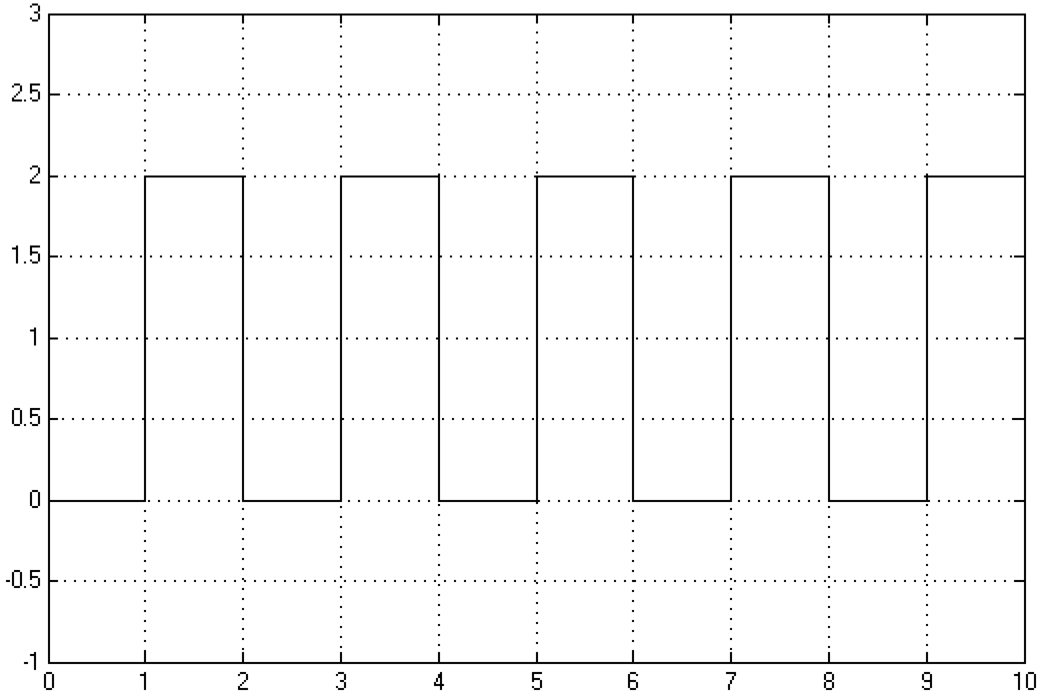
- `Discontinuous` — Each linear segment in the repeating sequence is defined by its duration, start value, and end value. If the end value of a segment is not the same as the start value of the next segment, they are connected by a vertical line.



- `Continuous` — Each linear segment in the repeating sequence is defined by its duration and start value. The end value of a segment is the same as the start value of the next segment.

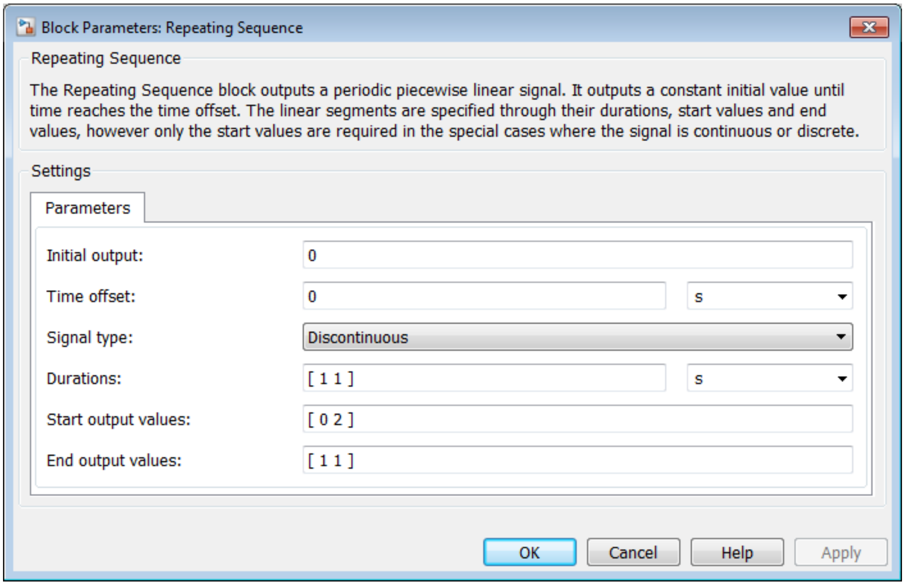


- `Discrete` — Each linear segment in the repeating sequence is defined by its duration and start value. The end value of a segment is the same as its start value.



Use this block to generate various types of physical signals, such as pulse, sawtooth, stair, and so on.

Dialog Box and Parameters



Repeating Sequence

The Repeating Sequence block outputs a periodic piecewise linear signal. It outputs a constant initial value until time reaches the time offset. The linear segments are specified through their durations, start values and end values, however only the start values are required in the special cases where the signal is continuous or discrete.

Settings

Initial output: 0

Time offset: 0 s

Signal type: Discontinuous

Durations: [1 1] s

Start output values: [0 2]

End output values: [1 1]

Initial output

The value of the output signal at time zero. The output of the block remains at this value until the simulation time reaches the **Time offset** value. The default value is `0`.

Time offset

The value of the initial time offset, before the start of the repeating sequence. During this time, the output of the block remains at the **Initial output** value. The default value is `0`.

Signal type

Select one of the following signal types:

- `Discontinuous` — For each linear segment in the repeating sequence, define its duration, start value, and end value. If the end value of a segment is not the same as the start value of the next segment, they are connected by a vertical line. This is the default method.
- `Continuous` — For each linear segment in the repeating sequence, define its duration and start value. The end value of a segment is the same as the start value of the next segment.

- `Discrete` — For each linear segment in the repeating sequence, define its duration and start value. The end value of a segment is the same as its start value.

Durations

Specify the linear segment durations as a 1–by–*n* row vector, where *n* is the number of linear segments in the repeating sequence. *n* must be no greater than 20. The default is `[ 1 1 ]`s, which means two linear segments, each lasting 1 second.

Start output values

Specify the start values of the output signal for each linear segment as a 1–by–*n* row vector, where *n* is the number of linear segments in the repeating sequence. The size of the vector must be no greater than 20 and must match the size of the **Durations** row vector. The default is `[ 0 2 ]`, which means that the first of the two linear segments starts at 0, and the second one starts at 2.

End output values

Specify the end values of the output signal for each linear segment as a 1–by–*n* row vector, where *n* is the number of linear segments in the repeating sequence. The size of the vector must be no greater than 20 and must match the size of the **Durations** row vector. The default is `[ 1 1 ]`. This parameter is only visible if the **Signal type** parameter is set to `Discontinuous`. For other signal types, the end value of a segment is defined either by the start value of the next segment (`Continuous`) or the start value of the same segment (`Discrete`).

Ports

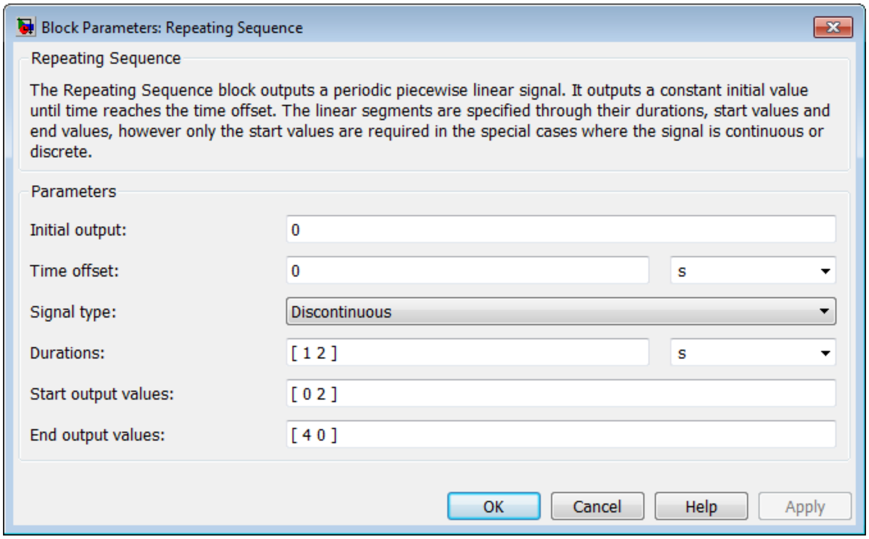
The block has one physical signal output port.

Examples

Discontinuous Repeating Sequence

This example shows the mapping between the block parameter values and the resulting output signal.

Set the block parameters as shown:



Block Parameters: Repeating Sequence

Repeating Sequence

The Repeating Sequence block outputs a periodic piecewise linear signal. It outputs a constant initial value until time reaches the time offset. The linear segments are specified through their durations, start values and end values, however only the start values are required in the special cases where the signal is continuous or discrete.

Parameters

Initial output: 0

Time offset: 0 s

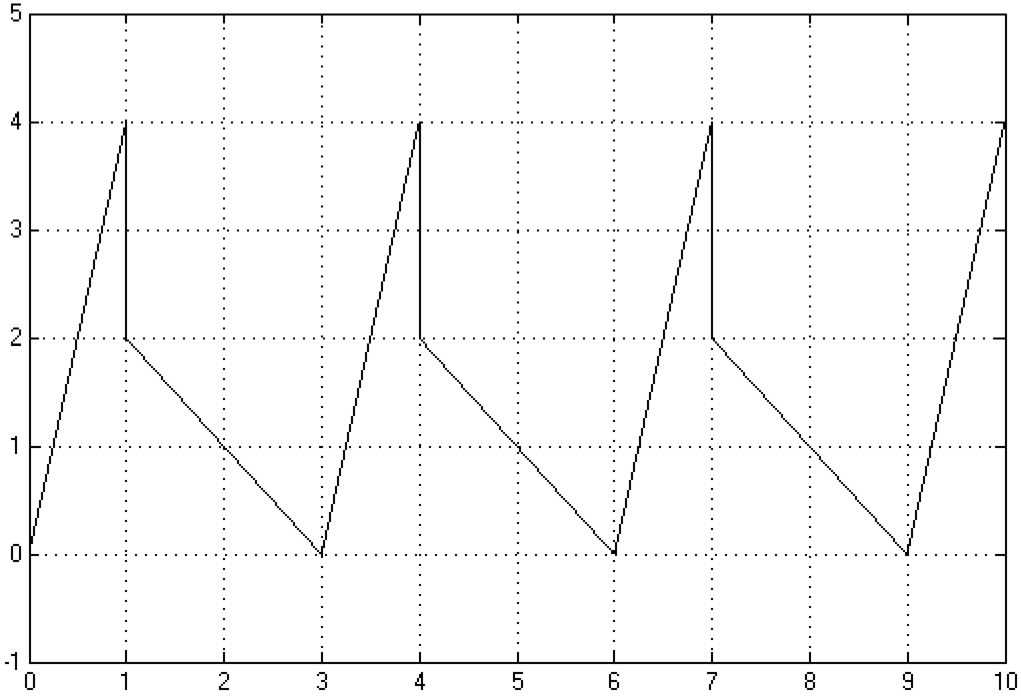
Signal type: Discontinuous

Durations: [1 2] s

Start output values: [0 2]

End output values: [4 0]

The following plot shows the resulting block output.



The signal starts at 0 and consists of two linear segments. The duration of the first segment is 1 second, the segment starts at 0 and ends at 4. The signal is discontinuous, and the end value of the first segment is different than the start value of the second segment, therefore they are connected by a vertical line. The second segment starts at 2, lasts for 2 seconds, and ends at 0, after which the sequence repeats.

See Also

`Counter`

Resistor

Linear resistor in electrical systems

Library

Electrical Elements

Description

The `Resistor` block models a linear resistor, described with the following equation:

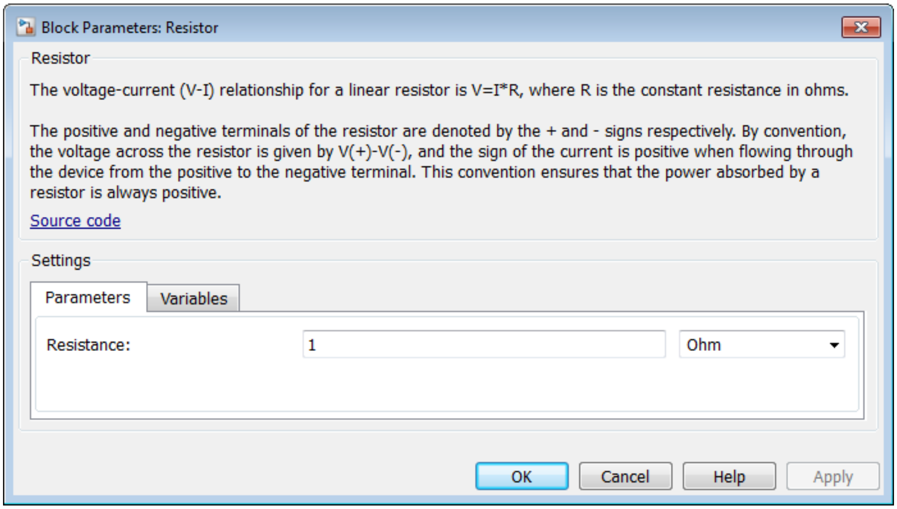
$$V = I \bullet R$$

where

V	Voltage
I	Current
R	Resistance

Connections + and – are conserving electrical ports corresponding to the positive and negative terminals of the resistor, respectively. By convention, the voltage across the resistor is given by $V(+) – V(–)$, and the sign of the current is positive when flowing through the device from the positive to the negative terminal. This convention ensures that the power absorbed by a resistor is always positive.

Dialog Box and Parameters



Block Parameters: Resistor

Resistor

The voltage-current (V-I) relationship for a linear resistor is V=I*R, where R is the constant resistance in ohms.

The positive and negative terminals of the resistor are denoted by the + and - signs respectively. By convention, the voltage across the resistor is given by V(+)-V(-), and the sign of the current is positive when flowing through the device from the positive to the negative terminal. This convention ensures that the power absorbed by a resistor is always positive.

Source code

Settings

Resistance: 1 Ohm

- “Parameters Tab” on page 1-431
- “Variables Tab” on page 1-431

Parameters Tab

Resistance

Resistance, in ohms. The default value is 1 Ω.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

+

Electrical conserving port associated with the resistor positive terminal.

-

Electrical conserving port associated with the resistor negative terminal.

See Also

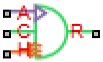
`Thermal Resistor` | `Variable Resistor`

Rotary Pneumatic Piston Chamber

Rotational pneumatic piston chamber based on ideal gas law

Library

Pneumatic Elements



Description

The `Rotary Pneumatic Piston Chamber` block models a pneumatic rotary piston chamber based on the ideal gas law and assuming constant specific heats. Use this model as a building block for pneumatic rotational actuators. The piston can generate torque in one direction only, and the direction is set by the **Chamber orientation** parameter.

The continuity equation for the network representation of the piston chamber is

$$G = \frac{V_0 + D \bullet \theta}{RT}\left(\frac{dp}{dt} - \frac{p}{T}\frac{dT}{dt}\right) + \frac{D}{RT} \bullet p \bullet \frac{d\theta}{dt}$$

where

G	Mass flow rate at input port
V_0	Initial chamber volume
D	Piston displacement (volume per unit angle)
Θ	Piston angle
p	Absolute pressure in the chamber
R	Specific gas constant
T	Absolute gas temperature
t	Time

The energy equation is

$$q = \frac{c_v}{R}\left(V_0 + D \bullet \theta\right)\frac{dp}{dt} + \frac{c_p \bullet D}{R} p \frac{d\theta}{dt} - q_w$$

where

q	Heat flow due to gas inflow in the chamber (through the pneumatic port)
q_w	Heat flow through the chamber walls (through the thermal port)
c_v	Specific heat at constant volume
c_p	Specific heat at constant pressure

The torque equation is

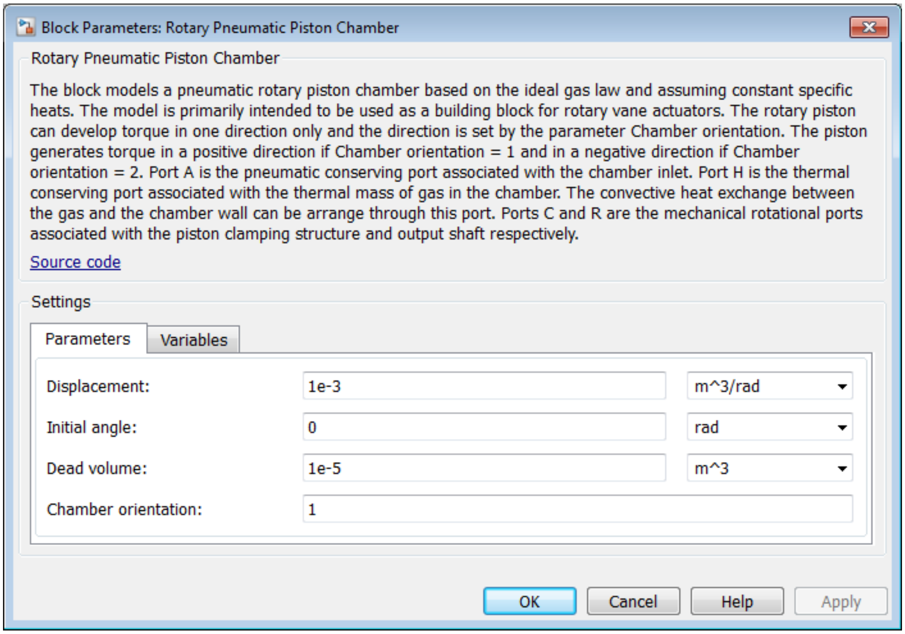
$$\tau = p \bullet D$$

Port A is the pneumatic conserving port associated with the chamber inlet. Port H is a thermal conserving port through which heat exchange with the environment takes place. Ports C and R are mechanical rotational conserving ports associated with the piston case and rod, respectively. The gas flow and the heat flow are considered positive if they flow into the chamber.

Basic Assumptions and Limitations

- The gas is ideal.
- Specific heats at constant pressure and constant volume, c_p and c_v, are constant.

Dialog Box and Parameters



Block Parameters: Rotary Pneumatic Piston Chamber

Rotary Pneumatic Piston Chamber

The block models a pneumatic rotary piston chamber based on the ideal gas law and assuming constant specific heats. The model is primarily intended to be used as a building block for rotary vane actuators. The rotary piston can develop torque in one direction only and the direction is set by the parameter Chamber orientation. The piston generates torque in a positive direction if Chamber orientation = 1 and in a negative direction if Chamber orientation = 2. Port A is the pneumatic conserving port associated with the chamber inlet. Port H is the thermal conserving port associated with the thermal mass of gas in the chamber. The convective heat exchange between the gas and the chamber wall can be arrange through this port. Ports C and R are the mechanical rotational ports associated with the piston clamping structure and output shaft respectively.

Source code

Settings

Parameters | Variables

Displacement:	1e-3	m^3/rad
Initial angle:	0	rad
Dead volume:	1e-5	m^3
Chamber orientation:	1	

- “Parameters Tab” on page 1-435
- “Variables Tab” on page 1-436

Parameters Tab

Displacement

Specify the effective piston displacement, as volume per unit angle. The default value is `.001` m^3/rad.

Initial angle

Specify the initial piston angle. The default value is `0`.

Dead volume

Specify the volume of gas in the chamber at zero piston position. The default value is `1e-5` m^3.

Chamber orientation

Specify the direction of torque generation. The piston generates torque in a positive direction if this parameter is set to `1` (the default). If you set this parameter to `2`, the piston generates torque in a negative direction.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

`A`

Pneumatic conserving port associated with the chamber inlet.

`H`

Thermal conserving port through which heat exchange with the environment takes place.

`R`

Mechanical rotational conserving port associated with the piston (rod).

`C`

Mechanical rotational conserving port associated with the reference (case).

See Also

`Constant Volume Pneumatic Chamber` | `Pneumatic Piston Chamber`

Rotational Damper

Viscous damper in mechanical rotational systems

Library

Mechanical Rotational Elements

Description

The `Rotational Damper` block represents an ideal mechanical rotational viscous damper described with the following equations:

$$T = D \cdot \omega$$

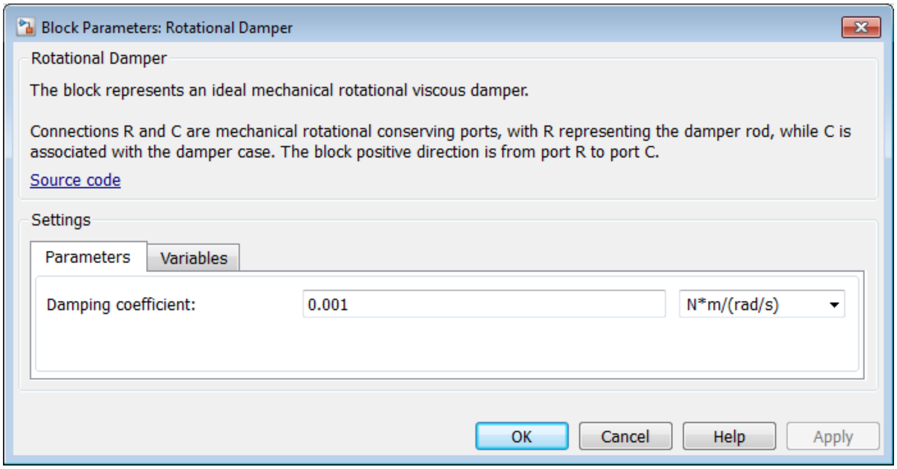
$$\omega = \omega_R - \omega_C$$

where

T	Torque transmitted through the damper
D	Damping (viscous friction) coefficient
ω	Relative angular velocity
ω_R, ω_C	Absolute angular velocities of terminals R and C, respectively

The block positive direction is from port R to port C. This means that the torque is positive if it acts in the direction from R to C.

Dialog Box and Parameters



Block Parameters: Rotational Damper

Rotational Damper

The block represents an ideal mechanical rotational viscous damper.

Connections R and C are mechanical rotational conserving ports, with R representing the damper rod, while C is associated with the damper case. The block positive direction is from port R to port C.

Source code

Settings

Parameters | Variables

Damping coefficient: 0.001 N*m/(rad/s)

- “Parameters Tab” on page 1-438
- “Variables Tab” on page 1-438

Parameters Tab

Damping coefficient

Damping coefficient, defined by viscous friction. The default value is `0.001` N*m/(rad/s).

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

R

Mechanical rotational conserving port.

`C`

Mechanical rotational conserving port.

See Also

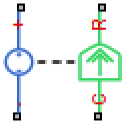
`Rotational Friction` | `Rotational Hard Stop` | `Rotational Spring`

Rotational Electromechanical Converter

Interface between electrical and mechanical rotational domains

Library

Electrical Elements



Description

The `Rotational Electromechanical Converter` block provides an interface between the electrical and mechanical rotational domains. It converts electrical energy into mechanical energy in the form of rotational motion, and vice versa. The converter is described with the following equations:

$$T = K \bullet I$$

$$V = K \bullet \omega$$

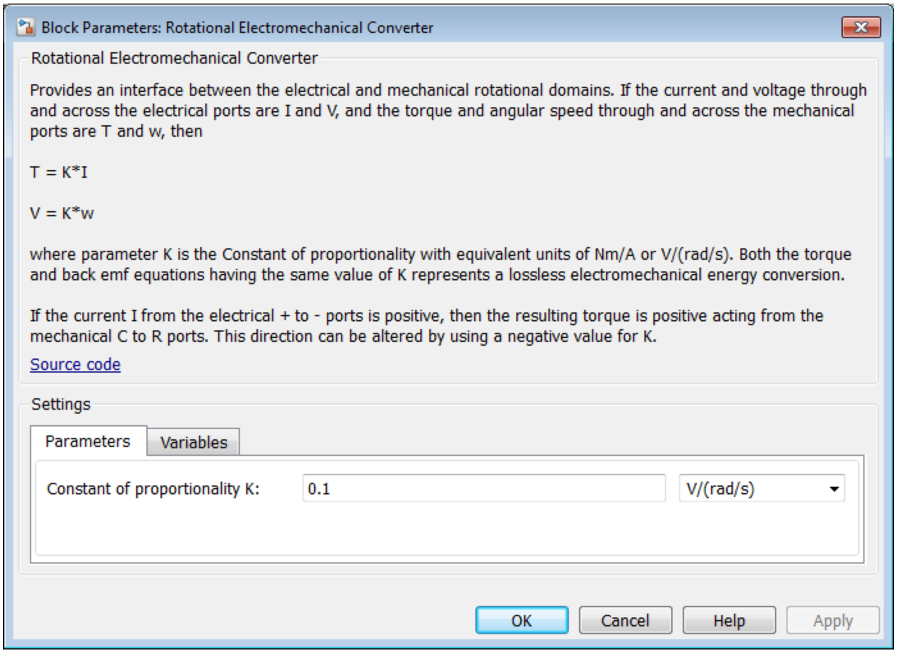
where

V	Voltage across the electrical ports of the converter
I	Current through the electrical ports of the converter
T	Torque
ω	Angular speed
K	Constant of proportionality

The Rotational Electromechanical Converter block represents a lossless electromechanical energy conversion, therefore the same constant of proportionality is used in both equations.

Connections + and – are conserving electrical ports corresponding to the positive and negative terminals of the converter, respectively. Connections C and R are conserving mechanical rotational ports. If the current flowing from the positive to the negative terminal is positive, then the resulting torque is positive acting from port C to port R. This direction can be altered by using a negative value for K.

Dialog Box and Parameters



Block Parameters: Rotational Electromechanical Converter

Rotational Electromechanical Converter

Provides an interface between the electrical and mechanical rotational domains. If the current and voltage through and across the electrical ports are I and V, and the torque and angular speed through and across the mechanical ports are T and w, then

T = K*I

V = K*w

where parameter K is the Constant of proportionality with equivalent units of Nm/A or V/(rad/s). Both the torque and back emf equations having the same value of K represents a lossless electromechanical energy conversion.

If the current I from the electrical + to - ports is positive, then the resulting torque is positive acting from the mechanical C to R ports. This direction can be altered by using a negative value for K.

Source code

Settings

Parameters | Variables

Constant of proportionality K: 0.1 V/(rad/s)

- “Parameters Tab” on page 1-441
- “Variables Tab” on page 1-442

Parameters Tab

Constant of proportionality K

Constant of proportionality for electromechanical conversions. The default value is `0.1` V/(rad/s).

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

`+`

Electrical conserving port associated with the converter positive terminal.

`-`

Electrical conserving port associated with the converter negative terminal.

`C`

Mechanical rotational conserving port.

`R`

Mechanical rotational conserving port.

See Also

`Translational Electromechanical Converter`

Rotational Free End

Rotational port terminator with zero torque

Library

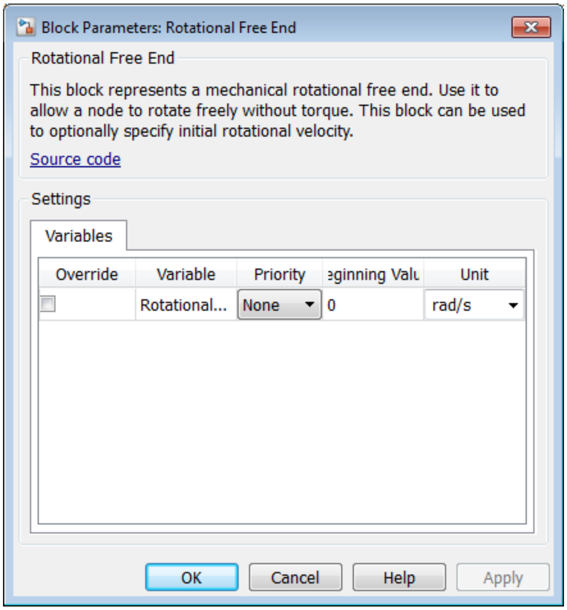
Mechanical Rotational Elements

Description

The `Rotational Free End` block represents a mechanical rotational port that rotates freely, without torque. Physical network block diagrams do not allow unconnected conserving ports. Use this block to terminate mechanical rotational ports on other blocks that you want to leave unconnected.

You can also use this block to set the initial rotational velocity at a node.

Dialog Box and Parameters



Block Parameters: Rotational Free End

Rotational Free End

This block represents a mechanical rotational free end. Use it to allow a node to rotate freely without torque. This block can be used to optionally specify initial rotational velocity.

Source code

Settings

Variables

Override	Variable	Priority	eginning Valu	Unit
□	Rotational...	None	0	rad/s

The `Rotational Free End` block has no parameters.

The **Variables** tab lets you set the priority and initial target value for the **Rotational velocity** variable prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has one mechanical rotational conserving port.

See Also

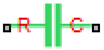
`Adiabatic Cup` | `Cap (TL)` | `Hydraulic Cap` | `Open Circuit` | `Perfect Insulator` | `Translational Free End`

Rotational Friction

Friction in contact between rotating bodies

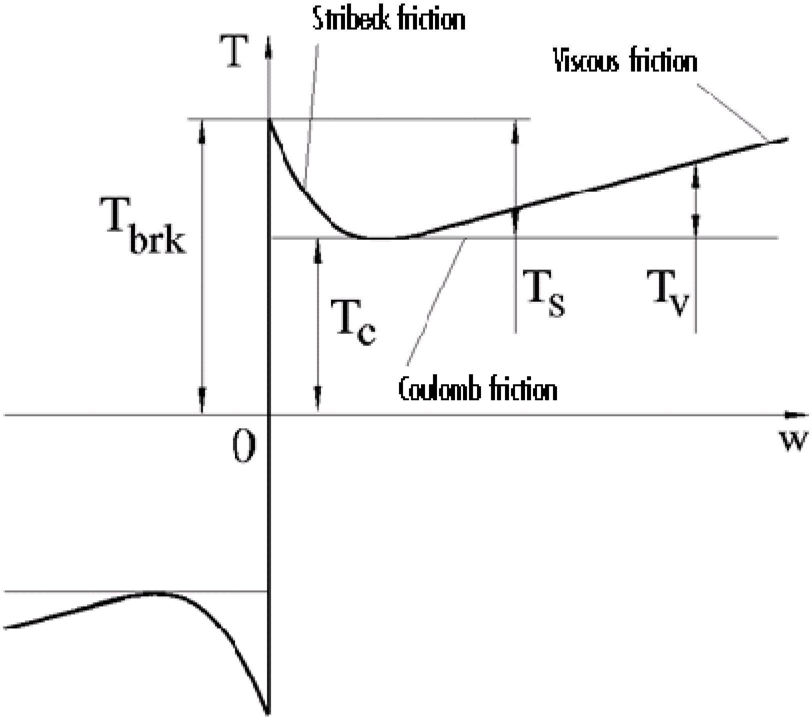
Library

Mechanical Rotational Elements



Description

The `Rotational Friction` block represents friction in contact between rotating bodies. The friction torque is simulated as a function of relative velocity and is assumed to be the sum of Stribeck, Coulomb, and viscous components, as shown in the following figure.



The Stribeck friction, T_S, is the negatively sloped characteristics taking place at low velocities (see [1]). The Coulomb friction, T_C, results in a constant torque at any velocity. The viscous friction, T_V, opposes motion with the torque directly proportional to the relative velocity. The sum of the Coulomb and Stribeck frictions at the vicinity of zero velocity is often referred to as the breakaway friction, T_{brk}. The friction is approximated with the following equations:

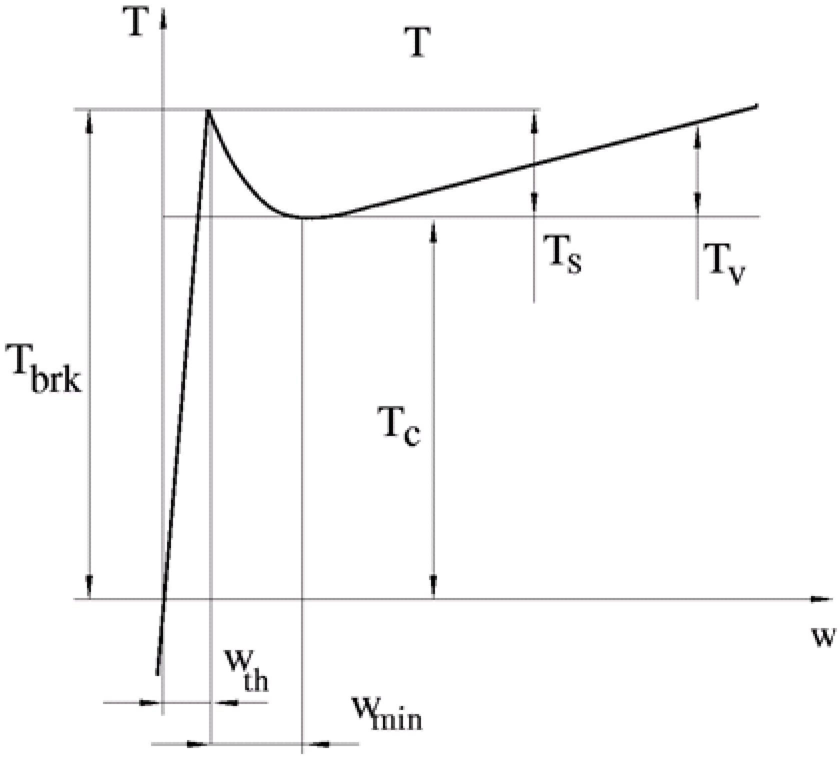
$$T = \left(T_C + (T_{brk} - T_C) \bullet \exp(-c_v \mid \omega \mid)\right) sign(\omega) + f\omega$$

$$\omega = \omega_R - \omega_C$$

where

T	Friction torque
T_C	Coulomb friction torque
T_{brk}	Breakaway friction torque
c_v	Coefficient
ω	Relative velocity
ω_R,ω_C	Absolute angular velocities of terminals R and C, respectively
f	Viscous friction coefficient

The approximation above is too idealistic and has a substantial drawback. The characteristic is discontinuous at ω = 0, which creates considerable computational problems. It has been proven that the discontinuous friction model is a nonphysical simplification in the sense that the mechanical contact with distributed mass and compliance cannot exhibit an instantaneous change in torque (see [1]). There are numerous models of friction without discontinuity. The `Rotational Friction` block implements one of the simplest versions of continuous friction models. The friction torque-relative velocity characteristic of this approximation is shown in the following figure.



The discontinuity is eliminated by introducing a very small, but finite, region in the zero velocity vicinity, within which friction torque is assumed to be linearly proportional to velocity, with the proportionality coefficient T_{brk}/ω_{th}, where ω_{th} is the velocity threshold. It has been proven experimentally that the velocity threshold in the range between 10^{-3} and 10^{-5} rad/s is a good compromise between the accuracy and computational robustness and effectiveness. Notice that friction torque computed with this approximation does not actually stop relative motion when an acting torque drops below breakaway friction level. The bodies will creep relative to each other at a very small velocity proportional to acting torque.

As a result of introducing the velocity threshold, the block equations are slightly modified:

- If $|\omega| >= \omega_{th}$,

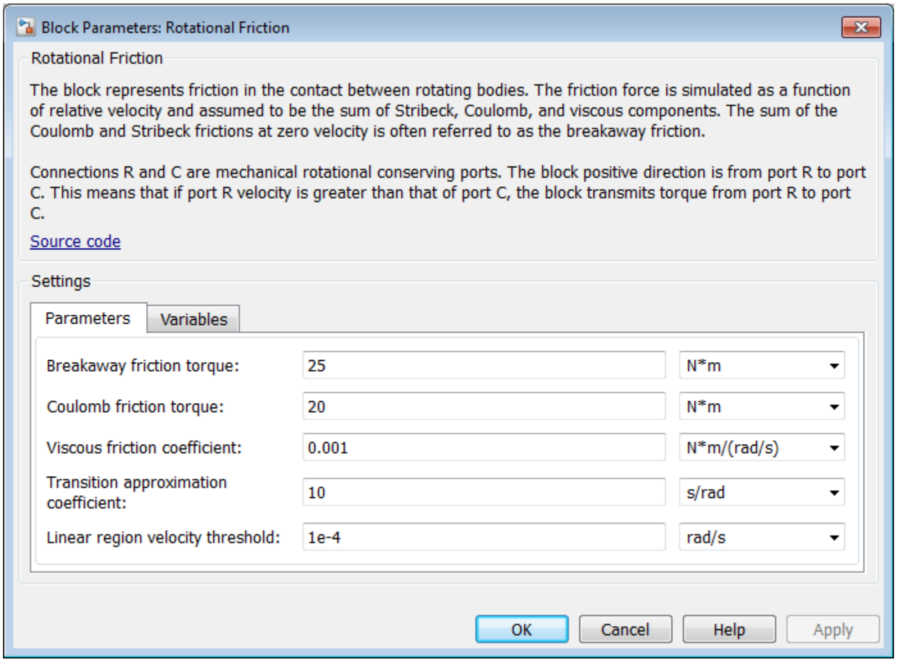
$$T = \left(T_C + \left(T_{brk} - T_C\right)\cdot\exp\left(-c_v\,|\,\omega\,|\right)\right)sign(\omega) + f\omega$$

- If $|\omega| < \omega_{th}$,

$$T = \omega\frac{\left(f\omega_{th} + \left(T_C + \left(T_{brk} - T_C\right)\cdot\exp\left(-c_v\omega_{th}\right)\right)\right)}{\omega_{th}}$$

The block positive direction is from port R to port C. This means that if the port R velocity is greater than that of port C, the block transmits torque from R to C.

Dialog Box and Parameters



Block Parameters: Rotational Friction

Rotational Friction

The block represents friction in the contact between rotating bodies. The friction force is simulated as a function of relative velocity and assumed to be the sum of Stribeck, Coulomb, and viscous components. The sum of the Coulomb and Stribeck frictions at zero velocity is often referred to as the breakaway friction.

Connections R and C are mechanical rotational conserving ports. The block positive direction is from port R to port C. This means that if port R velocity is greater than that of port C, the block transmits torque from port R to port C.

Source code

Settings

Parameters | Variables

Breakaway friction torque:	25	N*m
Coulomb friction torque:	20	N*m
Viscous friction coefficient:	0.001	N*m/(rad/s)
Transition approximation coefficient:	10	s/rad
Linear region velocity threshold:	1e-4	rad/s

- “Parameters Tab” on page 1-450

- “Variables Tab” on page 1-450

Parameters Tab

Breakaway friction torque

Breakaway friction torque, which is the sum of the Coulomb and the static frictions. It must be greater than or equal to the Coulomb friction torque value. The default value is 25 N*m.

Coulomb friction torque

Coulomb friction torque, which is the friction that opposes rotation with a constant torque at any velocity. The default value is 20 N*m.

Viscous friction coefficient

Proportionality coefficient between the friction torque and the relative angular velocity. The parameter value must be greater than or equal to zero. The default value is 0.001 N*m/(rad/s).

Transition approximation coefficient

The parameter sets the value of coefficient c_v, which is used for the approximation of the transition between the static and the Coulomb frictions. Its value is assigned based on the following considerations: the static friction component reaches approximately 95% of its steady-state value at velocity $3/c_v$, and 98% at velocity $4/c_v$, which makes it possible to develop an approximate relationship $c_v \sim= 4/\omega_{min}$, where ω_{min} is the relative velocity at which friction torque has its minimum value. By default, c_v is set to 10 rad/s, which corresponds to a minimum friction at velocity of about 0.4 s/rad.

Linear region velocity threshold

The parameter sets the small vicinity near zero velocity, within which friction torque is considered to be linearly proportional to the relative velocity. MathWorks recommends that you use values in the range between 1e-5 and 1e-3 rad/s. The default value is 1e-4 rad/s.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

`R`

Mechanical rotational conserving port.

`C`

Mechanical rotational conserving port.

Examples

The Mechanical Rotational System with Stick-Slip Motion example illustrates the use of the `Rotational Friction` block in mechanical systems. The friction element is installed between the load and the velocity source, and there is a difference between the breakaway and the Coulomb frictions. As a result, stick-slip motion is developed in the regions of constant velocities.

References

[1] B. Armstrong, C.C. de Wit, *Friction Modeling and Compensation*, The Control Handbook, CRC Press, 1995

See Also

`Rotational Damper` | `Rotational Hard Stop` | `Rotational Spring`

Rotational Hard Stop

Double-sided rotational hard stop

Library

Mechanical Rotational Elements

Description

The `Rotational Hard Stop` block represents a double-sided mechanical rotational hard stop that restricts motion of a body between upper and lower bounds. Both ports of the block are of mechanical rotational type. The impact interaction between the slider and the stops is assumed to be elastic. The stop is implemented as a spring that comes into contact with the slider as the gap is cleared. The spring opposes slider penetration into the stop with the force linearly proportional to this penetration. To account for energy dissipation and nonelastic effects, the damping is introduced as a block parameter, thus making it possible to account for energy loss.

The hard stop is described with the following equations:

$$T = \begin{cases} K_p \bullet \delta + D_p\left(\omega_R - \omega_C\right) & \text{for } \delta >= g_p \\ 0 & \text{for } g_n < \delta < g_p \\ K_n \bullet \delta + D_n\left(\omega_R - \omega_C\right) & \text{for } \delta <= g_n \end{cases}$$

$$\delta = \varphi_R - \varphi_C$$

$$\omega_R = \frac{d\varphi_R}{dt}$$

$$\omega_C = \frac{d\varphi_C}{dt}$$

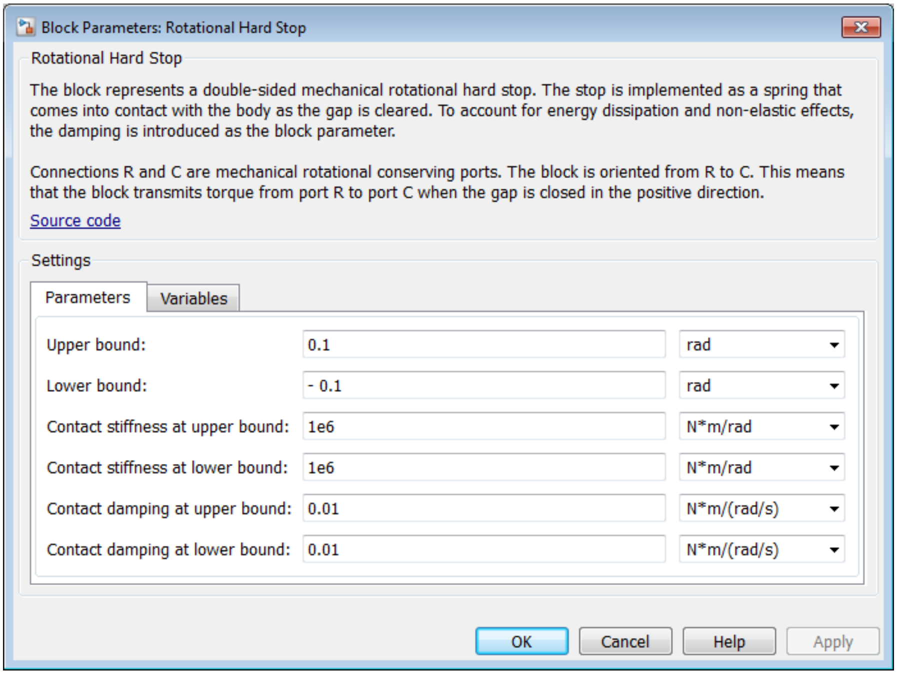
where

T	Interaction torque between the slider and the case
δ	Relative angular displacement between the slider and the case
g_p	Gap between the slider and the case in positive direction
g_n	Gap between the slider and the case in negative direction
ω_R, ω_C	Absolute angular velocities of terminals R and C, respectively
φ_R, φ_C	Absolute angular displacements of terminals R and C, respectively
K_p	Contact stiffness at positive restriction
K_n	Contact stiffness at negative restriction
D_p	Damping coefficient at positive restriction
D_n	Damping coefficient at negative restriction
t	Time

The equations are derived with respect to the local coordinate system whose axis is directed clockwise from port R to port C. The terms “positive” and “negative” in the variable descriptions refer to this coordinate system, and the gap in negative direction must be specified with negative value. If the local coordinate system is not aligned with the globally assigned positive direction, the gaps interchange their values with respective sign adjustment.

The block is oriented from R to C. This means that the block transmits torque from port R to port C when the gap in positive direction is cleared up.

Dialog Box and Parameters



Rotational Hard Stop

The block represents a double-sided mechanical rotational hard stop. The stop is implemented as a spring that comes into contact with the body as the gap is cleared. To account for energy dissipation and non-elastic effects, the damping is introduced as the block parameter.

Connections R and C are mechanical rotational conserving ports. The block is oriented from R to C. This means that the block transmits torque from port R to port C when the gap is closed in the positive direction.

Source code

Settings

Upper bound:	0.1	rad
Lower bound:	- 0.1	rad
Contact stiffness at upper bound:	1e6	N*m/rad
Contact stiffness at lower bound:	1e6	N*m/rad
Contact damping at upper bound:	0.01	N*m/(rad/s)
Contact damping at lower bound:	0.01	N*m/(rad/s)

- "Parameters Tab" on page 1-454
- "Variables Tab" on page 1-455

Parameters Tab

Upper bound

Gap between the slider and the upper bound. The direction is specified with respect to the local coordinate system, with the slider located in the origin. A positive value of the parameter specifies the gap between the slider and the upper bound. A negative value sets the slider as penetrating into the upper bound. The default value is `0.1` rad.

Lower bound

Gap between the slider and the lower bound. The direction is specified with respect to the local coordinate system, with the slider located in the origin. A negative value of the parameter specifies the gap between the slider and the lower bound. A positive value sets the slider as penetrating into the lower bound. The default value is `-0.1` rad.

Contact stiffness at upper bound

The parameter specifies the elastic property of colliding bodies when the slider hits the upper bound. The greater the value of the parameter, the less the bodies penetrate into each other, the more rigid the impact becomes. Lesser value of the parameter makes contact softer, but generally improves convergence and computational efficiency. The default value is `1e6` N*m/rad.

Contact stiffness at lower bound

The parameter specifies the elastic property of colliding bodies when the slider hits the lower bound. The greater the value of the parameter, the less the bodies penetrate into each other, the more rigid the impact becomes. Lesser value of the parameter makes contact softer, but generally improves convergence and computational efficiency. The default value is `1e6` N*m/rad.

Contact damping at upper bound

The parameter specifies dissipating property of colliding bodies when the slider hits the upper bound. At zero damping, the impact is close to an absolutely elastic one. The greater the value of the parameter, the more energy dissipates during an interaction. Keep in mind that damping affects slider motion as long as the slider is in contact with the stop, including the period when slider is pulled back from the contact. For computational efficiency and convergence reasons, MathWorks recommends that you assign a nonzero value to this parameter. The default value is 0.01 N*m*s/rad.

Contact damping at lower bound

The parameter specifies dissipating property of colliding bodies when the slider hits the lower bound. At zero damping, the impact is close to an absolutely elastic one. The greater the value of the parameter, the more energy dissipates during an interaction. Keep in mind that damping affects slider motion as long as the slider is in contact with the stop, including the period when slider is pulled back from the contact. For computational efficiency and convergence reasons, MathWorks recommends that you assign a nonzero value to this parameter. The default value is 0.01 N*m*s/rad.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

`R`

Mechanical rotational conserving port associated with the slider that travels between stops installed on the case.

`C`

Mechanical rotational conserving port associated with the case.

See Also

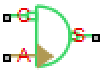
`Rotational Spring` | `Rotational Damper` | `Rotational Friction`

Rotational Hydro-Mechanical Converter

Interface between hydraulic and mechanical rotational domains

Library

Hydraulic Elements



Description

The `Rotational Hydro-Mechanical Converter` block models an ideal transducer that converts hydraulic energy into mechanical energy, in the form of rotational motion of the converter shaft, and vice versa. Physically, the converter represents the main component of a single-acting rotary vane actuator. The compressibility option makes the converter account for dynamic variations of the fluid density.

Using this block as a basic element, you can build a large variety of rotary actuators by adding application-specific effects, such as leakage, friction, hard stops, and so on.

The converter is simulated according to the following equations:

$$q = \frac{d\left(\frac{\rho}{\rho_l^0} V\right)}{dt} = \frac{d\left(\frac{\rho}{\rho_l^0}\right)}{dt} V + \frac{\rho}{\rho_l^0} \cdot \varepsilon \cdot (\omega_S - \omega_C) \cdot D$$

$$T = \varepsilon \cdot p \cdot D$$

$$\rho = \begin{cases} \dfrac{\left(\frac{\alpha}{1-\alpha}\right)\rho_g^0 + \rho_l^0}{\left(\frac{\alpha}{1-\alpha}\right)\left(\frac{p_0}{p}\right)^{\frac{1}{\gamma}} + e^{-\frac{p-p_0}{\beta_l}}} & \text{if compressibility is on} \\ \rho_l^0 & \text{if compressibility is off} \end{cases}$$

where

q	Flow rate to the converter chamber
D	Converter displacement, or fluid volume needed to rotate the shaft per angle unit
ω_S	Converter shaft angular velocity
ω_C	Converter case angular velocity
T	Torque on the shaft
p	Gauge pressure of fluid in the converter chamber
V	Piston volume
α	Relative amount of trapped air
ρ_l^0	Fluid density at atmospheric conditions
ρ_g^0	Gas density at atmospheric conditions
p_0	Atmospheric pressure
γ	Specific heat ratio
β_l	Bulk modulus at atmospheric conditions and no gas
ε	Converter orientation with respect to the globally assigned positive direction. If pressure applied at port A generates torque in positive direction, ε equals 1. If pressure applied at port A generates torque in negative direction, ε equals –1.

The piston volume is computed according to

$$V = V_{dead} + D \cdot (\theta_0 + \theta)$$

$$\frac{d\theta}{dt} = \varepsilon \cdot (\omega_S - \omega_C)$$

where

V_{dead}	Chamber dead volume
θ_0	Shaft initial angle
θ	Shaft rotation from initial position

Port A is a hydraulic conserving port associated with the converter inlet. Ports S and C are mechanical rotational conserving ports associated with the shaft and the case of the converter, respectively. Pressure at port A generates torque in the direction specified by the **Converter orientation** parameter.

The block dialog box does not have a **Source code** link. To view the underlying component source, open the following files in the MATLAB editor:

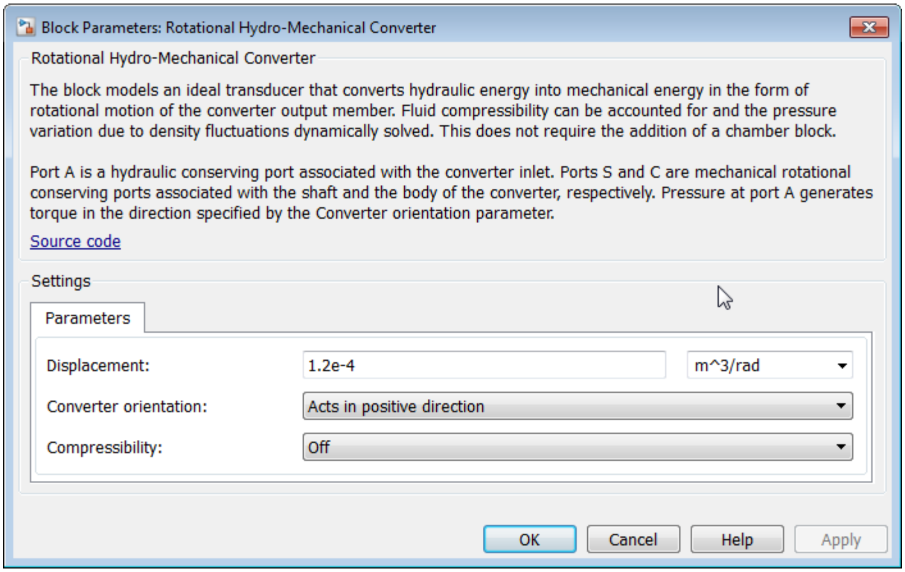
- For incompressible converter implementation — `*matlabroot*\toolbox\physmod\simscape\library\m\+foundation\+hydraulic\+elements\rotational_converter_incompressible.ssc`
- For compressible converter implementation — `*matlabroot*\toolbox\physmod\simscape\library\m\+foundation\+hydraulic\+elements\rotational_converter_compressible.ssc`

where *`matlabroot`* is your root folder.

Basic Assumptions and Limitations

The block simulates an ideal converter, with an option to account for fluid compressibility. Other effects, such as hard stops, inertia, or leakage, are modeled outside of the converter.

Dialog Box and Parameters



Rotational Hydro-Mechanical Converter

The block models an ideal transducer that converts hydraulic energy into mechanical energy in the form of rotational motion of the converter output member. Fluid compressibility can be accounted for and the pressure variation due to density fluctuations dynamically solved. This does not require the addition of a chamber block.

Port A is a hydraulic conserving port associated with the converter inlet. Ports S and C are mechanical rotational conserving ports associated with the shaft and the body of the converter, respectively. Pressure at port A generates torque in the direction specified by the Converter orientation parameter.

Displacement: 1.2e-4 m^3/rad

Converter orientation: Acts in positive direction

Compressibility: Off

Displacement

Effective converter displacement. The default value is `1.2e-4` m^3/rad.

Converter orientation

Specifies converter orientation with respect to the globally assigned positive direction. The converter can be installed in two different ways, depending upon whether it generates torque in the positive or in the negative direction when pressure is applied at its inlet. If pressure applied at port A generates torque in negative direction, set the parameter to `Acts in negative direction`. The default value is `Acts in positive direction`.

Compressibility

Specifies whether fluid density is taken as constant or varying with pressure. The default value is `Off`, in which case the block models an ideal transducer. If you select `On`, the block dialog box displays additional parameters that let you model dynamic variations of the fluid density without adding any extra blocks.

Shaft initial angle

Initial offset of the piston from the cylinder cap. The default value is `0`.

Chamber dead volume

Volume of fluid in the chamber at zero piston position. The default value is `1e-4` m^3.

Specific heat ratio

Gas-specific heat ratio. The default value is `1.4`.

Initial pressure

Initial pressure in the chamber. This parameter specifies the initial condition for use in computing the block's initial state at the beginning of a simulation run. The default value is `0`.

Restricted Parameters

When your model is in Restricted editing mode, you cannot modify the following parameters:

- **Converter orientation**
- **Compressibility**

All other block parameters are available for modification.

Ports

The block has the following ports:

`A`

Hydraulic conserving port associated with the converter inlet.

`S`

Mechanical rotational conserving port associated with the shaft of the converter.

`C`

Mechanical rotational conserving port associated with the case of the converter.

See Also

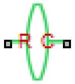
`Translational Hydro-Mechanical Converter`

Rotational Inerter

Two-port inertia in mechanical rotational systems

Library

Mechanical Rotational Elements



Description

The `Rotational Inerter` block represents a device that has torque proportional to the rate of change of the relative angular velocity across the ports. It is essentially a two-port inertia that works on the velocity difference between the ports, not the absolute velocity.

Use this block in high performance suspension systems, to decouple weave and roll modes, or in applications where you need to model a passively tuned mass-spring-damper response.

The block is described with the following equations:

$$T = B\frac{d\omega}{dt}$$

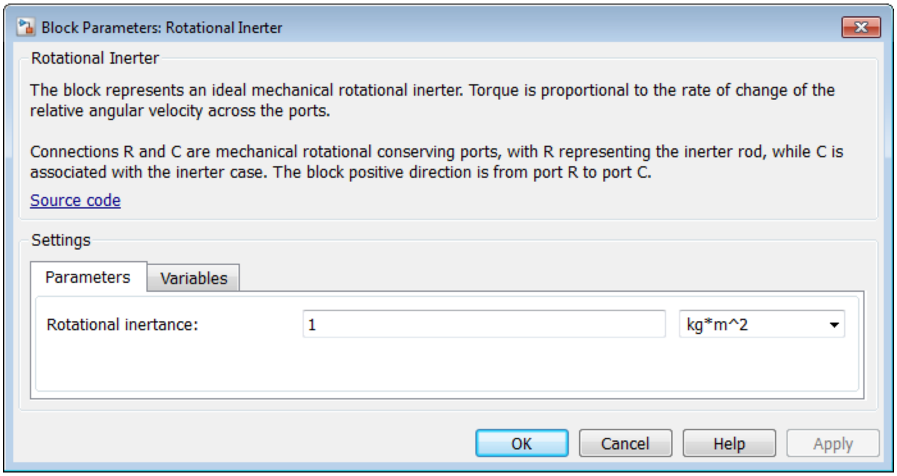
$$\omega = \omega_R - \omega_C$$

where

T	Torque transmitted through the inerter
B	Rotational inertance
ω	Relative angular velocity
ω_R, ω_C	Absolute angular velocities at ports R and C, respectively

The block positive direction is from port R to port C. This means that the torque is positive if it acts in the direction from R to C.

Dialog Box and Parameters


Block Parameters: Rotational Inerter

Rotational Inerter

The block represents an ideal mechanical rotational inerter. Torque is proportional to the rate of change of the relative angular velocity across the ports.

Connections R and C are mechanical rotational conserving ports, with R representing the inerter rod, while C is associated with the inerter case. The block positive direction is from port R to port C.

Source code

Settings

Rotational inertance: 1 kg*m^2

- “Parameters Tab” on page 1-463
- “Variables Tab” on page 1-463

Parameters Tab

Rotational inertance

Proportionality coefficient between the torque and the rate of change of the relative angular velocity across the ports. The default value is 1 kg*m/^2.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

R

Mechanical rotational conserving port associated with the rod.

`C`

Mechanical rotational conserving port associated with the case.

See Also

`Inertia`

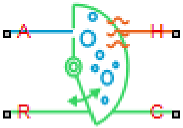
Introduced in R2015b

Rotational Mechanical Converter (2P)

Interface between two-phase fluid and mechanical rotational networks

Library

Two-Phase Fluid/Elements



Description

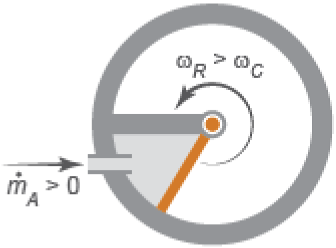
The `Rotational Mechanical Converter (2P)` block models an interface between two-phase fluid and mechanical rotational networks. The interface converts pressure in the fluid network into torque in the mechanical rotational network and vice versa.

This block enables you to model a rotary actuator powered by a two-phase fluid system. It does not, however, account for inertia, friction, or hard stops, common in rotary actuators. You can model these effects separately using Simscape blocks such as `Inertia`, `Rotational Friction`, and `Rotational Hard Stop`.

Port A represents the inlet through which fluid enters and exits the converter. Ports C and R represent the converter casing and moving interface, respectively. Port H represents the wall through which the converter exchanges heat with its surroundings.

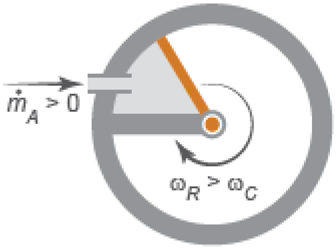
Torque Direction

The torque direction depends on the mechanical orientation of the converter. If the **Mechanical Orientation** parameter is positive, then a positive flow rate through the inlet tends to rotate the moving interface in the positive direction relative to the converter casing.



Positive Mechanical Orientation

If the **Mechanical Orientation** parameter is negative, then a positive mass flow rate through the inlet tends to rotate the moving interface in the negative direction relative to the converter casing.



Negative Mechanical Orientation

Flow and Thermal Resistances

The flow resistance between port A and the converter interior is assumed negligible. Pressure losses between the two is approximately zero. The pressure at port A is therefore equal to that in the converter:

$$p_A = p_I,$$

where:

- p_A is the pressure at port A.

- p_I is the pressure in the converter.

Similarly, the thermal resistance between port H and the converter interior is assumed negligible. The temperature gradient between the two is approximately zero. The temperature at port H is therefore equal to that in the converter:

$$T_H = T_I,$$

where:

- T_H is the temperature at port H.
- T_I is the temperature in the converter.

Fluid Volume

The volume of fluid in the converter is the sum of the dead and displaced fluid volumes. The dead volume is the amount of fluid left in the converter at a zero interface angle. This volume enables you to model the effects of dynamic compressibility and thermal capacity even when the interface is in its zero position.

The displacement volume is the amount of fluid added to the converter due to rotation of the moving interface. This volume increases with the interface angle. The total volume in the converter as a function of the interface angle is

$$V = V_{dead} + D_{vol}\theta_{int}\ _{or},$$

where:

- V is the total volume of fluid in the converter.
- V_{dead} is the dead volume of the converter.
- D_{vol} is the displaced fluid volume per unit rotation of the interface.
- θ_{int} is the rotation angle of the moving interface.
- $\in_{or}$ is an integer encoding the mechanical orientation of the converter:

$$_{or} = \begin{cases} +1, & \text{if the mechanical orientation is positive} \\ -1, & \text{if the mechanical orientation is negative} \end{cases}$$

Force Balance

At equilibrium, the internal pressure in the converter counteracts the external pressure of its surroundings and the torque exerted by the mechanical network on the moving interface. This torque is the reverse of that applied by the fluid network. The torque balance in the converter is therefore

$$p_I D_{vol} = p_{atm} D_{vol} - t_{int\ or},$$

where:

- p_{atm} is the environmental pressure outside the converter.
- t_{int} is the magnitude of the torque exerted by the fluid network on the moving interface.

Energy Balance

The total energy in the converter can change due to energy flow through the inlet, heat flow through the converter wall, and work done on the mechanical network. The energy flow rate, given by the energy conservation equation, is therefore

$$\dot{E} = \phi_A + \phi_H - p_I D_{vol} \dot{\theta}_{int\ or},$$

where:

- E is the total energy of the fluid in the converter.
- ϕ_{A} is the energy flow rate into the converter through port A.
- ϕ_{H} is the heat flow rate into the converter through port H.

Taking the fluid kinetic energy in the converter to be negligible, the total energy of the fluid reduces to:

$$E = M u_I,$$

where:

- M is the fluid mass in the converter.
- u_I is the specific internal energy of the fluid in the converter.

Mass Balance

The fluid mass in the converter can change due to flow through the inlet, represented by port A. The mass flow rate, given by the mass conservation equation, is therefore

$$\dot{M} = \dot{m}_A ,$$

where:

- $\dot{m}_A$ is the mass flow rate into the converter through port A.

A change in fluid mass can accompany a change in fluid volume, due to rotation of the moving interface. It can also accompany a change in mass density, due to an evolving pressure or specific internal energy in the converter. The mass rate of change in the converter is then

$$\dot{M} = \left[\left(\frac{\partial \rho}{\partial p} \right)_u \dot{p}_I + \left(\frac{\partial \rho}{\partial u} \right)_p \dot{u}_I \right] V + \frac{D_{vol} \dot{\theta}_{int\_or}}{v_I} ,$$

where:

- $\left(\frac{\partial \rho}{\partial p} \right)_u$ is the partial derivative of density with respect to pressure at constant specific internal energy.
- $\left(\frac{\partial \rho}{\partial u} \right)_p$ is the partial derivative of density with respect to specific internal energy at constant pressure.
- v_I is the specific volume of the fluid in the converter.

The block blends the density partial derivatives of the various domains using a cubic polynomial function. At a vapor quality of 0–0.1, this function blends the derivatives of the subcooled liquid and two-phase mixture domains. At a vapor quality of 0.9–1, it blends those of the two-phase mixture and superheated vapor domains.

The smoothed density partial derivatives introduce into the original mass conservation equation undesirable numerical errors. To correct for these errors, the block adds the correction term

$${}_{M} = \frac{M - V / v_I}{\tau},$$

where:

- ϵ_{M} is the correction term.
- τ is the phase-change time constant—the characteristic duration of a phase change event. This constant ensures that phase changes do not occur instantaneously, effectively introducing a time lag whenever they occur.

The final form of the mass conservation equation is

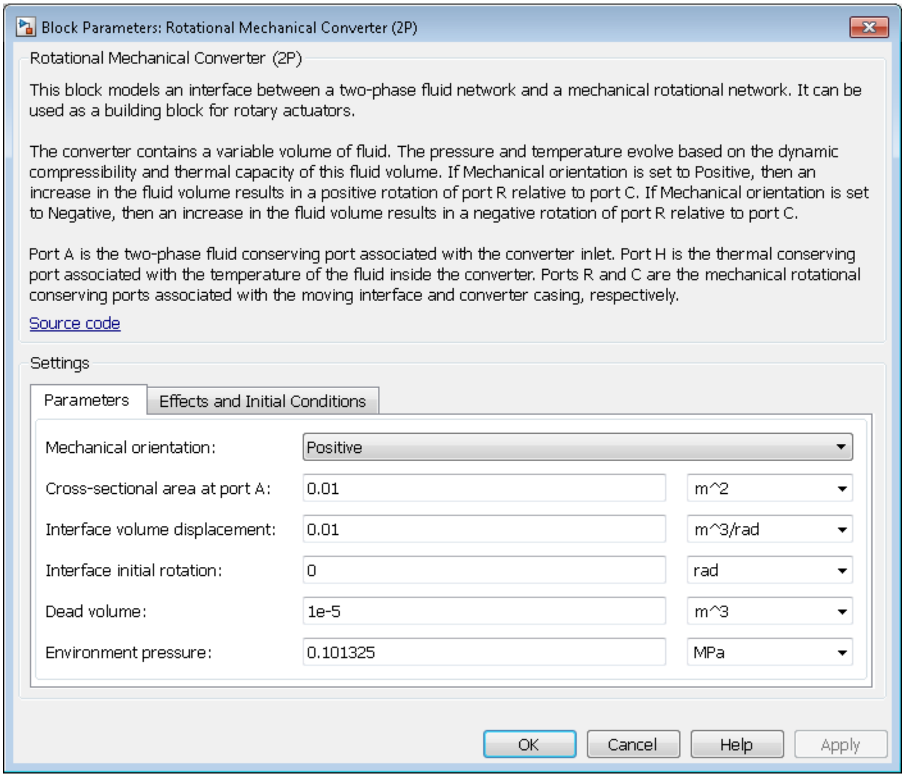
$$\left[\left(\frac{\partial \rho}{\partial p} \right)_u \dot{p}_I + \left(\frac{\partial \rho}{\partial u} \right)_p \dot{u}_I \right] V + \frac{D_{vol} \dot{\theta}_{int\_or}}{v_I} = \dot{m}_A + {}_{M} .$$

The block uses this equation to calculate the internal pressure in the converter given the mass flow rate through the inlet.

Assumptions and Limitations

- The converter walls are rigid. They do not deform under pressure.
- The flow resistance between port A and the converter interior is negligible. The pressure is the same at port A and in the converter interior.
- The thermal resistance between port H and the converter interior is negligible. The temperature is the same at port H and in the converter interior.
- The moving interface is perfectly sealed. No fluid leaks across the interface.
- Mechanical effects such as hard stops, inertia, and friction, are ignored.

Dialog Box and Parameters



Block Parameters: Rotational Mechanical Converter (2P)

Rotational Mechanical Converter (2P)

This block models an interface between a two-phase fluid network and a mechanical rotational network. It can be used as a building block for rotary actuators.

The converter contains a variable volume of fluid. The pressure and temperature evolve based on the dynamic compressibility and thermal capacity of this fluid volume. If Mechanical orientation is set to Positive, then an increase in the fluid volume results in a positive rotation of port R relative to port C. If Mechanical orientation is set to Negative, then an increase in the fluid volume results in a negative rotation of port R relative to port C.

Port A is the two-phase fluid conserving port associated with the converter inlet. Port H is the thermal conserving port associated with the temperature of the fluid inside the converter. Ports R and C are the mechanical rotational conserving ports associated with the moving interface and converter casing, respectively.

Source code

Settings

Parameters | Effects and Initial Conditions

Mechanical orientation: Positive

Cross-sectional area at port A: 0.01 m^2

Interface volume displacement: 0.01 m^3/rad

Interface initial rotation: 0 rad

Dead volume: 1e-5 m^3

Environment pressure: 0.101325 MPa

Parameters Tab

Mechanical orientation

Orientation of the moving interface relative to the two-phase fluid network. If the orientation is positive, then a positive flow into the converter results in a positive rotation of port R relative to port C. If the orientation is negative, then a positive flow into the converter results in a negative rotation of port R relative to port C. The default setting is `Positive`.

Cross-sectional area at port A

Area normal to the direction of flow at the converter inlet. The default value is `0.01` m^2.

Interface volume displacement

Displaced fluid volume per unit rotation of the moving interface. The default value is `0.01 m^3`/rad.

Interface initial rotation

Angle of the moving interface at the start of simulation. A zero angle corresponds to a total fluid volume in the converter equal to the specified dead volume. The default value is `0` rad.

This parameter must be greater than or equal to zero if the **Mechanical orientation** parameter is set to `Positive`. It must be smaller than or equal to zero if the **Mechanical orientation** parameter is set to `Negative`.

Dead volume

Volume of fluid left in the converter when the interface angle is zero. The dead volume enables the block to account for mass and energy storage in the converter even at a zero interface angle. The default value is `1e-5` m^3.

Environment pressure

Pressure outside the converter. This pressure acts against the internal pressure of the converter. A zero environment pressure corresponds to a moving interface rotating against a vacuum. The default value is `0.1013250` MPa.

Effects and Initial Conditions Tab

Initial fluid regime

Fluid regime at the start of simulation. The fluid can be a subcooled liquid, a two-phase mixture, or a superheated vapor. The default setting is `Subcooled liquid`.

Initial fluid pressure

Pressure in the converter at the start of simulation. The default value is `0.101325` MPa.

Initial fluid temperature

Temperature in the converter at the start of simulation. This parameter appears only when the **Initial fluid regime** parameter is set to `Subcooled liquid` or `Superheated vapor`. The default value is `293.15` K.

Phase change time constant

Characteristic duration of a phase-change event. This constant introduces a time lag into the transition between phases. The default value is `0.1` s.

Ports

The block has the following ports:

`A`

Two-phase fluid conserving port associated with the converter inlet.

`H`

Thermal conserving port representing the converter surface through which heat exchange occurs.

`R`

Mechanical rotational conserving port associated with the converter rotor.

`C`

Mechanical rotational conserving port associated with the converter case.

See Also

`Translational Mechanical Converter (2P)`

Rotational Mechanical Converter (TL)

Interface between thermal liquid and mechanical rotational networks

Library

Thermal Liquid/Elements

Description

The `Rotational Mechanical Converter (TL)` block represents the liquid side of a rotational mechanical interface. This interface converts liquid pressure into torque and vice versa. The output torque acts in a single direction, set using a **Mechanical orientation** parameter.

The rotational mechanical interface contains no hard stops. To include hard stops, use the Simscape `Rotational Hard Stop` block. A model of a rotational hydraulic actuator, for example, requires both blocks.

Port A is a thermal liquid conserving port corresponding to the converter inlet. Liquid pressure in the converter equals that at port A. Port Q is a thermal conserving port for modeling heat exchange between the converter liquid and the converter housing. Liquid temperature in the converter equals that at port Q.

Mass Balance

The mass conservation equation in the mechanical converter volume is

$$\dot{m}_{\mathrm{A}} = \varepsilon\rho D\Omega + \begin{cases} 0, & \text{if fluid dynamic compressibility is 'Off'} \\ V\rho\left(\dfrac{1}{\beta}\dfrac{dp}{dt} + \alpha\dfrac{dT}{dt}\right), & \text{if fluid dynamic compressibility is 'On'} \end{cases}$$

where:

- $\dot{m}_\mathrm{A}$ is the liquid mass flow rate into the converter through port A.
- ε is the mechanical orientation of the converter (1 if positive, -1 if negative).
- ρ is the liquid mass density.
- D is the converter displacement.
- Ω is the angular velocity of the converter interface (positive for converter expansion, negative for converter contraction).
- V is the liquid volume inside the converter.
- β is the liquid bulk modulus inside the converter.
- α is the coefficient of thermal expansion of the liquid.
- p is the liquid pressure inside the converter.
- T is the liquid temperature inside the converter.

Momentum Balance

The momentum conservation equation in the mechanical converter volume is

$$\tau = -\varepsilon\left(p - p_\mathrm{Atm}\right)D,$$

where:

- τ is the torque the liquid exerts on the converter interface.
- p_Atm is the atmospheric pressure.

Energy Balance

The energy conservation equation in the mechanical converter volume is

$$\frac{d\left(\rho u V\right)}{dt} = \phi_\mathrm{A} + Q_H - pD\varepsilon\Omega,$$

where:

- u is the liquid internal energy in the converter.
- ϕ_A is the total energy flow rate into the mechanical converter volume through port A.
- Q_H is the heat flow rate into the mechanical converter volume through the converter wall.

Block Source Code

To view the block source code, at the MATLAB command line enter:

```
edit <matlabroot>\toolbox\physmod\simscape\library\m\
+foundation\+thermal_liquid\+elements\<converter>.ssc
```

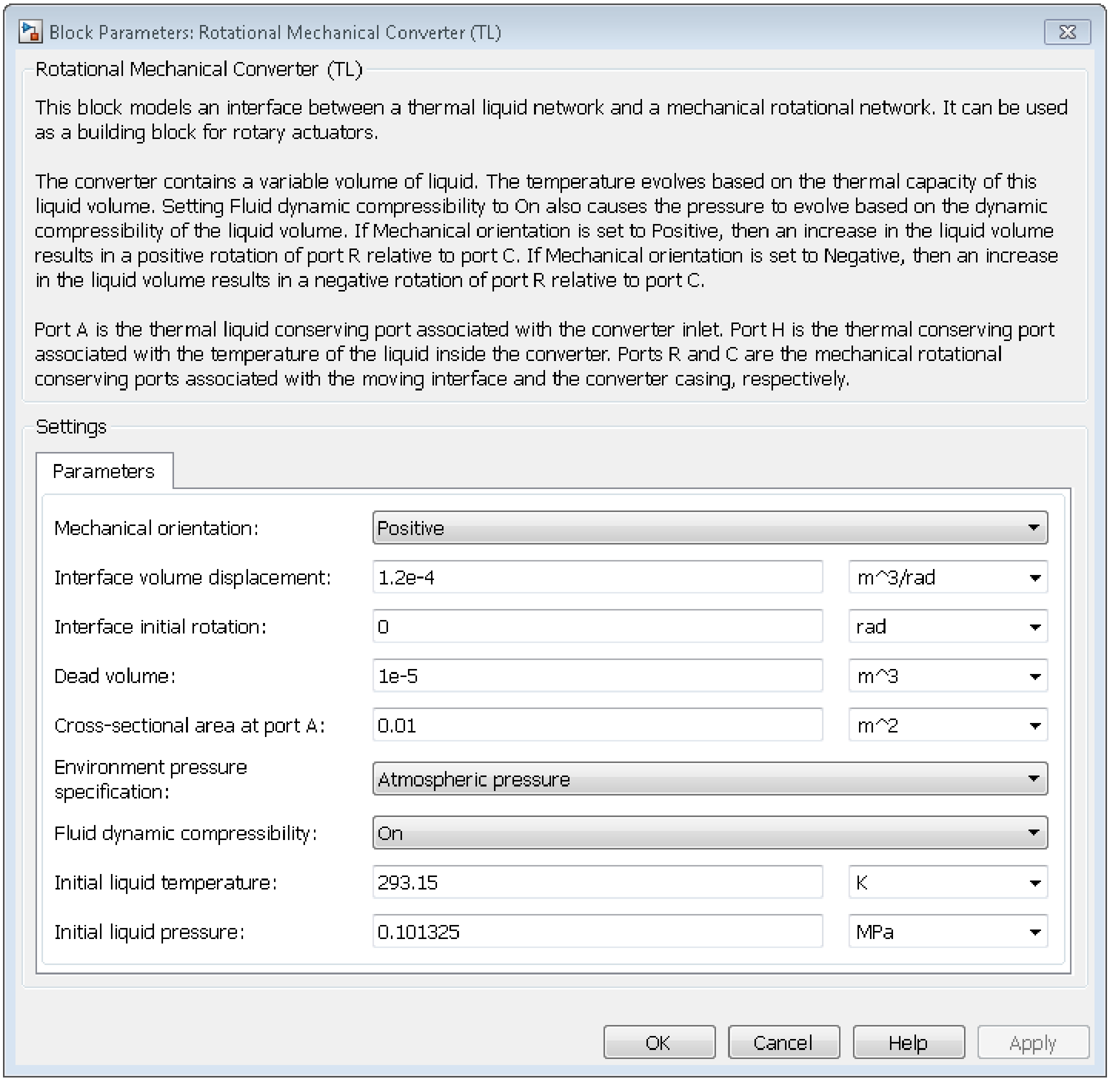
Replace `<matlabroot>` with the output of the `matlabroot` command, and `<converter>` with the compressibility configuration mode:

- `rotational_converter_compressibility` for the code corresponding to fluid dynamic compressibility 'On'
- `rotational_converter` for the code corresponding to fluid dynamic compressibility 'Off'

Assumptions and Limitations

- Converter walls are not compliant. They cannot deform regardless of internal pressure and temperature.
- The converter contains no mechanical hard stop.

Dialog Box and Parameters



Block Parameters: Rotational Mechanical Converter (TL)

Rotational Mechanical Converter (TL)

This block models an interface between a thermal liquid network and a mechanical rotational network. It can be used as a building block for rotary actuators.

The converter contains a variable volume of liquid. The temperature evolves based on the thermal capacity of this liquid volume. Setting Fluid dynamic compressibility to On also causes the pressure to evolve based on the dynamic compressibility of the liquid volume. If Mechanical orientation is set to Positive, then an increase in the liquid volume results in a positive rotation of port R relative to port C. If Mechanical orientation is set to Negative, then an increase in the liquid volume results in a negative rotation of port R relative to port C.

Port A is the thermal liquid conserving port associated with the converter inlet. Port H is the thermal conserving port associated with the temperature of the liquid inside the converter. Ports R and C are the mechanical rotational conserving ports associated with the moving interface and the converter casing, respectively.

Settings

Parameters

Mechanical orientation:	Positive	
Interface volume displacement:	1.2e-4	m^3/rad
Interface initial rotation:	0	rad
Dead volume:	1e-5	m^3
Cross-sectional area at port A:	0.01	m^2
Environment pressure specification:	Atmospheric pressure	
Fluid dynamic compressibility:	On	
Initial liquid temperature:	293.15	K
Initial liquid pressure:	0.101325	MPa

Mechanical orientation

Select the relative orientation of the converter with respect to the thermal liquid system. The relative orientation determines the rotation direction associated with positive flow into the converter. That direction is positive if the mechanical orientation of the converter is positive. It is negative if the mechanical orientation of the converter is negative. The default setting is `Positive`.

Interface volume displacement

Enter the displaced liquid volume corresponding to a unit rotation angle of the spinning converter interface. The default value is `1.2e-4` m^3/rad.

Interface initial rotation

Enter the rotation angle between the spinning converter interface and the clamping structure at time zero. The angle should be positive for positive mechanical orientations and negative for negative mechanical orientations. The default value is `0` rad.

Dead volume

Enter the liquid volume remaining in the converter at a zero rotation angle. The default value is `1e-5` m^3.

Cross-sectional area at port A

Enter the flow cross-sectional area at the converter inlet. The block uses this parameter for thermal conduction calculations. The default value is `0.01` m^2.

Environment pressure specification

Select a specification method for the environment pressure. Options include `Specified pressure` and `Atmospheric pressure`. The default setting is `Atmospheric pressure`.

Environment pressure

Enter the environment pressure for the component. This parameter is active only when the **Environment pressure specification** parameter is set to `Specified pressure`. The default value is `0.101325` MPa.

Fluid dynamic compressibility

Select whether to include the effect of fluid dynamic compressibility on the transient response of the converter model. Selecting `On` exposes an additional parameter. The default setting is `Off`.

Initial liquid temperature

Enter the liquid temperature in the converter at time zero. The default value is `293.15` K.

Initial liquid pressure

Enter the liquid pressure in the converter at time zero. This parameter is visible only if **Fluid dynamic compressibility** is `On`. The default value is `1` atm.

Ports

This block has four ports.

A	Thermal liquid conserving port
H	Thermal conserving port
R	Rotational mechanical conserving port associated with the moving interface
C	Rotational mechanical conserving port associated with the converter casing

See Also

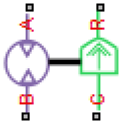
`Translational Mechanical Converter (TL)`

Rotational Pneumatic-Mechanical Converter

Interface between pneumatic and mechanical rotational domains

Library

Pneumatic Elements



Description

The `Rotational Pneumatic-Mechanical Converter` block provides an interface between the pneumatic and the mechanical rotational domains. Use it as a building block for modeling pneumatic pumps and motors.

The pneumatic flow rate and mechanical rotation are related by the following equations:

$$Q = D \cdot \omega$$

$$T = \begin{cases} D \cdot (p_A - p_B) \cdot \eta & \text{for } (p_A - p_B) \cdot \omega >= 0 \\ D \cdot (p_A - p_B) / \eta & \text{for } (p_A - p_B) \cdot \omega < 0 \end{cases}$$

where

Q	Volumetric flow rate flowing from port A to port B
p_A	Pressure at port A
p_B	Pressure at port B
ω	Shaft angular rotational speed

T	Mechanical torque
D	Volumetric displacement per unit rotation
η	Converter efficiency

The torque equation depends on the direction of power flow, and is always such that the conversion results in some thermal losses.

From considering energy flow, the heat flow out (q_o) of the converter must equate to the heat flow in (q_i) minus mechanical work done. Therefore, the heat equations are:

$$q_i = |G| \cdot c_p \cdot T_i$$

$$q_o = \begin{cases} q_i - D \cdot (p_A - p_B) \cdot \omega \cdot \eta & \text{for } (p_A - p_B) \cdot \omega >= 0 \\ q_i - D \cdot (p_A - p_B) \cdot \omega / \eta & \text{for } (p_A - p_B) \cdot \omega < 0 \end{cases}$$

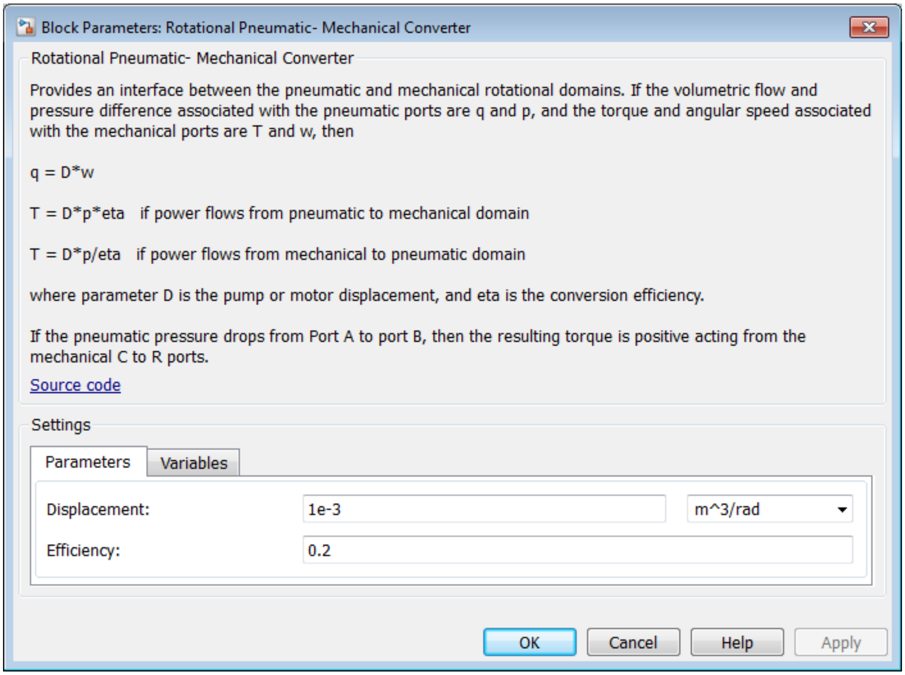
where G is the mass flow rate.

If the pneumatic pressure drops from port A to port B, then the resulting torque is positive acting from the mechanical port C to port R.

Basic Assumptions and Limitations

- Conversion efficiency is constant, that is, it does not depend on torque or speed.
- Gas flow rate is linearly dependent of pump speed.
- The process is adiabatic, that is, there is no heat transfer with the environment.
- Gravitational effects can be neglected.

Dialog Box and Parameters



Block Parameters: Rotational Pneumatic- Mechanical Converter

Rotational Pneumatic- Mechanical Converter

Provides an interface between the pneumatic and mechanical rotational domains. If the volumetric flow and pressure difference associated with the pneumatic ports are q and p, and the torque and angular speed associated with the mechanical ports are T and w, then

q = D*w

T = D*p*eta   if power flows from pneumatic to mechanical domain

T = D*p/eta   if power flows from mechanical to pneumatic domain

where parameter D is the pump or motor displacement, and eta is the conversion efficiency.

If the pneumatic pressure drops from Port A to port B, then the resulting torque is positive acting from the mechanical C to R ports.

Source code

Settings

Displacement: 1e-3 m^3/rad

Efficiency: 0.2

- "Parameters Tab" on page 1-482
- "Variables Tab" on page 1-483

Parameters Tab

Displacement

Specify the effective piston displacement, as volume per unit angle. The default value is `.001` m^3/rad.

Efficiency

Specify the converter efficiency. The default value is `0.2`.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

`A`

Pneumatic conserving port associated with the converter inlet.

`B`

Pneumatic conserving port associated with the converter outlet.

`R`

Mechanical rotational conserving port associated with the piston (rod).

`C`

Mechanical rotational conserving port associated with the reference (case).

See Also

`Rotary Pneumatic Piston Chamber`

Rotational Spring

Ideal spring in mechanical rotational systems

Library

Mechanical Rotational Elements

Description

The `Rotational Spring` block represents an ideal mechanical rotational linear spring, described with the following equations:

$$T = K \cdot \varphi$$

$$\varphi = \varphi_{init} + \varphi_R - \varphi_C$$

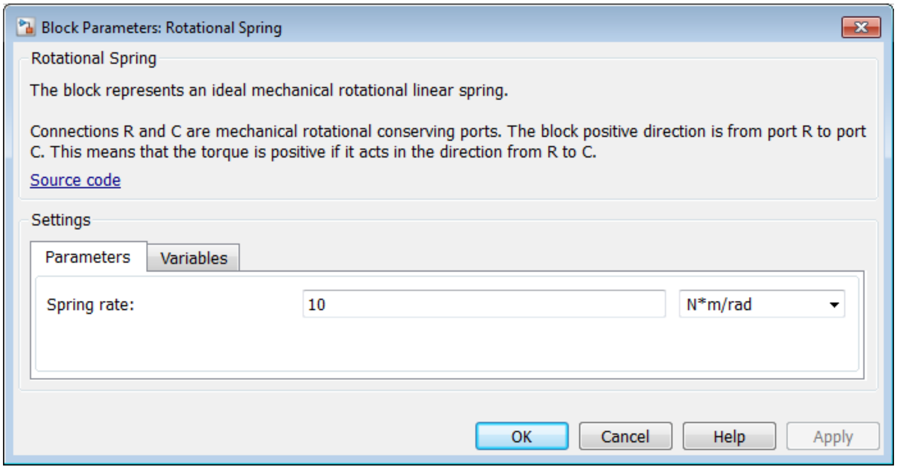
$$\omega = \frac{d\varphi}{dt}$$

where

T	Torque transmitted through the spring
K	Spring rate
φ	Relative displacement angle (spring deformation)
φ_{init}	Spring preliminary winding (spring offset)
φ_{R}, φ_{C}	Absolute angular displacements of terminals R and C, respectively
ω	Relative angular velocity
t	Time

The block positive direction is from port R to port C. This means that the torque is positive if it acts in the direction from R to C.

Dialog Box and Parameters



Block Parameters: Rotational Spring

Rotational Spring

The block represents an ideal mechanical rotational linear spring.

Connections R and C are mechanical rotational conserving ports. The block positive direction is from port R to port C. This means that the torque is positive if it acts in the direction from R to C.

Source code

Settings

Spring rate: 10 N*m/rad

- “Parameters Tab” on page 1-485
- “Variables Tab” on page 1-485

Parameters Tab

Spring rate

Spring rate. The default value is 10 N*m/rad.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

R

Mechanical rotational conserving port.

`C`

Mechanical rotational conserving port.

See Also

`Rotational Hard Stop` | `Rotational Damper` | `Rotational Friction`

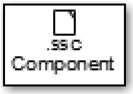
Simscape Component

Deploy Simscape language component as custom block in model diagram

Library

Utilities

Description

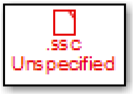


The `Simscape Component` block lets you generate a Simscape block directly from a textual component file, skipping the library build process.

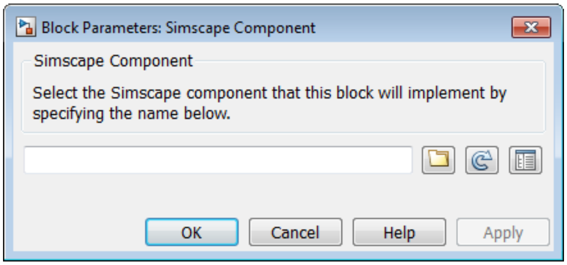
You can use the `ssc_build` command to generate a custom block library from a complete package of Simscape component files. However, you can also do on-the-fly conversion of a component file directly into a custom block in your model by using a `Simscape Component` block.

To deploy a component file directly into a block diagram:

1 Open the Simscape > Utilities library and add the `Simscape Component` block to your model. At first, the block does not point to any component file. Therefore, it does not have any ports, and the block icon states it is `Unspecified`.



2 Double-click the block to open the source file selector dialog box.



Block Parameters: Simscape Component

Simscape Component

Select the Simscape component that this block will implement by specifying the name below.

3 Browse to the desired Simscape language component file. The file does not have to be in a package. However, the directory where the file resides has to be on the MATLAB path. If the file resides in a package, then the package parent directory must be on the MATLAB path.

4 If you selected a file that is not on the MATLAB path, a File Not On Path dialog opens. Click **Add**.

5 Click **OK** to close the file selector dialog box. The block icon changes, and the block acquires the ports, parameters, and variables based on the selected source component.

   If you now double-click the block, its dialog box has all the same elements as if it was generated from the component file through a library build process: name, description, parameters, variables, and a link to **Source code**. However, the block dialog box has an additional **Choose source** button that lets you point the block to a different component file.

Source File Selector Dialog Box

When a `Simscape Component` block points to a valid Simscape language component file, its dialog box has the name, description, parameters, and variables defined by that source file. The source file selector dialog box opens in the following cases:

- When you add a new `Simscape Component` block to your model, to let you select the source component file.
- When you click the **Choose source** button in an existing `Simscape Component` block dialog, to let you select a different source component file.
- When you open a model with an unresolved `Simscape Component` block (because the underlying source component is no longer on the path) and double-click the block, to let you resolve the source location or select a different source component file.

A source component file can be located:

- In the current working directory
- In a directory on the MATLAB path
- In a package, with the package parent directory being on the MATLAB path

To specify the source file, you can either browse to it or type its name directly into the name field of the selector dialog box:

- If you type the name of the file, it must satisfy the location requirements, listed above. If the file resides in a package, you must provide the file name relative to the package root. If these conditions are not met when you type the file name, the source location cannot be resolved, and you get an error message.
- If you browse to the source file, you can select any Simscape source or protected file (that is, any file with the `.ssc` or `.sscp` extension). However, if the selected file does not satisfy the location requirements, a File Not On Path dialog opens. Click **Add** to add the appropriate directory to the MATLAB path and resolve the source location. If you click **Cancel**, the source location cannot be resolved and the source selection process is cancelled.

When the source location is successfully resolved, the name of the source file appears in the text field of the source file selector dialog box. The block name, description (if available), and the link to source code appear in the preview pane. Click **OK** or **Apply** to point the `Simscape Component` block to the selected source file:

- Clicking **Apply** updates the block icon, closes the file selector dialog box, and opens the block dialog box, which contains the parameters and variables.
- Clicking **OK** updates the block icon and closes the file selector dialog box, but does not open the block dialog box. Double-click the block if you wish to view or modify the block parameters and variables.

The buttons next to the text field in the source file selector dialog box perform the following actions:

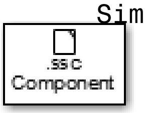
📁 Opens a file browser, to let you select the source component file. By default, the browser displays only the files with the `.ssc` or `.sscp` extension. If the `Simscape Component` block currently points to a source file, and the source location is successfully resolved, the browser opens in the directory where that source file resides. Otherwise, the browser opens in the current working directory.

Refreshes the preview pane of the source file selector dialog box. If you type the source component name directly into the text field of the selector dialog box, the preview pane does not automatically update. If you want to preview the block name, description, or source code of the source component before finalizing the selection, click this button.

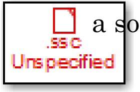
Opens the block dialog box, which contains the parameters and variables based on the selected component. This button and the **Choose source** button let you toggle between the file selector and the block dialog box for the `Simscape Component` block.

Block Icon Appearance

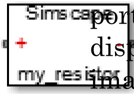
The `Simscape Component` block icon appearance changes depending on the block state.



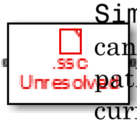
`Simscape Component` block in the library.



`Simscape Component` block just added to the model, when it is not pointing to a source component yet.



`Simscape Component` block pointing to a valid component file. The block ports are defined by the underlying component. By default, the block icon displays the component name (for example, `my_resistor`). If there is an image file with a matching name (for example, `my_resistor.png`) in the same directory as the source component file, this image replaces the default block icon. For more information, see “Customizing the Block Icon”.



`Simscape Component` block pointing to an unresolved component file. This can happen if the source component file got moved, or if it is no longer on the path. The **Add** button adds the folder to the path only for the duration of the current MATLAB session. If you do not save the path and then open the model in a subsequent session, the `Simscape Component` block becomes unresolved. If the source component is located in the current working directory, then there is no requirement for it to be on the path. However, if you later try to open the model from another directory, the `Simscape Component` block also becomes unresolved.

Related Examples

- “Deploy a Component File in Block Diagram”
- “Switch Between Different Source Components”
- “Prototype a Component and Get Instant Feedback”

More About

- “Selecting Component File Directly from Block”
- “Customizing the Block Name and Appearance”

Introduced in R2016a

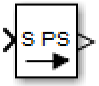
Simulink-PS Converter

Convert Simulink input signal into physical signal

Library

Utilities

Description



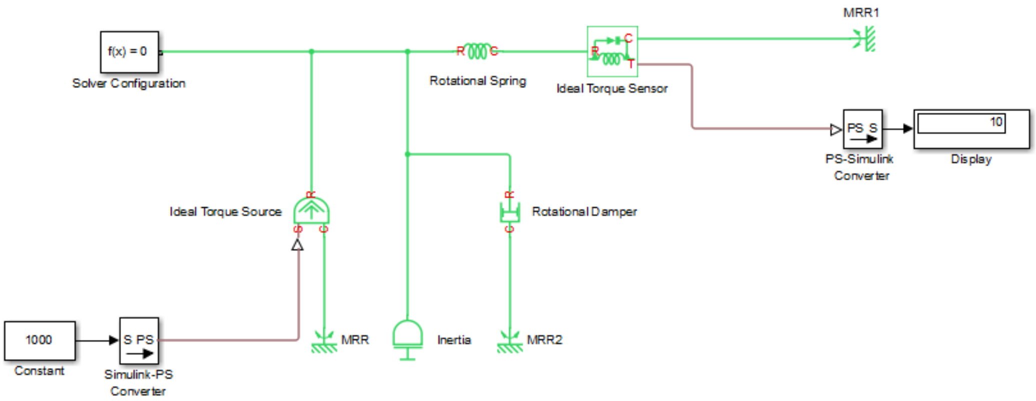
The `Simulink-PS Converter` block converts the input Simulink signal into a physical signal. Use this block to connect Simulink sources or other Simulink blocks to the inputs of a Physical Network diagram.

You specify the desired unit as the **Input signal unit** parameter. The parameter value controls the unit of the physical signal at the output port of the block, which serves as the input signal for the Simscape physical network.

Note: You can also specify a physical unit on the Simulink signal connected to the input port of the block. In this case, the software checks that the two units match (for more information, see “Working with Simulink Units”). The Simulink signal units do not propagate into the physical network.

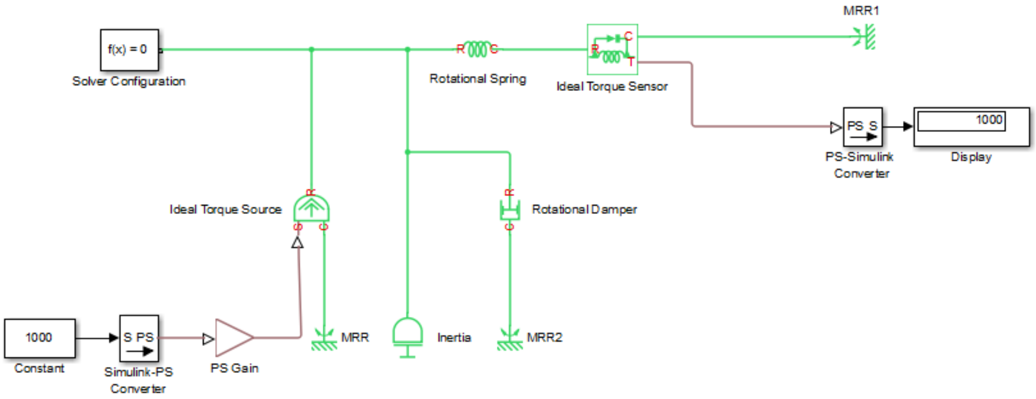
If you leave the block unitless, with the **Input signal unit** parameter set to `1`, then the physical signal unit is inferred from the destination block. The default destination block units are meter-kilogram-second or MKS (SI). If you specify different units, commensurate with the expected default units of the destination block input, then the unit manager attaches these units to the input Simulink signal value and performs the necessary unit conversion when providing the signal to the destination block.

In the diagram below, the `Ideal Torque Source` block expects a torque signal, in N*m, on its S port. The `Constant` source block provides the value for this input signal. If you left the `Simulink-PS Converter` block unitless, the `Ideal Torque Source` block would generate torque of 1000 N*m. The parameters of other blocks in this example are chosen so that the output value of the `Ideal Torque Sensor` block is equal to the torque generated by the `Ideal Torque Source` block, and therefore the `Display` block would show the value of 1000. If you change the **Input signal unit** parameter value in the `Simulink-PS Converter` block to `N*cm`, the unit manager performs the conversion and the `Ideal Torque Source` block generates torque of 10 N*m; the torque value in the `Display` block changes to 10, as shown in the diagram.



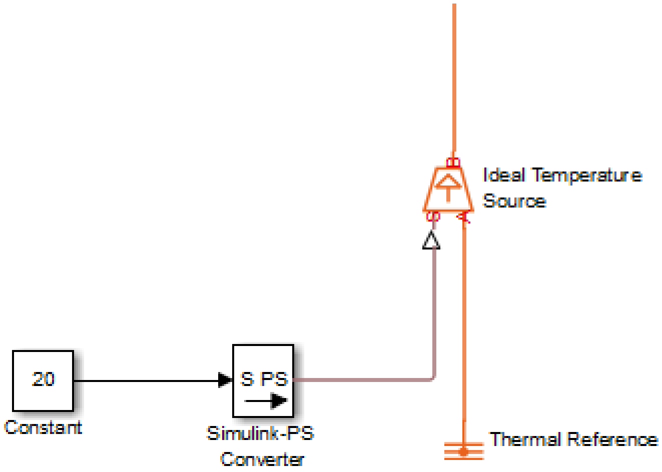
Note Currently, physical units are not propagated through the blocks in the Physical Signals library, such as `PS Add`, `PS Gain`, and so on. If your diagram contains a Physical Signals block after a `Simulink-PS Converter` block, the unit specification in the `Simulink-PS Converter` block does not propagate to the rest of the network.

In the following example, the `PS Gain` block is installed after the `Simulink-PS Converter` block. It stops the unit propagation to the rest of the physical network, and the `Ideal Torque Source` block will generate torque of 1000 N*m regardless of the **Input signal unit** parameter setting in the `Simulink-PS Converter` block.

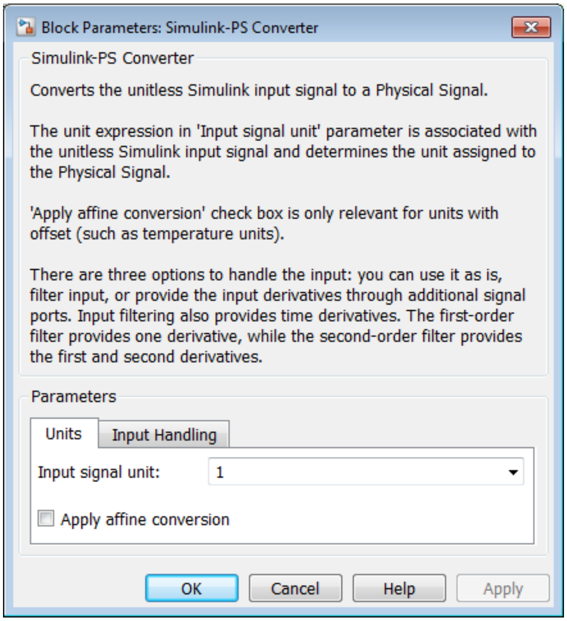


When the input signal is related to thermodynamic variables and contains units of temperature, you must decide whether affine conversion needs to be applied. For more information, see "When to Apply Affine Conversion". Usually, if the input signal represents a relative temperature, that is, a change in temperature, you need to apply linear conversion, $\Delta T_{new} = L * \Delta T_{old}$ (the default method). However, if the input signal represents an absolute temperature, you need to apply affine conversion, $T_{new} = L * T_{old} + O$.

For example, in the `Simulink-PS Converter` block shown in the following diagram, if you type `C` in the **Input signal unit** field and select the **Apply affine conversion** check box, the temperature generated by the `Ideal Temperature Source` block is equal to 293.15 K. However, if you leave the **Apply affine conversion** check box clear, the output of the `Ideal Temperature Source` block is 20 K.



Dialog Box and Parameters



Block Parameters: Simulink-PS Converter

Simulink-PS Converter

Converts the unitless Simulink input signal to a Physical Signal.

The unit expression in 'Input signal unit' parameter is associated with the unitless Simulink input signal and determines the unit assigned to the Physical Signal.

'Apply affine conversion' check box is only relevant for units with offset (such as temperature units).

There are three options to handle the input: you can use it as is, filter input, or provide the input derivatives through additional signal ports. Input filtering also provides time derivatives. The first-order filter provides one derivative, while the second-order filter provides the first and second derivatives.

Parameters

Input signal unit: 1

□ Apply affine conversion

The block dialog box has two tabs:

- “Units” on page 1-496
- “Input Handling” on page 1-496

Units

Input signal unit

Units to be assigned to the physical signal. These units must be commensurate with the expected default units of the destination block input. You can select a unit from the drop-down list, or type the desired unit name, such as `rpm`, or a valid expression, such as `rad/s`. For more information and a list of unit abbreviations, see “How to Specify Units in Block Dialogs”and “Unit Definitions”. The default value is `1`, which means that the units of the physical signal at the block output match the expected default units of the destination block input.

Apply affine conversion

This check box is applicable only for units that can be converted either with or without an affine offset, such as thermal units. For more information, see “Thermal Unit Conversions”.

Input Handling

Filtering and derivatives

This parameter lets you filter input and thus provide time derivatives of the input signal, or provide the time derivatives through additional input ports on the `Simulink-PS Converter` block:

- `Use input as is` — Do not perform input filtering or otherwise provide time derivatives of the input signal. This is the default method. If you use an explicit solver, MathWorks recommends that you provide input derivatives by selecting one of the other options for this parameter. For more information, see “Harmonizing Simulink and Simscape Solvers”.
- `Filter input` — Provide input derivatives by Filter the input through a low-pass filter, which also provides input derivatives. In this case, the input signal is modified (through filtering) before being converted to a physical signal. The first-order filter provides one derivative, while the second-order filter provides the first and second derivatives. If you use this option, set the appropriate **Input filtering time constant** parameter value, as described below.

- `Provide input derivative(s)` — Provide time derivatives of the input signal as additional input signals to the Simulink-PS Converter block. If you select this option, the input signal is not modified. You can provide just the first derivative, or both the first and second derivatives, by using the **Input derivatives** parameter, as described below.

Input filtering order

This parameter is applicable only if the **Filtering and derivatives** parameter is set to `Filter input`. It lets you specify the number of time derivatives computed for the input signal by selecting the filter order:

- `First-order filtering` — Provides only the first derivative.
- `Second-order filtering` — Provides the first and second derivatives.

Input filtering time constant (in seconds)

This parameter is applicable only if the **Filtering and derivatives** parameter is set to `Filter input`. It specifies the filter time constant, which controls the filtering of the input signal. The filtered input follows the true input but is smoothed, with a lag on the order of the time constant chosen. You should set the time constant to a value no larger than the smallest time interval of interest in the system. The trade-off in choosing a very small time constant is that the filtered input signal will be closer to the true input signal, at the cost of increasing the stiffness of the system and slowing down the simulation. The default value is `.001` s.

Input derivatives

This parameter is applicable only if the **Filtering and derivatives** parameter is set to `Provide input derivative(s)`. It lets you provide time derivatives of the input signal as additional input signals:

- `Provide first derivative` — If you select this option, an additional Simulink input port appears on the Simulink-PS Converter block, to let you connect the signal providing input derivatives.
- `Provide first and second derivatives` — If you select this option, two additional Simulink input ports appear on the Simulink-PS Converter block, to let you connect the signals providing input derivatives.

Restricted Parameters

When your model is in Restricted editing mode, you cannot modify any of the block parameters, with the following exception: if the **Filtering and derivatives** parameter is set to `Filter input` prior to entering Restricted mode, you can change the value of the **Input filtering time constant** parameter.

Ports

The block has one or two Simulink input ports, depending on the **Input derivatives** parameter value, located on its left side, and a physical signal output port, located on its right side (in the block default orientation).

See Also

`PS-Simulink Converter`

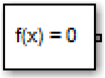
Solver Configuration

Physical Networks environment and solver configuration

Library

Utilities

Description



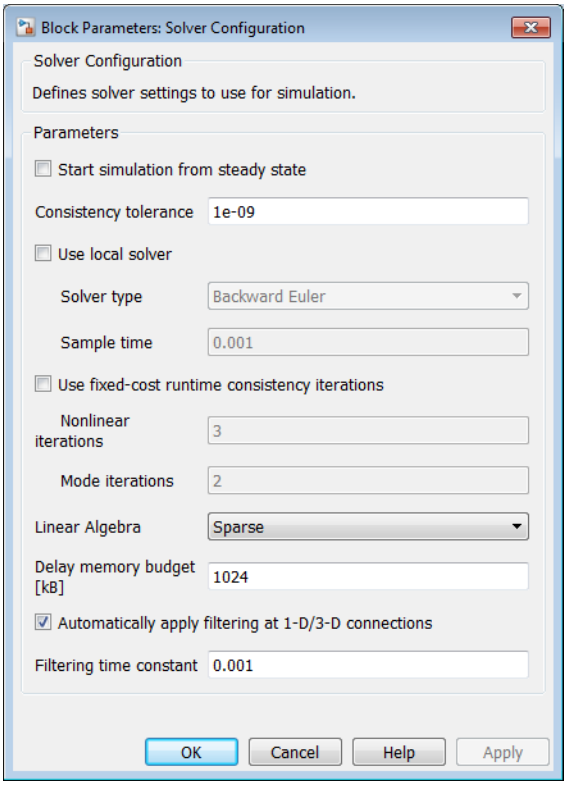
Each physical network represented by a connected Simscape block diagram requires solver settings information for simulation. The `Solver Configuration` block specifies the solver parameters that your model needs before you can begin simulation.

Each topologically distinct Simscape block diagram requires exactly one `Solver Configuration` block to be connected to it.

Ports

The block has one conserving port. You can add this block anywhere on a physical network circuit by creating a branching point and connecting it to the only port of the `Solver Configuration` block.

Dialog Box and Parameters



Block Parameters: Solver Configuration

Solver Configuration

Defines solver settings to use for simulation.

Parameters

□ Start simulation from steady state

Consistency tolerance: 1e-09

□ Use local solver

Solver type: Backward Euler

Sample time: 0.001

□ Use fixed-cost runtime consistency iterations

Nonlinear iterations: 3

Mode iterations: 2

Linear Algebra: Sparse

Delay memory budget [kB]: 1024

☑ Automatically apply filtering at 1-D/3-D connections

Filtering time constant: 0.001

Start simulation from steady state

When this box is selected, the solver attempts to find the steady state that would result if the inputs to the system were held constant for a sufficiently large time, starting from the initial state obtained from the initial conditions computation. For more information, see “Initial Conditions Computation”. Simulation then starts from this steady state.

Note Using the **Initial state** option on the **Data Import/Export** pane of the Configuration Parameters dialog box overrides the **Start simulation from steady state** option.

Consistency tolerance

This parameter affects the nonlinear solver used for computing initial conditions and for transient initialization. It determines how accurately the algebraic constraints are to be satisfied at the beginning of simulation and after every discrete event (for example, a discontinuity resulting from a valve opening, a hard stop, and so on). Decrease the parameter value (that is, tighten tolerance) to obtain a more reliable time simulation. Increase the parameter value (that is, relax the tolerance) if solving for initial conditions failed to converge, or to reduce the computation time.

The default value is `1e-9`, which is applicable to most cases.

Use local solver

Lets you use a sample-based local solver with a sample time specified by the **Sample time** parameter. In sample-based simulation, all the Physical Network states, which are otherwise continuous, become represented to Simulink as discrete states. The solver updates the states once per time step. This option is especially useful for generated code or hardware-in-the-loop (HIL) simulations.

Note If you use a local solver, simultaneous use of Simulink or Simulink Control Design™ linearization tools is not recommended.

Solver type

Select the solver type used for updating the states: `Backward Euler` or `Trapezoidal Rule`. The **Use local solver** check box must be selected. The default is `Backward Euler`.

Sample time

Specify the sample time for the local solver. The **Use local solver** check box must be selected. The sample time must be positive. The default is `.001` s.

Use fixed-cost runtime consistency iterations

Lets you perform transient initialization at a fixed computational cost.

If you select this check box, you can specify the maximum number of nonlinear and mode iterations for transient initialization. If the system does not converge upon reaching these numbers, it ignores the failure and goes to the next step.

If you clear the check box, the system uses a more robust and time-consuming algorithm, and errors out if it fails to reach convergence at the time of transient initialization.

Nonlinear iterations

Specify the maximum number of Newton iterations at the time of transient initialization. The **Use fixed-cost runtime consistency iterations** check box must be selected. The default number is `3`.

Mode iterations

Specify the maximum number of mode iterations at the time of transient initialization. The **Use fixed-cost runtime consistency iterations** check box must be selected. The default number is `2`.

Only one major mode update per step is performed when using local solvers, therefore this parameter is not available if the **Use local solver** check box is selected.

Linear Algebra

Specifies how the solver treats matrices. The parameter can have one of two values: `Sparse` or `Full`. The default value of the parameter is `Sparse`.

Your choice of this parameter value, `Sparse` or `Full`, is implemented in both model simulation and code generated from your model.

Delay memory budget [kB]

Specify the maximum memory budget, in kB, allowed for processing delays when simulating models that contain either blocks from the Delays library, or custom blocks using the `delay` Simscape language construct. The purpose of this parameter is to protect against excessive memory swapping. If this budget is exceeded, simulation errors out. You can adjust this value based on your available memory resources. The default number is `1024` kB.

Apply filtering at 1-D/3-D connections when needed

This option is applicable only for models that connect blocks from Simscape Multibody Second Generation library to Simscape blocks, or blocks from other add-on products. Use the Statistics Viewer to determine whether your model has 1-D/3-D connections. For more information, see “1-D/3-D Interface Statistics”.

When a Simscape Multibody block is connected directly to a Simscape network, an additional derivative may be required for the network to be solved. When you select this check box, the solver automatically applies input filtering to the signal entering the `Simulink-PS Converter` block to obtain this additional derivative. The **Filtering time constant** parameter provides the time constant for the delay.

Note This check box is selected by default. If you clear it, and the 1-D/3-D connection requires the additional derivative, the solver issues an error message.

Filtering time constant

This parameter specifies the filtering time constant for when the **Apply filtering at 1-D/3-D connections when needed** check box is selected. The parameter value applies globally to all connections belonging to the network that includes this Solver Configuration block. The default value is `0.001` s.

See Also

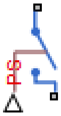
- "How Simscape Simulation Works"
- "Setting Up Solvers for Physical Models"
- "Making Optimal Solver Choices for Physical Simulation"
- "Finding an Operating Point"
- "Linearizing at an Operating Point"

Switch

Switch controlled by external physical signal

Library

Electrical Elements

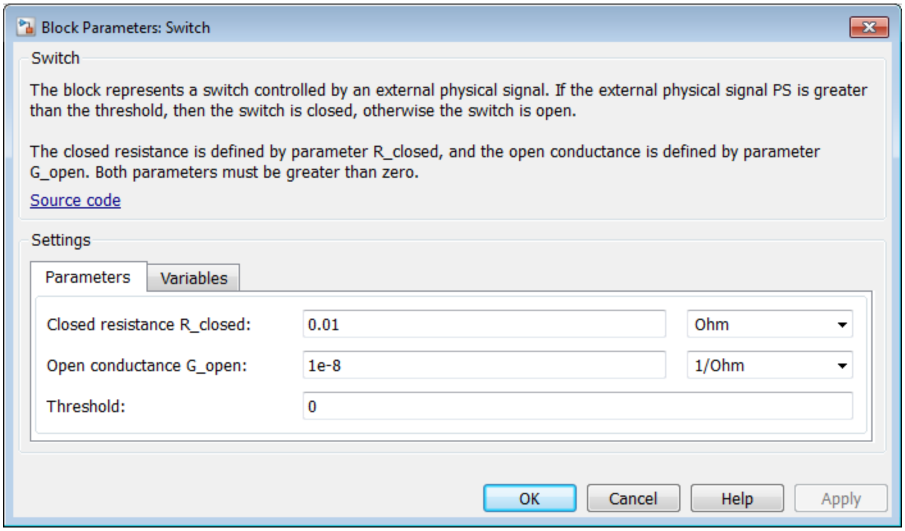


Description

The `Switch` block models a switch controlled by an external physical signal. If the external physical signal PS is greater than the value specified in the **Threshold** parameter, then the switch is closed, otherwise the switch is open.

Electrical switches add discontinuities to your model, and therefore your choice of the solver can influence the model behavior. For detailed information about the solver settings, see “Making Optimal Solver Choices for Physical Simulation”.

Dialog Box and Parameters



Block Parameters: Switch

Switch

The block represents a switch controlled by an external physical signal. If the external physical signal PS is greater than the threshold, then the switch is closed, otherwise the switch is open.

The closed resistance is defined by parameter R_closed, and the open conductance is defined by parameter G_open. Both parameters must be greater than zero.

Source code

Settings

Closed resistance R_closed: 0.01 Ohm

Open conductance G_open: 1e-8 1/Ohm

Threshold: 0

- “Parameters Tab” on page 1-505
- “Variables Tab” on page 1-506

Parameters Tab

Closed resistance R_closed

The resistance of the switch when it is closed. The parameter value must be greater than zero. The default value is `0.01` Ω.

Open conductance G_open

The conductance of the switch when it is open. The parameter value must be greater than zero. The default value is `1e-8` 1/Ω.

Threshold

The threshold value for opening and closing the switch. If the external physical signal PS is greater than this value, then the switch is closed, otherwise the switch is open. The default value is `0`.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has two electrical conserving ports and one physical signal port PS.

See Also

`PS Switch`

Reservoir (2P)

Two-phase fluid reservoir at constant temperature and pressure

Library

Two-Phase Fluid/Elements

Description

The `Reservoir (2P)` block sets pressure and temperature boundary conditions in a two-phase fluid network. The reservoir is assumed infinite in size, causing its pressure and specific internal energy to remain constant.

Port A represents the reservoir inlet. The flow resistance between port A and the reservoir interior is assumed negligible. The pressure at port A is therefore equal to that inside the reservoir.

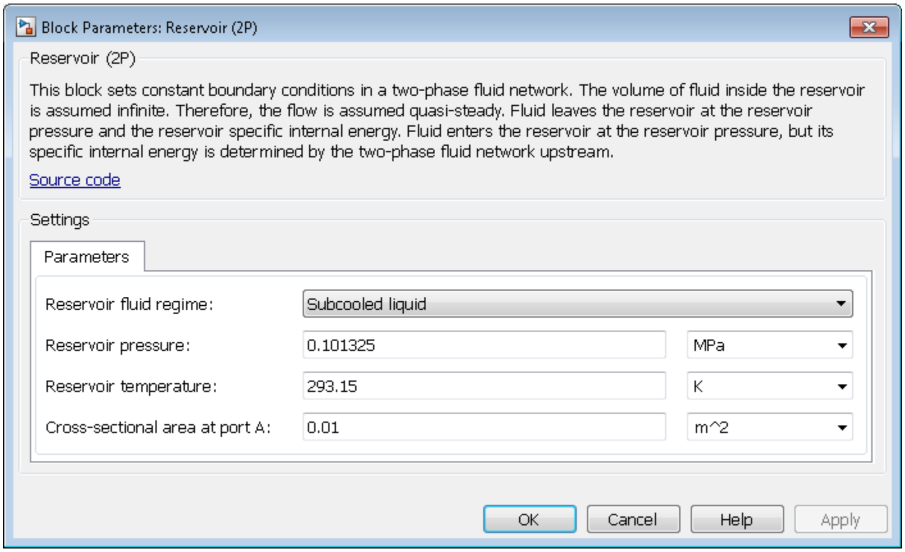
The specific internal energy at the reservoir inlet depends on the flow direction. If fluid leaves the reservoir, the fluid at port A is at the specific internal energy of the reservoir. The reservoir acts as an energy source. If fluid enters the reservoir, the fluid at port A is at the specific internal energy upstream of the reservoir. The reservoir acts as an energy sink.

This block also serves as a reference connection for the `Pressure & Internal Energy Sensor (2P)` block. In this case, the measured pressure and specific internal energy are relative to the reservoir pressure and specific internal energy.

Assumptions and Limitations

- The pressure and specific internal energy of the fluid are assumed constant in the reservoir.
- The flow resistance between port A and the reservoir interior is negligible. Pressure is the same at port A and in the reservoir interior.

Dialog Box and Parameters



Reservoir (2P)

This block sets constant boundary conditions in a two-phase fluid network. The volume of fluid inside the reservoir is assumed infinite. Therefore, the flow is assumed quasi-steady. Fluid leaves the reservoir at the reservoir pressure and the reservoir specific internal energy. Fluid enters the reservoir at the reservoir pressure, but its specific internal energy is determined by the two-phase fluid network upstream.

Source code

Settings

Parameters

Reservoir fluid regime: Subcooled liquid

Reservoir pressure: 0.101325 MPa

Reservoir temperature: 293.15 K

Cross-sectional area at port A: 0.01 m^2

Cross-sectional area at port A

Area normal to the direction of flow at the reservoir inlet. The default value is `0.01` m^2.

Reservoir fluid regime

Fluid phase in the reservoir. The fluid can be a subcooled liquid, a two-phase mixture, or a superheated vapor. The default setting is `Subcooled liquid`.

Reservoir pressure

Absolute pressure in the reservoir during simulation. The default value is `0.101325` MPa.

Reservoir temperature

Absolute temperature in the reservoir during simulation. This parameter appears only when the **Reservoir fluid regime** parameter is set to `Subcooled liquid` or `Superheated vapor`. The default value is `293.15` K.

Reservoir vapor quality

Mass fraction of vapor in the reservoir during simulation. This parameter appears only when the **Initial fluid regime** parameter is set to `Two-phase mixture`. The default value is `0.2`.

Ports

The block has one two-phase fluid conserving port, A, representing the reservoir inlet.

See Also

`Constant Volume Chamber (2P)`

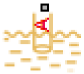
Reservoir (TL)

Thermal liquid reservoir at constant temperature and pressure

Library

Thermal Liquid/Elements

Description



The `Reservoir (TL)` block represents an infinite reservoir at fixed pressure and temperature. The reservoir and its inlet can be at atmospheric pressure or at a specified pressure. Port A, a thermal liquid conserving port, represents the reservoir inlet.

The inlet temperature depends on the direction of liquid flow. If liquid flows into the reservoir, the inlet temperature equals that of the upstream liquid. The reservoir acts as a heat sink. If liquid flows out of the reservoir, the inlet temperature equals that of the reservoir. The reservoir acts as a heat source.

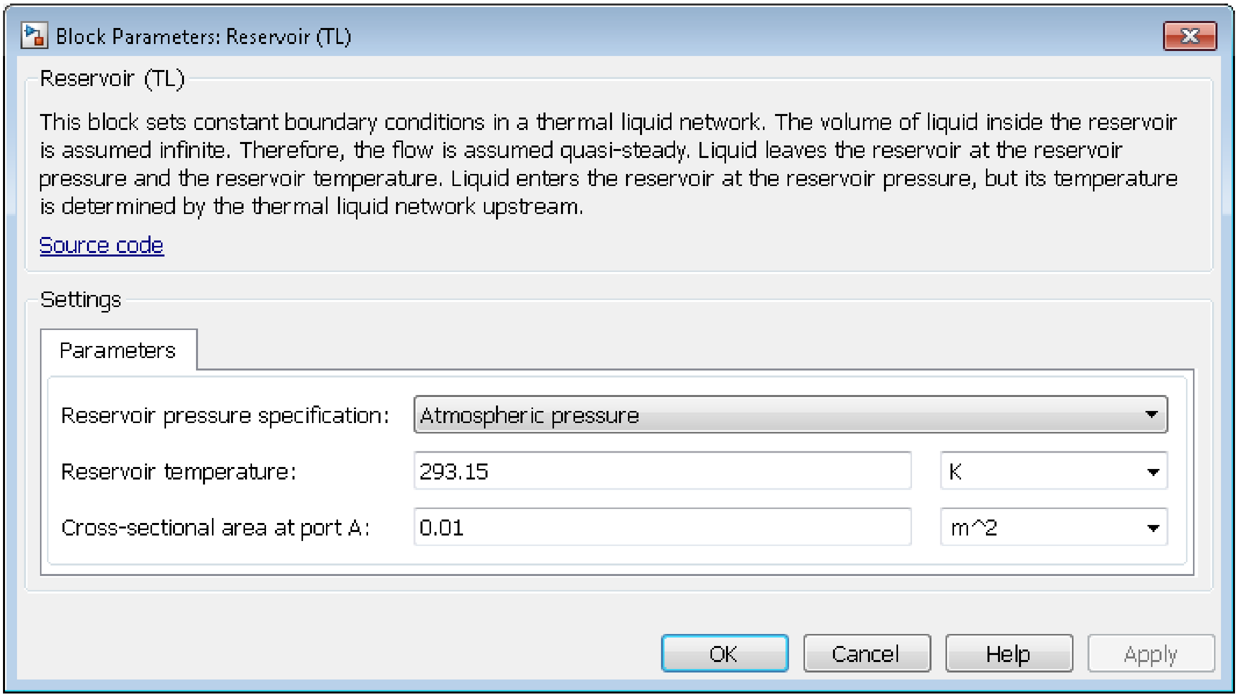
To ensure a smooth temperature change at the reservoir inlet during liquid flow reversal, the block includes heat conduction along a length equal to the effective diameter of the pipe. This diameter is a function of the specified cross-sectional area of the inlet pipe.

This block also functions as a reference point for pressure and temperature measurements in a pipe network. These measurements are relative to reservoir pressure and temperature, respectively.

Assumptions and Limitations

- Reservoir temperature is constant.

Dialog Box and Parameters



Reservoir (TL)

This block sets constant boundary conditions in a thermal liquid network. The volume of liquid inside the reservoir is assumed infinite. Therefore, the flow is assumed quasi-steady. Liquid leaves the reservoir at the reservoir pressure and the reservoir temperature. Liquid enters the reservoir at the reservoir pressure, but its temperature is determined by the thermal liquid network upstream.

Source code

Settings

Parameters

Reservoir pressure specification: Atmospheric pressure

Reservoir temperature: 293.15 K

Cross-sectional area at port A: 0.01 m^2

Reservoir pressure specification

Select whether to model the reservoir at atmospheric pressure or at a specified pressure. The default setting is `Atmospheric pressure`.

Reservoir pressure

Enter the desired pressure in the reservoir. This pressure remains constant during simulation. The default value is `1.01325` bar.

Reservoir temperature

Enter the desired temperature in the reservoir. The default value is `293.15` K.

Cross-sectional area at port A

Enter the cross-sectional area of the reservoir inlet pipe. The block uses this area to determine the characteristic length of the pipe along which heat conduction occurs. The default value is `1e-2` m^2.

Ports

The block has one thermal liquid conserving port, A.

See Also

`Constant Volume Chamber (TL)`

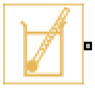
`Controlled Reservoir (TL)`

Thermal Liquid Settings (TL)

Fluid properties in thermal liquid network

Library

Thermal Liquid/Utilities



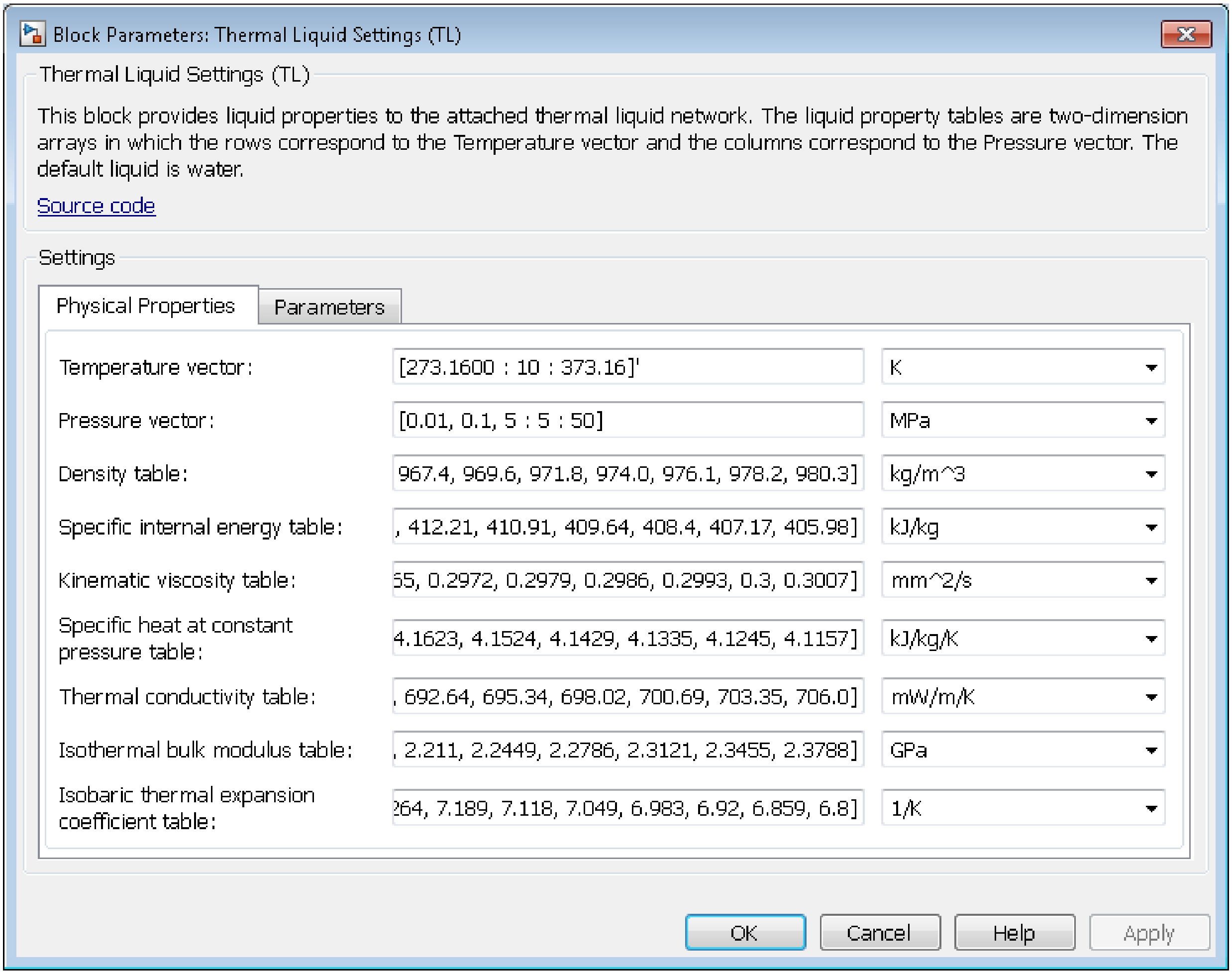
Description

The `Thermal Liquid Settings (TL)` block represents the liquid medium in a thermal liquid system. A set of physical properties governs the thermodynamic behavior of the liquid medium. The properties are global: they apply to the entire thermal liquid system containing this block. Each topologically distinct thermal liquid block network must contain exactly one Thermal Liquid Settings (TL) block.

Inputs for the physical properties of the liquid medium are lookup tables. The tables provide the numerical values of the physical properties at discrete temperatures and pressures. For temperatures and pressures not included in the table but within the data range, the block applies linear interpolation between the two nearest data points.

The block accepts the temperature-pressure validity region of a thermal liquid model as input. Adjust this region to ensure the model simulates only at acceptable temperature and pressure values, e.g., to avoid phase change or component failure.

Dialog Box and Parameters



Block Parameters: Thermal Liquid Settings (TL)

Thermal Liquid Settings (TL)

This block provides liquid properties to the attached thermal liquid network. The liquid property tables are two-dimension arrays in which the rows correspond to the Temperature vector and the columns correspond to the Pressure vector. The default liquid is water.

Source code

Settings

Temperature vector:	[273.1600 : 10 : 373.16]'	K
Pressure vector:	[0.01, 0.1, 5 : 5 : 50]	MPa
Density table:	967.4, 969.6, 971.8, 974.0, 976.1, 978.2, 980.3]	kg/m^3
Specific internal energy table:	, 412.21, 410.91, 409.64, 408.4, 407.17, 405.98]	kJ/kg
Kinematic viscosity table:	55, 0.2972, 0.2979, 0.2986, 0.2993, 0.3, 0.3007]	mm^2/s
Specific heat at constant pressure table:	4.1623, 4.1524, 4.1429, 4.1335, 4.1245, 4.1157]	kJ/kg/K
Thermal conductivity table:	, 692.64, 695.34, 698.02, 700.69, 703.35, 706.0]	mW/m/K
Isothermal bulk modulus table:	, 2.211, 2.2449, 2.2786, 2.3121, 2.3455, 2.3788]	GPa
Isobaric thermal expansion coefficient table:	264, 7.189, 7.118, 7.049, 6.983, 6.92, 6.859, 6.8]	1/K

Physical Properties

Temperature vector

Enter an N×1 column vector with the temperature values for the liquid property lookup tables. Each temperature value corresponds to a lookup table row. For smooth interpolation between lookup table data points, keep N large. The default vector is `[273.1600 : 10 : 373.16]'` K.

Pressure vector

Enter a 1×M row vector with the pressure values for the liquid property lookup tables. Each pressure value corresponds to a lookup table column. For smooth interpolation between lookup table data points, keep M large. The default vector is `[0.01, 0.1, 5 : 5 : 50]` MPa.

Density table

Enter an N×M matrix with the mass density lookup table values. The matrix rows correspond to different temperatures and the matrix columns to different pressures. The default matrix is 11×12 and provides values for water.

Specific internal energy table

Enter an N×M matrix with the internal energy lookup table values. The matrix rows correspond to different temperatures and the matrix columns to different pressures. The default matrix is 11×12 and provides values for water.

Kinematic viscosity table

Enter an N×M matrix with the kinematic viscosity lookup-table values. The matrix rows correspond to different temperatures and the matrix columns to different pressures. The default matrix is 11×12 and provides values for water.

Specific heat at constant pressure table

Enter an N×M matrix with the specific heat lookup table values at constant pressure. The matrix rows correspond to different temperatures and the matrix columns to different pressures. The default matrix is 11×12 and provides values for water.

Thermal conductivity table

Enter an N×M matrix with the thermal conductivity lookup table values. The matrix rows correspond to different temperatures and the matrix columns to different pressures. The default matrix is 11×12 and provides values for water.

Isothermal bulk modulus table

Enter an N×M matrix with the isothermal bulk modulus lookup table values. The matrix rows correspond to different temperatures and the matrix columns to different pressures. The default matrix is 11×12 and provides values for water.

Isobaric thermal expansion coefficient table

Enter an N×M matrix with the lookup table values of the isobaric thermal expansion coefficient. The matrix rows correspond to different temperatures and the matrix columns to different pressures. The default matrix is 11×12 and provides values for water.

The block uses the standard thermal expansion coefficient definition:

$$\alpha = \frac{1}{V}\left(\frac{\partial V}{\partial T}\right)_p = -\frac{1}{\rho}\left(\frac{\partial \rho}{\partial T}\right)_p,$$

where:

- α is the thermal expansion coefficient.
- V is the fluid volume.
- T is the fluid temperature.
- ρ is the fluid density.
- p is the fluid pressure.

Parameters

Valid pressure-temperature region parameterization

Select the parameterization for the valid pressure-temperature region. Simulation stops if pressure or temperature fall outside this valid range. Parameterization options include `By minimum and maximum values`, which provides a rectangular pressure-temperature region, and `By validity matrix`, which provides an arbitrarily shaped pressure-temperature region. The default parameterization is `By minimum and maximum values`.

Minimum valid temperature

Enter the lowest allowable value the liquid temperature can reach. This parameter appears when you select `By minimum and maximum values` in **Valid pressure-temperature region parameterization**. The default value is `273.16` K.

Maximum valid temperature

Enter the highest allowable value the liquid temperature can reach. This parameter appears when you select `By minimum and maximum values` in **Valid pressure-temperature region parameterization**. The default value is `373.16` K.

Minimum valid pressure

Enter the lowest allowable value the liquid pressure can reach. This parameter appears when you select `By minimum and maximum values` in **Valid pressure-temperature region parameterization**. The default value is `0.1` bar.

Maximum valid pressure

Enter the highest allowable value the liquid pressure can reach. This parameter appears when you select `By minimum and maximum values` in **Valid pressure-temperature region parameterization**. The default value is `500` bar.

Pressure-temperature validity Matrix

Enter an N×M matrix that specifies which pressure-temperature value pairs in the physical property lookup tables are valid. In this matrix, enter `1` for valid pressure-temperature pairs and `-1` for invalid pairs. This parameter is visible when you select `By validity matrix` in **Valid pressure-temperature region parameterization**. The default matrix is `ones(11,12)`, denoting that all temperature-pressure value pairs in the physical property lookup tables are valid.

Atmospheric pressure

Value of the absolute pressure in the atmosphere. The default value is `1` atm.

Ports

The block has one thermal liquid conserving port, A.

Thermal Mass

Mass in thermal systems

Library

Thermal Elements

Description

The `Thermal Mass` block represents a thermal mass, which reflects the ability of a material or a combination of materials to store internal energy. The property is characterized by mass of the material and its specific heat. The thermal mass is described with the following equation:

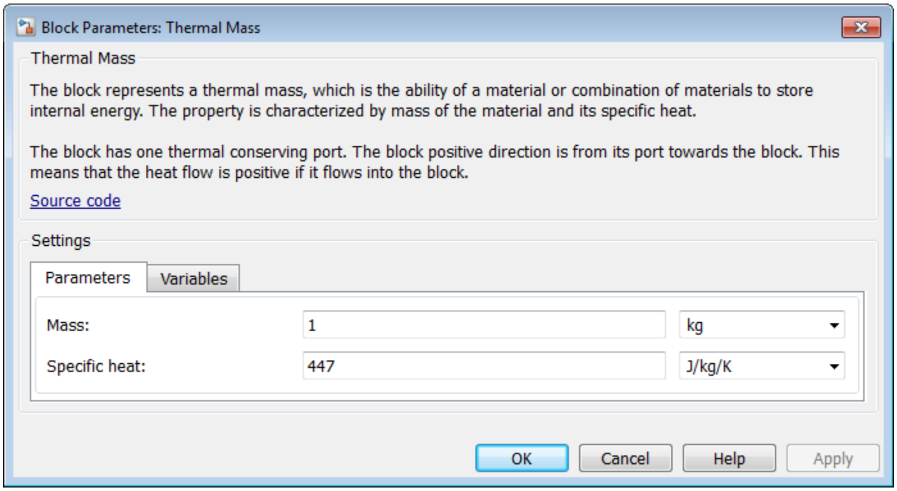
$$Q = c \cdot m \frac{dT}{dt}$$

where

Q	Heat flow
c	Specific heat of mass material
m	Mass
T	Temperature
t	Time

The block has one thermal conserving port. The block positive direction is from its port towards the block. This means that the heat flow is positive if it flows into the block.

Dialog Box and Parameters



Thermal Mass

The block represents a thermal mass, which is the ability of a material or combination of materials to store internal energy. The property is characterized by mass of the material and its specific heat.

The block has one thermal conserving port. The block positive direction is from its port towards the block. This means that the heat flow is positive if it flows into the block.

Source code

Mass: 1 kg

Specific heat: 447 J/kg/K

- "Parameters Tab" on page 1-519
- "Variables Tab" on page 1-519

Parameters Tab

Mass

Mass. The default value is 1 kg.

Specific heat

Specific heat of the material. The default value is 447 J/kg/K.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see "Set Priority and Initial Target for Block Variables".

Ports

The block has one thermal conserving port, associated with the mass connection to the system.

See Also

`Mass`

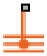
Thermal Reference

Reference connection for thermal ports

Library

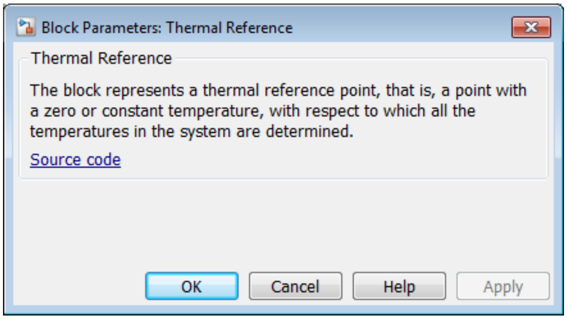
Thermal Elements

Description



The `Thermal Reference` block represents a thermal reference point, that is, a point with an absolute zero temperature, with respect to which all the temperatures in the system are determined.

Dialog Box and Parameters



Block Parameters: Thermal Reference

Thermal Reference

The block represents a thermal reference point, that is, a point with a zero or constant temperature, with respect to which all the temperatures in the system are determined.

Source code

The `Thermal Reference` block has no parameters.

Ports

The block has one thermal conserving port.

More About

- “Grounding Rules”

Thermal Resistor

Resistor with thermal port

Library

Electrical Elements

Description

The `Thermal Resistor` block represents a temperature-dependent resistor. The resistance when the temperature at the thermal port is T is
$R = R_0(1+\alpha(T-T_0))$
where:

- R_0 is the nominal resistance at the reference temperature T_0.
- α is the temperature coefficient.

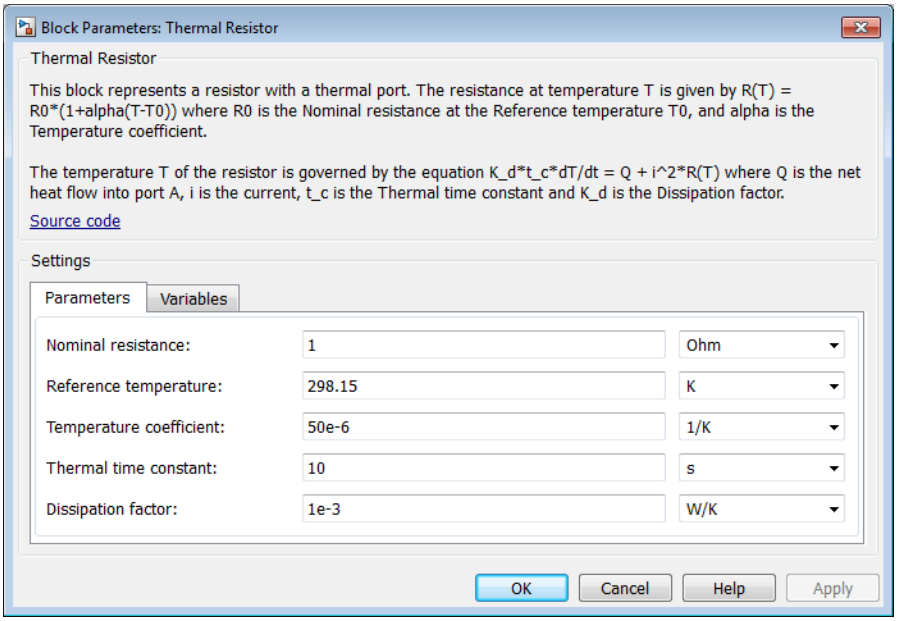
The following equation describes the thermal behavior of the block:

$$Q = K_d t_c \frac{dT}{dt} - i^2 R$$

where:

- Q is the net heat flow into port A.
- K_d is the **Dissipation factor** parameter value.
- t_c is the **Thermal time constant** parameter value.
- dT/dt is the rate of change of the temperature.
- i is the current through the resistor.

Dialog Box and Parameters



Block Parameters: Thermal Resistor

Thermal Resistor

This block represents a resistor with a thermal port. The resistance at temperature T is given by R(T) = R0*(1+alpha(T-T0)) where R0 is the Nominal resistance at the Reference temperature T0, and alpha is the Temperature coefficient.

The temperature T of the resistor is governed by the equation K_d*t_c*dT/dt = Q + i^2*R(T) where Q is the net heat flow into port A, i is the current, t_c is the Thermal time constant and K_d is the Dissipation factor.

Source code

Settings

Nominal resistance:	1	Ohm
Reference temperature:	298.15	K
Temperature coefficient:	50e-6	1/K
Thermal time constant:	10	s
Dissipation factor:	1e-3	W/K

- “Parameters Tab” on page 1-524
- “Variables Tab” on page 1-525

Parameters Tab

Nominal resistance

The nominal resistance of the thermistor at the reference temperature. Many datasheets quote the nominal resistance at 25°C (298.15 K) and list it as R25. The default value is 1 Ω.

Reference temperature

The temperature at which the nominal resistance was measured. The default value is 298.15 K.

Temperature coefficient

The coefficient α in the equation that describes resistance as a function of temperature. The default value is 5e-05 1/K.

Thermal time constant

The time it takes the resistor temperature to reach 63% of the final temperature change when a step change in ambient temperature occurs. The default value is `10` s.

Dissipation factor

The thermal power required to raise the thermal resistor temperature by one K. The default value is `0.001` W/K.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

In particular, the **Initial temperature** variable lets you set a high-priority target for the temperature of the thermal resistor at the start of the simulation. The default value is `298.15` K.

Ports

The block has the following ports:

`A`

Resistor thermal port

`+`

Positive electrical port

`-`

Negative electrical port

See Also

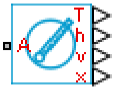
`Resistor` | `Variable Resistor`

Thermodynamic Properties Sensor (2P)

Measure temperature, specific enthalpy, specific volume, and vapor quality

Library

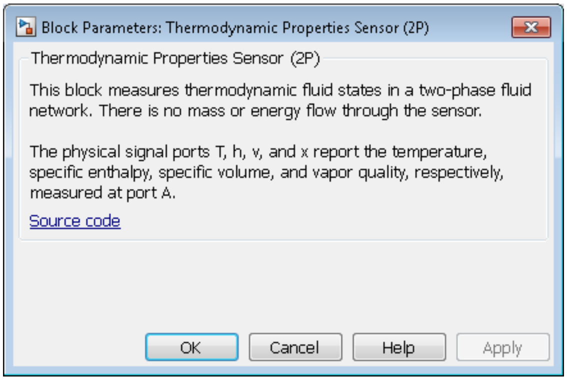
Two-Phase Fluid/Sensors



Description

The `Thermodynamic Properties Sensor (2P)` block measures temperature, specific enthalpy, specific volume, and vapor quality at a two-phase fluid node. Port A identifies the node at which the block measures these properties. All measurements are taken with respect to absolute zero.

Dialog Box and Parameters



Thermodynamic Properties Sensor (2P)

This block measures thermodynamic fluid states in a two-phase fluid network. There is no mass or energy flow through the sensor.

The physical signal ports T, h, v, and x report the temperature, specific enthalpy, specific volume, and vapor quality, respectively, measured at port A.

Source code

The block has no parameters.

Ports

The block has one two-phase fluid conserving port, A, and four physical signal output ports:

- T — Temperature
- h — Specific enthalpy
- v — Specific volume
- x — Vapor mass fraction (vapor quality)

See Also

`Two-Phase Fluid Properties (2P)`

Translational Damper

Viscous damper in mechanical translational systems

Library

Mechanical Translational Elements

Description

The `Translational Damper` block represents an ideal mechanical translational viscous damper, described with the following equations:

$$F = Dv$$

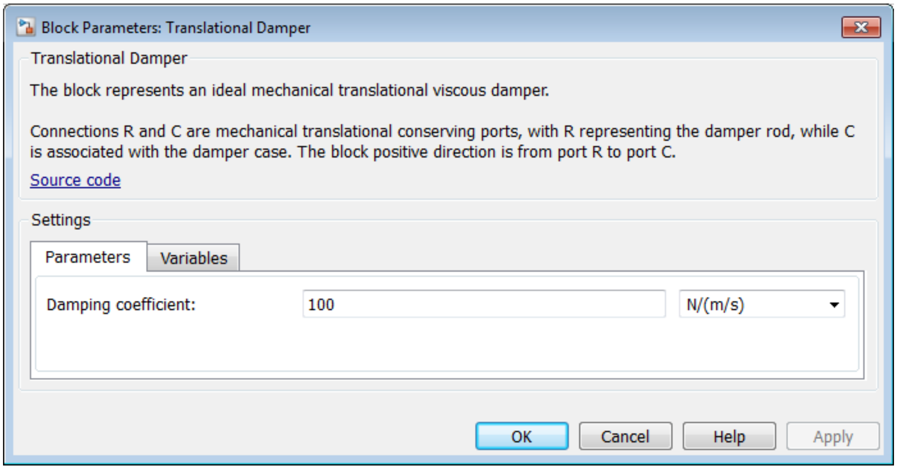
$$v = v_R - v_C$$

where

F	Force transmitted through the damper
D	Damping (viscous friction) coefficient
v	Relative velocity
v_R, v_C	Absolute velocities of terminals R and C, respectively

The block positive direction is from port R to port C. This means that the force is positive if it acts in the direction from R to C.

Dialog Box and Parameters



Block Parameters: Translational Damper

Translational Damper

The block represents an ideal mechanical translational viscous damper.

Connections R and C are mechanical translational conserving ports, with R representing the damper rod, while C is associated with the damper case. The block positive direction is from port R to port C.

Source code

Settings

Damping coefficient: 100 N/(m/s)

- “Parameters Tab” on page 1-529
- “Variables Tab” on page 1-529

Parameters Tab

Damping coefficient

Damping coefficient, defined by viscous friction. The default value is 100 N/(m/s).

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

R

Mechanical translational conserving port associated with the damper rod.

`C`

Mechanical translational conserving port associated with the damper case.

See Also

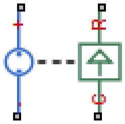
`Translational Friction` | `Translational Hard Stop` | `Translational Spring`

Translational Electromechanical Converter

Interface between electrical and mechanical translational domains

Library

Electrical Elements



Description

The `Translational Electromechanical Converter` block provides an interface between the electrical and mechanical translational domains. It converts electrical energy into mechanical energy in the form of translational motion, and vice versa. The converter is described with the following equations:

$$F = K \bullet I$$

$$V = K \bullet U$$

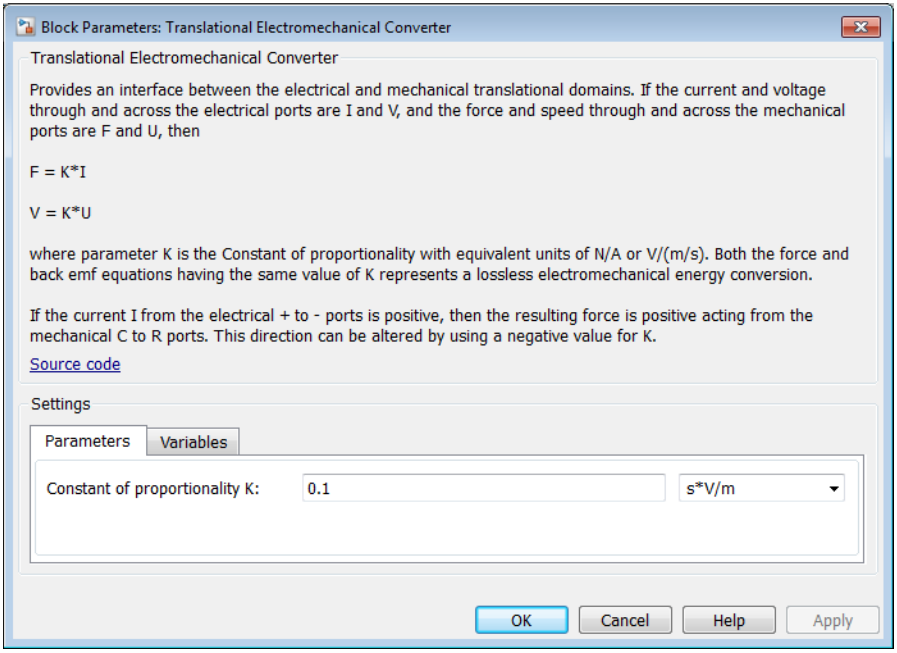
where

V	Voltage across the electrical ports of the converter
I	Current through the electrical ports of the converter
F	Force
U	Speed
K	Constant of proportionality

The `Translational Electromechanical Converter` block represents a lossless electromechanical energy conversion, therefore the same constant of proportionality is used in both equations.

Connections + and – are conserving electrical ports corresponding to the positive and negative terminals of the converter, respectively. Connections C and R are conserving mechanical translational ports. If the current flowing from the positive to the negative terminal is positive, then the resulting force is positive acting from port C to port R. This direction can be altered by using a negative value for K.

Dialog Box and Parameters



Block Parameters: Translational Electromechanical Converter

Translational Electromechanical Converter

Provides an interface between the electrical and mechanical translational domains. If the current and voltage through and across the electrical ports are I and V, and the force and speed through and across the mechanical ports are F and U, then

F = K*I

V = K*U

where parameter K is the Constant of proportionality with equivalent units of N/A or V/(m/s). Both the force and back emf equations having the same value of K represents a lossless electromechanical energy conversion.

If the current I from the electrical + to - ports is positive, then the resulting force is positive acting from the mechanical C to R ports. This direction can be altered by using a negative value for K.

Source code

Settings

Constant of proportionality K: 0.1 s*V/m

- “Parameters Tab” on page 1-532
- “Variables Tab” on page 1-533

Parameters Tab

Constant of proportionality K

Constant of proportionality for electromechanical conversions. The default value is `0.1` V/(m/s).

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

`+`

Electrical conserving port associated with the converter positive terminal.

`-`

Electrical conserving port associated with the converter negative terminal.

`C`

Mechanical translational conserving port.

`R`

Mechanical translational conserving port.

See Also

`Rotational Electromechanical Converter`

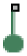
Translational Free End

Translational port terminator with zero force

Library

Mechanical Translational Elements

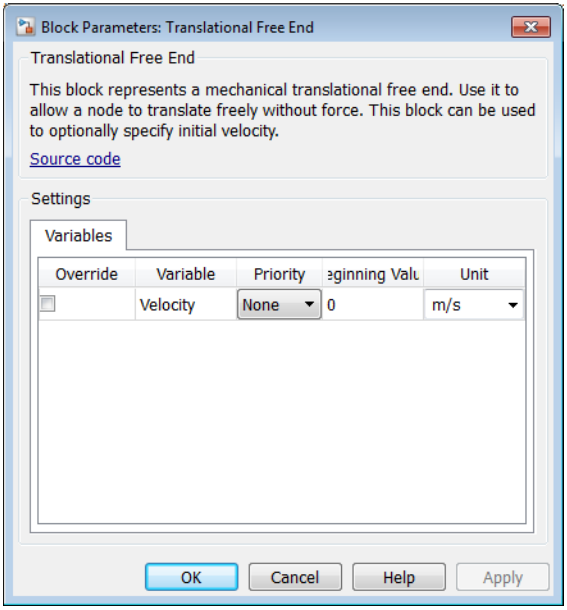
Description



The `Translational Free End` block represents a mechanical translational port that moves freely, without force. Physical network block diagrams do not allow unconnected conserving ports. Use this block to terminate mechanical translational ports on other blocks that you want to leave unconnected.

You can also use this block to set the initial translational velocity at a node.

Dialog Box and Parameters



Block Parameters: Translational Free End

Translational Free End

This block represents a mechanical translational free end. Use it to allow a node to translate freely without force. This block can be used to optionally specify initial velocity.

Source code

Settings

Variables

Override	Variable	Priority	eginning Valu	Unit
☐	Velocity	None	0	m/s

The `Translational Free End` block has no parameters.

The **Variables** tab lets you set the priority and initial target value for the **Velocity** variable prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has one mechanical translational conserving port.

See Also

`Adiabatic Cup` | `Cap (TL)` | `Hydraulic Cap` | `Open Circuit` | `Perfect Insulator` | `Rotational Free End`

Translational Friction

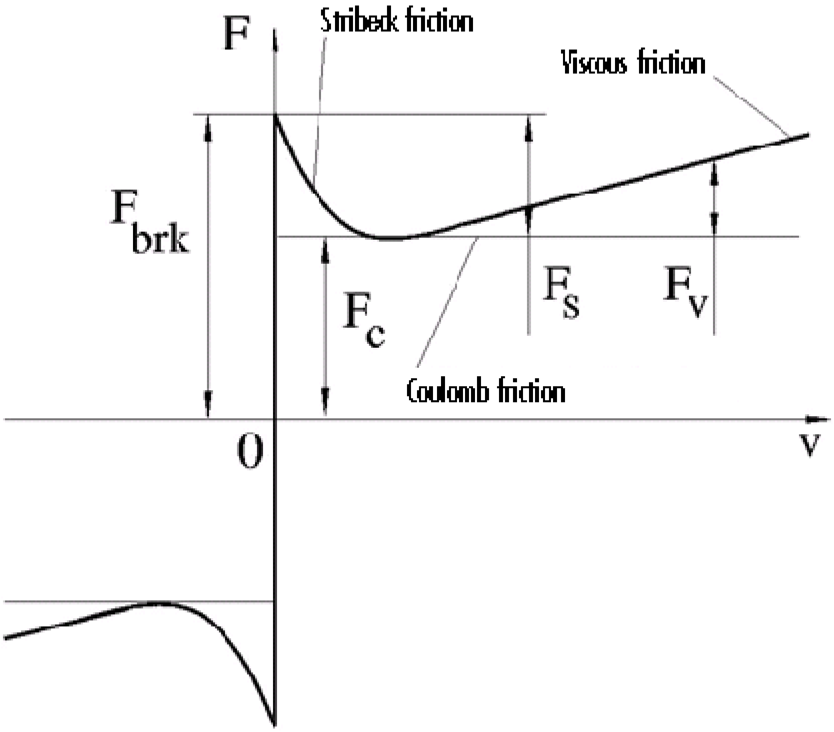
Friction in contact between moving bodies

Library

Mechanical Translational Elements

Description

The `Translational Friction` block represents friction in contact between moving bodies. The friction force is simulated as a function of relative velocity and is assumed to be the sum of Stribeck, Coulomb, and viscous components, as shown in the following figure.



The Stribeck friction, F_S, is the negatively sloped characteristics taking place at low velocities (see [1]). The Coulomb friction, F_C, results in a constant force at any velocity. The viscous friction, F_V, opposes motion with the force directly proportional to the relative velocity. The sum of the Coulomb and Stribeck frictions at the vicinity of zero velocity is often referred to as the breakaway friction, F_{brk}. The friction is approximated with the following equations:

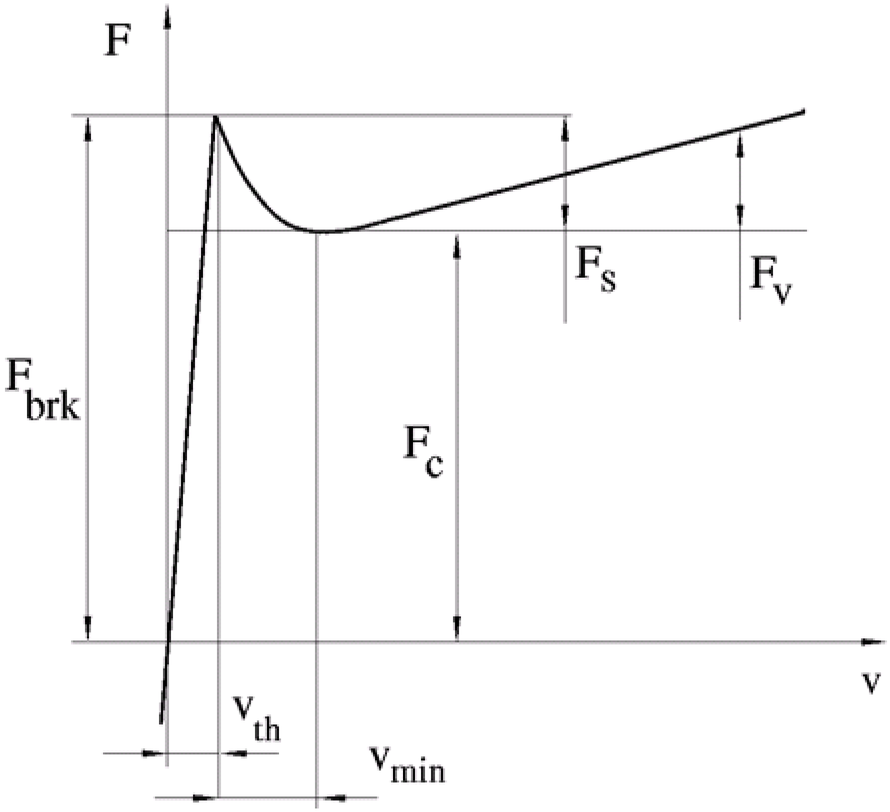
$$F = \left(F_C + \left(F_{brk} - F_C\right) \bullet \exp\left(-c_v \mid v \mid\right)\right) sign(v) + fv$$

$$v = v_R - v_C$$

where

F	Friction force
F_C	Coulomb friction
F_{brk}	Breakaway friction
c_v	Coefficient
v	Relative velocity
$v_{R,}v_C$	Absolute velocities of terminals R and C, respectively
f	Viscous friction coefficient

The approximation above is too idealistic and has a substantial drawback. The characteristic is discontinuous at $v = 0$, which creates considerable computational problems. It has been proven that the discontinuous friction model is a nonphysical simplification in the sense that the mechanical contact with distributed mass and compliance cannot exhibit an instantaneous change in force (see [1]). There are numerous models of friction without discontinuity. The `Translational Friction` block implements one of the simplest versions of continuous friction models. The friction force-relative velocity characteristic of this approximation is shown in the following figure.



The discontinuity is eliminated by introducing a very small, but finite, region in the zero velocity vicinity, within which friction force is assumed to be linearly proportional to velocity, with the proportionality coefficient F_{brk}/v_{th}, where v_{th} is the velocity threshold. It has been proven experimentally that the velocity threshold in the range between 10^{-4} and 10^{-6} m/s is a good compromise between the accuracy and computational robustness and effectiveness. Notice that friction force computed with this approximation does not actually stop relative motion when an acting force drops below breakaway friction level. The bodies will creep relative to each other at a very small velocity proportional to acting force.

As a result of introducing the velocity threshold, the block equations are slightly modified:

- If $|v| >= v_{th}$,

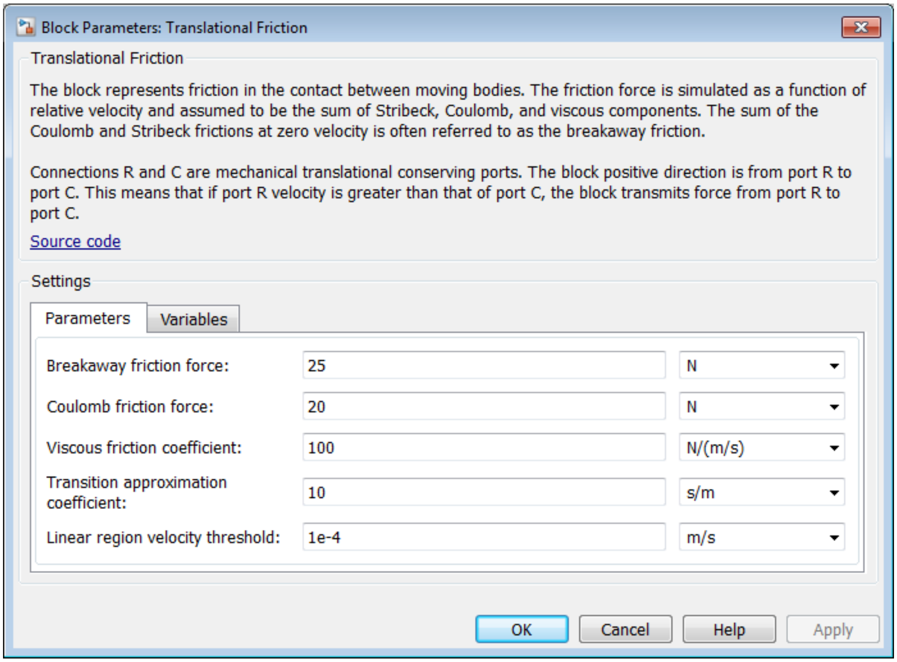
$$F = \left(F_C + \left(F_{brk} - F_C\right) \cdot \exp\left(-c_v \left| v \right|\right)\right) sign(v) + fv$$

- If $|v| < v_{th}$,

$$F = v \frac{\left(fv_{th} + \left(F_C + \left(F_{brk} - F_C\right) \cdot \exp\left(-c_v v_{th}\right)\right)\right)}{v_{th}}$$

The block positive direction is from port R to port C. This means that if the port R velocity is greater than that of port C, the block transmits force from R to C.

Dialog Box and Parameters



Translational Friction

The block represents friction in the contact between moving bodies. The friction force is simulated as a function of relative velocity and assumed to be the sum of Stribeck, Coulomb, and viscous components. The sum of the Coulomb and Stribeck frictions at zero velocity is often referred to as the breakaway friction.

Connections R and C are mechanical translational conserving ports. The block positive direction is from port R to port C. This means that if port R velocity is greater than that of port C, the block transmits force from port R to port C.

Source code

Settings

Breakaway friction force:	25	N
Coulomb friction force:	20	N
Viscous friction coefficient:	100	N/(m/s)
Transition approximation coefficient:	10	s/m
Linear region velocity threshold:	1e-4	m/s

- “Parameters Tab” on page 1-541
- “Variables Tab” on page 1-541

Parameters Tab

Breakaway friction force

Breakaway friction force, which is the sum of the Coulomb and the static frictions. It must be greater than or equal to the Coulomb friction force value. The default value is 25 N.

Coulomb friction force

Coulomb friction force, which is the friction that opposes motion with a constant force at any velocity. The default value is 20 N.

Viscous friction coefficient

Proportionality coefficient between the friction force and the relative velocity. The parameter value must be greater than or equal to zero. The default value is 100 N/(m/s).

Transition approximation coefficient

The parameter sets the value of coefficient c_v, which is used for the approximation of the transition between the static and the Coulomb frictions. Its value is assigned based on the following considerations: the static friction component reaches approximately 95% of its steady-state value at velocity $3/c_v$, and 98% at velocity $4/c_v$, which makes it possible to develop an approximate relationship c_v ~= $4/v_{min},$ where v_{min} is the relative velocity at which friction force has its minimum value. By default, c_v is set to 10 s/m, which corresponds to a minimum friction at velocity of about 0.4 m/s.

Linear region velocity threshold

The parameter sets the small vicinity near zero velocity, within which friction force is considered to be linearly proportional to the relative velocity. MathWorks recommends that you use values in the range between 1e-6 and 1e-4 m/s. The default value is 1e-4 m/s.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

`R`

Mechanical translational conserving port.

`C`

Mechanical translational conserving port.

References

[1] B. Armstrong, C.C. de Wit, *Friction Modeling and Compensation*, The Control Handbook, CRC Press, 1995

See Also

`Translational Damper` | `Translational Hard Stop` | `Translational Spring`

Translational Hard Stop

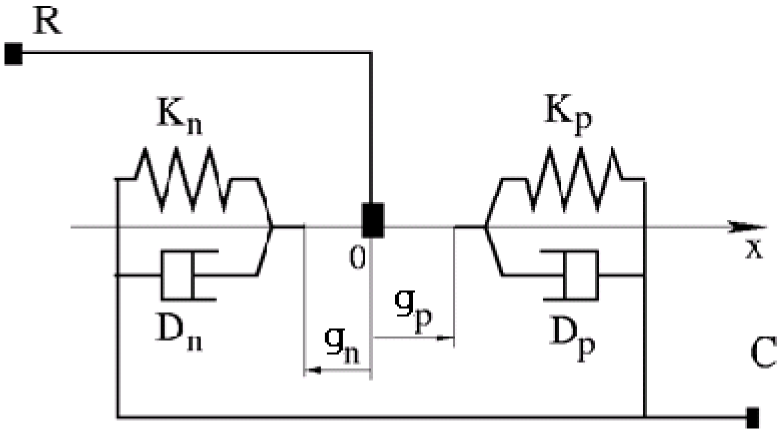
Double-sided translational hard stop

Library

Mechanical Translational Elements

Description

The `Translational Hard Stop` block represents a double-sided mechanical translational hard stop that restricts motion of a body between upper and lower bounds. Both ports of the block are of mechanical translational type. The impact interaction between the slider and the stops is assumed to be elastic. This means that the stop is represented as a spring that comes into contact with the slider as the gap is cleared and opposes slider penetration into the stop with the force linearly proportional to this penetration. To account for energy dissipation and nonelastic effects, the damping is introduced as the block's parameter, thus making it possible to account for energy loss. The following schematic shows the idealization of the mechanical translational hard stop adopted in the block:



The hard stop is described with the following equations:

$$F = \begin{cases} K_p \cdot \delta + D_p \left(v_R - v_C \right) & \text{for } \delta >= g_p \\ 0 & \text{for } g_n < \delta < g_p \\ K_n \cdot \delta + D_n \left(v_R - v_C \right) & \text{for } \delta <= g_n \end{cases}$$

$$\delta = x_R - x_C$$

$$v_R = \frac{dx_R}{dt}$$

$$v_C = \frac{dx_C}{dt}$$

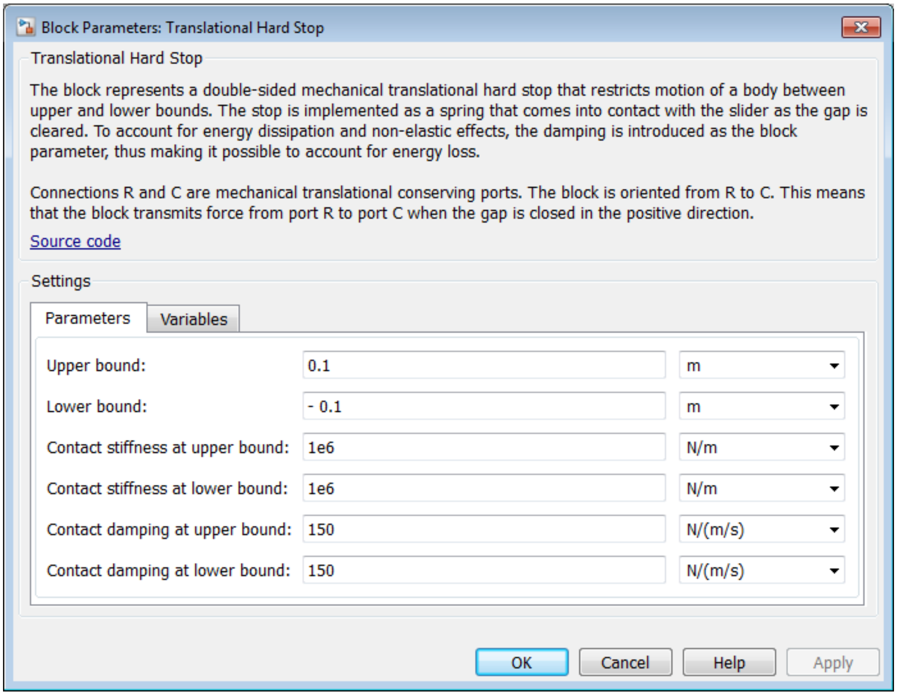
where

F	Interaction force between the slider and the case
δ	Relative displacement between the slider and the case
g_p	Gap between the slider and the case in positive direction
g_n	Gap between the slider and the case in negative direction
v_R, v_C	Absolute velocities of terminals R and C, respectively
x_R, x_C	Absolute displacements of terminals R and C, respectively
K_p	Contact stiffness at positive restriction
K_n	Contact stiffness at negative restriction
D_p	Damping coefficient at positive restriction
D_n	Damping coefficient at negative restriction
t	Time

The equations are derived with respect to the local coordinate system whose axis is directed from port R to port C. The terms “positive” and “negative” in the variable descriptions refer to this coordinate system, and the gap in negative direction must be specified with negative value. If the local coordinate system is not aligned with the globally assigned positive direction, the gaps interchange their values with respective sign adjustment.

The block is oriented from R to C. This means that the block transmits force from port R to port C when the gap in positive direction is cleared up.

Dialog Box and Parameters



Translational Hard Stop

The block represents a double-sided mechanical translational hard stop that restricts motion of a body between upper and lower bounds. The stop is implemented as a spring that comes into contact with the slider as the gap is cleared. To account for energy dissipation and non-elastic effects, the damping is introduced as the block parameter, thus making it possible to account for energy loss.

Connections R and C are mechanical translational conserving ports. The block is oriented from R to C. This means that the block transmits force from port R to port C when the gap is closed in the positive direction.

Source code

Settings

Upper bound:	0.1	m
Lower bound:	- 0.1	m
Contact stiffness at upper bound:	1e6	N/m
Contact stiffness at lower bound:	1e6	N/m
Contact damping at upper bound:	150	N/(m/s)
Contact damping at lower bound:	150	N/(m/s)

- “Parameters Tab” on page 1-545
- “Variables Tab” on page 1-547

Parameters Tab

Upper bound

Gap between the slider and the upper bound. The direction is specified with respect to the local coordinate system, with the slider located in the origin. A positive value of the parameter specifies the gap between the slider and the upper bound. A negative value sets the slider as penetrating into the upper bound. The default value is `0.1` m.

Lower bound

Gap between the slider and the lower bound. The direction is specified with respect to the local coordinate system, with the slider located in the origin. A negative value of the parameter specifies the gap between the slider and the lower bound. A positive value sets the slider as penetrating into the lower bound. The default value is `-0.1` m.

Contact stiffness at upper bound

The parameter specifies the elastic property of colliding bodies when the slider hits the upper bound. The greater the value of the parameter, the less the bodies penetrate into each other, the more rigid the impact becomes. Lesser value of the parameter makes contact softer, but generally improves convergence and computational efficiency. The default value is `1e6` N/m.

Contact stiffness at lower bound

The parameter specifies the elastic property of colliding bodies when the slider hits the lower bound. The greater the value of the parameter, the less the bodies penetrate into each other, the more rigid the impact becomes. Lesser value of the parameter makes contact softer, but generally improves convergence and computational efficiency. The default value is `1e6` N/m.

Contact damping at upper bound

The parameter specifies dissipating property of colliding bodies when the slider hits the upper bound. At zero damping, the impact is close to an absolutely elastic one. The greater the value of the parameter, the more energy dissipates during an interaction. Keep in mind that damping affects slider motion as long as the slider is in contact with the stop, including the period when slider is pulled back from the contact. For computational efficiency and convergence reasons, MathWorks recommends that you assign a nonzero value to this parameter. The default value is 150 N*s/m.

Contact damping at lower bound

The parameter specifies dissipating property of colliding bodies when the slider hits the lower bound. At zero damping, the impact is close to an absolutely elastic one. The greater the value of the parameter, the more energy dissipates during an interaction. Keep in mind that damping affects slider motion as long as the slider is in contact with the stop, including the period when slider is pulled back from the contact. For computational efficiency and convergence reasons, MathWorks recommends that you assign a nonzero value to this parameter. The default value is 150 N*s/m.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

`R`

Mechanical translational conserving port associated with the slider that travels between stops installed on the case.

`C`

Mechanical translational conserving port associated with the case.

Examples

The Mechanical System with Translational Hard Stop example illustrates the use of the `Translational Hard Stop` block in mechanical systems. Two masses are interacting through a hard stop. The mass on the left is driven by an ideal velocity source. Plotting the displacement of the second mass against the displacement of the first mass produces a typical hysteresis curve.

See Also

`Translational Damper` | `Translational Friction` | `Translational Spring`

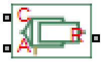
Translational Hydro-Mechanical Converter

Interface between hydraulic and mechanical translational domains

Library

Hydraulic Elements

Description



The `Translational Hydro-Mechanical Converter` block models an ideal transducer that converts hydraulic energy into mechanical energy, in the form of translational motion of the converter output member, and vice versa. The compressibility option makes the converter account for dynamic variations of the fluid density.

Using this block as a basic element, you can build a large variety of hydraulic cylinder models by adding application-specific effects, such as leakage, friction, hard stops, and so on.

The converter is simulated according to the following equations:

$$q = \frac{d\left(\frac{\rho}{\rho_l^0} V\right)}{dt} = \frac{d\left(\frac{\rho}{\rho_l^0}\right)}{dt} V + \frac{\rho}{\rho_l^0} \cdot \varepsilon \cdot (v_R - v_C) \cdot A$$

$$F = \varepsilon \cdot p \cdot A$$

$$\rho = \begin{cases} \dfrac{\left(\dfrac{\alpha}{1-\alpha}\right)\rho_g^0 + \rho_l^0}{\left(\dfrac{\alpha}{1-\alpha}\right)\left(\dfrac{p_0}{p}\right)^{\frac{1}{\gamma}} + e^{-\frac{p-p_0}{\beta_l}}} & \text{if compressibility is on} \\ \rho_l^0 & \text{if compressibility is off} \end{cases}$$

where

q	Flow rate to the converter chamber
A	Effective piston area
v_R	Converter rod velocity
v_C	Converter case velocity
F	Force developed by the converter
p	Gauge pressure of fluid in the converter chamber
V	Piston volume
α	Relative amount of trapped air
ρ_l^0	Fluid density at atmospheric conditions
ρ_g^0	Gas density at atmospheric conditions
p_0	Atmospheric pressure
γ	Specific heat ratio
β_l	Bulk modulus at atmospheric conditions and no gas
ε	Converter orientation with respect to the globally assigned positive direction. If pressure applied at port A exerts force in positive direction, ε equals 1. If pressure applied at port A exerts force in negative direction, ε equals –1.

The piston volume is computed according to

$$V = V_{dead} + A \cdot (x_0 + x)$$

$$\frac{dx}{dt} = \varepsilon \cdot (v_R - v_C)$$

where

V_{dead}	Chamber dead volume
x_0	Piston initial position
x	Piston displacement from initial position

Port A is a hydraulic conserving port associated with the converter inlet. Ports R and C are translational mechanical conserving ports associated with the rod and the case of the converter, respectively.

The block dialog box does not have a **Source code** link. To view the underlying component source, open the following files in the MATLAB editor:

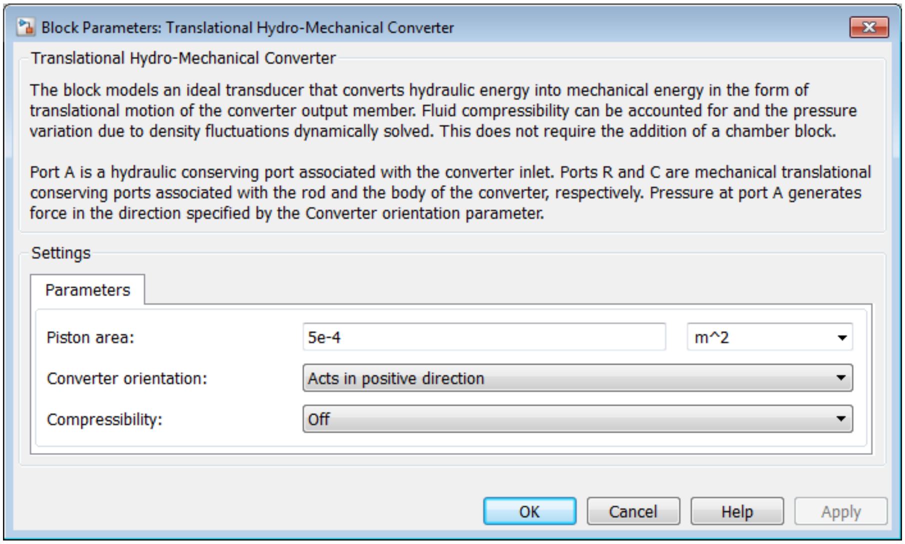
- For incompressible converter implementation — *`matlabroot`*`\toolbox\physmod\simscape\library\m\+foundation\+hydraulic\+elements\translational_converter_incompressible.ssc`
- For compressible converter implementation — *`matlabroot`*`\toolbox\physmod\simscape\library\m\+foundation\+hydraulic\+elements\translational_converter_compressible.ssc`

where *`matlabroot`* is your root folder.

Basic Assumptions and Limitations

The block simulates an ideal converter, with an option to account for fluid compressibility. Other effects, such as hard stops, inertia, or leakage, are modeled outside of the converter.

Dialog Box and Parameters



Block Parameters: Translational Hydro-Mechanical Converter

Translational Hydro-Mechanical Converter

The block models an ideal transducer that converts hydraulic energy into mechanical energy in the form of translational motion of the converter output member. Fluid compressibility can be accounted for and the pressure variation due to density fluctuations dynamically solved. This does not require the addition of a chamber block.

Port A is a hydraulic conserving port associated with the converter inlet. Ports R and C are mechanical translational conserving ports associated with the rod and the body of the converter, respectively. Pressure at port A generates force in the direction specified by the Converter orientation parameter.

Settings

Parameters

Piston area: 5e-4 m^2

Converter orientation: Acts in positive direction

Compressibility: Off

Piston area

Effective piston area. The default value is `5e-4` m^2.

Converter orientation

Specifies converter orientation with respect to the globally assigned positive direction. The converter can be installed in two different ways, depending upon whether it exerts force in the positive or in the negative direction when pressure is applied at its inlet. If pressure applied at port A exerts force in negative direction, set the parameter to `Acts in negative direction`. The default value is `Acts in positive direction`.

Compressibility

Specifies whether fluid density is taken as constant or varying with pressure. The default value is `Off`, in which case the block models an ideal transducer. If you select `On`, the block dialog box displays additional parameters that let you model dynamic variations of the fluid density without adding any extra blocks.

Piston initial position

Initial offset of the piston from the cylinder cap. The default value is `0`.

Chamber dead volume

Volume of fluid in the chamber at zero piston position. The default value is `1e-4` m^3.

Specific heat ratio

Gas-specific heat ratio. The default value is `1.4`.

Initial pressure

Initial pressure in the chamber. This parameter specifies the initial condition for use in computing the block's initial state at the beginning of a simulation run. The default value is `0`.

Restricted Parameters

When your model is in Restricted editing mode, you cannot modify the following parameters:

- **Converter orientation**
- **Compressibility**

All other block parameters are available for modification.

Ports

The block has the following ports:

`A`

Hydraulic conserving port associated with the converter inlet.

`R`

Mechanical translational conserving port associated with the rod of the converter.

`C`

Mechanical translational conserving port associated with the case of the converter.

See Also

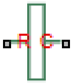
`Rotational Hydro-Mechanical Converter`

Translational Inerter

Two-port inertia in mechanical translational systems

Library

Mechanical Translational Elements



Description

The `Translational Inerter` block represents a device that has force proportional to the rate of change of the relative velocity across the ports. It is essentially a two-port inertia that works on the velocity difference between the ports, not the absolute velocity. An inerter is the mechanical equivalent of a capacitor. An inerter with one port connected to ground essentially behaves as a mass with the mass equal to the inerter's inertance.

Use this block in high performance suspension systems, to decouple weave and roll modes, or in applications where you need to model a passively tuned mass-spring-damper response.

The block is described with the following equations:

$$f = B\frac{dv}{dt}$$

$$v = v_R - v_C$$

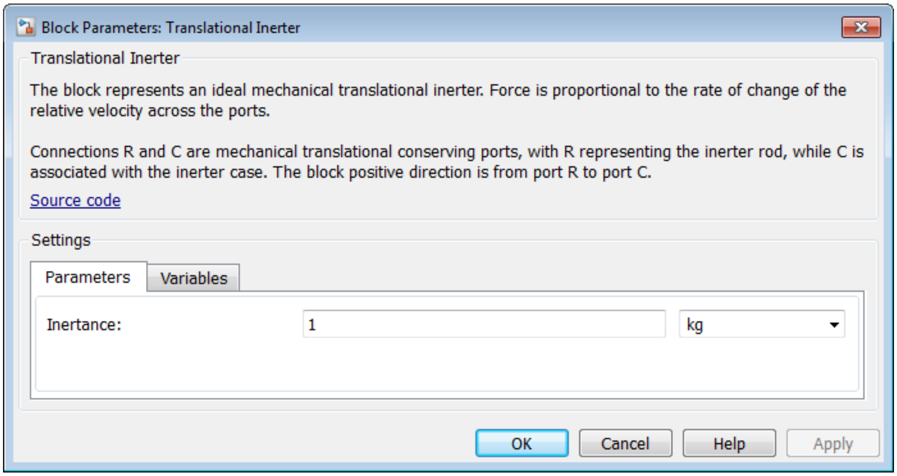
where

F	Force transmitted through the inerter
B	Inertance
v	Relative velocity

v_R, v_C	Absolute velocities at ports R and C, respectively

The block positive direction is from port R to port C. This means that the force is positive if it acts in the direction from R to C.

Dialog Box and Parameters



Block Parameters: Translational Inerter

Translational Inerter

The block represents an ideal mechanical translational inerter. Force is proportional to the rate of change of the relative velocity across the ports.

Connections R and C are mechanical translational conserving ports, with R representing the inerter rod, while C is associated with the inerter case. The block positive direction is from port R to port C.

Source code

Settings

Inertance: 1 kg

- “Parameters Tab” on page 1-554
- “Variables Tab” on page 1-554

Parameters Tab

Inertance

Proportionality coefficient between the force and the rate of change of the relative velocity across the ports. The default value is 1 kg.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

`R`

Mechanical translational conserving port associated with the rod.

`C`

Mechanical translational conserving port associated with the case.

See Also

`Mass`

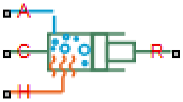
Introduced in R2015b

Translational Mechanical Converter (2P)

Interface between two-phase fluid and mechanical translational networks

Library

Two-Phase Fluid/Elements



Description

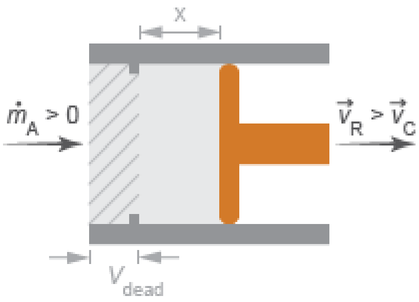
The `Translational Mechanical Converter (2P)` block models an interface between two-phase fluid and mechanical translational networks. The interface converts pressure in the fluid network into force in the mechanical translational network and vice versa.

This block enables you to model a linear actuator powered by a two-phase fluid system. It does not, however, account for mass, friction, or hard stops, common in linear actuators. You can model these effects separately using Simscape blocks such as `Mass`, `Translational Friction`, and `Translational Hard Stop`.

Port A represents the inlet through which fluid enters and exits the converter. Ports C and R represent the converter casing and moving interface, respectively. Port H represents the wall through which the converter exchanges heat with its surroundings.

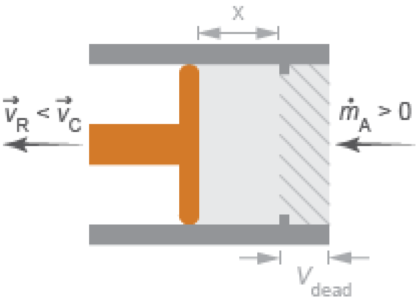
Force Direction

The force direction depends on the mechanical orientation of the converter. If the **Mechanical Orientation** parameter is set to positive, then a positive flow rate through the inlet tends to translate the moving interface in the positive direction relative to the converter casing.



Positive Mechanical Orientation

If the **Mechanical Orientation** parameter is set to negative, then a positive mass flow rate through the inlet tends to translate the moving interface in the negative direction relative to the converter casing.



Negative Mechanical Orientation

The flow resistance between port A and the converter interior is assumed negligible. Pressure losses between the two is approximately zero. The pressure at port A is therefore equal to that in the converter:

$$p_A = p_I,$$

where:

- p_A is the pressure at port A.
- p_I is the pressure in the converter.

Similarly, the thermal resistance between port H and the converter interior is assumed negligible. The temperature gradient between the two is approximately zero. The temperature at port H is therefore equal to that in the converter:

$$T_H = T_I,$$

where:

- T_H is the temperature at port H.
- T_I is the temperature in the converter.

Fluid Volume

The volume of fluid in the converter is the sum of the dead and displaced fluid volumes. The dead volume is the amount of fluid left in the converter at a zero interface displacement. This volume enables you to model the effects of dynamic compressibility and thermal capacity even when the interface is in its zero position.

The displacement volume is the amount of fluid added to the converter due to translation of the moving interface. This volume increases with the interface displacement. The total volume in the converter as a function of the interface displacement is

$$V = V_{dead} + S_{int} x_{int} \; _{or},$$

where:

- V is the total volume of fluid in the converter.
- V_{dead} is the dead volume of the converter.
- S_{int} is the cross-sectional area of the interface, assumed equal to that of the inlet.
- x_{int} is the displacement of the moving interface.
- $\in_{or}$ is an integer encoding the mechanical orientation of the converter:

$$_{or} = \begin{cases} +1, & \text{if the mechanical orientation is positive} \\ -1, & \text{if the mechanical orientation is negative} \end{cases}$$

Force Balance

At equilibrium, the internal pressure in the converter counteracts the external pressure of its surroundings and the force exerted by the mechanical network on the moving interface. This force is the reverse of that applied by the fluid network. The force balance in the converter is therefore

$$p_I S_{int} = p_{atm} S_{int} - F_{int\ \ or},$$

where:

- p_{atm} is the environmental pressure outside the converter.
- F_{int} is the magnitude of the force exerted by the fluid network on the moving interface.

Energy Balance

The total energy in the converter can change due to energy flow through the inlet, heat flow through the converter wall, and work done by the fluid network on the mechanical network. The energy flow rate, given by the energy conservation equation, is therefore

$$\dot{E} = \phi_A + \phi_H - p_I S_{int} \dot{x}_{int\ \ or},$$

where:

- E is the total energy of the fluid in the converter.
- ϕ_{A} is the energy flow rate into the converter through port A.
- ϕ_{H} is the heat flow rate into the converter through port H.

Taking the fluid kinetic energy in the converter to be negligible, the total energy of the fluid reduces to:

$$E = Mu_I,$$

where:

- M is the fluid mass in the converter.
- u_I is the specific internal energy of the fluid in the converter.

Mass Balance

The fluid mass in the converter can change due to flow through the inlet, represented by port A. The mass flow rate, given by the mass conservation equation, is therefore

$$\dot{M} = \dot{m}_A,$$

where:

- $\dot{m}_A$ is the mass flow rate into the converter through port A.

A change in fluid mass can accompany a change in fluid volume, due to rotation of the moving interface. It can also accompany a change in mass density, due to an evolving pressure or specific internal energy in the converter. The mass rate of change in the converter is then

$$\dot{M} = \left[\left(\frac{\partial\rho}{\partial p}\right)_u \dot{p}_I + \left(\frac{\partial\rho}{\partial u}\right)_p \dot{u}_I\right]V + \frac{S_{int}\dot{x}_{int\ or}}{v_I},$$

where:

- $\left(\frac{\partial\rho}{\partial p}\right)_u$ is the partial derivative of density with respect to pressure at constant specific internal energy.
- $\left(\frac{\partial\rho}{\partial u}\right)_p$ is the partial derivative of density with respect to specific internal energy at constant pressure.
- v_I is the specific volume of the fluid in the converter.

The block blends the density partial derivatives of the various domains using a cubic polynomial function. At a vapor quality of 0–0.1, this function blends the derivatives of the subcooled liquid and two-phase mixture domains. At a vapor quality of 0.9–1, it blends those of the two-phase mixture and superheated vapor domains.

The smoothed density partial derivatives introduce into the original mass conservation equation undesirable numerical errors. To correct for these errors, the block adds the correction term

$${}_{M} = \frac{M - V / v_I}{\tau},$$

where:

- $\in_{\mathrm{M}}$ is the correction term.
- τ is the phase-change time constant—the characteristic duration of a phase change event. This constant ensures that phase changes do not occur instantaneously, effectively introducing a time lag whenever they occur.

The final form of the mass conservation equation is

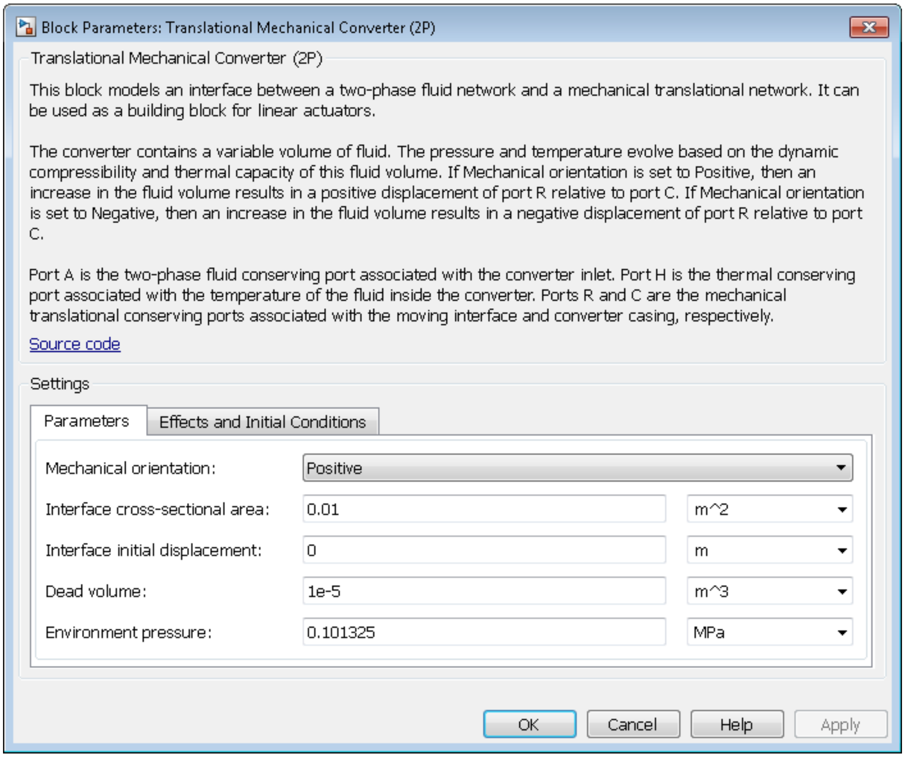
$$\left[\left(\frac{\partial\rho}{\partial p}\right)_u \dot{p}_I + \left(\frac{\partial\rho}{\partial u}\right)_p \dot{u}_I\right]V + \frac{D_{vol}\dot{\theta}_{int\ or}}{v_I} = \dot{m}_A + {}_{M}.$$

The block uses this equation to calculate the internal pressure in the converter given the mass flow rate through the inlet.

Assumptions and Limitations

- The converter walls are rigid. They do not deform under pressure.
- The flow resistance between port A and the converter interior is negligible. The pressure is the same at port A and in the converter interior.
- The thermal resistance between port H and the converter interior is negligible. The temperature is the same at port H and in the converter interior.
- The moving interface is perfectly sealed. No fluid leaks across the interface.
- Mechanical effects such as hard stops, inertia, and friction, are ignored.

Dialog Box and Parameters



Block Parameters: Translational Mechanical Converter (2P)
Settings
Parameters
Effects and Initial Conditions
OK
Cancel
Help
Apply

Translational Mechanical Converter (2P)

This block models an interface between a two-phase fluid network and a mechanical translational network. It can be used as a building block for linear actuators.

The converter contains a variable volume of fluid. The pressure and temperature evolve based on the dynamic compressibility and thermal capacity of this fluid volume. If Mechanical orientation is set to Positive, then an increase in the fluid volume results in a positive displacement of port R relative to port C. If Mechanical orientation is set to Negative, then an increase in the fluid volume results in a negative displacement of port R relative to port C.

Port A is the two-phase fluid conserving port associated with the converter inlet. Port H is the thermal conserving port associated with the temperature of the fluid inside the converter. Ports R and C are the mechanical translational conserving ports associated with the moving interface and converter casing, respectively.

Source code

Mechanical orientation:	Positive	
Interface cross-sectional area:	0.01	m^2
Interface initial displacement:	0	m
Dead volume:	1e-5	m^3
Environment pressure:	0.101325	MPa

Parameters Tab

Mechanical orientation

Alignment of the moving interface relative to the direction of flow. If the mechanical orientation is positive, a positive flow rate into the converter through port A corresponds to a positive translation of port R relative to port C. If the mechanical orientation is negative, a positive flow rate corresponds to a negative translation instead. The default setting is `Positive`.

Interface cross-sectional area

Area normal to the direction of flow at the converter inlet. The inlet area is assumed the same as the interface area. The default value is `0.01` m^2.

Interface initial displacement

Translational offset of the moving interface at the start of simulation. A zero displacement corresponds to a total fluid volume in the converter equal to the specified dead volume. The default value is `0` m.

This parameter must be greater than or equal to zero if the **Mechanical orientation** parameter is set to `Positive`. It must be smaller than or equal to zero if the **Mechanical orientation** parameter is set to `Negative`.

Dead volume

Volume of fluid left in the converter when the interface displacement is zero. The dead volume enables the block to account for mass and energy storage in the converter even at a zero interface displacement. The default value is `1e-5` m^3.

Environment pressure

Pressure outside the converter. This pressure acts against the internal pressure of the converter at the moving interface. A value of zero indicates the moving interface translates against a vacuum. The default value is `0.1013250` MPa.

Effects and Initial Conditions Tab

Initial fluid regime

Fluid regime at the start of simulation. The fluid can be a subcooled liquid, a two-phase mixture, or a superheated vapor. The default setting is `Subcooled liquid`.

Initial fluid pressure

Pressure in the converter at the start of simulation. The default value is `0.101325` MPa.

Initial fluid temperature

Temperature in the converter at the start of simulation. This parameter appears only when the **Initial fluid regime** parameter is set to `Subcooled liquid` or `Superheated vapor`. The default value is `293.15` K.

Phase change time constant

Characteristic duration of a phase-change event. This constant introduces a time lag into the transition between phases. The default value is `0.1` s.

Ports

The block has the following ports:

`A`

Two-phase fluid conserving port associated with the converter inlet.

`H`

Thermal conserving port representing the converter surface through which heat exchange occurs.

`R`

Mechanical translational conserving port associated with the converter rod.

`C`

Mechanical translational conserving port associated with the converter case.

See Also

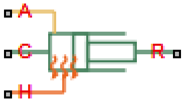
`Rotational Mechanical Converter (2P)`

Translational Mechanical Converter (TL)

Interface between thermal liquid and mechanical translational networks

Library

Thermal Liquid/Elements



Description

The `Translational Mechanical Converter (TL)` block represents the liquid side of a translational mechanical interface. This interface converts liquid pressure into force and vice versa. The output force acts in a single direction, set using a **Mechanical orientation** parameter.

The translational mechanical interface contains no hard stops. To include hard stops, use the Simscape `Translational Hard Stop` block. A model of a translational hydraulic actuator, for example, requires both blocks.

Port A is a thermal liquid conserving port corresponding to the converter inlet. The liquid pressure in the converter equals that at port A. Port Q is a thermal conserving port for modeling heat exchange between the converter liquid and the converter housing. The liquid temperature in the converter equals that at port Q.

Mass Balance

The mass conservation equation in the mechanical converter volume is

$$\dot{m}_{\mathrm{A}} = \varepsilon\,\rho A v + \begin{cases} 0, & \text{if fluid dynamic compressibility is'Off'} \\ V\rho\left(\dfrac{1}{\beta}\dfrac{dp}{dt} + \alpha\dfrac{dT}{dt}\right), & \text{if fluid dynamic compressibility is'On'} \end{cases}$$

where:

- $\dot{m}_{\mathrm{A}}$ is the liquid mass flow rate into the converter through port A.
- ε is the mechanical orientation of the converter (1 if positive, -1 if negative).
- ρ is the liquid mass density.
- A is the cross-sectional area of the converter interface.
- v is the translational velocity of the converter interface (positive for converter expansion, negative for converter contraction).
- V is the liquid volume inside the converter.
- β is the liquid bulk modulus inside the converter.
- α is the coefficient of thermal expansion of the liquid.
- p is the liquid pressure inside the converter.
- T is the liquid temperature inside the converter.

Momentum Balance

The momentum conservation equation in the mechanical converter volume is

$$F = -\varepsilon\left(p - p_{\mathrm{Atm}}\right)A$$

where:

- F is the force the liquid exerts on the converter interface.
- p_{Atm} is the atmospheric pressure.

Energy Balance

The energy conservation equation in the mechanical converter volume is

$$\frac{d(\rho u V)}{dt} = \phi_{\mathrm{A}} + Q_H - pA\varepsilon v,$$

where:

- u is the liquid internal energy.
- ϕ_A is the total energy flow rate into the mechanical converter volume through port A.
- Q_H is the heat flow rate into the mechanical converter volume through the converter wall.

Block Source Code

To view the block source code, at the MATLAB command line enter:

```
edit <matlabroot>\toolbox\physmod\simscape\library\m\
+foundation\+thermal_liquid\+elements\<converter>.ssc
```

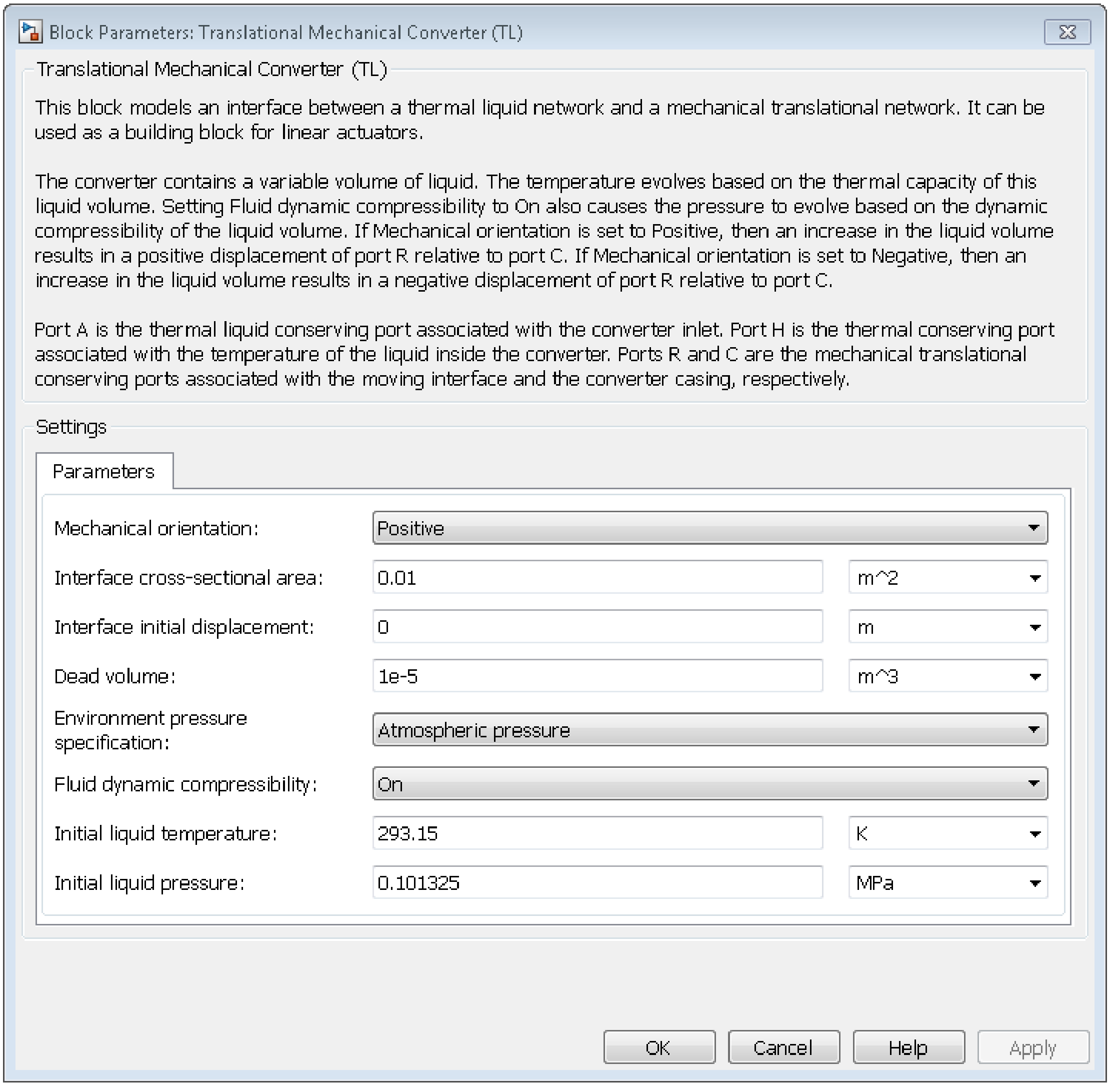
Replace `<matlabroot>` with the output of the `matlabroot` command, and `<converter>` with the compressibility configuration mode using this syntax:

- `translational_converter_compressibility` for the code corresponding to fluid dynamic compressibility ‘On’
- `translational_converter` for the code corresponding to fluid dynamic compressibility ‘Off’

Assumptions and Limitations

- Converter walls are not compliant. They cannot deform, regardless of internal pressure and temperature.
- The converter contains no mechanical hard stop.

Dialog Box and Parameters



Block Parameters: Translational Mechanical Converter (TL)

Translational Mechanical Converter (TL)

This block models an interface between a thermal liquid network and a mechanical translational network. It can be used as a building block for linear actuators.

The converter contains a variable volume of liquid. The temperature evolves based on the thermal capacity of this liquid volume. Setting Fluid dynamic compressibility to On also causes the pressure to evolve based on the dynamic compressibility of the liquid volume. If Mechanical orientation is set to Positive, then an increase in the liquid volume results in a positive displacement of port R relative to port C. If Mechanical orientation is set to Negative, then an increase in the liquid volume results in a negative displacement of port R relative to port C.

Port A is the thermal liquid conserving port associated with the converter inlet. Port H is the thermal conserving port associated with the temperature of the liquid inside the converter. Ports R and C are the mechanical translational conserving ports associated with the moving interface and the converter casing, respectively.

Settings

Parameters

Mechanical orientation:	Positive	
Interface cross-sectional area:	0.01	m^2
Interface initial displacement:	0	m
Dead volume:	1e-5	m^3
Environment pressure specification:	Atmospheric pressure	
Fluid dynamic compressibility:	On	
Initial liquid temperature:	293.15	K
Initial liquid pressure:	0.101325	MPa

Mechanical orientation

Select the relative orientation of the converter with respect to the thermal liquid system. The relative orientation determines the translation direction associated with positive flow into the converter. That direction is positive if the mechanical orientation of the converter is positive. It is negative if the mechanical orientation of the converter is negative. The default setting is `Positive`.

Interface cross-sectional area

Enter the cross-sectional area of the converter interface. This is the area the liquid must push to generate a force. The default value is `0.01` m^2.

Interface initial displacement

Enter the offset distance between the translating converter interface and the converter cap at time zero. The displacement should be positive for positive mechanical orientations and negative for negative mechanical orientations. The default value is `0` m.

Dead volume

Enter the liquid volume remaining in the converter at a zero offset distance. The default value is `1e-5` m^3.

Environment pressure specification

Select a specification method for the environment pressure. Options include `Specified pressure` and `Atmospheric pressure`. The default setting is `Atmospheric pressure`.

Environment pressure

Enter the environment pressure for the component. This parameter is active only when the **Environment pressure specification** parameter is set to `Specified pressure`. The default value is `0.101325` MPa.

Fluid dynamic compressibility

Select whether to include the effect of fluid dynamic compressibility on the transient response of the converter model. Selecting `On` exposes an additional parameter. The default setting is `Off`.

Initial liquid temperature

Enter the liquid temperature in the converter at time zero. The default value is `293.15` K.

Initial liquid pressure

Enter the liquid pressure in the converter at time zero. This parameter is visible only if **Fluid dynamic compressibility** is `On`. The default value is `1` atm.

Ports

This block has the following ports.

A	Thermal liquid conserving port
H	Thermal conserving port
R	Translational mechanical conserving port associated with the moving interface
C	Translational mechanical conserving port associated with the converter casing

See Also

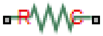
`Rotational Mechanical Converter (TL)`

Translational Spring

Ideal spring in mechanical translational systems

Library

Mechanical Translational Elements



Description

The `Translational Spring` block represents an ideal mechanical linear spring, described with the following equations:

$$F = Kx$$

$$x = x_{init} + x_R - x_C$$

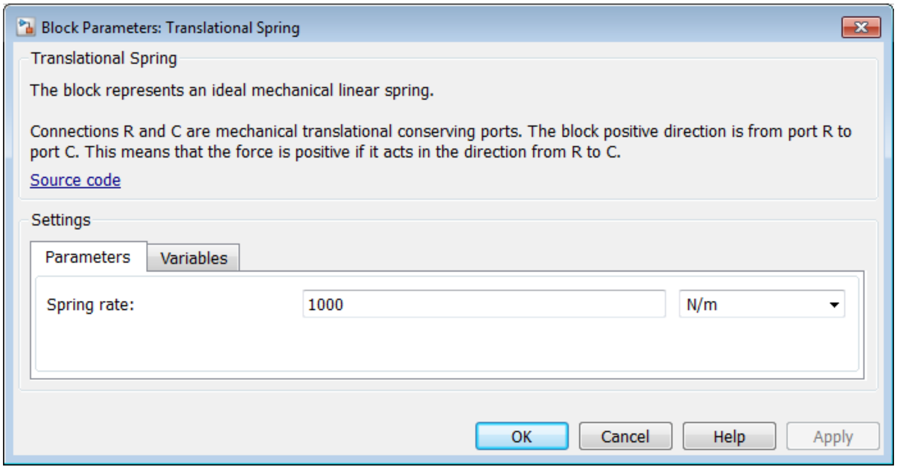
$$v = \frac{dx}{dt}$$

where

F	Force transmitted through the spring
K	Spring rate
x	Relative displacement (spring deformation)
x_{init}	Spring initial displacement (initial deformation); the spring can be initially compressed ($x_{init} > 0$) or stretched ($x_{init} < 0$)
x_R, x_C	Absolute displacements of terminals R and C, respectively
v	Relative velocity
t	Time

The block positive direction is from port R to port C. This means that the force is positive if it acts in the direction from R to C.

Dialog Box and Parameters



Block Parameters: Translational Spring

Translational Spring

The block represents an ideal mechanical linear spring.

Connections R and C are mechanical translational conserving ports. The block positive direction is from port R to port C. This means that the force is positive if it acts in the direction from R to C.

Source code

Settings

Spring rate: 1000 N/m

- "Parameters Tab" on page 1-572
- "Variables Tab" on page 1-572

Parameters Tab

Spring rate

Spring rate. The default value is 1000 N/m.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see "Set Priority and Initial Target for Block Variables".

Ports

The block has the following ports:

R

Mechanical translational conserving port.

`C`

Mechanical translational conserving port.

See Also

`Translational Damper` | `Translational Friction` | `Translational Hard Stop`

Two-Phase Fluid Properties (2P)

Fluid properties in two-phase fluid network

Library

Two-Phase Fluid/Utilities

Description

The `Two-Phase Fluid Properties (2P)` block provides the thermophysical properties of a two-phase fluid. The properties in this block apply to the entire two-phase fluid network—the group of continuously connected two-phase fluid blocks—to which the block connects.

A two-phase fluid network can contain a maximum of one instance of this block. If a network does not contain any instances of this block, the fluid properties are set to those of water. In models with different two-phase fluid networks, each network can contain a separate instance of this block.

The block parameterizes the fluid properties in terms of pressure and normalized internal energy—a linear transformation of the specific internal energy. In a subcooled liquid, the normalized internal energy definition is

$$\bar{u} = \frac{u - u_{min}}{u^{L}_{sat}(p) - u_{min}} - 1, \quad u_{min} \le u < u^{L}_{sat}(p),$$

where:

- $\bar{u}$ is the normalized internal energy of the fluid.
- u is the specific internal energy of the fluid.
- u_{min} is the lowest specific internal energy allowed in the two-phase fluid network.
- $u^{\mathrm{L}}_{\mathrm{sat}}$ is the specific internal energy of the liquid phase at saturation.

In a superheated vapor, the normalized internal energy definition is

$$\bar{u} = \frac{u - u_{max}}{u_{max} - u_{sat}^{V}(p)} + 2, \quad u^{V}{}_{sat}(p) < u \leq u_{\text{max}} ,$$

where:

- u_{max} is the highest specific internal energy allowed in the two-phase fluid network.
- $u^{\text{V}}{}_{\text{sat}}$ is the specific internal energy of the vapor phase at saturation.

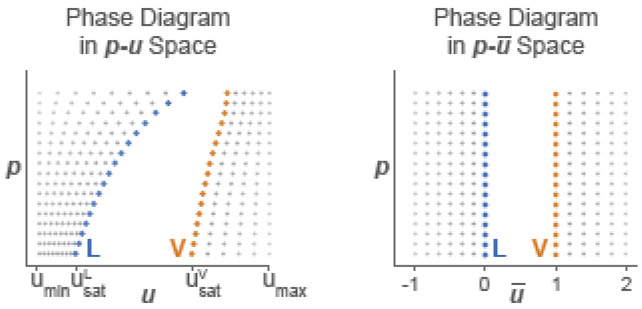
In a two-phase mixture, the normalized internal energy definition is

$$\bar{u} = \frac{u - u_{sat}^{L}(p)}{u_{sat}^{V}(p) - u_{sat}^{L}(p)}, \quad u^{L}{}_{sat}(p) \leq u \leq u^{V}{}_{sat}(p).$$

These expressions correspond to a normalized internal energy that is at all pressures -1 at the minimum valid specific internal energy, 0 at the liquid saturation boundary, +1 at the vapor saturation boundary, and +2 at the maximum valid specific internal energy.

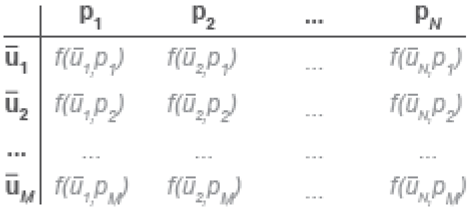
In a two-phase mixture, the normalized internal energy ranges in value from 0 to 1 and is therefore equivalent to vapor quality—the mass fraction of the vapor phase in a two-phase mixture. In subcooled liquid and superheated vapor, the normalized internal energy behaves as an extension of vapor quality.

The normalized internal energy provides an advantage over the specific internal energy. It transforms the p-u phase diagram so that the subcooled liquid and superheated vapor phases occupy distinct rectangular regions. This transformation, shown in the figure, enables you to specify the fluid properties on separate rectangular p-$\bar{u}$ grids, one for each phase.



A pressure vector, of length *N*, and two normalized internal energy vectors, of lengths M_L and M_V, provide the (p, $\bar{u}$) coordinates of the two grids. The pressure vector is common to both grids. The subcooled liquid grid is M_L-by-N in size and the superheated vapor grid M_V-by-N.

Two-way lookup tables provide the fluid property values on the (p, $\bar{u}$) grids. The table rows correspond to different normalized internal energies and the table columns to pressures. Fluid properties in the p-$\bar{u}$ continuum are computed using linear interpolation between the p-$\bar{u}$ data points.



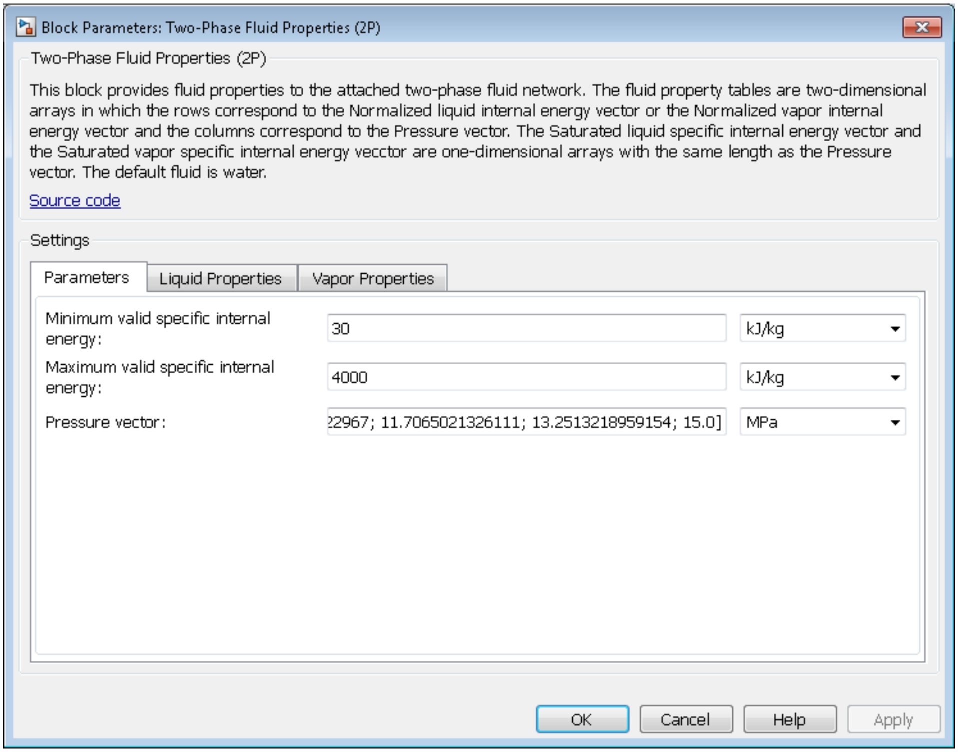
	p_1	p_2	...	p_N
$\bar{u}_1$	$f(\bar{u}_1,p_1)$	$f(\bar{u}_2,p_1)$	...	$f(\bar{u}_N,p_1)$
$\bar{u}_2$	$f(\bar{u}_1,p_2)$	$f(\bar{u}_2,p_2)$	...	$f(\bar{u}_N,p_2)$
...	...	...	...	...
$\bar{u}_M$	$f(\bar{u}_1,p_M)$	$f(\bar{u}_2,p_M)$	...	$f(\bar{u}_N,p_M)$

Two-Way Property Lookup Table

Saturated specific internal energy vectors provide the phase boundaries in the (p, $\bar{u}$) phase diagram. These separate the different regions of the phase diagram—subcooled liquid, two-phase mixture, and superheated vapor.

Along with the minimum and maximum valid specific internal energy values, the saturated specific internal energy vectors enable the Two-Phase Fluid blocks to convert the normalized internal energies specified in this block into the specific internal energies they use for calculation purposes.

Dialog Box and Parameters



Two-Phase Fluid Properties (2P)

This block provides fluid properties to the attached two-phase fluid network. The fluid property tables are two-dimensional arrays in which the rows correspond to the Normalized liquid internal energy vector or the Normalized vapor internal energy vector and the columns correspond to the Pressure vector. The Saturated liquid specific internal energy vector and the Saturated vapor specific internal energy vecctor are one-dimensional arrays with the same length as the Pressure vector. The default fluid is water.

Source code

Settings

Minimum valid specific internal energy: 30 kJ/kg

Maximum valid specific internal energy: 4000 kJ/kg

Pressure vector: 22967; 11.7065021326111; 13.2513218959154; 15.0] MPa

Parameters Tab

Minimum valid specific internal energy

Lowest specific internal energy allowed in the two-phase fluid network. The default value is 30 kJ/kg.

Maximum valid specific internal energy

Highest specific internal energy allowed in the two-phase fluid network. The default value is 4000 kJ/kg.

Pressure vector

Vector of length N containing the pressure values corresponding to the columns of the fluid property tables. The default vector is a logarithmically spaced 60-element vector ranging from 0.01 MPa to 15 MPa.

Liquid Properties Tab

Normalized liquid internal energy vector

Vector of length M_L containing the normalized internal energy values corresponding to the rows of the liquid property tables. The vector must start at `-1` and end at `0`. The default is a uniformly spaced 25-element vector.

Liquid specific volume table

$M_L \times N$ matrix containing the liquid specific volume values corresponding to the normalized liquid internal energy and pressure vectors. The default matrix is a 25 × 60 table for water.

Liquid specific entropy table

$M_L \times N$ matrix containing the liquid specific entropy values corresponding to the normalized liquid internal energy and pressure vectors. The default matrix is a 25 × 60 table for water.

Liquid temperature table

$M_L \times N$ matrix containing the liquid temperature values corresponding to the normalized liquid internal energy and pressure vectors. The default matrix is a 25 × 60 table for water.

Liquid kinematic viscosity table

$M_L \times N$ matrix containing the liquid kinematic viscosity values corresponding to the normalized liquid internal energy and pressure vectors. The default matrix is a 25 × 60 table for water.

Liquid thermal conductivity table

$M_L \times N$ matrix containing the liquid thermal conductivity values corresponding to the normalized liquid internal energy and pressure vectors. The default matrix is a 25 × 60 table for water.

Liquid Prandtl number table

$M_L \times N$ matrix containing the liquid Prandtl number values corresponding to the normalized liquid internal energy and pressure vectors. The default matrix is a 25 × 60 table for water.

Saturated liquid specific internal energy vector

Vector of length N containing the saturated liquid specific internal energy values corresponding to the pressure vector. The default is a 60-element vector for water.

Vapor Properties Tab

Normalized vapor internal energy vector

Vector of length M_V containing the normalized internal energy values corresponding to the rows of the vapor property tables. The vector must start at 1 and end at 2. The default is a uniformly spaced 25-element vector.

Vapor specific volume table

$M_V \times N$ matrix containing the vapor specific volume values corresponding to the normalized vapor internal energy and pressure vectors. The default matrix is a 25 × 60 table for water.

Vapor specific entropy table

$M_V \times N$ matrix containing the vapor specific entropy values corresponding to the normalized vapor internal energy and pressure vectors. The default matrix is a 25 × 60 table for water.

Vapor temperature table

$M_V \times N$ matrix containing the vapor temperature values corresponding to the normalized vapor internal energy and pressure vectors. The default matrix is a 25 × 60 table for water.

Vapor kinematic viscosity table

$M_V \times N$ matrix containing the vapor kinematic viscosity values corresponding to the normalized vapor internal energy and pressure vectors. The default matrix is a 25 × 60 table for water.

Vapor thermal conductivity table

$M_V \times N$ matrix containing the vapor thermal conductivity values corresponding to the normalized vapor internal energy and pressure vectors. The default matrix is a 25 × 60 table for water.

Vapor Prandtl number table

$M_V \times N$ matrix containing the vapor Prandtl number values corresponding to the normalized vapor internal energy and pressure vectors. The default matrix is a 25 × 60 table for water.

Saturated vapor specific internal energy vector

Vector of length N containing the saturated vapor specific internal energy values corresponding to the pressure vector. The default is a 60-element vector for water.

Ports

The block has a two-phase fluid conserving port. This port identifies the two-phase fluid network whose fluid properties the block provides.

See Also

`twoPhaseFluidTables`

Related Examples

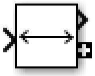
- “Manually Generate Fluid Property Tables”

Two-Way Connection

Two-way connector port for subsystem

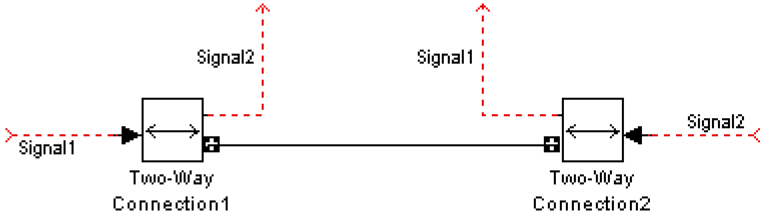
Library

Utilities



Description

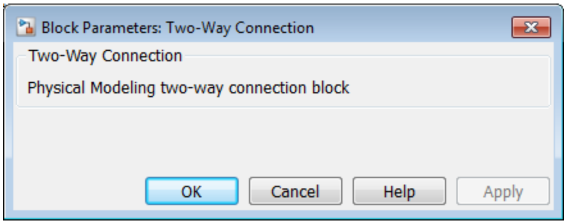
The `Two-Way Connection` block has a two-way connector port, which transports Simulink signals both ways. You connect this port to another two-way connector port. The schematic below illustrates how the two-way connection works. It carries the signal `Signal1` from the input port of the first `Two-Way Connection` block to the output port of the second `Two-Way Connection` block, and at the same time carries the signal `Signal2` from the input port of the second `Two-Way Connection` block to the output port of the first `Two-Way Connection` block.



The `Two-Way Connection` block supports invariant model architecture for top-down or bottom-up design. It lets you build subsystems as Simulink models, based on signals, and then connect them as if they are physical systems. Place the `Two-Way Connection` blocks inside the subsystem and connect them to the `Connection Port` blocks. Then the ports on the subsystem boundary appear as two-way connector ports ⊞.

Note `Two-Way Connection` blocks cannot be connected across nonvirtual subsystems.

Dialog Box and Parameters



Block Parameters: Two-Way Connection

Two-Way Connection

Physical Modeling two-way connection block

The block has no parameters.

Ports

The block has a Simulink input port, a Simulink output port, and a two-way connector port.

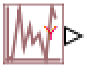
Uniform Random Number

Generate uniformly distributed random numbers for physical modeling

Library

Physical Signals/Sources

Description



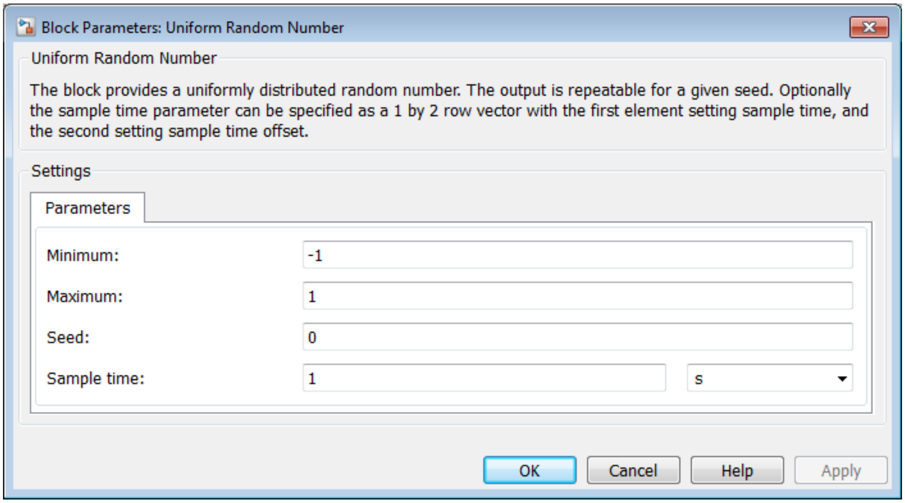
The `Uniform Random Number` block generates uniformly distributed random numbers over the interval you specify. To generate normally (Gaussian) distributed random numbers, use the `Random Number` block.

The block behavior is the same as the Simulink `Uniform Random Number` block (except that it generates a physical signal rather than a Simulink signal).

You have an option to specify an initial time offset as part of the **Sample time** parameter. In this case, the block outputs 0 until the simulation time reaches the *`offset`* value, at which point the random sequence starts.

`Uniform Random Number` blocks that use the same seed and parameters generate a repeatable sequence. The seed resets to the specified value each time a simulation starts.

Dialog Box and Parameters



Block Parameters: Uniform Random Number

Uniform Random Number

The block provides a uniformly distributed random number. The output is repeatable for a given seed. Optionally the sample time parameter can be specified as a 1 by 2 row vector with the first element setting sample time, and the second setting sample time offset.

Settings

Parameters

Minimum: -1

Maximum: 1

Seed: 0

Sample time: 1 s

Minimum

Specify the minimum output value. The default is `-1`.

Maximum

Specify the maximum output value. The default is `1`.

Seed

Specify the starting seed for the random number generator. Output is repeatable for a given seed. The seed must be an integer in the range of 0 to (2^32 – 1). The default is `0`.

Sample time

The value of the time *`step`* interval. The default *`step`* value is `1` s. To specify an initial time offset, enter the parameter value as `[`*`step`*`, `*`offset`*`]`, otherwise the *`offset`* value is assumed to be `0`. The offset must be less than the step size.

Ports

The block has one physical signal output port.

See Also

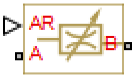
`Random Number`

Variable Area Hydraulic Orifice

Hydraulic variable orifice created by cylindrical spool and sleeve

Library

Hydraulic Elements



Description

The `Variable Area Hydraulic Orifice` block models a variable orifice created by a cylindrical sharp-edged spool and a variable-area slot in a sleeve. The area of the orifice is expected to be computed outside the block and imported via the AR physical signal connection. The **Minimum area** parameter specifies the minimum orifice area value. If the input signal falls below this level (for example, turns negative), the area is saturated to this value. The flow rate through the orifice is proportional to the orifice area and the pressure differential across the orifice.

The flow rate is determined according to the following equations:

$$q = C_D \cdot A\sqrt{\frac{2}{\rho}} \cdot \frac{p}{\left(p^2 + p_{cr}^2\right)^{1/4}}$$

$$p = p_A - p_B$$

$$p_{cr} = \frac{\rho}{2}\left(\frac{\mathrm{Re}_{cr} \cdot \nu}{C_D \cdot D_H}\right)^2$$

$$D_H = \sqrt{\frac{4A}{\pi}}$$

where

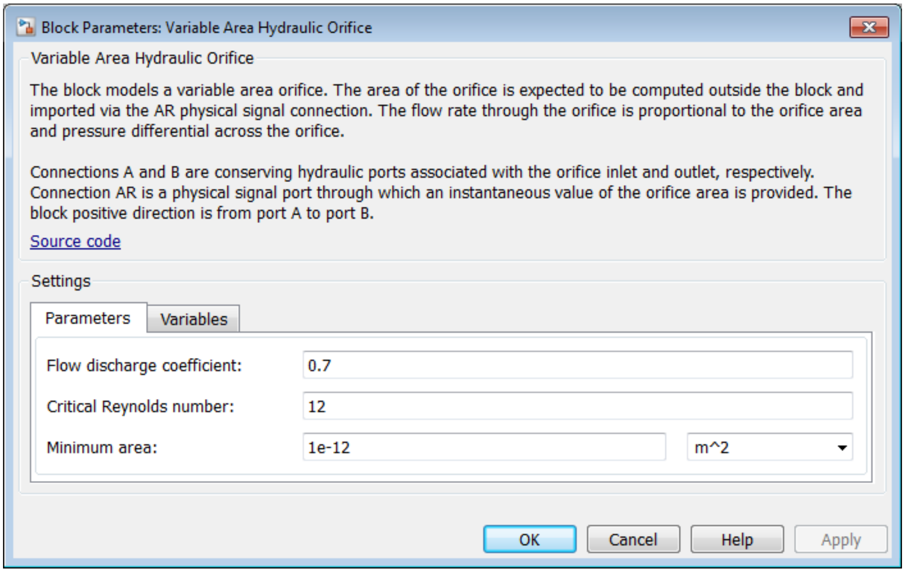
q	Flow rate
p	Pressure differential
p_{A}, p_{B}	Gauge pressures at the block terminals
C_{D}	Flow discharge coefficient
A	Orifice passage area
D_{H}	Orifice hydraulic diameter
ρ	Fluid density
ν	Fluid kinematic viscosity
p_{cr}	Minimum pressure for turbulent flow
Re_{cr}	Critical Reynolds number

The block positive direction is from port A to port B. This means that the flow rate is positive if it flows from A to B and the pressure differential is determined as $p = p_A - p_B$.

Basic Assumptions and Limitations

- Fluid inertia is not taken into account.

Dialog Box and Parameters



Block Parameters: Variable Area Hydraulic Orifice

Variable Area Hydraulic Orifice

The block models a variable area orifice. The area of the orifice is expected to be computed outside the block and imported via the AR physical signal connection. The flow rate through the orifice is proportional to the orifice area and pressure differential across the orifice.

Connections A and B are conserving hydraulic ports associated with the orifice inlet and outlet, respectively. Connection AR is a physical signal port through which an instantaneous value of the orifice area is provided. The block positive direction is from port A to port B.

Source code

Settings

Parameters | Variables

Flow discharge coefficient: 0.7

Critical Reynolds number: 12

Minimum area: 1e-12 m^2

- "Parameters Tab" on page 1-588
- "Variables Tab" on page 1-589

Parameters Tab

Flow discharge coefficient

Semi-empirical parameter for orifice capacity characterization. Its value depends on the geometrical properties of the orifice, and usually is provided in textbooks or manufacturer data sheets. The default value is `0.7`.

Critical Reynolds number

The maximum Reynolds number for laminar flow. The transition from laminar to turbulent regime is assumed to take place when the Reynolds number reaches this value. The value of the parameter depends on the orifice geometrical profile. You can find recommendations on the parameter value in hydraulics textbooks. The default value is `12`, which corresponds to a round orifice in thin material with sharp edges.

Minimum area

Leakage area of the completely closed orifice. If the input signal falls below this level (for example, turns negative), the area is saturated to this value. The parameter value must be greater than zero. The default value is `1e-12` m^2.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Global Parameters

Parameters determined by the type of working fluid:

- **Fluid density**
- **Fluid kinematic viscosity**

Use the `Hydraulic Fluid` block or the `Custom Hydraulic Fluid` block to specify the fluid properties.

Ports

The block has the following ports:

A

Hydraulic conserving port associated with the orifice inlet.

B

Hydraulic conserving port associated with the orifice outlet.

AR

Physical signal port that provides the value of the orifice area.

See Also

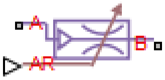
`Constant Area Hydraulic Orifice`

Variable Area Pneumatic Orifice

Sharp-edged variable-area orifice in pneumatic systems

Library

Pneumatic Elements



Description

The `Variable Area Pneumatic Orifice` block models the flow rate of an ideal gas through a sharp-edged variable-area orifice. The area of the orifice is expected to be computed outside the block and imported via the AR physical signal connection. The **Minimum area** parameter specifies the minimum orifice area value. If the input signal falls below this level (for example, turns negative), the area is saturated to this value.

The flow rate through the orifice is proportional to the orifice area and the pressure differential across the orifice.

$$G = C_d \bullet A \bullet p_i \sqrt{\frac{2\gamma}{\gamma - 1} \bullet \frac{1}{RT_i} \left[\left(\frac{p_o}{p_i} \right)^{\frac{2}{\gamma}} - \left(\frac{p_o}{p_i} \right)^{\frac{\gamma+1}{\gamma}} \right]}$$

where

G	Mass flow rate
C_d	Discharge coefficient, to account for effective loss of area due to orifice shape
A	Orifice cross-sectional area
p_i, p_o	Absolute pressures at the orifice inlet and outlet, respectively. The inlet and outlet change depending on flow direction. For positive flow ($G > 0$), $p_i = p_A$, otherwise $p_i = p_B$.

γ	The ratio of specific heats at constant pressure and constant volume, c_p / c_v
R	Specific gas constant
T	Absolute gas temperature

The choked flow occurs at the critical pressure ratio defined by

$$\beta_{cr} = \frac{p_o}{p_i} = \left(\frac{2}{\gamma + 1}\right)^{\frac{\gamma}{\gamma - 1}}$$

after which the flow rate depends on the inlet pressure only and is computed with the expression

$$G = C_d \bullet A \bullet p_i \sqrt{\frac{\gamma}{RT_i} \bullet \beta_{cr}^{\frac{\gamma+1}{\gamma}}}$$

The square root relationship has infinite gradient at zero flow, which can present numerical solver difficulties. Therefore, for very small pressure differences, defined by p_o / p_i > 0.999, the flow equation is replaced by a linear flow-pressure relationship

$$G = kC_d \bullet A \bullet T_i^{-0.5} (p_i - p_o)$$

where k is a constant such that the flow predicted for p_o / p_i is the same as that predicted by the original flow equation for p_o / p_i = 0.999.

The heat flow out of the orifice is assumed equal to the heat flow into the orifice, based on the following considerations:

- The orifice is square-edged or sharp-edged, and as such is characterized by an abrupt change of the downstream area. This means that practically all the dynamic pressure is lost in the expansion.
- The lost energy appears in the form of internal energy that rises the output temperature and makes it very close to the inlet temperature.

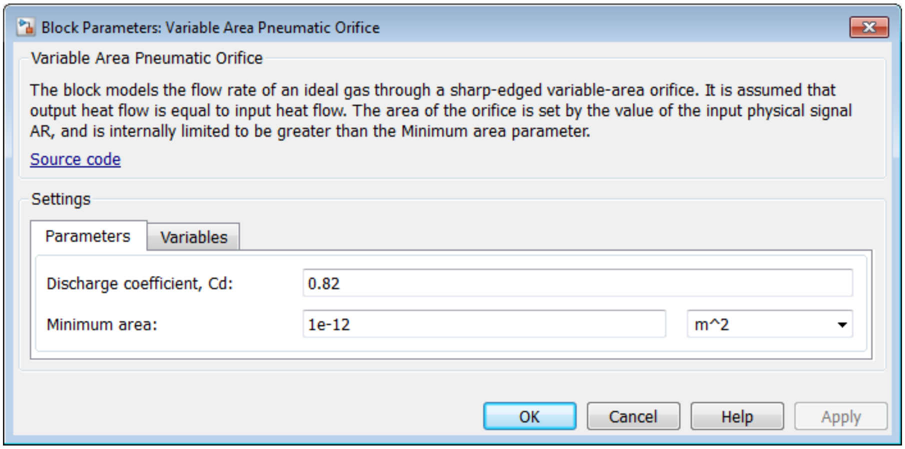
Therefore, $q_i = q_o$, where q_i and q_o are the input and output heat flows, respectively.

The block positive direction is from port A to port B. This means that the flow rate is positive if it flows from A to B.

Basic Assumptions and Limitations

- The gas is ideal.
- Specific heats at constant pressure and constant volume, c_p and c_v, are constant.
- The process is adiabatic, that is, there is no heat transfer with the environment.
- Gravitational effects can be neglected.
- The orifice adds no net heat to the flow.

Dialog Box and Parameters



Block Parameters: Variable Area Pneumatic Orifice

Variable Area Pneumatic Orifice

The block models the flow rate of an ideal gas through a sharp-edged variable-area orifice. It is assumed that output heat flow is equal to input heat flow. The area of the orifice is set by the value of the input physical signal AR, and is internally limited to be greater than the Minimum area parameter.

Source code

Settings

Discharge coefficient, Cd: 0.82

Minimum area: 1e-12 m^2

- "Parameters Tab" on page 1-592
- "Variables Tab" on page 1-593

Parameters Tab

Discharge coefficient, Cd

Semi-empirical parameter for orifice capacity characterization. Its value depends on the geometrical properties of the orifice, and usually is provided in textbooks or manufacturer data sheets. The default value is `0.82`.

Minimum area

Specifies the minimum orifice area value. If the input signal falls below this level (for example, turns negative), the area is saturated to this value. The default value is `1e-12` m^2.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

A

Pneumatic conserving port associated with the orifice inlet for positive flow.

B

Pneumatic conserving port associated with the orifice outlet for positive flow.

AR

Physical signal port that provides the value of the orifice area.

See Also

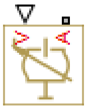
`Constant Area Pneumatic Orifice` | `Constant Area Pneumatic Orifice (ISO 6358)`

Variable Hydraulic Chamber

Hydraulic capacity of variable volume with compressible fluid

Library

Hydraulic Elements



Description

The `Variable Hydraulic Chamber` block models fluid compressibility in variable volume chambers. The fluid is considered to be a mixture of liquid and a small amount of entrained, nondissolved gas. Use this block together with the `Translational Hydro-Mechanical Converter` block.

Note The `Variable Hydraulic Chamber` block takes into account only the flow rate caused by fluid compressibility. The fluid volume consumed to create piston velocity is accounted for in the `Translational Hydro-Mechanical Converter` block.

The chamber is simulated according to the following equations (see [1, 2]):

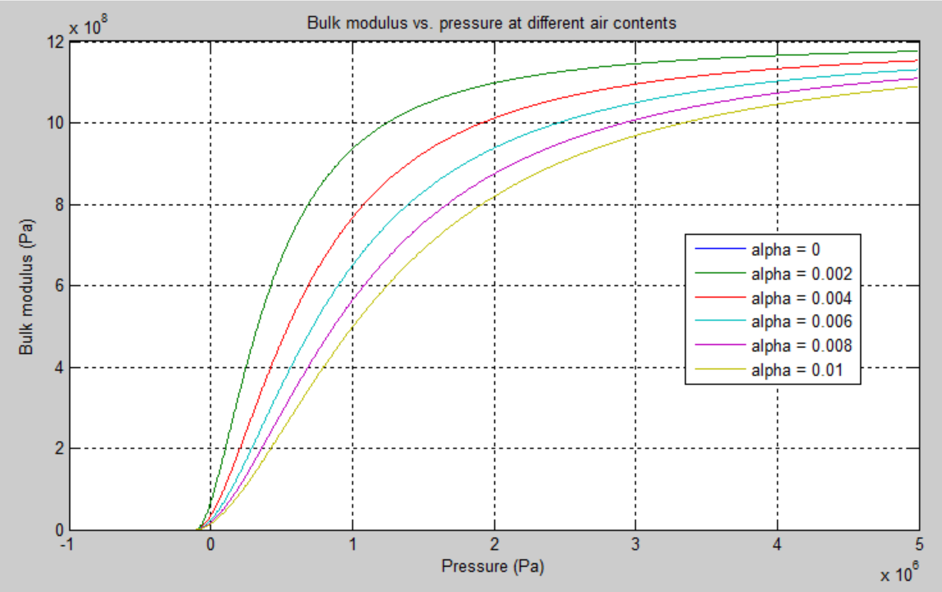
$$q = \frac{V_0 + V}{E} \bullet \frac{dp}{dt}$$

$$E = E_l \frac{1 + \alpha \left(\frac{p_a}{p_a + p} \right)^{1/n}}{1 + \alpha \frac{p_a^{1/n}}{n \bullet (p_a + p)^{\frac{n+1}{n}}} E_l}$$

where

q	Flow rate due to fluid compressibility
V_0	Initial volume of fluid in the chamber
V	Chamber volume change, provided through port V
E	Fluid bulk modulus
E_l	Pure liquid bulk modulus
p	Gauge pressure of fluid in the chamber
p_a	Atmospheric pressure
a	Relative gas content at atmospheric pressure, $a = V_\mathrm{G}/V_\mathrm{L}$
V_G	Gas volume at atmospheric pressure
V_L	Volume of liquid
n	Gas-specific heat ratio

The main objective of representing fluid as a mixture of liquid and gas is to introduce an approximate model of cavitation, which takes place in a chamber if pressure drops below fluid vapor saturation level. As it is seen in the graph below, the bulk modulus of a mixture decreases at $p \to p_a$, thus considerably slowing down further pressure change. At high pressure, $p >> p_a$, a small amount of nondissolved gas has practically no effect on the system behavior.



Cavitation is an inherently thermodynamic process, requiring consideration of multiple-phase fluids, heat transfers, etc., and as such cannot be accurately simulated with Simscape software. But the simplified version implemented in the block is good enough to signal if pressure falls below dangerous level, and to prevent computation failure that normally occurs at negative pressures.

If pressure falls below absolute vacuum (–101325 Pa), the simulation stops and an error message is displayed.

Port A is a hydraulic conserving port associated with the chamber inlet. Port V is a physical signal port that provides the chamber volume variation.

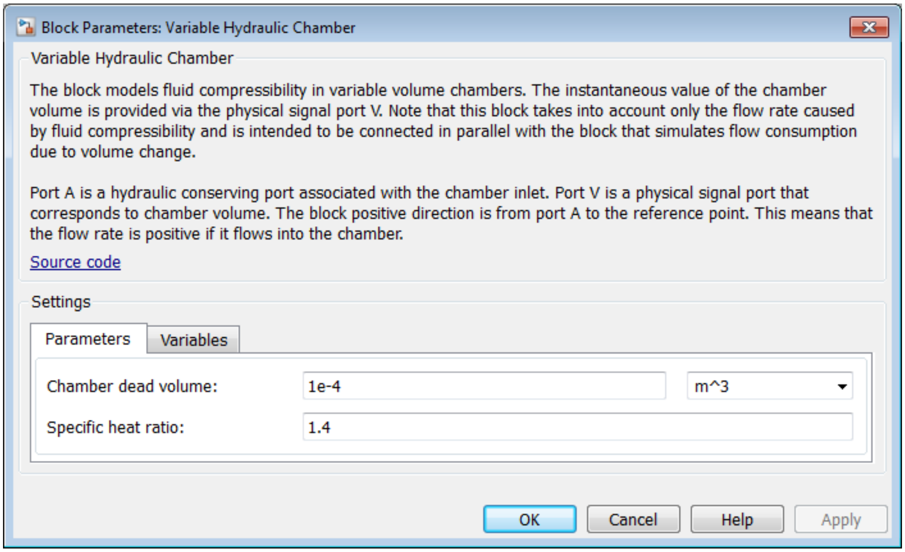
The block positive direction is from port A to the reference point. This means that the flow rate is positive if it flows into the chamber.

Basic Assumptions and Limitations

- Fluid density remains constant.
- Chamber volume can not be less that the dead volume.

- Fluid fills the entire chamber volume.

Dialog Box and Parameters



Variable Hydraulic Chamber

The block models fluid compressibility in variable volume chambers. The instantaneous value of the chamber volume is provided via the physical signal port V. Note that this block takes into account only the flow rate caused by fluid compressibility and is intended to be connected in parallel with the block that simulates flow consumption due to volume change.

Port A is a hydraulic conserving port associated with the chamber inlet. Port V is a physical signal port that corresponds to chamber volume. The block positive direction is from port A to the reference point. This means that the flow rate is positive if it flows into the chamber.

Chamber dead volume: 1e-4 m^3

Specific heat ratio: 1.4

- “Parameters Tab” on page 1-597
- “Variables Tab” on page 1-598

Parameters Tab

Chamber dead volume

Minimal volume of fluid in the chamber. The default value is `1e-4` m^3.

Specific heat ratio

Gas-specific heat ratio. The default value is `1.4`.

Restricted Parameters

When your model is in Restricted editing mode, you cannot modify the following parameter:

- **Chamber orientation**

All other block parameters are available for modification.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Global Parameters

Parameters determined by the type of working fluid:

- **Fluid density**
- **Fluid kinematic viscosity**

Use the `Hydraulic Fluid` block or the `Custom Hydraulic Fluid` block to specify the fluid properties.

Ports

The block has the following ports:

`A`

Hydraulic conserving port associated with the chamber inlet.

`V`

Physical signal port that provides the chamber volume variation.

References

[1] Manring, N.D., *Hydraulic Control Systems*, John Wiley & Sons, New York, 2005

[2] Meritt, H.E., *Hydraulic Control Systems*, John Wiley & Sons, New York, 1967

See Also

`Constant Volume Hydraulic Chamber`

Variable Local Restriction (2P)

Time-varying flow resistance

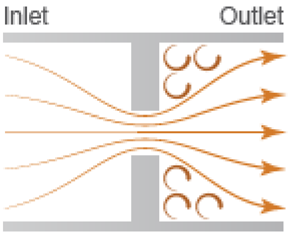
Library

Two-Phase Fluid/Elements

Description

The `Variable Local Restriction (2P)` block models the pressure drop due to a time-varying flow resistance such as a valve. Ports A and B represent the restriction inlet and outlet. Port AR sets the time-varying restriction area, specified as a physical signal.

The restriction consists of a contraction followed by a sudden expansion in flow area. The contraction causes the fluid to accelerate and its pressure to drop. The expansion recovers the lost pressure though only in part, as the flow separates from the wall, losing momentum in the process.



Local Restriction Schematic

The restriction is adiabatic. It does not exchange heat with its surroundings. The net energy flow rate into the restriction follows from the energy conservation equation

$$\phi_I + \phi_O = 0,$$

where:

- ϕ_I is the energy flow rate into the restriction through the inlet.
- ϕ_O is the energy flow rate into the restriction through the outlet.

Momentum Balance in the Contraction Zone

The momentum balance in the contraction zone, located between the inlet and aperture, is

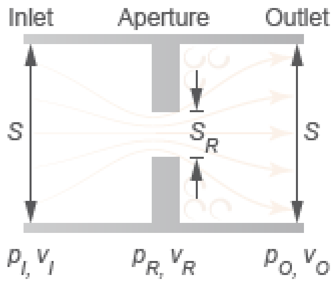
$$p_I S - p_R S_{VC} - p_{avg}\left(S - S_{VC}\right) = \dot{m}\Delta\vec{v}_{IR},$$

where:

- p_I is the pressure at the inlet.
- p_R is the pressure at the restriction aperture.
- p_{avg} is the area-averaged pressure at the wall containing the aperture:

$$p_{avg} = \frac{p_I S + p_R S_{VC}}{S + S_{VC}}$$

- S is the flow cross-sectional area at the inlet and outlet.
- S_{VC} is the vena contracta flow area.
- $\dot{m}$ is the mass flow rate from the inlet to the outlet.
- $\Delta\vec{v}_{IR}$ is the velocity change from the inlet to the aperture.



Local Restriction Variables

Inserting p_{avg} and rearranging terms yields the pressure difference between the inlet and aperture as a function of the ideal mass flow rate:

$$\left(p_I - p_R\right) S_{eqv} = \dot{m} \Delta \vec{v}_{IR},$$

where:

- S_{eqv} is an equivalent cross-sectional area given by

$$S_{eqv} = \frac{2SS_{VC}}{S + S_{VC}}.$$

Momentum Balance in the Expansion Zone

The flow exits the aperture as a jet. In the exit plane, the average pressure outside the jet is approximately equal to that inside the jet. The momentum balance in the expansion zone, located between the aperture and outlet, is then

$$p_R S_{VC} + p_R \left(S - S_{VC}\right) - p_O S = -\dot{m} \Delta \vec{v}_{OR},$$

where:

- p_{O} is the pressure at the outlet.
- $\Delta \vec{v}_{OR}$ is the velocity change from the outlet to the restriction aperture.

Rearranging terms yields the pressure difference between the outlet and aperture as a function of the ideal mass flow rate:

$$\left(p_O - p_R\right) S = \dot{m} \Delta \vec{v}_{OR}.$$

Vena Contracta Flow Area

The vena contracta is the point in the fluid stream where the flow area is at a minimum. Due to the sharp restriction angle, this flow area is generally smaller than the specified restriction area. The block defines the vena contracta flow area as

$$S_{VC} = \frac{C_d S S_R}{\sqrt{S^2 - \left(1 - C_d^2\right) S_R^2}},$$

where:

- C_d is the discharge coefficient relating the ideal mass flow rate to the actual flow rate.
- S_R is the specified restriction area.

Change in Velocity

The changes in velocity across the contraction and expansion zones vary with the flow regime—laminar or turbulent. The transition between the two occurs when the mass flow rate reaches a critical value:

$$\dot{m}_{crit} = \frac{Re_{crit} \nu_{avg}}{\upsilon_{avg}} \sqrt{\frac{\pi S_R}{4}},$$

where:

- $\dot{m}_{crit}$ is the critical mass flow rate separating the laminar and turbulent flow regimes.
- Re_crit is the critical Reynolds number separating the laminar and turbulent flow regimes.
- ν_avg is the average kinematic viscosity in the restriction, defined as

$$\nu_{avg} = \frac{\nu_I + \nu_O}{2}.$$

- ν_I is the kinematic viscosity at the inlet.
- ν_O is the kinematic viscosity at the outlet.
- υ_avg is the average specific volume in the restriction, defined as

$$\upsilon_{avg} = \frac{\upsilon_I + \upsilon_O}{2}.$$

- v_{I} is the specific volume at the inlet.
- v_{O} is the specific volume at the outlet.

In the turbulent regime, the change in velocity varies linearly with the ideal mass flow rate:

$$\Delta\vec{v}_{IR}^{turb} = \dot{m}\left(\frac{v_R}{S_{VC}} - \frac{v_I}{S}\right),$$

while in the expansion zone it is

$$\Delta\vec{v}_{OR}^{turb} = \dot{m}\left(\frac{v_R}{S_{VC}} - \frac{v_O}{S}\right),$$

where:

- $\Delta\vec{v}_{IR}{}^{turb}$ is the change in velocity from the inlet to the restriction aperture in the turbulent regime.
- $\Delta\vec{v}_{OR}{}^{turb}$ is the change in velocity from the outlet to the restriction aperture in the turbulent regime.

In the laminar regime, the change in velocity is independent of the ideal mass flow rate. In the contraction zone, this change is

$$\Delta\vec{v}_{IR}^{lam} = \dot{m}_{crit}\left(\frac{v_R + v_I}{2}\right)\left(\frac{1}{S_{VC}} - \frac{1}{S}\right),$$

while in the expansion zone it is

$$\Delta\vec{v}_{OR}^{lam} = \dot{m}_{crit}\left(\frac{v_R + v_O}{2}\right)\left(\frac{1}{S_{VC}} - \frac{1}{S}\right),$$

where:

- $\Delta\vec{v}_{IR}{}^{lam}$ is the change in velocity from the inlet to the restriction aperture in the laminar regime.
- $\Delta\vec{v}_{OR}{}^{lam}$ is the change in velocity from the outlet to the restriction aperture in the laminar regime.

Quadratic functions blend the laminar- and turbulent-flow expressions, preventing numerical discontinuities due to transitions in flow regime. In the contraction zone, the general velocity change is

$$\Delta\vec{v}_{IR} = \sqrt{\left(\Delta\vec{v}_{IR}^{turb}\right)^2 + \left(\Delta\vec{v}_{IR}^{lam}\right)^2},$$

while in the contraction zone it is

$$\Delta\vec{v}_{OR} = \sqrt{\left(\Delta\vec{v}_{OR}^{turb}\right)^2 + \left(\Delta\vec{v}_{OR}^{lam}\right)^2}.$$

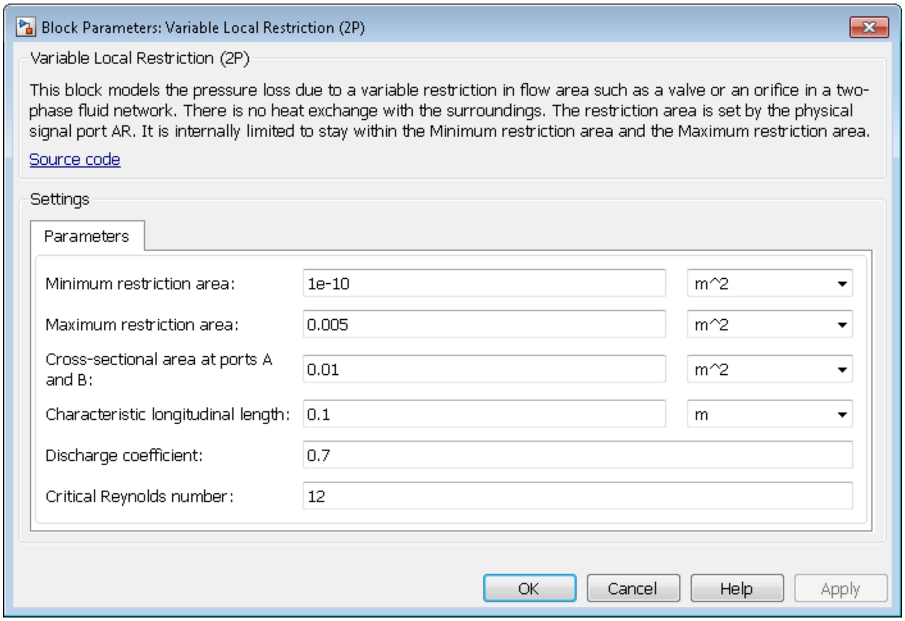
In the laminar regime, the turbulent-flow terms become negligible, reducing the velocity changes in the expansion and contraction zones to $\Delta\vec{v}_{IR}{}^{lam}$ and $\Delta\vec{v}_{OR}{}^{lam}$. Substituting these terms into the momentum balance equations reveals a linear relationship between the pressure drop and the mass flow rate:

$$\Delta P \propto \dot{m}$$

In the turbulent regime, the laminar-flow terms become negligible, reducing the velocity changes in the expansion and contraction zones to $\Delta\vec{v}_{IR}{}^{turb}$ and $\Delta\vec{v}_{OR}{}^{turb}$. Substituting these terms into the momentum balance equations reveals a quadratic relationship between the pressure drop and the mass flow rate:

$$\Delta P \propto \dot{m}^2$$

Dialog Box and Parameters



Variable Local Restriction (2P)

This block models the pressure loss due to a variable restriction in flow area such as a valve or an orifice in a two-phase fluid network. There is no heat exchange with the surroundings. The restriction area is set by the physical signal port AR. It is internally limited to stay within the Minimum restriction area and the Maximum restriction area.

Source code

Settings

Parameters

Minimum restriction area:	1e-10	m^2
Maximum restriction area:	0.005	m^2
Cross-sectional area at ports A and B:	0.01	m^2
Characteristic longitudinal length:	0.1	m
Discharge coefficient:	0.7	
Critical Reynolds number:	12	

Parameters Tab

Cross-sectional area at ports A and B

Area normal to the direction of flow at the inlet and outlet. The two cross-sectional areas are assumed identical. The default value is `0.01` m^2.

Characteristic longitudinal length

Average distance the flow must traverse between the inlet and outlet. The default value is `0.1` m.

Flow discharge coefficient

Ratio of the actual mass flow rate through the restriction to its ideal, or theoretical, value. The discharge coefficient helps to account for restriction geometry. The default value is `0.7`.

Critical Reynolds number based on restriction diameter

Reynolds number at which flow transitions between laminar and turbulent regimes. The default value is `12`.

Ports

The block has two two-phase fluid conserving ports.

See Also

`Local Restriction (2P)`

Variable Local Restriction (TL)

Time-varying reduction in flow area

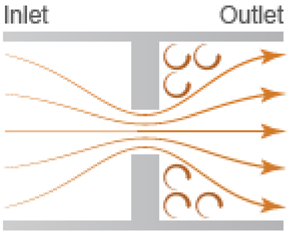
Library

Thermal Liquid/Elements

Description

The `Local Restriction (TL)` block models the pressure drop due to a time-varying reduction in flow area such as a valve. Ports A and B represent the restriction inlets. Port AR sets the time-varying restriction area, specified as a physical signal.

The restriction consists of a contraction followed by a sudden expansion in flow area. The contraction causes the fluid to accelerate and its pressure to drop. The pressure drop is assumed to persist in the expansion zone—an approximation suitable for narrow restrictions.



Local Restriction Schematic

Mass Balance

The mass balance in the restriction is

$$0 = \dot{m}_{\mathrm{A}} + \dot{m}_{\mathrm{B}},$$

where:

- $\dot{m}_\mathrm{A}$ is the mass flow rate into the restriction through port A.
- $\dot{m}_\mathrm{B}$ is the mass flow rate into the restriction through port B.

Momentum Balance

The pressure difference between ports A and B follows from the momentum balance in the restriction:

$$p_\mathrm{A} - p_\mathrm{B} = \frac{\dot{m}_A \left(\dot{m}_A{}^8 + \dot{m}_{Ac}{}^8\right)^{1/8}}{2 C_\mathrm{d}^2 S_R \rho_\mathrm{u}},$$

where:

- p_A is the pressure at port A.
- p_B is the pressure at port B.
- C_d is the discharge coefficient of the restriction aperture.
- S_R is the cross-sectional area of the restriction aperture.
- ρ_u is the liquid density upstream of the restriction aperture.
- $\dot{m}_\mathrm{Ac}$ is the critical mass flow rate at port A.

The critical mass flow rate at port A is

$$\dot{m}_\mathrm{Ac} = \mathrm{Re}_\mathrm{c} \sqrt{\pi S_R} \frac{\mu_\mathrm{u}}{2},$$

where:

- Re_c is the critical Reynolds number,

$$\mathrm{Re}_c = \frac{\left|\dot{m}_\mathrm{Ac}\right| D}{S_\mathrm{R} \mu_\mathrm{u}},$$

D is the hydraulic diameter of the restriction aperture.

- μ_u is the liquid dynamic viscosity upstream of the restriction aperture.

The discharge coefficient is the ratio of the actual mass flow rate through the local restriction to the ideal mass flow rate,

$$C_d = \frac{\dot{m}_{ideal}}{\dot{m}},$$

where:

- $\dot{m}$ is the actual mass flow rate through the local restriction.
- $\dot{m}_{ideal}$ is the ideal mass flow rate through the local restriction:

$$\dot{m}_{ideal} = S_R \sqrt{\frac{2\rho_u \left(p_A - p_B\right)}{1 - \left(S_R / S\right)^2}}.$$

where S is the inlet cross-sectional area.

Energy Balance

The energy balance in the restriction is

$$\phi_A + \phi_B = 0,$$

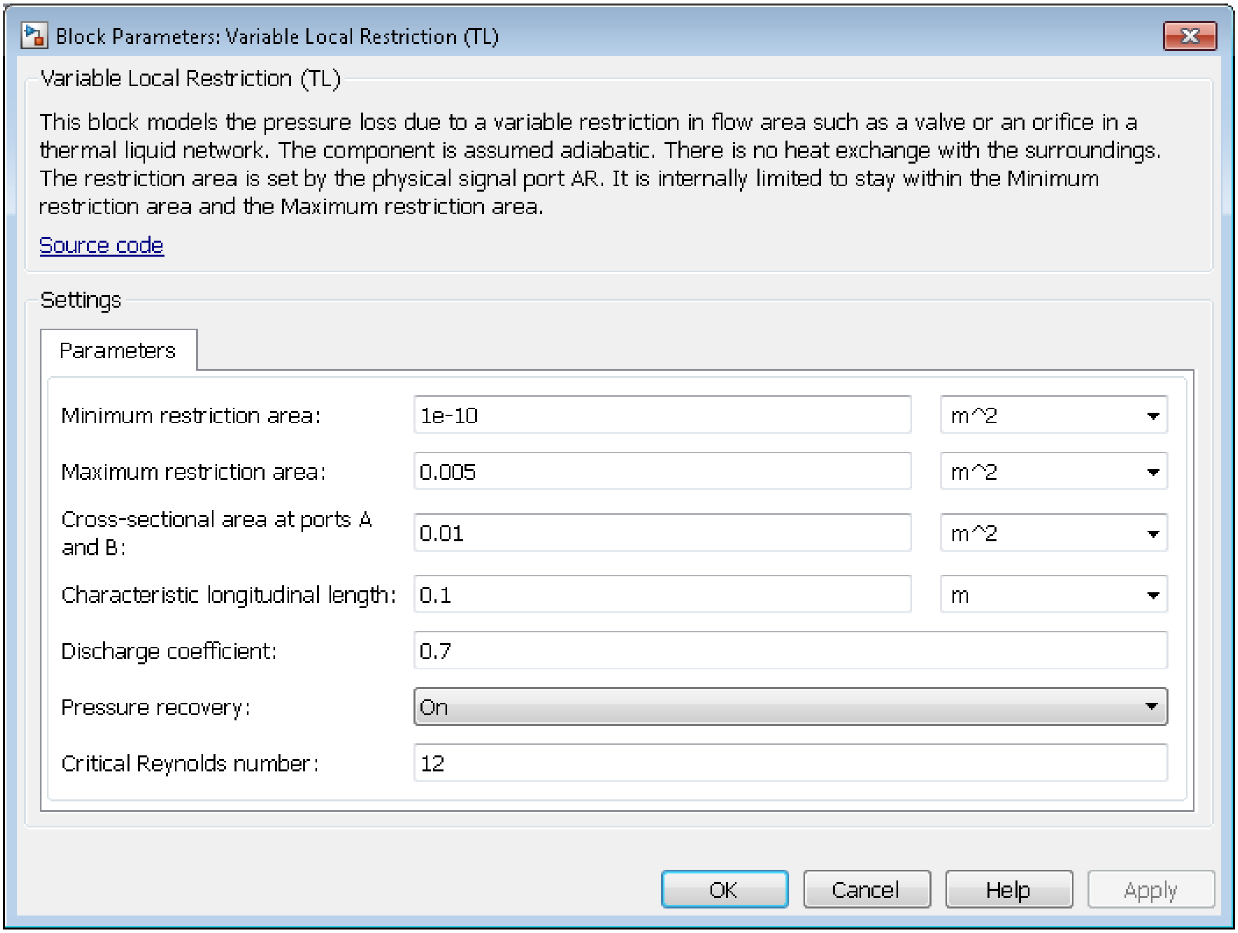
where:

- ϕ_A is the energy flow rate into the restriction through port A.
- ϕ_B is the energy flow rate into the restriction through port B.

Assumptions and Limitations

- The restriction is adiabatic. It does not exchange heat with its surroundings.
- The dynamic compressibility and thermal capacity of the liquid are negligible.

Dialog Box and Parameters



Variable Local Restriction (TL)

This block models the pressure loss due to a variable restriction in flow area such as a valve or an orifice in a thermal liquid network. The component is assumed adiabatic. There is no heat exchange with the surroundings. The restriction area is set by the physical signal port AR. It is internally limited to stay within the Minimum restriction area and the Maximum restriction area.

Minimum restriction area:	1e-10	m^2
Maximum restriction area:	0.005	m^2
Cross-sectional area at ports A and B:	0.01	m^2
Characteristic longitudinal length:	0.1	m
Discharge coefficient:	0.7	
Pressure recovery:	On	
Critical Reynolds number:	12	

Parameters

Minimum restriction area

Enter the lower bound for the restriction area range. This is the lowest allowed value for the restriction cross-sectional area. The input signal AR saturates at this value to prevent the restriction area from decreasing any further. The default value is `1e-10` m^2 .

Maximum restriction area

Enter the upper bound for the restriction area range. This is the highest allowed value for the restriction cross-sectional area. The input signal AR saturates at this value to prevent the restriction area from increasing any further. The default value is `0.005` m^2.

Cross-sectional area at ports A and B

Enter the flow cross-sectional area of the local restriction ports. This area is assumed the same for the two ports. The default value is `0.01` m^2 .

Characteristic longitudinal length

Enter the approximate longitudinal length of the local restriction. This length provides a measure of the longitudinal scale of the restriction. The default value is `0.1` m.

Discharge coefficient

Enter the discharge coefficient of the local restriction. The discharge coefficient is a semi-empirical parameter commonly used to characterize the flow capacity of an orifice. This parameter is defined as the ratio of the actual mass flow rate through the orifice to the ideal mass flow rate:

$$C_d = \frac{\dot{m}_{ideal}}{\dot{m}},$$

where C_d is the discharge coefficient, $\dot{m}$ is the actual mass flow rate through the orifice, and $\dot{m}_{ideal}$ is the ideal mass flow rate:

$$\dot{m}_{ideal} = S_r \sqrt{\frac{2\rho\left(p_A - p_B\right)}{1-\left(S_r / S\right)^2}}.$$

The default value is `0.7`, corresponding to a sharp-edged orifice.

Pressure recovery

Specify whether to account for pressure recovery at the local restriction outlet. Options include `On` and `Off`. The default setting is `On`.

Critical Reynolds number

Enter the Reynolds number for the transition between laminar and turbulent flow regimes. The default value is `12`, corresponding to a sharp-edged orifice.

Ports

The block has two thermal liquid conserving ports, A and B, and one physical signal port, AR.

See Also

`Local Restriction (TL)`

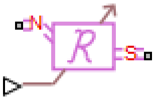
`Pipe (TL)`

Variable Reluctance

Variable reluctance in electromagnetic systems

Library

Magnetic Elements



Description

The `Variable Reluctance` block models a variable reluctance, that is, a component that resists flux flow. The ratio of the magnetomotive force (mmf) across the component to the resulting flux that flows through the component is defined as the reluctance, and is dependent on the value of the input physical signal.

The block is based on the following equations:

$$MMF = \Phi \cdot \Re$$

$$\Re = \frac{X}{\mu_0 \cdot \mu_r \cdot A}$$

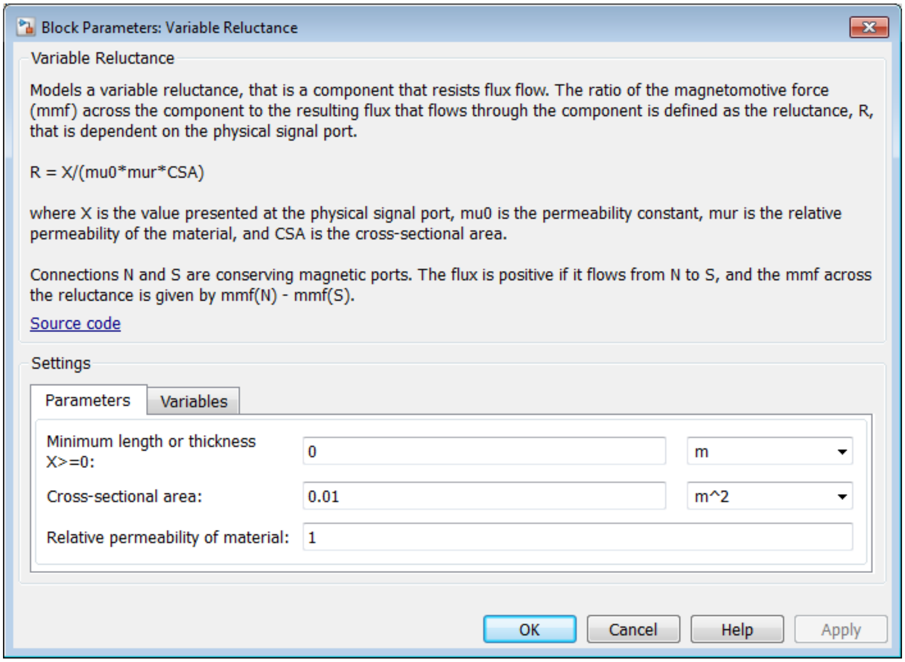
where

MMF	Magnetomotive force (mmf) across the component
Φ	Flux through the component
$\Re$	Reluctance
X	Value presented at the physical signal port
μ_0	Permeability constant

μ_r	Relative permeability of the material
A	Cross-sectional area of the section being modeled

Connections N and S are magnetic conserving ports. The mmf across the reluctance is given by $MMF(N)-MMF(S)$, and the sign of the flux is positive when flowing through the device from N to S.

Dialog Box and Parameters



Block Parameters: Variable Reluctance

Variable Reluctance

Models a variable reluctance, that is a component that resists flux flow. The ratio of the magnetomotive force (mmf) across the component to the resulting flux that flows through the component is defined as the reluctance, R, that is dependent on the physical signal port.

R = X/(mu0*mur*CSA)

where X is the value presented at the physical signal port, mu0 is the permeability constant, mur is the relative permeability of the material, and CSA is the cross-sectional area.

Connections N and S are conserving magnetic ports. The flux is positive if it flows from N to S, and the mmf across the reluctance is given by mmf(N) - mmf(S).

Source code

Settings

Parameters | Variables

Minimum length or thickness X>=0: 0 m

Cross-sectional area: 0.01 m^2

Relative permeability of material: 1

- “Parameters Tab” on page 1-614
- “Variables Tab” on page 1-615

Parameters Tab

Minimum length or thickness X>=0

The minimum value of length of air gap or thickness of section. If the input signal falls below this level (for example, turns negative), this minimum value is used. The parameter value must be nonnegative. The default value is `0`.

Cross-sectional area

Area of the section being modeled. The default value is `0.01` m^2.

Relative permeability of material

Relative permeability of the section material. The default value is `1`.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

`N`

Magnetic conserving port associated with the block North terminal.

`S`

Magnetic conserving port associated with the block South terminal.

The block also has one physical signal input port that provides the value of the length of air gap or thickness of section.

See Also

`Fundamental Reluctance` | `Reluctance`

Variable Resistor

Linear variable resistor in electrical systems

Library

Electrical Elements

Description

The `Variable Resistor` block models a linear variable resistor, described with the following equation:

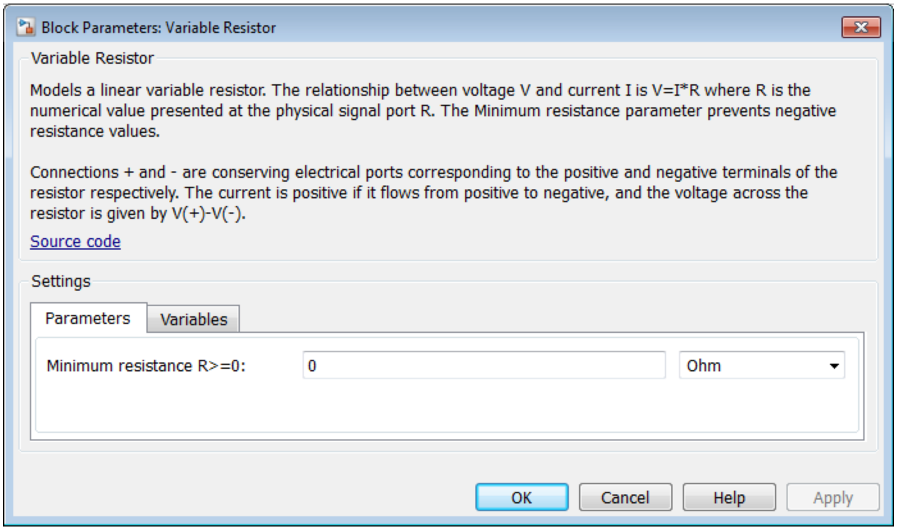
$$V = I \bullet R$$

where

V	Voltage
I	Current
R	Resistance, i.e., the value presented at the control port

Connections + and – are conserving electrical ports corresponding to the positive and negative terminals of the resistor, respectively. P is a physical signal input port that controls the resistance value. The current is positive if it flows from positive to negative, and the voltage across the resistor is equal to the difference between the voltage at the positive and the negative terminal, $V(+) – V(–)$.

Dialog Box and Parameters



Block Parameters: Variable Resistor

Variable Resistor

Models a linear variable resistor. The relationship between voltage V and current I is V=I*R where R is the numerical value presented at the physical signal port R. The Minimum resistance parameter prevents negative resistance values.

Connections + and - are conserving electrical ports corresponding to the positive and negative terminals of the resistor respectively. The current is positive if it flows from positive to negative, and the voltage across the resistor is given by V(+)-V(-).

Source code

Settings

Minimum resistance R>=0: 0 Ohm

- “Parameters Tab” on page 1-617
- “Variables Tab” on page 1-617

Parameters Tab

Minimum resistance R>=0

The minimum resistance value. If the input signal falls below this level (for example, turns negative), this minimum resistance value is used. The parameter value must be nonnegative. The default value is 0.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has the following ports:

`+`

Electrical conserving port associated with the resistor positive terminal.

`-`

Electrical conserving port associated with the resistor negative terminal.

`P`

Physical signal input port that provides the resistance value.

See Also

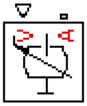
`Resistor` | `Thermal Resistor`

Variable Volume Chamber

Hydraulic capacity of variable volume with compressible fluid

Library

None (kept for compatibility purposes only)



Description

The Variable Volume Chamber block has been deprecated and removed from the library as of Version 3.0 (R2008b). Documentation is kept for compatibility reasons. If you use this block in your older models, it will still work. However, support may be discontinued in a future version. Replace this block with the Hydraulic Piston Chamber block.

See Also

Constant Volume Hydraulic Chamber

Hydraulic Piston Chamber

Translational Hydro-Mechanical Converter

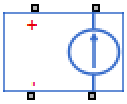
Variable Hydraulic Chamber

Voltage-Controlled Current Source

Linear voltage-controlled current source

Library

Electrical Sources



Description

The `Voltage-Controlled Current Source` block models a linear voltage-controlled current source, described with the following equation:

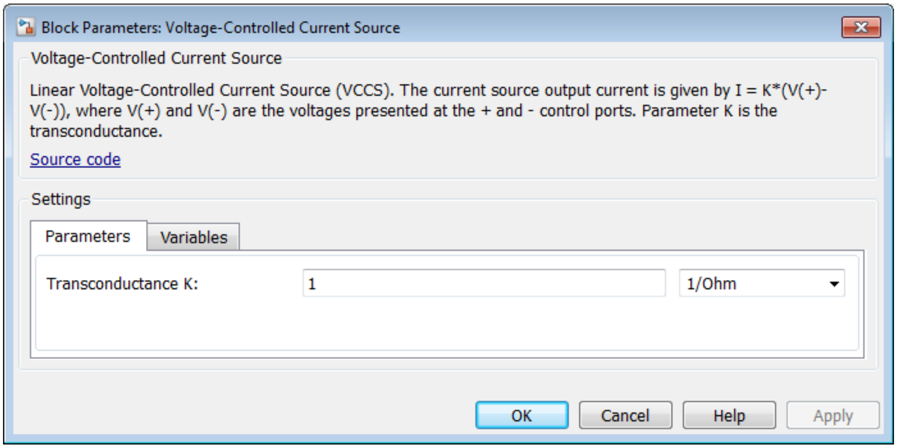
$$I = K \bullet \left(V(+) - V(-) \right)$$

where

I	Current
K	Transconductance
V(+),*V(-)*	Voltages presented at the + and – control ports

To use the block, connect the + and – ports on the left side of the block (the control ports) to the control voltage source. The two ports on the right side of the block (the output ports) generate the output current. The arrow indicates the positive direction of the current flow.

Dialog Box and Parameters



Block Parameters: Voltage-Controlled Current Source

Voltage-Controlled Current Source

Linear Voltage-Controlled Current Source (VCCS). The current source output current is given by I = K*(V(+)-V(-)), where V(+) and V(-) are the voltages presented at the + and - control ports. Parameter K is the transconductance.

Source code

Settings

Transconductance K: 1 1/Ohm

- "Parameters Tab" on page 1-621
- "Variables Tab" on page 1-621

Parameters Tab

Transconductance K

Transconductance, or the change in output current divided by the change in input voltage that causes it. The default value is 1 1/Ω.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see "Set Priority and Initial Target for Block Variables".

Ports

The block has four electrical conserving ports. Connections + and – on the left side of the block are the control ports. The other two ports are the electrical terminals that provide the output current. The arrow indicates the positive direction of the current flow.

See Also

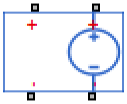
`Current-Controlled Current Source` | `Current-Controlled Voltage Source` | `Voltage-Controlled Voltage Source`

Voltage-Controlled Voltage Source

Linear voltage-controlled voltage source

Library

Electrical Sources



Description

The `Voltage-Controlled Voltage Source` block models a linear voltage-controlled voltage source, described with the following equation:

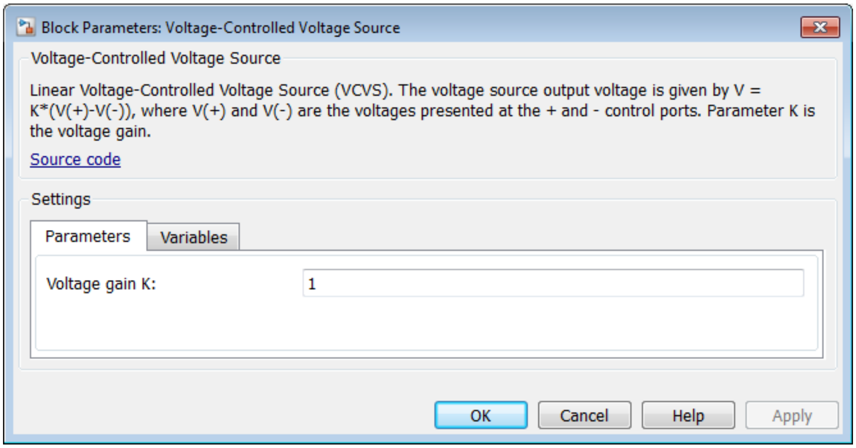
$$V = K \bullet \left(V(+) - V(-) \right)$$

where

V	Output voltage
K	Voltage gain
V(+),*V(-)*	Voltages presented at the + and – control ports

To use the block, connect the + and – ports on the left side of the block (the control ports) to the control voltage source. The two ports on the right side of the block (the output ports) generate the output voltage. Polarity is indicated by the + and – signs.

Dialog Box and Parameters



Voltage-Controlled Voltage Source

Linear Voltage-Controlled Voltage Source (VCVS). The voltage source output voltage is given by V = K*(V(+)-V(-)), where V(+) and V(-) are the voltages presented at the + and - control ports. Parameter K is the voltage gain.

Source code

Settings

Parameters | Variables

Voltage gain K: 1

- “Parameters Tab” on page 1-624
- “Variables Tab” on page 1-624

Parameters Tab

Voltage gain K

The change in the output voltage divided by the change in the control voltage that causes it. The default value is 1.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see “Set Priority and Initial Target for Block Variables”.

Ports

The block has four electrical conserving ports. Connections + and – on the left side of the block are the control ports. The other two ports are the electrical terminals that provide the output voltage. Polarity is indicated by the + and – signs.

See Also

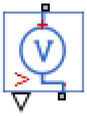
`Current-Controlled Current Source` | `Current-Controlled Voltage Source` | `Voltage-Controlled Current Source`

Voltage Sensor

Voltage sensor in electrical systems

Library

Electrical Sensors

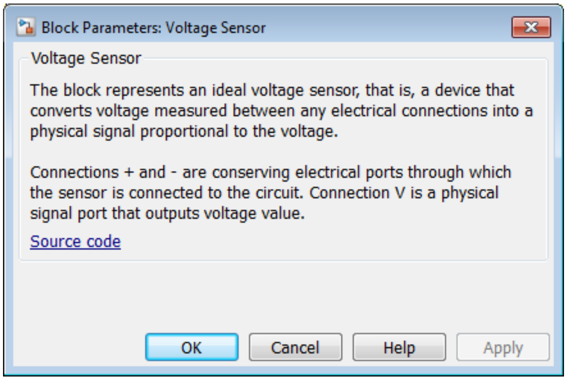


Description

The Voltage Sensor block represents an ideal voltage sensor, that is, a device that converts voltage measured between two points of an electrical circuit into a physical signal proportional to the voltage.

Connections + and – are electrical conserving ports through which the sensor is connected to the circuit. Connection V is a physical signal port that outputs the measurement result.

Dialog Box and Parameters


Block Parameters: Voltage Sensor

Voltage Sensor

The block represents an ideal voltage sensor, that is, a device that converts voltage measured between any electrical connections into a physical signal proportional to the voltage.

Connections + and - are conserving electrical ports through which the sensor is connected to the circuit. Connection V is a physical signal port that outputs voltage value.

Source code

The block has no parameters.

Ports

The block has the following ports:

`+`

Electrical conserving port associated with the sensor positive terminal.

`-`

Electrical conserving port associated with the sensor negative terminal.

`V`

Physical signal output port for voltage.

See Also

`Current Sensor` | `PS-Simulink Converter`

More About

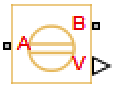
- “Connecting Simscape Diagrams to Simulink Sources and Scopes”

Volumetric Flow Rate Sensor (TL)

Measure volumetric flow rate

Library

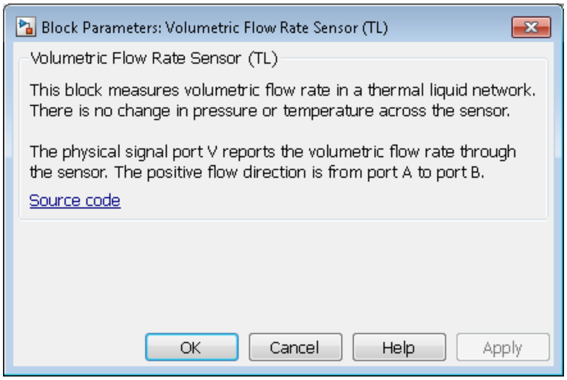
Thermal Liquid/Sensors



Description

The `Volumetric Flow Rate Sensor (TL)` block measures the volumetric flow rate through the thermal liquid branch defined by ports A and B. The flow rate is positive if fluid flows from port A to port B.

Dialog Box and Parameters



Block Parameters: Volumetric Flow Rate Sensor (TL)

Volumetric Flow Rate Sensor (TL)

This block measures volumetric flow rate in a thermal liquid network. There is no change in pressure or temperature across the sensor.

The physical signal port V reports the volumetric flow rate through the sensor. The positive flow direction is from port A to port B.

Source code

The block has no parameters.

Ports

- A — Thermal Liquid conserving port representing source inlet A

- B — Thermal Liquid conserving port representing source inlet B
- V — Physical signal output port for sensing the volumetric flow rate

See Also

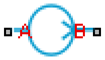
`Controlled Volumetric Flow Rate Source (TL)`

Volumetric Flow Rate Source (2P)

Generate constant volumetric flow rate

Library

Two-Phase Fluid/Sources



Description

The `Volumetric Flow Rate Source (2P)` block generates a constant volumetric flow rate through its outlet. The source is ideal. It maintains the specified flow rate regardless of the pressure differential between the inlet and outlet. Losses due to friction are assumed negligible.

Only the volumetric flow rate at the source outlet is fixed. The rate at the inlet can differ from the specified value if the specific volume changes within the source. However, due to mass conservation, the mass flow rates at the inlet and outlet are always identical.

The ports representing the inlet and outlet change with the flow rate sign. If the flow rate is positive, fluid flows from port A to port B and the outlet is at port B. If the flow rate is negative, fluid flows from port B to port A and the outlet is at port A.

The volumetric and mass flow rates at the source outlet are related through the expression

$$\dot{V} = \begin{cases} \dot{m} v_B, & \dot{V} \ge 0 \\ \dot{m} v_A, & \dot{V} < 0 \end{cases},$$

where:

- $\dot{V}$ is the volumetric flow rate.
- $\dot{m}$ is the mass flow rate from port A to port B.

- v_A is the specific volume at port A.
- v_B is the specific volume at port B.

The energy balance at the source is a function of the energy flow rates through ports A and B and the work done on the fluid:

$$\phi_A + \phi_B + \phi_{work} = 0,$$

where:

- ϕ_A is the energy flow rate into the source through port A.
- ϕ_B is the energy flow rate into the source through port B.
- ϕ_{work} is the isentropic work done on the fluid.

For a subcooled liquid, the isentropic work term is

$$\phi_{work}^{L} = \dot{m}\left(p_B - p_A\right)v_{avg},$$

where:

- ϕ^{L}_{work} is the isentropic work done on the subcooled liquid.
- p_A is the pressure at port A.
- p_B is the pressure at port B.
- v_{avg} is the average of the specific volumes at ports A and B,

$$v_{avg} = \frac{v_A + v_B}{2}.$$

If the fluid is a superheated vapor, the isentropic work is

$$\phi_{work}^{V} = \dot{m}\left(u_B^{isen} + p_B v_B + \frac{1}{2}\left(\frac{\dot{m}v_B}{S}\right) - u_A^{isen} - p_A v_A - \frac{1}{2}\left(\frac{\dot{m}v_B}{S}\right)\right),$$

where:

- ϕ^{V}_{work} is the isentropic work done on the superheated vapor.

- u_A^{isen} is the isentropic specific internal energy at port A.
- u_B^{isen} is the isentropic specific internal energy at port B.

The isentropic specific internal energies at ports A and B follow from the expressions

$$\frac{u_A^{isen} + u_B^{isen}}{2} = \frac{u_A + u_B}{2}$$

and

$$s_{table}\left(\bar{u}_A^{isen}, p_A\right) = s_{table}\left(\bar{u}_B^{isen}, p_B\right),$$

where:

- u_A is the specific internal energy at port A.
- u_B is the specific internal energy at port B.
- $S_{table}(\bar{u}, p)$ is the interpolation of the specific entropy table at the normalized internal energy $\bar{u}$ and pressure p.
- $\bar{u}_A^{isen}$ is the isentropic normalized internal energy at port A.
- $\bar{u}_B^{isen}$ is the isentropic normalized internal energy at port B.

The normalized internal energy at port A is a function of the specific internal energy at that port, as described by the expression

$$\bar{u}_A^{isen} = \begin{cases} \dfrac{u_A^{isen} - u_{min}}{u_{sat}^L(p_A) - u_{min}} - 1, & u_A^{isen} < u_{sat}^L(p_A) \\ \dfrac{u_A^{isen} - u_{sat}^L(p_A)}{u_{sat}^V(p_A) - u_{sat}^L(p_A)}, & u_{sat}^L(p_A) \le u_A^{isen} \le u_{sat}^V(p_A), \\ \dfrac{u_A^{isen} - u_{max}}{u_{max} - u_{sat}^V(p_A)} + 2, & u_{sat}^V(p_A) < u_A^{isen} \end{cases}$$

where:

- u_{min} is the minimum valid specific internal energy.
- u_{max} is the maximum valid specific internal energy.
- $u^{\text{L}}{}_{\text{sat}}(\text{p})$ is the interpolation of the saturated liquid specific internal energy vector at pressure p.
- $u^{\text{V}}{}_{\text{sat}}(\text{p})$ is the interpolation of the saturated vapor specific internal energy vector at pressure p.

Similarly, the normalized internal energy at port B is a function of the specific internal energy at that port, as described by the expression

$$\bar{u}_B^{isen} = \begin{cases} \dfrac{u_B^{isen} - u_{min}}{u_{sat}^L(p_B) - u_{min}} - 1, & u_B^{isen} < u_{sat}^L(p_B) \\ \dfrac{u_B^{isen} - u_{sat}^L(p_B)}{u_{sat}^V(p_B) - u_{sat}^L(p_B)}, & u_{sat}^L(p_B) \le u_B^{isen} \le u_{sat}^V(p_B). \\ \dfrac{u_B^{isen} - u_{max}}{u_{max} - u_{sat}^V(p_B)} + 2, & u_{sat}^V(p_B) < u_B^{isen} \end{cases}$$

The normalized internal energy at either port falls in the range -1 to 0 for a subcooled liquid, 0 to 1 for a two-phase fluid, and 1 to 2 for a superheated vapor. The isentropic work as a function of the average normalized internal energy is

$$\phi_{work} = \begin{cases} \phi_{work}^L, & \bar{u}_{avg} < 0 \\ \left(1 - \bar{u}_{avg}\right)\phi_{work}^L + \bar{u}_{avg}\phi_{work}^V, & 0 \le \bar{u}_{avg} \le 1, \\ \phi_{work}^V, & 1 < \bar{u}_{avg} \end{cases}$$

where:

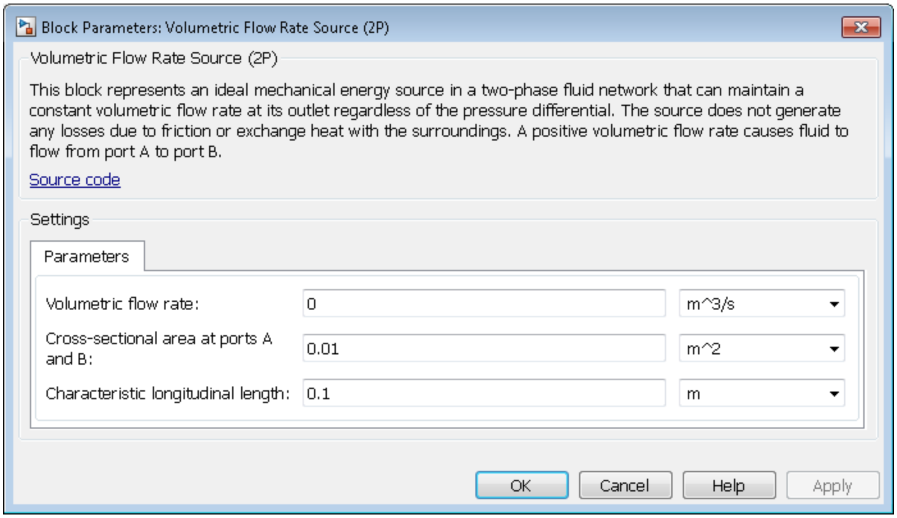
- $\bar{u}_{avg}$ is the average of the normalized internal energies at ports A and B,

$$\bar{u}_{avg} = \frac{\bar{u}_A + \bar{u}_B}{2}.$$

Assumptions and Limitations

- The source is ideal. Losses due to friction are assumed negligible.
- The source is adiabatic. Heat exchange with the surroundings is assumed negligible.
- Work done by the source is isentropic—that is, reversible and adiabatic.

Dialog Box and Parameters



Block Parameters: Volumetric Flow Rate Source (2P)

Volumetric Flow Rate Source (2P)

This block represents an ideal mechanical energy source in a two-phase fluid network that can maintain a constant volumetric flow rate at its outlet regardless of the pressure differential. The source does not generate any losses due to friction or exchange heat with the surroundings. A positive volumetric flow rate causes fluid to flow from port A to port B.

Source code

Settings

Parameters

Volumetric flow rate:	0	m^3/s
Cross-sectional area at ports A and B:	0.01	m^2
Characteristic longitudinal length:	0.1	m

Volumetric flow rate

Fluid volume flowing from port A to port B per unit time. The volumetric flow rate is constant throughout simulation. The default value is `0` m^3/s.

Cross-sectional area at ports A and B

Area normal to the direction of flow at the source inlet and outlet. The two cross-sectional areas are assumed identical. The default value is `0.01` m^2.

Characteristic longitudinal length

Average distance the fluid traverses in the source before it reaches the outlet. The default value is `0.1` m.

Ports

The block has two two-phase fluid conserving ports, A and B.

See Also

`Controlled Mass Flow Rate Source (2P)` | `Controlled Volumetric Flow Rate Source (2P)` | `Mass Flow Rate Source (2P)`

Volumetric Flow Rate Source (TL)

Generate constant volumetric flow rate

Library

Thermal Liquid/Sources

Description

The `Volumetric Flow Rate Source (TL)` block generates a constant volumetric flow rate through its outlet. The source is ideal. It maintains the specified flow rate regardless of the pressure differential between the inlet and outlet. Losses due to friction are assumed negligible.

Only the volumetric flow rate at the source outlet is fixed. The rate at the inlet can differ from the specified value if the specific volume changes within the source. However, due to mass conservation, the mass flow rates at the inlet and outlet are always identical.

The ports representing the inlet and outlet change with the flow rate sign. If the flow rate is positive, fluid flows from port A to port B and the outlet is at port B. If the flow rate is negative, fluid flows from port B to port A and the outlet is at port A.

The volumetric and mass flow rates at the source outlet are related through the expression

$$\dot{V} = \begin{cases} \dot{m} v_B, & \dot{V} \geq 0 \\ \dot{m} v_A, & \dot{V} < 0 \end{cases},$$

where:

- $\dot{V}$ is the volumetric flow rate.

- $\dot{m}$ is the mass flow rate from port A to port B.
- v_A is the specific volume at port A.
- v_B is the specific volume at port B.

The energy balance at the source is a function of the energy flow rates through ports A and B and the work done on the fluid:

$$\phi_A + \phi_B + \phi_{work} = 0,$$

where:

- ϕ_A is the energy flow rate into the source through port A.
- ϕ_B is the energy flow rate into the source through port B.
- ϕ_{work} is the isentropic work done on the fluid.

The isentropic work term is

$$\phi_{work} = \dot{m}\left(p_B - p_A\right)v_{avg},$$

where:

- ϕ_{work} is the isentropic work done on the thermal liquid.
- p_A is the pressure at port A.
- p_B is the pressure at port B.
- v_{avg} is the average of the specific volumes at ports A and B,

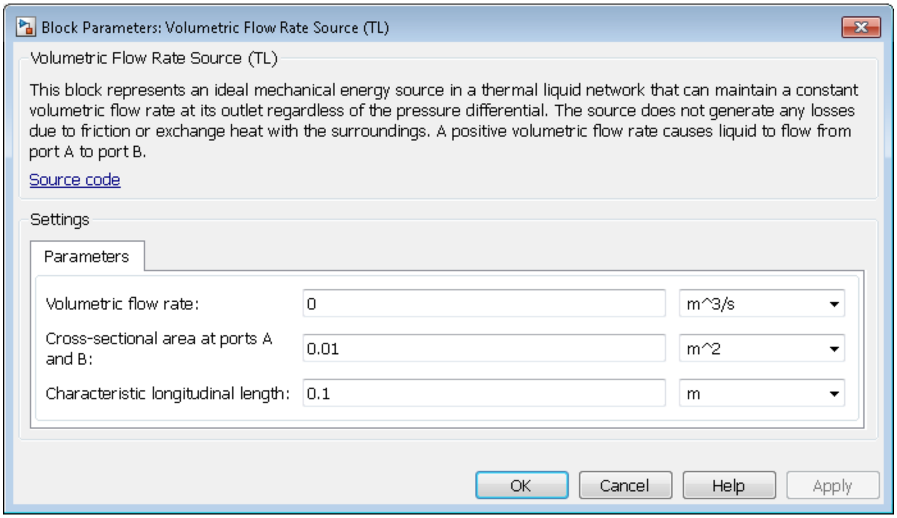
$$v_{avg} = \frac{v_A + v_B}{2}.$$

Assumptions and Limitations

- The source is ideal. Losses due to friction are assumed negligible.
- The source is adiabatic. Heat exchange with the surroundings is assumed negligible.

- Work done by the source is isentropic—that is, reversible and adiabatic.

Dialog Box and Parameters



Block Parameters: Volumetric Flow Rate Source (TL)

Volumetric Flow Rate Source (TL)

This block represents an ideal mechanical energy source in a thermal liquid network that can maintain a constant volumetric flow rate at its outlet regardless of the pressure differential. The source does not generate any losses due to friction or exchange heat with the surroundings. A positive volumetric flow rate causes liquid to flow from port A to port B.

Source code

Settings

Parameters

Volumetric flow rate: 0 m^3/s

Cross-sectional area at ports A and B: 0.01 m^2

Characteristic longitudinal length: 0.1 m

Volumetric flow rate

Fluid volume flowing from port A to port B per unit time. The volumetric flow rate is constant throughout simulation. The default value is `0` m^3/s.

Cross-sectional area at ports A and B

Area normal to the direction of flow at the source inlet and outlet. The two cross-sectional areas are assumed identical. The default value is `0.01` m^2.

Characteristic longitudinal length

Average distance the fluid traverses in the source before it reaches the outlet. The default value is `0.1` m.

Ports

- A — Thermal Liquid conserving port representing source inlet A
- B — Thermal Liquid conserving port representing source inlet B

See Also

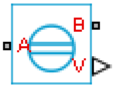
`Controlled Mass Flow Rate Source (TL)` | `Controlled Volumetric Flow Rate Source (TL)` | `Mass Flow Rate Source (TL)`

Volumetric Flow Sensor (2P)

Measure volumetric flow rate

Library

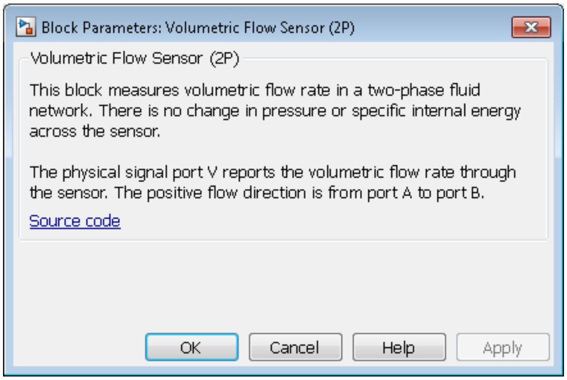
Two-Phase Fluid/Sensors



Description

The `Volumetric Flow Sensor (2P)` block measures the volumetric flow rate through the two-phase fluid branch defined by ports A and B. The flow rate is positive if fluid flows from port A to port B.

Dialog Box and Parameters



Block Parameters: Volumetric Flow Sensor (2P)

Volumetric Flow Sensor (2P)

This block measures volumetric flow rate in a two-phase fluid network. There is no change in pressure or specific internal energy across the sensor.

The physical signal port V reports the volumetric flow rate through the sensor. The positive flow direction is from port A to port B.

Source code

The block has no parameters.

Ports

The block has two two-phase fluid conserving ports, A and B. Physical signal port V outputs the volumetric flow rate value.

See Also

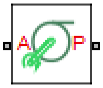
`Controlled Volumetric Flow Rate Source (2P)`

Wheel and Axle

Wheel and axle mechanism in mechanical systems

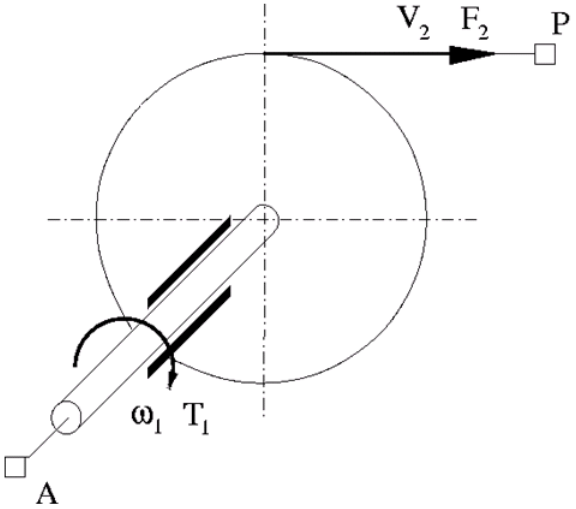
Library

Mechanisms



Description

The `Wheel and Axle` block represents a wheel and axle mechanism shown in the following schematic.



The wheel and the axle have the same axis, and the axis is assumed to be rigidly connected to the frame, thus making this mechanism an ideal converter of mechanical rotational into mechanical translational motion. The mechanism has two connections: a mechanical rotational port A, which corresponds to the axle, and a mechanical translational port P, which corresponds to the wheel periphery. The mechanism is described with the following equations:

$$T = r \bullet F \bullet or$$

$$v = r \bullet \omega \bullet or$$

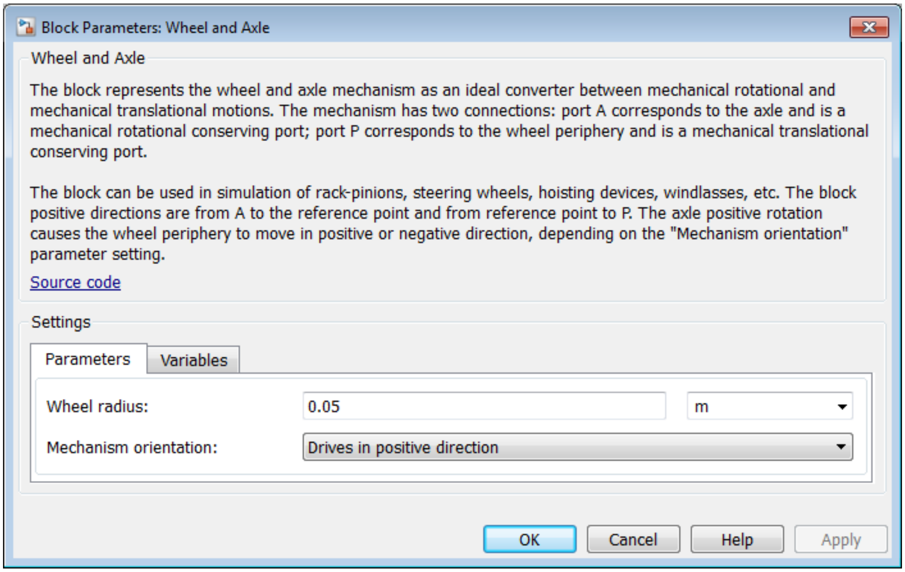
where

T	Torque on the axle
F	Force on the wheel periphery
ω	Angular velocity
v	Linear velocity on the wheel periphery
r	Wheel radius
or	Mechanism orientation indicator. The variable assumes +1 value if axle rotation in the globally assigned positive direction is converted into translational motion in positive direction, and –1 if positive rotation results in translational motion in negative direction.

The block can be used in simulation of rack-pinions, steering wheels, hoisting devices, windlasses, and so on.

The block positive directions are from A to the reference point and from the reference point to P.

Dialog Box and Parameters



Wheel and Axle

The block represents the wheel and axle mechanism as an ideal converter between mechanical rotational and mechanical translational motions. The mechanism has two connections: port A corresponds to the axle and is a mechanical rotational conserving port; port P corresponds to the wheel periphery and is a mechanical translational conserving port.

The block can be used in simulation of rack-pinions, steering wheels, hoisting devices, windlasses, etc. The block positive directions are from A to the reference point and from reference point to P. The axle positive rotation causes the wheel periphery to move in positive or negative direction, depending on the "Mechanism orientation" parameter setting.

Source code

Settings

Wheel radius: 0.05 m

Mechanism orientation: Drives in positive direction

- “Parameters Tab” on page 1-644
- “Variables Tab” on page 1-645

Parameters Tab

Wheel radius

Radius of the wheel. The default value is `0.05` m.

Mechanism orientation

The parameter can be set to one of two options: `Drives in positive direction` or `Drives in negative direction`. The value `Drives in positive direction` specifies a mechanism where axle rotation in the globally assigned positive direction is converted into translational motion in positive direction. The value `Drives in negative direction` specifies a mechanism where axle rotation in the globally assigned positive direction is converted into translational motion in negative direction. The default value is `Drives in positive direction`.

Restricted Parameters

When your model is in Restricted editing mode, you cannot modify the following parameter:

- **Mechanism orientation**

All other block parameters are available for modification.

Variables Tab

Use the **Variables** tab to set the priority and initial target values for the block variables prior to simulation. For more information, see "Set Priority and Initial Target for Block Variables".

Ports

The block has the following ports:

A

Mechanical rotational conserving port associated with the axle.

P

Mechanical translational conserving port associated with the wheel periphery.

Examples

The Simple Mechanical System example illustrates the use of the `Wheel and Axle` block in mechanical systems.

Functions — Alphabetical List

pm_adddimension

Adds new dimension to unit registry

Syntax

```
pm_adddimension(dimension,unitname)
```

Description

`pm_adddimension(dimension,unitname)` adds a new unit dimension with a fundamental unit, `unitname`.

Examples

Add Unit Dimension

Add a new unit dimension.

```
pm_adddimension('length','m')
```

The unit registry contains a new dimension, `length`, with a fundamental unit of meter, `m`.

Input Arguments

`dimension` — Name of dimension to add to the unit registry
string

Name of dimension to add to the unit registry, specified as a string. You can specify any string.

Data Types: `char`

`unitname` — Fundamental unit for new dimension
string

Fundamental unit used for the new dimension, specified as a string. The string must be a valid unit name: it must begin with a letter and contain only letters and numbers.

Data Types: `char`

More About

- "Unit Definitions"

See Also

`pm_addunit` | `pm_getdimensions` | `pm_getunits`

Introduced in R2006b

pm_addunit

Add new unit to unit registry

Syntax

```
pm_addunit(unitname, conversion, unitexpression)
```

Description

`pm_addunit(unitname, conversion, unitexpression)` introduces a new unit, `unitname`, defined as `conversion * unitexpression`.

The first argument, `unitname`, must be a valid unit name, that is, it must begin with a letter and contain only letters and numbers.

The second argument, `conversion`, may be either a positive real scalar or a 1x2 array. If this argument has two elements, then it is specifying an affine conversion, with the first element (a positive real number) being the linear conversion coefficient, and the second being the offset. For more information, see "Thermal Unit Conversions".

The third argument, `unitexpression`, must be a valid unit expression in terms of units already defined in the unit registry.

The following operators are supported in the unit mathematical expressions:

`*`	Multiplication
`/`	Division
`^`	Power
`+, -`	Plus, minus — for exponents only
`()`	Brackets to specify evaluation order

Examples

Add a new unit centimeter, `cm`, in terms of meter, `m`:

```
pm_addunit('cm', 0.01, 'm');
```

Add a new unit newton, N, in terms of kilograms, meters, and seconds:

```
pm_addunit('N', 1, 'kg*m/s^2');
```

Add a new unit Fahrenheit, Fh, in terms of Celsius:

```
pm_addunit('Fh', [5/9 -32*5/9], 'C');
```

See Also

pm_adddimension | pm_getdimensions | pm_getunits

pm_getdimensions

Get information about all dimensions in unit registry

Syntax

```
[dimensions, units] = pm_getdimensions
```

Description

`[dimensions, units] = pm_getdimensions` returns all dimensions registered in the unit registry in a cell array , `dimensions`. Their corresponding units are returned in the `units` cell array.

Examples

List all dimensions currently defined in the registry:

```
pm_getdimensions

ans =

    'charge'
    'length'
    'mass'
    'mole'
    'temperature'
    'time'
```

See Also

`pm_adddimension` | `pm_addunit` | `pm_getunits`

pm_getunits

Get information about all units in unit registry

Syntax

```
[units, conversions, expressions] = pm_getunits
```

Description

`[units, conversions, expressions] = pm_getunits` returns all units in the registry in a cell array , `units`. Their corresponding conversions and base expressions are returned in `conversions` and `expressions`, respectively. For fundamental units, the conversion is `1.0` and the base expression is the unit itself.

Examples

List all units currently defined in the registry:

```
pm_getunits

ans =

    'm'
    'kg'
    's'
    'C'
    'K'
    'mol'
    'cm'
    'mm'
    'km'
    'um'
    'degC'
    'degF'
    'degR'
    'deltaK'
    'deltadegC'
    'deltadegF'
```

```
'deltadegR'
'R'
'Fh'
'in'
'ft'
'mi'
'yd'
'l'
'gal'
'igal'
'g'
'mg'
'lbm'
'oz'
'slug'
'N'
'lbf'
'dyn'
'lb'
'mN'
'min'
'hr'
'ms'
'us'
'ns'
'rad'
'deg'
'rev'
'mph'
'fpm'
'fps'
'rpm'
'Hz'
'kHz'
'MHz'
'GHz'
'gee'
'J'
'kJ'
'Btu_IT'
'Btu'
'eV'
'W'
'HP_DIN'
```

```
'HP'
'V'
'A'
'F'
'H'
'Ohm'
'S'
'c'
'Wb'
'T'
'G'
'mV'
'kV'
'pA'
'nA'
'uA'
'mA'
'kA'
'pF'
'nF'
'uF'
'mF'
'nH'
'uH'
'mH'
'kOhm'
'MOhm'
'GOhm'
'nS'
'uS'
'mS'
'uW'
'mW'
'kW'
'MW'
'lpm'
'gpm'
'P'
'Poise'
'cP'
'reyn'
'St'
'cSt'
'newt'
```

```
    'Newt'
    'Pa'
    'bar'
    'psi'
    'atm'
    'uPa'
    'kPa'
    'MPa'
    'GPa'
    'kbar'
```

See Also

pm_adddimension | pm_addunit | pm_getdimensions

simscape.dependency.file

Package: simscape.dependency

Check dependencies for single file

Syntax

```
[fn_list, missing] = simscape.dependency.file('fileName')
[fn_list, missing] = simscape.dependency.file('fileName',
dependencyType)
[fn_list, missing] = simscape.dependency.file('fileName',
dependencyType, isRecursive)
[fn_list, missing] = simscape.dependency.file('fileName',
dependencyType, isRecursive, doTMWFile)
```

Description

`[fn_list, missing] = simscape.dependency.file('fileName')` returns two cell arrays of strings: full path names of existing dependency files, *`fn_list`*, and missing files, *`missing`*. These cell arrays list the existing and missing files that are needed for the specified Simscape file to build successfully, or to correctly visualize and execute in MATLAB.

`[fn_list, missing] = simscape.dependency.file('fileName', dependencyType)` returns dependency files of the specified type.

`[fn_list, missing] = simscape.dependency.file('fileName', dependencyType, isRecursive)` lets you specify whether analysis is recursive on the generated dependency files. By default, returns only the top-level dependency files.

`[fn_list, missing] = simscape.dependency.file('fileName', dependencyType, isRecursive, doTMWFile)` lets you specify whether to include files inside the MATLAB root folder (installation directory) in the analysis.

Input Arguments

`dependencyType`

Enumerated value of type `Simscape.DependencyType`, which specifies the type of returned files:

`All` (default)	All the dependency files
`Auxiliary`	Files that are not necessary to convert the file and use it in block diagrams, but are needed to visualize it correctly, for example, block icon images
`Core`	Files necessary to convert the file and use it in block diagrams, for example, a domain file referenced by the component file being analyzed
`Derived`	Internally generated files that are not necessary for sharing the component file being analyzed, but including them will avoid rebuilding the library on the same platform.
`Simulink`	Additional files that help visualize the block generated from the component file being analyzed. These files are not necessary for simulation.

These enumerated values have the following order: `Core`, `Derived`, `Auxiliary`, `Simulink`, `All`. The return is accumulative. This means that for a requested file type, all earlier file types are also returned. For example, if you specify *`dependencyType`* as `Simscape.DependencyType.Derived`, the analysis returns both Core and Derived files.

`doTMWFile`

Logical value that indicates whether the file analysis includes files inside the MATLAB root folder (installation directory):
`true` (default)
`false`

`fileName`

The name of the Simscape file (with path), or class method, for which the dependencies are checked. In case of multiple files with the same name, only the first file of the specified name on the MATLAB path is analyzed.

`isRecursive`

Logical value that indicates whether the analysis is recursive on the generated dependency files:
`true`
`false` (default)

More About

- “Checking File and Model Dependencies”

See Also

`simscape.dependency.lib` | `simscape.dependency.model`

simscape.dependency.lib

Package: simscape.dependency

Check dependencies for library package

Syntax

```
[fn_list, missing] = simscape.dependency.lib('libName')
[fn_list, missing] = simscape.dependency.lib('libName',
dependencyType)
[fn_list, missing] = simscape.dependency.lib('libName',
dependencyType, 'mdlFileName')
[fn_list, missing] = simscape.dependency.lib('libName',
dependencyType, 'mdlFileName', isRecursive)
[fn_list, missing] = simscape.dependency.lib('libName',
dependencyType, 'mdlFileName', isRecursive, doTMWFile)
```

Description

`[fn_list, missing] = simscape.dependency.lib('libName')` returns two cell arrays of strings: full path names of existing dependency files, `fn_list`, and missing files, `missing`. These cell arrays list the existing and missing files that are needed for the specified Simscape library package to build successfully, or to correctly visualize and execute in MATLAB.

`[fn_list, missing] = simscape.dependency.lib('libName', dependencyType)` returns dependency files of the specified type.

`[fn_list, missing] = simscape.dependency.lib('libName', dependencyType, 'mdlFileName')` lets you specify the name of the library model. When not specified, or specified as an empty string (`''`), `libName_lib` is used.

`[fn_list, missing] = simscape.dependency.lib('libName', dependencyType, 'mdlFileName', isRecursive)` lets you specify whether analysis is recursive on the generated dependency files. By default, returns only the top-level dependency files.

[*fn_list*, *missing*] = simscape.dependency.lib('*libName*', *dependencyType*, '*mdlFileName*', *isRecursive*, *doTMWFile*) lets you specify whether to include files inside the MATLAB root folder (installation directory) in the analysis.

If the package contains Simscape protected files, with the corresponding Simscape source files in the same folder, the analysis returns the names of protected files and then analyzes the source files for further dependencies. If the package contains Simscape protected files without the corresponding source files, the protected file names are returned without further analysis.

Input Arguments

dependencyType

Enumerated value of type `Simscape.DependencyType`, which specifies the type of returned files:

`All` (default)	All the dependency files
`Auxiliary`	Files that are not necessary to build the library, or run the models built from its blocks, but are needed to visualize it correctly, for example, block icon images or `lib.m` files.
`Core`	Files necessary to build the library or run the models built from its blocks, such as Simscape files or MATLAB files.
`Derived`	Internally generated files that are not necessary for sharing the library, but including them will avoid rebuilding the library on the same platform.
`Simulink`	Additional files that help visualize the blocks generated from the library components. These files are not necessary for simulation.

These enumerated values have the following order: `Core`, `Derived`, `Auxiliary`, `Simulink`, `All`. The return is accumulative. This means that for a requested file type, all earlier file types are also returned. For example, if you specify `dependencyType` as `Simscape.DependencyType.Derived`, the analysis returns both Core and Derived files.

doTMWFile

Logical value that indicates whether the file analysis includes files inside the MATLAB root folder (installation directory):
`true` (default)
`false`

isRecursive

Logical value that indicates whether the analysis is recursive on the generated dependency files:
`true`
`false` (default)

libName

The name of a Simscape library package. The package folder name begins with a leading + character, whereas the argument to `simscape.dependency.lib` must omit the + character. You must run the command from the folder containing the top-level package, or from inside the package folder. In the latter case, you can omit the name of the library package if it is the only argument.

mdlFileName

The name of the library model (either without path, or with relative path, or with absolute path). The model file extension (`.slx` or `.mdl`) is optional.

Default: *`libName`*`_lib`

More About

- "Checking File and Model Dependencies"

See Also

`simscape.dependency.file` | `simscape.dependency.model`

simscape.dependency.model

Package: simscape.dependency

Check dependencies for model

Syntax

```
[fn_list, missing, reference2fnList, reference2missing] =
simscape.dependency.model('modelName')
```

Description

`[fn_list, missing, reference2fnList, reference2missing] = simscape.dependency.model('modelName')` checks dependencies for a model containing Simscape and Simulink blocks. *`modelName`* specifies the name of the model (either without path, or with relative path, or with absolute path). The model file extension (`.slx` or `.mdl`) is optional.

You must open the model first.

This command returns dependency information regarding Simscape files and blocks only. To perform a complete dependencies check for a model, use the Simulink Manifest Tools. For more information, see “Analyze Model Dependencies” in the *Simulink User's Guide*.

If during the analysis this command encounters a Simscape file located inside the MATLAB root folder, it returns the file name without performing any further analysis on this file, because all the dependent files in this case are part of standard MathWorks installation.

Output Arguments

`fn_list`

A cell array of strings containing the full paths of all existing files referenced by the model *`modelName`*.

missing

A cell array of strings containing the names of all files that are referenced by the model *modelName* but cannot be found.

reference2fnList

A list of structures, each of which includes a field `'names'` as a list of file names causing the reference, and a field `'type'` as the reference type for each file. Two reference types are used: `'Simscape component'` indicates reference from a model block. `'Simscape'` indicates reference from a file.

reference2missing

A list of structures, each of which includes a field `'names'` as a list of missing file names, and a field `'type'` as the reference type for each file. Two reference types are used: `'Simscape component'` indicates reference from a model block. `'Simscape'` indicates reference from a file.

More About

- "Checking File and Model Dependencies"

See Also

`simscape.dependency.file` | `simscape.dependency.lib`

simscape.logging.export

Save logged simulation data in HDF5 file

Syntax

```
simscape.logging.export(simlog,fileName)
```

Description

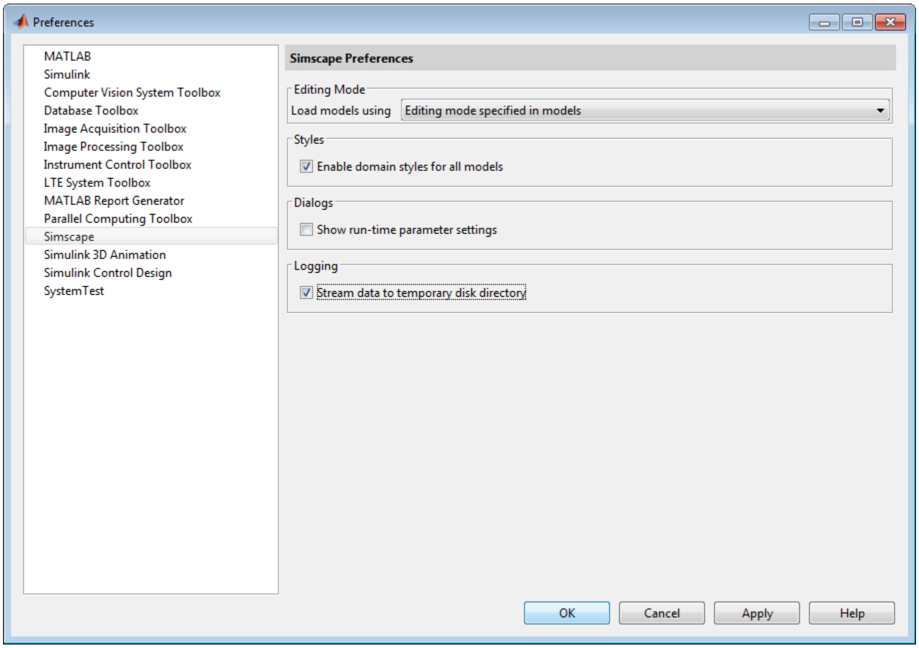
`simscape.logging.export(simlog,fileName)` saves the `simlog` object, containing logged simulation data, for future use. You can use this function only for data logged with the **Stream data to temporary disk directory** preference turned on.

When you stream simulation data to disk, the data is stored as a `simlog` object in a temporary file, and the workspace logging variable references the `simlog` object. The temporary file persists as long as there is a logging variable in the workspace that references the file. This function lets you save the `simlog` object to a different file, specified by the `fileName` argument, in HDF5 format.

Examples

Save Logged Simulation Data Streamed to Disk

To enable streaming data to disk, on the MATLAB Toolstrip, click **Preferences**. In the left pane of the Preferences dialog box, select **Simscape**, then select the **Stream data to temporary disk directory** check box.



Simscape Preferences

Editing Mode
Load models using: Editing mode specified in models

Styles
☑ Enable domain styles for all models

Dialogs
□ Show run-time parameter settings

Logging
☑ Stream data to temporary disk directory

Open the Permanent Magnet DC Motor example model, which already has data logging enabled, and run the simulation:

```
ssc_dcmotor
sim('ssc_dcmotor');
```

During the simulation, logged data is streamed to disk, to a temporary HDF5 file. After the simulation, you see the simulation log variable `simlog_ssc_dcmotor` (as specified by the **Workspace variable name** model configuration parameter) in your current workspace:

```
simlog_ssc_dcmotor
```

```
simlog_ssc_dcmotor =

  Node with properties:

              id: 'ssc_dcmotor'
     loggingMode: 'disk'
    MRRef_Torque: [1x1 simscape.logging.Node]
     Load_Torque: [1x1 simscape.logging.Node]
```

```
      DC_Voltage: [1x1 simscape.logging.Node]
        DC_Motor: [1x1 simscape.logging.Node]
            ERef: [1x1 simscape.logging.Node]
         Sensing: [1x1 simscape.logging.Node]
     MRRef_Motor: [1x1 simscape.logging.Node]
```

The `loggingMode: 'disk'` property of the `simlog_ssc_dcmotor` variable indicates that this variable points to the temporary file on disk, which contains the simulation data. The temporary file exists as long as the variable exists in your workspace, then it is deleted.

To save the logged simulation data for future use, type:

```
simscape.logging.export(simlog_ssc_dcmotor,'C:\Work\motor_run1.h5');
```

This command creates a file under `C:\Work`, named `motor_run1.h5`, and stores the logged simulation data in this file, in HDF5 format.

To retrieve the logged simulation data at a later time and associate it with a workspace variable, use the `simscape.logging.import` function.

Input Arguments

`simlog` — Logged simulation data

`Node` object

Logged simulation data, specified as a `Node` object, with the `loggingMode` property set to `'disk'`. You refer to the `simlog` object by the name of the corresponding simulation log workspace variable. You specify the name of the simulation log variable by using the **Workspace variable name** parameter in the **Simscape** pane of the Configuration Parameters dialog box.

`fileName` — File name and path

string

File name and path, specified as a string. The function stores the `simlog` object in the specified file, in HDF5 format. The `fileName` string must include the `.h5` extension. If you do not include the path, the file resides in the current working directory.

If the file already exists, the function overwrites it without a warning. However, if you import a node from a file, and then try to export it to the same file, a message informs you that in this case the file cannot be overwritten.

Example: `'C:\Work\motor_run1.h5'`

Data Types: `char`

More About

- “About Simulation Data Logging”
- “Stream Logging Data to Disk”

See Also

`simscape.logging.import`

Introduced in R2016a

simscape.logging.import

Create simulation log variable to access data in HDF5 file

Syntax

```
var = simscape.logging.import(fileName)
```

Description

`var = simscape.logging.import(fileName)` creates a workspace variable `var`, of type `simscape.logging.Node`, which references the `simlog` object in the specified HDF5 file.

You can use this function to view and analyze simulation data that was logged with the **Stream data to temporary disk directory** preference turned on.

When you stream simulation data to disk, you can save the `simlog` object as an HDF5 file by using the `simscape.logging.export` function. The `simscape.logging.import` function lets you retrieve that data at a later time, for example, when the model is not in memory. The function associates data in the file with the workspace variable `var`, which you can use to access the logged simulation data. If you do not assign a variable name when calling the function, then the workspace variable name is `ans`.

Examples

View Simulation Data Stored in File

This example shows how you can view and analyze logged simulation data, previously saved in an HDF5 file. It builds up on the `simscape.logging.export` example, which shows how to save logged simulation data, streamed to disk, in a file named `C:\Work\motor_run1.h5`.

To retrieve that data at a later time, even when the model is not in memory, type:

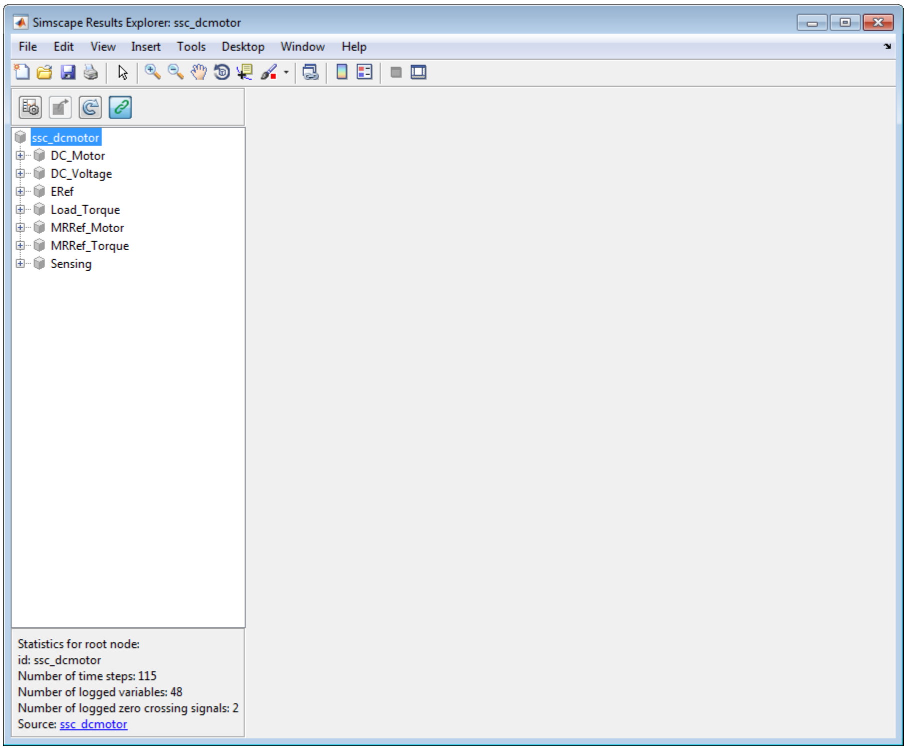
```
run1 = simscape.logging.import('C:\Work\motor_run1.h5')

run1 = 

  Node with properties:

              id: 'ssc_dcmotor'
     loggingMode: 'disk'
    MRRef_Torque: [1x1 simscape.logging.Node]
     Load_Torque: [1x1 simscape.logging.Node]
      DC_Voltage: [1x1 simscape.logging.Node]
        DC_Motor: [1x1 simscape.logging.Node]
            ERef: [1x1 simscape.logging.Node]
         Sensing: [1x1 simscape.logging.Node]
     MRRef_Motor: [1x1 simscape.logging.Node]
```

Variable `run1`, of type `Node`, appears in your current workspace. Its properties are identical to the properties of the simulation log variable `simlog_ssc_dcmotor`, which was created as a result of simulating the `ssc_dcmotor` model and logging data to disk.

Explore the simulation data:

```
sscexplore(run1)
```

A new Simscape Results Explorer window opens. It contains logged simulation data, previously saved to disk. The root node, `ssc_dcmotor`, is selected in the left pane by default. As you expand and select nodes in the left pane, the corresponding plots appear in the right pane.


Simscape Results Explorer: ssc_dcmotor
File Edit View Insert Tools Desktop Window Help
ssc_dcmotor
DC_Motor
DC_Voltage
ERef
Load_Torque
MRRef_Motor
MRRef_Torque
Sensing

Statistics for root node:
id: ssc_dcmotor
Number of time steps: 115
Number of logged variables: 48
Number of logged zero crossing signals: 2
Source: ssc_dcmotor

Input Arguments

`fileName` — File name and path

string

File name and path, specified as a string, including the `.h5` extension. The file must be in HDF5 format and contain logged simulation data, specified as a `Node` object. If you omit the extension, or try to import an HDF5 that contains some other type of data, you get an error message.

Example: `'C:\Work\motor_run1.h5'`

Data Types: `char`

More About

- “About Simulation Data Logging”
- “Stream Logging Data to Disk”
- “About the Simscape Results Explorer”

See Also

`simscape.logging.export` | `sscexplore`

Introduced in R2016a

simscape.logging.plot

Package: simscape.logging

Plot logged simulation data for node or series

Syntax

```
h = simscape.logging.plot(obj,Name,Value)
```

Description

`h = simscape.logging.plot(obj,Name,Value)` plots the simulation series values along the *y*-axis, with time along the *x*-axis. `obj` is an object (or a homogeneous cell array of objects) of class `simscape.logging.Node` or `simscape.logging.Series`. If `obj` is a node, plots all nonempty series associated with the specified node and its children. You can filter data being plotted by using the name-value pair arguments. Depending on the type of `obj`, `h` is a structure (for a node) or a cell array (for a series) of handles to the resulting figures.

Input Arguments

`obj`

An object of class `simscape.logging.Node` or `simscape.logging.Series`. Can also be a homogeneous cell array of objects of either of these two classes. `obj` must include a full identifier path to the node or series, starting with the workspace log variable name.

The following table describes the resulting plots based on the type of the `obj` argument:

Scalar series object	Plots the simulation series values along the *y*-axis, with time along the *x*-axis.
Nonscalar series object	Plots each dimension of the series values on a different axis in the same figure window.

Cell array of series objects	Plots all series objects with commensurate units on the same axis (superimposed), and each dimension for a nonscalar series on a different axis in the same figure window. The input arguments are binned based on commensurate units. For each bin, all series objects with the same dimension as the first series object in that bin are plotted and others are ignored.
Node object	Plots all nonempty series associated with the node and its children (up to the level defined by the `depth`). If a node has multiple children, at level 1, that are simulation variable nodes, these children are plotted in the same figure window but on a different axis. Descendants at other levels are plotted in different figure windows. All dimensions of a nonscalar series are plotted on the same axis.
Cell array of node objects	Plots commensurate series superimposed on the same axis. Intended for use to compare simulation data from different runs. All entries of the cell array are required to be equivalent to each other, meaning that the node objects must have same hierarchy, and the series objects for each node must have the same dimensions and commensurate units.

Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name,Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (`' '`). You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

`'depth'`

Plot data for children at *n* levels, where *n* is a nonnegative integer, for example:

`0`	No children; plot the nonempty series of the specified node only.
`1`	Plot the nonempty series of the specified node and its children.
`2`	Plot the nonempty series of the specified node, its children, and their children.

This argument is ignored if `obj` is a series.

Default: Plots all descendants of the node object that have nonempty series.

'names'

Adds the plot legend. The number of elements must be same as the number of elements of `obj`.

Default: No legend.

'time'

Plot data in the specified time range only. Provide a 1x2 vector `[`*`start_time end_time`*`]` to specify the time range. `[]` plots all data.

Default: Plots all data.

'units'

Plot the series values in the specified units. This argument filters the data to plot only nodes and series that are commensurate with the specified unit. The value can be a single unit or a cell array of units. Unit names must appear inside single quotes (`''`).

Default: Plots all data.

Output Arguments

h

A structure or a cell array of handles to the resulting plot figure windows, depending on the type of `obj`. If `obj` is a series, `h` is a cell array. If `obj` is a node, `h` is a structure with the same hierarchy as the object being plotted. For example, if a specific child is not plotted then that field in the output structure is empty.

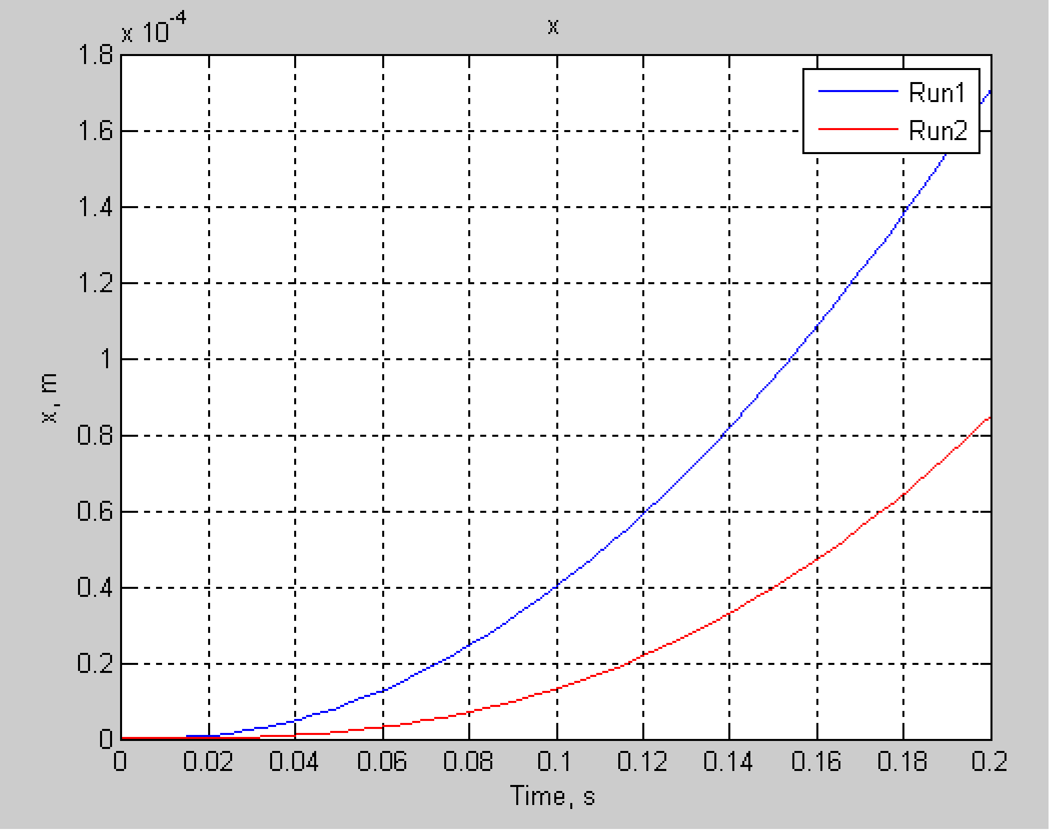
Examples

Plot all positions and velocities (series that are commensurate with units of `mm` and `mm/s`) in those units, respectively, for the top-level model node (with the default workspace variable name, `simlog`), its children and their children, within the time range between 1 and 3 seconds:

```
h = simscape.logging.plot(simlog, 'units', {'mm', 'mm/s'}, 'time', [1 3], 'depth', 2);
```

Compare data from two simulation runs. Supposing you use the workspace variable name `simlog1` to log the data from the first run, and the workspace variable name `simlog2` to log the data from the second run, the following command plots deformation of the Translational Spring block TS from both runs on the same axis, with the corresponding legend:

```
simscape.logging.plot({simlog1.TS.x simlog2.TS.x}, 'names', {'Run1' 'Run2'});
```



More About

- "Log and Plot Simulation Data"

See Also

`simscape.logging.plotxy` | simscape.logging.Node.plot | simscape.logging.Series.plot

simscape.logging.plotxy

Package: simscape.logging

Plot logged simulation data for one node or series against another

Syntax

```
h = simscape.logging.plotxy(x,y,Name,Value)
```

Description

`h = simscape.logging.plotxy(x,y,Name,Value)` plots the simulation series values of object `y` along the *y*-axis, with series values of object `x` along the *x*-axis. `x` and `y` are objects (or homogeneous cell arrays of objects) of class `simscape.logging.Series` or `simscape.logging.Node`. If `x` or `y` is a node, it must be a simulation variable node (one that has a direct child series). The values of this child series are then plotted along the respective axis.

If `x` and `y` are cell arrays, they must be of the same size, or one of them can be a scalar. `x` and `y` must have the same time vectors. The remaining arguments are optional and provided as name-value pairs.

`h` is a cell array of figure handles, one for each `y` versus `x` plot generated.

Input Arguments

x

An object of class `simscape.logging.Series`. Can also be an object of class `simscape.logging.Node`, in which case it must be a simulation variable node (one that has a direct child series). The values of this series are plotted along the *x*-axis. Can also be a homogeneous cell array of objects of either of these two classes. `x` must include a full identifier path to the node or series, starting with the workspace log variable name.

y

An object of class `simscape.logging.Series`. Can also be an object of class `simscape.logging.Node`, in which case it must be a simulation variable node (one that has a direct child series). The values of this series are plotted along the *y*-axis. Can also be a homogeneous cell array of objects of either of these two classes. `y` must include a full identifier path to the node or series, starting with the workspace log variable name. If `x` and `y` are cell arrays, they must be of the same size, or one of them can be a scalar. `x` and `y` must have the same time vectors.

Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name,Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (`' '`). You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

'time'

Plot data in the specified time range only. Provide a 1x2 vector `[`*`start_time end_time`*`]` to specify the time range. `[]` plots all data.

Default: Plots all data.

'xname'

Adds the *x*-axis name to the plot. Must be either a scalar or a cell array of the same size as `x`. Axis names must appear inside single quotes (`''`).

Default: Variable name.

'yname'

Adds the *y*-axis name to the plot. Must be either a scalar or a cell array of the same size as `y`. Axis names must appear inside single quotes (`''`).

Default: Variable name.

'xunit'

Plot the series values along the *x*-axis in the specified units. The specified unit must be commensurate with the unit of the series values. Unit name must appear inside single quotes (`''`).

Default: Default unit of the series values.

'yunit'

Plot the series values along the *y*-axis in the specified units. The specified unit must be commensurate with the unit of the series values. Unit name must appear inside single quotes ('').

Default: Default unit of the series values.

Output Arguments

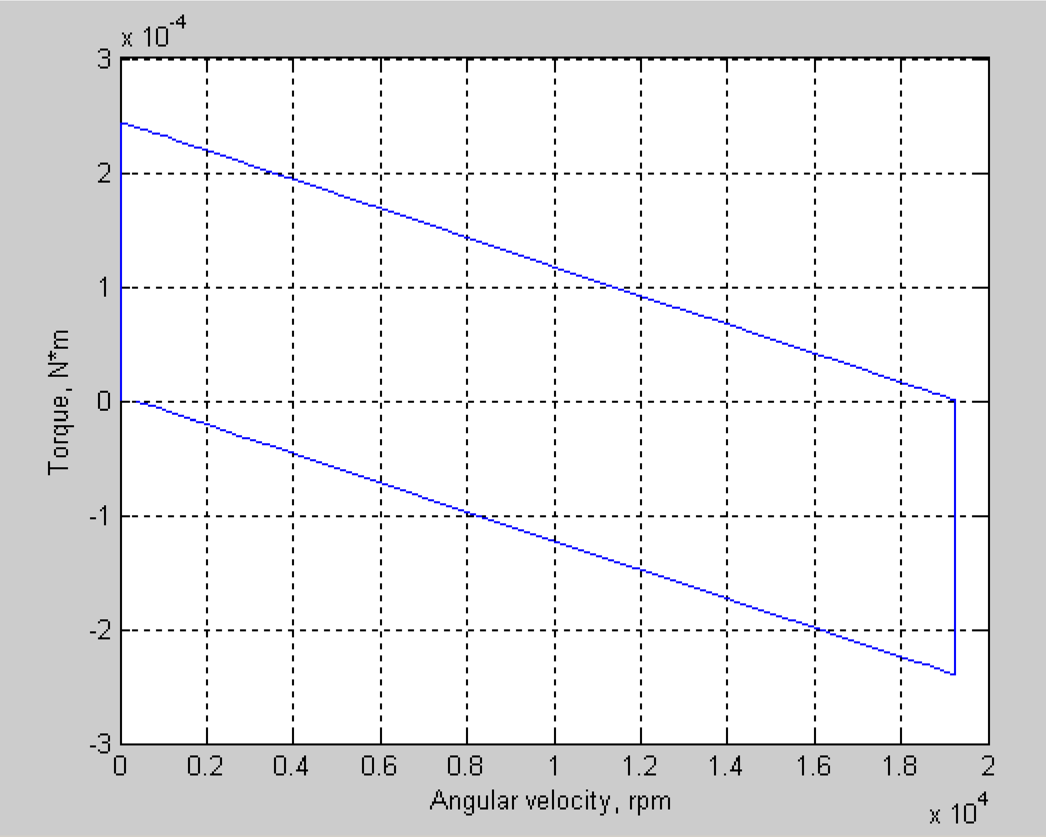
h

A cell array of handles to the resulting plot figure windows.

Examples

Plot the motor torque, in default units, against its angular velocity, in `rpm`, and add axis names:

```
plotxy(simlog.Rotational_Electromechanical_Converter.R.w, simlog.Motor_Inertia_J.t, ...
   'xunit', 'rpm', 'xname', 'Angular velocity', 'yname', 'Torque')
```



More About

- “Log and Plot Simulation Data”

See Also

`simscape.logging.plot` | simscape.logging.Node.plotxy | simscape.logging.Series.plotxy

simscape.logging.Node class

Package: simscape.logging

Represent hierarchy tree for simulation data

Description

This class represents the hierarchy of nodes for logging simulation data in a model. The tree starts with the workspace variable, which represents simulation data for the whole model, and recursively creates nodes for each of the children. The children are defined depending on the type of the parent node:

- For the top-level simulation log workspace variable, the children are all the Simscape blocks (and subsystems containing Simscape blocks) in the top-level model diagram.
- For a subsystem or a structural block, the children are all the constituent Simscape blocks and subsystems.
- For a block, the children are all its physical ports, Through and Across variables, and all internal variables defined in the block's Simscape file.
- For a physical port, the children are all its Across variables.

Final nodes in this recursion correspond to all the variables logged for the model. Final nodes do not have children nodes, and contain the series data logged during simulation.

You cannot construct an object of this class. The object is constructed automatically during simulation, as part of the simulation log workspace variable, if you enable data logging for the model.

Properties

`id`

The string identifying the `Node` object. For the simulation log workspace variable, this is the name of the top-level block diagram. For blocks and subsystems, the `id` is constructed automatically as a valid MATLAB identifier based on the name of the block or subsystem. For other types, the `id` is the name of the corresponding port or variable.

`loggingMode`

Identifies the logging method of the `Node` object, depending on the **Stream data to temporary disk directory** preference value. If the **Stream data to temporary disk directory** preference is turned off, then the simulation data is logged into workspace and the `loggingMode` value is `memory`. This is the default. If the **Stream data to temporary disk directory** preference is turned off, then the simulation data is streamed into a temporary file on disk and the `loggingMode` value is `disk`.

`series`

For `Node` objects that do not have children nodes, and therefore correspond to the logged variables, the `series` property returns an object of the simscape.logging.Series class that contains the simulation series data for this variable. For nodes that do not represent variables, the `series` property is hidden. If you access the hidden `series` property for such node, the property returns an object of the `simscape.logging.Series` class representing an empty series (with zero points).

The other properties are dynamic, and represent all the children of the `Node` object.

Methods

getSource	Navigate from node object to block that generated it
plot	Plot all series associated with node object
plotxy	Plot series associated with two node objects against each other
print	Print complete logging tree of node object

Copy Semantics

Handle. To learn how handle classes affect copy operations, see Copying Objects in the MATLAB Programming Fundamentals documentation.

See Also

simscape.logging.Series

Tutorials

- “Log and Plot Simulation Data”

How To

- “Enable Data Logging for the Whole Model”
- “Log Data for Selected Blocks Only”
- “Stream Logging Data to Disk”

getSource

Class: simscape.logging.Node
Package: simscape.logging

Navigate from node object to block that generated it

Syntax

```
block_id = getSource(node)
```

Description

`block_id = getSource(node)` returns the Simulink identifier (SID) of the block that generated data in the specified `simscape.logging.Node` object. If the node object corresponds to a variable, returns the parent block for that variable. Before you call this method, you must load the model. You must also have the simulation log variable in your current workspace. Create the simulation log variable by simulating the model with data logging turned on, or load a previously saved variable from a file.

Input Arguments

`node` — Node in the simulation data log tree

`Node` object

Node in the simulation data log tree, specified as a `Node` object. You specify the name of the simulation log variable by using the **Workspace variable name** parameter on the **Simscape** pane of the Configuration Parameters dialog box. To specify a node within the simulation log variable, provide the complete path to that node through the simulation data tree, starting with the top-level variable name.

Example: `simlog.DC_Motor.Inertia`

Output Arguments

`block_id` — Simulink identifier of the block corresponding to the specified node

SID

Simulink identifier (SID) of the block that generated data in the specified node object.

Examples

Get Full Block Path Name for Node in Simulation Log Tree

Open the Full-Wave Bridge Rectifier example model and run the simulation:

```
ssc_bridge_rectifier
sim('ssc_bridge_rectifier');
```

The model has data logging enabled for all blocks, with **Workspace variable name** parameter set to `simlog_ssc_bridge_rectifier`. Therefore, running the simulation creates the simulation log variable in your current workspace.

Print the complete logging tree for the model:

```
simlog_ssc_bridge_rectifier.print
```

```
ssc_bridge_rectifier
+-AC_Voltage_Source
| +-i
| +-n
| | +-v
| +-p
| | +-v
| +-v
+-C
| +-i
| +-n
| | +-v
| +-p
| | +-v
| +-v
| +-vc
+-Diode_1
| +-SimulationStatistics
| | +-zc_0
| |   +-crossings
| |   +-values
| +-i
| +-n
| | +-v
| +-p
| | +-v
| +-v
+-Diode_2
| +-SimulationStatistics
| | +-zc_0
| |   +-crossings
| |   +-values
| +-i
| +-n
| | +-v
| +-p
| | +-v
| +-v
+-Diode_3
| +-SimulationStatistics
| | +-zc_0
| |   +-crossings
| |   +-values
| +-i
| +-n
| | +-v
| +-p
| | +-v
| +-v
+-Diode_4
| +-SimulationStatistics
| | +-zc_0
| |   +-crossings
| |   +-values
| +-i
| +-n
| | +-v
| +-p
| | +-v
| +-v
+-ERef_T1
| +-V
| | +-v
| +-i
+-ERef_T2
| +-V
| | +-v
| +-i
+-Ideal_Transformer
```

```
  | +-i1
  | +-i2
  | +-n1
  | | +-v
  | +-n2
  | | +-v
  | +-p1
  | | +-v
  | +-p2
  | | +-v
  | +-v1
  | +-v2
  +-Load
  | +-i
  | +-n
  | | +-v
  | +-p
  | | +-v
  | +-v
  +-Voltage_Sensor
    +-V
    +-i1
    +-n
    | +-v
    +-p
    | +-v
    +-v1
```

Find Simulink identifier for the block corresponding to the `Diode_1` node:

```
id = getSource(simlog_ssc_bridge_rectifier.Diode_1)
```

```
id =

ssc_bridge_rectifier:3
```

`ssc_bridge_rectifier:3` is the Simulink identifier of the block corresponding to the specified node.

Based on the Simulink identifier, get the full block path name:

```
blockName = getfullname(id)
```

```
blockName =
ssc_bridge_rectifier/Diode 1
```

`ssc_bridge_rectifier/Diode 1` is the full path and name of the block.

See Also

simscape.logging.Node | simscape.logging.Node.print |
`simscape.logging.sli.findNode` | `simscape.logging.sli.findPath`

More About

- “About Simulation Data Logging”

Introduced in R2015b

plot

Class: simscape.logging.Node
Package: simscape.logging

Plot all series associated with node object

Syntax

```
h = plot(node,Name,Value)
```

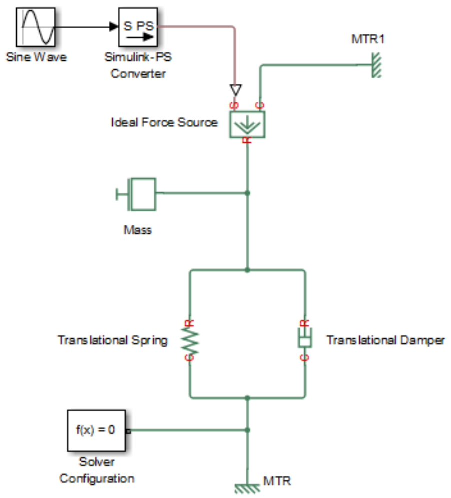
Description

`h = plot(node,Name,Value)` plots all nonempty series associated with the specified node and its children. You can filter data being plotted by using the name-value pair arguments. `h` is a structure of handles to the resulting figures. `node` is an object of class `simscape.logging.Node`. `node` must include a full identifier path to the node, starting with the workspace log variable name.

For more information, including the descriptions of name-value pair arguments, see the `simscape.logging.plot` reference page.

Examples

Consider the following model. The model name is `simple_mech2`, and data logging is enabled with the default workspace variable name, `simlog`.



The following is a complete logging tree for the model:

```
simlog.print
     simple_mech2
     +-Ideal_Force_Source
     | +-C
     | | +-v
     | +-R
     | | +-v
     | +-S
     | +-f
     | +-v
     +-MTR
     | +-V
     | | +-v
     | +-f
     +-MTR1
     | +-V
     | | +-v
     | +-f
     +-Mass
     | +-M
     | | +-v
     | +-f
     +-Simulink_PS_Converter
```

```
      +-Translational_Damper
      | +-C
      | | +-v
      | +-R
      | | +-v
      | +-f
      | +-v
      +-Translational_Spring
        +-C
        | +-v
        +-R
        | +-v
        +-f
        +-v
        +-x
```

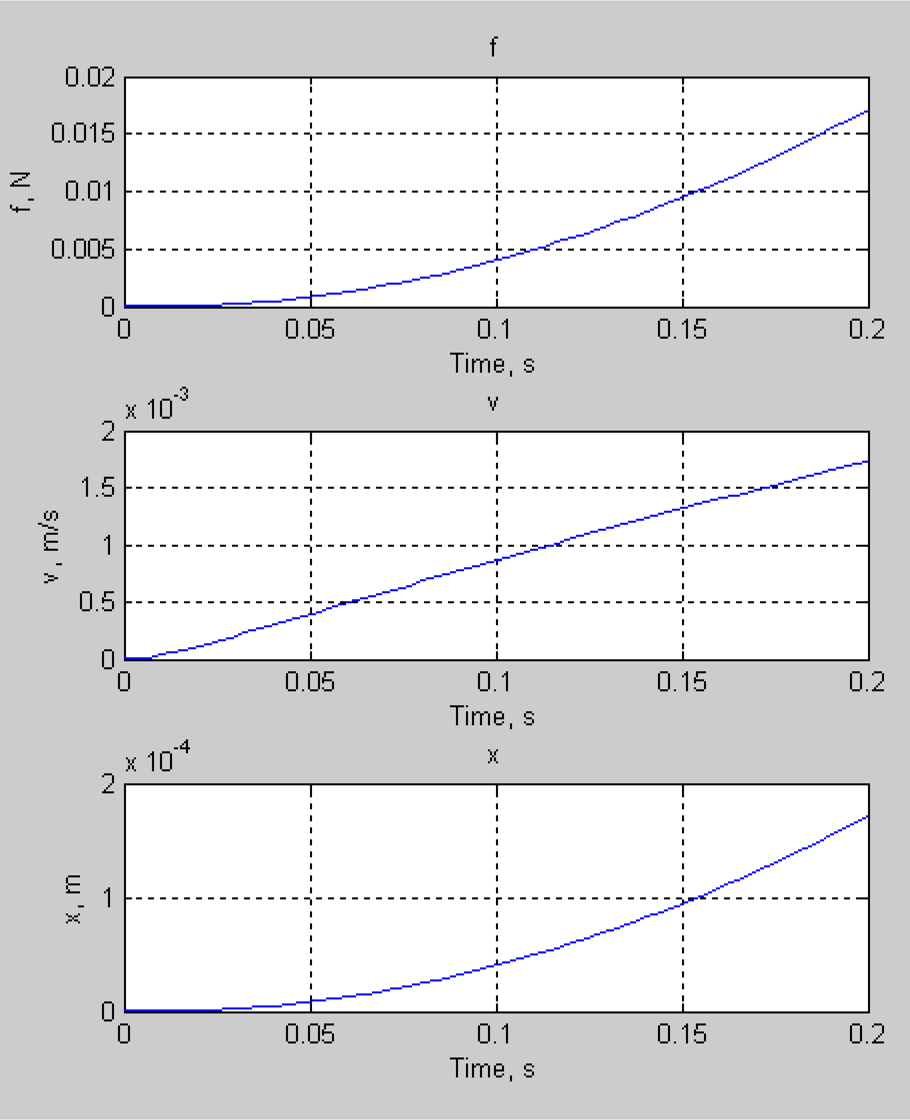
Plot velocities of all the blocks in the model:

```
plot(simlog, 'units', 'm/s', 'depth', 2)
```

This command filters simulation data in two ways. It plots only series that are commensurate with units `m/s` (that is, velocities), based on the `units` argument. And because of the `depth` argument, it plots only those velocity variables that are associated with the block itself. If you refer to the logging tree, only the Ideal Force Source, Translational Damper, and Translational Spring blocks have a velocity (`v`) variable at the second level. Because of the `depth` argument, velocities of the block ports (one level down) do not get plotted.

The next command plots all the variables associated with the Translational Spring block, but not with its ports:

```
plot(simlog.Translational_Spring, 'depth', 1)
```



Alternatives

Use the `simscape.logging.plot` function.

See Also

simscape.logging.Node | simscape.logging.Node.plotxy

plotxy

Class: simscape.logging.Node
Package: simscape.logging

Plot series associated with two node objects against each other

Syntax

```
h = plotxy(x,y,Name,Value)
```

Description

`h = plotxy(x,y,Name,Value)` plots the simulation series values of node `y` along the *y*-axis, with series values of node `x` along the *x*-axis. `h` is a cell array of handles to the resulting figures. Arguments `x` and `y` are objects (`y` can be a cell array of objects) of class `simscape.logging.Node`. Each object must be a simulation variable node (one that has a direct child series). The values of this child series are plotted along the respective axis. All series must have the same time vectors.

Each object name must include a full identifier path to the node, starting with the workspace log variable name. The remaining arguments are optional and provided as name-value pairs.

For more information, including the descriptions of name-value pair arguments, see the `simscape.logging.plotxy` reference page.

Examples

Plot velocities of ports C and R of the Translational Spring block TS against each other, in `mm/s`:

```
plotxy(simlog.TS.C.v, simlog.TS.R.v, 'xunits', 'mm/s', 'yunits', 'mm/s')
```

Alternatives

Use the `simscape.logging.plotxy` function.

See Also

simscape.logging.Node | simscape.logging.Node.plot

print

Class: simscape.logging.Node
Package: simscape.logging

Print complete logging tree of node object

Syntax

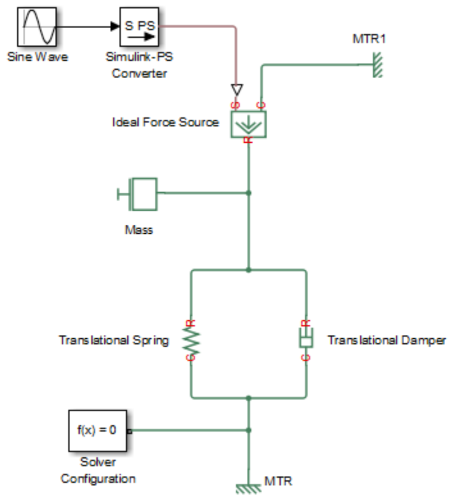
```
path_to_node.print
```

Description

path_to_node.print prints the complete logging tree starting with the specified node. *path_to_node* is a full identifier path to the node, starting with the workspace log variable name.

Examples

Consider the following model. The model name is simple_mech2, and data logging is enabled with the default workspace variable name, simlog.



Return the complete logging tree for the whole model:

```
simlog.print
     simple_mech2
     +-Ideal_Force_Source
     | +-C
     | | +-v
     | +-R
     | | +-v
     | +-S
     | +-f
     | +-v
     +-MTR
     | +-V
     | | +-v
     | +-f
     +-MTR1
     | +-V
     | | +-v
     | +-f
     +-Mass
     | +-M
     | | +-v
     | +-f
     +-Simulink_PS_Converter
     +-Translational_Damper
     | +-C
     | | +-v
     | +-R
     | | +-v
     | +-f
     | +-v
     +-Translational_Spring
       +-C
       | +-v
       +-R
       | +-v
       +-f
       +-v
       +-x
```

Print the logging tree just for the Mass block:

```
simlog.Mass.print
     Mass
     +-M
     | +-v
     +-f
```

See Also

simscape.logging.Node

simscape.logging.Series class

Package: simscape.logging

Represent time-value series for simulation data

Description

This class represents simulation data for a variable in a model. The series is a representation containing time-value pairs for each simulation step. The size of the series is determined by the number of simulation steps. You can also limit the size by specifying the maximum number of logged steps when you set your data logging preferences.

You cannot construct an object of this class. The object is constructed automatically during simulation, as part of the simulation log workspace variable, if you enable data logging for the model.

Properties

`points`

Size or number of steps in the simulation series.

`dimension`

Dimension of variable represented by the series.

`unit`

The default unit associated with the values in the series.

Methods

plot	Plot series values against time
plotxy	Plot two series against each other
time	Extract time vector from simulation series

values	Extract values vector from simulation series

Copy Semantics

Handle. To learn how handle classes affect copy operations, see Copying Objects in the MATLAB Programming Fundamentals documentation.

See Also

simscape.logging.Node

Tutorials

- “Log and Plot Simulation Data”

How To

- “Enable Data Logging for the Whole Model”
- “Log Data for Selected Blocks Only”

plot

Class: simscape.logging.Series
Package: simscape.logging

Plot series values against time

Syntax

```
h = plot(series,Name,Value)
```

Description

`h = plot(series,Name,Value)` plots the simulation series values along the *y*-axis, with time along the *x*-axis. You can filter data being plotted by using the name-value pair arguments. `h` is a cell array of handles to the resulting figures. `series` is an object of class `simscape.logging.Series`. `series` must include a full identifier path to the series, starting with the workspace log variable name.

For more information, including the descriptions of name-value pair arguments, see the `simscape.logging.plot` reference page.

Examples

Plot velocity of port R of the Translational Spring block, in `mm/s`:

```
plot(simlog.Translational_Spring.R.v.series, 'units', 'mm/s')
```

Alternatives

Use the `simscape.logging.plot` function.

See Also

simscape.logging.Series | simscape.logging.Series.plotxy

plotxy

Class: simscape.logging.Series
Package: simscape.logging

Plot two series against each other

Syntax

```
h = plotxy(x,y,Name,Value)
```

Description

`h = plotxy(x,y,Name,Value)` plots values of the simulation series `y` along the *y*-axis, with values of the simulation series `x` along the *x*-axis. `h` is a cell array of handles to the resulting figures. Arguments `x` and `y` are objects (`y` can be a cell array of objects) of class `simscape.logging.Series`. `Each object name` must include a full identifier path to the series, starting with the workspace log variable name. The series must have the same time vectors. The remaining arguments are optional and provided as name-value pairs.

For more information, including the descriptions of name-value pair arguments, see the `simscape.logging.plotxy` reference page.

Examples

Plot velocities of ports C and R of the Translational Spring block TS against each other, in `mm/s`:

```
plotxy(simlog.TS.C.v.series, simlog.TS.R.v.series, 'xunits', 'mm/s', 'yunits', 'mm/s')
```

Alternatives

Use the `simscape.logging.plotxy` function.

See Also

simscape.logging.Series | simscape.logging.Series.plot

time

Class: simscape.logging.Series
Package: simscape.logging

Extract time vector from simulation series

Syntax

```
ta = path_to_var.series.time
```

Description

ta = *path_to_var*.series.time returns a row vector of simulation times contained in the series. *path_to_var* is a full identifier path to the variable node associated with the series.

Examples

Return simulation time data for the deformation of a Translational Spring block, located at the top level of the model diagram:

```
t1 = simlog.Translational_Spring.x.series.time

t1 =

         0
    0.0020
    0.0040
    0.0060
    0.0100
    0.0140
    0.0180
    0.0220
    0.0260
    0.0300
    0.0340
    0.0380
    0.0420
    0.0460
    0.0500
    0.0540
    0.0580
    0.0620
    0.0660
    0.0700
    0.0740
    0.0780
    0.0820
    0.0860
    0.0900
    0.0940
    0.0980
    0.1020
    0.1060
    0.1100
    0.1140
    0.1180
    0.1220
    0.1260
    0.1300
    0.1340
    0.1380
    0.1420
    0.1460
    0.1500
    0.1540
    0.1580
    0.1620
    0.1660
    0.1700
    0.1740
    0.1780
    0.1820
    0.1860
    0.1900
    0.1940
    0.1980
    0.2000
```

See Also

simscape.logging.Series | simscape.logging.Series.values

values

Class: simscape.logging.Series
Package: simscape.logging

Extract values vector from simulation series

Syntax

```
va = path_to_var.series.values
va = path_to_var.series.values('unit')
```

Description

`va = path_to_var.series.values` returns a row vector of variable values contained in the series, in default units. `path_to_var` is a full identifier path to the variable node associated with the series.

`va = path_to_var.series.values('unit')` returns a row vector of variable values in the specified units. `unit` must be commensurate with the default units of the variable.

For nonscalar variables of size *m*-by-*n*, this method returns a row vector of `m*n*steps` size, where `steps` is the number of steps in the series, and each `m*n` block represents the logged value for the variable in a column major form. For example, if a variable size is 2-by-2, then the first four elements in the row vector are the a_{11}, a_{21}, a_{12}, and a_{22} elements at the first time step.

Examples

Return the deformation values of a Translational Spring block, located at the top level of the model diagram:

```
v1 = simlog.Translational_Spring.x.series.values

v1 =

  1.0e-003 *

         0
```

```
    0.0000
    0.0000
    0.0001
    0.0002
    0.0004
    0.0007
    0.0012
    0.0018
    0.0025
    0.0034
    0.0044
    0.0056
    0.0070
    0.0085
    0.0101
    0.0119
    0.0139
    0.0160
    0.0183
    0.0207
    0.0233
    0.0260
    0.0289
    0.0319
    0.0351
    0.0384
    0.0419
    0.0455
    0.0492
    0.0531
    0.0572
    0.0614
    0.0657
    0.0702
    0.0748
    0.0796
    0.0845
    0.0895
    0.0947
    0.1000
    0.1055
    0.1111
    0.1168
    0.1227
    0.1287
    0.1348
    0.1411
    0.1475
    0.1540
    0.1607
    0.1675
    0.1710
```

The previous command returns the deformation values in meters (the default unit of the series). To return the same deformation values in different units, for example, in inches, type:

```
v1 = simlog.Translational_Spring.x.series.values('in')

v1 =

         0
    0.0000
    0.0000
    0.0000
    0.0000
    0.0000
    0.0000
    0.0000
    0.0001
    0.0001
    0.0001
    0.0002
    0.0002
    0.0003
    0.0003
    0.0004
    0.0005
    0.0005
    0.0006
    0.0007
    0.0008
    0.0009
    0.0010
    0.0011
    0.0013
    0.0014
    0.0015
    0.0016
    0.0018
    0.0019
    0.0021
    0.0023
    0.0024
    0.0026
    0.0028
    0.0029
    0.0031
    0.0033
    0.0035
    0.0037
    0.0039
    0.0042
    0.0044
    0.0046
    0.0048
    0.0051
    0.0053
    0.0056
    0.0058
    0.0061
    0.0063
    0.0066
    0.0067
```

See Also

simscape.logging.Series | simscape.logging.Series.time

simscape.logging.sli.findNode

Find `Node` object corresponding to block or subsystem

Syntax

```
node = simscape.logging.sli.findNode(simlog,block)
```

Description

`node = simscape.logging.sli.findNode(simlog,block)` returns a `simscape.logging.Node` object that contains the logged simulation data for the specified block or subsystem in a model. Before you call this function, you must load the model. You must also have the simulation log variable in your current workspace. Create the simulation log variable by simulating the model with data logging turned on, or load a previously saved variable from a file.

Examples

Find Node for the Current Block

Open the Permanent Magnet DC Motor example model, which already has data logging enabled, and run the simulation to create the simulation log variable `simlog_ssc_dcmotor` (as specified by the **Workspace variable name** model configuration parameter) in your current workspace:

```
ssc_dcmotor
sim('ssc_dcmotor');
```

Open the DC Motor subsystem and select the Inertia block.

Find node corresponding to the selected block:

```
n = simscape.logging.sli.findNode(simlog_ssc_dcmotor,gcbh)
```

```
n =
  Node with properties:

    id: 'Inertia'
     w: [1x1 simscape.logging.Node]
     t: [1x1 simscape.logging.Node]
     I: [1x1 simscape.logging.Node]
```

`n` is the `Node` object corresponding to the selected block.

Find Node Using Full Block Path Name

Open the Permanent Magnet DC Motor example model, which already has data logging enabled, and run the simulation to create the simulation log variable `simlog_ssc_dcmotor` (as specified by the **Workspace variable name** model configuration parameter) in your current workspace:

```
ssc_dcmotor
sim('ssc_dcmotor');
```

Find node corresponding to the Inertia block in the DC Motor subsystem:

```
n = simscape.logging.sli.findNode(simlog_ssc_dcmotor,'ssc_dcmotor/DC Motor/Inertia')

n =

  Node with properties:

    id: 'Inertia'
     w: [1x1 simscape.logging.Node]
     t: [1x1 simscape.logging.Node]
     I: [1x1 simscape.logging.Node]
```

`n` is the `Node` object corresponding to the Inertia block in the DC Motor subsystem.

Find node corresponding to the DC Motor subsystem:

```
m = simscape.logging.sli.findNode(simlog_ssc_dcmotor,'ssc_dcmotor/DC Motor')

m =

  Node with properties:

                                  id: 'DC_Motor'
                    Rotor_Resistance: [1x1 simscape.logging.Node]
                    Rotor_Inductance: [1x1 simscape.logging.Node]
```

```
    Rotational_Electromechanical_Converter: [1x1 simscape.logging.Node]
                                   Inertia: [1x1 simscape.logging.Node]
                                  Friction: [1x1 simscape.logging.Node]
```

`m` is the `Node` object corresponding to the whole DC Motor subsystem.

Input Arguments

`simlog` — Simulation log variable

`Node` object

Simulation log workspace variable that contains the logged model simulation data, specified as a `Node` object. You specify the name of the simulation log variable by using the **Workspace variable name** parameter in the **Simscape** pane of the Configuration Parameters dialog box.

`block` — Block name or identifier

handle | string | `Simulink.Block` object | SID

Block or subsystem name or identifier, specified as a handle, full path to a block or subsystem in the model, `Simulink.Block` object, or a valid Simulink identifier (SID).

Data Types: `double` | `char`

Output Arguments

`node` — Node in the simulation data log tree corresponding to the specified block

`Node` object

Node in the simulation data log tree corresponding to the specified block, returned as a `Node` object. The `Node` object, which is of class `simscape.logging.Node`, contains logged simulation data for the specified block. Returns empty `[]` if the node is not found.

More About

- "About Simulation Data Logging"
- "Data Logging Options"

See Also

`simscape.logging.sli.findPath`

Introduced in R2014b

simscape.logging.sli.findPath

Find path to node in logged simulation data tree

Syntax

```
[isvalid nodepath] = simscape.logging.sli.findPath(simlog,block)
```

Description

`[isvalid nodepath] = simscape.logging.sli.findPath(simlog,block)` returns a logical value and a path to the node in the simulation data tree `simlog`. The node contains logged simulation data for the specified block or subsystem in a model. Before you call this function, you must load the model. You must also have the simulation log variable in your current workspace. Create the simulation log variable by simulating the model with data logging turned on, or load a previously saved variable from a file.

Examples

Find Path for the Current Block Node

Open the Permanent Magnet DC Motor example model, which already has data logging enabled, and run the simulation to create the simulation log variable `simlog_ssc_dcmotor` (as specified by the **Workspace variable name** model configuration parameter) in your current workspace:

```
ssc_dcmotor
sim('ssc_dcmotor');
```

Open the DC Motor subsystem and select the Inertia block.

Find path to the node corresponding to the selected block:

```
[a b] = simscape.logging.sli.findPath(simlog_ssc_dcmotor,gcbh)
```

```
a =
     1


b =

DC_Motor.Inertia
```

a returns 1, indicating that the valid path to the node was found. b is a string containing the path in the simulation log variable to the Node object corresponding to the selected block.

Find Path to the Node Using Full Block Path Name

Open the Permanent Magnet DC Motor example model, which already has data logging enabled, and run the simulation to create the simulation log variable simlog_ssc_dcmotor (as specified by the **Workspace variable name** model configuration parameter) in your current workspace:

```
ssc_dcmotor
sim('ssc_dcmotor');
```

Find path to the node corresponding to the Inertia block in the DC Motor subsystem:

```
[a b] = simscape.logging.sli.findPath(simlog_ssc_dcmotor,'ssc_dcmotor/DC Motor/Inertia
```

```
a =

     1


b =

DC_Motor.Inertia
```

a returns 1, indicating that the valid path to the node was found. b is a string containing the path in the simulation log variable to the Node object corresponding to the selected block.

Find path to the node corresponding to the top-level model:

```
[a1 b1] = simscape.logging.sli.findPath(simlog_ssc_dcmotor,'ssc_dcmotor')
```

```
a1 =
     1


b1 =

     ''
```

a1 returns 1, indicating that the valid path to the node was found. b1 is an empty string, because ssc_dcmotor is the name of the top-level model.

Input Arguments

simlog — Simulation log variable

Node object

Simulation log workspace variable that contains the logged model simulation data, specified as a Node object. You specify the name of the simulation log variable by using the **Workspace variable name** parameter on the **Simscape** pane of the Configuration Parameters dialog box.

block — Block name or identifier

handle | string | Simulink.Block object | SID

Block or subsystem name or identifier, specified as a handle, full path to a block or subsystem in the model, Simulink.Block object, or a valid Simulink identifier (SID).

Data Types: double | char

Output Arguments

isvalid — Logical value indicating whether the match between block and node is found

0 | 1

Logical value indicating whether the match between block and node is found, returned as true (1) or false (0). Returns true (1) if the simulation data log tree contains a node corresponding to the specified block. Returns false (0) if a matching node was not found. The function can return false if the model is configured to log data only for selected blocks (rather than for the whole model) and the specified block was not selected for logging. The function can also return false if the specified block does not produce logged simulation data (for example, a Solver Configuration block or a scope).

`nodepath` — Path to the corresponding node in the simulation data log tree
string

Path to the node containing logged simulation data for the specified block, returned as a string. If `isvalid` returns false (0), then `nodepath` is an empty string. If `block` is the top-level model in the block diagram, then `nodepath` is also an empty string, but `isvalid` returns true (1).

More About

- "About Simulation Data Logging"
- "Data Logging Options"

See Also

`simscape.logging.sli.findNode`

Introduced in R2014b

sl_postprocess

Make postprocessing customizations when building custom block library

Syntax

```
sl_postprocess(h)
```

Description

`sl_postprocess(h)` takes a handle to the custom block library, `h`, and allows you to make library postprocessing customizations (for example, add a forwarding table).

If a Simscape file package being built contains a `sl_postprocess.m` file, then `ssc_build` calls `sl_postprocess` once the block library (*`package_name`*`_lib`) is generated but before it is saved to disk. If `sl_postprocess` generates an error, the library does not build.

You can include a `sl_postprocess.m` file at any level in the library package. At the top level, it makes postprocessing changes to the whole custom block library. Similarly, if the `sl_postprocess.m` file resides in a sublibrary in the package, it takes a handle to that sublibrary and makes the corresponding changes.

Examples

If you rename a block or change a parameter name, you need to add a forwarding table to update old models that reference the block. However, if you manually add a forwarding table to a custom library, it will get overwritten every time you rebuild the library. Instead, include a `sl_postprocess.m` file in the library package, which will add the forwarding table automatically upon rebuilding the library:

```
- +MySimscape
|-- sl_postprocess.m
|-- +Mechanical
| |-- spring.ssc
| |-- ...
```

The sl_postprocess.m file contains a forwarding table:

```
function sl_postprocess(h)
% Forwarding table for the spring block
ft = { {'MySimscape_lib/Mechanical/Ideal Spring', 'MySimscape_lib/Mechanical/Rotational Spring'} }
set_param(h, 'ForwardingTable', ft);
end
```

This forwarding table indicates that the custom block name for the spring.ssc component has changed from 'Ideal Spring' to 'Rotational Spring'.

Note that if you have customized the library names using lib.m files, you have to use these custom names in the forwarding table (for example, 'Mechanical Library' instead of 'Mechanical').

See Also

ssc_build

sscexplore

Open Simscape Results Explorer to interact with logged simulation data

Syntax

```
sscexplore(node)
sscexplore(node,nodepath)
```

Description

`sscexplore(node)` opens a new Simscape Results Explorer window containing logged simulation data for the specified node in a simulation log variable. Before you call this function, you must have the simulation log variable in your current workspace. Create the simulation log variable by simulating the model with data logging turned on, or load a previously saved variable from a file. If `node` is the name of the simulation log variable, then the Simscape Results Explorer window contains the data for the whole model. If `node` is the name of a node in the simulation data tree, then the Simscape Results Explorer window contains the data for that node only.

`sscexplore(node,nodepath)` opens a new Simscape Results Explorer window that contains logged simulation data for the specified node, `node`, but opens at a subnode specified by `nodepath`.

Examples

Explore Logged Simulation Data for the Whole Model, Starting at the Root

Open the Permanent Magnet DC Motor example model:

```
ssc_dcmotor
```

This example model has data logging enabled for the whole model, with the **Workspace variable name** parameter set to `simlog_ssc_dcmotor`.

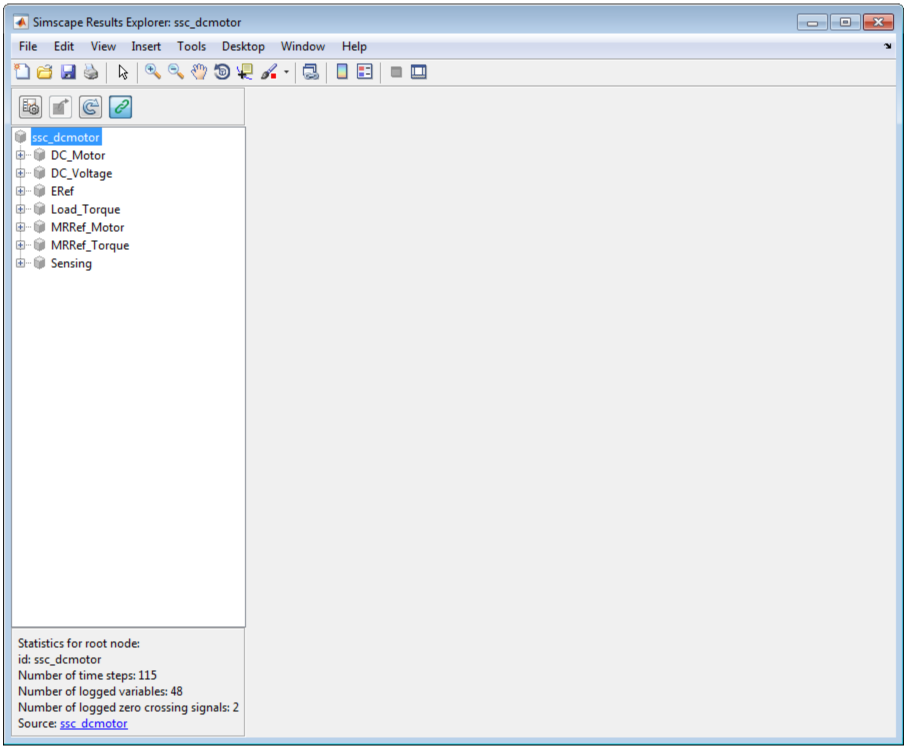
Simulate the model to log the simulation data:

```
sim('ssc_dcmotor');
```

Explore the simulation data:

```
sscexplore(simlog_ssc_dcmotor)
```

A new Simscape Results Explorer window opens. It contains logged simulation data for the whole model. The root node, `ssc_dcmotor`, is selected in the left pane by default. As you expand and select nodes in the left pane, the corresponding plots appear in the right pane.



Statistics for root node:
id: ssc_dcmotor
Number of time steps: 115
Number of logged variables: 48
Number of logged zero crossing signals: 2
Source: ssc_dcmotor

Explore Logged Simulation Data for the Whole Model, Starting at a Specific Node

Open the Permanent Magnet DC Motor example model:

```
ssc_dcmotor
```

This example model has data logging enabled for the whole model, with the **Workspace variable name** parameter set to `simlog_ssc_dcmotor`.

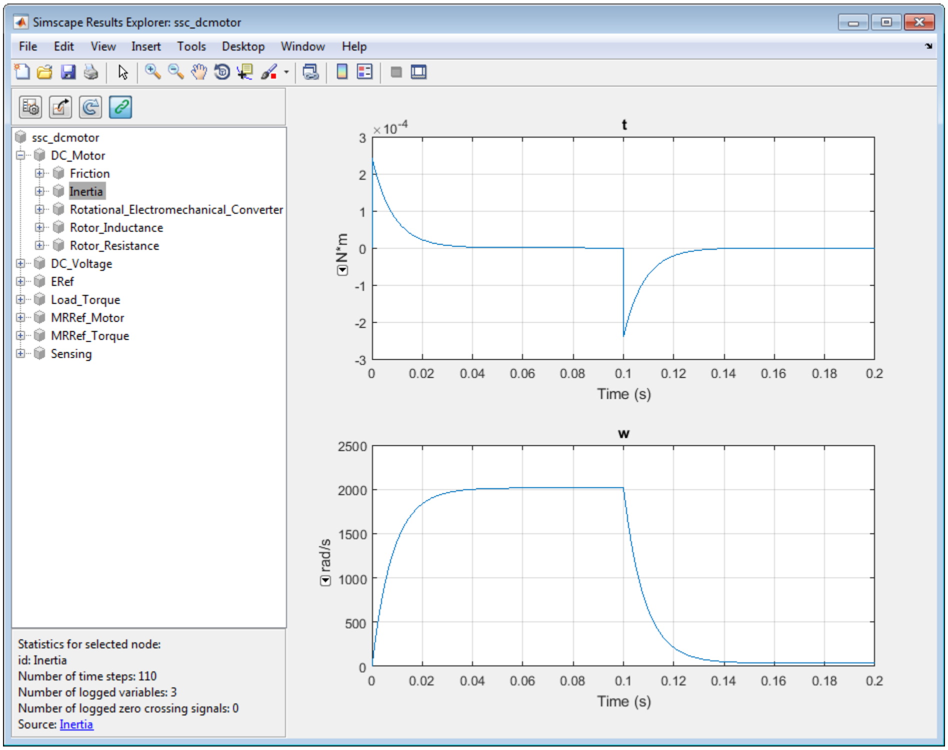
Simulate the model to log the simulation data:

```
sim('ssc_dcmotor');
```

Explore the simulation data:

```
sscexplore(simlog_ssc_dcmotor,'DC_Motor.Inertia')
```

A new Simscape Results Explorer window opens. It contains logged simulation data for the whole model, but the data exploration starts with the node specified by the `nodepath` argument. This node corresponds to the Inertia block in the DC Motor subsystem.



Statistics for selected node:
id: Inertia
Number of time steps: 110
Number of logged variables: 3
Number of logged zero crossing signals: 0
Source: Inertia

Explore Logged Simulation Data Only for a Specific Node

Open the Permanent Magnet DC Motor example model:

```
ssc_dcmotor
```

This example model has data logging enabled for the whole model, with the **Workspace variable name** parameter set to `simlog_ssc_dcmotor`.

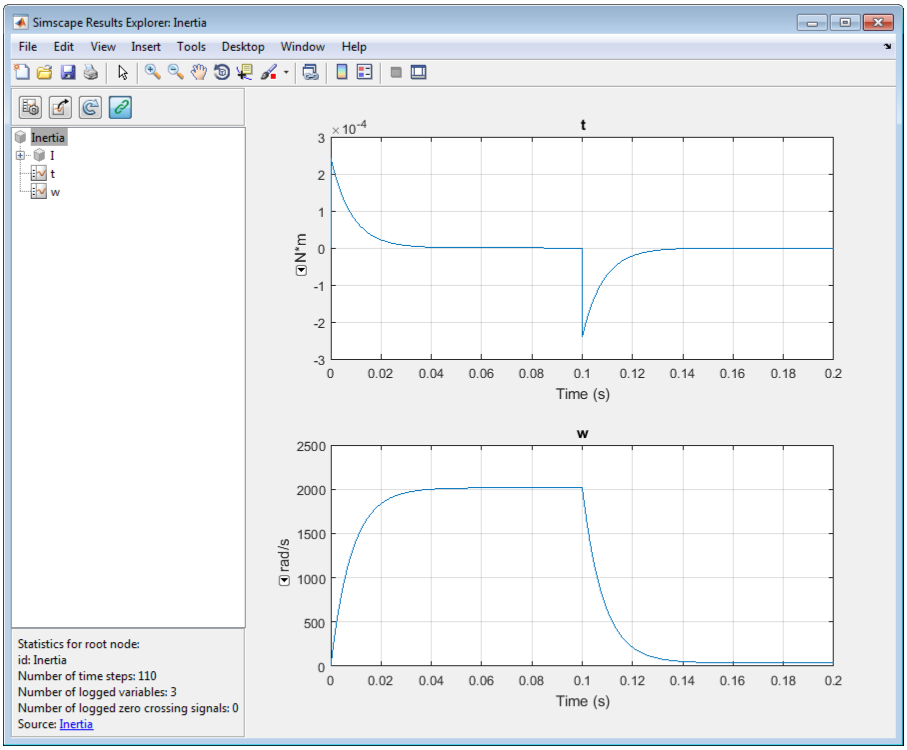
Simulate the model to log the simulation data:

```
sim('ssc_dcmotor');
```

Explore the simulation data:

```
sscexplore(simlog_ssc_dcmotor.DC_Motor.Inertia)
```

A new Simscape Results Explorer window opens. It contains just the logged simulation data for the node specified in the `node` argument. This node corresponds to the Inertia block in the DC Motor subsystem.



Statistics for root node:
id: Inertia
Number of time steps: 110
Number of logged variables: 3
Number of logged zero crossing signals: 0
Source: Inertia

Input Arguments

`node` — Simulation log variable, or a specific node within the simulation log variable

`Node` object

Simulation log workspace variable, or a node within this variable, that contains the logged model simulation data, specified as a `Node` object. You specify the name of the simulation log variable by using the **Workspace variable name** parameter on the **Simscape** pane of the Configuration Parameters dialog box. To specify a node within the simulation log variable, provide the complete path to that node through the simulation data tree, starting with the top-level variable name.

Example: `simlog.DC_Motor.Motor_Inertia_J`

`nodepath` — Path to a subnode to open

string

Path to a subnode to open, specified as a string. If you omit the `nodepath` argument, then the Simscape Results Explorer window opens at the root of the specified node, `node`. If you specify `nodepath`, then the Simscape Results Explorer window still contains all the simulation data for the `node`, but opens at the subnode within it, specified by the `nodepath`. Use the `simscape.logging.sli.findPath` function to find the `nodepath` value for a block or subsystem.

Example: `'DC_Motor.Motor_Inertia_J'`

Data Types: `char`

More About

- "About Simulation Data Logging"
- "Data Logging Options"
- "About the Simscape Results Explorer"

See Also

`simscape.logging.sli.findPath`

Introduced in R2014b

sscprintzcs

Print zero crossing information for logged simulation data

Syntax

```
sscprintzcs(node)
sscprintzcs(node,verbosity)
```

Description

`sscprintzcs(node)`prints information about zero crossings detected during simulation, based on logged simulation data specified by `node`. Before you call this function, you must have the simulation log variable, which includes simulation statistics data, in your current workspace. Create the workspace variable by simulating the model with simulation statistics logging turned on, or load a previously saved variable from a file.

`sscprintzcs(node,verbosity)` prints detailed information about zero crossings. The `verbosity` argument controls the level of detail.

Examples

Print Information About Blocks That Produce Zero Crossings

Open the Permanent Magnet DC Motor example model:

```
ssc_dcmotor
```

This example model has data logging and simulation statistics logging enabled, with the **Workspace variable name** parameter set to `simlog_ssc_dcmotor`.

Simulate the model to log the simulation data:

```
sim('ssc_dcmotor');
```

Get the zero crossing information at the block level:

```
sscprintzcs(simlog_ssc_dcmotor)
```

```
ssc_dcmotor (2 signals, 2 crossings)
  +-DC_Motor (2 signals, 2 crossings)
    +-Friction (2 signals, 2 crossings)
```

The results show that the only block that can produce zero crossings is the Friction block in the DC Motor subsystem. It has two signals that can produce zero crossings, and two actual zero crossings are detected.

Print Information About Signals That Produce Zero Crossings

Open the Permanent Magnet DC Motor example model:

```
ssc_dcmotor
```

This example model has data logging and simulation statistics logging enabled, with the **Workspace variable name** parameter set to `simlog_ssc_dcmotor`.

Simulate the model to log the simulation data:

```
sim('ssc_dcmotor');
```

Get the zero crossing information at the signal level:

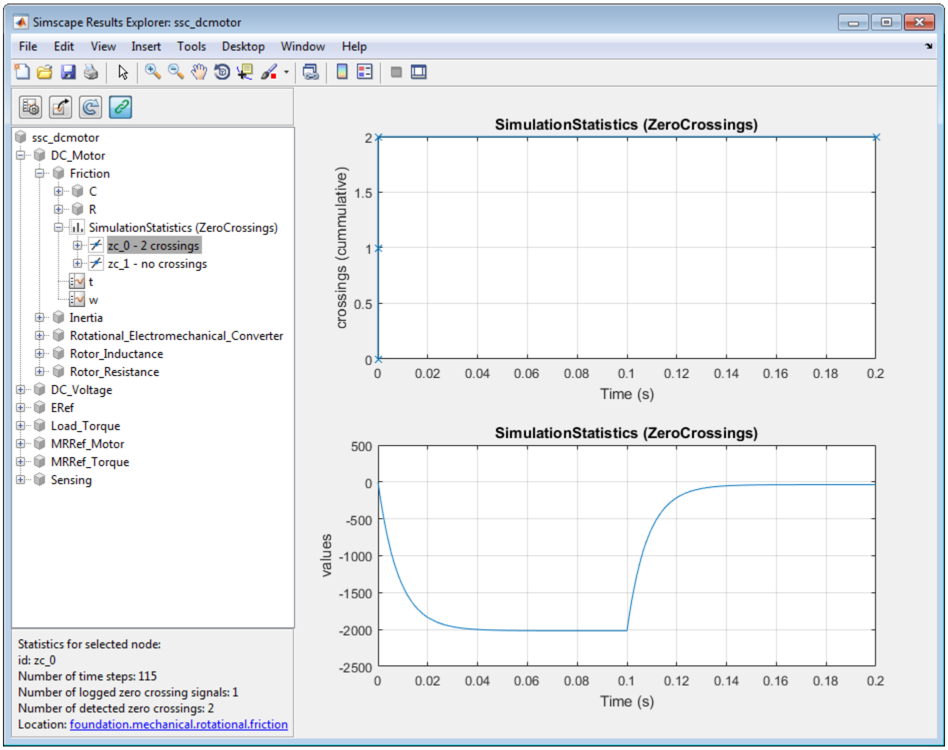
```
sscprintzcs(simlog_ssc_dcmotor,1)
```

```
ssc_dcmotor (2 signals, 2 crossings)
  +-DC_Motor (2 signals, 2 crossings)
    +-Friction (2 signals, 2 crossings)
      -zc_0    2
      -zc_1    0
```

The results show that the only block that can produce zero crossings in the Friction block in the DC Motor subsystem. It has two signals that can produce zero crossings, `zc_0` and `zc_1`, and two actual zero crossings are detected. Both zero crossings are detected for the `zc_0` signal. Signal `zc_1` did not produce zero crossings during simulation.

Use the `sscexplore` function to further explore the zero crossing data.

```
sscexplore(simlog_ssc_dcmotor,'DC_Motor.Friction.SimulationStatistics.zc_0')
```



Statistics for selected node:
id: zc_0
Number of time steps: 115
Number of logged zero crossing signals: 1
Number of detected zero crossings: 2
Location: foundation.mechanical.rotational.friction

Input Arguments

node — Simulation log variable, or a specific node within the simulation log variable

Node object

Simulation log workspace variable that contains the logged model simulation data, including simulation statistics, specified as a Node object. You specify the name of the simulation log variable by using the **Workspace variable name** parameter on the **Simscape** pane of the Configuration Parameters dialog box. You can also specify a node within the simulation log variable by providing the complete path to that node through the simulation data tree. In this case, the function prints information only about zero crossings found in that particular node.

Example: `simlog.DC_Motor`

`verbosity` — Level of detail in printed information about zero crossings

0 (default) | 1 | 2

Level of detail in printed information about zero crossings, specified as a number:

- 0 — Block-level information
- 1 — Signal-level information
- 2 — Signal-level information, including location

Data Types: `double`

More About

- “About Simulation Data Logging”
- “Data Logging Options”
- “About the Simscape Results Explorer”

See Also

`sscexplore`

Introduced in R2014b

ssc_build

Build custom library from collection of Simscape files

Syntax

```
ssc_build package
```

Description

`ssc_build` *`package`* generates a custom Simscape library file, named *`package`*`_lib`, containing all the sublibraries and blocks generated from the Simscape files (either source or protected) located in the package and its subdirectories. Simscape protected files have higher precedence than the source files when you build a library. If both the protected and the source files are present in the package, and the source files are out of date, `ssc_build` will use the protected files to build the library, but you will get a warning.

The argument, *`package`*, must be a top-level package name.

Note The package directory name begins with a leading `+` character, whereas the argument to `ssc_build` must omit the `+` character.

The package must be located in a directory on the MATLAB path. The *`package`*`_lib` is automatically placed in the package parent directory. For more information, see "Building Custom Block Libraries".

If you run the `ssc_build` command from inside the package directory structure, you can omit the argument.

Examples

For example, your top-level package directory, where you store your Simscape files, is named `+SimscapeCustomBlocks`. To generate a custom block library, at the MATLAB Command prompt, type:

```
ssc_build SimscapeCustomBlocks;
```

This command generates a Simulink model file called `SimscapeCustomBlocks_lib` in the parent directory of the top-level package (that is, in the same directory that contains your `+SimscapeCustomBlocks` package).

See Also

`sl_postprocess` | `ssc_clean` | `ssc_mirror` | `ssc_protect`

ssc_clean

Clean all derived files generated by library build process

Syntax

```
ssc_clean package
```

Description

`ssc_clean` *`package`* deletes all derived files generated by `ssc_build` in the package named *`package`*, including the library file.

The argument, *`package`*, must be a top-level package name.

Note The package directory name begins with a leading + character, whereas the argument to `ssc_clean` must omit the + character.

Running `ssc_clean` before rebuilding a library forces `ssc_build` to generate all derived files in the package, rather than regenerate only those files that have changed. You do not need to run `ssc_clean` before regular iterative library builds.

When you upgrade to a new version of Simscape software, run `ssc_clean` and then rebuild the custom block libraries.

When deploying your libraries on multiple platforms, you do not need to run `ssc_clean` on each platform. Use `ssc_clean` at the beginning of deployment and then just run `ssc_build` on each platform.

Examples

To clean all derived files from the package directory `+MyPackage`, invoke the following from the directory containing the package directory `+MyPackage`:

```
ssc_clean MyPackage;
```

See Also

`ssc_build`

ssc_mirror

Create protected mirror of library of Simscape files

Syntax

```
ssc_mirror package mirrordir buildmirror
```

Description

The `ssc_mirror` command lets you protect and build a whole package of Simscape files in one step.

`ssc_mirror` *`package mirrordir`* `buildmirror` creates a protected mirror of a package of Simscape files in a specified directory *`mirrordir`*, and also optionally builds a custom library from these files.

The first argument, *`package`*, must be a top-level package name.

Note The package directory name begins with a leading `+` character, whereas the argument to `ssc_mirror` must omit the `+` character.

The second argument, *`mirrordir`*, is the directory where the protected package is placed. The `ssc_mirror` command creates this directory, if it does not exist, recreates the whole package structure under it, generates the protected files, and places them in the appropriate mirror locations.

If the `buildmirror` flag is set to `true`, the `ssc_mirror` command also builds a custom Simscape library file, named *`package`*`_lib`, containing all the sublibraries and blocks generated from the Simscape files in the mirrored package (similar to the `ssc_build` command), and places the *`package`*`_lib` file in the *`mirrordir`* directory. The `buildmirror` flag is optional and the default is `false`, that is, by default the package is mirrored and protected but the library is not built.

For more information, see “Using Source Protection for Simscape Files”.

Examples

For example, your top-level package directory, where you store your Simscape files, is named +SimscapeCustomBlocks. To protect, mirror, and generate a custom block library from this package in the directory C:\Work\deploy, at the MATLAB Command prompt, type:

```
ssc_mirror SimscapeCustomBlocks C:\Work\deploy true;
```

This command creates a mirror package, equivalent to the +SimscapeCustomBlocks package but consisting of Simscape protected files, in the directory C:\Work\deploy, and generates a file called SimscapeCustomBlocks_lib in the C:\Work\deploy directory.

See Also

sl_postprocess | ssc_build | ssc_clean | ssc_protect

ssc_new

Create new Simscape model populated by required and commonly used blocks

Syntax

```
ssc_new
ssc_new('modelname')
ssc_new('modelname','domain')
ssc_new('modelname','domain','solver')
```

Description

`ssc_new` creates a new Simscape model, with required and commonly used blocks already on the model canvas, and opens the Simscape library.

The function also turns on simulation data logging for the whole model, using the default workspace variable name `simlog` and limiting the logged simulation data to 10000 points. For more information, see “Data Logging”.

By default, the function uses the Simulink default new model name `untitled` and the recommended solver `ode23t`.

`ssc_new('modelname')`creates a new Simscape model with the specified name.

`ssc_new('modelname','domain')`creates a new Simscape model with the specified name and with domain-specific reference block added to the model canvas. Valid domains types are `'electrical'`, `'hydraulic'`, `'magnetic'`, `'pneumatic'`, `'rotational'`, `'translational'`, `'thermal'`, and `'thermal_liquid'`. You can use a cell array of domain types to add more than one type of reference block.

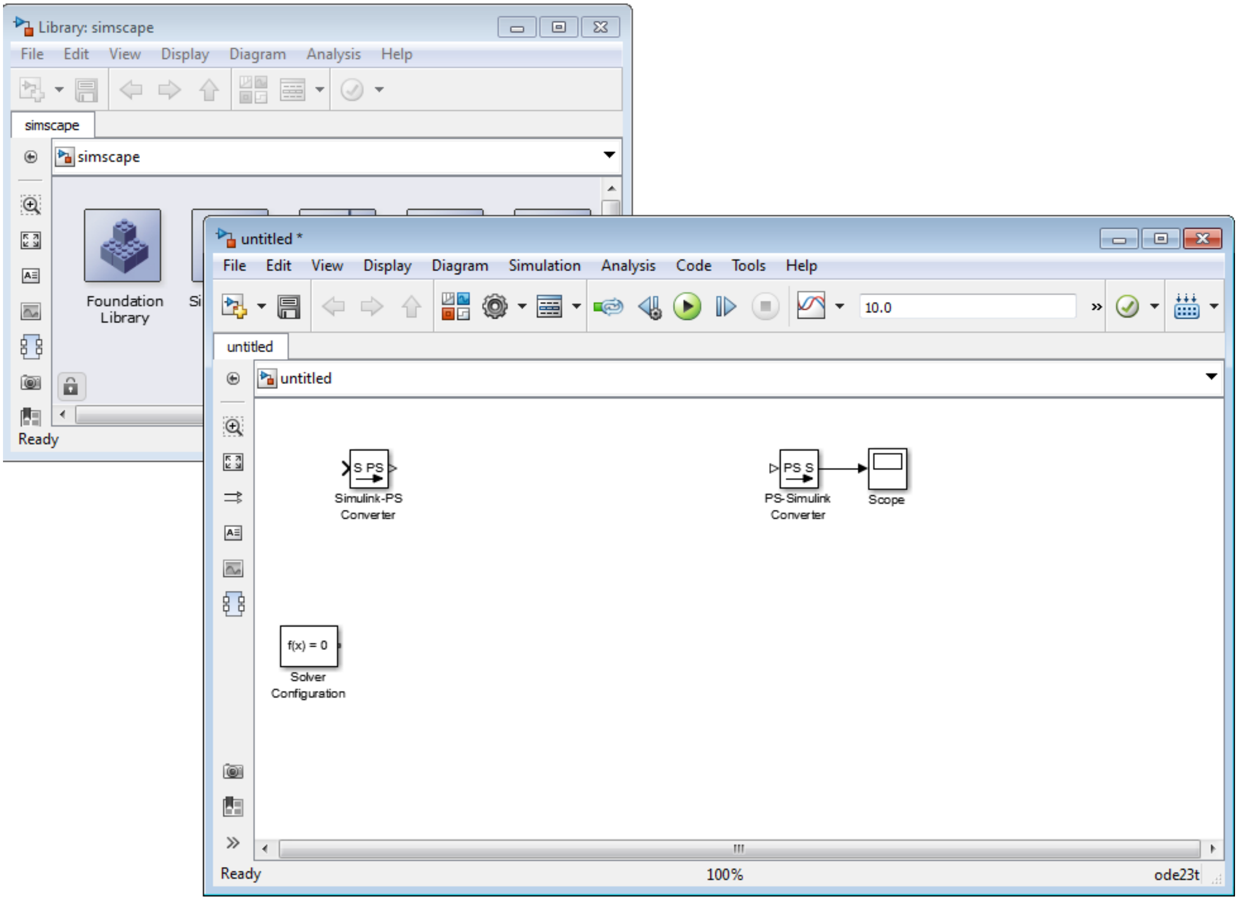
`ssc_new('modelname','domain','solver')` creates a new Simscape model with the specified name, domain type, and with the specified solver type. Recommended solver types for Simscape models are `'ode15s'`, `'ode23t'`, and `'ode14x'`. You can use other Simulink solvers, but, depending on the particular model, they may be less suitable. For more information, see “Setting Up Solvers for Physical Models”.

Examples

To create a generic Simscape model, type:

```
ssc_new
```

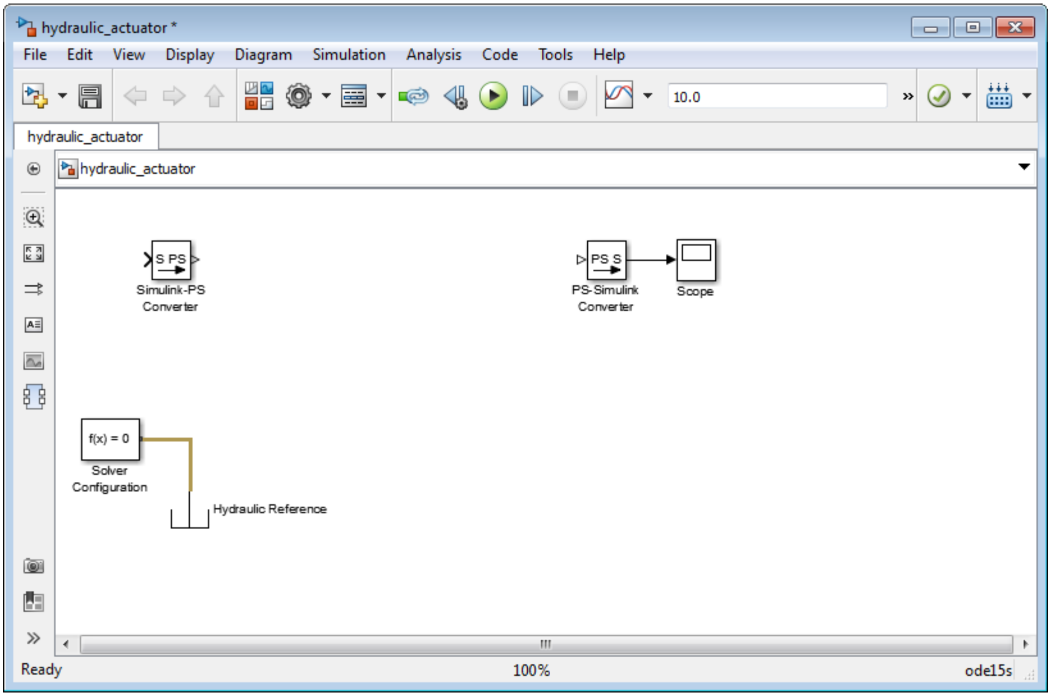
The software opens the main Simscape library and creates a new untitled model, which contains a Solver Configuration block with the default solver set to `ode23t`, a Simulink-PS Converter block, and a PS-Simulink Converter block connected to a Scope block.



To create a hydraulic model, called `hydraulic_actuator` and using the `ode15s` solver, type:

```
ssc_new('hydraulic_actuator','hydraulic','ode15s')
```

The software opens the main Simscape library and creates the following model.



After using `ssc_new`, continue developing your model by copying the blocks, as needed, and adding other blocks from the Simscape libraries.

More About

- “Creating a New Simscape Model”

ssc_protect

Generate Simscape protected files from source files

Syntax

```
ssc_protect filename
ssc_protect filename -inplace
ssc_protect dirname
ssc_protect dirname -inplace
```

Description

The `ssc_protect` command creates content-obscured files (Simscape protected files) from Simscape source files, to enable model sharing without disclosing the component or domain source. While Simscape source files have the extension `.ssc`, Simscape protected files have the extension `.sscp`.

`ssc_protect` *`filename`* generates a Simscape protected file, named *`filename`*`.sscp`, from the Simscape source file named *`filename`*`.ssc`, and places the protected file in your current working directory. *`filename`* can include absolute path to the file, or relative path if the file is in a subfolder of the current working directory. If this path includes package directories, the package structure will be recreated under the current working directory (unless it already exists) and the protected file placed in the package (see examples). The extension `.ssc` in *`filename`* is optional.

`ssc_protect` *`filename`* `-inplace` generates a Simscape protected file, named *`filename`*`.sscp`, from the Simscape source file named *`filename`*`.ssc`, and places the protected file in the same directory as the source file.

`ssc_protect` *`dirname`* generates Simscape protected files from all the Simscape source files in the directory named *`dirname`*, and places the protected files under your current working directory. If the path to *`dirname`* includes package directories, the package structure will be recreated under the current working directory (unless it already exists) and the protected files placed in the package, similar to when protecting a single file.

`ssc_protect` *`dirname`* `-inplace` generates Simscape protected files from all the Simscape source files in the directory named *`dirname`*, and places the protected files in the same directory as the source files.

Note Existing Simscape protected files are overwritten without warning.

For more information, see “Using Source Protection for Simscape Files”.

Simscape protected files have higher precedence than the source files when you build a library. If the protected and the source files are in the same directory, and protected files are out of date, `ssc_build` will use the protected files to build the library, but you will get a warning.

Examples

To protect a single file, with the protected file placed under your current working directory, at the MATLAB Command prompt, type:

```
ssc_protect C:\Work\libraries\source\+SimscapeLibrary\+MechanicalElements\my_spring.ssc
```

This command creates a folder called `+SimscapeLibrary` and a subfolder called `+MechanicalElements` in your current working directory (unless these folders already exist) and generates a file called `my_spring.sscp` in the `+MechanicalElements` folder.

To protect a single file, with the protected file placed in the same directory as the source file, type:

```
ssc_protect C:\Work\libraries\source\+SimscapeLibrary\+MechanicalElements\my_spring.ssc -inplace
```

This command generates a file called `my_spring.sscp` in the `C:\Work\libraries\source\+SimscapeLibrary\+MechanicalElements` folder.

To protect all files in a directory, with the protected files placed under your current working directory, type:

```
ssc_protect C:\Work\libraries\source\+SimscapeLibrary\+MechanicalElements
```

This command generates protected files for each source file in the `C:\Work\libraries\source\+SimscapeLibrary\+MechanicalElements` folder, and places the protected files in a folder called `+SimscapeLibrary\+MechanicalElements` in your current working directory (creating this folder structure, if it does not exist).

To protect all files in a directory, with the protected files placed in the same directory as the source files, type:

```
ssc_protect C:\Work\libraries\source\+SimscapeLibrary\+MechanicalElements -inplace
```

This command generates protected files for each source file in the `C:\Work\libraries\source\+SimscapeLibrary\+MechanicalElements` folder, and places the protected files in the same folder.

See Also

`ssc_build` | `ssc_clean` | `ssc_mirror`

ssc_reserved

List reserved words

Syntax

```
ssc_reserved
words = ssc_reserved
```

Description

`ssc_reserved` returns a list of reserved Simscape language words. Simscape language has certain words, in addition to its keywords, that you cannot use as model or member names. This list may change from release to release, as limitations are removed. Use the `ssc_reserved` command to see the current list of reserved words.

`words = ssc_reserved` returns a list of reserved words in `words` as a cell array of strings.

`ssc_reserved` does not list the Simscape language keywords.

Examples

List the currently reserved words:

```
ssc_reserved

ans =

    'across_variable'
    'build'
    'description'
    'descriptor'
    'element'
    'input'
    'interface_input'
    'interface_node'
```

```
'interface_output'
'item_type'
'local_variable'
'name'
'node'
'output'
'parameter'
'setup'
'signal'
'source'
'terminal'
'through_variable'
'variable'
```

You cannot use any of these words as model names (domain or component) or member names (parameter, variable, and so on). In addition to these reserved words, you cannot use any of the Simscape language keywords as model or member names.

ssc_update

Update Simscape component files to use new syntax

Syntax

```
ssc_update package
```

Description

The `ssc_update` command runs a script that updates the legacy component files containing `across` and `through` statements. Upon encountering a Simscape component file written in the old format, the script creates a backup copy of the file (*`filename`*`.ssc.bak`), removes the `through` and `across` statements from the `setup` section, replaces the `through` statements with the corresponding `branches` section and adds the equations equivalent to the `across` statements to the `equations` section of the file.

`ssc_update` *`package`* updates all the legacy component files located in the package. The argument, *`package`*, must be a top-level package name.

Note The package directory name begins with a leading + character, whereas the argument to `ssc_update` must omit the + character.

If you run the `ssc_update` command from inside the package directory structure, you can omit the argument.

Examples

For example, you have a custom package `+MyCapacitors`, which contains a component file `IdealCapacitor.ssc`, written in the old format:

```
component IdealCapacitor
% Ideal Capacitor
% Models an ideal (lossless) capacitor.
```

```
  nodes
    p = foundation.electrical.electrical; % +:top
    n = foundation.electrical.electrical; % -:bottom
  end
  parameters
    C = { 1, 'F' };   % Capacitance
    V0 = { 0, 'V' };  % Initial voltage
  end
  variables
    i = { 0, 'A'   }; % Current through variable
    v = { 0, 'V'   }; % Voltage across variable
  end
  function setup
    if C <= 0
        error( 'Capacitance must be greater than zero' )
    end
    through( i, p.i, n.i ); % Through variable i from node p to node n
    across( v, p.v, n.v );  % Across variable v from p to n
    v = V0;
  end
  equations
    i == C*v.der;    % Equation
  end
end
```

To update the file to the new format, at the MATLAB command prompt, type:

```
ssc_update MyCapacitors;
```

This command creates a backup copy of the component file, `IdealCapacitor.ssc.bak`, in the same folder where the original file resides, and rewrites the `IdealCapacitor.ssc` file as follows:

```
component IdealCapacitor
% Ideal Capacitor
% Models an ideal (lossless) capacitor.

  nodes
    p = foundation.electrical.electrical; % +:top
    n = foundation.electrical.electrical; % -:bottom
  end
  parameters
    C = { 1, 'F' };   % Capacitance
    V0 = { 0, 'V' };  % Initial voltage
  end
  variables
    i = { 0, 'A'   }; % Current through variable
    v = { 0, 'V'   }; % Voltage across variable
  end
  function setup
    if C <= 0
        error( 'Capacitance must be greater than zero' )
    end
    v = V0;
  end

  branches
    i : p.i -> n.i; % Through variable i from node p to node n
  end

  equations
    v == p.v - n.v; % Across variable v from p to n

    i == C*v.der;    % Equation
  end
end
```

As you can see, the original `through` statement

```
through( i, p.i, n.i ); % Through variable i from node p to node n
```

has been replaced with the `branches` section:

```
branches
  i : p.i -> n.i; % Through variable i from node p to node n
end
```

The `across` statement

```
across( v, p.v, n.v );  % Across variable v from p to n
```

has been replaced with the equation

```
v == p.v - n.v; % Across variable v from p to n
```

in the `equations` section.

The other two statements in the `setup` section have been left unchanged.

twoPhaseFluidTables

Generate fluid property tables from REFPROP database

Syntax

```
fluidTables = twoPhaseFluidTables(uRange,pRange,mLiquid,mVapor,n,
substance,refpropPath)
```

Description

`fluidTables = twoPhaseFluidTables(uRange,pRange,mLiquid,mVapor,n, substance,refpropPath)` returns the property tables for a two-phase fluid from the National Institute of Standards and Technology (NIST) REFPROP database. The input parameters specify the valid specific internal energy and pressure ranges, table dimensions, and fluid name. You use the fluid property tables as inputs in the `Two-Phase Fluid Properties (2P)` block.

Each table column corresponds to a different pressure. Each row corresponds to a different normalized internal energy—a transformation of the specific internal energy that converts the liquid and vapor regions of the fluid phase diagram into rectangular areas. This transformation enables you to format the property tables as rectangular matrices.

Before using this function for the first time, you must download additional MATLAB support files from the NIST website and save them in your REFPROP installation folder. Use the NIST search engine to find the files by name. The 32-bit MATLAB version requires one support file:

- `rp_proto.m`

The 64-bit MATLAB version requires two support files:

- `refprp64_thunk_pcwin64.dll`
- `rp_proto64.m`

This function has been tested against NIST Standard Reference Database 23: REFPROP Version 9.1. REFPROP 9.1 is supported only on Windows.

Examples

Get Water Property Tables

Generate 25×60 fluid property tables for water at specific internal energies of 30–4,000 kJ/kg and pressures of 0.01–15 MPa. Assume that the liquid and vapor tables have the same numbers of rows. Assume also that the REFPROP software installation is in this folder:

```
C:\Program Files\REFPROP\
```

1 At the MATLAB command prompt, enter the following code.

```
fluidTables = twoPhaseFluidTables([30,4000],[0.01,15],25,25,60,...
'water','C:\Program Files\REFPROP\')
```

```
fluidTables =

         p: [1x60 double]
    liquid: [1x1 struct]
     vapor: [1x1 struct]
     u_min: 30
     u_max: 4000
     p_min: 0.0100
     p_max: 15
```

2 List the fields in the liquid and vapor substructures. At the MATLAB command prompt enter:

```
fluidTables.liquid
```

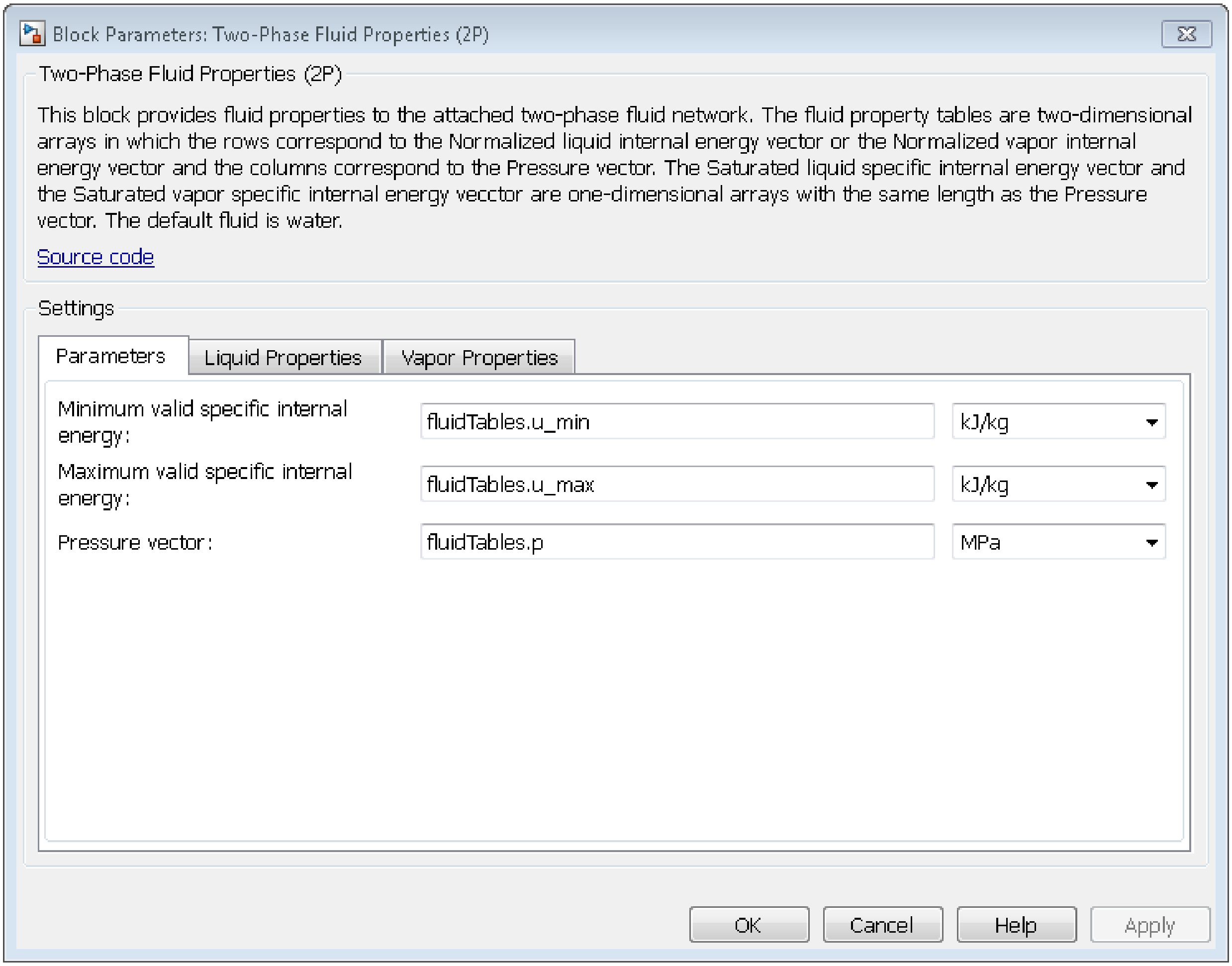
and

```
fluidTables.vapor
```

```
ans =

    unorm: [25x1 double]
        v: [25x60 double]
        s: [25x60 double]
        T: [25x60 double]
       nu: [25x60 double]
        k: [25x60 double]
       Pr: [25x60 double]
    u_sat: [1x60 double]
        u: [25x60 double]
```

3 Enter the structure field names as inputs in the Two-Phase Fluid Properties (2P) block dialog box. Ensure that the tables are on the MATLAB `path`.

In the **Parameters** tab, enter the field names `u_min`, `u_max`, and `p` from the `fluidTables` structure as shown in the figure.



Block Parameters: Two-Phase Fluid Properties (2P)

Two-Phase Fluid Properties (2P)

This block provides fluid properties to the attached two-phase fluid network. The fluid property tables are two-dimensional arrays in which the rows correspond to the Normalized liquid internal energy vector or the Normalized vapor internal energy vector and the columns correspond to the Pressure vector. The Saturated liquid specific internal energy vector and the Saturated vapor specific internal energy vecctor are one-dimensional arrays with the same length as the Pressure vector. The default fluid is water.

Source code

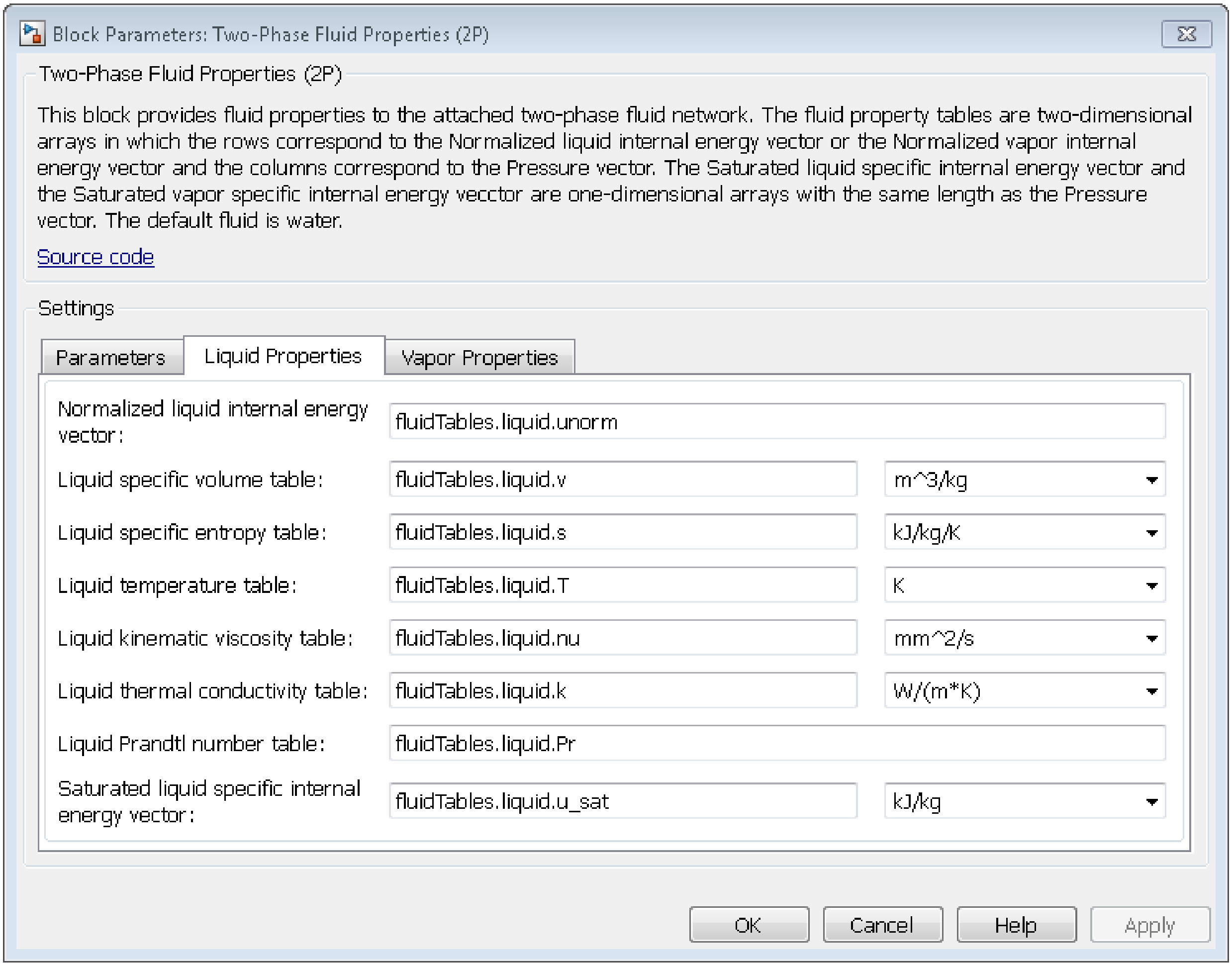
Settings

Minimum valid specific internal energy: fluidTables.u_min kJ/kg

Maximum valid specific internal energy: fluidTables.u_max kJ/kg

Pressure vector: fluidTables.p MPa

In the **Liquid Properties** tab, enter the field names from the `fluidTables.liquid` substructure as shown in the figure.



Block Parameters: Two-Phase Fluid Properties (2P)

Two-Phase Fluid Properties (2P)

This block provides fluid properties to the attached two-phase fluid network. The fluid property tables are two-dimensional arrays in which the rows correspond to the Normalized liquid internal energy vector or the Normalized vapor internal energy vector and the columns correspond to the Pressure vector. The Saturated liquid specific internal energy vector and the Saturated vapor specific internal energy vecctor are one-dimensional arrays with the same length as the Pressure vector. The default fluid is water.

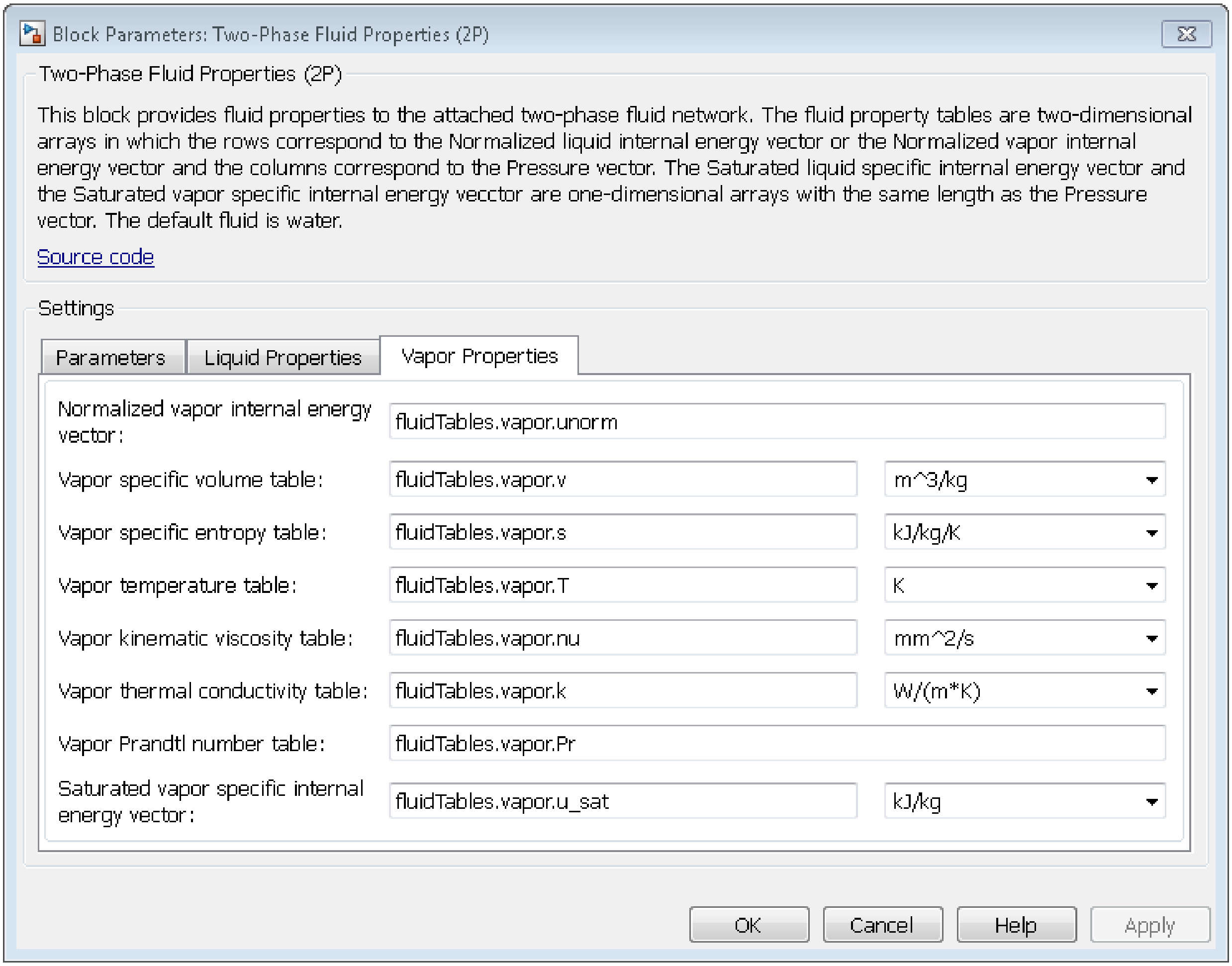
Source code

Settings

Normalized liquid internal energy vector:	fluidTables.liquid.unorm	
Liquid specific volume table:	fluidTables.liquid.v	m^3/kg
Liquid specific entropy table:	fluidTables.liquid.s	kJ/kg/K
Liquid temperature table:	fluidTables.liquid.T	K
Liquid kinematic viscosity table:	fluidTables.liquid.nu	mm^2/s
Liquid thermal conductivity table:	fluidTables.liquid.k	W/(m*K)
Liquid Prandtl number table:	fluidTables.liquid.Pr	
Saturated liquid specific internal energy vector:	fluidTables.liquid.u_sat	kJ/kg

Liquid Properties Tab Inputs

In the **Vapor Properties** tab, enter the field names from the `fluidTables.vapor` substructure as shown in the figure.



Block Parameters: Two-Phase Fluid Properties (2P)

Two-Phase Fluid Properties (2P)

This block provides fluid properties to the attached two-phase fluid network. The fluid property tables are two-dimensional arrays in which the rows correspond to the Normalized liquid internal energy vector or the Normalized vapor internal energy vector and the columns correspond to the Pressure vector. The Saturated liquid specific internal energy vector and the Saturated vapor specific internal energy vecctor are one-dimensional arrays with the same length as the Pressure vector. The default fluid is water.

Source code

Settings

Normalized vapor internal energy vector:	fluidTables.vapor.unorm	
Vapor specific volume table:	fluidTables.vapor.v	m^3/kg
Vapor specific entropy table:	fluidTables.vapor.s	kJ/kg/K
Vapor temperature table:	fluidTables.vapor.T	K
Vapor kinematic viscosity table:	fluidTables.vapor.nu	mm^2/s
Vapor thermal conductivity table:	fluidTables.vapor.k	W/(m*K)
Vapor Prandtl number table:	fluidTables.vapor.Pr	
Saturated vapor specific internal energy vector:	fluidTables.vapor.u_sat	kJ/kg

Vapor Properties Tab Inputs

- "Manually Generate Fluid Property Tables"

Input Arguments

`uRange` — Specific internal energy range

array

Specific internal energy range, specified as a two-element array with the minimum and maximum specific internal energies of the fluid property tables. The specific internal energies must be in units of kJ/kg.

Example: `[30,4000]`

`pRange` — Pressure range

array

Pressure range, specified as a two-element array with the minimum and maximum pressures of the fluid property tables. The pressures must be in units of MPa.

Example: `[0.01,15]`

`mLiquid` — Number of rows in liquid property tables

scalar

Number of rows to include in the liquid property tables, specified as a scalar. Each row corresponds to a different normalized liquid internal energy.

Example: 25

`mVapor` — Number of rows in vapor property tables

scalar

Number of rows to include in the vapor property tables, specified as a scalar. Each row corresponds to a different normalized vapor internal energy.

Example: 25

`n` — Number of columns in fluid property tables

scalar

Number of columns to include in the fluid property tables, specified as a scalar. This number is common to liquid and vapor property tables. Each column corresponds to a different pressure.

Example: 60

`substance` — Fluid name

string

Fluid for which to get the property tables, specified as a string. The fluid name must be listed in the REFPROP database. A list of fluid names is available in the fluids subfolder of the REFPROP installation.

Example: `'water'`

`refpropPath` — Path to REFPROP folder

string

Path to the folder with the REFPROP installation, specified as a string. The path can be absolute or relative.

Example: `'C:\Program Files\REFPROP\'`

Output Arguments

`fluidTables` — Fluid property tables

structure

Fluid property tables, returned as a structure array with these fields.

Field	Description
`P`	`n`-element vector with the lookup-table pressures in units of MPa
`liquid`	Substructure with liquid property tables
`vapor`	Substructure with vapor property tables
`u_min`	Minimum specific internal energy allowed during simulation, in units of kJ/kg
`u_max`	Maximum specific internal energy allowed during simulation, in units of kJ/kg
`p_min`	Minimum pressure allowed during simulation, in units of MPa
`p_max`	Maximum pressure allowed during simulation, in units of MPa

The `fluidTables.liquid` substructure contains these additional fields.

Field	Description
unorm	mLiquid-element vector with the normalized internal energies of the liquid phase
v	mLiquid-by-n matrix with the specific volumes of the liquid phase in units of m^3/kg
s	mLiquid-by-n matrix with the specific entropies of the liquid phase in units of kJ/(kg*K)
T	mLiquid-by-n matrix with the temperature of the liquid phase in units of K
nu	mLiquid-by-n matrix with the kinematic viscosities of the liquid phase in units of mm^2/s
k	mLiquid-by-n matrix with the thermal conductivities of the liquid phase in units of W/(m*K)
Pr	mLiquid-by-n matrix with the Prandtl numbers of the liquid phase
u_sat	n-element vector with the saturated liquid specific internal energies in units of kJ/kg
u	mLiquid-by-n matrix with the specific internal energies of the liquid phase in units of kJ/k

The fluidTables.vapor substructure contains these additional fields:

Field	Description
unorm	mVapor-element vector with the normalized internal energies of the vapor phase
v	mVapor-by-n matrix with the specific volumes of the vapor phase in units of m^3/kg

Field	Description
s	mVapor-by-n matrix with the specific entropies of the vapor phase in units of kJ/(kg*K)
T	mVapor-by-n matrix with the temperature of the vapor phase in units of K
nu	mVapor-by-n matrix with the kinematic viscosities of the vapor phase in units of mm^2/s
k	mVapor-by-n matrix with the thermal conductivities of the vapor phase in units of W/(m*K)
Pr	mVapor-by-n matrix with the Prandtl numbers of the vapor phase
u_sat	n-element vector with the saturated vapor specific internal energies in units of kJ/kg
u	mVapor-by-n matrix with the specific internal energies of the vapor phase in units of kJ/k

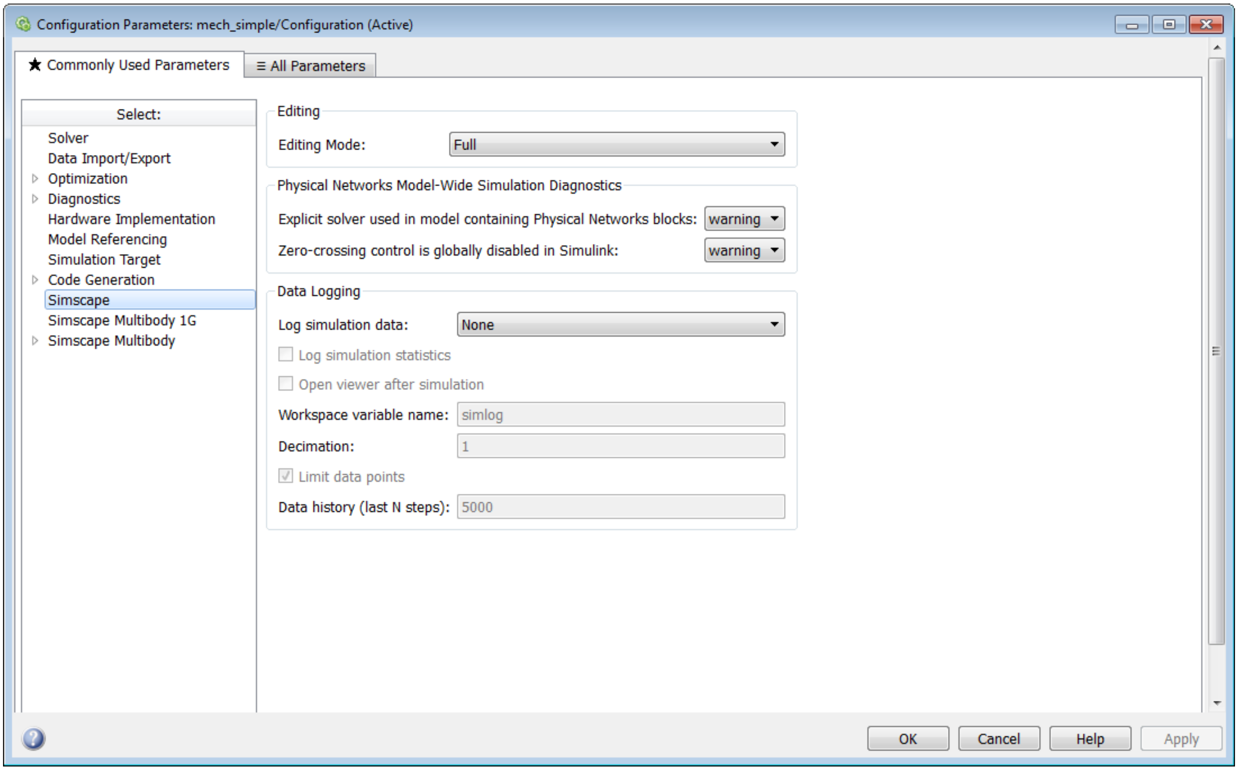
See Also

`Two-Phase Fluid Properties (2P)`

Introduced in R2015b

Configuration Parameters

Simscape Pane: General



Editing Mode: Full

Explicit solver used in model containing Physical Networks blocks: warning

Zero-crossing control is globally disabled in Simulink: warning

Log simulation data: None

□ Log simulation statistics

□ Open viewer after simulation

Workspace variable name: simlog

Decimation: 1

☑ Limit data points

Data history (last N steps): 5000

In this section...

In this section...

Simscape Pane Overview

The **Editing Mode** parameter controls the Simscape Editing Mode functionality, which allows you to open, simulate, and save models that contain blocks from add-on products in Restricted mode, without checking out add-on product licenses, as long as the products are installed on your machine. Simscape add-on products include Simscape Driveline™, Simscape Electronics™, Simscape Fluids, and Simscape Multibody. Use this functionality to perform multidomain physical modeling and simulation while minimizing the number of required licenses.

Note Unless your organization uses concurrent licenses, see the Simscape product page on the MathWorks Web site for specific information on how to install add-on products on your machine, to be able to work in Restricted mode.

The parameters in the **Physical Networks Model-Wide Simulation Diagnostics** section let you configure your preferences for solver-related warnings when you simulate models containing blocks from Simscape libraries.

The parameters in the **Data Logging** section let you log simulation data to workspace.

Configuration

This pane appears only if your model contains a block from the Simscape libraries (including Simscape add-on products).

See Also

- “About the Simscape Editing Mode”
- Working with Restricted and Full Modes
- “Harmonizing Simulink and Simscape Solvers”
- “About Simulation Data Logging”

Editing Mode

Set the editing mode of the model to either Full or Restricted.

Settings

Default: `Full`

`Full`

Sets the editing mode of the model to Full. In this mode, you can make any modifications to the model.

When you open a model in Full mode, the license manager checks out all the add-on product licenses for the blocks present in the model.

When you switch from Restricted to Full mode, the license manager checks whether the required add-on product licenses are available and checks them out. If some of the add-on product licenses are not available, the license manager issues an error and the model stays in Restricted mode.

`Restricted`

Sets the editing mode of the model to Restricted. In this mode, you can simulate the model, generate code, and make limited modifications.

When you open a model in Restricted mode, the license manager does not check out the add-on product licenses.

When you switch from Full to Restricted mode, all the add-on product licenses for the blocks present in the model remain checked out until the end of the MATLAB session.

Command-Line Information

Parameter: `EditingMode`
Type: string
Value: `'Full' | 'Restricted'`
Default: `'Full'`

See Also

- Saving a Model in Restricted Mode
- Switching from Restricted to Full Mode

Explicit solver used in model containing Physical Networks blocks

Specify whether or not the system will issue a warning or error upon simulation if the model uses an explicit solver.

Settings

Default: `warning`

`warning`

Makes the system issue a warning upon simulation if the model uses an explicit solver.

It is possible to choose any variable-step or fixed-step solver for models containing Simscape blocks. When you first create a model, the default Simulink solver is ode45. However, implicit solvers, such as ode14x, ode23t, and ode15s, are a better choice for a typical model. In particular, for stiff systems, implicit solvers typically take many fewer timesteps than explicit solvers, such as ode45, ode113, and ode1. To alert you to a potential issue, the system issues a warning when you use an explicit solver in a model containing Simscape blocks.

`error`

Makes the system issue an error upon simulation if the model uses an explicit solver.

If your model is stiff, and the use of explicit solvers undesirable, you may choose to select this option to avoid troubleshooting errors in the future.

`none`

Turns off issuing a warning or error upon simulation with explicit solver.

For models that are not stiff, explicit solvers can be effective, often taking fewer timesteps than implicit solvers. If you work with such models and use explicit solvers, select this option to turn off the warning upon simulation.

Command-Line Information

Parameter: `ExplicitSolverDiagnosticOptions`
Type: string
Value: `'warning' | 'error' | 'none'`
Default: `'warning'`

See Also

"Switching from the Default Explicit Solver to Other Simulink Solvers"

Zero-crossing control is globally disabled in Simulink

Specify whether or not the system will issue a warning or error upon simulation if the **Zero-crossing control** parameter in the **Solver** pane is set to `Disable all`, which means that zero-crossing control is globally disabled.

Settings

Default: `warning`

`warning`

Makes the system issue a warning upon simulation if zero-crossing control is globally disabled.

`error`

Makes the system issue an error upon simulation if zero-crossing control is globally disabled.

Command-Line Information

Parameter: `GlobalZcOffDiagnosticOptions`
Type: string
Value: `'warning' | 'error'`
Default: `'warning'`

See Also

"Enabling or Disabling Simulink Zero-Crossing Detection"

Log simulation data

Specify whether or not the system logs simulation data to workspace.

Settings

Default: `None`

`None`

Performs no data logging upon simulation.

`All`

Upon simulating the model, logs simulation data from all the Simscape blocks in the model to a workspace variable specified by the **Workspace variable name** parameter.

`Use local settings`

Upon simulating the model, logs simulation data from selected Simscape blocks only to a workspace variable specified by the **Workspace variable name** parameter. If using this setting, you have to select blocks for data logging prior to simulating the model, otherwise no data will be logged.

Command-Line Information

Parameter: `SimscapeLogType`
Type: string
Value: `'none'` | `'all'` | `'local'`
Default: `'none'`

See Also

“Data Logging”

Log simulation statistics

Specify whether to log simulation statistics as part of simulation data.

Settings

Default: off

☑ On

Logs simulation statistics.

□ Off

Does not log simulation statistics.

Command-Line Information

Parameter: `SimscapeLogSimulationStatistics`
Type: string
Value: `'on' | 'off'`
Default: `'off'`

See Also

"Data Logging"

Open viewer after simulation

Specify whether to open Simscape Results Explorer at the end of simulation run.

Settings

Default: off

☑ On

Automatically opens Simscape Results Explorer at the end of simulation run. If there is an open Simscape Results Explorer window linked to the session, reloads the simulation data into this window at the end of simulation run.

□ Off

Does not open Simscape Results Explorer automatically.

Command-Line Information

Parameter: `SimscapeLogOpenViewer`
Type: string
Value: `'on' | 'off'`
Default: `'off'`

See Also

"Data Logging"

Workspace variable name

Specify the name of the workspace variable for simulation data logging.

Settings

Default: `simlog`

- The default value logs all the simulation data to a workspace variable named `simlog`.
- You can specify any other valid string as the workspace variable name.

Command-Line Information

Parameter: `SimscapeLogName`
Type: string
Value: any valid value
Default: `'simlog'`

See Also

“Data Logging”

Decimation

Lets you limit data points being logged, by skipping time steps. Logs data points for the first time step and every *n*th time step thereafter, where *n* is the decimation factor.

Settings

Default: 1

- The default value logs simulation data for each step.
- You can specify any other positive integer number. For example, specifying 2 logs data points for every other time step, while specifying 10 logs data points for just one in ten steps.

Tips

- Saving data to workspace can slow down the simulation and consume memory. Use this parameter to limit the number of data points saved.
- Another way to limit the number of data points saved is using the **Limit data points** check box in conjunction with the **Data history (last N steps)** parameter. The two methods work independently from each other and can be used separately or together.

Command-Line Information

Parameter: `SimscapeLogDecimation`
Type: numeric
Value: any positive integer value
Default: 1

See Also

"Data Logging"

Limit data points

Specify that the number of data points logged to workspace is limited to the value corresponding to the number of simulation steps specified by the **Data history (last N steps)** parameter.

Settings

Default: on

☑ On

Limits the number of data points exported to workspace to those for the number of steps specified by the **Data history (last N steps)** parameter.

□ Off

Does not limit the number of data points.

Tips

- Saving data to workspace can slow down the simulation and consume memory. Use this parameter to limit the number of data points saved.
- Another way to limit the number of data points saved is using the **Decimation** parameter. The two methods work independently from each other and can be used separately or together.
- You must select the **Limit data points** check box before specifying the number of steps in the **Data history (last N steps)** parameter.

Command-Line Information

Parameter: `SimscapeLogLimitData`
Type: string
Value: `'on' | 'off'`
Default: `'on'`

See Also

“Data Logging”

Data history (last N steps)

Specify the number of simulation steps to limit the number of data points output to workspace. The workspace variable defined by the **Workspace variable name** parameter contains the data points corresponding to the last N steps of the simulation, where N is the value you specify for the **Data history (last N steps)** parameter. If the simulation contains fewer steps than the number specified, the workspace variable contains the data points for the whole simulation.

Settings

Default: `5000`

- The default value logs simulation data for the last 5000 steps.
- You can specify any other positive integer number.

Tips

- Saving data to workspace can slow down the simulation and consume memory. Use this parameter to limit the number of data points saved.
- You must select the **Limit data points** check box before specifying the number of steps in the **Data history (last N steps)** parameter.

Command-Line Information

Parameter: `SimscapeLogDataHistory`
Type: numeric
Value: any positive integer value
Default: `5000`

See Also

"Data Logging"

Model Advisor Checks

Simscape Model Advisor Checks

In this section...

Simscape Checks Overview

Use Simscape Model Advisor checks to identify Simscape blocks with ambiguous setting of parameter units, or outdated Simscape blocks in your model.

See Also

- Consulting Model Advisor

Modeling Physical Systems Checks Overview

Use the Modeling Physical Systems Model Advisor checks to identify Simscape blocks with ambiguous setting of parameter units.

See Also

- Consulting Model Advisor

Check consistency of block parameter units

Check model for Simscape blocks with ambiguous setting of parameter units.

Description

This check identifies blocks in your model that have an ambiguous setting of parameter units. This situation most often applies to frequency and angular velocity units.

For example, a parameter expected in `Hz` (1/s) may be specified in the block dialog with unit of `rad/s`. These units are commensurate, but not directly convertible, and using one instead of the other may result in unexpected conversion factors applied to the numerical value by the block equations. The purpose of the check is to verify that the specified unit matches your design intent.

Available with Simscape.

Results and Recommended Actions

Condition	Recommended Action
This model contains blocks where parameter units are not directly convertible to those expected by the block.	Double-click the highlighted block, verify the parameter unit setting and correct it, if necessary. Then save and reload the model.

Condition	Recommended Action
After running the check, you get a table of results in the right pane of the Model Advisor window. Each cell in the first column of the table contains a link to the problematic block, and the corresponding cell in the second column contains the name of parameter in question, the expected unit, and the specified unit. Clicking a link highlights the corresponding block in the model.	

See Also

- “Units for Angular Velocity and Frequency”

Check for outdated Simscape blocks

Check model for Simscape blocks that should be updated to the current version of the product.

Description

This check identifies blocks in your model that do not match the latest version of the block in the Simscape block libraries.

Blocks from previous versions may be missing parameters available in the latest version. In this case, simulating the model may produce warnings or unexpected results.

Available with Simscape.

Results and Recommended Actions

Condition	Recommended Action
This model contains outdated Simscape blocks. After running the check, you get a list of links to the outdated blocks in	To update the blocks, scroll down the right pane of the Model Advisor window and click the **Update** button. • If the automatic update is successful, the **Result** box displays a message that

Condition	Recommended Action
the right pane of the Model Advisor window. Clicking a link highlights the corresponding block in the model.	all blocks have been updated to the current Simscape version. • If the message says that some of the blocks could not be updated automatically, rerun the check and manually replace the outdated blocks with the latest version from the block library. Alternately, you can consult the Upgrade Advisor to migrate the model to the latest version of Simscape software.

See Also

- "Model Upgrades"

Simscape Checks Overview

Use these checks to optimize real-time simulation performance of models containing Simscape blocks. The top-level **Simscape checks** are applicable to all physical models. If you have add-on product licenses, the **Simscape checks** folder also includes corresponding subfolders, such as **Driveline checks** or **Electronics checks**. Each of the subfolders contains checks that target specific blocks from that add-on product. If your model contains blocks from an add-on product, run the checks in the respective subfolder in addition to the top-level **Simscape checks**.

See Also

- "Improve Simulation Performance Using Performance Advisor "

Check Simscape Solver Configuration block settings

Check model for Solver Configuration blocks with settings that are suboptimal for real-time simulation.

Description

This check identifies Solver Configuration blocks in your model where settings are suboptimal for real-time simulation.

For optimal results, Solver Configuration blocks should have the following options selected: **Use local solver** and **Use fixed-cost runtime consistency iterations**.

Available with Simscape.

Results and Recommended Actions

Condition	Recommended Action
This model contains Solver Configuration blocks that do not use local solver or fixed-cost runtime consistency iterations. After running the check, you get a table of results in the right pane of the Performance Advisor window. Each cell in the first column of the table contains a link to the problematic Solver Configuration block. The corresponding cells in the second and third columns contain the current setting for **Use local solver** and **Use fixed-cost runtime consistency iterations**, respectively. Clicking a link highlights the corresponding block in the model.	To update the blocks, scroll down the right pane of the Performance Advisor window and click the **Update** button. Alternately, double-click the highlighted block, select the **Use local solver** and **Use fixed-cost runtime consistency iterations** check boxes, verify the **Sample time** parameter value and correct it, if necessary. Then save and reload the model. After updating the blocks, either manually or automatically, rerun the check. If the check passes, the table of results contains links to all the Solver Configuration blocks in the model, along with the local solver **Sample time** parameter value for each block. Check these values for consistency.

See Also

- `Solver Configuration`

Check Fluid dynamic compressibility option

Check model for blocks with **Fluid dynamic compressibility** settings that are suboptimal for real-time simulation.

Description

This check identifies blocks in your model where the **Fluid dynamic compressibility** parameter setting is suboptimal for real-time simulation. This parameter exists in Thermal Liquid blocks, such as pipes and energy converters.

For optimal results, **Fluid dynamic compressibility** should be set to `Off`.

Available with Simscape.

Results and Recommended Actions

Condition	Recommended Action
This model contains Thermal Liquid blocks that account for fluid dynamic compressibility. After running the check, you get a table of results in the right pane of the Performance Advisor window. Each cell in the first column of the table contains a link to the problematic block. The corresponding cell in the second column contains the current setting for the **Fluid dynamic compressibility** parameter. Clicking a link highlights the corresponding block in the model.	To update the blocks, scroll down the right pane of the Performance Advisor window and click the **Update** button. If the automatic update is successful, the **Result** box displays a message that all blocks with a **Fluid dynamic compressibility** option have been updated.

See Also

- "Modeling Thermal Liquid Systems"

Electronics Checks Overview

Use these checks to optimize real-time simulation performance of your Simscape Electronics model. These checks target specific Simscape Electronics blocks. Run these checks in addition to the top-level **Simscape checks**, which are applicable to all physical models.

See Also

- “Improve Simulation Performance Using Performance Advisor ”

Check Simulation mode option

Check model for blocks with **Simulation mode** settings that are suboptimal for real-time simulation.

Description

This check identifies blocks in your model where the **Simulation mode** parameter setting is suboptimal for real-time simulation. This parameter exists in two types of blocks:

- Pulse-width modulated (PWM) actuators and drivers, such as H-Bridge, where you can choose between `PWM` and `Averaged` modes.
- Stepper motors and drivers, where you can choose between `Stepping` and `Averaged` modes.

For optimal results, **Simulation mode** should be set to `Averaged`.

Available with Simscape Electronics.

Results and Recommended Actions

Condition	Recommended Action
This model contains blocks where the **Simulation mode** parameter setting is other than `Averaged`. After running the check, you get a table of results in the right pane of the Performance Advisor window. Each cell in the first column of the table contains a link to the problematic block. The corresponding cell in the second column contains the current setting for the **Simulation mode** parameter. Clicking a link highlights the corresponding block in the model.	To update the blocks, scroll down the right pane of the Performance Advisor window and click the **Update** button. If the automatic update is successful, the **Result** box displays a message that all blocks with a **Simulation mode** option have been updated. After updating the blocks, verify that parameters specific to the `Averaged` option (for example, **Step rate sensitivity**) have suitable values.

See Also

- `Controlled PWM Voltage`
- `Generic Linear Actuator`
- `Generic Rotary Actuator`
- `H-Bridge`
- `Stepper Motor`
- `Stepper Motor Driver`
- `Unipolar Stepper Motor`
- `Unipolar Stepper Motor Driver`

Check Noise mode option

Check model for blocks with **Noise mode** settings that are suboptimal for real-time simulation.

Description

This check identifies blocks in your model where the **Noise mode** parameter setting is suboptimal for real-time simulation. This parameter exists in blocks that can generate thermal noise, such as resistors and electrical sources, and you can enable or disable this option. Simulating with noise enabled slows down simulation. For optimal results, **Noise mode** should be set to `Disabled`.

Available with Simscape Electronics.

Results and Recommended Actions

Condition	Recommended Action
This model contains blocks where thermal noise generation is enabled. After running the check, you get a table of results in the right pane of the Performance Advisor window. Each cell in the first column of the table contains a link to the problematic block. The corresponding cell in the second column contains the	To update the blocks, scroll down the right pane of the Performance Advisor window and click the **Update** button. If the automatic update is successful, the **Result** box displays a message that all blocks with a **Noise mode** option have been updated.

Condition	Recommended Action
current setting for the **Noise mode** parameter. Clicking a link highlights the corresponding block in the model.	

See Also

- `Current Source`
- `Resistor`
- `Voltage Source`

Check Transmission Line blocks

Check model for `Transmission Line` blocks with **Model type** settings that are suboptimal for real-time simulation.

Description

This check identifies `Transmission Line` blocks in your model where the **Model type** parameter setting is suboptimal for real-time simulation. For optimal results, **Model type** should be set to `Delay-based and lossless`. This option is the most efficient numerically, because the other options need multiple segments (typically several tens of segments) to get reasonable accuracy.

Available with Simscape Electronics.

Results and Recommended Actions

Condition	Recommended Action
This model contains `Transmission Line` blocks where the **Model type** setting is other than `Delay-based and lossless`. After running the check, you get a table of results in the right pane of the Performance Advisor window. Each cell in the first column of the table contains	To update the blocks, scroll down the right pane of the Performance Advisor window and click the **Update** button. If the automatic update is successful, the **Result** box displays a message that all `Transmission Line` blocks have been updated.

Condition	Recommended Action
a link to the problematic block. The corresponding cell in the second column contains the current setting for the **Model type** parameter. Clicking a link highlights the corresponding block in the model.	After updating the blocks, verify that parameters specific to the `Delay-based and lossless` option (such as **Transmission delay** and **Characteristic impedance**) have suitable values.

See Also

- `Transmission Line`

Check Model dynamics option

Check model for blocks with **Model dynamics** settings that are suboptimal for real-time simulation.

Description

This check identifies blocks in your model where the **Model dynamics** or **Dynamics** parameter setting is suboptimal for real-time simulation. This parameter exists in several types of blocks, and the drop-down options vary between block types. For optimal results, the option that corresponds to not modeling the dynamics should be selected in all cases:

- For switches, Voltage-Controlled Oscillator, DC-DC Converter — `No dynamics`
- For Accelerometer, Gyro, Pressure Transducer blocks — `No dynamics - Suitable for HIL`

Available with Simscape Electronics.

Results and Recommended Actions

Condition	Recommended Action
This model contains blocks with dynamics modeling enabled. After running the check, you get a table of results in the right pane of the	To update the blocks, scroll down the right pane of the Performance Advisor window and click the **Update** button.

Condition	Recommended Action
Performance Advisor window. Each cell in the first column of the table contains a link to the problematic block. The corresponding cell in the second column contains the current setting for the **Model dynamics** or **Dynamics** parameter. Clicking a link highlights the corresponding block in the model.	If the automatic update is successful, the **Result** box displays a message that all blocks with a **Model dynamics** option have been updated.

See Also

- `Accelerometer`
- `DC-DC Converter`
- `DPDT Switch`
- `DPST Switch`
- `Gyro`
- `Pressure Transducer`
- `SPDT Switch`
- `SPST Switch`
- `Voltage-Controlled Oscillator`

Check Resolver parameterization option

Check model for `Resolver` blocks with **Parameterization** settings that are suboptimal for real-time simulation.

Description

This check identifies `Resolver` blocks in your model where the **Parameterization** parameter setting is suboptimal for real-time simulation. For optimal results, **Parameterization** should be set to `Specify transformation ratio and omit dynamics`.

Available with Simscape Electronics.

Results and Recommended Actions

Condition	Recommended Action
This model contains `Resolver` blocks where the **Parameterization** setting is other than `Specify transformation ratio and omit dynamics`. After running the check, you get a table of results in the right pane of the Performance Advisor window. Each cell in the first column of the table contains a link to the problematic block. The corresponding cell in the second column contains the current setting for the **Parameterization** parameter. Clicking a link highlights the corresponding block in the model.	To update the blocks, scroll down the right pane of the Performance Advisor window and click the **Update** button. If the automatic update is successful, the **Result** box displays a message that all `Resolver` blocks have been updated.

See Also

- `Resolver`

Fluids Checks Overview

Use these checks to optimize real-time simulation performance of your Simscape Fluids model. These checks target specific Simscape Fluids blocks. Run these checks in addition to the top-level **Simscape checks**, which are applicable to all physical models.

See Also

- “Improve Simulation Performance Using Performance Advisor ”

Check Valve opening dynamics option

Check model for valve blocks with **Opening dynamics** settings that are suboptimal for real-time simulation.

Description

This check identifies blocks in your model where the **Opening dynamics** parameter setting is suboptimal for real-time simulation. This parameter exists in several directional and pressure control valves. By default, these valve models do not include opening dynamics. For optimal results, **Opening dynamics** should be set to `Include valve opening dynamics`. This option avoids instantaneous area changes, which is important in simulations with the local solver, and provides continuous behavior that is more physically realistic.

Available with Simscape Fluids.

Results and Recommended Actions

Condition	Recommended Action
This model contains valves with opening dynamics modeling disabled. After running the check, you get a table of results in the right pane of the Performance Advisor window. Each cell in the first column of the table contains a link to the problematic block. The corresponding cell in the second column indicates the current setting for modeling the valve opening dynamics. Clicking a link highlights the corresponding block in the model.	To update the blocks, scroll down the right pane of the Performance Advisor window and click the **Update** button. If the automatic update is successful, the **Result** box displays a message that all blocks with an **Opening dynamics** option have been updated.

See Also

- `Check Valve`
- `Hydraulically Operated Remote Control Valve`
- `Pilot-Operated Check Valve`
- `Pressure Compensator`
- `Pressure Reducing 3-Way Valve`
- `Pressure Reducing Valve`
- `Pressure Relief Valve`
- `Shuttle Valve`

Driveline Checks Overview

Use these checks to optimize real-time simulation performance of your Simscape Driveline model. These checks target specific Simscape Driveline blocks. Run these checks in addition to the top-level **Simscape checks**, which are applicable to all physical models.

See Also

- “Improve Simulation Performance Using Performance Advisor ”

Check Gear friction model option

Check model for gear blocks with **Friction model** settings that are suboptimal for real-time simulation.

Description

This check identifies gear blocks in your model where the **Friction model** parameter setting is suboptimal for real-time simulation. This parameter exists in all gears, and the drop-down options vary between blocks. For optimal results, the option that corresponds to not modeling the friction losses should be selected in all cases:

- For `Worm Gear`, `Sun-Planet Worm Gear`, and `Leadscrew` blocks — `No friction losses — Suitable for HIL simulation`
- For all other gears — `No meshing losses — Suitable for HIL simulation`

This check does not apply to thermal variants of gear blocks, because these variants always model friction losses.

Available with Simscape Driveline.

Results and Recommended Actions

Condition	Recommended Action
This model contains gear blocks where modeling of the friction or meshing losses is enabled. After running the check, you get a table of results in the right pane of the	To update the blocks, scroll down the right pane of the Performance Advisor window and click the **Update** button.

Condition	Recommended Action
Performance Advisor window. Each cell in the first column of the table contains a link to the problematic block. The corresponding cell in the second column contains the current setting for the **Friction model** parameter. Clicking a link highlights the corresponding block in the model.	If the automatic update is successful, the **Result** box displays a message that all gear blocks with a friction losses option have been updated.

See Also

- “Gears”

Check Tire compliance option

Check model for tire blocks with **Compliance** settings that are suboptimal for real-time simulation.

Description

This check identifies tire blocks in your model where the **Compliance** parameter setting is suboptimal for real-time simulation. This parameter exists in all tire blocks and specifies whether the model includes longitudinal stiffness and damping. For optimal results, **Compliance** should be set to `No compliance — Suitable for HIL simulation`.

Available with Simscape Driveline.

Results and Recommended Actions

Condition	Recommended Action
This model contains tire blocks where the model includes longitudinal stiffness and damping. After running the check, you get a table of results in the right pane of the Performance Advisor window. Each cell in the first column of the table contains a link	To update the blocks, scroll down the right pane of the Performance Advisor window and click the **Update** button. If the automatic update is successful, the **Result** box displays a message that all tire

Condition	Recommended Action
to the problematic block. The corresponding cell in the second column indicates the current setting for the **Compliance** parameter. Clicking a link highlights the corresponding block in the model.	blocks with a compliance option have been updated.

See Also

- `Tire (Friction Parameterized)`
- `Tire (Magic Formula)`
- `Tire (Simple)`

Check Engine time constant option

Check model for `Generic Engine` blocks with **Engine time constant** settings that are suboptimal for real-time simulation.

Description

This check identifies `Generic Engine` blocks in your model where the **Engine time constant** parameter setting is suboptimal for real-time simulation. This parameter lets you model engine dynamics, that is, the time lag of the engine response. For optimal results, **Engine time constant** should be set to `No time constant — Suitable for HIL simulation`.

Available with Simscape Driveline.

Results and Recommended Actions

Condition	Recommended Action
This model contains `Generic Engine` blocks where the model includes the time lag of the engine response. After running the check, you get a table of results in the right pane of the Performance Advisor window. Each cell in	To update the blocks, scroll down the right pane of the Performance Advisor window and click the **Update** button. If the automatic update is successful, the **Result** box displays a message that all the

Condition	Recommended Action
the first column of the table contains a link to the problematic block. The corresponding cell in the second column indicates the current setting for modeling the engine dynamics. Clicking a link highlights the corresponding block in the model.	`Generic Engine` blocks with an **Engine time constant** option have been updated.

See Also

- `Generic Engine`

Check Dog clutch model option

Check model for dog clutch blocks with **Torque transmission model** settings that are suboptimal for real-time simulation.

Description

This check identifies blocks in your model where the **Torque transmission model** parameter setting is suboptimal for real-time simulation. This parameter exists in all blocks that let you model a dog clutch, such as `Dog Clutch`, `Synchronizer`, and `Double-Sided Synchronizer`. The parameter controls whether the torque transmission model accounts for backlash, torsional compliance, and contact forces between ring and hub teeth. For optimal results, **Torque transmission model** should be set to `Friction clutch approximation - Suitable for HIL and linearization`, which models clutch engagement simply as a friction phenomenon between the ring and the hub.

Available with Simscape Driveline.

Results and Recommended Actions

Condition	Recommended Action
This model contains dog clutch blocks where the torque transmission model accounts for backlash and other special effects.	To update the blocks, scroll down the right pane of the Performance Advisor window and click the **Update** button.

Condition	Recommended Action
After running the check, you get a table of results in the right pane of the Performance Advisor window. Each cell in the first column of the table contains a link to the problematic block. The corresponding cell in the second column indicates the current torque transmission model setting. Clicking a link highlights the corresponding block in the model.	If the automatic update is successful, the **Result** box displays a message that all the blocks with a **Torque transmission model** option have been updated.

See Also

- `Dog Clutch`
- `Double-Sided Synchronizer`
- `Synchronizer`

Check Losses model option

Check model for `Variable Ratio Transmission` blocks with **Losses model** settings that are suboptimal for real-time simulation.

Description

This check identifies `Variable Ratio Transmission` blocks in your model where the **Losses model** parameter setting is suboptimal for real-time simulation. This parameter specifies how to implement friction losses from nonideal torque transfer. For optimal results, **Losses model** should be set to `No losses — Suitable for HIL simulation`.

Available with Simscape Driveline.

Results and Recommended Actions

Condition	Recommended Action
This model contains `Variable Ratio Transmission` blocks where the torque transmission model accounts for friction losses from nonideal torque transfer.	To update the blocks, scroll down the right pane of the Performance Advisor window and click the **Update** button.

Condition	Recommended Action
After running the check, you get a table of results in the right pane of the Performance Advisor window. Each cell in the first column of the table contains a link to the problematic block. The corresponding cell in the second column indicates the current setting for modeling the friction losses. Clicking a link highlights the corresponding block in the model.	If the automatic update is successful, the **Result** box displays a message that all `Variable Ratio Transmission` blocks with a **Losses model** option have been updated.

See Also

- `Variable Ratio Transmission`

Check Model transmission lag option

Check model for `Torque Converter` blocks with **Model transmission lag** settings that are suboptimal for real-time simulation.

Description

This check identifies `Torque Converter` blocks in your model where the **Model transmission lag** parameter setting is suboptimal for real-time simulation. This parameter specifies how to model transmission lag from input to output driveshaft. For optimal results, **Model transmission lag** should be set to `No lag — Suitable for HIL simulation`.

Available with Simscape Driveline.

Results and Recommended Actions

Condition	Recommended Action
This model contains `Torque Converter` blocks where torque is transferred with a time lag. After running the check, you get a table of results in the right pane of the	To update the blocks, scroll down the right pane of the Performance Advisor window and click the **Update** button. If the automatic update is successful, the **Result** box displays a message that

Condition	Recommended Action
Performance Advisor window. Each cell in the first column of the table contains a link to the problematic block. The corresponding cell in the second column indicates the current setting for modeling the transmission lag. Clicking a link highlights the corresponding block in the model.	all `Torque Converter` blocks with a **Model transmission lag** option have been updated.

See Also

- `Torque Converter`

Check Hard stop model option

Check model for blocks with **Hard stop model** settings that are suboptimal for real-time simulation.

Description

This check identifies `Shock Absorber` and `Torsional Spring-Damper` blocks in your model where the **Hard stop model** parameter setting is suboptimal for real-time simulation. This parameter controls whether the model includes hard stops. For optimal results, **Hard stop model** should be set to `No hard-stops — Suitable for HIL simulation`, which eliminates the hard stop force contribution and enhances simulation speed.

Available with Simscape Driveline.

Results and Recommended Actions

Condition	Recommended Action
This model contains `Shock Absorber` or `Torsional Spring-Damper` blocks with hard stops. After running the check, you get a table of results in the right pane of the	To update the blocks, scroll down the right pane of the Performance Advisor window and click the **Update** button. If the automatic update is successful, the **Result** box displays a message that all the

Condition	Recommended Action
Performance Advisor window. Each cell in the first column of the table contains a link to the problematic block. The corresponding cell in the second column indicates the current hard stop model setting. Clicking a link highlights the corresponding block in the model.	blocks with a **Hard stop model** option have been updated.

See Also

- `Shock Absorber`
- `Torsional Spring-Damper`

Power Systems Checks Overview

Use these checks to optimize real-time simulation performance of your Simscape Power Systems™ model. These checks target specific Simscape Power Systems blocks. Run these checks in addition to the top-level **Simscape checks**, which are applicable to all physical models.

See Also

- "Improve Simulation Performance Using Performance Advisor "

Check Stator zero-sequence inductance

Check model for Simscape Power Systems Simscape Components blocks with **Stator zero-sequence inductance, L0** or **Stator zero-sequence reactance, X0** settings that are suboptimal for real-time simulation.

Description

This check identifies blocks in your model where the **Stator zero-sequence inductance, L0** or **Stator zero-sequence reactance, X0** parameter setting is suboptimal for real-time simulation. These parameters exist in multiple blocks in the Machines library. For optimal results, set the **Stator zero-sequence inductance, L0** or **Stator zero-sequence reactance, X0** parameters to a value greater than zero. In absence of manufacturer data, set **Stator zero-sequence inductance, L0** equal to the stator leakage inductance, or set **Stator zero-sequence reactance, X0** equal to the stator leakage reactance.

Available with Simscape Power Systems.

Results and Recommended Actions

Condition	Recommended Action
This model contains blocks where either **Stator zero-sequence inductance, L0** or **Stator zero-sequence reactance, X0** parameter has a value of 0. After running the check, you get a table of results in the right pane of the Performance Advisor window. Each cell in the first column of the table contains a link to the problematic block. The corresponding cell in the second column indicates which of the parameters, **LO** (inductance) or **XO** (reactance) has the suboptimal setting. Clicking a link highlights the corresponding block in the model.	To update the blocks, scroll down the right pane of the Performance Advisor window and click the **Update** button. Depending on the parameter present in the block, the automatic update: • Sets **Stator zero-sequence inductance, L0** equal to the **Stator leakage inductance, Lls** parameter value • Sets **Stator zero-sequence reactance, X0** equal to the **Stator leakage reactance, Xls** parameter value If the automatic update is successful, the **Result** box displays a message that all blocks with a suboptimal **Stator zero-sequence inductance, L0** or **Stator zero-sequence reactance, X0** value have been updated.

See Also

- “Machines”

A

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Glossary

across variables

Variables that are measured with a gauge connected in parallel to an element.

add-on products

Products in the Physical Modeling family that use Simscape platform and, as a result, share common functionality such as physical units management, editing modes, and so on.

conserving ports

Bidirectional hydraulic or mechanical ports that represent physical connections and relate physical variables based on the Physical Network approach.

globally assigned positive direction

Direction considered positive for a model diagram.

nonrestricted parameters

Parameters that are available for modification when you open a model in Restricted mode. Usually, these are the block parameters with plain numerical values, such as **Chamber volume** or **Wheel radius**. Information on restricted and nonrestricted parameters is listed in block reference pages.

physical connections

Bidirectional connections between the blocks that mimic physical connections between elements.

physical signal ports

Unidirectional ports (inports and outports) transferring signals that use an internal Simscape engine for computations.

restricted parameters

Parameters that are not available for modification when you open a model in Restricted mode. You have to be in Full mode to modify them. Usually, these are the block parameterization options, such as **Chamber specification** or **Mechanism orientation**. Information on restricted and nonrestricted parameters is listed in block reference pages.

through variables

Variables that are measured with a gauge connected in series to an element.