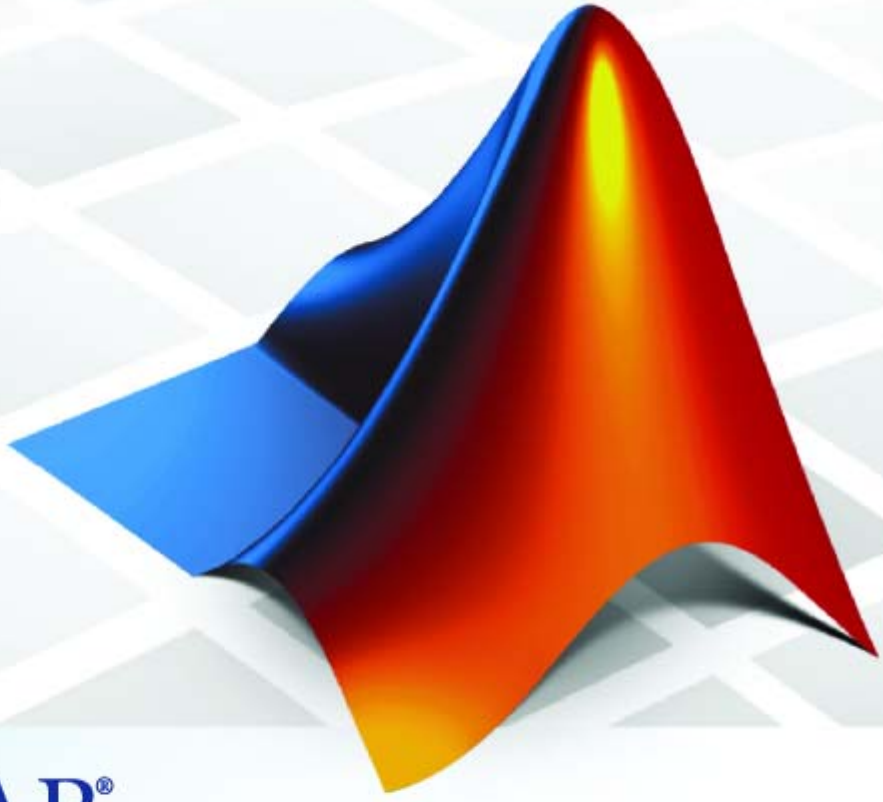
Simscape™ 1
Reference



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Simscape Reference

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Revision History

March 2007	Online only	New for Version 1.0 (Release R2007a)

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1

Blocks — By Category

Foundation (p. 1-2)	Basic electrical, hydraulic, mechanical, and physical signal blocks
Utilities (p. 1-10)	Essential environment blocks for creating Physical Networks models

Foundation

Electrical (p. 1-2)	Basic electrical diagram blocks, such as inductors, diodes, capacitors, sensors and sources
Hydraulic (p. 1-4)	Basic hydraulic diagram blocks, such as orifices, chambers, sensors and sources, and hydraulic utilities
Mechanical (p. 1-6)	Mechanical elements for rotational and translational motion, as well as mechanical sensors and sources
Physical Signals (p. 1-8)	Blocks for transmitting physical control signals

Electrical

Electrical Elements (p. 1-2)	Electrical building blocks, such as inductors, diodes, and capacitors
Electrical Sensors (p. 1-3)	Current and voltage sensors
Electrical Sources (p. 1-3)	Current and voltage sources

Electrical Elements

Capacitor	Simulate linear capacitor in electrical systems
Diode	Simulate piecewise linear diode in electrical systems
Electrical Reference	Simulate connection to electrical ground
Ideal Transformer	Simulate ideal transformer in electrical systems
Inductor	Simulate linear inductor in electrical systems

Mutual Inductor	Simulate mutual inductor in electrical systems
Op-Amp	Simulate ideal operational amplifier
Resistor	Simulate linear resistor in electrical systems
Rotational Electromechanical Converter	Provide interface between electrical and mechanical rotational domains
Switch	Simulate switch controlled by external physical signal
Translational Electromechanical Converter	Provide interface between electrical and mechanical translational domains
Variable Resistor	Simulate linear variable resistor in electrical systems

Electrical Sensors

Current Sensor	Simulate current sensor in electrical systems
Voltage Sensor	Simulate voltage sensor in electrical systems

Electrical Sources

AC Current Source	Simulate ideal sinusoidal current source
AC Voltage Source	Simulate ideal constant voltage source
Controlled Current Source	Simulate ideal current source driven by input signal
Controlled Voltage Source	Simulate ideal voltage source driven by input signal

Current-Controlled Current Source	Simulate linear current-controlled current source
Current-Controlled Voltage Source	Simulate linear current-controlled voltage source
DC Current Source	Simulate ideal constant current source
DC Voltage Source	Simulate ideal constant voltage source
Voltage-Controlled Current Source	Simulate linear voltage-controlled current source
Voltage-Controlled Voltage Source	Simulate linear voltage-controlled voltage source

Hydraulic

Hydraulic Elements (p. 1-4)	Hydraulic building blocks, such as orifices, chambers, and hydro-mechanical converters
Hydraulic Sensors and Sources (p. 1-5)	Hydraulic sensors and sources
Hydraulic Utilities (p. 1-5)	Basic hydraulic environment blocks, such as custom hydraulic fluid

Hydraulic Elements

Constant Area Orifice	Simulate hydraulic orifice with constant cross-sectional area
Constant Volume Chamber	Simulate hydraulic capacity of constant volume
Fluid Inertia	Simulate pressure differential across tube or channel due to change in fluid velocity

Hydraulic Reference	Simulate connection to atmospheric pressure
Linear Hydraulic Resistance	Simulate hydraulic pipeline with linear resistance losses
Resistive Tube	Simulate hydraulic pipeline which accounts for friction losses only
Rotational Hydro-Mechanical Converter	Simulate ideal hydro-mechanical transducer as building block for rotary actuators
Translational Hydro-Mechanical Converter	Simulate single chamber of hydraulic cylinder as building block for various cylinder models
Variable Area Orifice	Simulate hydraulic variable orifice created by cylindrical spool and sleeve
Variable Volume Chamber	Simulate hydraulic capacity of variable volume with compressible fluid

Hydraulic Sensors and Sources

Ideal Hydraulic Flow Rate Sensor	Simulate ideal flow meter
Ideal Hydraulic Flow Rate Source	Simulate ideal source of hydraulic energy, characterized by flow rate
Ideal Hydraulic Pressure Sensor	Simulate ideal pressure sensing device
Ideal Hydraulic Pressure Source	Simulate ideal source of hydraulic energy, characterized by pressure

Hydraulic Utilities

Custom Hydraulic Fluid	Set working fluid properties by specifying parameter values

Mechanical

Mechanical Sensors and Sources (p. 1-6)	Mechanical sensors and sources
Mechanisms (p. 1-7)	Various simple mechanisms
Rotational Elements (p. 1-7)	Mechanical elements for rotational motion
Translational Elements (p. 1-7)	Mechanical elements for translational motion

Mechanical Sensors and Sources

Ideal Angular Velocity Source	Simulate ideal angular velocity source in mechanical rotational systems
Ideal Force Sensor	Simulate force sensor in mechanical translational systems
Ideal Force Source	Simulate ideal source of mechanical energy that generates force proportional to the input signal
Ideal Rotational Motion Sensor	Simulate motion sensor in mechanical rotational systems
Ideal Torque Sensor	Simulate torque sensor in mechanical rotational systems
Ideal Torque Source	Simulate ideal source of mechanical energy that generates torque proportional to the input signal
Ideal Translational Motion Sensor	Simulate motion sensor in mechanical translational systems
Ideal Translational Velocity Source	Simulate ideal velocity source in mechanical translational systems

Mechanisms

Gear Box	Simulate gear boxes in mechanical systems
Lever	Simulate lever in mechanical systems
Wheel and Axle	Simulate wheel and axle mechanism in mechanical systems

Rotational Elements

Inertia	Simulate inertia in mechanical rotational systems
Mechanical Rotational Reference	Simulate reference for mechanical rotational ports
Rotational Damper	Simulate viscous damper in mechanical rotational systems
Rotational Friction	Simulate friction in contact between rotating bodies
Rotational Hard Stop	Simulate double-sided rotational hard stop
Rotational Spring	Simulate ideal spring in mechanical rotational systems

Translational Elements

Mass	Simulate mass in mechanical translational systems
Mechanical Translational Reference	Simulate reference for mechanical translational ports
Translational Damper	Simulate viscous damper in mechanical translational systems

Translational Friction	Simulate friction in contact between moving bodies
Translational Hard Stop	Simulate double-sided translational hard stop
Translational Spring	Simulate ideal spring in mechanical translational systems

Physical Signals

Functions (p. 1-8)	Perform math operations on physical signals
Linear Operators (p. 1-9)	Simulate continuous-time functions for physical signals
Lookup Tables (p. 1-9)	Perform one- and two-dimensional table lookup to generate physical signals
Nonlinear Operators (p. 1-9)	Simulate discontinuities, such as saturation or dead zone, for physical signals

Functions

PS Add	Add two physical signal inputs
PS Divide	Compute simple division of two input physical signals
PS Gain	Multiply input physical signal by constant
PS Product	Multiply two physical signal inputs
PS Subtract	Compute simple subtraction of two input physical signals

Linear Operators

PS Integrator	Integrate physical signal

Lookup Tables

PS Lookup Table (1D)	Approximate one-dimensional function using specified lookup method
PS Lookup Table (2D)	Approximate two-dimensional function using specified lookup method

Nonlinear Operators

PS Dead Zone	Provide region of zero output for physical signals
PS Saturation	Limit range of physical signal

Utilities

Connection Port	Create Physical Modeling connector port for subsystem
PS-Simulink Converter	Convert physical signal into Simulink output signal
Simulink-PS Converter	Convert Simulink input signal into physical signal
Solver Configuration	Represent Physical Networks environment and solver configuration
Two-Way Connection	Create two-way connector port for subsystem

2

Blocks – Alphabetical List

AC Current Source

Purpose

Simulate 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:

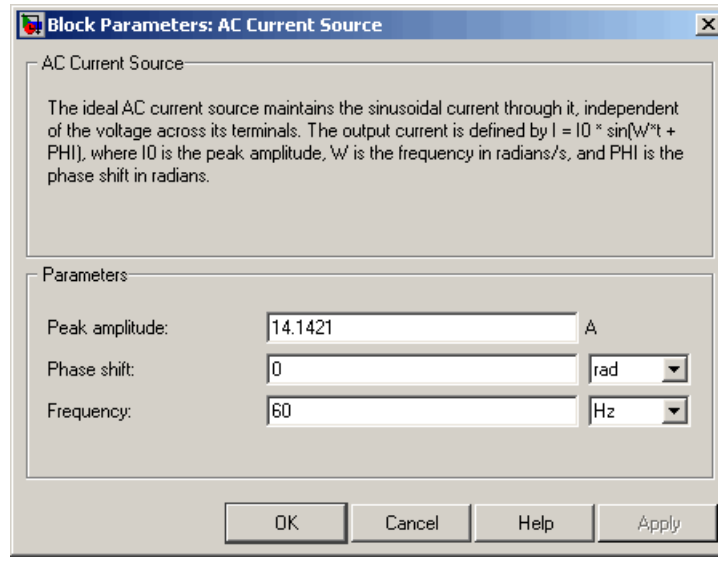
$$I = I_0 \cdot \sin(\omega \cdot t + \varphi)$$

where

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

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

Dialog Box and Parameters



Peak amplitude

Peak current amplitude. The default value is 10*sqrt(2), or `14.1421` A.

Phase shift

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

Frequency

Current frequency. 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

Purpose

Simulate 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:

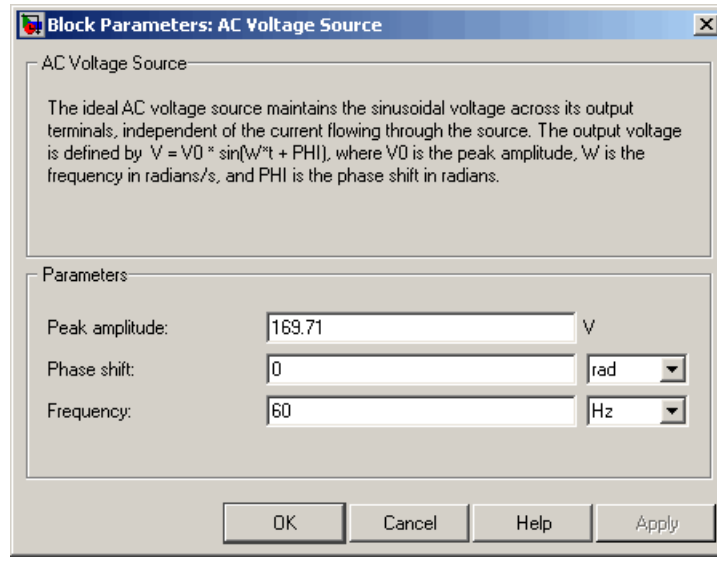
$$V = V_0 \cdot \sin(\omega \cdot t + \varphi)$$

where

V	Voltage
V_0	Peak amplitude
ω	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, $V(+) - V(-)$.

Dialog Box and Parameters



Peak amplitude

Peak voltage amplitude. The default value is 120*sqrt(2), or `169.71` V.

Phase shift

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

Frequency

Voltage frequency. 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

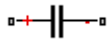
Purpose

Simulate 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 **Initial voltage** parameter sets the initial voltage across the capacitor.

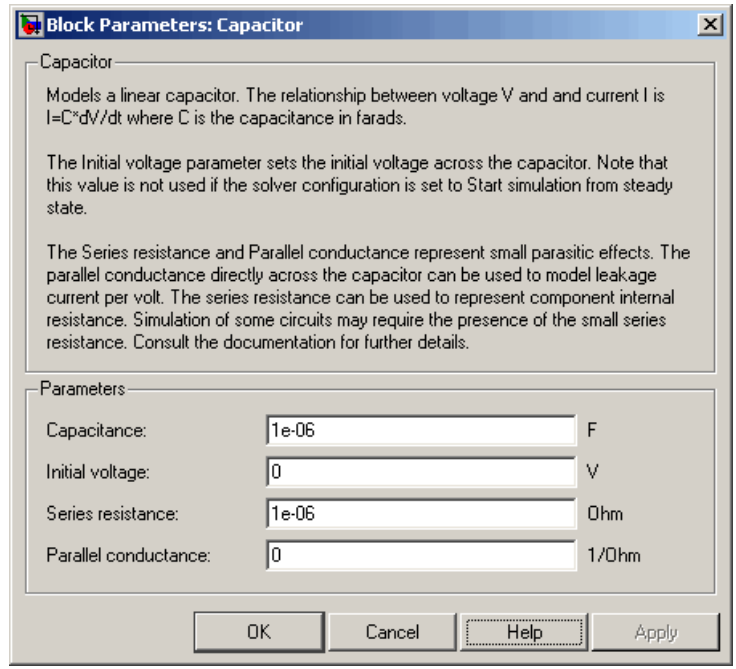
Note This value is not used if the solver configuration is set to **Start simulation from steady state**.

The **Series resistance** and **Parallel conductance** parameters represent small parasitic effects. The parallel conductance directly across the capacitor can be used to model leakage current per volt. The series resistance can be used to represent component internal resistance. Simulation of some circuits may require the presence of the small series resistance. For more information, see “Modeling Best Practices” in the Simscape User’s Guide.

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



Capacitance

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

Initial voltage

Initial voltage across the capacitor. This parameter is not used if the solver configuration is set to **Start simulation from steady state**. The default value is 0.

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`.

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.

Connection Port

Purpose

Create Physical Modeling connector port for subsystem

Library

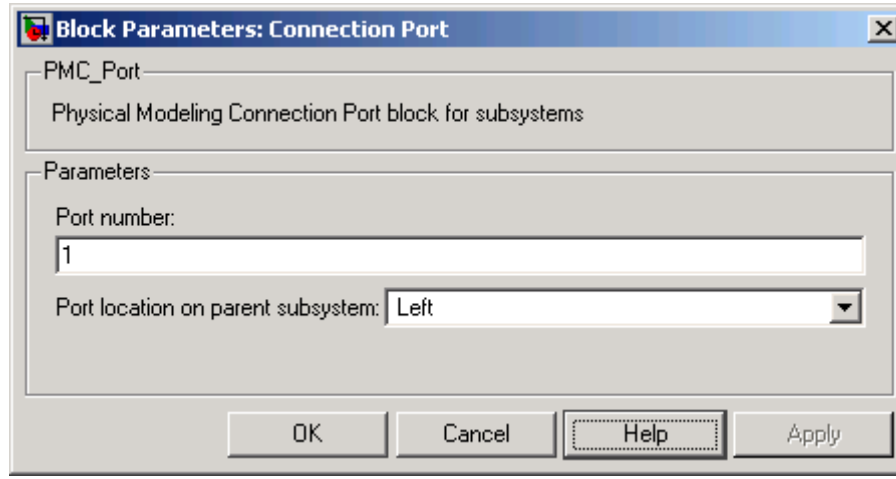
Utilities

Description

The Connection Port block is used to export both the conserving and the physical signal connections to the outside boundary of a subsystem block, similar to the Inport and Outport blocks in Simulink.

The ports on the subsystem boundary appear as the square Conserving ports ▣, as triangular Physical Signal ports ▷, or as two-way connector ports ✚, depending on the type of port to which the Connection Port block is connected inside the subsystem. In other words, if a Connection Port block is connected to a Conserving port in a subsystem, it appears as a Conserving port on the outside boundary of the subsystem. If it is connected to a Physical Signal inport or outport inside the subsystem, it appears as a Physical Signal inport or outport, respectively, on the outside boundary of the subsystem. If it is connected to a two-way connector port of the Two-Way Connection block inside the subsystem, it appears as a two-way connector port on the outside boundary of the subsystem.

Dialog Box and Parameters



Port number

Labels the subsystem connector port created by this block. Each connector port on the boundary of a single subsystem requires a unique number as a label. The default value for the first port is `1`.

Port location on parent subsystem

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

See Also

In the Using Simulink documentation, see “Creating Block Masks”.

Constant Area Orifice

Purpose

Simulate hydraulic orifice with constant cross-sectional area

Library

Hydraulic Elements

Description

The Constant Area Orifice block models a sharp-edged constant-area orifice. The model distinguishes between the laminar and turbulent flow regimes by comparing the Reynolds number with its critical value. The flow rate through the orifice is proportional to the pressure differential across the orifice, and is determined according to the following equations:

$$q = \begin{cases} C_D \cdot A \sqrt{\frac{2}{\rho} |p|} \cdot sign(p) & \text{for } Re >= Re_{cr} \\ 2 C_{DL} \cdot A \frac{D_H}{\nu \cdot \rho} p & \text{for } Re < Re_{cr} \end{cases}$$

$$p = p_A - p_B$$

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

$$C_{DL} = \left(\frac{C_D}{\sqrt{\mathrm{Re}_{cr}}} \right)^2$$

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

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
Re	Reynolds number
Re_{cr}	Critical Reynolds number

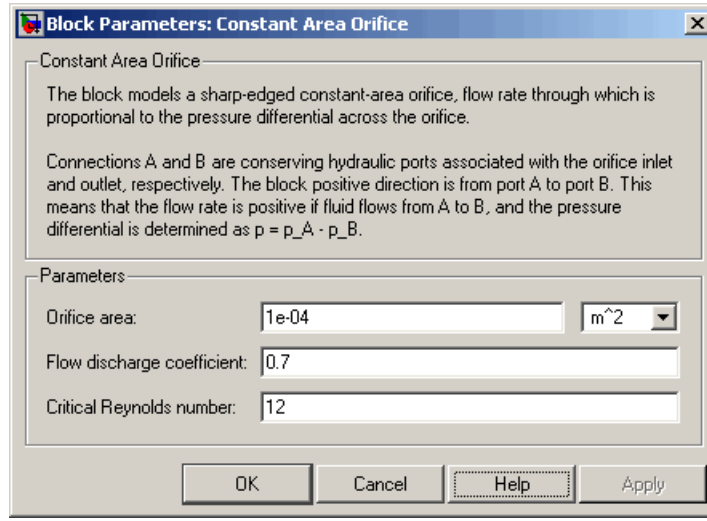
The block positive direction is from port A to port B. This means that the flow rate is positive if it flows from A to B, and the pressure differential is determined as $p = p_A - p_B$.

Basic Assumptions and Limitations

The model is based on the following assumptions:

- Fluid inertia is not taken into account.
- The transition between laminar and turbulent regimes is assumed to be sharp and taking place exactly at $Re=Re_{cr}$.

Dialog Box and Parameters



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 supposed to take place when the Reynolds number reaches this value. The value of the parameter depends on orifice geometrical profile, and the recommendations on the parameter value can be found in hydraulic textbooks. The default value is `12`, which corresponds to a round orifice in thin material with sharp edges.

Global Parameters

Fluid density

The parameter is determined by the type of working fluid selected for the system under design. Use the Custom Hydraulic Fluid block, or the Hydraulic Fluid block available with SimHydraulics™, to specify the fluid properties.

Fluid kinematic viscosity

The parameter is determined by the type of working fluid selected for the system under design. Use the Custom Hydraulic Fluid block, or the Hydraulic Fluid block available with SimHydraulics, 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 Orifice

Constant Volume Chamber

Purpose

Simulate hydraulic capacity of constant volume

Library

Hydraulic Elements

Description

The Constant Volume 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:

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

$$q = \frac{dV_f}{dt}$$

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. The mixture bulk modulus is determined as:

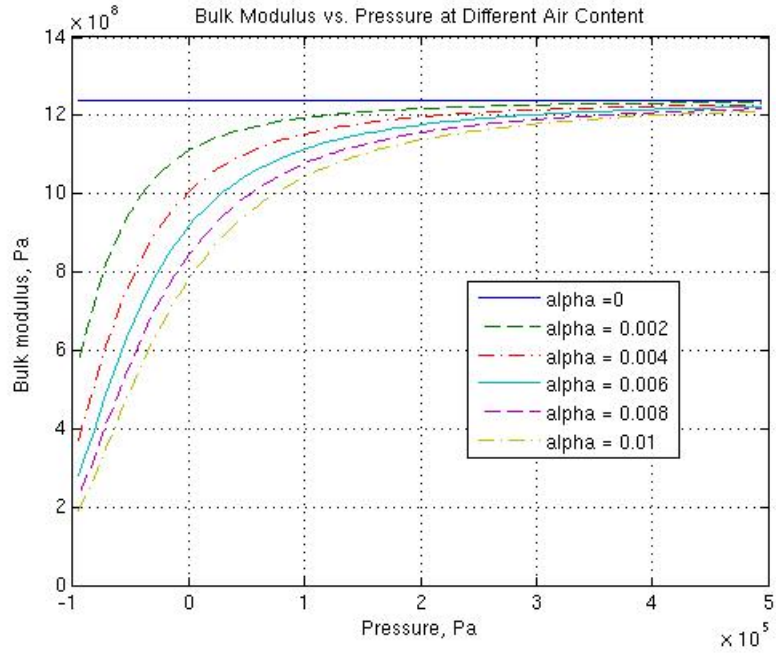
$$E = E_l \frac{1 + \alpha\left(\frac{p_a}{p_a + p}\right)^{1/n}}{1 + \alpha\frac{p_a^{1/n}}{n(p_a + p)^{\frac{n+1}{n}}}E_l}$$

where

E_1	Pure liquid bulk modulus
p_α	Atmospheric pressure
α	Relative gas content at atmospheric pressure, $\alpha = V_G/V_L$
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 in SimHydraulics. 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 it is known that cavitation is unlikely in the system under design, you can set the relative gas content in the fluid properties to zero, thus increasing the speed of computations. Use the Hydraulic Fluid or the Custom Hydraulic Fluid block to set the fluid properties.

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

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

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

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 [1]):

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

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 [2]).

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.

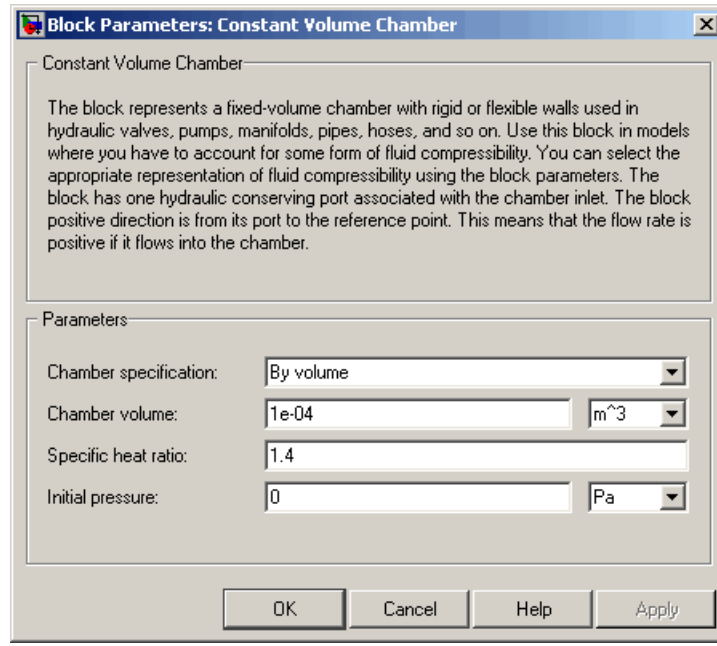
The block has one hydraulic conserving port associated with the chamber inlet. The block positive direction is from its port to the reference point. This means that the flow rate is positive if it flows into the chamber.

Basic Assumptions and Limitations

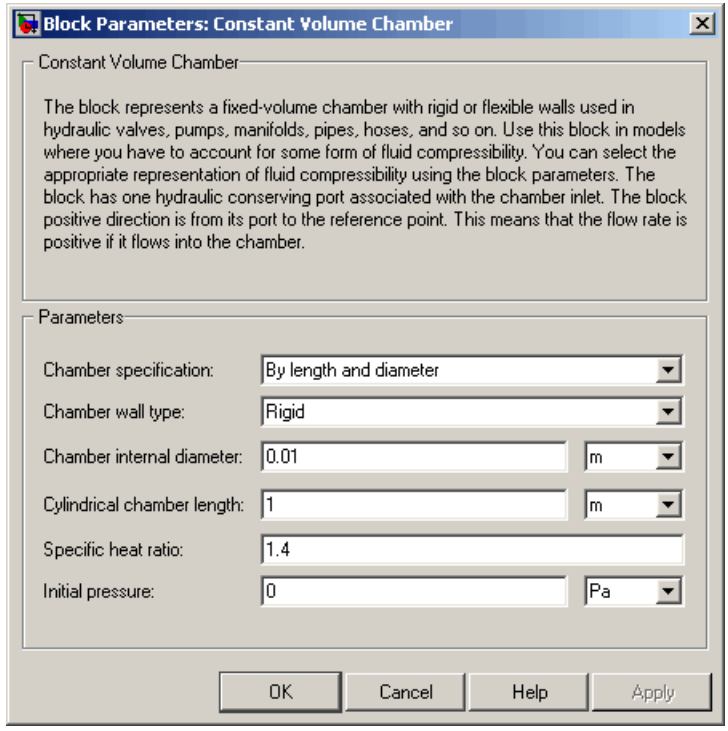
The model is based on the following assumptions:

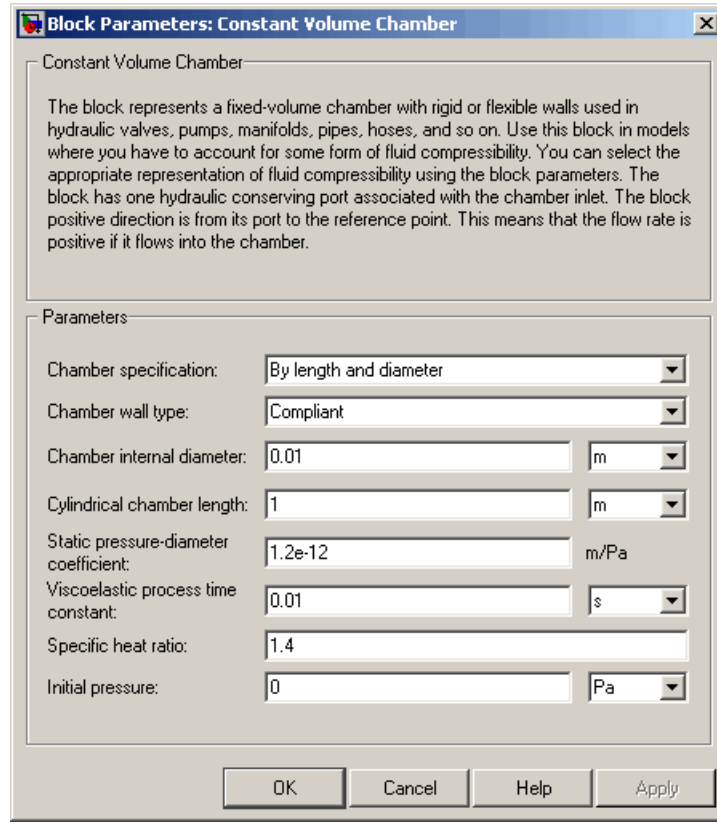
- No inertia associated with pipe walls is taken into account.
- Chamber with compliant walls is assumed to have a cylindrical shape. Chamber with rigid wall can have any shape.

Dialog Box and Parameters



Constant Volume Chamber





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`.

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. For more information, see "Computing Initial Conditions". The default value is `0`.

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.

Global Parameters

Fluid bulk modulus

The parameter is determined by the type of working fluid selected for the system under design. Use the Hydraulic Fluid block or the Custom Hydraulic Fluid block to specify the fluid properties.

Nondissolved gas ratio

Nondissolved gas relative content determined as a ratio of gas volume to the liquid volume. The parameter is determined by the type of working fluid selected for the system under design. 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] Meritt, H.E., *Hydraulic Control Systems*, John Wiley & Sons, New York, 1967

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

Examples

The Constant Volume Chamber Test Rig demo (`sh_constant_chamber_test_rig`) is specifically designed to demonstrate the Constant Volume Chamber block behavior at different regimes. The chamber is placed between two linear hydraulic resistances and subjected to an abrupt pressure change from 0 to 5 MPa at the beginning of simulation.

If air content is set to zero and chamber walls are rigid, the pressure change can easily be determined analytically. The Simulink Transfer Fcn block simulates this regime for a metal cylindrical pipe with 0.03 m internal diameter, 0.036 m external diameter, and 16.5 m length. The output of this block serves as a reference during all other regimes. You can investigate chamber characteristics, for example, by changing air content in the fluid, by switching from rigid to compliant walls, by changing the viscoelastic time constant or the pressure-diameter coefficient.

See Also

Variable Volume Chamber

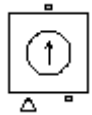
Purpose

Simulate ideal current source driven by input signal

Library

Electrical Sources

Description

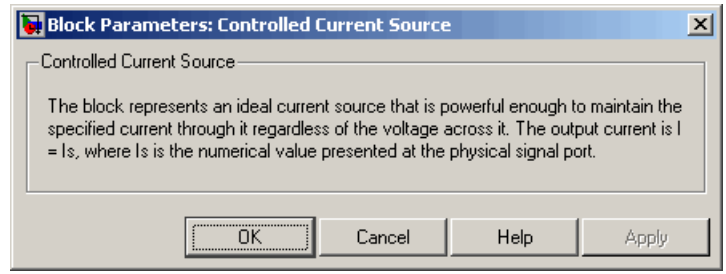


The Controlled Current Source block represents an ideal current source that is powerful enough to maintain the specified current through it regardless of the voltage across the source.

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



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 Voltage Source

Purpose

Simulate ideal voltage source driven by input signal

Library

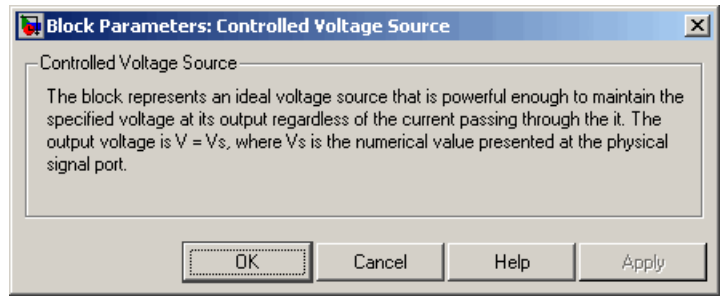
Electrical Sources

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

Dialog Box and Parameters



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

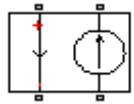
Purpose

Simulate 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:

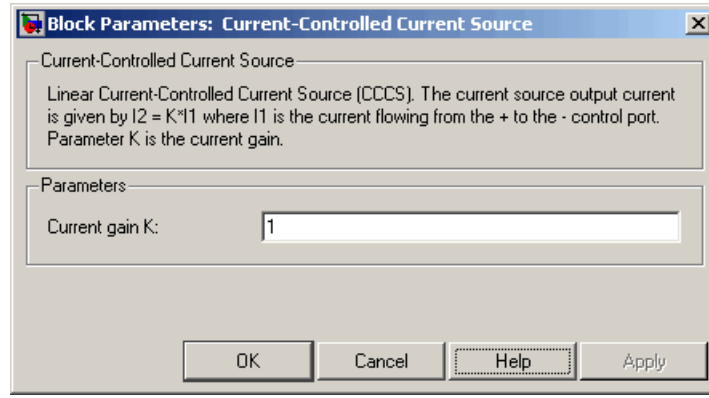
$$I2 = K \cdot I1$$

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



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.

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

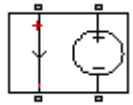
Purpose

Simulate 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:

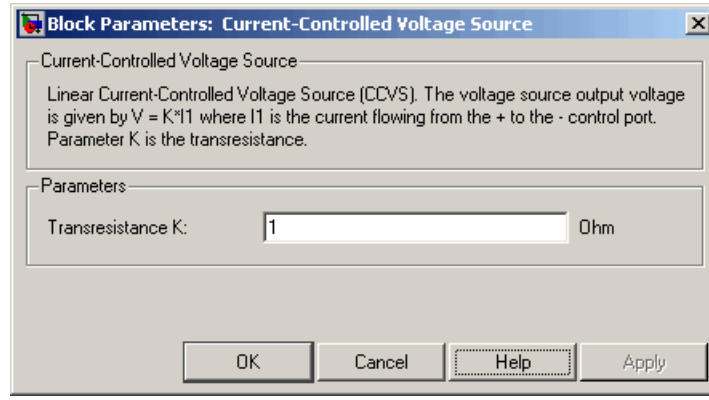
$$V = K \square I1$$

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



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.

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

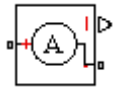
Purpose

Simulate current sensor in electrical systems

Library

Electrical Sensors

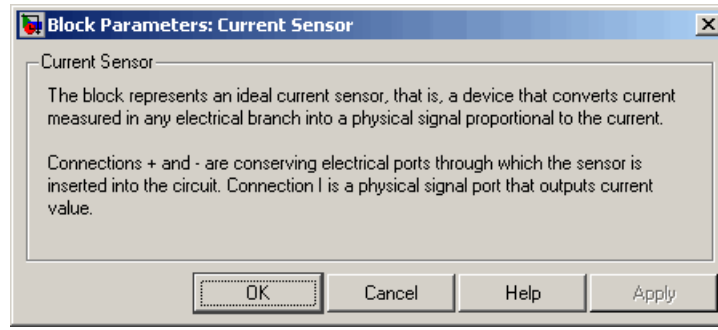
Description



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



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 Voltage Sensor

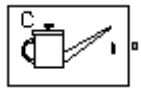
Purpose

Set working fluid properties by specifying parameter values

Library

Hydraulic Utilities

Description



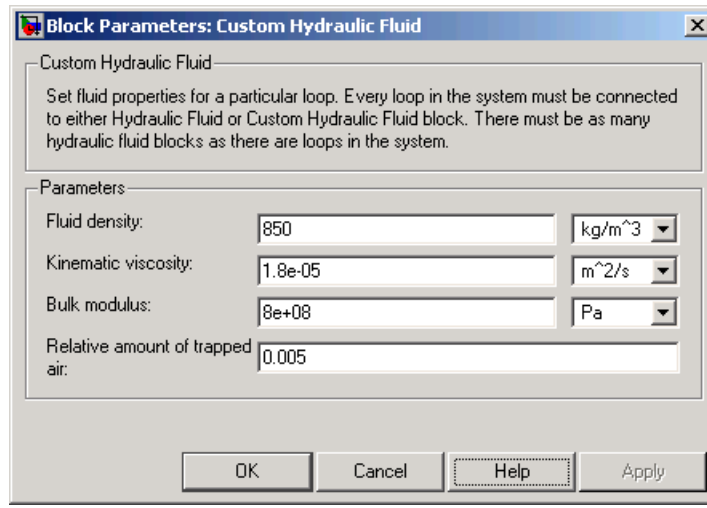
The Custom Hydraulic Fluid block lets you specify the type of hydraulic fluid used in a loop of hydraulic blocks. It provides the hydraulic fluid properties, such as kinematic viscosity, density, and bulk modulus, for all the hydraulic blocks in the loop. These fluid properties are assumed to be constant 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, SimHydraulics 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 exactly one Custom Hydraulic Fluid block or Hydraulic Fluid block to be connected to it. Therefore, there must be as many Custom Hydraulic Fluid blocks (or Hydraulic Fluid blocks) as there are loops in the system.

Dialog Box and Parameters



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

Bulk modulus of the working fluid. 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. The default value is 0.005.

Ports

The block has one hydraulic conserving port.

See Also

Hydraulic Fluid

Purpose

Simulate ideal constant current source

Library

Electrical Sources

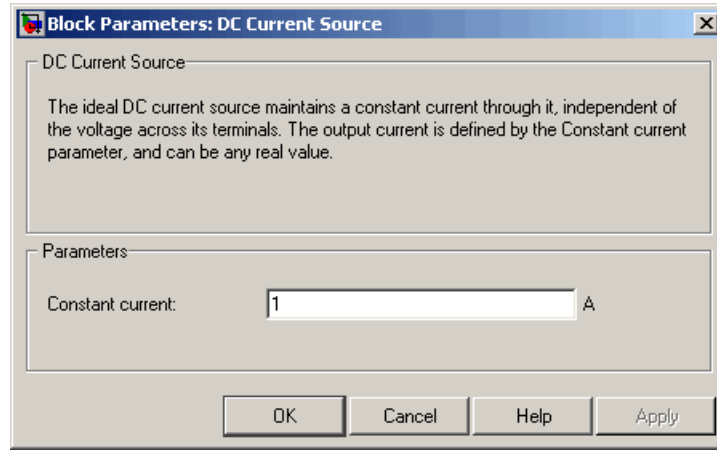
Description

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



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

Purpose

Simulate ideal constant voltage source

Library

Electrical Sources

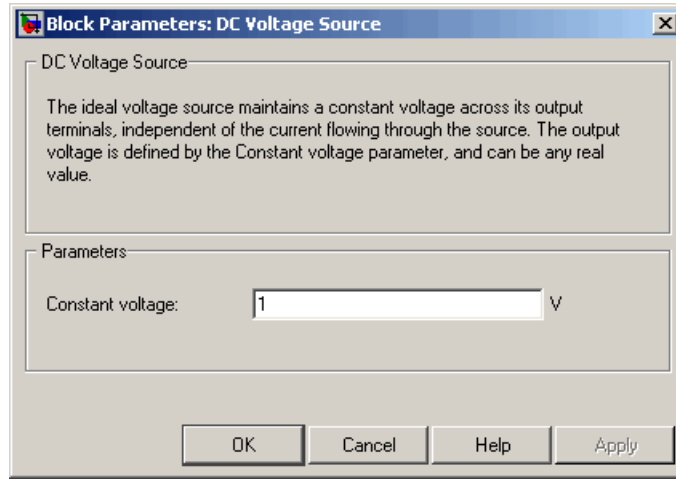
Description

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



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

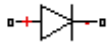
Purpose

Simulate 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:

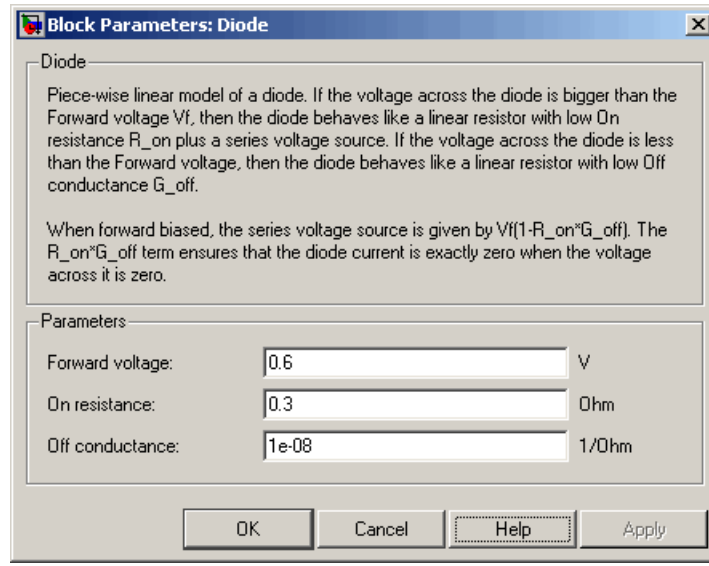
$$V = Vf(1 - R_{on} \cdot G_{off})$$

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



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.

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.

Purpose

Simulate connection to electrical ground

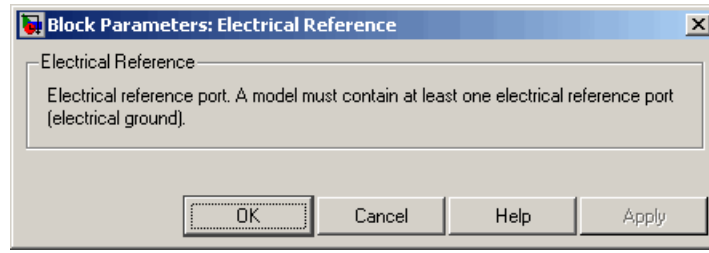
Library

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 must contain at least one Electrical Reference block.

Dialog Box and Parameters



The Electrical Reference block has no parameters.

Ports

The block has one electrical conserving port.

See Also

Hydraulic Reference

Mechanical Rotational Reference

Mechanical Translational Reference

Fluid Inertia

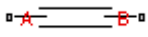
Purpose

Simulate 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.

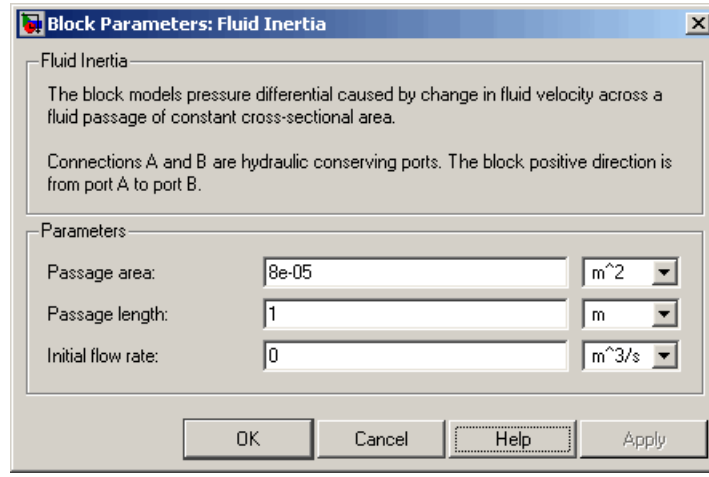
The block positive direction is from port A to port B. This means that the flow rate is positive if it flows from A to B.

Assumptions and Limitations

The model is based on the following assumptions:

- Fluid density remains constant.

Dialog Box and Parameters



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 "Computing Initial Conditions". The default value is `0`.

Global Parameters

Fluid density

The parameter is determined by the type of working fluid selected for the system under design. 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.

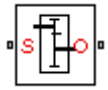
Purpose

Simulate gear boxes 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:

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

$$T_2 = N \cdot T_1$$

$$P_1 = \omega_1 \cdot T_1$$

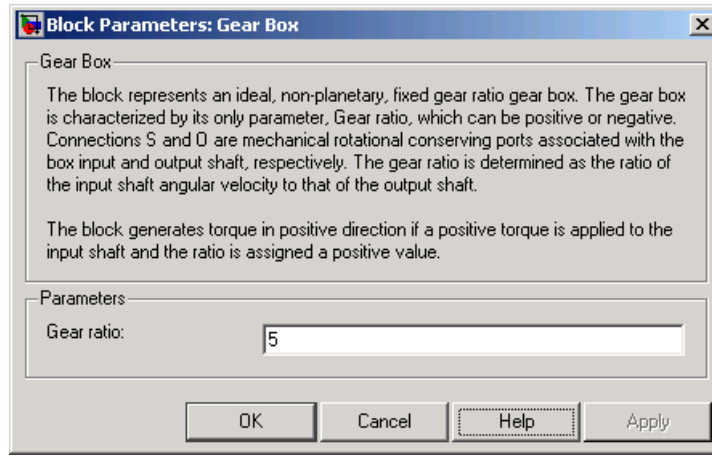
$$P_2 = -\omega_2 \cdot T_2$$

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 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`.

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.

Purpose

Simulate connection to atmospheric pressure

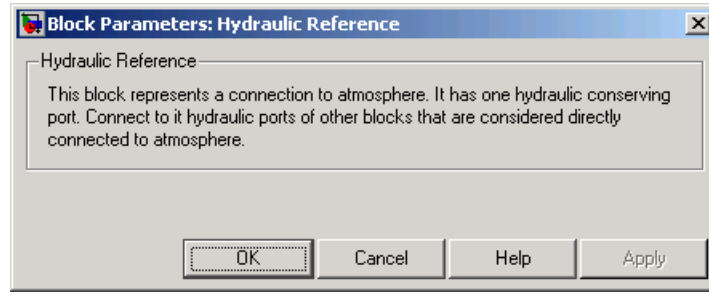
Library

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



The Hydraulic Reference block has no parameters.

Ports

The block has one hydraulic conserving port.

See Also

Electrical Reference

Mechanical Rotational Reference

Mechanical Translational Reference

Ideal Angular Velocity Source

Purpose

Simulate ideal angular velocity source in mechanical rotational systems

Library

Mechanical Sensors and Sources

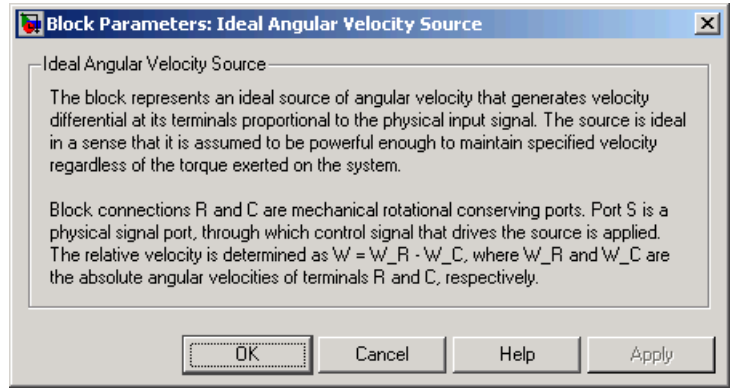
Description

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



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 Force Source

Ideal Torque Source

Ideal Translational Velocity Source

Ideal Force Sensor

Purpose

Simulate force sensor in mechanical translational systems

Library

Mechanical Sensors and Sources

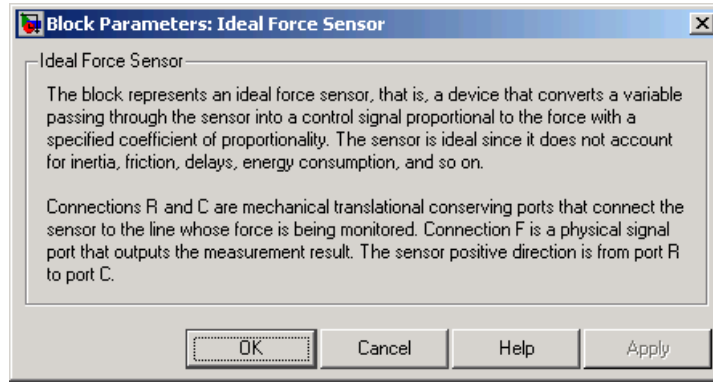
Description

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



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 Rotational Motion Sensor

Ideal Torque Sensor

Ideal Translational Motion Sensor

Ideal Force Source

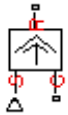
Purpose

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

Library

Mechanical Sensors and Sources

Description

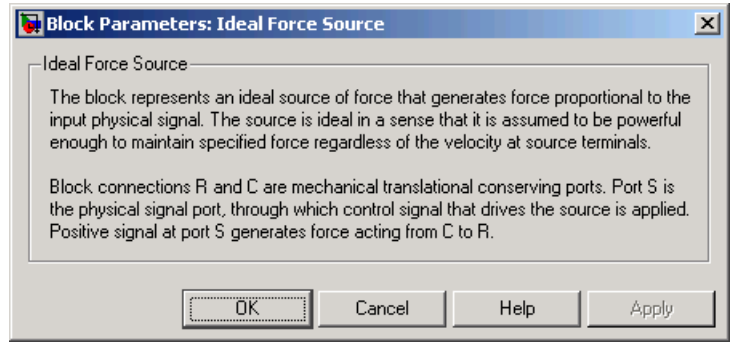


The Ideal Force Source block represents an ideal source of mechanical energy that generates force proportional to the input physical signal. The source is ideal in a sense that it is assumed to be powerful enough to maintain specified force at its output regardless of the velocity at source terminals.

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 $v = v_R - v_C$, 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



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 Angular Velocity Source

Ideal Torque Source

Ideal Translational Velocity Source

Ideal Hydraulic Flow Rate Sensor

Purpose

Simulate ideal flow meter

Library

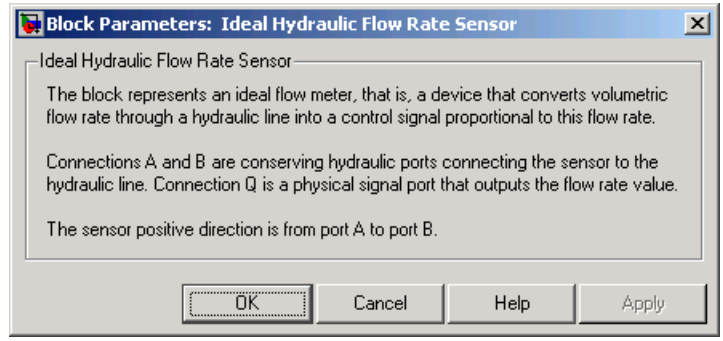
Hydraulic Sensors and Sources

Description

The Ideal 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



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

Ideal Hydraulic Flow Rate Source

Ideal Hydraulic Pressure Sensor

Ideal Hydraulic Flow Rate Source

Purpose

Simulate ideal source of hydraulic energy, characterized by flow rate

Library

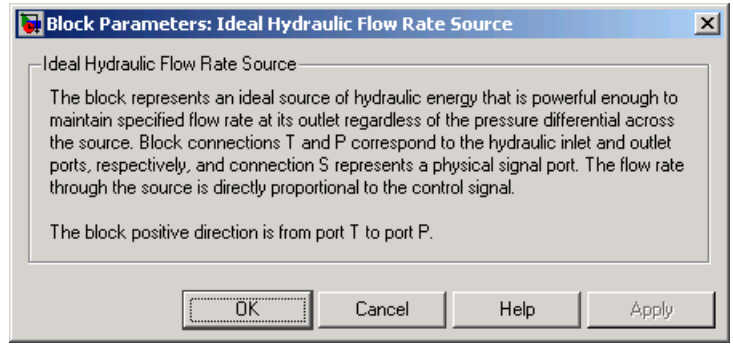
Hydraulic Sensors and Sources

Description

The Ideal 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 $p = p_T - p_P$ 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



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

Ideal Hydraulic Flow Rate Sensor

Ideal Hydraulic Pressure Source

Ideal Hydraulic Pressure Sensor

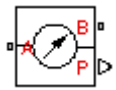
Purpose

Simulate ideal pressure sensing device

Library

Hydraulic Sensors and Sources

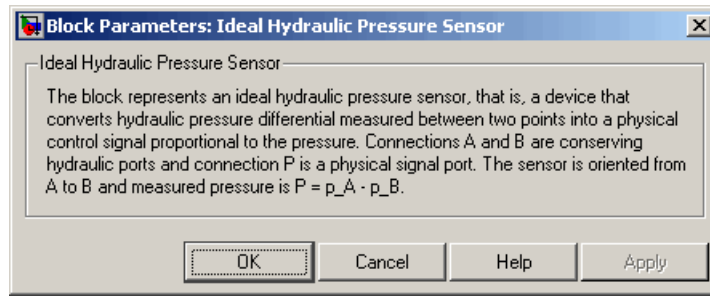
Description



The Ideal 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 flow rate is positive if it flows from A to B.

Dialog Box and Parameters



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

Ideal Hydraulic Flow Rate Sensor

Ideal Hydraulic Pressure Source

Ideal Hydraulic Pressure Source

Purpose

Simulate ideal source of hydraulic energy, characterized by pressure

Library

Hydraulic Sensors and Sources

Description

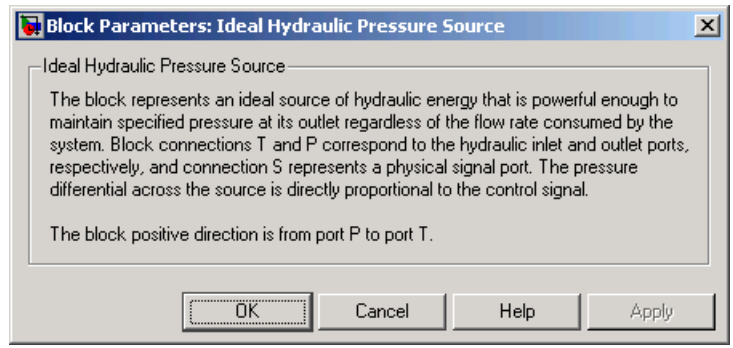
The Ideal Hydraulic Pressure Source block represents an ideal source of hydraulic energy that is powerful enough to maintain specified pressure at its outlet regardless of the flow rate consumed by the system. Block connections T and P correspond to the hydraulic inlet and outlet ports, respectively,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



The block has no parameters.

Ports

The block has the following ports:

P
: Hydraulic conserving port associated with the source inlet.

T
: Hydraulic conserving port associated with the source outlet.

S
: Control signal port.

See Also

Ideal Hydraulic Flow Rate Source

Ideal Hydraulic Pressure Sensor

Ideal Rotational Motion Sensor

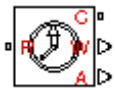
Purpose

Simulate motion sensor in mechanical rotational systems

Library

Mechanical Sensors and Sources

Description



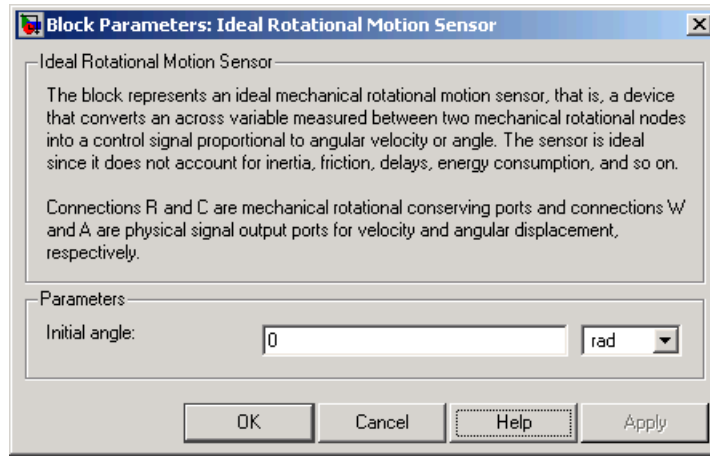
The Ideal Rotational Motion Sensor block represents an ideal mechanical rotational motion sensor, that is, a device that converts an across variable measured between two mechanical rotational nodes into a control signal proportional to angular velocity or angle. You can specify the initial angular position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



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 Force Sensor

Ideal Torque Sensor

Ideal Translational Motion Sensor

Ideal Torque Sensor

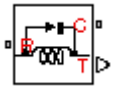
Purpose

Simulate torque sensor in mechanical rotational systems

Library

Mechanical Sensors and Sources

Description

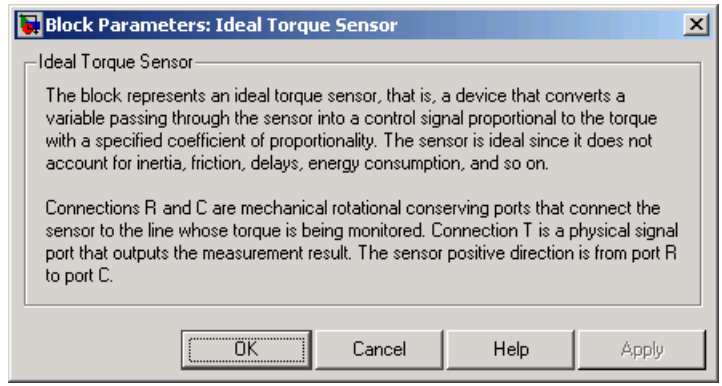


The Ideal Torque Sensor block represents a device that converts a variable passing through the sensor into a control signal proportional to the torque. The sensor is ideal since it does not account for inertia, friction, delays, energy consumption, and so on.

Connections R and C are mechanical rotational conserving ports that connect the block to the 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 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 Force Sensor

Ideal Rotational Motion Sensor

Ideal Translational Motion Sensor

Ideal Torque Source

Purpose

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

Library

Mechanical Sensors and Sources

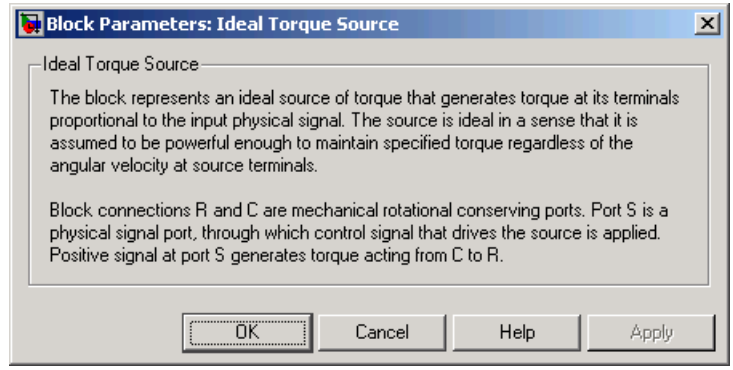
Description

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



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 Angular Velocity Source

Ideal Force Source

Ideal Translational Velocity Source

Ideal Transformer

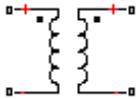
Purpose

Simulate ideal transformer in electrical systems

Library

Electrical Elements

Description



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

$$V1 = N \cdot V2$$

$$I2 = N \cdot I1$$

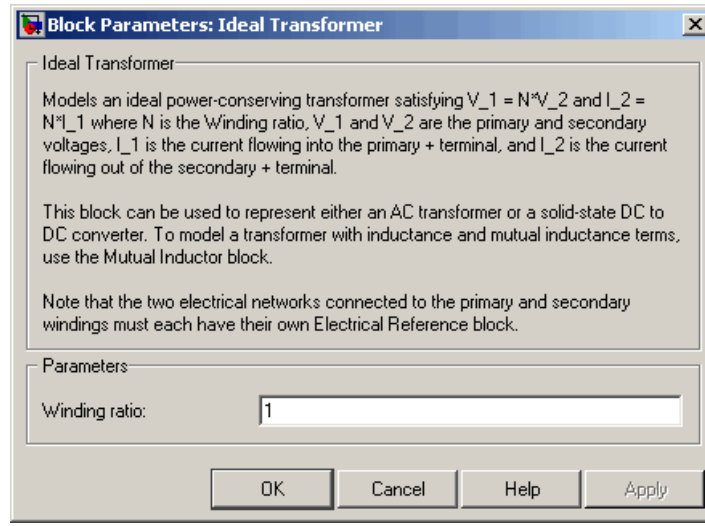
where

`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



Winding ratio

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

Ports

The block has four electrical conserving ports. Polarity is indicated by the + and – signs.

See Also

Mutual Inductor

Ideal Translational Motion Sensor

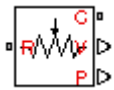
Purpose

Simulate motion sensor in mechanical translational systems

Library

Mechanical Sensors and Sources

Description



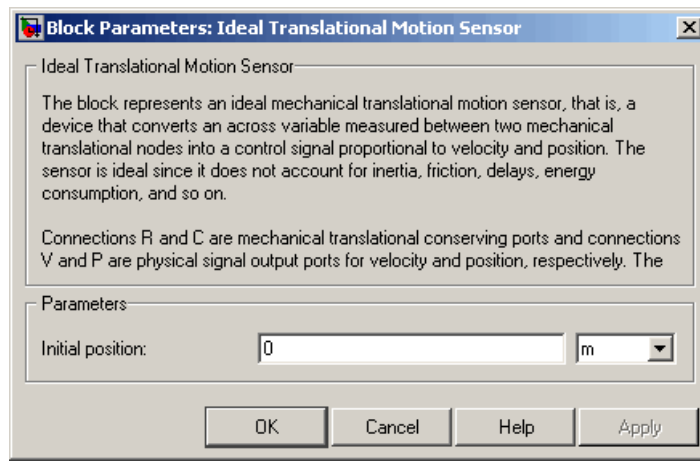
The Ideal Translational Motion Sensor block represents a device that converts an across variable measured between two mechanical translational nodes into a control signal proportional to velocity or position. You can specify the initial position (offset) as a block parameter.

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



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 Force Sensor

Ideal Rotational Motion Sensor

Ideal Torque Sensor

Ideal Translational Velocity Source

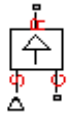
Purpose

Simulate ideal velocity source in mechanical translational systems

Library

Mechanical Sensors and Sources

Description

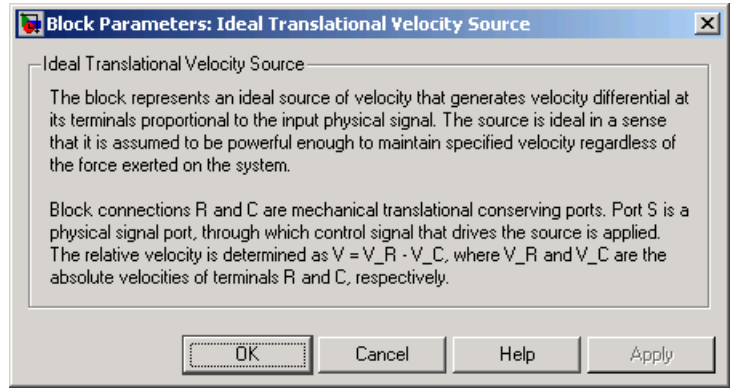


The Ideal Translational Velocity Source block represents an ideal source of velocity that generates velocity differential at its terminals proportional to the input physical signal. The source is ideal in a sense that it is assumed to be powerful enough to maintain specified velocity regardless of the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



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 Angular Velocity Source

Ideal Force Source

Ideal Torque Source

Inductor

Purpose

Simulate 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 **Initial current** parameter sets the initial current through the inductor.

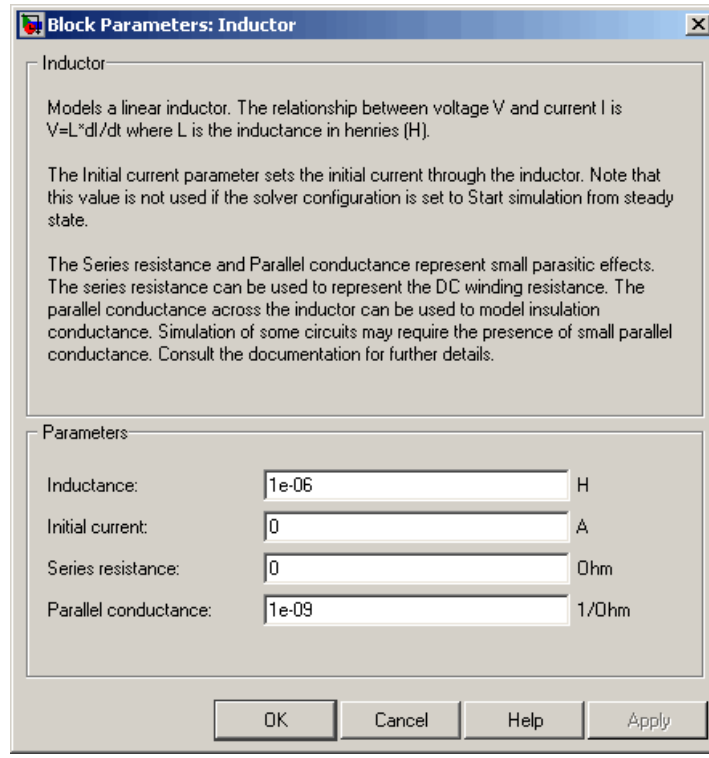
Note This value is not used if the solver configuration is set to **Start simulation from steady state**.

The **Series resistance** and **Parallel conductance** parameters represent small parasitic effects. The series resistance can be used to represent the DC winding resistance. 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. For more information, see “Modeling Best Practices” in the Simscape User’s Guide.

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



Inductance

Inductance, in henries. The default value is `1` µH.

Initial current

Initial current through the inductor. This parameter is not used if the solver configuration is set to **Start simulation from steady state**. The default value is `0`.

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.

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.

Purpose

Simulate inertia in mechanical rotational systems

Library

Mechanical Rotational Elements

Description

The Inertia block represents an ideal mechanical rotational inertia, described with the following equation:

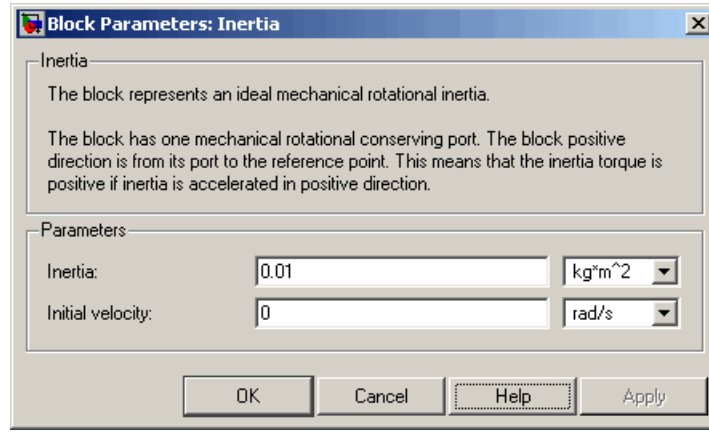
$$T = J\frac{d\omega}{dt}$$

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
Inertia. The default value is `0.001` kg*m^2.

Initial velocity
Initial angular velocity of the inertia. 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 "Computing Initial Conditions". The default value is `0`.

Ports

The block has one mechanical rotational conserving port, associated with the inertia connection to the system.

See Also

Mass

Purpose

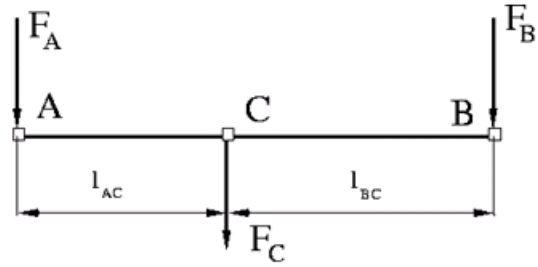
Simulate lever in mechanical systems

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

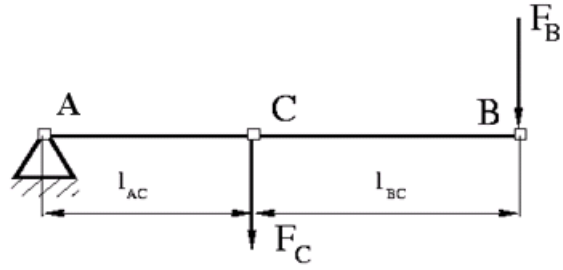
v_A, v_B, v_C Lever joints velocities

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.

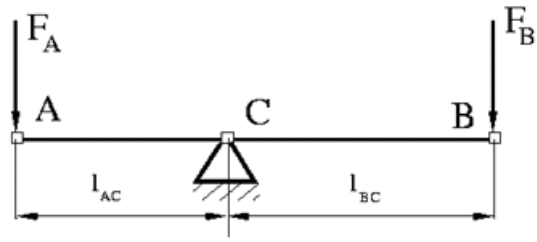


It is described with the following equations:

$$v_C = K_{BC} \cdot v_B$$

$$F_B = K_{BC} \cdot F_C$$

The next illustration shows a schematic of a second-class lever, with the fulcrum in the middle.



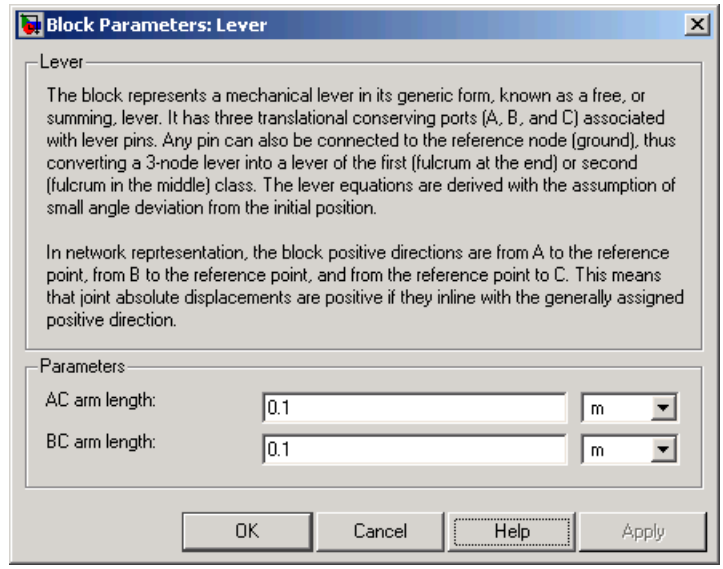
It is described with the following equations:

$$v_A = -\frac{l_{AC}}{l_{BC}} v_B$$

$$F_B = -\frac{l_{AC}}{l_{BC}} F_A$$

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



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.

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 demo (`ssc_linkage_mechanism`) 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

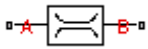
Purpose

Simulate hydraulic pipeline with linear resistance losses

Library

Hydraulic Elements

Description

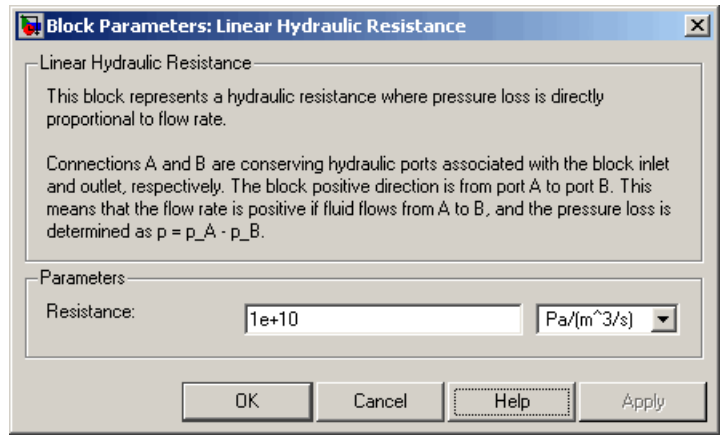


The Linear Hydraulic Resistance block represents a hydraulic resistance where pressure loss is directly proportional to flow rate. This block can be useful at preliminary stages of development, or as a powerful means to speed up the simulation, especially if the flow rate varies insignificantly with 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



Resistance

The linear resistance coefficient. The default value is `10e9` Pa/(m^3/s).

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

Resistive Tube

Mass

Purpose

Simulate mass in mechanical translational systems

Library

Mechanical Translational Elements

Description

The Mass block represents an ideal mechanical translational mass, described with the following equation:

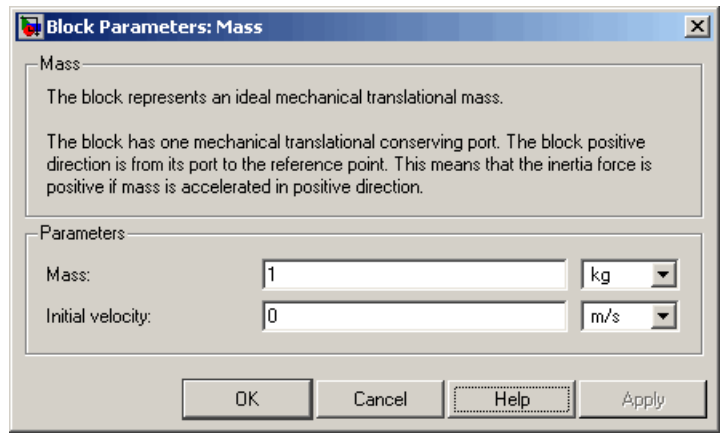
$$F = m\frac{dv}{dt}$$

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
Mass. The default value is 1 kg.

Initial velocity
Initial velocity of the mass. 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 "Computing Initial Conditions". The default value is 0.

Ports

The block has one mechanical translational conserving port, associated with the mass connection to the system.

See Also

Inertia

Mechanical Rotational Reference

Purpose

Simulate reference for mechanical rotational ports

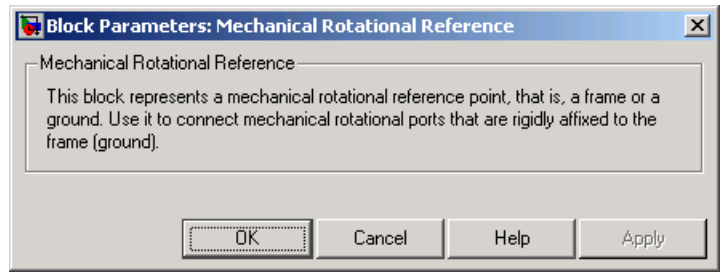
Library

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



The Mechanical Rotational Reference block has no parameters.

Ports

The block has one mechanical rotational port.

See Also

Electrical Reference

Hydraulic Reference

Mechanical Translational Reference

Purpose

Simulate reference for mechanical translational ports

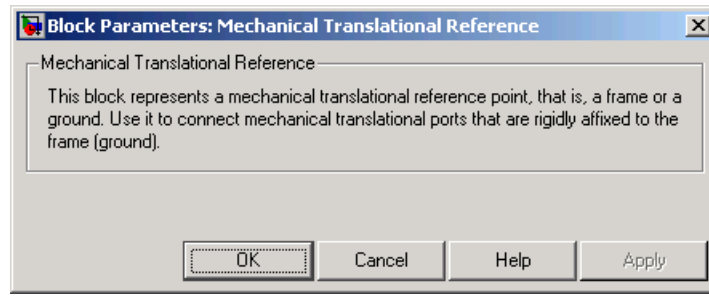
Library

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



The Mechanical Translational Reference block has no parameters.

Ports

The block has one mechanical translational port.

See Also

Electrical Reference

Hydraulic Reference

Mechanical Rotational Reference

Mutual Inductor

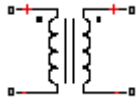
Purpose

Simulate mutual inductor in electrical systems

Library

Electrical Elements

Description



The Mutual Inductor block models a mutual inductor, described with the following equations:

$$V1 = L1\frac{dI1}{dt} + M\frac{dI2}{dt}$$

$$V2 = L2\frac{dI2}{dt} + M\frac{dI1}{dt}$$

$$M = k\sqrt{L1 \cdot L2}$$

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

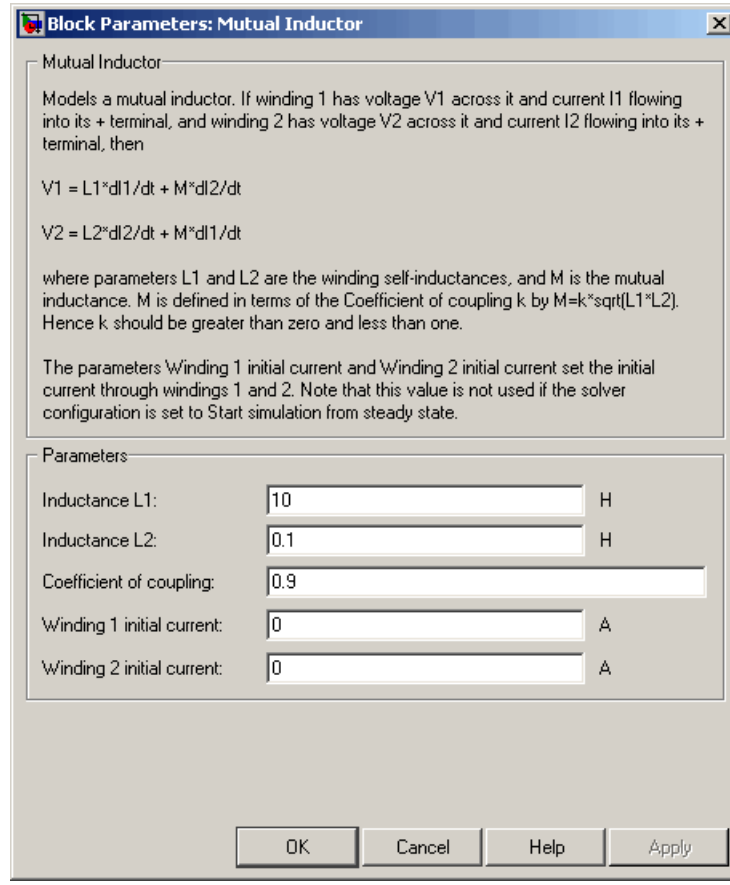
The **Winding 1 initial current** and **Winding 2 initial current** parameters set the initial current through windings 1 and 2.

Note These values are not used if the solver configuration is set to **Start simulation from steady state**.

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



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`.

Winding 1 initial current
Initial current through the first winding. This parameter is not used if the solver configuration is set to **Start simulation from steady state**. The default value is `0`.

Winding 2 initial current
Initial current through the second winding. This parameter is not used if the solver configuration is set to **Start simulation from steady state**. The default value is `0`.

Ports

The block has four electrical conserving ports. Polarity is indicated by the + and – signs.

See Also

Ideal Transformer

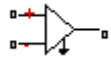
Purpose

Simulate ideal operational amplifier

Library

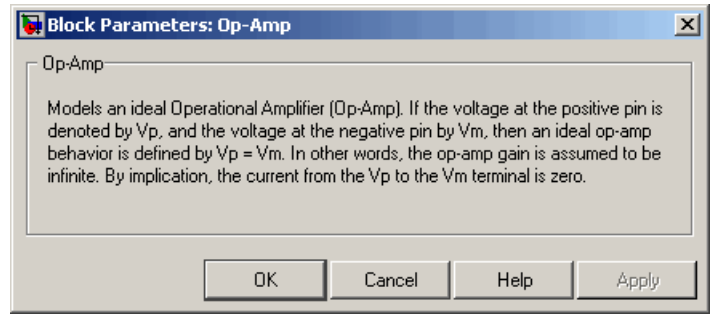
Electrical Elements

Description



The Op-Amp block 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.

Dialog Box and Parameters



The Op-Amp block has no parameters.

Ports

The block has three electrical conserving ports.

PS Add

Purpose

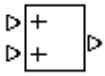
Add two physical signal inputs

Library

Physical Signals/Functions

Description

The PS Add block outputs the sum of two input physical signals:

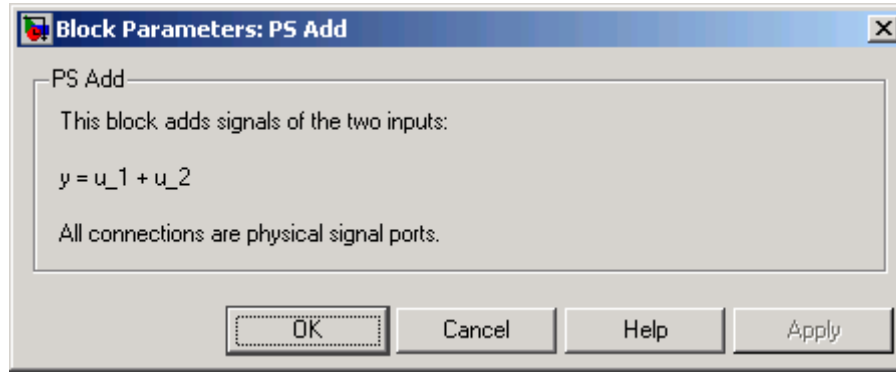


$$y = u_1 + u_2$$

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



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 Product

PS Subtract

PS Dead Zone

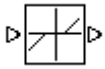
Purpose

Provide region of zero output for physical signals

Library

Physical Signals/Nonlinear Operators

Description

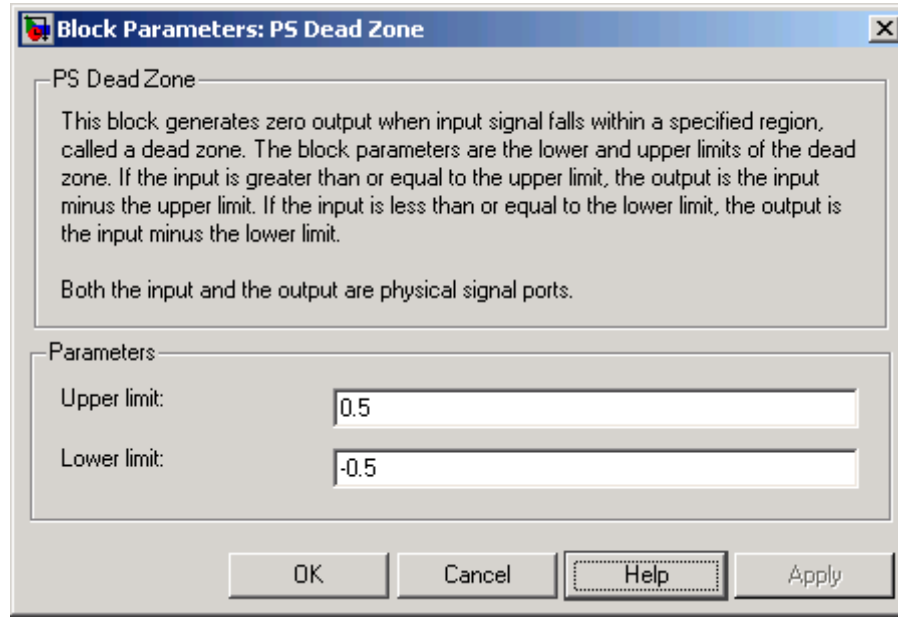


The PS Dead Zone block generates zero output when input signal falls within a specified region, called a dead zone. You can specify the lower and upper limits of the dead zone as block parameters. The block output depends on the input and dead zone:

- 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



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

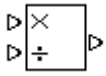
Purpose

Compute simple division of two input physical signals

Library

Physical Signals/Functions

Description



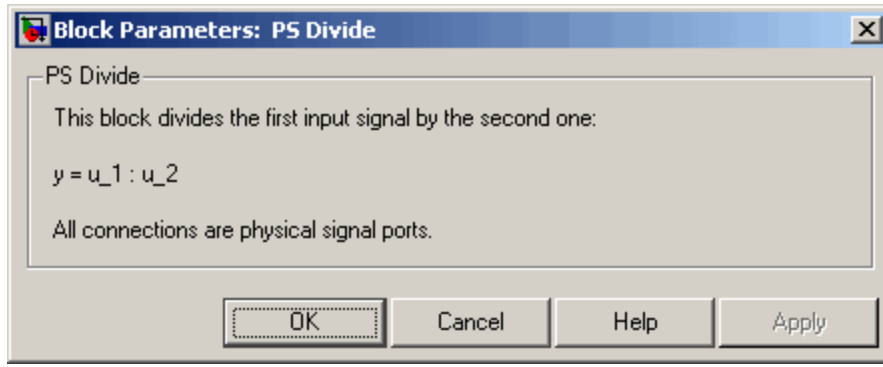
The PS Divide block divides one physical signal input by another and outputs the difference:

$$y = u_1 \div u_2$$

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



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 Product

PS Subtract

PS Gain

Purpose

Multiply input physical signal by constant

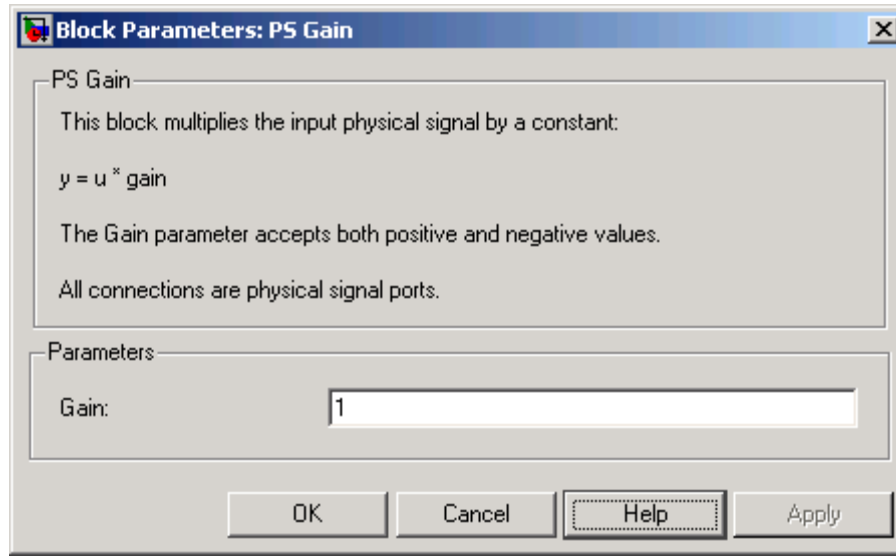
Library

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



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 Add

PS Divide

PS Product

PS Subtract

PS Integrator

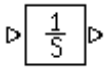
Purpose

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:

$$x = y(t)$$

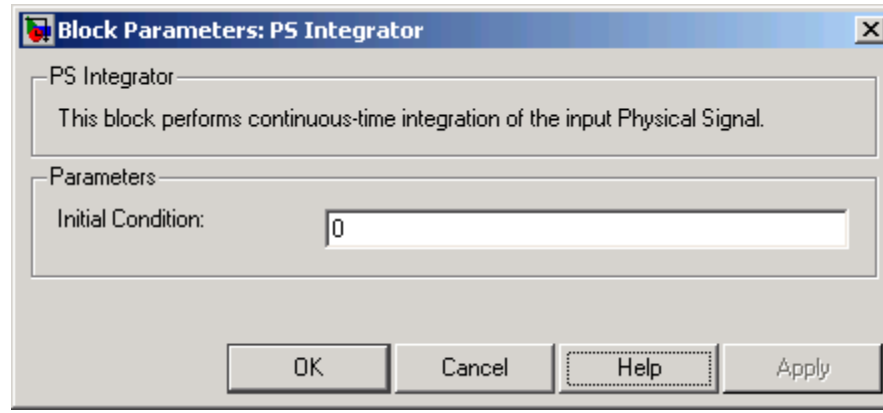
$$x_0 = y_0$$

$$\dot{x} = u(t)$$

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



Initial Condition

Specify the initial condition for use in computing the block's initial state at the beginning of a simulation run. For more information, see "Computing Initial Conditions". The default value is `0`.

Ports

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

PS Lookup Table (1D)

Purpose

Approximate one-dimensional function using specified lookup method

Library

Physical Signals/Lookup Tables

Description

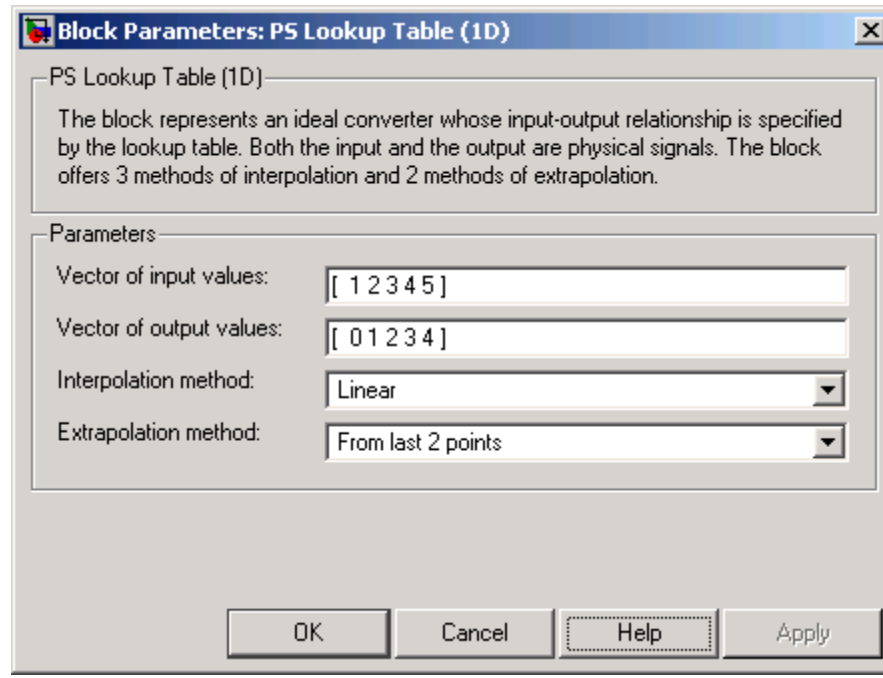
The PS Lookup Table (1D) block computes an approximation to some function `y=f(x)` given data vectors `x` and `y`. Both the input and the output are physical signals.

Note To map two physical signal inputs to an output, use the PS Lookup Table (2-D) block.

The length of the `x` and `y` data vectors provided to this block must match. Also, the `x` data vector must be *strictly monotonically increasing* (i.e., the value of the next element in the vector is greater than the value of the preceding element).

You define the lookup table by specifying the **Vector of input values** parameter as a 1-by-`n` vector and the **Vector of output values** parameter as a 1-by-`n` vector. The block generates output based on the input values using the selected interpolation and extrapolation methods. You have a choice of three interpolation methods and two extrapolation methods.

Dialog Box and Parameters



Vector of input values

Specify the vector of input values as a tabulated 1-by-n array. The input values vector must be strictly monotonically increasing. The values can be non-uniformly spaced.

Vector of output values

Specify the vector of output values as a tabulated 1-by-n array. The output values vector must be 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.

- `Cubic` — Uses the Piecewise Cubic Hermite Interpolation Polinomial (PCHIP). For more information, see [1] and the `pchip` MATLAB function.
- `Spline` — Uses the cubic spline interpolation algorithm described in [2].

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:

- `From last 2 points` — Extrapolates using the linear method (regardless of the interpolation method specified), based on the last two output values at the appropriate end of the range. That is, the block uses the first and second specified output values if the input value is below the specified range, and the two last specified output values if the input value is above the specified range.
- `From last point` — Uses the last specified output value at the appropriate end of the range. That is, the block uses the last specified output value for all input values greater than the last specified input argument, and the first specified output value for all input values less than the first specified input argument.

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.

References

[1] D. Kahaner, Cleve Moler, Stephen Nash, *Numerical Methods and Software*, Prentice Hall, 1988

[2] W.H. Press, B.P. Flannery, S.A. Teulkolsky, W.T. Wetterling, *Numerical Recipes in C: The Art of Scientific Computing*, Cambridge University Press, 1992

See Also

PS Lookup Table (2D)

PS Lookup Table (2D)

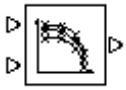
Purpose

Approximate two-dimensional function using specified lookup method

Library

Physical Signals/Lookup Tables

Description

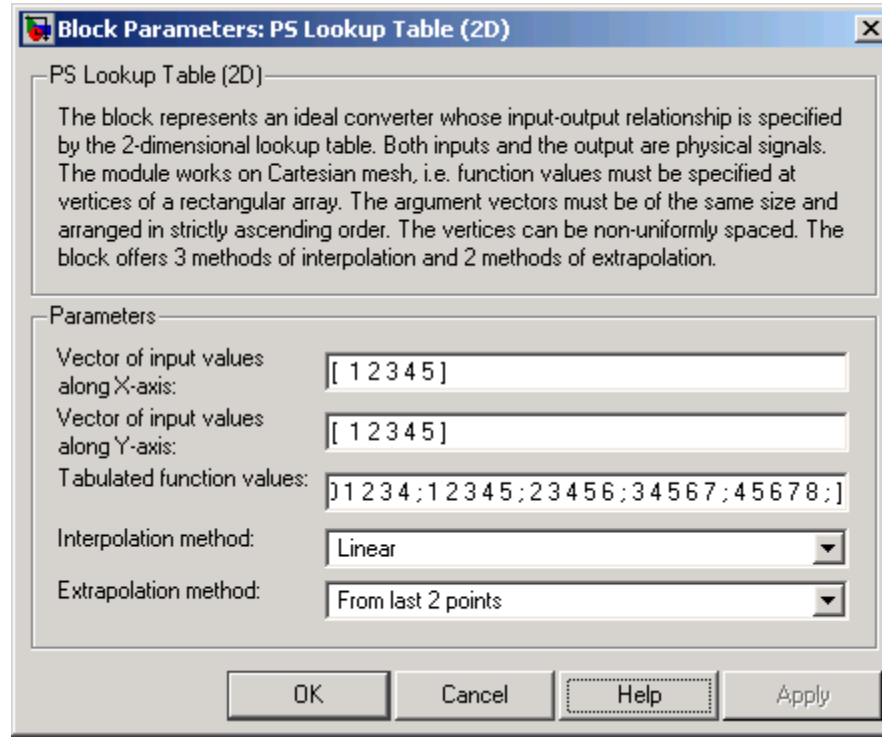


The PS Lookup Table (2D) block computes an approximation to some function `z=f(x,y)` given the `x`, `y`, `z` data points. The two inputs and the output are physical signals.

The `x` and `y` data vectors must be *strictly monotonically increasing* (i.e., the value of the next element in the vector is greater than the value of the preceding element). The matrix size of the tabulated function values must match the dimensions defined by the input vectors.

You define the lookup table by specifying the **Vector of input values along X-axis** parameter as a 1-by-`m` vector of `x` data points, the **Vector of input values along Y-axis** parameter as a 1-by-`n` vector of `y` data points, and the **Tabulated function values** as an `m`-by-`n` matrix of `z` data points. The block works on Cartesian mesh, i.e., function values must be specified at vertices of a rectangular array. The block generates output based on the input grid lookup using the selected interpolation and extrapolation methods. You have a choice of three interpolation methods and two extrapolation methods.

Dialog Box and Parameters



Vector of input values along X-axis

Specify the vector of input values along the *x*-axis as a tabulated 1-by-`m` array. The input values vector must be strictly monotonically increasing. The values can be non-uniformly spaced.

Vector of input values along Y-axis

Specify the vector of input values along the *y*-axis as a tabulated 1-by-`n` array. The input values vector must be strictly monotonically increasing. The values can be non-uniformly spaced.

Tabulated function values

Specify the output values as a tabulated `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 a bilinear interpolation algorithm, which is an extension of linear interpolation for functions in two variables. The method performs linear interpolation first in *x*-direction and then in *y*-direction.
- `Cubic` — Uses the bicubic interpolation algorithm described in [1].
- `Spline` — Uses the bicubic spline interpolation algorithm described in [1].

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:

- `From last 2 points` — Extrapolates using the linear method (regardless of the interpolation method specified) based on the last two output values at the appropriate grid location, similar to PS Lookup Table (1D) block.
- `From last point` — Uses the last specified output value at the appropriate grid location, similar to PS Lookup Table (1D) block..

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.

References

[1] W.H.Press, B.P.Flannery, S.A.Teulkolsky, W.T.Wetterling, *Numerical Recipes in C: The Art of Scientific Computing*, Cambridge University Press, 1992

See Also

PS Lookup Table (1D)

PS Product

Purpose

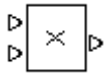
Multiply two physical signal inputs

Library

Physical Signals/Functions

Description

The PS Product block outputs the product of two input physical signals:

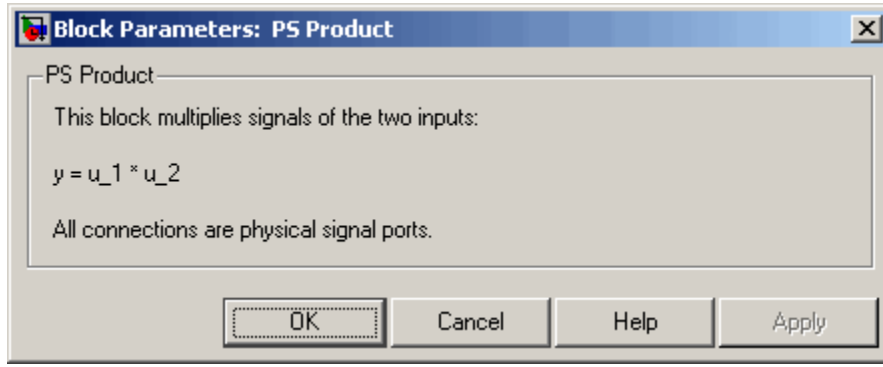


$$y = u_1 u_2$$

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



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 Add

PS Divide

PS Gain

PS Subtract

PS Saturation

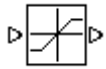
Purpose

Limit range of physical signal

Library

Physical Signals/Nonlinear Operators

Description

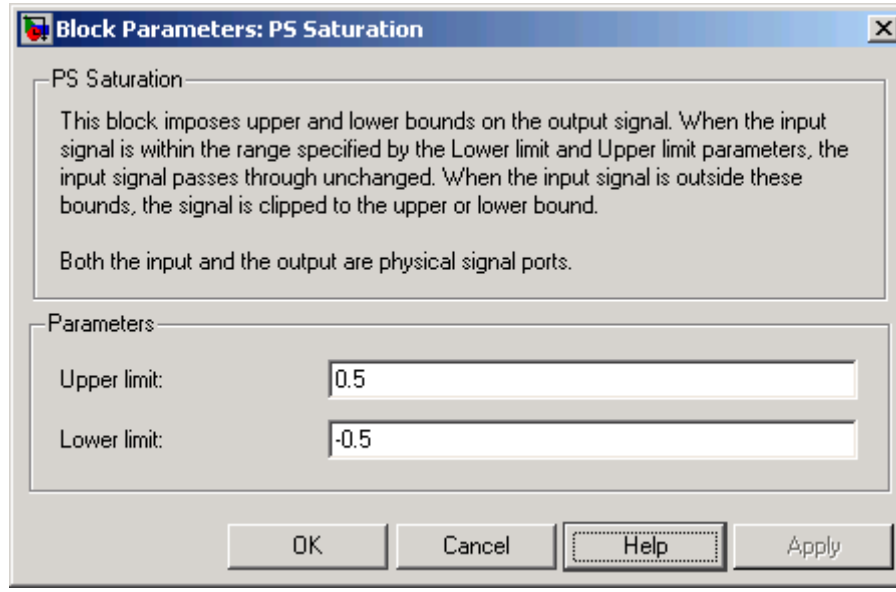


The PS Saturation block imposes upper and lower bounds on a physical signal. When the input signal is within the range specified by the **Lower limit** and **Upper limit** parameters, the input signal passes through unchanged. When the input signal is outside these bounds, the signal is clipped to the 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



Upper limit

The upper bound on the input signal. When the input signal to the 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 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 Subtract

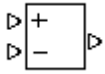
Purpose

Compute simple subtraction of two input physical signals

Library

Physical Signals/Functions

Description



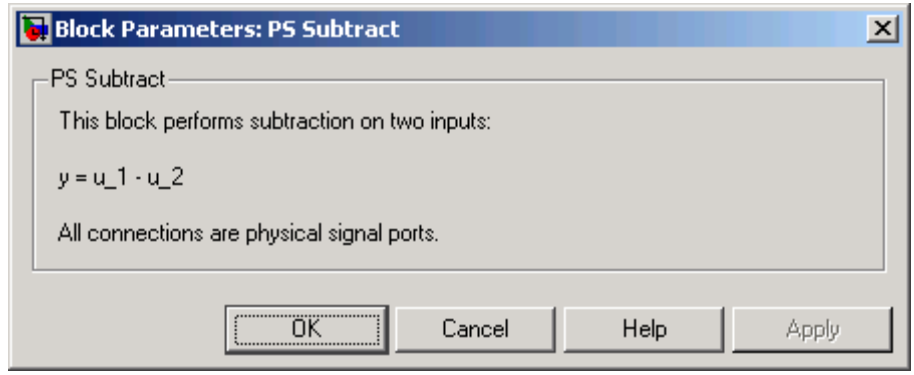
The PS Subtract block subtracts one physical signal input from another and outputs the difference:

$$y = u_1 - u_2$$

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



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 Add

PS Divide

PS Gain

PS Product

PS-Simulink Converter

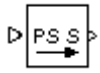
Purpose

Convert physical signal into Simulink output signal

Library

Utilities

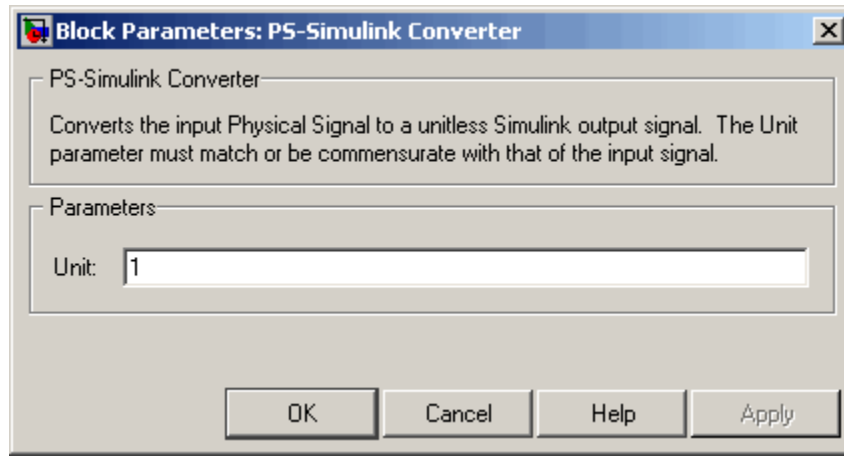
Description



The PS-Simulink Converter block converts a physical signal, in specified units, into a unitless Simulink signal. You specify the desired units as the **Unit** parameter.

Use this block to connect outputs of a Physical Network diagram to Simulink scopes or other Simulink blocks.

Dialog Box and Parameters



Unit

Units for the physical signal. You can 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 "Working with Physical Units". The system compares the units you specifies with the actual units of the input physical signal and applies a gain equal to the conversion factor before outputting the Simulink signal. 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.

Restricted Parameters

When your model is in Restricted editing mode, you cannot modify the **Unit** parameter.

Ports

The block has a physical signal input port, located on its left-hand side, and a Simulink output port, located on its right-hand side (in the block default orientation).

See Also

Simulink-PS Converter

Resistive Tube

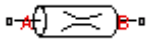
Purpose

Simulate hydraulic pipeline which accounts for friction losses only

Library

Hydraulic Elements

Description



The 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:

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

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

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

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

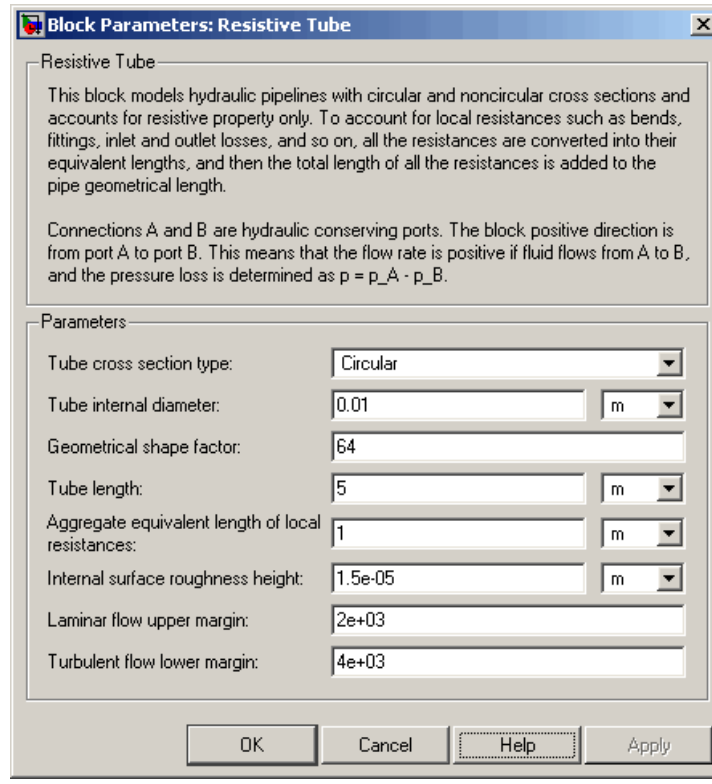
The block positive direction is from port A to port B. This means that the flow rate is positive if it flows from A to B, and the pressure loss is determined as $p = p_A - p_B$.

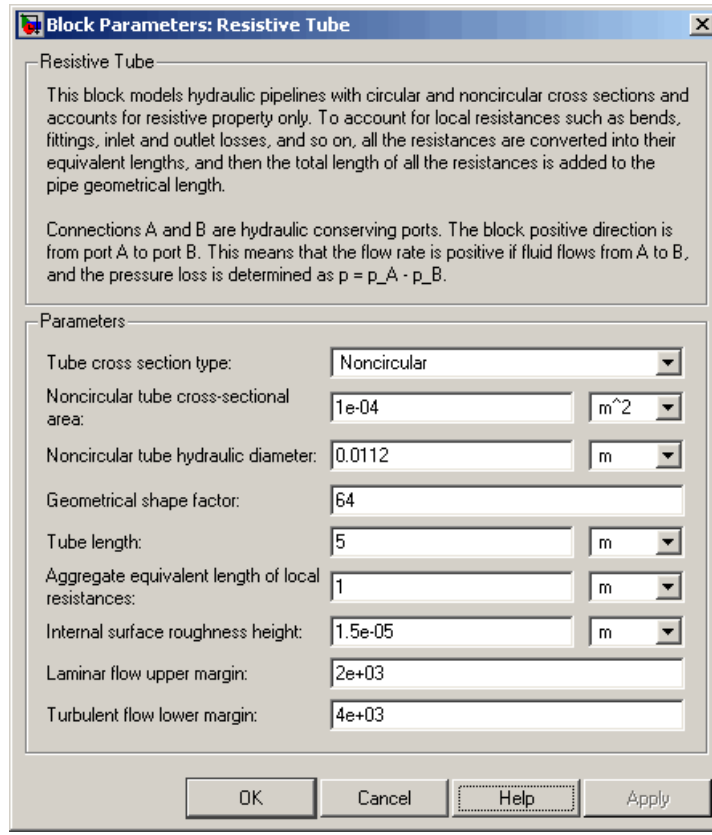
Basic Assumptions and Limitations

The model is based on the following assumptions:

- 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





Tube cross section type

The parameter can have one of two values: `Circular` or `Noncircular`. For a circular tube, you need to specify its internal diameter. For a noncircular tube, you need to 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
The parameter is used for computing friction factor at laminar flow and depends of the shape of the tube cross section. For a tube with noncircular cross section, you must 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 (see [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.

Global Parameters

Fluid density
The parameter is determined by the type of working fluid selected for the system under design. Use the Hydraulic Fluid block or the Custom Hydraulic Fluid block to specify the fluid properties.

Fluid kinematic viscosity
The parameter is determined by the type of working fluid selected for the system under design. 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

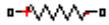
Purpose

Simulate linear resistor in electrical systems

Library

Electrical Elements

Description



The Resistor block models a linear resistor, described with the following equation:

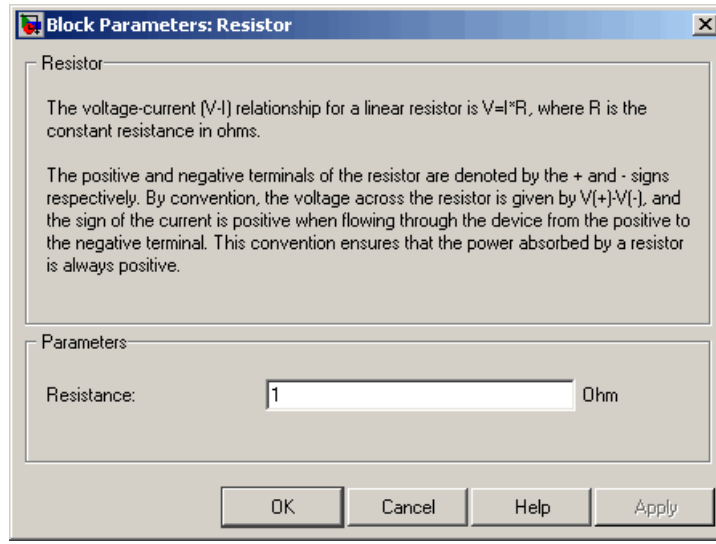
$$V = I \square R$$

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



Resistance

Resistance, in ohms. The default value is 1 Ω.

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

Variable Resistor

Purpose

Simulate 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:

$$T = D\omega$$

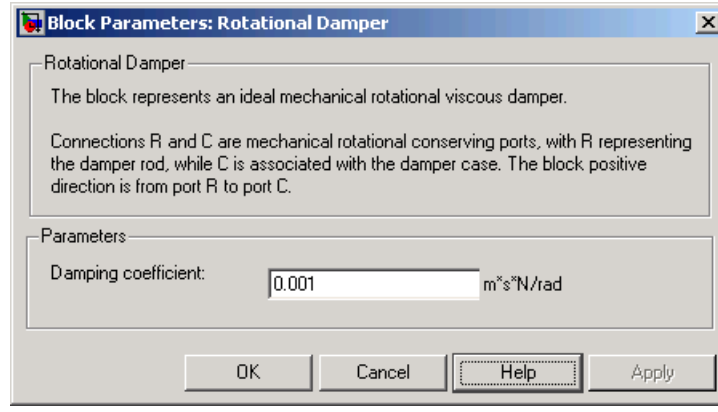
$$\omega = \omega_R - \omega_C$$

where

T	Torque transmitted through the spring
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



Damping coefficient
Damping coefficient, defined by viscose friction. The default value is `0.001` N*m/(rad/s).

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

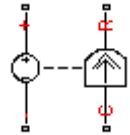
Purpose

Provide 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:

$$T = K \cdot I$$

$$V = K \cdot \omega$$

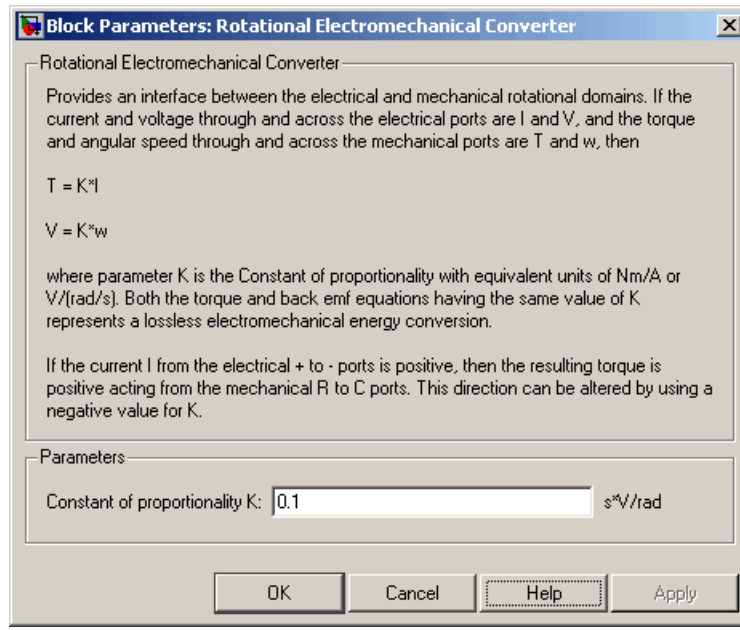
where

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



Constant of proportionality K

Constant of proportionality for electromechanical conversions. The default value is `0.1` V/(rad/s).

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 Friction

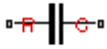
Purpose

Simulate friction in contact between rotating bodies

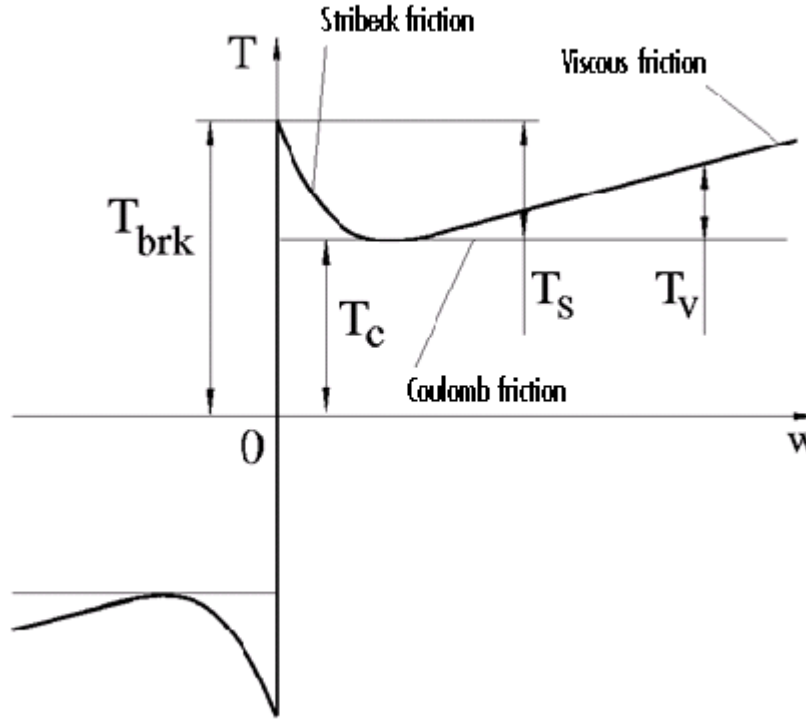
Library

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 is the negatively sloped characteristics taking place at low velocities (see [1]). The Coulomb friction results in a

constant torque at any velocity. The viscous friction 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. The friction is approximated with the following equations:

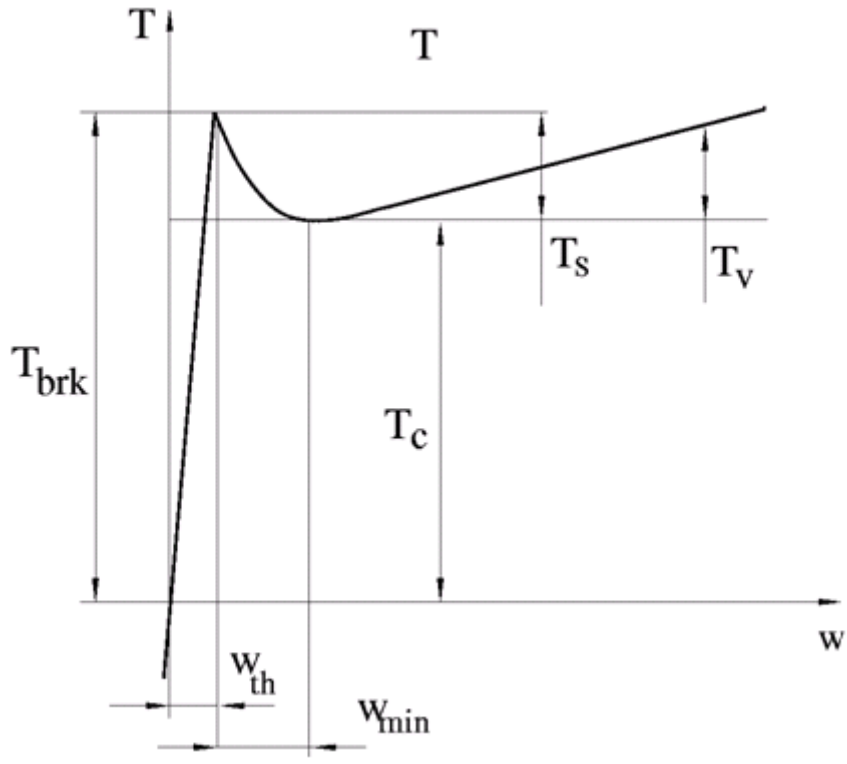
$$T = \left(T_C + \left(T_{brk} - T_C\right)\exp\left(-c_v \mid \omega \mid\right)\right) sign\left(\omega\right) + f\omega$$

$$\omega = \omega_R - \omega_C$$

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 $\omega = 0$, 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 $|\omega| >= \omega_{th}$,

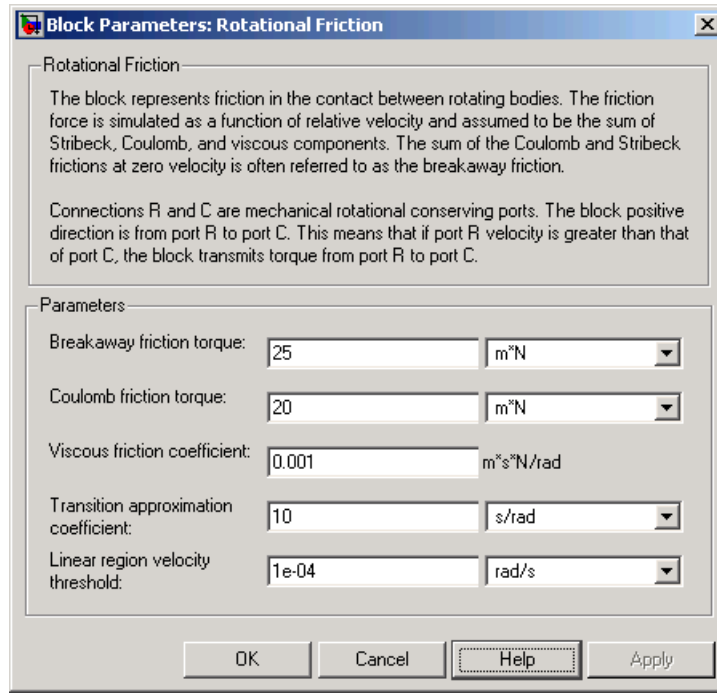
$$T = \left(T_C + (T_{brk} - T_C) \exp\left(-c_v |\omega|\right)\right) sign(\omega) + f\omega$$

- If $|\omega| < \omega_{th}$,

$$T = \omega \frac{\left(f\omega_{th} + \left(T_C + (T_{brk} - T_C) \exp\left(-c_v \omega_{th}\right)\right)\right)}{\omega_{th}}$$

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



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. The 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.

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 demo (`ssc_rot_system_stick_slip`) 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

Rotational Friction

See Also

Rotational Damper

Rotational Hard Stop

Rotational Spring

Purpose

Simulate 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:

$$T = \begin{cases} K_p \cdot \delta + D_p \left(\omega_R - \omega_C \right) & \text{for } \delta >= g_p \\ 0 & \text{for } g_n < \delta < g_p \\ K_n \cdot \delta + D_n \left(\omega_R - \omega_C \right) & \text{for } \delta <= g_n \end{cases}$$

$$\delta = \varphi_R - \varphi_C$$

$$\omega_R = \frac{d\varphi_R}{dt}$$

$$\omega_C = \frac{d\varphi_C}{dt}$$

where

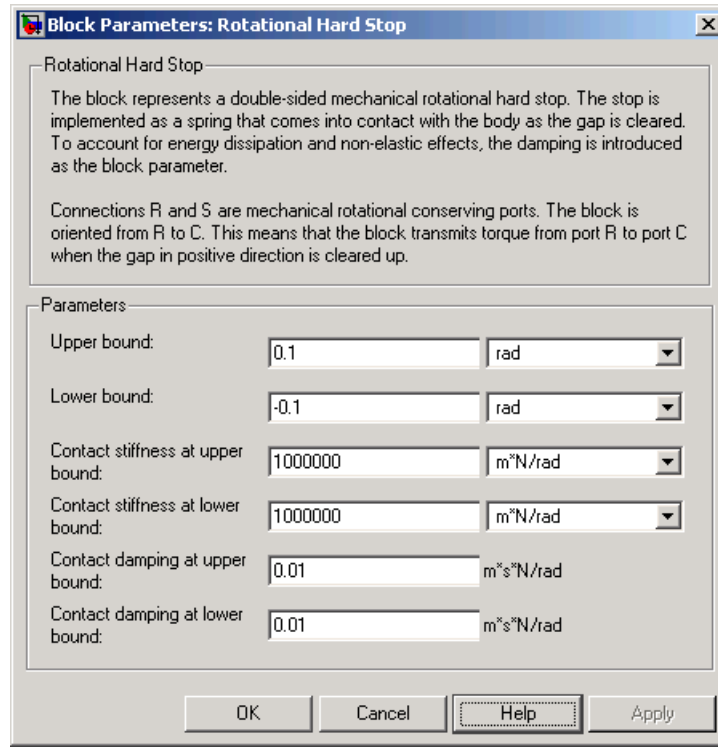
T	Interaction torque between the slider and the case
δ	Relative angular displacement between the slider and the case

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



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, The 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, The MathWorks recommends that you assign a nonzero value to this parameter. The default value is 0.01 N*m*s/rad.

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 Damper

Rotational Friction

Rotational Spring

Rotational Hydro-Mechanical Converter

Purpose

Simulate ideal hydro-mechanical transducer as building block for rotary actuators

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. Using this block as a basic element, you can build a large variety of rotary actuators by adding application-specific effects, such as fluid compressibility, leakage, friction, hard stops, and so on.

The converter is simulated according to the following equations:

$$q = D(\omega_S - \omega_C)\,or$$

$$T = D\,p\,or$$

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
F	Torque on the shaft
p	Gauge pressure of fluid in the converter chamber
or	Converter orientation with respect to the globally assigned positive direction. If pressure applied at port A generates torque in positive direction, *or* equals 1. If pressure applied at port A generates torque in negative direction, *or* equals –1.

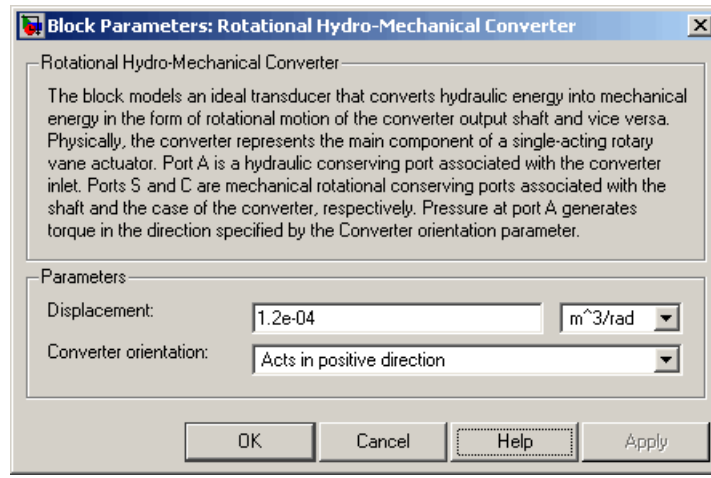
Port A is a hydraulic conserving port associated with the converter inlet. Ports S and C are mechanical rotational conserving ports associated with the shaft and the case of the converter, respectively. Pressure at port A generates torque in the direction specified by the **Converter orientation** parameter.

Basic Assumptions and Limitations

The model is based on the following assumption:

- The block simulates an ideal converter, with only the transduction property considered. No inertia, friction, leakage, or other effects are taken into account.

Dialog Box and Parameters



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`.

Restricted Parameters

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

- **Converter orientation**

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

Purpose

Simulate 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:

$$T = K\varphi$$

$$\varphi = \varphi_{init} + \varphi_R - \varphi_C$$

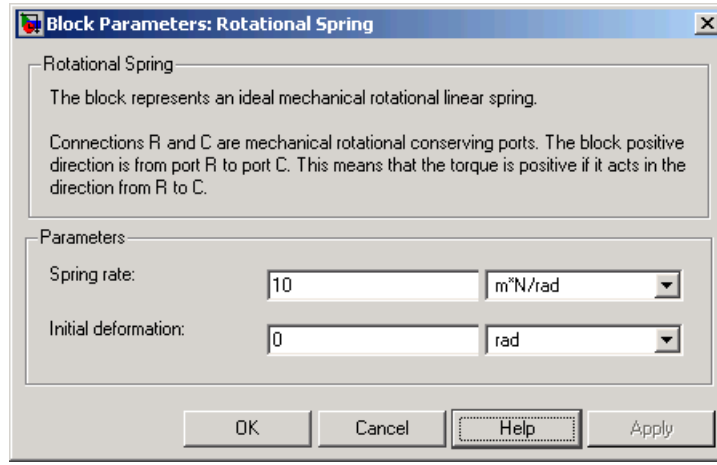
$$\omega = \frac{d\varphi}{dt}$$

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



Spring rate

Spring rate. The default value is 10 N*m/rad.

Initial deformation

Spring initial deformation, or offset, in angular units. The deformation is determined as $\phi = \phi_{init} + \phi_R - \phi_C$, where ϕ_{init} is the initial deformation, and ϕ_R,$\phi_C$are the absolute angular displacements of terminals R and C in the globally assigned positive direction. The spring can be initially compressed ($\phi_{init} > 0$) or stretched ($\phi_{init} < 0$). 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 "Computing Initial Conditions". The default value is 0.

Ports

The block has the following ports:

R

Mechanical rotational conserving port.

C

Mechanical rotational conserving port.

See Also

Rotational Damper

Rotational Friction

Rotational Hard Stop

Simulink-PS Converter

Purpose

Convert Simulink input signal into physical signal

Library

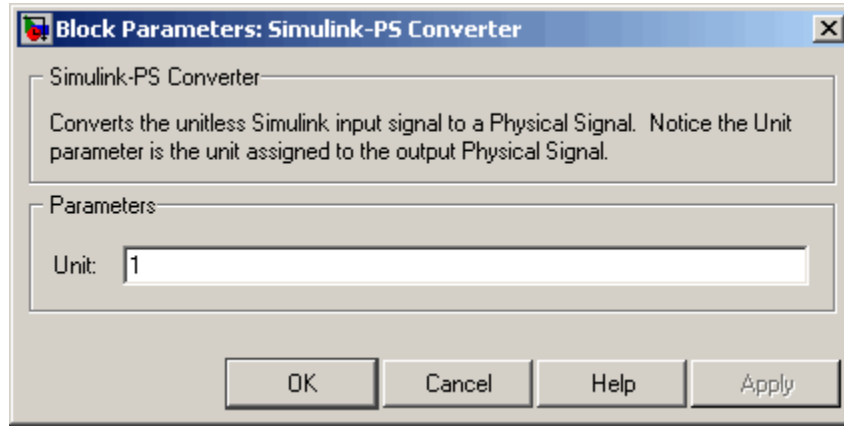
Utilities

Description

The Simulink-PS Converter block converts the input Simulink signal into a physical signal, in specified units. The input Simulink signal must be a continuous sample-time signal. You specify the desired units as the **Unit** parameter. If you leave the block unitless, with the **Unit** parameter set to `1`, then the physical signal units are inferred from the destination block. The default destination block units are meter-kilogram-second or MKS (SI).

Use this block to connect Simulink sources or other Simulink blocks to the inputs of a Physical Network diagram.

Dialog Box and Parameters



Unit

Units to be assigned to the physical signal. You can 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 "Working with Physical Units". 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.

Restricted Parameters

When your model is in Restricted editing mode, you cannot modify the **Unit** parameter.

Ports

The block has a Simulink input port, located on its left-hand side, and a physical signal output port, located on its right-hand side (in the block default orientation).

See Also

PS-Simulink Converter

Solver Configuration

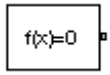
Purpose

Represent Physical Networks environment and solver configuration

Library

Utilities

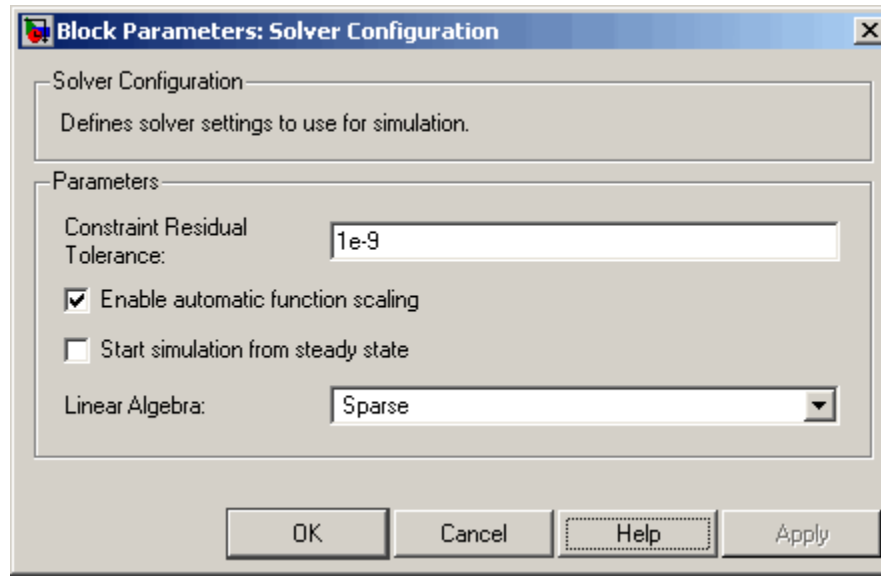
Description



Each hydro-mecahnical device represented by a connected SimHydraulics block diagram requires global environment information for simulation. The Solver Configuration block specifies this global information and connects the solver that your model needs before you can begin simulation.

Each topologically distinct SimHydraulics block diagram requires exactly one Solver Configuration block to be connected to it.

Dialog Box and Parameters



Constraint Residual Tolerance

Specify the relative tolerance. The default value is `1e-9`.

Enable automatic function scaling
Enables automatic scaling of equations at the time of transient initialization. This makes the equations more stable numerically, but it may slow down the simulation.

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 “Computing Initial Conditions”. Simulation then starts from this steady state.

Linear Algebra
Specifies how the solver treats matrices. The parameter can have one of two values: `Sparse` or `Full`. `Sparse` provides faster results. `Full` is more robust. The default value of the parameter is `Sparse`.

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.

Switch

Purpose

Simulate switch controlled by external physical signal

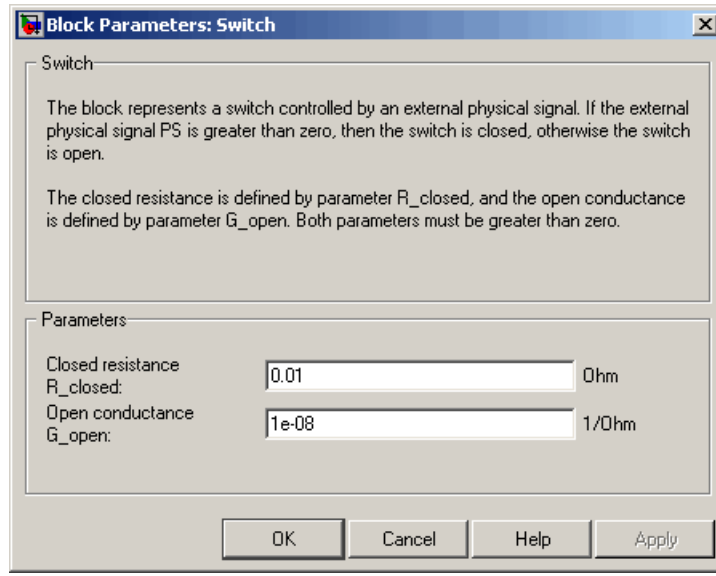
Library

Electrical Elements

Description

The Switch block models a switch controlled by an external physical signal. If the external physical signal PS is greater than zero, then the switch is closed, otherwise the switch is open.

Dialog Box and Parameters



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.

Ports

The block has two electrical conserving ports and one physical signal port PS.

Translational Damper

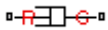
Purpose

Simulate 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:

$$F = Dv$$

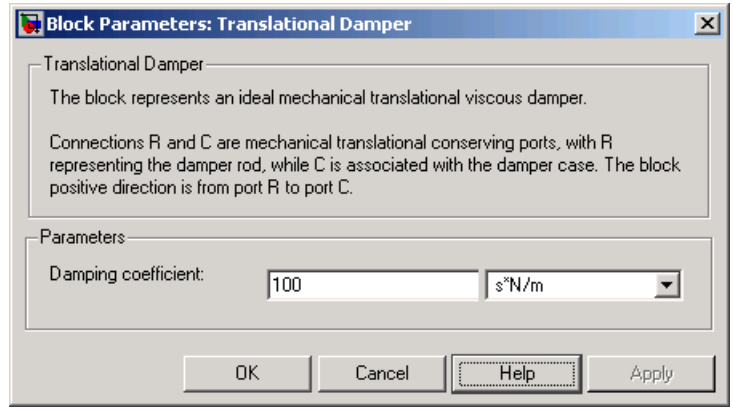
$$v = v_R - v_C$$

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



Damping coefficient

Damping coefficient, defined by viscose friction. The default value is 100 N/(m/s).

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

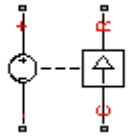
Purpose

Provide 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:

$$F = K \cdot I$$

$$V = K \cdot U$$

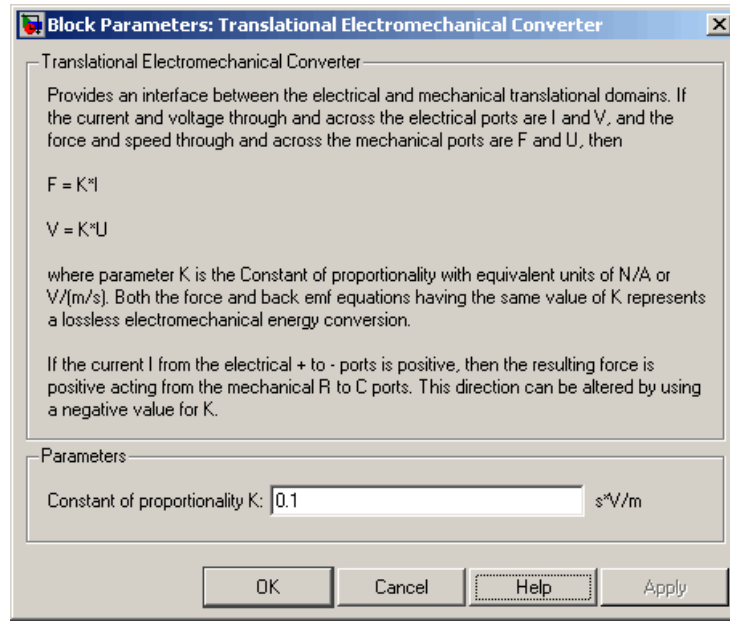
where

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



Constant of proportionality K

Constant of proportionality for electromechanical conversions. The default value is `0.1` V/(m/s).

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

Purpose

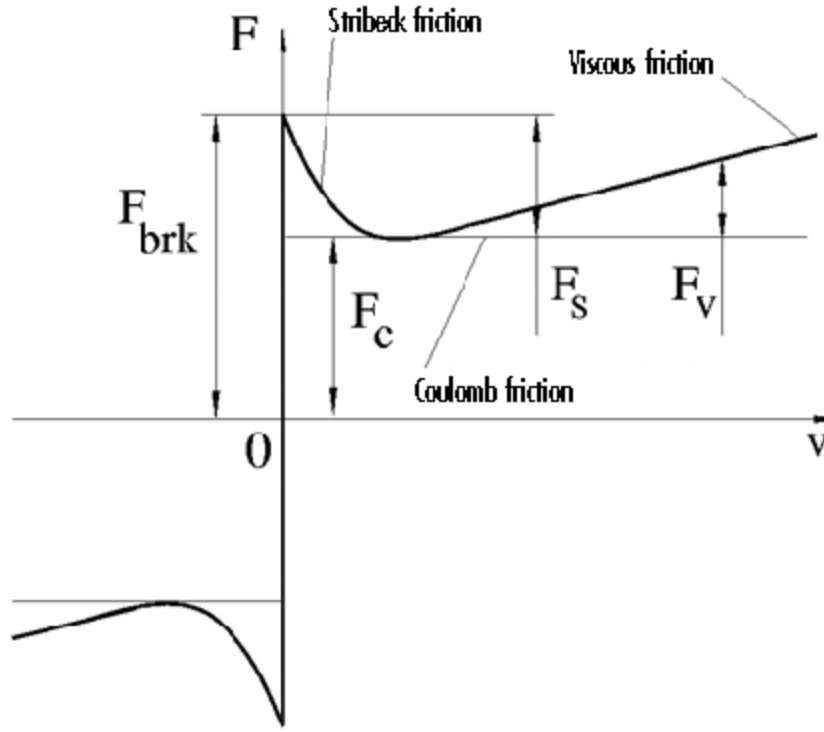
Simulate friction in contact between moving bodies

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 is the negatively sloped characteristics taking place at low velocities (see [1]). The Coulomb friction results in a

constant force at any velocity. The viscous friction 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. The friction is approximated with the following equations:

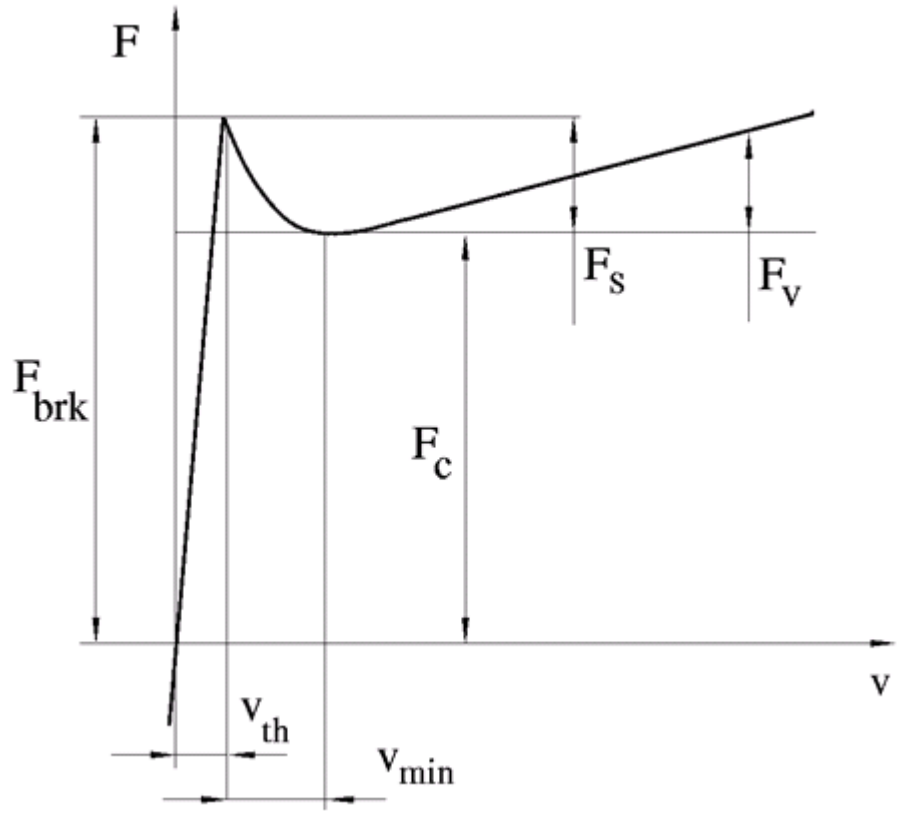
$$F = \left(F_C + \left(F_{brk} - F_C\right)\exp\left(-c_v \mid v \mid\right)\right) sign\left(v\right) + fv$$

$$v = v_R - v_C$$

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 $|v| >= v_{th}$,

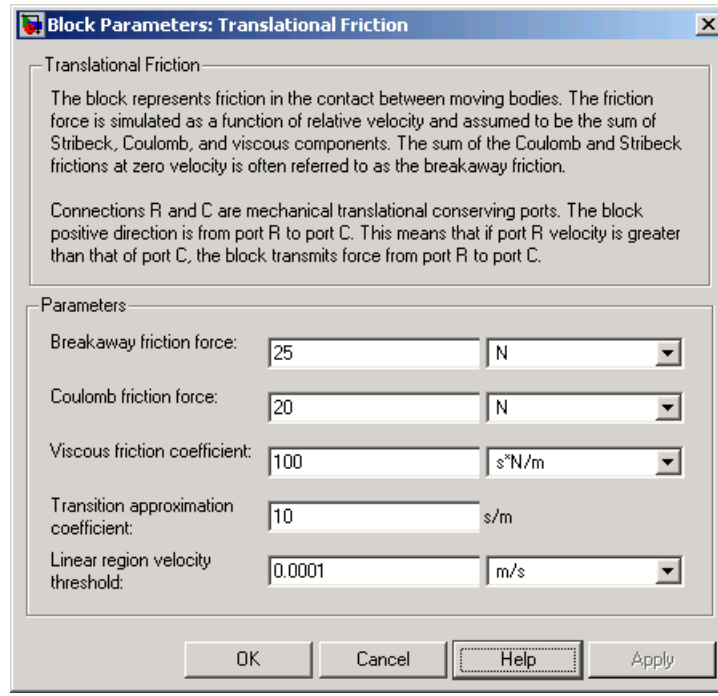
$$F = \left(F_C + \left(F_{brk} - F_C\right)\exp\left(-c_v\,|v|\right)\right)sign(v) + fv$$

- If $|v| < v_{th}$,

$$F = v\frac{\left(fv_{th} + \left(F_C + \left(F_{brk} - F_C\right)\exp\left(-c_v v_{th}\right)\right)\right)}{v_{th}}$$

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



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 $c_v \sim= 4/v_{min}$, 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. The 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.

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

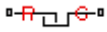
Purpose

Simulate double-sided translational hard stop

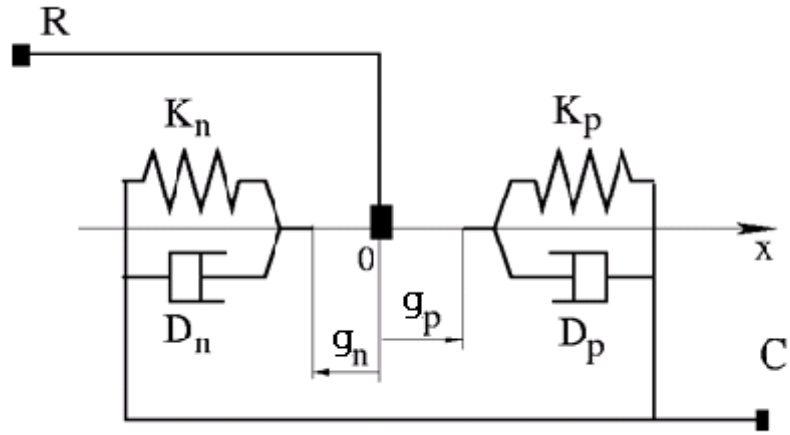
Library

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

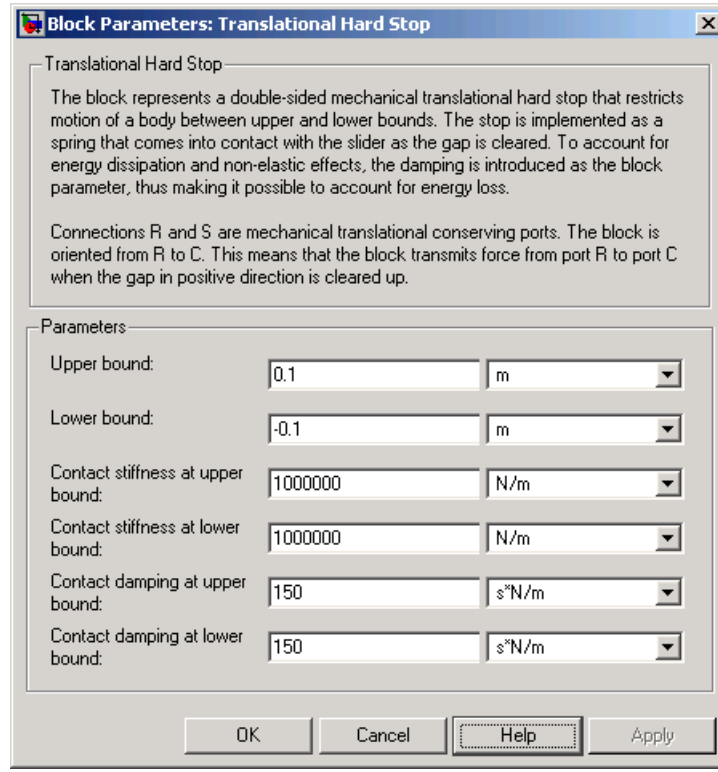
F	Interaction force between the slider and the case
δ	Relative displacement between the slider and the case
g_p	Gap between the slider and the case in positive direction
g_n	Gap between the slider and the case in negative direction
v_R, v_C	Absolute velocities of terminals R and C, respectively
x_R, 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



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 `0.005` 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 `-0.005` 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 `10e6` 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 `10e6` 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, The 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, The MathWorks recommends that you assign a nonzero value to this parameter. The default value is 150 N*s/m.

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 demo (`ssc_mechanical_system_translational_hardstop`) 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

Purpose

Simulate single chamber of hydraulic cylinder as building block for various cylinder models

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. Using this block as a basic element, you can build a large variety of hydraulic cylinder models by adding application-specific effects, such as fluid compressibility, leakage, friction, hard stops, and so on.

The converter is simulated according to the following equations:

$$q = A(v_R - v_C)\,or$$

$$F = A\,p\,or$$

where

q	Flow rate due to fluid compressibility
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
or	Converter orientation with respect to the globally assigned positive direction. If pressure applied at port A exerts force in positive direction, *or* equals 1. If pressure applied at port A exerts force in negative direction, *or* equals –1.

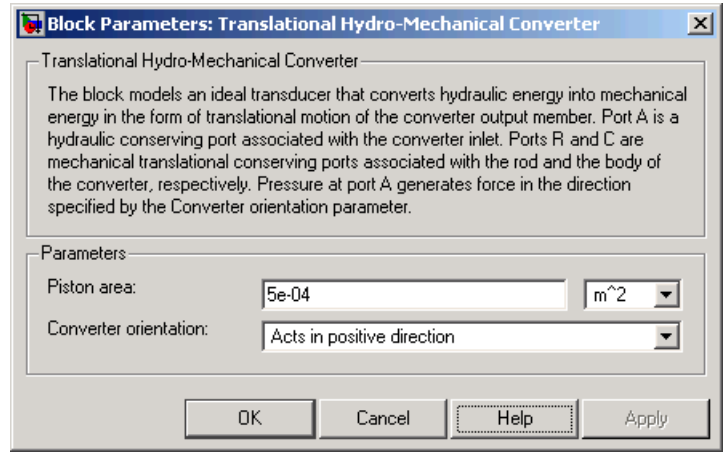
Port A is a hydraulic conserving port associated with the converter inlet. Ports R and C are translational mechanical conserving ports associated with the rod and the case of the converter, respectively.

Basic Assumptions and Limitations

The model is based on the following assumption:

- The block simulates an ideal converter, with only the transduction property considered. No inertia, friction, leakage, or other effects are taken into account.

Dialog Box and Parameters



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`.

Restricted Parameters

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

- **Converter orientation**

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.

Examples

The Closed-Loop Circuit with 4-Way Valve and Custom Cylinder demo (`sh_closed_loop_circuit_4_way_valve_cust_cyl`) and the Hydraulic Flapper-Nozzle Amplifier demo (`sh_hydraulic_flapper_nozzle_amplifier`) illustrate the use of the Translational Hydro-Mechanical Converter block in hydraulic systems.

See Also

Rotational Hydro-Mechanical Converter

Purpose

Simulate 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:

$$F = Kx$$

$$x = x_{init} + x_R - x_C$$

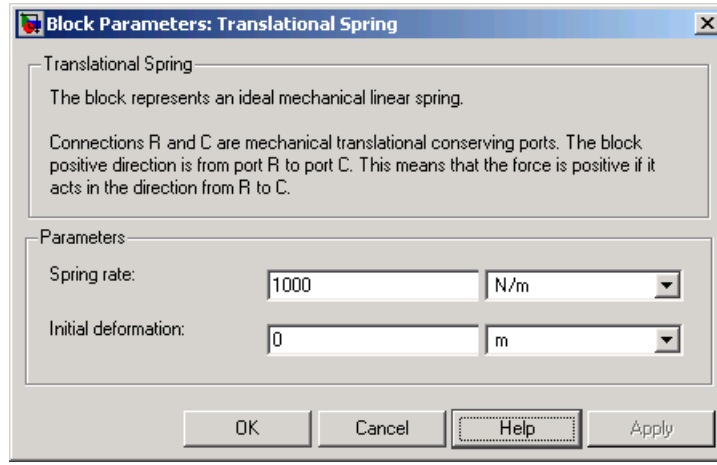
$$v = \frac{dx}{dt}$$

where

F	Force transmitted through the spring
K	Spring rate
x	Relative displacement (spring deformation)
x_{init}	Spring initial displacement (spring offset)
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



Spring rate

Spring rate. The default value is 1000 N/m.

Initial deformation

Spring initial deformation, or offset, in length units. The deformation is determined as $x = x_{init} + x_R - x_C$, where x_{init} is the initial deformation, andx_R, x_C are the absolute displacements of terminals R and C in the globally assigned positive direction. The spring can be initially compressed ($x_{init} > 0$) or stretched ($x_{init} < 0$). 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 "Computing Initial Conditions". The default value is 0.

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-Way Connection

Purpose

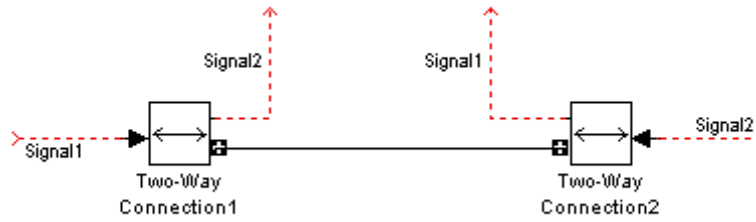
Create two-way connector port for subsystem

Library

Utilities

Description

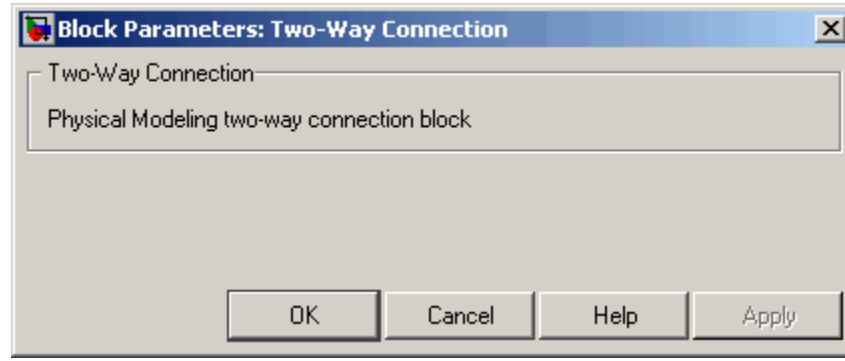
The Two-Way Connection block has a two-way connector port, which transports Simulink signals both ways. You connect this port to another two-way connector port. The schematic below illustrates how the two-way connection works. It carries the signal `Signal1` from the input port of the first Two-Way Connection 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



The block has no parameters.

Ports

The block has a Simulink input port, a Simulink output port, and a two-way connector port.

See Also

In the Using Simulink documentation, see “Creating Block Masks”.

Variable Area Orifice

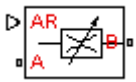
Purpose

Simulate hydraulic variable orifice created by cylindrical spool and sleeve

Library

Hydraulic Elements

Description



The Variable Area 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 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:

$$q = \begin{cases} C_D \cdot A \sqrt{\frac{2}{\rho} |p|} \cdot sign(p) & \text{for } Re >= Re_{cr} \\ 2 C_{DL} \cdot A \frac{D_H}{\nu \cdot \rho} p & \text{for } Re < Re_{cr} \end{cases}$$

$$p = p_A - p_B$$

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

$$C_{DL} = \left(\frac{C_D}{\sqrt{\mathrm{Re}_{cr}}} \right)^2$$

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

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, provided through the signal port
D_H	Orifice hydraulic diameter
ρ	Fluid density
ν	Fluid kinematic viscosity

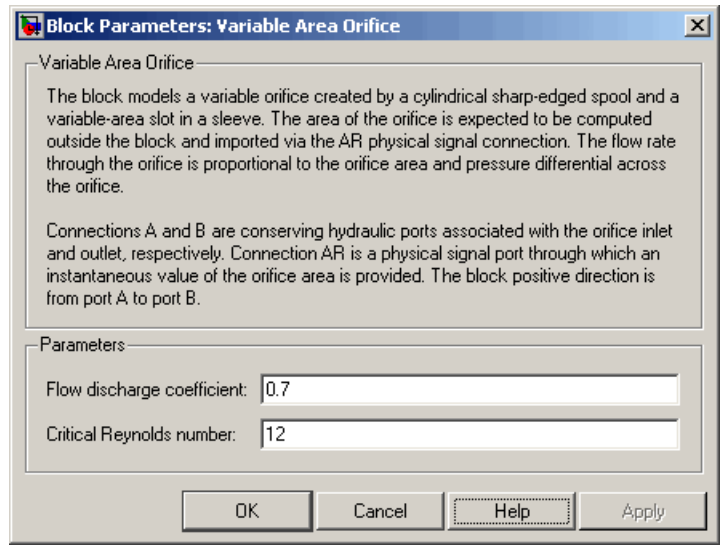
The block positive direction is from port A to port B. This means that the flow rate is positive if it flows from A to B and the pressure differential is determined as $p = p_A - p_B$.

Basic Assumptions and Limitations

The model is based on the following assumptions:

- Fluid inertia is not taken into account.
- The transition between laminar and turbulent regimes is assumed to be sharp and taking place exactly at $Re=Re_{cr}$.

Dialog Box and Parameters



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 supposed to take place when the Reynolds number reaches this value. The value of the parameter depends on orifice geometrical profile, and the recommendations on the parameter value can be found in hydraulic textbooks. The default value is `12`, which corresponds to a round orifice in thin material with sharp edges.

Global Parameters

Fluid density

The parameter is determined by the type of working fluid selected for the system under design. Use the Custom Hydraulic Fluid

block, or the Hydraulic Fluid block available with SimHydraulics, to specify the fluid properties.

Fluid kinematic viscosity
The parameter is determined by the type of working fluid selected for the system under design. Use the Custom Hydraulic Fluid block, or the Hydraulic Fluid block available with SimHydraulics, 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 Orifice

Variable Resistor

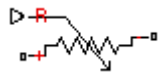
Purpose

Simulate linear variable resistor in electrical systems

Library

Electrical Elements

Description



The Variable Resistor block models a linear variable resistor, described with the following equation:

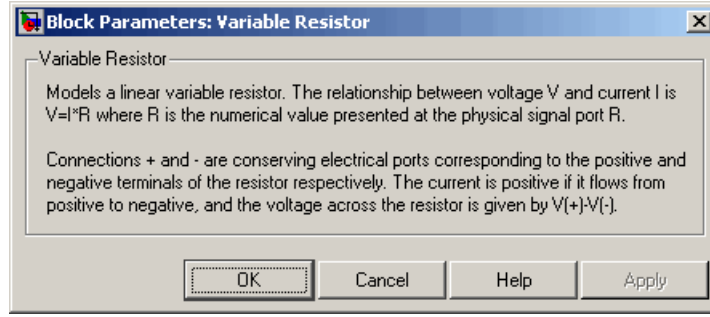
$$V = I \square R$$

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



The block has no parameters.

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

Variable Volume Chamber

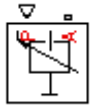
Purpose

Simulate hydraulic capacity of variable volume with compressible fluid

Library

Hydraulic Elements

Description



The Variable Volume Chamber block models fluid compressibility in variable volume chambers, such as hydraulic cylinder cavities. 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 Volume 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:

$$q = \frac{V_0 + A \cdot x \cdot or}{E} \cdot \frac{dp}{dt}$$

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

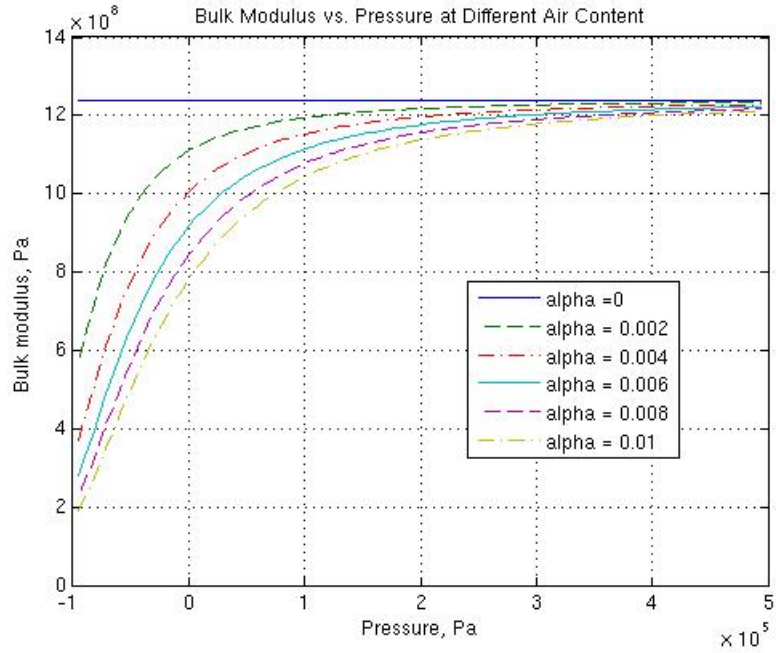
where

q	Flow rate due to fluid compressibility
V_0	Initial volume of fluid in the chamber
A	Effective piston area
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_1	Pure liquid bulk modulus
p	Gauge pressure of fluid in the chamber
p_α	Atmospheric pressure
α	Relative gas content at atmospheric pressure, $\alpha = V_G/V_L$
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 in SimHydraulics. 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 it is known that cavitation is unlikely in the system under design, you can set the relative gas content in the fluid properties to zero, thus increasing the speed of computations.

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

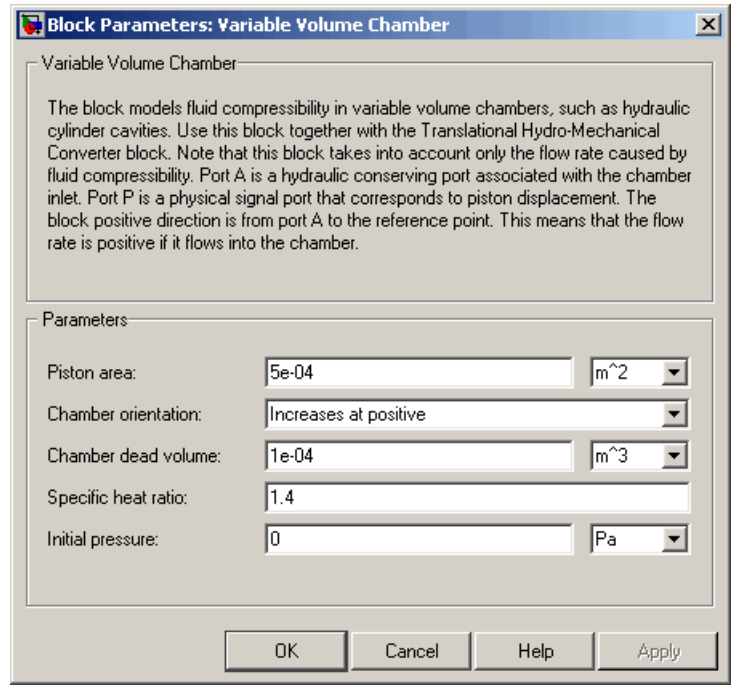
The block positive direction is from port A to the reference point. This means that the flow rate is positive if it flows into the chamber.

Basic Assumptions and Limitations

The model is based on the following assumptions:

- Fluid density remains constant.
- Fluid fills the entire chamber volume.

Dialog Box and Parameters



Piston area

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

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 `Decreases at positive`. The default value is `Increases at positive`.

Chamber dead volume
Volume of fluid in the chamber at initial 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. For more information, see "Computing Initial Conditions". The default value is `0`.

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.

Global Parameters

Fluid bulk modulus
The parameter is determined by the type of working fluid selected for the system under design. Use the Hydraulic Fluid block or the Custom Hydraulic Fluid block to specify the fluid properties.

Nondissolved gas ratio
Nondissolved gas relative content determined as a ratio of gas volume to the liquid volume. The parameter is determined by the type of working fluid selected for the system under design. 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.

Examples

The Variable Volume Chamber Test Rig demo (`sh_variable_chamber_test_rig`) is specifically designed to demonstrate the Variable Volume Chamber block behavior at different regimes. Each chamber is installed between two equal fixed-area orifices. The top chamber is set to increase its volume with the piston motion in positive direction, while the bottom chamber volume decreases at the same time.

See Also

Constant Volume Chamber

Translational Hydro-Mechanical Converter

Voltage-Controlled Current Source

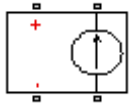
Purpose

Simulate 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:

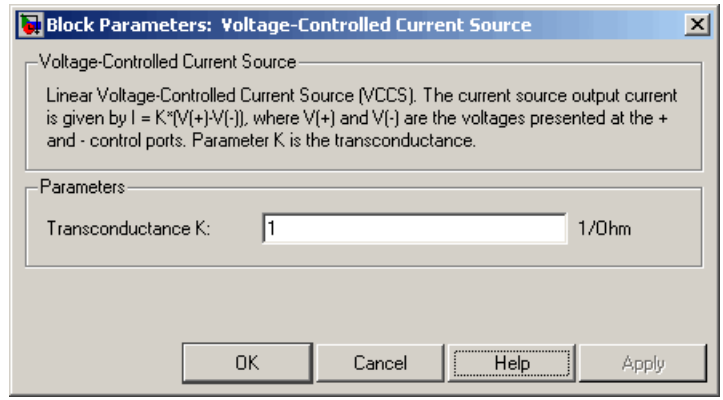
$$I = K\left(V(+) - V(-)\right)$$

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



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.

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

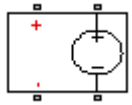
Purpose

Simulate 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:

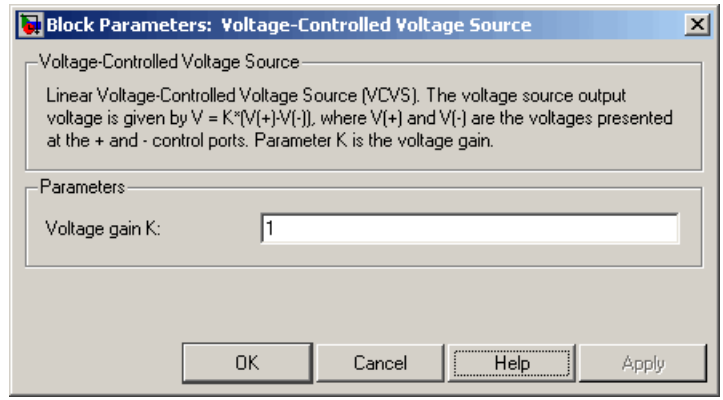
$$V = K\,(V(+) - V(-))$$

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 gain K

The change in the output voltage divided by the change in the control voltage that causes it. The default value is 1.

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

Purpose

Simulate voltage sensor in electrical systems

Library

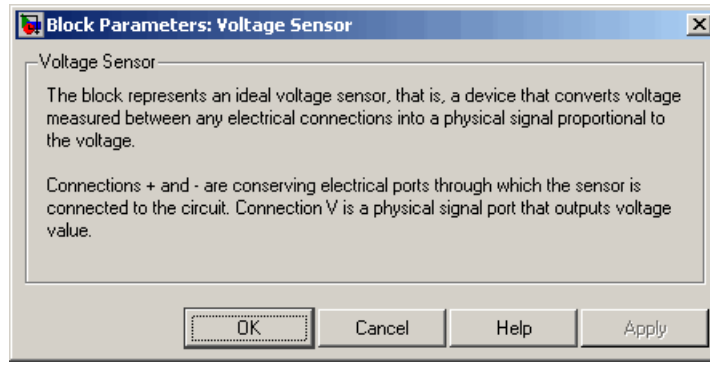
Electrical Sensors

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



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

Wheel and Axle

Purpose

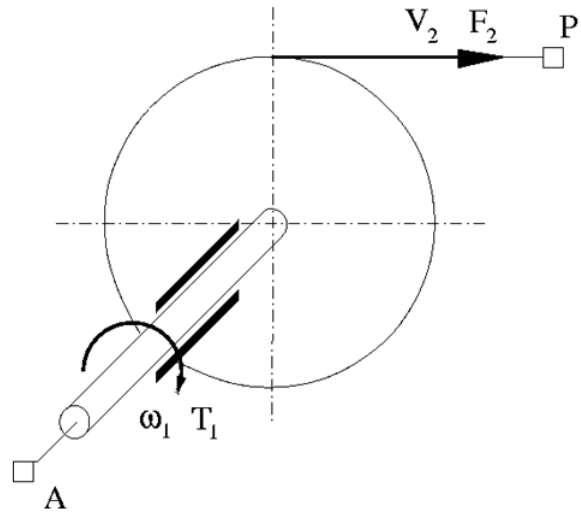
Simulate wheel and axle mechanism in mechanical systems

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:

$$T = r \cdot F \cdot or$$

$$v = r \cdot \omega \cdot or$$

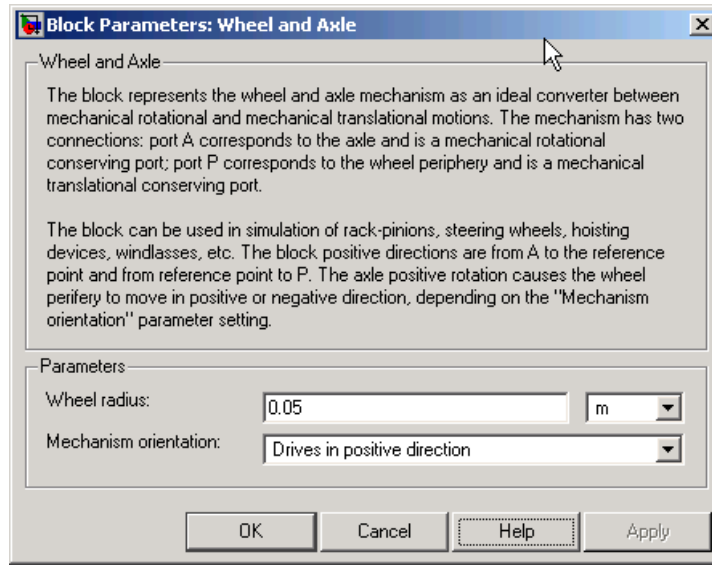
where

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 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.

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 demo (`ssc_simple_mechanical_system`) illustrates the use of the Wheel and Axle block in mechanical systems.

See Also

Gear Box

3

Commands — Alphabetical List

`pm_adddimension`	Add new dimension to unit registry
`pm_addunit`	Add new unit to unit registry
`pm_getunits`	Get information about all units in unit registry

pm_adddimension

Purpose

Add new dimension to unit registry

Syntax

```
pm_adddimension(dimension, unitname)
```

Description

`pm_adddimension(dimension, unitname)` adds a new dimension named `dimension` with a fundamental unit, `unitname`. `dimension` may be any string. `unitname` must be a valid unit name, that is, it must begin with a letter and contain only letters and numbers.

Examples

Add a new unit dimension, `length`, with a fundamental unit of meter, `m`:

```
pm_adddimension('length', 'm');
```

See Also

`pm_addunit`, `pm_getunits`

Purpose

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`. `conversion` must be a positive real scalar, and `unitexpression` must be a valid unit expression in terms of units already defined in the unit registry.

The new unit name, `unitname`, must be a valid unit name, that is, it must begin with a letter and contain only letters and numbers.

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');
```

See Also

`pm_adddimension`, `pm_getunits`

pm_getunits

Purpose

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'
    'rad'
    'cm'
    'mm'
    'km'
    'in'
    'ft'
    'mi'
    'yd'
    'l'
    'gal'
    'g'
    'mg'
    'lbm'
    'oz'
    'slug'
    'N'
```

```
'lbf'
'dyn'
'lb'
'min'
'hr'
'deg'
'rev'
'mph'
'fpm'
'fps'
'rpm'
'J'
'Btu'
'W'
'HP'
'V'
'A'
'F'
'H'
'Ohm'
'Pa'
'bar'
'psi'
'atm'
'lpm'
'gpm'
'Poise'
'cP'
'reyn'
'St'
'cSt'
'Newt'
```

See Also

pm_adddimension, pm_addunit

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