Simscape™ Multibody™

Reference
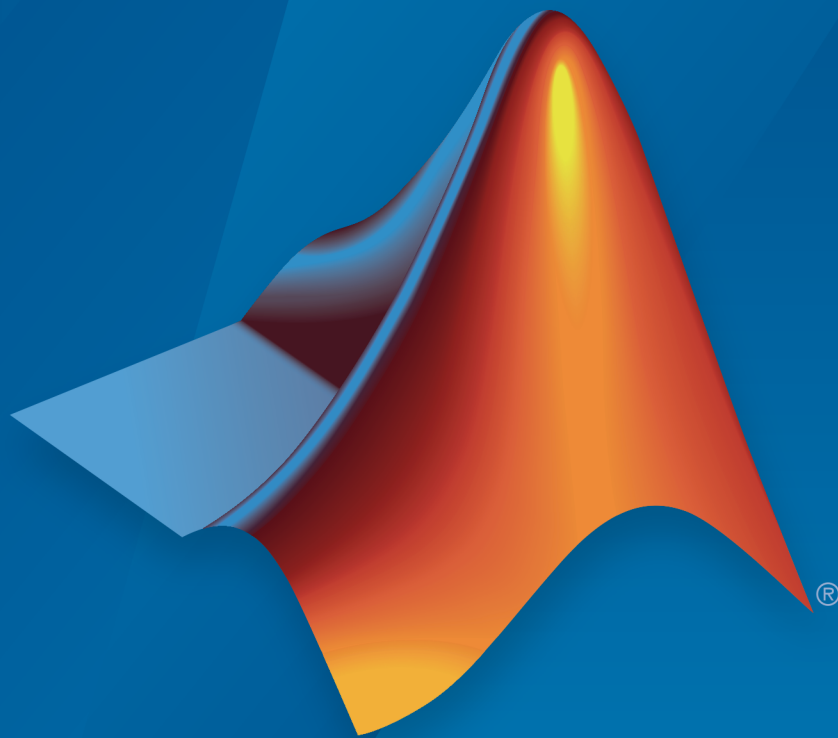
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Blocks—Alphabetical List

6-DOF Joint

Joint with one spherical and three prismatic primitives

Library

Joints

Description

This block represents a joint with three translational and three rotational degrees of freedom. Three prismatic primitives provide the translational degrees of freedom. One spherical primitive provides the three rotational degrees of freedom.

Joint Degrees of Freedom

The joint block represents motion between the base and follower frames as a sequence of time-varying transformations. Each joint primitive applies one transformation in this sequence. The transformation translates or rotates the follower frame with respect to the joint primitive base frame. For all but the first joint primitive, the base frame coincides with the follower frame of the previous joint primitive in the sequence.

At each time step during the simulation, the joint block applies the sequence of time-varying frame transformations in this order:

1   Translation:

   a   Along the X axis of the X Prismatic Primitive (Px) base frame.

   b   Along the Y axis of the Y Prismatic Primitive (Py) base frame. This frame is coincident with the X Prismatic Primitive (Px) follower frame.

   c   Along the Z axis of the Z Prismatic Primitive (Pz) base frame. This frame is coincident with the Y Prismatic Primitive (Py) follower frame.

2   Rotation:

   •   About a general 3-D axis resolved in the base frame. This frame is coincident with the Z Prismatic Primitive (Pz) follower frame.

The figure shows the sequence in which the joint transformations occur at a given simulation time step. The resulting frame of each transformation serves as the base frame for the following transformation. Because 3-D rotation occurs as a single rotation about an arbitrary 3-D axis (as opposed to three separate rotations about the X, Y, Z axes), gimbal lock does not occur.

Joint Transformation Sequence

A set of optional state targets guide assembly for each joint primitive. Targets include position and velocity. A priority level sets the relative importance of the state targets. If two targets are incompatible, the priority level determines which of the targets to satisfy.

Internal mechanics parameters account for energy storage and dissipation at each joint primitive. Springs act as energy storage elements, resisting any attempt to displace the joint primitive from its equilibrium position. Joint dampers act as energy dissipation elements. Springs and dampers are strictly linear.

Each joint primitive has a set of optional actuation and sensing ports. Actuation ports accept physical signal inputs that drive the joint primitives. These inputs can be forces and torques or a desired joint trajectory. Sensing ports provide physical signal outputs that measure joint primitive motion as well as actuation forces and torques. Actuation modes and sensing types vary with joint primitive.

Dialog Box and Parameters

6-DOF Joint : 6-DOF Joint

Description

Represents a 6-DOF joint between two frames. This joint has three translational and three rotational degrees of freedom represented by three prismatic primitives axes along a set of mutually orthogonal axes, plus a spherical primitive. This joint allows unconstrained 3-D translation and rotation. The follower origin first translates relative to the base frame. The follower frame then rotates freely, with the follower origin as the pivot.

In the expandable nodes under Properties, specify the state, actuation method, sensing capabilities, and internal mechanics of the primitives of this joint. After you apply these settings, the block displays the corresponding physical signal ports.

Ports B and F are frame ports that represent the base and follower frames, respectively. The joint direction is defined by motion of the follower frame relative to the base frame.

Properties

- **X Prismatic Primitive (Px)**
  - State Targets
  - Internal Mechanics
  - Actuation
  - Sensing
- Y Prismatic Primitive (Py)
- Z Prismatic Primitive (Pz)
- Spherical Primitive (S)
- Composite Force/Torque Sensing

OK | Cancel | Help | Apply

Prismatic Primitive: State Targets

Specify the prismatic primitive state targets and their priority levels. A state target is the desired value for one of the joint state parameters—position and velocity. The priority level is the relative importance of a state target. It determines how precisely the target must be met. Use the Model Report tool in Mechanics Explorer to check the assembly status for each joint state target.

Specify Position Target

Select this option to specify the desired joint primitive position at time zero. This is the relative position, measured along the joint primitive axis, of the follower frame origin with respect to the base frame origin. The specified target is resolved in the base frame. Selecting this option exposes priority and value fields.

Specify Velocity Target

Select this option to specify the desired joint primitive velocity at time zero. This is the relative velocity, measured along the joint primitive axis, of the follower frame origin with respect to the base frame origin. It is resolved in the base frame. Selecting this option exposes priority and value fields.

Priority

Select state target priority. This is the importance level assigned to the state target. If all state targets cannot be simultaneously satisfied, the priority level determines which targets to satisfy first and how closely to satisfy them. This option applies to both position and velocity state targets.

Priority Level	Description
High (desired)	Satisfy state target precisely
Low (approximate)	Satisfy state target approximately

Note: During assembly, high-priority targets behave as exact guides. Low-priority targets behave as rough guides.

Value

Enter the state target numerical value. The default is 0. Select or enter a physical unit. The default is m for position and m/s for velocity.

Prismatic Primitive: Internal Mechanics

Specify the prismatic primitive internal mechanics. Internal mechanics include linear spring forces, accounting for energy storage, and damping forces, accounting for energy dissipation. You can ignore internal mechanics by keeping spring stiffness and damping coefficient values at 0.

Equilibrium Position

Enter the spring equilibrium position. This is the distance between base and follower frame origins at which the spring force is zero. The default value is 0. Select or enter a physical unit. The default is m.

Spring Stiffness

Enter the linear spring constant. This is the force required to displace the joint primitive by a unit distance. The default is 0. Select or enter a physical unit. The default is N/m.

Damping Coefficient

Enter the linear damping coefficient. This is the force required to maintain a constant joint primitive velocity between base and follower frames. The default is 0. Select or enter a physical unit. The default is N/(m/s).

Prismatic Primitive: Actuation

Specify actuation options for the prismatic joint primitive. Actuation modes include **Force** and **Motion**. Selecting Provided by Input from the drop-down list for an actuation mode adds the corresponding physical signal port to the block. Use this port to specify the input signal. Actuation signals are resolved in the base frame.

Force

Select an actuation force setting. The default setting is None.

Actuation Force Setting	Description
None	No actuation force.
Provided by Input	Actuation force from physical signal input. The signal provides the force acting on the follower frame with respect to the base frame along the joint primitive axis. An equal and opposite force acts on the base frame.

Actuation Force Setting	Description
`Automatically computed`	Actuation force from automatic calculation. Simscape™ Multibody™ computes and applies the actuation force based on model dynamics.

Motion

Select an actuation motion setting. The default setting is `Automatically Computed`.

Actuation Motion Setting	Description
`Provided by Input`	Joint primitive motion from physical signal input. The signal provides the desired trajectory of the follower frame with respect to the base frame along the joint primitive axis.
`Automatically computed`	Joint primitive motion from automatic calculation. Simscape Multibody computes and applies the joint primitive motion based on model dynamics.

Prismatic Primitive: Sensing

Select the variables to sense in the prismatic joint primitive. Selecting a variable exposes a physical signal port that outputs the measured quantity as a function of time. Each quantity is measured for the follower frame with respect to the base frame. It is resolved in the base frame. You can use the measurement signals for analysis or as input in a control system.

Position

Select this option to sense the relative position of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Velocity

Select this option to sense the relative velocity of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Acceleration

Select this option to sense the relative acceleration of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Actuator Force

Select this option to sense the actuation force acting on the follower frame with respect to the base frame along the joint primitive axis.

Spherical Primitive: State Targets

Specify the spherical primitive state targets and their priority levels. A state target is the desired value for one of the joint state parameters—position and velocity. The priority level is the relative importance of a state target. It determines how precisely the target must be met. Use the Model Report tool in Mechanics Explorer to check the assembly status for each joint state target.

Specify Position Target

Select this option to specify the desired joint primitive position at time zero. This is the relative rotation of the follower frame with respect to the base frame. It is resolved in the base frame. Selecting this option exposes priority and value fields.

Priority

Select state target priority. This is the importance level assigned to the state target. If all state targets cannot be simultaneously satisfied, the priority level determines which targets to satisfy first and how closely to satisfy them. This option applies to both position and velocity state targets.

Priority Level	Description
High (desired)	Satisfy state target precisely
Low (approximate)	Satisfy state target approximately

Note: During assembly, high-priority targets behave as exact guides. Low-priority targets behave as rough guides.

Value

Select a method to specify the joint primitive state target.

Method	Description
None	Constrain the base and follower frames to share the same orientation.

Method	Description
`Aligned Axes`	Set frame rotation by aligning two follower frame axes with two base frame axes.
`Standard Axis`	Specify frame rotation as an angle about a standard axis (*x*, *y*, or *z*).
`Arbitrary Axis`	Specify frame rotation as an angle about a general [*x*, *y*, *z*] axis.
`Rotation Sequence`	Specify frame rotation as a sequence of three elementary rotations.
`Rotation Matrix`	Specify frame rotation as a right-handed orthogonal rotation matrix.

`Aligned Axes`

Select two pairs of base-follower frame axes.

Parameter	Description
Pair 1	First pair of base-follower frame axes to align.
Pair 2	Second pair of base-follower frame axes to align. Axis choices depend on **Pair 1** axis selections.

`Standard Axis`

Select a standard rotation axis, resolved in the base frame, and specify the follower frame rotation angle.

Parameter	Description
Axis	Standard rotation axis (X, Y, or Z) resolved in the base frame.
Angle	Follower frame rotation angle about the rotation axis with respect to the base frame.

`Arbitrary Axis`

Select a general 3-D rotation axis, resolved in the base frame, and specify the follower frame rotation angle.

Parameter	Description
Axis	General rotation axis [X Y Z] resolved in the base frame.
Angle	Follower frame rotation angle about the rotation axis with respect to the base frame.

Rotation Sequence

Specify a sequence of three elementary rotations about the selected permutation of x, y, and z axes. These rotation sequences are also known as Euler and Tait-Bryan sequences. The rotations are those of the follower frame relative to the frame selected in the **Rotate About** parameter.

If you set the **Rotate About** parameter to `Follower Frame`, the follower frame rotates about its own axes. These axes change orientation with each successive rotation. If you set the **Rotate About** parameter to `Base Frame`, the follower frame rotates about the fixed base frame axes.

Parameter	Description
Rotation About	Frame whose axes to rotate the follower frame about.
Sequence	Sequence of axes about which to apply the elementary rotations.
Angles	Three-element vector with elementary rotation angles about the axes specified in the **Sequence** parameter.

Rotation Matrix

Specify the 3×3 transformation matrix of a proper rotation between the base and follower frames. The matrix must be orthogonal and have determinant +1. The default matrix is `[1 0 0; 0 1 0; 0 0 1]`.

Specify Velocity Target

Select this option to specify the desired joint primitive velocity at time zero. This is the relative angular velocity of the follower frame with respect to the base frame. It

is resolved in the base frame. Selecting this option exposes priority and value fields. The priority field is identical to that used for the position state target.

Value

Enter a three element vector with the angular velocity components of the follower frame with respect to the base frame. Select a physical unit. The default is `deg/s` (degree/second).

Resolution Frame

From the drop-down list, select a resolution frame. This is the frame in which the state target is resolved. It identifies the axes the velocity vector components apply to. The default is `Follower`.

Spherical Primitive: Internal Mechanics

Specify the spherical primitive internal mechanics. This includes linear spring and damping forces, accounting for energy storage and dissipation, respectively. To ignore internal mechanics, keep spring stiffness and damping coefficient values at the default value of `0`.

Equilibrium Position

Select a method to specify the spring equilibrium position. The equilibrium position is the rotation angle between base and follower port frames at which the spring torque is zero.

Method	Description
None	Constrain the base and follower frames to share the same orientation.
Aligned Axes	Set frame rotation by aligning two follower frame axes with two base frame axes.
Standard Axis	Specify frame rotation as an angle about a standard axis (x, y, or z).
Arbitrary Axis	Specify frame rotation as an angle about a general [x, y, z] axis.
Rotation Sequence	Specify frame rotation as a sequence of three elementary rotations.

Method	Description
`Rotation Matrix`	Specify frame rotation as a right-handed orthogonal rotation matrix.

Aligned Axes

Select two pairs of base-follower frame axes.

Parameter	Description
Pair 1	First pair of base-follower frame axes to align.
Pair 2	Second pair of base-follower frame axes to align. Axis choices depend on **Pair 1** axis selections.

Standard Axis

Select a standard rotation axis, resolved in the base frame, and specify the follower frame rotation angle.

Parameter	Description
Axis	Standard rotation axis (X, Y, or Z) resolved in the base frame.
Angle	Follower frame rotation angle about the rotation axis with respect to the base frame.

Arbitrary Axis

Select a general 3-D rotation axis, resolved in the base frame, and specify the follower frame rotation angle.

Parameter	Description
Axis	General rotation axis [X Y Z] resolved in the base frame.
Angle	Follower frame rotation angle about the rotation axis with respect to the base frame.

Rotation Sequence

Specify a sequence of three elementary rotations about the selected permutation of x, y, and z axes. These rotation sequences are also known as Euler and Tait-Bryan sequences. The rotations are those of the follower frame relative to the frame selected in the **Rotate About** parameter.

If you set the **Rotate About** parameter to `Follower Frame`, the follower frame rotates about its own axes. These axes change orientation with each successive rotation. If you set the **Rotate About** parameter to `Base Frame`, the follower frame rotates about the fixed base frame axes.

Parameter	Description
Rotation About	Frame whose axes to rotate the follower frame about.
Sequence	Sequence of axes about which to apply the elementary rotations.
Angles	Three-element vector with elementary rotation angles about the axes specified in the **Sequence** parameter.

Rotation Matrix

Specify the 3×3 transformation matrix of a proper rotation between the base and follower frames. The matrix must be orthogonal and have determinant +1. The default matrix is [1 0 0; 0 1 0; 0 0 1].

Spring Stiffness

Enter the linear spring constant. This is the torque required to displace the joint primitive by a unit angle. The term linear refers to the mathematical form of the spring equation. The default is 0. Select a physical unit. The default is N*m/deg.

Damping Coefficient

Enter the linear damping coefficient. This is the torque required to maintain a constant joint primitive angular velocity between base and follower frames. The default is 0. Select a physical unit. The default is N*m/(deg/s).

Spherical Primitive: Actuation

Specify actuation options for the spherical joint primitive. Actuation modes include **Torque** only. Selecting a torque input adds the corresponding physical signal port to the block. Use this port to specify the actuation torque signal.

Torque

Select a source for the actuation torque. The default setting is `None`.

Actuation Torque Setting	Description
None	Apply no actuation torque.
Provided by Input	Apply an actuation torque based on a physical signal. The signal specifies the torque acting on the follower frame with respect to the base frame. An equal and opposite torque acts on the base frame. Selecting this option exposes additional parameters.

Torque (X), Torque (Y), Torque (Z)

Select in order to actuate the spherical joint primitive about each standard Cartesian axis (X, Y, Z) separately. The block exposes the corresponding physical signal ports. Use these ports to specify the actuation torque signals. The signals must be scalar values.

Torque (XYZ)

Select in order to actuate the spherical joint primitive about an arbitrary axis [X Y Z]. The block exposes the corresponding physical signal port. Use this port to specify the actuation torque signal. The signal must be a 3-D vector.

Frame

Select the frame to resolve the actuation torque signal in. The axes of this frame establish the directions of the X, Y, and Z torque components. The default setting is `Base`.

Spherical Primitive: Sensing

Select the motion variables to sense in the spherical joint primitive. The block adds the corresponding physical signal ports. Use these ports to output the numerical values of the motion variables.

The block measures each motion variable for the follower frame with respect to the base frame. It resolves that variable in the resolution frame that you select from the **Frame** drop-down list.

Motion Variables	Description
Position	Quaternion describing follower frame rotation with respect to base frame. The quaternion coefficients are $$\left[\cos\left(\frac{\theta}{2}\right), n_x \sin\left(\frac{\theta}{2}\right), n_y \sin\left(\frac{\theta}{2}\right), n_z \sin\left(\frac{\theta}{2}\right)\right].$$ The measurement is the same in all measurement frames.
Velocity (X), **Velocity (Y)**, **Velocity (Z)**	Angular velocity components about X, Y, and Z axes.
Velocity	3–D angular velocity vector with components about X, Y, and Z axes.
Acceleration (X), **Acceleration (Y)**, **Acceleration (Z)**	Angular acceleration components about X, Y, and Z axes.
Acceleration	3–D angular acceleration vector with components about X, Y, and Z axes.

Frame

Select the frame to resolve the measurement in. The axes of this frame establish the directions of X, Y, and Z vector components. The default setting is `Base`.

Composite Force/Torque Sensing

Select the composite, or joint-wide, forces and torques to sense. These are forces and torques that act not at individual joint primitives but at the whole joint. Options include constraint and total forces and torques.

During simulation, the block computes the selected composite forces and torques acting between the base and follower port frames. It outputs these variables using physical signal output ports. Check the port labels to identify the output variables at different ports.

Direction

Forces and torques acting at joints do so in pairs. Newton's third law of motion requires that every action be accompanied by an equal and opposite reaction. If the base frame of a joint exerts a force or torque on the follower frame, then the follower frame must exert an equal and opposite force or torque on the base frame.

Select whether to sense the composite forces and torques exerted by the base frame on the follower frame or vice versa. The force and torque vector components are positive if they point along the positive X, Y, and Z axes of the selected resolution frame.

Resolution Frame

You can resolve a vector quantity into Cartesian components in different frames. If the resolution frames have different orientations, then the measured components are themselves different—even though the vector quantity remains the same.

Select the frame in which to resolve the sensed force and torque variables. Possible resolution frames include `Base` and `Follower`. The block outputs the Cartesian components of the sensed force and torque vectors as observed in this frame.

Constraint Force

Joint blocks with fewer than three translational degrees of freedom forbid motion along one or more axes. For example, the Gimbal Joint block forbids translation along all axes. To prevent translation along an axis, a joint block applies a constraint force between its base and follower port frames. Constraint forces are orthogonal to joint translation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint force vector [fc_x, fc_y, fc_z] acting at the joint. Only constraint force components that are orthogonal to the joint translational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port fc.

Constraint Torque

Joint blocks with fewer than three rotational degrees of freedom forbid motion about one or more axes. For example, the Cartesian Joint block forbids rotation about all axes. To prevent rotation about an axis, a joint block applies a constraint torque between its base and follower port frames. Constraint torques are orthogonal to joint rotation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint torque vector [tc_x, tc_y, tc_z] acting at the joint. Only constraint torque components that are orthogonal to the joint rotational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port tc.

Total Force

A joint block generally applies various forces between its port frames:

- Actuation forces that drive prismatic joint primitives.

- Internal spring and damper forces that resist motion at prismatic joint primitives.
- Constraint forces that forbid motion in directions orthogonal to prismatic joint primitives.

The net sum of the different force components equals the total force acting between the joint port frames. Select the check box to compute and output the 3-D total force vector $[ft_x, ft_y, ft_z]$. Selecting this option causes the block to expose physical signal port ft.

Total Torque

A joint block generally applies various torques between its port frames:

- Actuation torques that drive revolute or spherical joint primitives.
- Internal spring and damper torques that resist motion at revolute or spherical joint primitives.
- Constraint torques that forbid motion in directions orthogonal to the revolute or spherical joint primitive axes.

The net sum of the different torque components equals the total torque acting at a joint. Select the check box to compute and output the 3-D total torque vector $[tt_x, tt_y, tt_z]$. Selecting this option causes the block to expose physical signal port tt.

Ports

This block has two frame ports. It also has optional physical signal ports for specifying actuation inputs and sensing dynamical variables such as forces, torques, and motion. You expose an optional port by selecting the sensing check box corresponding to that port.

Frame Ports

- B — Base frame
- F — Follower frame

Actuation Ports

The prismatic joint primitives provide the following actuation ports:

- fx, fy, fz — Actuation forces of the X, Y, and Z prismatic joint primitives
- px, py, pz — Desired trajectories of the X, Y, and Z prismatic joint primitives

The spherical joint primitive provides the following actuation ports:

- t — Actuation torque vector [tx, ty, tz] acting on the spherical joint primitive
- tx, ty, tz — X, Y, and Z components of the actuation torque acting on the spherical joint primitive

Sensing Ports

The prismatic primitives provide the following sensing ports:

- px, py, pz — Positions of the X, Y, and Z prismatic joint primitives
- vx, vy, vz — Velocities of the X, Y, and Z prismatic joint primitives
- ax, ay, az — Accelerations of the X, Y, and Z prismatic joint primitives
- fx, fy, fz — Actuation forces acting on the X, Y, and Z prismatic joint primitives

The spherical primitive provides the following sensing ports:

- Q — Orientation of the spherical joint primitive in quaternion form
- wx, wy, wz — X, Y, and Z angular velocity components of the spherical joint primitive
- w — Angular velocity [wx, wy, wz] of the spherical joint primitive
- bx, by, bz — X, Y, and Z angular acceleration components of the spherical joint primitive
- b — Angular acceleration [bx, by, bz] of the spherical joint primitive

The following sensing ports provide the composite forces and torques acting on the joint:

- fc — Constraint force
- tc — Constraint torque
- ft — Total force
- tt — Total torque

See Also
Bushing Joint | Prismatic Joint | Spherical Joint

More About

- "Motion Sensing"
- "Measurement Frames"
- "Actuating and Sensing with Physical Signals"

Angle Constraint

Fixed angle between two frame Z axes

Library

Constraints

Description

This block applies a fixed angle between the Z axes of the base and follower port frames. The frames lose one rotational degree of freedom if the constraint angle is greater than 0° and smaller than 180°. They lose two rotational degrees of freedom if the constraint angle is exactly 0° or 180°—that is, if the frames are parallel or anti-parallel. The figure shows the constraint angle between two frames.
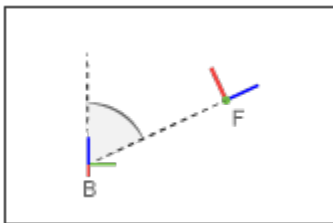
Dialog Box and Parameters
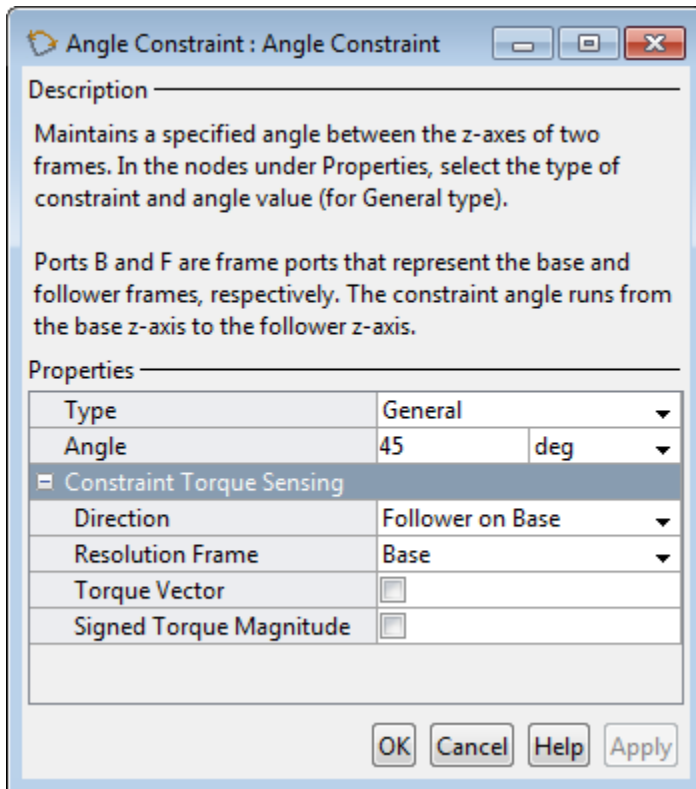
Type

Angle constraint type. The default setting is General.

Type	Purpose
Parallel	Align the base and follower frame +Z axes.
Anti-Parallel	Align the base frame +Z axis with the follower frame -Z axis.
Perpendicular	Make the base and follower frame Z axes perpendicular to each other.

Type	Purpose
General	Hold the specified angle between the Z axes of the base and follower port frames.

Angle

Constraint angle between the base and follower frame Z axes. The angle must lie in the range $0 < \theta < 180$ deg. For an angle of 0 or 180 deg, set **Type** to Parallel or Anti-Parallel instead. The default value is 45 deg.

Constraint Torque Sensing

Select whether to compute and output the distance constraint torque vector and its magnitude. The distance constraint torque is the torque the block must apply in order to maintain the angle you specify between the base and follower port frames.

Direction

Constraint torques act in pairs. As expressed by Newton's third law of motion, if the base port frame exerts a constraint torque on the follower port frame, then the follower port frame must exert an equal and opposite torque on the base port frame. Select which of the two constraint torques to sense:

- Follower on Base — Sense the constraint torque that the follower port frame exerts on the base port frame.
- Base on Follower — Sense the constraint torque that the base port frame exerts on the follower port frame.

Resolution Frame

The block expresses the constraint torque vector in terms of its Cartesian vector components. The splitting of a vector into vector components is known as vector resolution. The frame whose axes define the vector component directions is known as the resolution frame. Select whether to resolve the constraint torque vector in the base or follower port frame.

Torque Vector

Compute and output the Cartesian components of the angle constraint torque vector. The output signal is a three-dimensional vector with components expressed about the X, Y, and Z axes of the resolution frame.

Signed Torque Magnitude

Compute and output the magnitude of the angle constraint torque, including its sign.

Ports

The block provides two frame ports:

- B — Base frame port
- F — Follower frame port

In addition, the block provides two physical signal output ports:

- t — Angle constraint torque vector
- tm — Signed magnitude of the angle constraint torque

See Also

Bevel Gear Constraint | Common Gear Constraint | Distance Constraint | Point on Curve Constraint | Rack and Pinion Constraint

Bearing Joint

Joint with one prismatic and three revolute primitives

Library

Joints

Description

This block represents a joint with one translational and three rotational degrees of freedom. One prismatic primitive provides the translational degree of freedom. Three revolute primitives provide the three rotational degrees of freedom.
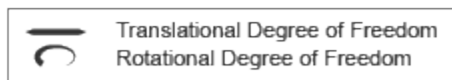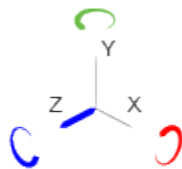
Joint Degrees of Freedom

The joint block represents motion between the base and follower frames as a sequence of time-varying transformations. Each joint primitive applies one transformation in this sequence. The transformation translates or rotates the follower frame with respect to the joint primitive base frame. For all but the first joint primitive, the base frame coincides with the follower frame of the previous joint primitive in the sequence.

At each time step during the simulation, the joint block applies the sequence of time-varying frame transformations in this order:

1   Translation:

- Along the Z axis of the Z Prismatic Primitive (Pz) base frame.

2   Rotation:

a   About the X axis of the X Revolute Primitive (Rx) base frame. This frame is coincident with the Z Prismatic Primitive (Pz) follower frame.

b   About the Y axis of the Y Revolute Primitive (Ry) base frame. This frame is coincident with the X Revolute Primitive (Rx) follower frame.

c   About the Z axis of the Z Revolute Primitive (Rz) base frame. This frame is coincident with the Y Revolute Primitive (Ry) follower frame.

The figure shows the sequence in which the joint transformations occur at a given simulation time step. The resulting frame of each transformation serves as the base frame for the following transformation. Because 3-D rotation occurs as a sequence, it is possible for two axes to align, causing to the loss of one rotational degree of freedom. This phenomenon is known as gimbal lock.

Joint Transformation Sequence

A set of optional state targets guide assembly for each joint primitive. Targets include position and velocity. A priority level sets the relative importance of the state targets. If two targets are incompatible, the priority level determines which of the targets to satisfy.

Internal mechanics parameters account for energy storage and dissipation at each joint primitive. Springs act as energy storage elements, resisting any attempt to displace the joint primitive from its equilibrium position. Joint dampers act as energy dissipation elements. Springs and dampers are strictly linear.

Each joint primitive has a set of optional actuation and sensing ports. Actuation ports accept physical signal inputs that drive the joint primitives. These inputs can be forces and torques or a desired joint trajectory. Sensing ports provide physical signal outputs that measure joint primitive motion as well as actuation forces and torques. Actuation modes and sensing types vary with joint primitive.

Dialog Box and Parameters

Bearing Joint : Bearing Joint

Description

Represents a bearing joint between two frames. This joint has one translational and three rotational degrees of freedom represented by one prismatic primitive and three revolute primitives along a set of mutually orthogonal axes. This joint prohibits relative translation in the base xy-plane. The follower origin first translates along the base z-axis, while the base and follower axes remain aligned. The follower axes then rotate around the follower x-axis, y-axis, and z-axis, in that order.

In the expandable nodes under Properties, specify the state, actuation method, sensing capabilities, and internal mechanics of the primitives of this joint. After you apply these settings, the block displays the corresponding physical signal ports.

Ports B and F are frame ports that represent the base and follower frames, respectively. The joint direction is defined by motion of the follower frame relative to the base frame.

Properties

- ⊟ Z Prismatic Primitive (Pz)
  - ⊞ State Targets
  - ⊞ Internal Mechanics
  - ⊞ Actuation
  - ⊞ Sensing
- ⊞ X Revolute Primitive (Rx)
- ⊞ Y Revolute Primitive (Ry)
- ⊞ Z Revolute Primitive (Rz)
- ⊞ Composite Force/Torque Sensing

OK   Cancel   Help   Apply

Prismatic Primitive: State Targets

Specify the prismatic primitive state targets and their priority levels. A state target is the desired value for one of the joint state parameters—position and velocity. The priority level is the relative importance of a state target. It determines how precisely the target must be met. Use the Model Report tool in Mechanics Explorer to check the assembly status for each joint state target.

Specify Position Target

Select this option to specify the desired joint primitive position at time zero. This is the relative position, measured along the joint primitive axis, of the follower frame origin with respect to the base frame origin. The specified target is resolved in the base frame. Selecting this option exposes priority and value fields.

Specify Velocity Target

Select this option to specify the desired joint primitive velocity at time zero. This is the relative velocity, measured along the joint primitive axis, of the follower frame origin with respect to the base frame origin. It is resolved in the base frame. Selecting this option exposes priority and value fields.

Priority

Select state target priority. This is the importance level assigned to the state target. If all state targets cannot be simultaneously satisfied, the priority level determines which targets to satisfy first and how closely to satisfy them. This option applies to both position and velocity state targets.

Priority Level	Description
High (desired)	Satisfy state target precisely
Low (approximate)	Satisfy state target approximately

Note: During assembly, high-priority targets behave as exact guides. Low-priority targets behave as rough guides.

Value

Enter the state target numerical value. The default is 0. Select or enter a physical unit. The default is m for position and m/s for velocity.

Prismatic Primitive: Internal Mechanics

Specify the prismatic primitive internal mechanics. Internal mechanics include linear spring forces, accounting for energy storage, and damping forces, accounting for energy dissipation. You can ignore internal mechanics by keeping spring stiffness and damping coefficient values at 0.

Equilibrium Position

Enter the spring equilibrium position. This is the distance between base and follower frame origins at which the spring force is zero. The default value is 0. Select or enter a physical unit. The default is m.

Spring Stiffness

Enter the linear spring constant. This is the force required to displace the joint primitive by a unit distance. The default is 0. Select or enter a physical unit. The default is N/m.

Damping Coefficient

Enter the linear damping coefficient. This is the force required to maintain a constant joint primitive velocity between base and follower frames. The default is 0. Select or enter a physical unit. The default is N/(m/s).

Prismatic Primitive: Actuation

Specify actuation options for the prismatic joint primitive. Actuation modes include **Force** and **Motion**. Selecting Provided by Input from the drop-down list for an actuation mode adds the corresponding physical signal port to the block. Use this port to specify the input signal. Actuation signals are resolved in the base frame.

Force

Select an actuation force setting. The default setting is None.

Actuation Force Setting	Description
None	No actuation force.
Provided by Input	Actuation force from physical signal input. The signal provides the force acting on the follower frame with respect to the base frame along the joint primitive axis. An equal and opposite force acts on the base frame.

Actuation Force Setting	Description
`Automatically computed`	Actuation force from automatic calculation. Simscape Multibody computes and applies the actuation force based on model dynamics.

Motion

Select an actuation motion setting. The default setting is `Automatically Computed`.

Actuation Motion Setting	Description
`Provided by Input`	Joint primitive motion from physical signal input. The signal provides the desired trajectory of the follower frame with respect to the base frame along the joint primitive axis.
`Automatically computed`	Joint primitive motion from automatic calculation. Simscape Multibody computes and applies the joint primitive motion based on model dynamics.

Prismatic Primitive: Sensing

Select the variables to sense in the prismatic joint primitive. Selecting a variable exposes a physical signal port that outputs the measured quantity as a function of time. Each quantity is measured for the follower frame with respect to the base frame. It is resolved in the base frame. You can use the measurement signals for analysis or as input in a control system.

Position

Select this option to sense the relative position of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Velocity

Select this option to sense the relative velocity of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Acceleration

Select this option to sense the relative acceleration of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Actuator Force

Select this option to sense the actuation force acting on the follower frame with respect to the base frame along the joint primitive axis.

Revolute Primitive: State Targets

Specify the revolute primitive state targets and their priority levels. A state target is the desired value for one of the joint state parameters—position and velocity. The priority level is the relative importance of a state target. It determines how precisely the target must be met. Use the Model Report tool in Mechanics Explorer to check the assembly status for each joint state target.

Specify Position Target

Select this option to specify the desired joint primitive position at time zero. This is the relative rotation angle, measured about the joint primitive axis, of the follower frame with respect to the base frame. The specified target is resolved in the base frame. Selecting this option exposes priority and value fields.

Specify Velocity Target

Select this option to specify the desired joint primitive velocity at time zero. This is the relative angular velocity, measured about the joint primitive axis, of the follower frame with respect to the base frame. It is resolved in the base frame. Selecting this option exposes priority and value fields.

Priority

Select state target priority. This is the importance level assigned to the state target. If all state targets cannot be simultaneously satisfied, the priority level determines which targets to satisfy first and how closely to satisfy them. This option applies to both position and velocity state targets.

Priority Level	Description
High (desired)	Satisfy state target precisely
Low (approximate)	Satisfy state target approximately

Note: During assembly, high-priority targets behave as exact guides. Low-priority targets behave as rough guides.

Value

> Enter the state target numerical value. The default is 0. Select or enter a
> physical unit. The default is deg for position and deg/s for velocity.

Revolute Primitive: Internal Mechanics

Specify the revolute primitive internal mechanics. Internal mechanics include linear
spring torques, accounting for energy storage, and linear damping torques, accounting
for energy dissipation. You can ignore internal mechanics by keeping spring stiffness and
damping coefficient values at 0.

Equilibrium Position

> Enter the spring equilibrium position. This is the rotation angle between base and
> follower frames at which the spring torque is zero. The default value is 0. Select or
> enter a physical unit. The default is deg.

Spring Stiffness

> Enter the linear spring constant. This is the torque required to rotate the joint
> primitive by a unit angle. The default is 0. Select or enter a physical unit. The default
> is N*m/deg.

Damping Coefficient

> Enter the linear damping coefficient. This is the torque required to maintain a
> constant joint primitive angular velocity between base and follower frames. The
> default is 0. Select or enter a physical unit. The default is N*m/(deg/s).

Revolute Primitive: Actuation

Specify actuation options for the revolute joint primitive. Actuation modes include
Torque and **Motion**. Selecting Provided by Input from the drop-down list for an
actuation mode adds the corresponding physical signal port to the block. Use this port to
specify the input signal. Input signals are resolved in the base frame.

Torque

> Select an actuation torque setting. The default setting is None.

Actuation Torque Setting	Description
None	No actuation torque.

Actuation Torque Setting	Description
`Provided by Input`	Actuation torque from physical signal input. The signal provides the torque acting on the follower frame with respect to the base frame about the joint primitive axis. An equal and opposite torque acts on the base frame.
`Automatically computed`	Actuation torque from automatic calculation. Simscape Multibody computes and applies the actuation torque based on model dynamics.

Motion

Select an actuation motion setting. The default setting is `Automatically Computed`.

Actuation Motion Setting	Description
`Provided by Input`	Joint primitive motion from physical signal input. The signal provides the desired trajectory of the follower frame with respect to the base frame along the joint primitive axis.
`Automatically computed`	Joint primitive motion from automatic calculation. Simscape Multibody computes and applies the joint primitive motion based on model dynamics.

Revolute Primitive: Sensing

Select the variables to sense in the revolute joint primitive. Selecting a variable exposes a physical signal port that outputs the measured quantity as a function of time. Each quantity is measured for the follower frame with respect to the base frame. It is resolved in the base frame. You can use the measurement signals for analysis or as input in a control system.

Position

Select this option to sense the relative rotation angle of the follower frame with respect to the base frame about the joint primitive axis.

Velocity

Select this option to sense the relative angular velocity of the follower frame with respect to the base frame about the joint primitive axis.

Acceleration

Select this option to sense the relative angular acceleration of the follower frame with respect to the base frame about the joint primitive axis.

Actuator Torque

Select this option to sense the actuation torque acting on the follower frame with respect to the base frame about the joint primitive axis.

Composite Force/Torque Sensing

Select the composite, or joint-wide, forces and torques to sense. These are forces and torques that act not at individual joint primitives but at the whole joint. Options include constraint and total forces and torques.

During simulation, the block computes the selected composite forces and torques acting between the base and follower port frames. It outputs these variables using physical signal output ports. Check the port labels to identify the output variables at different ports.

Direction

Forces and torques acting at joints do so in pairs. Newton's third law of motion requires that every action be accompanied by an equal and opposite reaction. If the base frame of a joint exerts a force or torque on the follower frame, then the follower frame must exert an equal and opposite force or torque on the base frame.

Select whether to sense the composite forces and torques exerted by the base frame on the follower frame or vice versa. The force and torque vector components are positive if they point along the positive X, Y, and Z axes of the selected resolution frame.

Resolution Frame

You can resolve a vector quantity into Cartesian components in different frames. If the resolution frames have different orientations, then the measured components are themselves different—even though the vector quantity remains the same.

Select the frame in which to resolve the sensed force and torque variables. Possible resolution frames include `Base` and `Follower`. The block outputs the Cartesian components of the sensed force and torque vectors as observed in this frame.

Constraint Force

Joint blocks with fewer than three translational degrees of freedom forbid motion along one or more axes. For example, the Gimbal Joint block forbids translation along all axes. To prevent translation along an axis, a joint block applies a constraint force between its base and follower port frames. Constraint forces are orthogonal to joint translation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint force vector [fc_x, fc_y, fc_z] acting at the joint. Only constraint force components that are orthogonal to the joint translational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port fc.

Constraint Torque

Joint blocks with fewer than three rotational degrees of freedom forbid motion about one or more axes. For example, the Cartesian Joint block forbids rotation about all axes. To prevent rotation about an axis, a joint block applies a constraint torque between its base and follower port frames. Constraint torques are orthogonal to joint rotation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint torque vector [tc_x, tc_y, tc_z] acting at the joint. Only constraint torque components that are orthogonal to the joint rotational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port tc.

Total Force

A joint block generally applies various forces between its port frames:

- Actuation forces that drive prismatic joint primitives.
- Internal spring and damper forces that resist motion at prismatic joint primitives.
- Constraint forces that forbid motion in directions orthogonal to prismatic joint primitives.

The net sum of the different force components equals the total force acting between the joint port frames. Select the check box to compute and output the 3-D total force vector [ft_x, ft_y, ft_z]. Selecting this option causes the block to expose physical signal port ft.

Total Torque

A joint block generally applies various torques between its port frames:

- Actuation torques that drive revolute or spherical joint primitives.

- Internal spring and damper torques that resist motion at revolute or spherical joint primitives.
- Constraint torques that forbid motion in directions orthogonal to the revolute or spherical joint primitive axes.

The net sum of the different torque components equals the total torque acting at a joint. Select the check box to compute and output the 3-D total torque vector [tt_x, tt_y, tt_z]. Selecting this option causes the block to expose physical signal port tt.

Ports

This block has two frame ports. It also has optional physical signal ports for specifying actuation inputs and sensing dynamical variables such as forces, torques, and motion. You expose an optional port by selecting the sensing check box corresponding to that port.

Frame Ports

- B — Base frame
- F — Follower frame

Actuation Ports

The prismatic joint primitive provides the following actuation ports:

- fz — Actuation force acting on the Z prismatic joint primitive
- pz — Desired trajectory of the Z prismatic joint primitive

The revolute joint primitives provide the following actuation ports:

- tx, ty, tz — Actuation torques acting on the X, Y, and Z revolute joint primitives
- qx, qy, qz — Desired rotations of the X, Y, and Z revolute joint primitives

Sensing Ports

The prismatic primitive provides the following sensing ports:

- pz — Position of the Z prismatic joint primitive

- vz — Velocity of the Z prismatic joint primitive
- az — Acceleration of the Z prismatic joint primitive
- fz — Actuation force acting on the Z prismatic joint primitive

The revolute primitives provide the following sensing ports:

- qx, qy, qz — Angular positions of the X, Y, and Z revolute joint primitives
- wx, wy, wz — Angular velocities of the X, Y, and Z revolute joint primitives
- bx, by, bz — Angular accelerations of the X, Y, and Z revolute joint primitives
- tx, ty, tz — Actuation torques acting on the X, Y, and Z revolute joint primitives

The following sensing ports provide the composite forces and torques acting on the joint:

- fc — Constraint force
- tc — Constraint torque
- ft — Total force
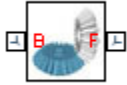- tt — Total torque

See Also
`Prismatic Joint` | `Revolute Joint`

More About
- "Actuating and Sensing with Physical Signals"
- "Motion Sensing"
- "Rotational Measurements"
- "Translational Measurements"

Bevel Gear Constraint

Kinematic constraint for transferring rotational motion at a fixed ratio about arbitrarily oriented axes

Library

Gears and Couplings/Gears

Description

This block represents a bevel gear constraint between two frames. The constraint restricts motion such that rotation of the base frame causes rotation of the follower frame and vice-versa. The two frames spin as meshed gears about the individual Z axes, each aligned with a bevel gear shaft.

The two shafts can lie at an arbitrary angle to each other. This angle, always between 0° and 180°, corresponds to a configuration in which the two +Z axes are either parallel or converging toward each other. At 90° the two shafts are perpendicular. At 0°, the two gears are parallel and the bevel gear functions as a spur gear.

During simulation, the remainder of the mechanism must hold the gears in alignment. The gear shafts must lie at the distance and angle specified in the block dialog box. The distance between the base and follower frame origins, which represent the two gear shafts, follows from the law of cosines:

$$D^2 = R_B{}^2 + R_F{}^2 - 2 \cdot R_B \cdot R_F \cdot \cos(\pi - \theta),$$

where:

- D is the distance between the two frame origins.

- R_B, R_F are the pitch radii of the base gear and follower gears.
- θ is the angle between the base and follower gear shafts.
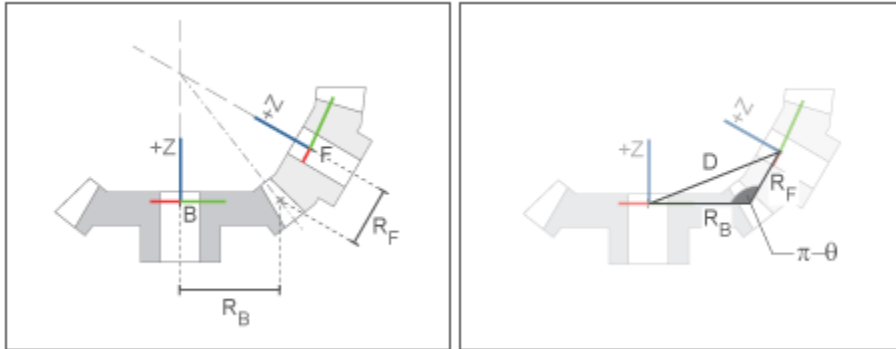
Bevel gear Schematic

Dialog Box and Parameters
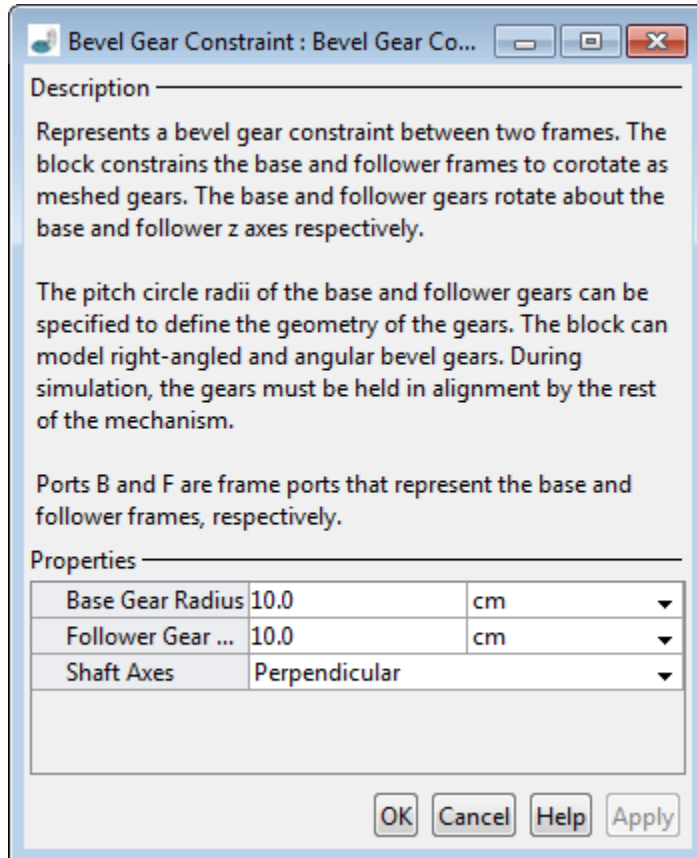
Base Gear Radius

Enter the pitch circle radius of the base gear. This is the radius at which the base gear teeth contact the follower gear teeth. Select a physical unit. The default is `10.0` cm.

Follower Gear Radius

Enter the pitch circle radius of the follower gear. This is the radius at which the follower gear teeth contact the base gear teeth. Select a physical unit. The default is `10.0` cm.

Shaft Axes

Select the relative orientation between the spinning shafts of the base and follower gears. Options include `Perpendicular` and `Arbitrarily Oriented`:

- `Perpendicular` — Orient the two spinning shafts at a right angle to each other. This is the default setting.
- `Arbitrarily Oriented` — Orient the two spinning shafts at a general angle to each other. Selecting this option exposes an additional parameter.

   Angle Between Shafts

   Enter the angle between the spinning shafts of the base and follower gears. Select a physical unit. The default value is `90` deg.

Ports

The block contains frame ports B and F, representing base and follower frames, respectively.

See Also

Angle Constraint | Common Gear Constraint | Common Gear Constraint | Point on Curve Constraint | Rack and Pinion Constraint

Bushing Joint

Joint with three prismatic and three revolute primitives

Library

Joints

Description

This block represents a joint with three translational and three rotational degrees of freedom. Three prismatic primitives provide the translational degrees of freedom. Three revolute primitives provide the rotational degrees of freedom.

Joint Degrees of Freedom

The joint block represents motion between the base and follower frames as a sequence of time-varying transformations. Each joint primitive applies one transformation in this sequence. The transformation translates or rotates the follower frame with respect to the joint primitive base frame. For all but the first joint primitive, the base frame coincides with the follower frame of the previous joint primitive in the sequence.

At each time step during the simulation, the joint block applies the sequence of time-varying frame transformations in this order:

1   Translation:

    a   Along the X axis of the X Prismatic Primitive (Px) base frame.

    b   Along the Y axis of the Y Prismatic Primitive (Py) base frame. This frame is coincident with the X Prismatic Primitive (Px) follower frame.

    c   Along the Z axis of the Z Prismatic Primitive (Pz) base frame. This frame is coincident with the Y Prismatic Primitive (Py) follower frame.

2   Rotation:

    a   About the X axis of the X Revolute Primitive (Rx) base frame. This frame is coincident with the Z Prismatic Primitive (Pz) follower frame.

    b   About the Y axis of the Y Revolute Primitive (Ry) base frame. This frame is coincident with the X Revolute Primitive (Rx) follower frame.

    c   About the Z axis of the Z Revolute Primitive (Rz) base frame. This frame is coincident with the Y Revolute Primitive (Ry) follower frame.

The figure shows the sequence in which the joint transformations occur at a given simulation time step. The resulting frame of each transformation serves as the base frame for the following transformation. Because 3-D rotation occurs as a sequence, it is possible for two axes to align, causing to the loss of one rotational degree of freedom. This phenomenon is known as gimbal lock.

Joint Transformation Sequence

A set of optional state targets guide assembly for each joint primitive. Targets include position and velocity. A priority level sets the relative importance of the state targets. If two targets are incompatible, the priority level determines which of the targets to satisfy.

Internal mechanics parameters account for energy storage and dissipation at each joint primitive. Springs act as energy storage elements, resisting any attempt to displace the joint primitive from its equilibrium position. Joint dampers act as energy dissipation elements. Springs and dampers are strictly linear.

Each joint primitive has a set of optional actuation and sensing ports. Actuation ports accept physical signal inputs that drive the joint primitives. These inputs can be forces and torques or a desired joint trajectory. Sensing ports provide physical signal outputs that measure joint primitive motion as well as actuation forces and torques. Actuation modes and sensing types vary with joint primitive.

Bushing Joint : Bushing Joint

Description

Represents a bushing joint between two frames. This joint has three translational and three rotational degrees of freedom represented by three prismatic primitives and three revolute primitives. Each set of primitive axes is mutually orthogonal. This joint allows unconstrained, combined 3-D translation and rotation. The follower frame first translates along the follower x-axis, y-axis, and z-axis, in that order, then rotates around each axis in the same order.

In the expandable nodes under Properties, specify the state, actuation method, sensing capabilities, and internal mechanics of the primitives of this joint. After you apply these settings, the block displays the corresponding physical signal ports.

Ports B and F are frame ports that represent the base and follower frames, respectively. The joint direction is defined by motion of the follower frame relative to the base frame.

Properties

- ☐ X Prismatic Primitive (Px)
  - ☐ State Targets
  - ☐ Internal Mechanics
  - ☐ Actuation
  - ☐ Sensing
- ☐ Y Prismatic Primitive (Py)
- ☐ Z Prismatic Primitive (Pz)
- ☐ X Revolute Primitive (Rx)
- ☐ Y Revolute Primitive (Ry)
- ☐ Z Revolute Primitive (Rz)
- ☐ Composite Force/Torque Sensing

[OK] [Cancel] [Help] [Apply]

Prismatic Primitive: State Targets

Specify the prismatic primitive state targets and their priority levels. A state target is the desired value for one of the joint state parameters—position and velocity. The priority level is the relative importance of a state target. It determines how precisely the target must be met. Use the Model Report tool in Mechanics Explorer to check the assembly status for each joint state target.

Specify Position Target

Select this option to specify the desired joint primitive position at time zero. This is the relative position, measured along the joint primitive axis, of the follower frame origin with respect to the base frame origin. The specified target is resolved in the base frame. Selecting this option exposes priority and value fields.

Specify Velocity Target

Select this option to specify the desired joint primitive velocity at time zero. This is the relative velocity, measured along the joint primitive axis, of the follower frame origin with respect to the base frame origin. It is resolved in the base frame. Selecting this option exposes priority and value fields.

Priority

Select state target priority. This is the importance level assigned to the state target. If all state targets cannot be simultaneously satisfied, the priority level determines which targets to satisfy first and how closely to satisfy them. This option applies to both position and velocity state targets.

Priority Level	Description
High (desired)	Satisfy state target precisely
Low (approximate)	Satisfy state target approximately

Note: During assembly, high-priority targets behave as exact guides. Low-priority targets behave as rough guides.

Value

Enter the state target numerical value. The default is 0. Select or enter a physical unit. The default is m for position and m/s for velocity.

Prismatic Primitive: Internal Mechanics

Specify the prismatic primitive internal mechanics. Internal mechanics include linear spring forces, accounting for energy storage, and damping forces, accounting for energy dissipation. You can ignore internal mechanics by keeping spring stiffness and damping coefficient values at 0.

Equilibrium Position

Enter the spring equilibrium position. This is the distance between base and follower frame origins at which the spring force is zero. The default value is 0. Select or enter a physical unit. The default is m.

Spring Stiffness

Enter the linear spring constant. This is the force required to displace the joint primitive by a unit distance. The default is 0. Select or enter a physical unit. The default is N/m.

Damping Coefficient

Enter the linear damping coefficient. This is the force required to maintain a constant joint primitive velocity between base and follower frames. The default is 0. Select or enter a physical unit. The default is N/(m/s).

Prismatic Primitive: Actuation

Specify actuation options for the prismatic joint primitive. Actuation modes include **Force** and **Motion**. Selecting Provided by Input from the drop-down list for an actuation mode adds the corresponding physical signal port to the block. Use this port to specify the input signal. Actuation signals are resolved in the base frame.

Force

Select an actuation force setting. The default setting is None.

Actuation Force Setting	Description
None	No actuation force.
Provided by Input	Actuation force from physical signal input. The signal provides the force acting on the follower frame with respect to the base frame along the joint primitive axis. An equal and opposite force acts on the base frame.

Actuation Force Setting	Description
Automatically computed	Actuation force from automatic calculation. Simscape Multibody computes and applies the actuation force based on model dynamics.

Motion

Select an actuation motion setting. The default setting is Automatically Computed.

Actuation Motion Setting	Description
Provided by Input	Joint primitive motion from physical signal input. The signal provides the desired trajectory of the follower frame with respect to the base frame along the joint primitive axis.
Automatically computed	Joint primitive motion from automatic calculation. Simscape Multibody computes and applies the joint primitive motion based on model dynamics.

Prismatic Primitive: Sensing

Select the variables to sense in the prismatic joint primitive. Selecting a variable exposes a physical signal port that outputs the measured quantity as a function of time. Each quantity is measured for the follower frame with respect to the base frame. It is resolved in the base frame. You can use the measurement signals for analysis or as input in a control system.

Position

Select this option to sense the relative position of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Velocity

Select this option to sense the relative velocity of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Acceleration

Select this option to sense the relative acceleration of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Actuator Force

Select this option to sense the actuation force acting on the follower frame with respect to the base frame along the joint primitive axis.

Revolute Primitive: State Targets

Specify the revolute primitive state targets and their priority levels. A state target is the desired value for one of the joint state parameters—position and velocity. The priority level is the relative importance of a state target. It determines how precisely the target must be met. Use the Model Report tool in Mechanics Explorer to check the assembly status for each joint state target.

Specify Position Target

Select this option to specify the desired joint primitive position at time zero. This is the relative rotation angle, measured about the joint primitive axis, of the follower frame with respect to the base frame. The specified target is resolved in the base frame. Selecting this option exposes priority and value fields.

Specify Velocity Target

Select this option to specify the desired joint primitive velocity at time zero. This is the relative angular velocity, measured about the joint primitive axis, of the follower frame with respect to the base frame. It is resolved in the base frame. Selecting this option exposes priority and value fields.

Priority

Select state target priority. This is the importance level assigned to the state target. If all state targets cannot be simultaneously satisfied, the priority level determines which targets to satisfy first and how closely to satisfy them. This option applies to both position and velocity state targets.

Priority Level	Description
High (desired)	Satisfy state target precisely
Low (approximate)	Satisfy state target approximately

Note: During assembly, high-priority targets behave as exact guides. Low-priority targets behave as rough guides.

Value

> Enter the state target numerical value. The default is 0. Select or enter a physical unit. The default is deg for position and deg/s for velocity.

Revolute Primitive: Internal Mechanics

Specify the revolute primitive internal mechanics. Internal mechanics include linear spring torques, accounting for energy storage, and linear damping torques, accounting for energy dissipation. You can ignore internal mechanics by keeping spring stiffness and damping coefficient values at 0.

Equilibrium Position

> Enter the spring equilibrium position. This is the rotation angle between base and follower frames at which the spring torque is zero. The default value is 0. Select or enter a physical unit. The default is deg.

Spring Stiffness

> Enter the linear spring constant. This is the torque required to rotate the joint primitive by a unit angle. The default is 0. Select or enter a physical unit. The default is N*m/deg.

Damping Coefficient

> Enter the linear damping coefficient. This is the torque required to maintain a constant joint primitive angular velocity between base and follower frames. The default is 0. Select or enter a physical unit. The default is N*m/(deg/s).

Revolute Primitive: Actuation

Specify actuation options for the revolute joint primitive. Actuation modes include **Torque** and **Motion**. Selecting Provided by Input from the drop-down list for an actuation mode adds the corresponding physical signal port to the block. Use this port to specify the input signal. Input signals are resolved in the base frame.

Torque

> Select an actuation torque setting. The default setting is None.

Actuation Torque Setting	Description
None	No actuation torque.

Actuation Torque Setting	Description
`Provided by Input`	Actuation torque from physical signal input. The signal provides the torque acting on the follower frame with respect to the base frame about the joint primitive axis. An equal and opposite torque acts on the base frame.
`Automatically computed`	Actuation torque from automatic calculation. Simscape Multibody computes and applies the actuation torque based on model dynamics.

Motion

Select an actuation motion setting. The default setting is `Automatically Computed`.

Actuation Motion Setting	Description
`Provided by Input`	Joint primitive motion from physical signal input. The signal provides the desired trajectory of the follower frame with respect to the base frame along the joint primitive axis.
`Automatically computed`	Joint primitive motion from automatic calculation. Simscape Multibody computes and applies the joint primitive motion based on model dynamics.

Revolute Primitive: Sensing

Select the variables to sense in the revolute joint primitive. Selecting a variable exposes a physical signal port that outputs the measured quantity as a function of time. Each quantity is measured for the follower frame with respect to the base frame. It is resolved in the base frame. You can use the measurement signals for analysis or as input in a control system.

Position

Select this option to sense the relative rotation angle of the follower frame with respect to the base frame about the joint primitive axis.

Velocity

Select this option to sense the relative angular velocity of the follower frame with respect to the base frame about the joint primitive axis.

Acceleration

Select this option to sense the relative angular acceleration of the follower frame with respect to the base frame about the joint primitive axis.

Actuator Torque

Select this option to sense the actuation torque acting on the follower frame with respect to the base frame about the joint primitive axis.

Composite Force/Torque Sensing

Select the composite, or joint-wide, forces and torques to sense. These are forces and torques that act not at individual joint primitives but at the whole joint. Options include constraint and total forces and torques.

During simulation, the block computes the selected composite forces and torques acting between the base and follower port frames. It outputs these variables using physical signal output ports. Check the port labels to identify the output variables at different ports.

Direction

Forces and torques acting at joints do so in pairs. Newton's third law of motion requires that every action be accompanied by an equal and opposite reaction. If the base frame of a joint exerts a force or torque on the follower frame, then the follower frame must exert an equal and opposite force or torque on the base frame.

Select whether to sense the composite forces and torques exerted by the base frame on the follower frame or vice versa. The force and torque vector components are positive if they point along the positive X, Y, and Z axes of the selected resolution frame.

Resolution Frame

You can resolve a vector quantity into Cartesian components in different frames. If the resolution frames have different orientations, then the measured components are themselves different—even though the vector quantity remains the same.

Select the frame in which to resolve the sensed force and torque variables. Possible resolution frames include `Base` and `Follower`. The block outputs the Cartesian components of the sensed force and torque vectors as observed in this frame.

Constraint Force

Joint blocks with fewer than three translational degrees of freedom forbid motion along one or more axes. For example, the Gimbal Joint block forbids translation along all axes. To prevent translation along an axis, a joint block applies a constraint force between its base and follower port frames. Constraint forces are orthogonal to joint translation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint force vector [fc_x, fc_y, fc_z] acting at the joint. Only constraint force components that are orthogonal to the joint translational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port fc.

Constraint Torque

Joint blocks with fewer than three rotational degrees of freedom forbid motion about one or more axes. For example, the Cartesian Joint block forbids rotation about all axes. To prevent rotation about an axis, a joint block applies a constraint torque between its base and follower port frames. Constraint torques are orthogonal to joint rotation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint torque vector [tc_x, tc_y, tc_z] acting at the joint. Only constraint torque components that are orthogonal to the joint rotational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port tc.

Total Force

A joint block generally applies various forces between its port frames:

- Actuation forces that drive prismatic joint primitives.
- Internal spring and damper forces that resist motion at prismatic joint primitives.
- Constraint forces that forbid motion in directions orthogonal to prismatic joint primitives.

The net sum of the different force components equals the total force acting between the joint port frames. Select the check box to compute and output the 3-D total force vector [ft_x, ft_y, ft_z]. Selecting this option causes the block to expose physical signal port ft.

Total Torque

A joint block generally applies various torques between its port frames:

- Actuation torques that drive revolute or spherical joint primitives.

- Internal spring and damper torques that resist motion at revolute or spherical joint primitives.
- Constraint torques that forbid motion in directions orthogonal to the revolute or spherical joint primitive axes.

The net sum of the different torque components equals the total torque acting at a joint. Select the check box to compute and output the 3-D total torque vector [tt_x, tt_y, tt_z]. Selecting this option causes the block to expose physical signal port tt.

Ports

This block has two frame ports. It also has optional physical signal ports for specifying actuation inputs and sensing dynamical variables such as forces, torques, and motion. You expose an optional port by selecting the sensing check box corresponding to that port.

Frame Ports

- B — Base frame
- F — Follower frame

Actuation Ports

The prismatic joint primitives provide the following actuation ports:

- fx, fy, fz — Actuation forces acting on the X, Y, and Z prismatic joint primitives
- px, py, pz — Desired trajectories of the X, Y, Z prismatic joint primitives

The revolute joint primitives provide the following actuation ports:

- tx, ty, tz — Actuation torques acting on the X, Y, and Z revolute joint primitives
- qx, qy, qz — Desired rotations of the X, Y, and Z revolute joint primitives

Sensing Ports

The prismatic joint primitives provide the following sensing ports:

- px, py, pz — Positions of the X, Y, and Z prismatic joint primitives

- vx, vy, vz — Velocities of the X, Y, and Z prismatic joint primitives
- ax, ay, az — Accelerations of the X, Y, and Z prismatic joint primitives
- fx, fy, fz — Actuation forces acting on the X, Y, and Z prismatic joint primitives

The revolute joint primitives provide the following sensing ports:

- qx, qy, qz — Angular positions of the X, Y, and Z revolute joint primitives
- wx, wy, wz — Angular velocities of the X, Y, and Z revolute joint primitives
- bx, by, bz — Angular accelerations of the X, Y, and Z revolute joint primitives
- tx, ty, tz — Actuation torques acting on the X, Y, and Z revolute joint primitives

The following sensing ports provide the composite forces and torques acting on the joint:

- fc — Constraint force
- tc — Constraint torque
- ft — Total force
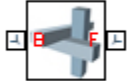- tt — Total torque

See Also
`6-DOF Joint` | `Gimbal Joint` | `Prismatic Joint` | `Revolute Joint`

More About
- "Actuating and Sensing with Physical Signals"
- "Motion Sensing"
- "Rotational Measurements"
- "Translational Measurements"

Cartesian Joint

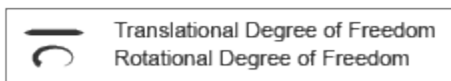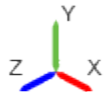Joint with three prismatic primitives

Library

Joints

Description

This block represents a joint with three translational degrees of freedom. Three prismatic primitives provide the three translational degrees of freedom. The base and follower frames remain parallel during simulation.

Translational Degree of Freedom
Rotational Degree of Freedom

Joint Degrees of Freedom

The joint block represents motion between the base and follower frames as a sequence of time-varying transformations. Each joint primitive applies one transformation in this sequence. The transformation translates the follower frame with respect to the joint primitive base frame. For all but the first joint primitive, the base frame coincides with the follower frame of the previous joint primitive in the sequence.

At each time step during the simulation, the joint block applies the sequence of time-varying frame transformations in this order:

1 Translation:

    a Along the X axis of the X Prismatic Primitive (Px) base frame.

    b Along the Y axis of the Y Prismatic Primitive (Py) base frame. This frame is coincident with the X Prismatic Primitive (Px) follower frame.

    c Along the Z axis of the Z Prismatic Primitive (Pz) base frame. This frame is coincident with the Y Prismatic Primitive (Py) follower frame.

The figure shows the sequence in which the joint transformations occur at a given simulation time step. The resulting frame of each transformation serves as the base frame for the following transformation.

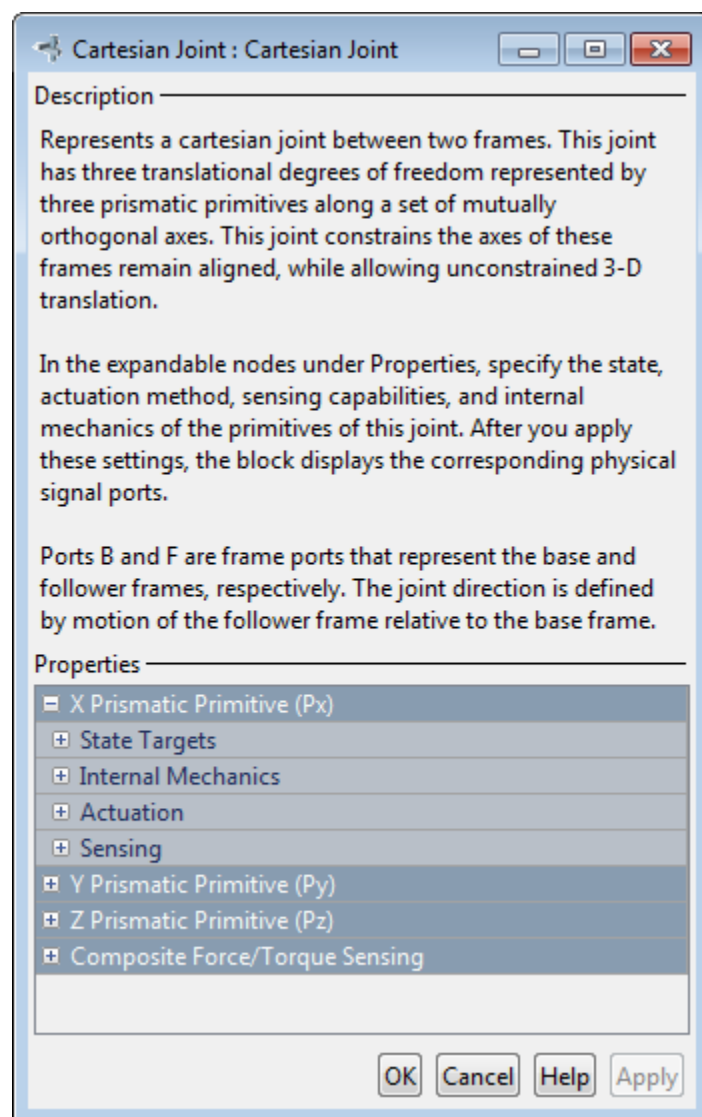**Joint Transformation Sequence**

A set of optional state targets guide assembly for each joint primitive. Targets include position and velocity. A priority level sets the relative importance of the state targets. If two targets are incompatible, the priority level determines which of the targets to satisfy.

Internal mechanics parameters account for energy storage and dissipation at each joint primitive. Springs act as energy storage elements, resisting any attempt to displace the joint primitive from its equilibrium position. Joint dampers act as energy dissipation elements. Springs and dampers are strictly linear.

Each joint primitive has a set of optional actuation and sensing ports. Actuation ports accept physical signal inputs that drive the joint primitives. These inputs can be forces and torques or a desired joint trajectory. Sensing ports provide physical signal outputs that measure joint primitive motion as well as actuation forces and torques. Actuation modes and sensing types vary with joint primitive.

Dialog Box and Parameters

Cartesian Joint : Cartesian Joint

Description

Represents a cartesian joint between two frames. This joint has three translational degrees of freedom represented by three prismatic primitives along a set of mutually orthogonal axes. This joint constrains the axes of these frames remain aligned, while allowing unconstrained 3-D translation.

In the expandable nodes under Properties, specify the state, actuation method, sensing capabilities, and internal mechanics of the primitives of this joint. After you apply these settings, the block displays the corresponding physical signal ports.

Ports B and F are frame ports that represent the base and follower frames, respectively. The joint direction is defined by motion of the follower frame relative to the base frame.

Properties

- X Prismatic Primitive (Px)
  - State Targets
  - Internal Mechanics
  - Actuation
  - Sensing
- Y Prismatic Primitive (Py)
- Z Prismatic Primitive (Pz)
- Composite Force/Torque Sensing

OK Cancel Help Apply

Prismatic Primitive: State Targets

Specify the prismatic primitive state targets and their priority levels. A state target is the desired value for one of the joint state parameters—position and velocity. The priority level is the relative importance of a state target. It determines how precisely the target must be met. Use the Model Report tool in Mechanics Explorer to check the assembly status for each joint state target.

Specify Position Target

Select this option to specify the desired joint primitive position at time zero. This is the relative position, measured along the joint primitive axis, of the follower frame origin with respect to the base frame origin. The specified target is resolved in the base frame. Selecting this option exposes priority and value fields.

Specify Velocity Target

Select this option to specify the desired joint primitive velocity at time zero. This is the relative velocity, measured along the joint primitive axis, of the follower frame origin with respect to the base frame origin. It is resolved in the base frame. Selecting this option exposes priority and value fields.

Priority

Select state target priority. This is the importance level assigned to the state target. If all state targets cannot be simultaneously satisfied, the priority level determines which targets to satisfy first and how closely to satisfy them. This option applies to both position and velocity state targets.

Priority Level	Description
High (desired)	Satisfy state target precisely
Low (approximate)	Satisfy state target approximately

Note: During assembly, high-priority targets behave as exact guides. Low-priority targets behave as rough guides.

Value

Enter the state target numerical value. The default is 0. Select or enter a physical unit. The default is m for position and m/s for velocity.

Prismatic Primitive: Internal Mechanics

Specify the prismatic primitive internal mechanics. Internal mechanics include linear spring forces, accounting for energy storage, and damping forces, accounting for energy dissipation. You can ignore internal mechanics by keeping spring stiffness and damping coefficient values at 0.

Equilibrium Position

Enter the spring equilibrium position. This is the distance between base and follower frame origins at which the spring force is zero. The default value is 0. Select or enter a physical unit. The default is m.

Spring Stiffness

Enter the linear spring constant. This is the force required to displace the joint primitive by a unit distance. The default is 0. Select or enter a physical unit. The default is N/m.

Damping Coefficient

Enter the linear damping coefficient. This is the force required to maintain a constant joint primitive velocity between base and follower frames. The default is 0. Select or enter a physical unit. The default is N/(m/s).

Prismatic Primitive: Actuation

Specify actuation options for the prismatic joint primitive. Actuation modes include **Force** and **Motion**. Selecting Provided by Input from the drop-down list for an actuation mode adds the corresponding physical signal port to the block. Use this port to specify the input signal. Actuation signals are resolved in the base frame.

Force

Select an actuation force setting. The default setting is None.

Actuation Force Setting	Description
None	No actuation force.
Provided by Input	Actuation force from physical signal input. The signal provides the force acting on the follower frame with respect to the base frame along the joint primitive axis. An equal and opposite force acts on the base frame.

Actuation Force Setting	Description
`Automatically computed`	Actuation force from automatic calculation. Simscape Multibody computes and applies the actuation force based on model dynamics.

Motion

Select an actuation motion setting. The default setting is `Automatically Computed`.

Actuation Motion Setting	Description
`Provided by Input`	Joint primitive motion from physical signal input. The signal provides the desired trajectory of the follower frame with respect to the base frame along the joint primitive axis.
`Automatically computed`	Joint primitive motion from automatic calculation. Simscape Multibody computes and applies the joint primitive motion based on model dynamics.

Prismatic Primitive: Sensing

Select the variables to sense in the prismatic joint primitive. Selecting a variable exposes a physical signal port that outputs the measured quantity as a function of time. Each quantity is measured for the follower frame with respect to the base frame. It is resolved in the base frame. You can use the measurement signals for analysis or as input in a control system.

Position

Select this option to sense the relative position of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Velocity

Select this option to sense the relative velocity of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Acceleration

Select this option to sense the relative acceleration of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Actuator Force

Select this option to sense the actuation force acting on the follower frame with respect to the base frame along the joint primitive axis.

Composite Force/Torque Sensing

Select the composite, or joint-wide, forces and torques to sense. These are forces and torques that act not at individual joint primitives but at the whole joint. Options include constraint and total forces and torques.

During simulation, the block computes the selected composite forces and torques acting between the base and follower port frames. It outputs these variables using physical signal output ports. Check the port labels to identify the output variables at different ports.

Direction

Forces and torques acting at joints do so in pairs. Newton's third law of motion requires that every action be accompanied by an equal and opposite reaction. If the base frame of a joint exerts a force or torque on the follower frame, then the follower frame must exert an equal and opposite force or torque on the base frame.

Select whether to sense the composite forces and torques exerted by the base frame on the follower frame or vice versa. The force and torque vector components are positive if they point along the positive X, Y, and Z axes of the selected resolution frame.

Resolution Frame

You can resolve a vector quantity into Cartesian components in different frames. If the resolution frames have different orientations, then the measured components are themselves different—even though the vector quantity remains the same.

Select the frame in which to resolve the sensed force and torque variables. Possible resolution frames include `Base` and `Follower`. The block outputs the Cartesian components of the sensed force and torque vectors as observed in this frame.

Constraint Force

Joint blocks with fewer than three translational degrees of freedom forbid motion along one or more axes. For example, the Gimbal Joint block forbids translation along all axes. To prevent translation along an axis, a joint block applies a constraint

force between its base and follower port frames. Constraint forces are orthogonal to joint translation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint force vector [fc_x, fc_y, fc_z] acting at the joint. Only constraint force components that are orthogonal to the joint translational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port fc.

Constraint Torque

Joint blocks with fewer than three rotational degrees of freedom forbid motion about one or more axes. For example, the Cartesian Joint block forbids rotation about all axes. To prevent rotation about an axis, a joint block applies a constraint torque between its base and follower port frames. Constraint torques are orthogonal to joint rotation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint torque vector [tc_x, tc_y, tc_z] acting at the joint. Only constraint torque components that are orthogonal to the joint rotational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port tc.

Total Force

A joint block generally applies various forces between its port frames:

- Actuation forces that drive prismatic joint primitives.
- Internal spring and damper forces that resist motion at prismatic joint primitives.
- Constraint forces that forbid motion in directions orthogonal to prismatic joint primitives.

The net sum of the different force components equals the total force acting between the joint port frames. Select the check box to compute and output the 3-D total force vector [ft_x, ft_y, ft_z]. Selecting this option causes the block to expose physical signal port ft.

Total Torque

A joint block generally applies various torques between its port frames:

- Actuation torques that drive revolute or spherical joint primitives.
- Internal spring and damper torques that resist motion at revolute or spherical joint primitives.
- Constraint torques that forbid motion in directions orthogonal to the revolute or spherical joint primitive axes.

The net sum of the different torque components equals the total torque acting at a joint. Select the check box to compute and output the 3-D total torque vector [tt_x, tt_y, tt_z]. Selecting this option causes the block to expose physical signal port tt.

Ports

This block has two frame ports. It also has optional physical signal ports for specifying actuation inputs and sensing dynamical variables such as forces, torques, and motion. You expose an optional port by selecting the sensing check box corresponding to that port.

Frame Ports

- B — Base frame
- F — Follower frame

Actuation Ports

The prismatic joint primitives provide the following actuation ports:

- fx, fy, fz — Actuation forces acting on the X, Y, and Z prismatic joint primitives
- px, py, pz — Desired trajectories of the X, Y, Z prismatic joint primitives

Sensing Ports

The prismatic joint primitives provide the following sensing ports:

- px, py, pz — Positions of the X, Y, and Z prismatic joint primitives
- vx, vy, vz — Velocities of the X, Y, and Z prismatic joint primitives
- ax, ay, az — Accelerations of the X, Y, and Z prismatic joint primitives
- fx, fy, fz — Actuation forces acting on the X, Y, and Z prismatic joint primitives

The following sensing ports provide the composite forces and torques acting on the joint:

- fc — Constraint force
- tc — Constraint torque

- ft — Total force
- tt — Total torque
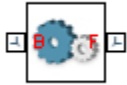
See Also

`Prismatic Joint` | `Rectangular Joint`

More About

- "Actuating and Sensing with Physical Signals"
- "Motion Sensing"
- "Translational Measurements"

Common Gear Constraint

Kinematic constraint for transferring rotational motion at a fixed ratio about parallel axes

Library

Gears and Couplings/Gears

Description

This block represents a common gear constraint between two frames, base and follower. The constraint restricts motion, forcing the frames to spin in sync. Each frame, possessing at least one rotational degree of freedom, spins about its individual Z axis.

To assemble, the common gear constraint imposes several restrictions on the relative position and orientation of the port frames. Through blocks such as Rigid Transform, Joints, and Constraints, the remainder of the model must provide the geometric and kinematic relationships to satisfy these restrictions:

- The Z axes of the base and follower frames must point in the same direction.
- The X and Y axes of the base and follower frames, and therefore the frame origins themselves, must lie in the same plane.

The common gear constraint can be internal or external. If the constraint is internal, the base and follower gear shafts spin in the same direction. If it is external, the shafts spin in opposite directions. The tooth ratio between the two gears determines the magnitude of the angular velocity ratio:

$$\left| \frac{\omega_F}{\omega_B} \right| = \frac{N_B}{N_F} = \frac{R_B}{R_F},$$

where:

- ω_B and ω_F are the angular velocities of the base and follower gears.

- N_B and N_F are the tooth numbers of the base and follower gears.

- R_B and R_F are the pitch radii of the base and follower gears. These are the radii of the gear pitch circles, imaginary circles tangent to each other at the tooth-tooth contact point.
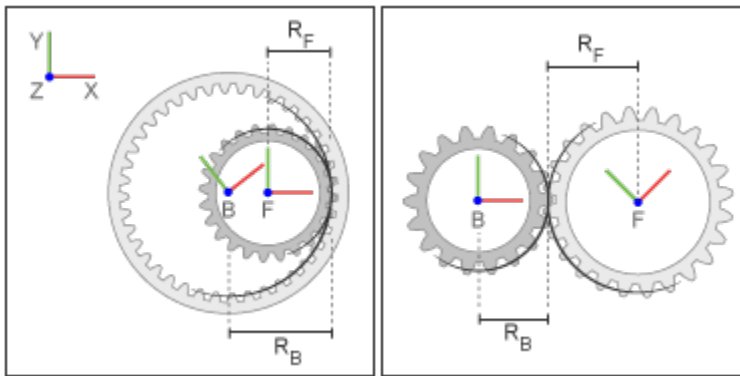
Gear Frames and Dimensions

Dialog Box and Parameters
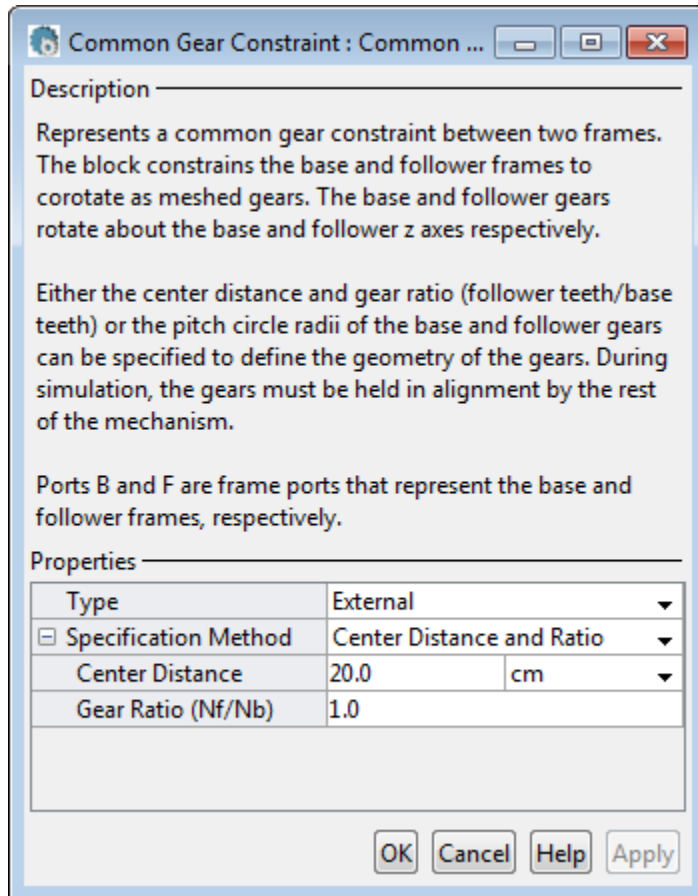
Type

> Select gear type. Options include internal or external. Internal gears have teeth along the inner circumference. External gears have teeth along the outer circumference. The default type is `External`.

Specification Method

> Select the method to specify the common gear with. Options include `Center Distance and Ratio` and `Pitch Circle Radii`.

Center Distance and Ratio

Specify the common gear constraint in terms of the center-to-center separation distance and the gear teeth ratio (Nf/Nb).

Center Distance

Enter the center-to-center distance between base and follower gears. Select a physical unit. The default value is `20.0 cm`.

Gear Ratio

Enter the gear teeth ratio between base and follower gears. This ratio is Nf/Nb, where Nf and Nb represent the number of teeth in the follower and base gears, respectively. The default value is `1.0`.

Pitch Circle Radii

Specify the common gear in terms of the base and follower gear radii.

Base Gear Radius

Enter the radius of the gear associated with the base frame. Select a physical unit. The default value is `10.0 cm`.

Follower Gear Radius

Enter the radius of the gear associated with the follower frame. Select a physical unit. The default value is `10.0 cm`.
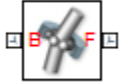
Ports

The block contains frame ports B and F, representing base and follower frames, respectively.

See Also

Angle Constraint | Bevel Gear Constraint | Distance Constraint | Point on Curve Constraint | Rack and Pinion Constraint

Constant Velocity Joint

Joint with two rotational DoFs between shafts constrained to spin with equal velocity

Library

Joints

Description

This block represents a joint with two rotational degrees of freedom constrained to maintain a constant angular velocity about the base and follower Z axes. The base and follower frame origins remain coincident throughout simulation.

The joint applies three rotation transformations between the base and follower frames in the sequence azimuth → bend angle → -azimuth. Each transformation takes place relative to the intermediate frame resulting from any prior transformations. For example, the bend angle transformation takes place relative to the intermediate frame resulting from the azimuth transformation.
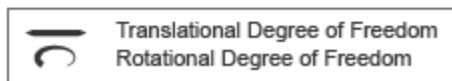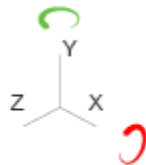
Joint Degrees of Freedom

A set of optional state targets guide assembly for the joint primitive. Targets include position and velocity. A priority level sets the relative importance of the state targets. If two targets are incompatible, the priority level determines which of the targets to satisfy.

Optional sensing ports output the joint primitive motion through physical signals. Motion variables that you can sense include joint position, velocity, and acceleration. Selecting a variable in the Sensing menu exposes the physical signal port for that variable.

Dialog Box and Parameters

Constant Velocity Joint : Constant Vel...

Description

Represents a constant-velocity joint between two frames. This joint has two degrees of freedom represented by one constant-velocity primitive. The joint constrains the origins of the two frames to be coincident and enforces a kinematic constraint which provides a constant-velocity relationship between the base and follower frames. Specifically, if the base and follower frame z-axes are both fixed with respect to a common reference frame, then the component along the follower frame's z-axis of the follower frame's angular velocity with respect to the common reference frame is equal to the component along the base frame's z-axis of the base frame's angular velocity with respect to the common reference frame.

In the expandable nodes under Properties, specify the state and sensing capabilities of the primitives of this joint. After you apply these settings, the block displays the corresponding physical signal ports.

Ports B and F are frame ports that represent the base and follower frames, respectively. The joint direction is defined by motion of the follower frame relative to the base frame.

Properties

⊟ Constant Velocity Primitive (CV)
⊞ State Targets
⊞ Sensing
⊞ Composite Force/Torque Sensing

OK Cancel Help Apply

Constant Velocity Primitive: State Targets

Specify Position Target

Desired joint primitive position at the start of simulation. This is the relative angular position of the follower frame relative to the base frame. Selecting this option exposes priority and value fields.

Specify Velocity Target

Desired joint velocity at the start of simulation. This is the relative angular velocity of the follower frame relative to the base frame. Selecting this option exposes priority and value fields.

Priority

Select state target priority. This is the importance level assigned to the state target. If all state targets cannot be simultaneously satisfied, the priority level determines which targets to satisfy first and how closely to satisfy them. This option applies to both position and velocity state targets.

Priority Level	Description
High (desired)	Satisfy state target precisely
Low (approximate)	Satisfy state target approximately

Note: During assembly, high-priority targets behave as exact guides. Low-priority targets behave as rough guides.

Value

Joint primitive angles to specify. Angles include bend and azimuth angles.

Value: **Bend Angle**

Angle between the base and follower frame Z axes. The block applies this angle about the rotated Y axis resulting from the azimuth transformation. At zero bend angle, the follower frame Z axis is coincident with the base frame Z axis.

Value: **Azimuth**

Angle about the base frame Z axis prior to bending. At zero azimuth, the base and follower Z axes are in the XZ plane of the base frame.

Constant Velocity Primitive: Sensing

Select the variables to sense in the constant velocity joint primitive. Selecting a variable exposes a physical signal port that outputs the measured quantity as a function of time. Each quantity is measured for the follower frame with respect to the base frame. It is resolved in the base frame.

Variable	Description
Bend Angle: **Position**	Angle between the base and follower frame Z axes
Bend Angle: **Velocity**	First time derivative of the bend angle.
Bend Angle: **Acceleration**	Second time derivative of the bend angle.
Azimuth: **Position**	Angle about the base frame Z axis prior to bending.
Azimuth: **Velocity**	First time derivative of the azimuth angle.
Azimuth: **Acceleration**	Second time derivative of the azimuth angle.

Composite Force/Torque Sensing

Select the composite, or joint-wide, forces and torques to sense. These are forces and torques that act not at individual joint primitives but at the whole joint. Options include constraint and total forces and torques.

During simulation, the block computes the selected composite forces and torques acting between the base and follower port frames. It outputs these variables using physical signal output ports. Check the port labels to identify the output variables at different ports.

Direction

Forces and torques acting at joints do so in pairs. Newton's third law of motion requires that every action be accompanied by an equal and opposite reaction. If the base frame of a joint exerts a force or torque on the follower frame, then the follower frame must exert an equal and opposite force or torque on the base frame.

Select whether to sense the composite forces and torques exerted by the base frame on the follower frame or vice versa. The force and torque vector components are

positive if they point along the positive X, Y, and Z axes of the selected resolution frame.

Resolution Frame

You can resolve a vector quantity into Cartesian components in different frames. If the resolution frames have different orientations, then the measured components are themselves different—even though the vector quantity remains the same.

Select the frame in which to resolve the sensed force and torque variables. Possible resolution frames include `Base` and `Follower`. The block outputs the Cartesian components of the sensed force and torque vectors as observed in this frame.

Constraint Force

Joint blocks with fewer than three translational degrees of freedom forbid motion along one or more axes. For example, the Gimbal Joint block forbids translation along all axes. To prevent translation along an axis, a joint block applies a constraint force between its base and follower port frames. Constraint forces are orthogonal to joint translation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint force vector [fc_x, fc_y, fc_z] acting at the joint. Only constraint force components that are orthogonal to the joint translational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port fc.

Constraint Torque

Joint blocks with fewer than three rotational degrees of freedom forbid motion about one or more axes. For example, the Cartesian Joint block forbids rotation about all axes. To prevent rotation about an axis, a joint block applies a constraint torque between its base and follower port frames. Constraint torques are orthogonal to joint rotation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint torque vector [tc_x, tc_y, tc_z] acting at the joint. Only constraint torque components that are orthogonal to the joint rotational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port tc.

Total Force

A joint block generally applies various forces between its port frames:

- Actuation forces that drive prismatic joint primitives.

- Internal spring and damper forces that resist motion at prismatic joint primitives.

- Constraint forces that forbid motion in directions orthogonal to prismatic joint primitives.

The net sum of the different force components equals the total force acting between the joint port frames. Select the check box to compute and output the 3-D total force vector [ft_x, ft_y, ft_z]. Selecting this option causes the block to expose physical signal port ft.

Total Torque

A joint block generally applies various torques between its port frames:

- Actuation torques that drive revolute or spherical joint primitives.
- Internal spring and damper torques that resist motion at revolute or spherical joint primitives.
- Constraint torques that forbid motion in directions orthogonal to the revolute or spherical joint primitive axes.

The net sum of the different torque components equals the total torque acting at a joint. Select the check box to compute and output the 3-D total torque vector [tt_x, tt_y, tt_z]. Selecting this option causes the block to expose physical signal port tt.

Ports

This block has two frame ports. It also has optional physical signal ports for sensing dynamical variables such as forces, torques, and motion. You expose an optional port by selecting the sensing check box corresponding to that port.

Frame Ports

- B — Base frame
- F — Follower frame

Sensing Ports

The constant velocity joint primitive provides the following sensing ports:

- qb — Bend angle
- wb — First time-derivative of the bend angle

- bb — Second time-derivative of the bend angle
- qa — Azimuth angle
- wa — First time-derivative of the azimuth angle
- ba — Second time-derivative of the azimuth angle

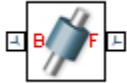The following sensing ports provide the composite forces and torques acting on the joint:

- fc — Constraint force
- tc — Constraint torque
- ft — Total force
- tt — Total torque

See Also
`Universal Joint`

Cylindrical Joint

Joint with one prismatic and one revolute primitives possessing parallel motion axes

Library

Joints

Description

This block represents a joint with one translational and one rotational degree of freedom. One prismatic primitive provides the translational degree of freedom. One revolute primitive provides the rotational degree of freedom. The translation and rotation axes remain aligned during simulation.
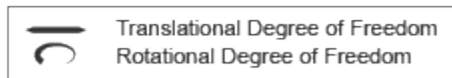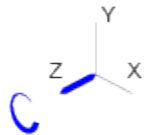
Joint Degrees of Freedom

The joint block represents motion between the base and follower frames as a sequence of time-varying transformations. Each joint primitive applies one transformation in this sequence. The transformation translates or rotates the follower frame with respect to the

joint primitive base frame. For all but the first joint primitive, the base frame coincides with the follower frame of the previous joint primitive in the sequence.

At each time step during the simulation, the joint block applies the sequence of time-varying frame transformations in this order:
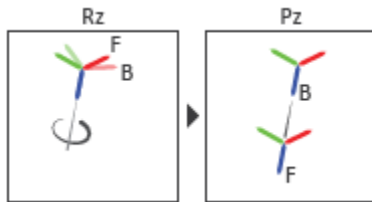
1 Rotation:

- About the Z axis of the Z Revolute Primitive (Rz) base frame.

2 Translation:

- Along the Z axis of the Z Prismatic Primitive (Pz) base frame.

The figure shows the sequence in which the joint transformations occur at a given simulation time step. The resulting frame of each transformation serves as the base frame for the following transformation.
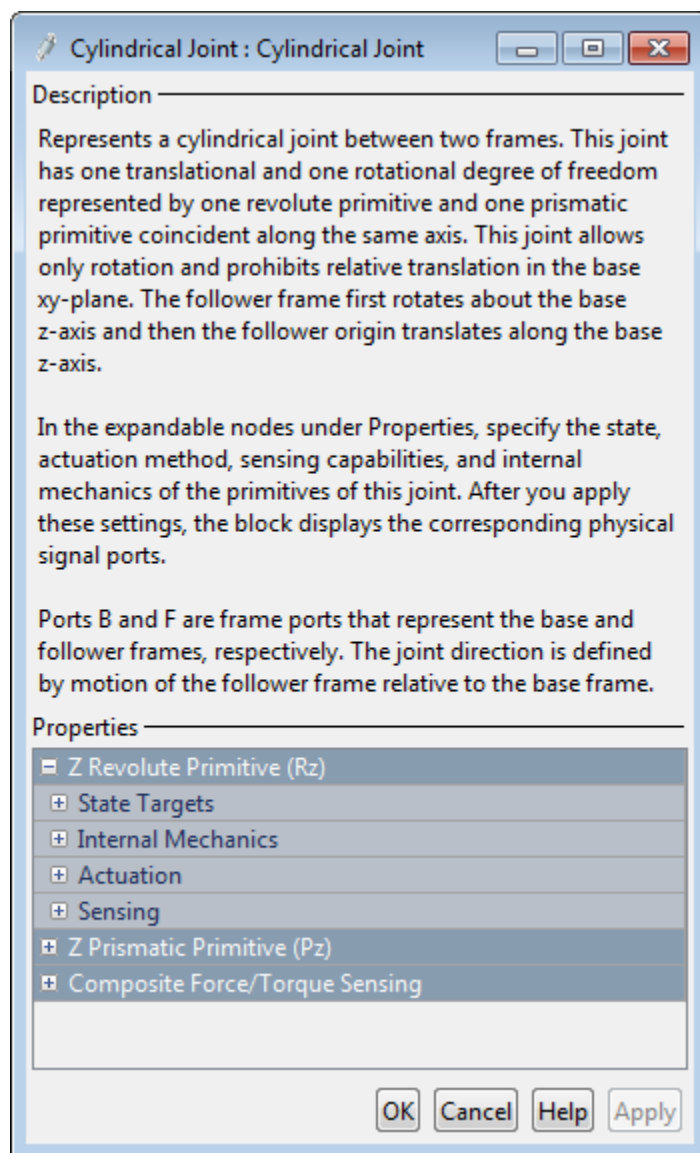

Joint Transformation Sequence

A set of optional state targets guide assembly for each joint primitive. Targets include position and velocity. A priority level sets the relative importance of the state targets. If two targets are incompatible, the priority level determines which of the targets to satisfy.

Internal mechanics parameters account for energy storage and dissipation at each joint primitive. Springs act as energy storage elements, resisting any attempt to displace the joint primitive from its equilibrium position. Joint dampers act as energy dissipation elements. Springs and dampers are strictly linear.

Each joint primitive has a set of optional actuation and sensing ports. Actuation ports accept physical signal inputs that drive the joint primitives. These inputs can be forces and torques or a desired joint trajectory. Sensing ports provide physical signal outputs that measure joint primitive motion as well as actuation forces and torques. Actuation modes and sensing types vary with joint primitive.

Dialog Box and Parameters

Cylindrical Joint : Cylindrical Joint

Description

Represents a cylindrical joint between two frames. This joint has one translational and one rotational degree of freedom represented by one revolute primitive and one prismatic primitive coincident along the same axis. This joint allows only rotation and prohibits relative translation in the base xy-plane. The follower frame first rotates about the base z-axis and then the follower origin translates along the base z-axis.

In the expandable nodes under Properties, specify the state, actuation method, sensing capabilities, and internal mechanics of the primitives of this joint. After you apply these settings, the block displays the corresponding physical signal ports.

Ports B and F are frame ports that represent the base and follower frames, respectively. The joint direction is defined by motion of the follower frame relative to the base frame.

Properties

- Z Revolute Primitive (Rz)
  - State Targets
  - Internal Mechanics
  - Actuation
  - Sensing
- Z Prismatic Primitive (Pz)
- Composite Force/Torque Sensing

OK Cancel Help Apply

Revolute Primitive: State Targets

Specify the revolute primitive state targets and their priority levels. A state target is the desired value for one of the joint state parameters—position and velocity. The priority level is the relative importance of a state target. It determines how precisely the target must be met. Use the Model Report tool in Mechanics Explorer to check the assembly status for each joint state target.

Specify Position Target

Select this option to specify the desired joint primitive position at time zero. This is the relative rotation angle, measured about the joint primitive axis, of the follower frame with respect to the base frame. The specified target is resolved in the base frame. Selecting this option exposes priority and value fields.

Specify Velocity Target

Select this option to specify the desired joint primitive velocity at time zero. This is the relative angular velocity, measured about the joint primitive axis, of the follower frame with respect to the base frame. It is resolved in the base frame. Selecting this option exposes priority and value fields.

Priority

Select state target priority. This is the importance level assigned to the state target. If all state targets cannot be simultaneously satisfied, the priority level determines which targets to satisfy first and how closely to satisfy them. This option applies to both position and velocity state targets.

Priority Level	Description
High (desired)	Satisfy state target precisely
Low (approximate)	Satisfy state target approximately

Note: During assembly, high-priority targets behave as exact guides. Low-priority targets behave as rough guides.

Value

Enter the state target numerical value. The default is 0. Select or enter a physical unit. The default is deg for position and deg/s for velocity.

Revolute Primitive: Internal Mechanics

Specify the revolute primitive internal mechanics. Internal mechanics include linear spring torques, accounting for energy storage, and linear damping torques, accounting for energy dissipation. You can ignore internal mechanics by keeping spring stiffness and damping coefficient values at 0.

Equilibrium Position

Enter the spring equilibrium position. This is the rotation angle between base and follower frames at which the spring torque is zero. The default value is 0. Select or enter a physical unit. The default is deg.

Spring Stiffness

Enter the linear spring constant. This is the torque required to rotate the joint primitive by a unit angle. The default is 0. Select or enter a physical unit. The default is N*m/deg.

Damping Coefficient

Enter the linear damping coefficient. This is the torque required to maintain a constant joint primitive angular velocity between base and follower frames. The default is 0. Select or enter a physical unit. The default is N*m/(deg/s).

Revolute Primitive: Actuation

Specify actuation options for the revolute joint primitive. Actuation modes include **Torque** and **Motion**. Selecting Provided by Input from the drop-down list for an actuation mode adds the corresponding physical signal port to the block. Use this port to specify the input signal. Input signals are resolved in the base frame.

Torque

Select an actuation torque setting. The default setting is None.

Actuation Torque Setting	Description
None	No actuation torque.
Provided by Input	Actuation torque from physical signal input. The signal provides the torque acting on the follower frame with respect to the base frame about the joint primitive axis. An equal and opposite torque acts on the base frame.

Actuation Torque Setting	Description
`Automatically computed`	Actuation torque from automatic calculation. Simscape Multibody computes and applies the actuation torque based on model dynamics.

Motion

Select an actuation motion setting. The default setting is `Automatically Computed`.

Actuation Motion Setting	Description
`Provided by Input`	Joint primitive motion from physical signal input. The signal provides the desired trajectory of the follower frame with respect to the base frame along the joint primitive axis.
`Automatically computed`	Joint primitive motion from automatic calculation. Simscape Multibody computes and applies the joint primitive motion based on model dynamics.

Revolute Primitive: Sensing

Select the variables to sense in the revolute joint primitive. Selecting a variable exposes a physical signal port that outputs the measured quantity as a function of time. Each quantity is measured for the follower frame with respect to the base frame. It is resolved in the base frame. You can use the measurement signals for analysis or as input in a control system.

Position

Select this option to sense the relative rotation angle of the follower frame with respect to the base frame about the joint primitive axis.

Velocity

Select this option to sense the relative angular velocity of the follower frame with respect to the base frame about the joint primitive axis.

Acceleration

Select this option to sense the relative angular acceleration of the follower frame with respect to the base frame about the joint primitive axis.

Actuator Torque

Select this option to sense the actuation torque acting on the follower frame with respect to the base frame about the joint primitive axis.

Prismatic Primitive: State Targets

Specify the prismatic primitive state targets and their priority levels. A state target is the desired value for one of the joint state parameters—position and velocity. The priority level is the relative importance of a state target. It determines how precisely the target must be met. Use the Model Report tool in Mechanics Explorer to check the assembly status for each joint state target.

Specify Position Target

Select this option to specify the desired joint primitive position at time zero. This is the relative position, measured along the joint primitive axis, of the follower frame origin with respect to the base frame origin. The specified target is resolved in the base frame. Selecting this option exposes priority and value fields.

Specify Velocity Target

Select this option to specify the desired joint primitive velocity at time zero. This is the relative velocity, measured along the joint primitive axis, of the follower frame origin with respect to the base frame origin. It is resolved in the base frame. Selecting this option exposes priority and value fields.

Priority

Select state target priority. This is the importance level assigned to the state target. If all state targets cannot be simultaneously satisfied, the priority level determines which targets to satisfy first and how closely to satisfy them. This option applies to both position and velocity state targets.

Priority Level	Description
High (desired)	Satisfy state target precisely
Low (approximate)	Satisfy state target approximately

Note: During assembly, high-priority targets behave as exact guides. Low-priority targets behave as rough guides.

Value

> Enter the state target numerical value. The default is 0. Select or enter a physical unit. The default is m for position and m/s for velocity.

Prismatic Primitive: Internal Mechanics

Specify the prismatic primitive internal mechanics. Internal mechanics include linear spring forces, accounting for energy storage, and damping forces, accounting for energy dissipation. You can ignore internal mechanics by keeping spring stiffness and damping coefficient values at 0.

Equilibrium Position

> Enter the spring equilibrium position. This is the distance between base and follower frame origins at which the spring force is zero. The default value is 0. Select or enter a physical unit. The default is m.

Spring Stiffness

> Enter the linear spring constant. This is the force required to displace the joint primitive by a unit distance. The default is 0. Select or enter a physical unit. The default is N/m.

Damping Coefficient

> Enter the linear damping coefficient. This is the force required to maintain a constant joint primitive velocity between base and follower frames. The default is 0. Select or enter a physical unit. The default is N/(m/s).

Prismatic Primitive: Actuation

Specify actuation options for the prismatic joint primitive. Actuation modes include **Force** and **Motion**. Selecting Provided by Input from the drop-down list for an actuation mode adds the corresponding physical signal port to the block. Use this port to specify the input signal. Actuation signals are resolved in the base frame.

Force

> Select an actuation force setting. The default setting is None.

Actuation Force Setting	Description
None	No actuation force.

Actuation Force Setting	Description
Provided by Input	Actuation force from physical signal input. The signal provides the force acting on the follower frame with respect to the base frame along the joint primitive axis. An equal and opposite force acts on the base frame.
Automatically computed	Actuation force from automatic calculation. Simscape Multibody computes and applies the actuation force based on model dynamics.

Motion

Select an actuation motion setting. The default setting is `Automatically Computed`.

Actuation Motion Setting	Description
Provided by Input	Joint primitive motion from physical signal input. The signal provides the desired trajectory of the follower frame with respect to the base frame along the joint primitive axis.
Automatically computed	Joint primitive motion from automatic calculation. Simscape Multibody computes and applies the joint primitive motion based on model dynamics.

Prismatic Primitive: Sensing

Select the variables to sense in the prismatic joint primitive. Selecting a variable exposes a physical signal port that outputs the measured quantity as a function of time. Each quantity is measured for the follower frame with respect to the base frame. It is resolved in the base frame. You can use the measurement signals for analysis or as input in a control system.

Position

Select this option to sense the relative position of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Velocity

Select this option to sense the relative velocity of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Acceleration

Select this option to sense the relative acceleration of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Actuator Force

Select this option to sense the actuation force acting on the follower frame with respect to the base frame along the joint primitive axis.

Composite Force/Torque Sensing

Select the composite, or joint-wide, forces and torques to sense. These are forces and torques that act not at individual joint primitives but at the whole joint. Options include constraint and total forces and torques.

During simulation, the block computes the selected composite forces and torques acting between the base and follower port frames. It outputs these variables using physical signal output ports. Check the port labels to identify the output variables at different ports.

Direction

Forces and torques acting at joints do so in pairs. Newton's third law of motion requires that every action be accompanied by an equal and opposite reaction. If the base frame of a joint exerts a force or torque on the follower frame, then the follower frame must exert an equal and opposite force or torque on the base frame.

Select whether to sense the composite forces and torques exerted by the base frame on the follower frame or vice versa. The force and torque vector components are positive if they point along the positive X, Y, and Z axes of the selected resolution frame.

Resolution Frame

You can resolve a vector quantity into Cartesian components in different frames. If the resolution frames have different orientations, then the measured components are themselves different—even though the vector quantity remains the same.

Select the frame in which to resolve the sensed force and torque variables. Possible resolution frames include `Base` and `Follower`. The block outputs the Cartesian components of the sensed force and torque vectors as observed in this frame.

Constraint Force

Joint blocks with fewer than three translational degrees of freedom forbid motion along one or more axes. For example, the Gimbal Joint block forbids translation along all axes. To prevent translation along an axis, a joint block applies a constraint force between its base and follower port frames. Constraint forces are orthogonal to joint translation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint force vector [fc_x, fc_y, fc_z] acting at the joint. Only constraint force components that are orthogonal to the joint translational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port fc.

Constraint Torque

Joint blocks with fewer than three rotational degrees of freedom forbid motion about one or more axes. For example, the Cartesian Joint block forbids rotation about all axes. To prevent rotation about an axis, a joint block applies a constraint torque between its base and follower port frames. Constraint torques are orthogonal to joint rotation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint torque vector [tc_x, tc_y, tc_z] acting at the joint. Only constraint torque components that are orthogonal to the joint rotational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port tc.

Total Force

A joint block generally applies various forces between its port frames:

- Actuation forces that drive prismatic joint primitives.
- Internal spring and damper forces that resist motion at prismatic joint primitives.
- Constraint forces that forbid motion in directions orthogonal to prismatic joint primitives.

The net sum of the different force components equals the total force acting between the joint port frames. Select the check box to compute and output the 3-D total force vector [ft_x, ft_y, ft_z]. Selecting this option causes the block to expose physical signal port ft.

Total Torque

A joint block generally applies various torques between its port frames:

- Actuation torques that drive revolute or spherical joint primitives.

- Internal spring and damper torques that resist motion at revolute or spherical joint primitives.
- Constraint torques that forbid motion in directions orthogonal to the revolute or spherical joint primitive axes.

The net sum of the different torque components equals the total torque acting at a joint. Select the check box to compute and output the 3-D total torque vector [tt_x, tt_y, tt_z]. Selecting this option causes the block to expose physical signal port tt.

Ports

This block has two frame ports. It also has optional physical signal ports for specifying actuation inputs and sensing dynamical variables such as forces, torques, and motion. You expose an optional port by selecting the sensing check box corresponding to that port.

Frame Ports

- B — Base frame
- F — Follower frame

Actuation Ports

The prismatic joint primitive provides the following actuation ports:

- fz — Actuation force acting on the Z prismatic joint primitive
- pz — Desired trajectory of the Z prismatic joint primitive

The revolute joint primitive provides the following actuation ports:

- tz — Actuation torque acting on the Z revolute joint primitive
- qz — Desired rotation of the Z revolute joint primitive

Sensing Ports

The prismatic joint primitive provides the following sensing ports:

- pz — Position of the Z prismatic joint primitive

- vz — Velocity of the Z prismatic joint primitive
- az — Acceleration of the Z prismatic joint primitive
- fz — Actuation force acting on the Z prismatic joint primitive

The revolute joint primitive provides the following sensing ports:

- qz — Angular position of the Z revolute joint primitive
- wz — Angular velocity of the Z revolute joint primitive
- bz — Angular acceleration of the Z revolute joint primitive
- tz — Actuation torque acting on the Z revolute joint primitive

The following sensing ports provide the composite forces and torques acting on the joint:

- fc — Constraint force
- tc — Constraint torque
- ft — Total force
- tt — Total torque

See Also
`Prismatic Joint` | `Revolute Joint`

More About
- "Actuating and Sensing with Physical Signals"
- "Motion Sensing"
- "Rotational Measurements"
- "Translational Measurements"

Distance Constraint

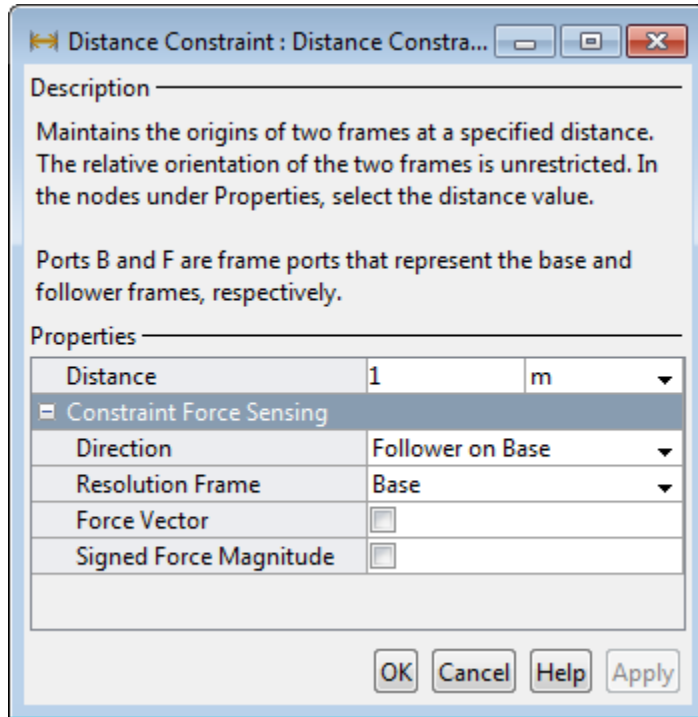Fixed distance between two frame origins

Library

Constraints

Description

This block applies a fixed distance between the origins of the base and follower port frames. The frames lose one translational degree of freedom with respect to each other. The constraint distance between the frame origins, labeled *D* in the figure, must be greater than zero.
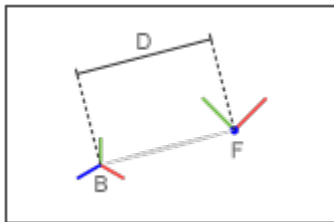
The block provides constraint force sensing in the form of a vector or a signed magnitude. These quantities are contained in physical signals that the block outputs through Simscape PS ports. The constraint force is the force required to maintain the specified distance between the port frame origins.

Dialog Box and Parameters

Distance

Constraint distance between the base and follower frame origins. The distance must be greater than zero. For a distance of zero, use a `Spherical Joint` or `Gimbal Joint` block instead. The default value is `1 m`.

Constraint Force Sensing

Select whether to compute and output the distance constraint force vector and its signed magnitude. The distance constraint force is the force that the block must apply in order to maintain the distance you specify between the base and follower port frames.

Direction

Constraint forces act in pairs. As expressed by Newton's third law of motion, if the base port frame exerts a constraint force on the follower port frame, then the follower

port frame must exert an equal and opposite force on the base port frame. Select which of the two constraint forces to sense:

- `Follower on Base` — Sense the constraint force that the follower port frame exerts on the base port frame.
- `Base on Follower` — Sense the constraint force that the base port frame exerts on the follower port frame.

Resolution Frame

The block expresses the constraint force vector in terms of its Cartesian vector components. The splitting of a vector into vector components is known as vector resolution. The frame whose axes define the vector component directions is known as the resolution frame. Select whether to resolve the constraint force vector in the base or follower port frame.

Force Vector

Compute and output the Cartesian components of the distance constraint force vector. The output signal is a three-dimensional vector, $[f_x, f_y, f_z]$.

Signed Force Magnitude

Compute and output the magnitude of the distance constraint force, including its sign.

Ports

The block provides two frame ports:

- B — Base frame port
- F — Follower frame port

In addition, the block provides two physical signal output ports:

- f — Distance constraint force vector
- fm — Signed magnitude of the distance constraint force

See Also
Angle Constraint | Bevel Gear Constraint | Common Gear Constraint | Point on Curve Constraint | Rack and Pinion Constraint

Internal Force

General force acting reciprocally between two frame origins

Library

Forces and Torques

Description

This block represents a general force pair acting reciprocally between base and follower frame origins. The two forces in the pair have equal magnitude but opposite directions. One force acts on the base frame origin, along the vector connecting follower to base frame origins. The other force acts on the follower frame origin, along the vector connecting base to follower frame origins.

To specify the internal force, the block provides physical signal port **fm**. A positive input signal represents a repulsive force, which pushes base and follower frame origins apart. A negative input signal represents an attractive force, which pulls base and follower frame origins together. If at any time the two frame origins are coincident, the internal force direction becomes undefined and Simscape Multibody might stop with an error.

Dialog Box and Parameters
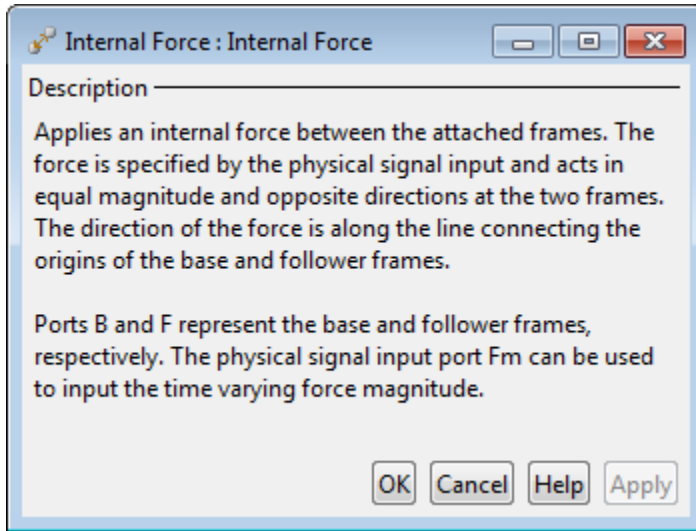
Ports

This block contains frame ports **B** and **F**, representing base and follower port frames, respectively. A physical signal port, **fm**, provides the means to specify the internal force acting between the two port frames.

See Also
```
External Force and Torque | Inverse Square Law Force | Spring and
Damper Force
```

More About
*   "Actuating and Sensing with Physical Signals"

External Force and Torque

General force and torque arising outside the modeled system

Library

Forces and Torques

Description

This block represents a general force and torque that an external agency applies on a rigid body frame. The force and torque input can be constant or it can vary with time. The block provides a set of physical signal ports that you use to specify this input. The ports are hidden by default. Selecting an actuation mode exposes the corresponding physical signal port.

Each force and torque input acts on the origin of the follower frame in a direction that depends on the chosen force type and resolution frame. A force/torque vector component acts along/about the associated Cartesian axis, resolved in the chosen resolution frame. For example, the **Force(X)** input acts along the X axis of the resolution frame. A complete force/torque vector acts in the general direction that its components specify, resolved in the chosen resolution frame.

A force input with a positive value acts along the positive direction of the associated axis. A torque input with a positive value acts about the associated axis according to the right-hand rule.

Dialog Box and Parameters
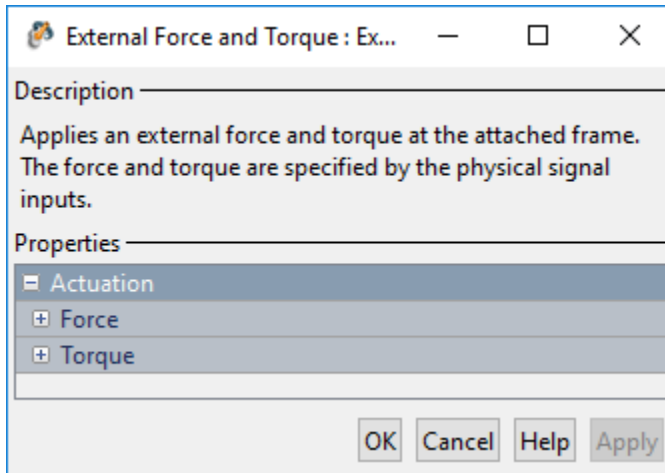
Actuation: Force

Select the force inputs to specify and the frame to resolve them in.

Force Resolution Frame

Select the frame to resolve each force signal in. The components of the force vector align with the axes of the resolution frame. The default setting is `Attached Frame`. The table summarizes the resolution frames that you can select.

Resolution Frame	Description
`World`	Resolve each force component in the World frame of the model.
`Attached Frame`	Resolve each force component in the follower frame of the External Force and Torque block. The follower frame is the attached frame of the block.

Force Inputs

Select the force inputs to specify. Options include the complete force vector and the separate components of that vector. Selecting a force input exposes the physical

signal port associated with that input. Use that port to specify the force input via physical signals. The table summarizes the force inputs that you can select.

Force Input	Description	Input
Force(X), **Force(Y)**, **Force(Z)**	Specify separately the force components acting on the origin of the follower frame along the X, Y, and Z axes of the resolution frame	Scalar
Force	Specify the complete force vector [fx fy fz] acting on the origin of the follower frame along the X, Y, and Z axes of the resolution frame	Three-element vector

Actuation: Torque

Select the torque inputs to specify and the frame to resolve them in.

Torque Resolution Frame

Select the frame to resolve each torque signal in. The components of the torque vector align with the axes of the resolution frame. The default setting is `Attached Frame`. The table summarizes the resolution frames that you can select.

Resolution Frame	Description
`World`	Resolve each torque component in the World frame of the model.
`Attached Frame`	Resolve each torque component in the follower frame of the External Force and Torque block. The follower frame is the attached frame of the block.

Torque Inputs

Select the torque inputs to specify. Options include the complete torque vector and the separate components of that vector. Selecting a torque input exposes the physical

signal port associated with that input. Use that port to specify the torque input via physical signals. The table summarizes the torque inputs that you can select.

Force Input	Description	Input
Torque(X), **Torque(Y)**, **Torque(Z)**	Specify separately the torque components acting on the origin of the follower frame about the X, Y, and Z axes of the resolution frame	Scalar
Torque	Specify the complete torque vector [fx fy fz] acting on the origin of the follower frame about a general direction in the resolution frame	Three-element vector

Ports

The block contains frame port F, representing the follower frame. Selecting an actuation mode exposes additional physical signal ports. Use the ports to input the selected actuation signals.

Each physical signal port has a unique label. The table identifies the actuation modes that the port labels correspond to.

Port Label	Description
fx, fy, fz	Force vector components acting on the origin of the follower frame along the X, Y, and Z axes, respectively
f	Force vector [fx, fy, fz] acting on the origin of the follower frame along a general direction [X Y Z]
tx, ty, tz	Torque vector components acting on the origin of the follower frame about the X, Y, and Z axes, respectively

Port Label	Description
t	Torque vector [tx ty tz] acting on the origin of the follower frame about a general direction [X Y Z]

See Also
Internal Force | Inverse Square Law Force | Spring and Damper Force

More About
·   "Actuating and Sensing with Physical Signals"
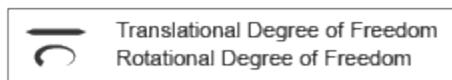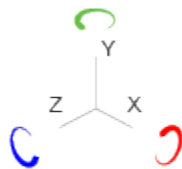
Gimbal Joint

Joint with three revolute primitives

Library

Joints

Description

This block represents a joint with three rotational degrees of freedom. Three revolute primitives provide the three rotational degrees of freedom. The base and follower frame origins remain coincident during simulation.
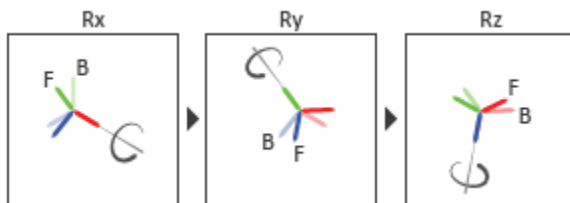

	Translational Degree of Freedom
	Rotational Degree of Freedom

Joint Degrees of Freedom

The joint block represents motion between the base and follower frames as a sequence of time-varying transformations. Each joint primitive applies one transformation in this sequence. The transformation translates or rotates the follower frame with respect to the joint primitive base frame. For all but the first joint primitive, the base frame coincides with the follower frame of the previous joint primitive in the sequence.

At each time step during the simulation, the joint block applies the sequence of time-varying frame transformations in this order:

1 Rotation:

   a About the X axis of the X Revolute Primitive (Rx) base frame.

   b About the Y axis of the Y Revolute Primitive (Ry) base frame. This frame is coincident with the X Revolute Primitive (Rx) follower frame.

   c About the Z axis of the Z Revolute Primitive (Rz) base frame. This frame is coincident with the Y Revolute Primitive (Ry) follower frame.

The figure shows the sequence in which the joint transformations occur at a given simulation time step. The resulting frame of each transformation serves as the base frame for the following transformation. Because 3-D rotation occurs as a sequence, it is possible for two axes to align, causing to the loss of one rotational degree of freedom. This phenomenon is known as gimbal lock.
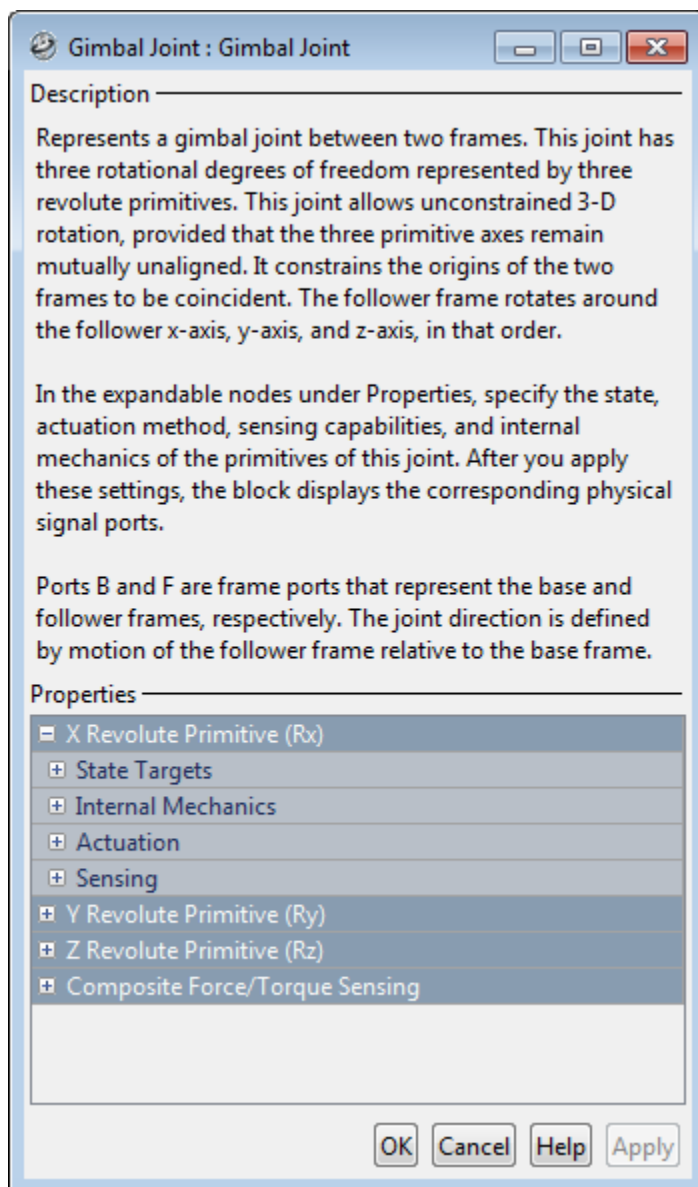

Joint Transformation Sequence

A set of optional state targets guide assembly for each joint primitive. Targets include position and velocity. A priority level sets the relative importance of the state targets. If two targets are incompatible, the priority level determines which of the targets to satisfy.

Internal mechanics parameters account for energy storage and dissipation at each joint primitive. Springs act as energy storage elements, resisting any attempt to displace the joint primitive from its equilibrium position. Joint dampers act as energy dissipation elements. Springs and dampers are strictly linear.

Each joint primitive has a set of optional actuation and sensing ports. Actuation ports accept physical signal inputs that drive the joint primitives. These inputs can be forces and torques or a desired joint trajectory. Sensing ports provide physical signal outputs that measure joint primitive motion as well as actuation forces and torques. Actuation modes and sensing types vary with joint primitive.

Dialog Box and Parameters

Revolute Primitive: State Targets

Specify the revolute primitive state targets and their priority levels. A state target is the desired value for one of the joint state parameters—position and velocity. The priority level is the relative importance of a state target. It determines how precisely the target must be met. Use the Model Report tool in Mechanics Explorer to check the assembly status for each joint state target.

Specify Position Target

Select this option to specify the desired joint primitive position at time zero. This is the relative rotation angle, measured about the joint primitive axis, of the follower frame with respect to the base frame. The specified target is resolved in the base frame. Selecting this option exposes priority and value fields.

Specify Velocity Target

Select this option to specify the desired joint primitive velocity at time zero. This is the relative angular velocity, measured about the joint primitive axis, of the follower frame with respect to the base frame. It is resolved in the base frame. Selecting this option exposes priority and value fields.

Priority

Select state target priority. This is the importance level assigned to the state target. If all state targets cannot be simultaneously satisfied, the priority level determines which targets to satisfy first and how closely to satisfy them. This option applies to both position and velocity state targets.

Priority Level	Description
High (desired)	Satisfy state target precisely
Low (approximate)	Satisfy state target approximately

Note: During assembly, high-priority targets behave as exact guides. Low-priority targets behave as rough guides.

Value

Enter the state target numerical value. The default is 0. Select or enter a physical unit. The default is deg for position and deg/s for velocity.

Revolute Primitive: Internal Mechanics

Specify the revolute primitive internal mechanics. Internal mechanics include linear spring torques, accounting for energy storage, and linear damping torques, accounting for energy dissipation. You can ignore internal mechanics by keeping spring stiffness and damping coefficient values at 0.

Equilibrium Position

Enter the spring equilibrium position. This is the rotation angle between base and follower frames at which the spring torque is zero. The default value is 0. Select or enter a physical unit. The default is deg.

Spring Stiffness

Enter the linear spring constant. This is the torque required to rotate the joint primitive by a unit angle. The default is 0. Select or enter a physical unit. The default is N*m/deg.

Damping Coefficient

Enter the linear damping coefficient. This is the torque required to maintain a constant joint primitive angular velocity between base and follower frames. The default is 0. Select or enter a physical unit. The default is N*m/(deg/s).

Revolute Primitive: Actuation

Specify actuation options for the revolute joint primitive. Actuation modes include **Torque** and **Motion**. Selecting Provided by Input from the drop-down list for an actuation mode adds the corresponding physical signal port to the block. Use this port to specify the input signal. Input signals are resolved in the base frame.

Torque

Select an actuation torque setting. The default setting is None.

Actuation Torque Setting	Description
None	No actuation torque.
Provided by Input	Actuation torque from physical signal input. The signal provides the torque acting on the follower frame with respect to the base frame about the joint primitive axis. An equal and opposite torque acts on the base frame.

Actuation Torque Setting	Description
`Automatically computed`	Actuation torque from automatic calculation. Simscape Multibody computes and applies the actuation torque based on model dynamics.

Motion

Select an actuation motion setting. The default setting is `Automatically Computed`.

Actuation Motion Setting	Description
`Provided by Input`	Joint primitive motion from physical signal input. The signal provides the desired trajectory of the follower frame with respect to the base frame along the joint primitive axis.
`Automatically computed`	Joint primitive motion from automatic calculation. Simscape Multibody computes and applies the joint primitive motion based on model dynamics.

Revolute Primitive: Sensing

Select the variables to sense in the revolute joint primitive. Selecting a variable exposes a physical signal port that outputs the measured quantity as a function of time. Each quantity is measured for the follower frame with respect to the base frame. It is resolved in the base frame. You can use the measurement signals for analysis or as input in a control system.

Position

Select this option to sense the relative rotation angle of the follower frame with respect to the base frame about the joint primitive axis.

Velocity

Select this option to sense the relative angular velocity of the follower frame with respect to the base frame about the joint primitive axis.

Acceleration

Select this option to sense the relative angular acceleration of the follower frame with respect to the base frame about the joint primitive axis.

Actuator Torque

Select this option to sense the actuation torque acting on the follower frame with respect to the base frame about the joint primitive axis.

Composite Force/Torque Sensing

Select the composite, or joint-wide, forces and torques to sense. These are forces and torques that act not at individual joint primitives but at the whole joint. Options include constraint and total forces and torques.

During simulation, the block computes the selected composite forces and torques acting between the base and follower port frames. It outputs these variables using physical signal output ports. Check the port labels to identify the output variables at different ports.

Direction

Forces and torques acting at joints do so in pairs. Newton's third law of motion requires that every action be accompanied by an equal and opposite reaction. If the base frame of a joint exerts a force or torque on the follower frame, then the follower frame must exert an equal and opposite force or torque on the base frame.

Select whether to sense the composite forces and torques exerted by the base frame on the follower frame or vice versa. The force and torque vector components are positive if they point along the positive X, Y, and Z axes of the selected resolution frame.

Resolution Frame

You can resolve a vector quantity into Cartesian components in different frames. If the resolution frames have different orientations, then the measured components are themselves different—even though the vector quantity remains the same.

Select the frame in which to resolve the sensed force and torque variables. Possible resolution frames include `Base` and `Follower`. The block outputs the Cartesian components of the sensed force and torque vectors as observed in this frame.

Constraint Force

Joint blocks with fewer than three translational degrees of freedom forbid motion along one or more axes. For example, the Gimbal Joint block forbids translation along all axes. To prevent translation along an axis, a joint block applies a constraint

force between its base and follower port frames. Constraint forces are orthogonal to joint translation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint force vector [fc_x, fc_y, fc_z] acting at the joint. Only constraint force components that are orthogonal to the joint translational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port fc.

Constraint Torque

Joint blocks with fewer than three rotational degrees of freedom forbid motion about one or more axes. For example, the Cartesian Joint block forbids rotation about all axes. To prevent rotation about an axis, a joint block applies a constraint torque between its base and follower port frames. Constraint torques are orthogonal to joint rotation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint torque vector [tc_x, tc_y, tc_z] acting at the joint. Only constraint torque components that are orthogonal to the joint rotational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port tc.

Total Force

A joint block generally applies various forces between its port frames:

- Actuation forces that drive prismatic joint primitives.
- Internal spring and damper forces that resist motion at prismatic joint primitives.
- Constraint forces that forbid motion in directions orthogonal to prismatic joint primitives.

The net sum of the different force components equals the total force acting between the joint port frames. Select the check box to compute and output the 3-D total force vector [ft_x, ft_y, ft_z]. Selecting this option causes the block to expose physical signal port ft.

Total Torque

A joint block generally applies various torques between its port frames:

- Actuation torques that drive revolute or spherical joint primitives.
- Internal spring and damper torques that resist motion at revolute or spherical joint primitives.
- Constraint torques that forbid motion in directions orthogonal to the revolute or spherical joint primitive axes.

The net sum of the different torque components equals the total torque acting at a joint. Select the check box to compute and output the 3-D total torque vector [tt_x, tt_y, tt_z]. Selecting this option causes the block to expose physical signal port tt.

Ports

This block has two frame ports. It also has optional physical signal ports for specifying actuation inputs and sensing dynamical variables such as forces, torques, and motion. You expose an optional port by selecting the sensing check box corresponding to that port.

Frame Ports

- B — Base frame
- F — Follower frame

Actuation Ports

The revolute joint primitives provide the following actuation ports:

- tx, ty, tz — Actuation torques acting on the X, Y, and Z revolute joint primitives
- qx, qy, qz — Desired rotations of the X, Y, and Z revolute joint primitives

Sensing Ports

The revolute joint primitives provide the following sensing ports:

- qx, qy, qz — Angular positions of the X, Y, and Z revolute joint primitives
- wx, wy, wz — Angular velocities of the X, Y, and Z revolute joint primitives
- bx, by, bz — Angular accelerations of the X, Y, and Z revolute joint primitives
- tx, ty, tz — Actuation torques acting on the X, Y, and Z revolute joint primitives

The following sensing ports provide the composite forces and torques acting on the joint:

- fc — Constraint force
- tc — Constraint torque

- ft — Total force
- tt — Total torque

See Also
Bushing Joint | Revolute Joint | Spherical Joint

More About
- "Actuating and Sensing with Physical Signals"
- "Motion Sensing"
- "Rotational Measurements"

Graphic

Marker with graphic properties
Library: Body Elements

Description

The Graphic block adds a simple marker to the attached frame. The marker has a simple geometry, color, and no inertia. You can use this block to highlight a frame of interest in the Mechanics Explorer visualization pane. The graphic marker has no impact on model dynamics.

Graphic Marker Geometries

Ports

Frame

R — Reference frame
frame

Local reference frame of the graphic marker. Connect to a frame line or frame port to define the relative position and orientation of the marker.

Parameters

Shape — Marker geometry type
Sphere (default) | Cube | Frame

Marker shape to show in the Mechanics Explorer visualization pane.

`Size` — Absolute size in pixels
10 (default)

Marker size in pixels. Zooming has no impact on the apparent marker size.

`Visual Properties` — Parameterizations for color and opacity
Simple (default) | Advanced

Parameterization for specifying visual properties. Select `Simple` to specify color and opacity. Select `Advanced` to add specular highlights, ambient shadows, and self-illumination effects.

`Simple: Color` — True color as [R,G,B] vector on 0–1 scale
[0.5 0.5 0.5] (default)

RGB color vector with red (R), green (G), and blue (B) color amounts specified on a 0–1 scale. A color picker provides an alternative interactive means of specifying a color. If you change the **Visual Properties** setting to `Advanced`, the color specified in this parameter becomes the **Diffuse Color** vector.

`Simple: Opacity` — Surface opacity as scalar number on 0–1 scale
1.0 (default)

Graphic opacity specified on a scale of 0–1. An opacity of `0` corresponds to a completely transparent graphic and an opacity of `1` to a completely opaque graphic.

`Advanced: Diffuse Color` — True color as [R,G,B,A] vector on 0–1 scale
[0.5 0.5 0.5] (default)

True color under direct white light specified as an [R,G,B] or [R,G,B,A] vector on a 0–1 scale. An optional fourth element specifies the color opacity also on a scale of 0–1. Omitting the opacity element is equivalent to specifying a value of `1`.

`Advanced: Specular Color` — Highlight color as [R,G,B,A] vector on 0–1 scale
[0.5 0.5 0.5 1.0] (default)

Color of specular highlights specified as an [R,G,B] or [R,G,B,A] vector on a 0–1 scale. The optional fourth element specifies the color opacity. Omitting the opacity element is equivalent to specifying a value of `1`.

Advanced: `Ambient Color` — Shadow color as [R,G,B,A] vector on 0–1 scale
[0.5 0.5 0.5 1.0] (default)

Color of shadow areas in diffuse ambient light, specified as an [R,G,B] or [R,G,B,A] vector on a 0–1 scale. The optional fourth element specifies the color opacity. Omitting the opacity element is equivalent to specifying a value of 1.

Advanced: `Emissive Color` — Self-illumination color as [R,G,B] vector on 0–1 scale
[0.5 0.5 0.5 1.0] (default)

Surface color due to self illumination, specified as an [R,G,B] or [R,G,B,A] vector on a 0–1 scale. The optional fourth element specifies the color opacity. Omitting the opacity element is equivalent to specifying a value of 1.

Advanced: `Shininess` — Highlight sharpness as scalar number on 0–128 scale
75 (default)

Sharpness of specular light reflections, specified as a scalar number on a 0–128 scale. Increase the shininess value for smaller but sharper highlights. Decrease the value for larger but smoother highlights.

More About

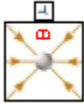· "Solid Visual Properties"

See Also
Inertia | Solid | Spline

Introduced in R2012a

Gravitational Field

Field of force due to point mass

## Library

Forces and Torques

Description

This block represents the gravitational field of a point mass. This field applies a gravitational force at the center of mass of each rigid body. The force magnitude decays with the square distance from the field origin, coincident with the base port frame origin. The force on a rigid body follows from Newton's universal gravitation law:

$$F_g = -G \frac{Mm}{R_{BF}^2},$$

where:

- F_g is the force that the gravitational field exerts on a given rigid body.
- G is the universal gravitational constant, 6.67384×10^{-11} m^{3}kg^{-1}s^{-2}.
- M is the total mass generating the gravitational field.
- m is the total mass of the rigid body the gravitational force acts upon.
- R_{BF} is the distance between the source mass position and the rigid body center of mass.

The figure shows these variables. The plot shows the inverse square dependence between the gravitational force and distance.
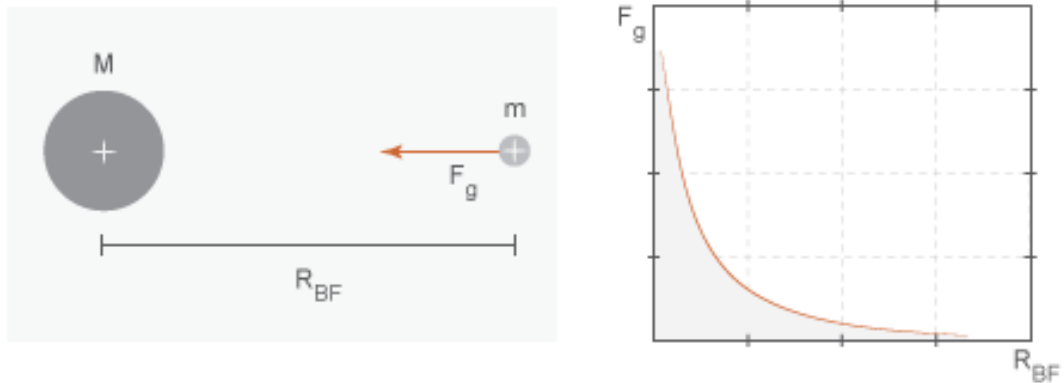
The source mass can be positive or negative. Combine multiple instances of this block to model the gravitational effects that positive and negative mass disturbances impose on a stronger gravitational field, such as a reduction in the gravitational pull of a planet due to a concentration of low-density material along a portion of its surface.

This block excludes the gravitational forces that other rigid bodies exert on the field source mass. To include these forces, you can connect Gravitational Field blocks to other rigid bodies in the model. Alternatively, you can use the Inverse Square Law Force block to model the gravitational forces between a single pair of rigid bodies.

The gravitational field is time invariant. To specify a time-varying, spatially uniform field, use the `Mechanism Configuration` block.

Dialog Box and Parameters
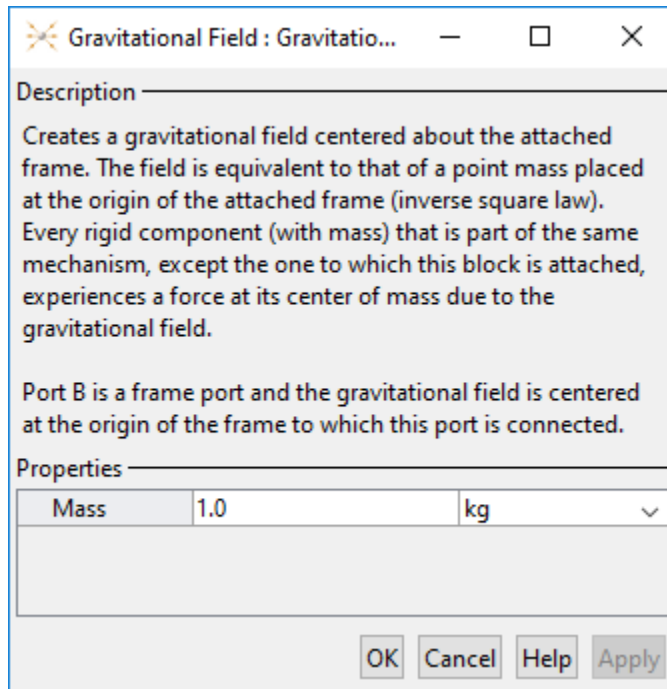
Mass

    Total mass generating the gravitational field. The resulting gravitational forces are directly proportional to this mass. This mass adds no inertia to the model. The default value for the mass parameter is `1.0` kg.

Ports

Frame port B represents a frame with origin at the point mass responsible for the gravitational field.

See Also

`Inverse Square Law Force` | `Mechanism Configuration`

Related Examples

- "Model Gravity in a Planetary System"

Inertia

Mass and inertia tensor of solid mass
Library: Body Elements

Description

The Inertia block adds the inertial properties of a point or distributed mass to the attached frame. The inertia type depends on the parameterization selected. A `Point Mass` parameterization enables you to model a concentrated mass with no rotational inertia. A `Custom` parameterization enables you to model a distributed mass with the specified moments and products of inertia. An inertia icon identifies the inertia location in the Mechanics Explorer visualization pane.

Ports

Frame

R — Reference frame
frame

Local reference frame of the inertia element. Connect to a frame line or frame port to define the relative position and orientation of the inertia.

Parameters

Type — Inertia parameterization to use
Point Mass (default) | Custom

Inertia parameterization to use. Select `Point Mass` to represent a mass with no rotational inertia. Select `Custom` to represent a distributed mass with rotational inertia.

`Mass` — Aggregate mass of the solid
1 kg (default)

Aggregate mass of the solid. The mass can be a positive or negative value. Specify a negative mass to model the aggregate effect of voids and cavities in a compound body.

`Custom: Center of Mass` — Center-of-mass coordinates
[0 0 0] m (default)

[x y z] coordinates of the center of mass relative to the block reference frame. The center of mass coincides with the center of gravity in uniform gravitational fields only.

`Custom: Moments of Inertia` — Diagonal elements of inertia tensor
[1 1 1] kg*m^2 (default)

Three-element vector with the $[I_{xx}\ I_{yy}\ I_{zz}]$ moments of inertia specified relative to a frame with origin at the center of mass and axes parallel to the block reference frame. The moments of inertia are the diagonal elements of the inertia tensor

$$\begin{pmatrix} I_{xx} & & \\ & I_{yy} & \\ & & I_{zz} \end{pmatrix},$$

where:

- $I_{xx} = \int_V \left(y^2 + z^2 \right) dm$

- $I_{yy} = \int_V \left(x^2 + z^2 \right) dm$

- $I_{zz} = \int_V \left(x^2 + y^2 \right) dm$

`Custom: Products of Inertia` — Off-diagonal elements of inertia tensor
[0 0 0] kg*m^2 (default)

Three-element vector with the $[I_{yz}\ I_{zx}\ I_{xy}]$ products of inertia specified relative to a frame with origin at the center of mass and axes parallel to the block reference frame. The products of inertia are the off-diagonal elements of the inertia tensor

$$\begin{pmatrix} & I_{xy} & I_{zx} \\ I_{xy} & & I_{yz} \\ I_{zx} & I_{yz} & \end{pmatrix},$$

where:

- $$I_{yz} = -\int_V yz \, dm$$

- $$I_{zx} = -\int_V zx \, dm$$

- $$I_{xy} = -\int_V xy \, dm$$

More About

- "Solid Inertia"

See Also
```
Graphic | Solid | Spline
```

Introduced in R2012a

Inverse Square Law Force

Force proportional to the inverse square distance between two frame origins


Library

Forces and Torques

Description

This block represents a force pair that is inversely proportional to the square distance between the base and follower frame origins. The two forces in the pair have equal magnitude but opposite directions. One force acts on the base frame origin, along the vector connecting the follower to base frame origins. The other force acts on the follower frame origin, along the vector connecting base to follower frame origins.

The value of the force depends on a force constant that you specify. A positive force constant represents a repulsive force that pushes the two frame origins apart. A negative force constant represents an attractive force that pulls the two frame origins together.

Dialog Box and Parameters
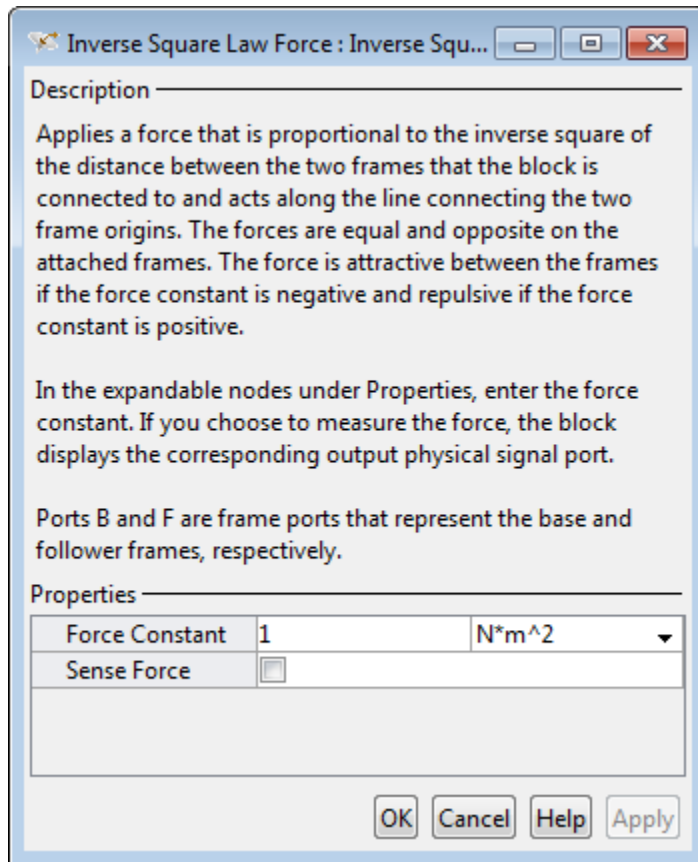
Force Constant

Specify the proportionality constant of the inverse square law force. This constant is a lumped parameter that encodes the dependence of the force magnitude on the inverse square distance between the two frame origins. The default value is 1. Select or specify a physical unit.

Sense Force

Select the check box to sense the signed magnitude of the inverse square law force acting between the two frame origins. The block exposes an additional physical signal

port to output the force signal. The output signal is a scalar value. This value is positive if the force is repulsive; it is negative if the force is attractive.

Ports

The block contains frame ports B and F, representing base and follower frames, respectively.

Selecting **Sense Force** in the block dialog box exposes an additional physical signal port, **fm**.
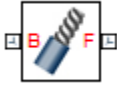
See Also
```
External Force and Torque | Internal Force | Spring and Damper Force
```

More About

·   "Actuating and Sensing with Physical Signals"

Lead Screw Joint

Joint with coupled rotational and translational degrees of freedom

Library

Joints

Description

This block represents a joint with one rotational degree of freedom coupled with one translational degree of freedom. The coupling between the two degrees of freedom ensures that whenever the joint frames rotate relative to each other, they also translate by a commensurate amount and vice-versa. The joint lead determines the translation distance associated with a unit rotation angle while the joint direction determines whether a positive angle results in a positive or negative translation.

During assembly and simulation, the joint aligns the Z axes of its port frames. The common Z axis functions as the rotation and translation axis. Whenever the joint frames rotate, they do so about the common Z axis, and whenever the joint frames translate, they do so along the common Z axis. You can orient the motion axis in a different direction by applying rotation transforms to the joint frames through Rigid Transform blocks.
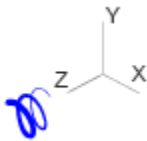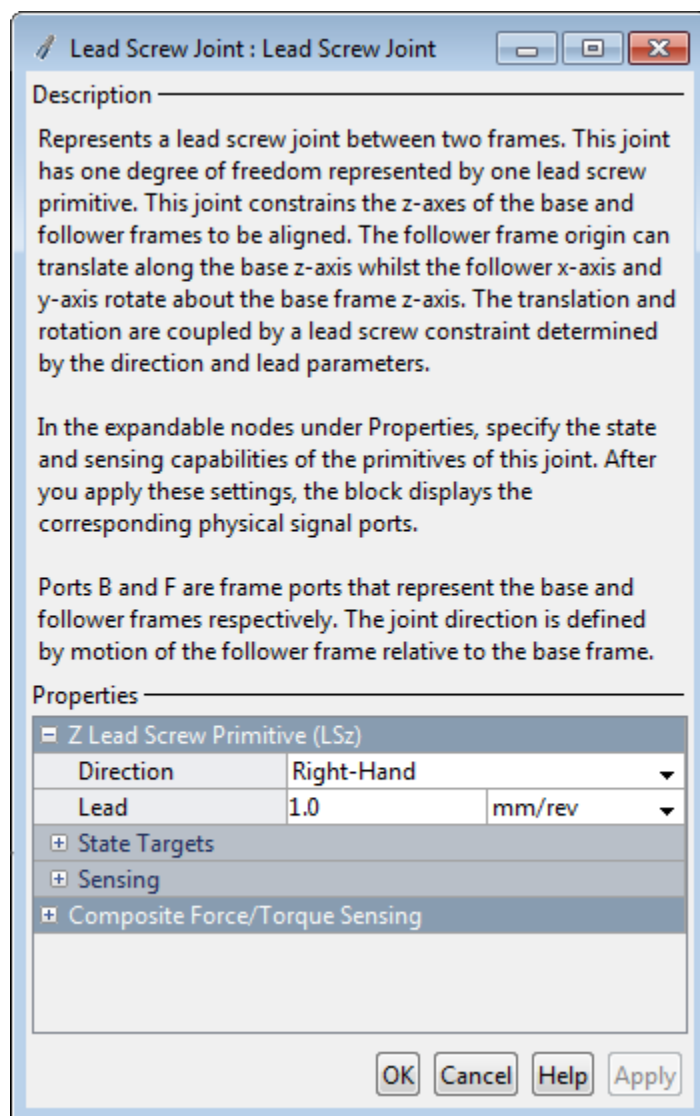

Joint Degrees of Freedom

A set of optional state targets guide assembly for the joint primitive. Targets include position and velocity. You can specify these based on the relative rotation or translation

between the joint frames. A priority level sets the relative importance of the state targets. If two targets are incompatible, the priority level determines which of the targets to satisfy.

Each joint primitive has a set of optional sensing ports. These ports provide physical signal outputs that measure joint primitive motion. Variables that you can sense include those describing translational motion, rotational motion, and constraint forces and torques.

Dialog Box and Parameters

Lead Screw Joint : Lead Screw Joint

Description

Represents a lead screw joint between two frames. This joint has one degree of freedom represented by one lead screw primitive. This joint constrains the z-axes of the base and follower frames to be aligned. The follower frame origin can translate along the base z-axis whilst the follower x-axis and y-axis rotate about the base frame z-axis. The translation and rotation are coupled by a lead screw constraint determined by the direction and lead parameters.

In the expandable nodes under Properties, specify the state and sensing capabilities of the primitives of this joint. After you apply these settings, the block displays the corresponding physical signal ports.

Ports B and F are frame ports that represent the base and follower frames respectively. The joint direction is defined by motion of the follower frame relative to the base frame.

Properties

Z Lead Screw Primitive (LSz)		
Direction	Right-Hand	
Lead	1.0	mm/rev
⊞ State Targets		
⊞ Sensing		
⊞ Composite Force/Torque Sensing		

OK Cancel Help Apply

Lead Screw Primitive

Direction

Handedness of motion between the joint frames. Motion is right-handed if a positive rotation leads to a positive translation and left-handed if a positive rotation leads to a negative translation. The default setting is `Right-Hand`.

Lead

Translation distance between the joint frames due to a unit rotation angle. The larger the lead, the longer the frames must translate before completing a full revolution. The default value is `1.0` mm/rev.

Lead Screw Primitive: State Targets

Specify the lead screw primitive state targets and their priority levels. A state target is the desired value for one of the joint state variables—position or velocity. The priority level is the relative importance of a state target. It determines how precisely the target must be satisfied.

Specify Position Target

Desired joint primitive position at the start of simulation. This is the relative position, rotational or translational, of the follower frame relative to the base frame. Selecting this option exposes priority and value fields.

Specify Velocity Target

Desired joint velocity at the start of simulation. This is the relative velocity, rotational or translational, of the follower frame relative to the base frame. Selecting this option exposes priority and value fields.

Priority

Select state target priority. This is the importance level assigned to the state target. If all state targets cannot be simultaneously satisfied, the priority level determines which targets to satisfy first and how closely to satisfy them. This option applies to both position and velocity state targets.

Priority Level	Description
High (desired)	Satisfy state target precisely
Low (approximate)	Satisfy state target approximately

Note: During assembly, high-priority targets behave as exact guides. Low-priority targets behave as rough guides.

Based On

Motion type that the state target is based on. Options include `Rotation` and `Translation`. The default setting is `Translation`.

Value

Desired value of the position or velocity state target. The default value is `0`.

Lead Screw Primitive: Sensing

Select the variables to sense in the lead screw primitive. Selecting a variable exposes a physical signal port that outputs the measured quantity as a function of time. Each quantity is measured for the follower frame with respect to the base frame. It is resolved in the base frame.

Variable	Description
`Rotation`: **Position**	Rotation angle of the follower frame relative to the base frame about the common Z axis. Selecting the check box exposes a physical signal port labeled q.
`Rotation`: **Velocity**	Rotational velocity of the follower frame relative to the base frame about the common Z axis. Selecting the check box exposes a physical signal port labeled w.
`Rotation`: **Acceleration**	Rotational acceleration of the follower frame relative to the base frame about the common Z axis. Selecting the check box exposes a physical signal port labeled b.
`Translation`: **Position**	Offset distance of the follower frame relative to the base frame along the common Z axis. Selecting the check box exposes a physical signal port labeled p.
`Translation`: **Velocity**	Translational velocity of the follower frame relative to the base frame along the

Variable	Description
	common Z axis. Selecting the check box exposes a physical signal port labeled v.
`Translation:` **Acceleration**	Translational acceleration of the follower frame relative to the base frame along the common Z axis. Selecting the check box exposes a physical signal port labeled a.

Composite Force/Torque Sensing

Select the composite, or joint-wide, forces and torques to sense. These are forces and torques that act not at individual joint primitives but at the whole joint. Options include constraint and total forces and torques.

During simulation, the block computes the selected composite forces and torques acting between the base and follower port frames. It outputs these variables using physical signal output ports. Check the port labels to identify the output variables at different ports.

Direction

Forces and torques acting at joints do so in pairs. Newton's third law of motion requires that every action be accompanied by an equal and opposite reaction. If the base frame of a joint exerts a force or torque on the follower frame, then the follower frame must exert an equal and opposite force or torque on the base frame.

Select whether to sense the composite forces and torques exerted by the base frame on the follower frame or vice versa. The force and torque vector components are positive if they point along the positive X, Y, and Z axes of the selected resolution frame.

Resolution Frame

You can resolve a vector quantity into Cartesian components in different frames. If the resolution frames have different orientations, then the measured components are themselves different—even though the vector quantity remains the same.

Select the frame in which to resolve the sensed force and torque variables. Possible resolution frames include `Base` and `Follower`. The block outputs the Cartesian components of the sensed force and torque vectors as observed in this frame.

Constraint Force

Joint blocks with fewer than three translational degrees of freedom forbid motion along one or more axes. For example, the Gimbal Joint block forbids translation along all axes. To prevent translation along an axis, a joint block applies a constraint force between its base and follower port frames. Constraint forces are orthogonal to joint translation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint force vector [fc_x, fc_y, fc_z] acting at the joint. Only constraint force components that are orthogonal to the joint translational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port fc.

Constraint Torque

Joint blocks with fewer than three rotational degrees of freedom forbid motion about one or more axes. For example, the Cartesian Joint block forbids rotation about all axes. To prevent rotation about an axis, a joint block applies a constraint torque between its base and follower port frames. Constraint torques are orthogonal to joint rotation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint torque vector [tc_x, tc_y, tc_z] acting at the joint. Only constraint torque components that are orthogonal to the joint rotational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port tc.

Total Force

A joint block generally applies various forces between its port frames:

- Actuation forces that drive prismatic joint primitives.
- Internal spring and damper forces that resist motion at prismatic joint primitives.
- Constraint forces that forbid motion in directions orthogonal to prismatic joint primitives.

The net sum of the different force components equals the total force acting between the joint port frames. Select the check box to compute and output the 3-D total force vector [ft_x, ft_y, ft_z]. Selecting this option causes the block to expose physical signal port ft.

Total Torque

A joint block generally applies various torques between its port frames:

- Actuation torques that drive revolute or spherical joint primitives.
- Internal spring and damper torques that resist motion at revolute or spherical joint primitives.

- Constraint torques that forbid motion in directions orthogonal to the revolute or spherical joint primitive axes.

The net sum of the different torque components equals the total torque acting at a joint. Select the check box to compute and output the 3-D total torque vector [tt_x, tt_y, tt_z]. Selecting this option causes the block to expose physical signal port tt.

Ports

This block has two frame ports. It also has optional physical signal ports for sensing dynamical variables such as forces, torques, and motion. You expose an optional port by selecting the sensing check box corresponding to that port.

Frame Ports

- B — Base frame
- F — Follower frame

Sensing Ports

The lead screw joint primitive provides the following sensing ports:

- q — Angular position
- w — Angular velocity
- b — Angular acceleration
- p — Linear position
- v — Linear velocity
- a — Linear acceleration

The following sensing ports provide the composite forces and torques acting on the joint:

- fc — Constraint force
- tc — Constraint torque
- ft — Total force
- tt — Total torque

See Also

`Prismatic Joint | Revolute Joint`

Mechanism Configuration

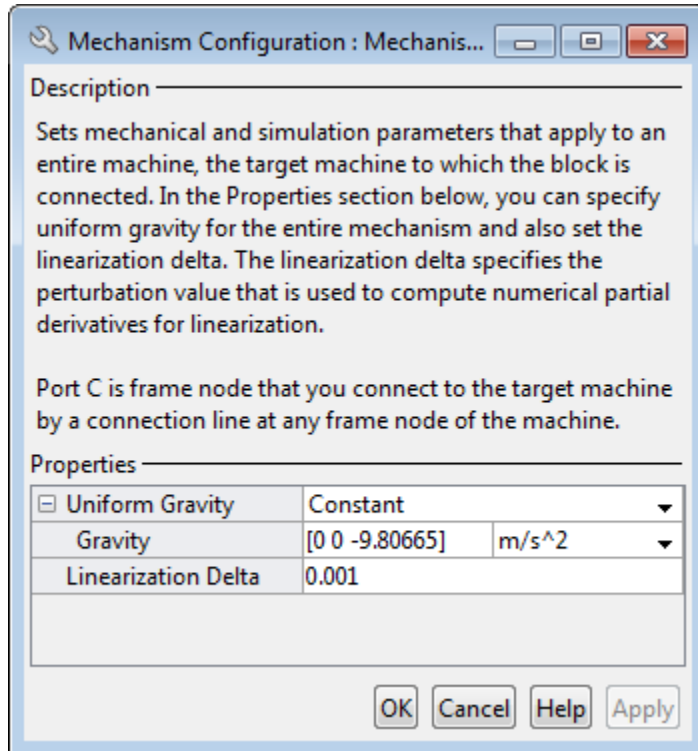Mechanism-wide simulation and mechanical parameters

Library

Utilities

Description

This block provides mechanical and simulation parameters to a mechanism, i.e., a self-contained group of interconnected Simscape Multibody blocks. Parameters include gravity and a linearization delta for computing numerical partial derivatives during linearization. These parameters apply only to the target mechanism, i.e., the mechanism that the block connects to.

The Mechanism Configuration block is optional. If you omit it, the gravitational acceleration vector is set to zero. Use only one instance of this block per mechanism, setting uniform gravity to None if that mechanism contains one or more Gravitational Field blocks.

Dialog Box and Parameters

Mechanism Configuration : Mechanis...

Description

Sets mechanical and simulation parameters that apply to an entire machine, the target machine to which the block is connected. In the Properties section below, you can specify uniform gravity for the entire mechanism and also set the linearization delta. The linearization delta specifies the perturbation value that is used to compute numerical partial derivatives for linearization.

Port C is frame node that you connect to the target machine by a connection line at any frame node of the machine.

Properties

⊟ Uniform Gravity	Constant	▼
Gravity	[0 0 -9.80665]	m/s^2 ▼
Linearization Delta	0.001	

OK Cancel Help Apply

Uniform Gravity

Type of gravitational acceleration vector in effect at the target mechanism. Options include:

- None — Specify zero gravity. The block automatically applies the gravitational acceleration vector [0 0 0] to the target mechanism. If the mechanism contains one or more Gravitational Field blocks, you must select this option.

- Constant — Specify a gravitational acceleration vector that remains constant in space and in time. Selecting this option exposes an additional parameter, **Gravity**. If the target mechanism contains one or more Gravitational Field blocks, you must select None instead.

- Time-Varying — Specify a gravitational acceleration vector that remains constant in space but varies in time. Selecting this option exposes a physical

1-135

signal port. Use that port to specify the time-varying gravitational acceleration vector. If the target mechanism contains one or more Gravitational Field blocks, you must select None instead.

Gravity

Nominal acceleration vector due to gravity. The block resolves this vector in the mechanism World frame. The default vector is [0 0 −9.80665] m/s^2.

Linearization Delta

Perturbation value for computing numerical partial derivatives during linearization. The default value is 0.001.

Ports

Port	Description
C	Frame port that identifies the target mechanism to which the block parameters apply.
g	Physical signal port through which you specify a time-varying gravity vector.

See Also
Gravitational Field

Pin Slot Joint

Joint with one prismatic and one revolute primitives possessing mutually orthogonal motion axes

Library

Joints

Description

This block represents a joint with one translational and one rotational degrees of freedom. One prismatic primitive provides the translational degree of freedom. One revolute primitive provides the rotational degree of freedom. Prismatic and revolute axes are mutually orthogonal.
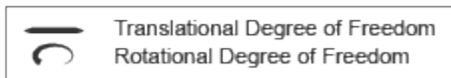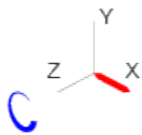
Joint Degrees of Freedom

The joint block represents motion between the base and follower frames as a sequence of time-varying transformations. Each joint primitive applies one transformation in this sequence. The transformation translates or rotates the follower frame with respect to the

joint primitive base frame. For all but the first joint primitive, the base frame coincides with the follower frame of the previous joint primitive in the sequence.

At each time step during the simulation, the joint block applies the sequence of time-varying frame transformations in this order:

1 Translation:

- Along the X axis of the X Prismatic Primitive (Px) base frame.

2 Rotation:

- About the Z axis of the Z Revolute Primitive (Rz) base frame. This frame is coincident with the X Prismatic Primitive (Px) follower frame.

The figure shows the sequence in which the joint transformations occur at a given simulation time step. The resulting frame of each transformation serves as the base frame for the following transformation.

Joint Transformation Sequence

A set of optional state targets guide assembly for each joint primitive. Targets include position and velocity. A priority level sets the relative importance of the state targets. If two targets are incompatible, the priority level determines which of the targets to satisfy.

Internal mechanics parameters account for energy storage and dissipation at each joint primitive. Springs act as energy storage elements, resisting any attempt to displace the joint primitive from its equilibrium position. Joint dampers act as energy dissipation elements. Springs and dampers are strictly linear.

Each joint primitive has a set of optional actuation and sensing ports. Actuation ports accept physical signal inputs that drive the joint primitives. These inputs can be forces and torques or a desired joint trajectory. Sensing ports provide physical signal outputs that measure joint primitive motion as well as actuation forces and torques. Actuation modes and sensing types vary with joint primitive.

Dialog Box and Parameters

Prismatic Primitive: State Targets

Specify the prismatic primitive state targets and their priority levels. A state target is the desired value for one of the joint state parameters—position and velocity. The priority level is the relative importance of a state target. It determines how precisely the target must be met. Use the Model Report tool in Mechanics Explorer to check the assembly status for each joint state target.

Specify Position Target

Select this option to specify the desired joint primitive position at time zero. This is the relative position, measured along the joint primitive axis, of the follower frame origin with respect to the base frame origin. The specified target is resolved in the base frame. Selecting this option exposes priority and value fields.

Specify Velocity Target

Select this option to specify the desired joint primitive velocity at time zero. This is the relative velocity, measured along the joint primitive axis, of the follower frame origin with respect to the base frame origin. It is resolved in the base frame. Selecting this option exposes priority and value fields.

Priority

Select state target priority. This is the importance level assigned to the state target. If all state targets cannot be simultaneously satisfied, the priority level determines which targets to satisfy first and how closely to satisfy them. This option applies to both position and velocity state targets.

Priority Level	Description
High (desired)	Satisfy state target precisely
Low (approximate)	Satisfy state target approximately

Note: During assembly, high-priority targets behave as exact guides. Low-priority targets behave as rough guides.

Value

Enter the state target numerical value. The default is 0. Select or enter a physical unit. The default is m for position and m/s for velocity.

Prismatic Primitive: Internal Mechanics

Specify the prismatic primitive internal mechanics. Internal mechanics include linear spring forces, accounting for energy storage, and damping forces, accounting for energy dissipation. You can ignore internal mechanics by keeping spring stiffness and damping coefficient values at 0.

Equilibrium Position

Enter the spring equilibrium position. This is the distance between base and follower frame origins at which the spring force is zero. The default value is 0. Select or enter a physical unit. The default is m.

Spring Stiffness

Enter the linear spring constant. This is the force required to displace the joint primitive by a unit distance. The default is 0. Select or enter a physical unit. The default is N/m.

Damping Coefficient

Enter the linear damping coefficient. This is the force required to maintain a constant joint primitive velocity between base and follower frames. The default is 0. Select or enter a physical unit. The default is N/(m/s).

Prismatic Primitive: Actuation

Specify actuation options for the prismatic joint primitive. Actuation modes include **Force** and **Motion**. Selecting Provided by Input from the drop-down list for an actuation mode adds the corresponding physical signal port to the block. Use this port to specify the input signal. Actuation signals are resolved in the base frame.

Force

Select an actuation force setting. The default setting is None.

Actuation Force Setting	Description
None	No actuation force.
Provided by Input	Actuation force from physical signal input. The signal provides the force acting on the follower frame with respect to the base frame along the joint primitive axis. An equal and opposite force acts on the base frame.

Actuation Force Setting	Description
`Automatically computed`	Actuation force from automatic calculation. Simscape Multibody computes and applies the actuation force based on model dynamics.

Motion

Select an actuation motion setting. The default setting is `Automatically Computed`.

Actuation Motion Setting	Description
`Provided by Input`	Joint primitive motion from physical signal input. The signal provides the desired trajectory of the follower frame with respect to the base frame along the joint primitive axis.
`Automatically computed`	Joint primitive motion from automatic calculation. Simscape Multibody computes and applies the joint primitive motion based on model dynamics.

Prismatic Primitive: Sensing

Select the variables to sense in the prismatic joint primitive. Selecting a variable exposes a physical signal port that outputs the measured quantity as a function of time. Each quantity is measured for the follower frame with respect to the base frame. It is resolved in the base frame. You can use the measurement signals for analysis or as input in a control system.

Position

Select this option to sense the relative position of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Velocity

Select this option to sense the relative velocity of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Acceleration

Select this option to sense the relative acceleration of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Actuator Force

Select this option to sense the actuation force acting on the follower frame with respect to the base frame along the joint primitive axis.

Revolute Primitive: State Targets

Specify the revolute primitive state targets and their priority levels. A state target is the desired value for one of the joint state parameters—position and velocity. The priority level is the relative importance of a state target. It determines how precisely the target must be met. Use the Model Report tool in Mechanics Explorer to check the assembly status for each joint state target.

Specify Position Target

Select this option to specify the desired joint primitive position at time zero. This is the relative rotation angle, measured about the joint primitive axis, of the follower frame with respect to the base frame. The specified target is resolved in the base frame. Selecting this option exposes priority and value fields.

Specify Velocity Target

Select this option to specify the desired joint primitive velocity at time zero. This is the relative angular velocity, measured about the joint primitive axis, of the follower frame with respect to the base frame. It is resolved in the base frame. Selecting this option exposes priority and value fields.

Priority

Select state target priority. This is the importance level assigned to the state target. If all state targets cannot be simultaneously satisfied, the priority level determines which targets to satisfy first and how closely to satisfy them. This option applies to both position and velocity state targets.

Priority Level	Description
High (desired)	Satisfy state target precisely
Low (approximate)	Satisfy state target approximately

Note: During assembly, high-priority targets behave as exact guides. Low-priority targets behave as rough guides.

Value

> Enter the state target numerical value. The default is 0. Select or enter a physical unit. The default is `deg` for position and `deg/s` for velocity.

Revolute Primitive: Internal Mechanics

Specify the revolute primitive internal mechanics. Internal mechanics include linear spring torques, accounting for energy storage, and linear damping torques, accounting for energy dissipation. You can ignore internal mechanics by keeping spring stiffness and damping coefficient values at 0.

Equilibrium Position

> Enter the spring equilibrium position. This is the rotation angle between base and follower frames at which the spring torque is zero. The default value is 0. Select or enter a physical unit. The default is `deg`.

Spring Stiffness

> Enter the linear spring constant. This is the torque required to rotate the joint primitive by a unit angle. The default is 0. Select or enter a physical unit. The default is `N*m/deg`.

Damping Coefficient

> Enter the linear damping coefficient. This is the torque required to maintain a constant joint primitive angular velocity between base and follower frames. The default is 0. Select or enter a physical unit. The default is `N*m/(deg/s)`.

Revolute Primitive: Actuation

Specify actuation options for the revolute joint primitive. Actuation modes include **Torque** and **Motion**. Selecting `Provided by Input` from the drop-down list for an actuation mode adds the corresponding physical signal port to the block. Use this port to specify the input signal. Input signals are resolved in the base frame.

Torque

> Select an actuation torque setting. The default setting is `None`.

Actuation Torque Setting	Description
None	No actuation torque.

Actuation Torque Setting	Description
Provided by Input	Actuation torque from physical signal input. The signal provides the torque acting on the follower frame with respect to the base frame about the joint primitive axis. An equal and opposite torque acts on the base frame.
Automatically computed	Actuation torque from automatic calculation. Simscape Multibody computes and applies the actuation torque based on model dynamics.

Motion

Select an actuation motion setting. The default setting is Automatically Computed.

Actuation Motion Setting	Description
Provided by Input	Joint primitive motion from physical signal input. The signal provides the desired trajectory of the follower frame with respect to the base frame along the joint primitive axis.
Automatically computed	Joint primitive motion from automatic calculation. Simscape Multibody computes and applies the joint primitive motion based on model dynamics.

Revolute Primitive: Sensing

Select the variables to sense in the revolute joint primitive. Selecting a variable exposes a physical signal port that outputs the measured quantity as a function of time. Each quantity is measured for the follower frame with respect to the base frame. It is resolved in the base frame. You can use the measurement signals for analysis or as input in a control system.

Position

Select this option to sense the relative rotation angle of the follower frame with respect to the base frame about the joint primitive axis.

Velocity

Select this option to sense the relative angular velocity of the follower frame with respect to the base frame about the joint primitive axis.

Acceleration

Select this option to sense the relative angular acceleration of the follower frame with respect to the base frame about the joint primitive axis.

Actuator Torque

Select this option to sense the actuation torque acting on the follower frame with respect to the base frame about the joint primitive axis.

Composite Force/Torque Sensing

Select the composite, or joint-wide, forces and torques to sense. These are forces and torques that act not at individual joint primitives but at the whole joint. Options include constraint and total forces and torques.

During simulation, the block computes the selected composite forces and torques acting between the base and follower port frames. It outputs these variables using physical signal output ports. Check the port labels to identify the output variables at different ports.

Direction

Forces and torques acting at joints do so in pairs. Newton's third law of motion requires that every action be accompanied by an equal and opposite reaction. If the base frame of a joint exerts a force or torque on the follower frame, then the follower frame must exert an equal and opposite force or torque on the base frame.

Select whether to sense the composite forces and torques exerted by the base frame on the follower frame or vice versa. The force and torque vector components are positive if they point along the positive X, Y, and Z axes of the selected resolution frame.

Resolution Frame

You can resolve a vector quantity into Cartesian components in different frames. If the resolution frames have different orientations, then the measured components are themselves different—even though the vector quantity remains the same.

Select the frame in which to resolve the sensed force and torque variables. Possible resolution frames include `Base` and `Follower`. The block outputs the Cartesian components of the sensed force and torque vectors as observed in this frame.

Constraint Force

Joint blocks with fewer than three translational degrees of freedom forbid motion along one or more axes. For example, the Gimbal Joint block forbids translation along all axes. To prevent translation along an axis, a joint block applies a constraint force between its base and follower port frames. Constraint forces are orthogonal to joint translation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint force vector [fc_x, fc_y, fc_z] acting at the joint. Only constraint force components that are orthogonal to the joint translational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port fc.

Constraint Torque

Joint blocks with fewer than three rotational degrees of freedom forbid motion about one or more axes. For example, the Cartesian Joint block forbids rotation about all axes. To prevent rotation about an axis, a joint block applies a constraint torque between its base and follower port frames. Constraint torques are orthogonal to joint rotation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint torque vector [tc_x, tc_y, tc_z] acting at the joint. Only constraint torque components that are orthogonal to the joint rotational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port tc.

Total Force

A joint block generally applies various forces between its port frames:

- Actuation forces that drive prismatic joint primitives.
- Internal spring and damper forces that resist motion at prismatic joint primitives.
- Constraint forces that forbid motion in directions orthogonal to prismatic joint primitives.

The net sum of the different force components equals the total force acting between the joint port frames. Select the check box to compute and output the 3-D total force vector [ft_x, ft_y, ft_z]. Selecting this option causes the block to expose physical signal port ft.

Total Torque

A joint block generally applies various torques between its port frames:

- Actuation torques that drive revolute or spherical joint primitives.

- Internal spring and damper torques that resist motion at revolute or spherical joint primitives.
- Constraint torques that forbid motion in directions orthogonal to the revolute or spherical joint primitive axes.

The net sum of the different torque components equals the total torque acting at a joint. Select the check box to compute and output the 3-D total torque vector [tt_x, tt_y, tt_z]. Selecting this option causes the block to expose physical signal port tt.

Ports

This block has two frame ports. It also has optional physical signal ports for specifying actuation inputs and sensing dynamical variables such as forces, torques, and motion. You expose an optional port by selecting the sensing check box corresponding to that port.

Frame Ports

- B — Base frame
- F — Follower frame

Actuation Ports

The prismatic joint primitive provides the following actuation ports:

- fx — Actuation force acting on the X prismatic joint primitive
- px — Desired trajectory of the X prismatic joint primitive

The revolute joint primitive provides the following actuation ports:

- tz — Actuation torque acting on the Z revolute joint primitive
- qz — Desired rotation of the Z revolute joint primitive

Sensing Ports

The prismatic joint primitive provides the following sensing ports:

- px — Position of the X prismatic joint primitive

- vx — Velocity of the X prismatic joint primitive
- ax — Acceleration of the X prismatic joint primitive
- fx — Actuation force acting on the X prismatic joint primitive

The revolute joint primitive provides the following sensing ports:

- qz — Angular position of the Z revolute joint primitive
- wz — Angular velocity of the Z revolute joint primitive
- bz — Angular acceleration of the Z revolute joint primitive
- tz — Actuation torque acting on the Z revolute joint primitive

The following sensing ports provide the composite forces and torques acting on the joint:

- fc — Constraint force
- tc — Constraint torque
- ft — Total force
- tt — Total torque

See Also

Cylindrical Joint | Prismatic Joint | Revolute joint

More About

- "Actuating and Sensing with Physical Signals"
- "Motion Sensing"
- "Rotational Measurements"
- "Translational Measurements"

Planar Joint

Joint with one revolute and two prismatic primitives

Library

Joints

Description

This block represents a joint with one rotational and two translational degrees of freedom. Two prismatic primitives provide the two translational degrees of freedom. One revolute primitive provides the rotational degree of freedom.

Joint Degrees of Freedom

The joint block represents motion between the base and follower frames as a sequence of time-varying transformations. Each joint primitive applies one transformation in this sequence. The transformation translates or rotates the follower frame with respect to the

joint primitive base frame. For all but the first joint primitive, the base frame coincides with the follower frame of the previous joint primitive in the sequence.

At each time step during the simulation, the joint block applies the sequence of time-varying frame transformations in this order:

1 Translation:

   a Along the X axis of the X Prismatic Primitive (Px) base frame.

   b Along the Y axis of the Y Prismatic Primitive (Py) base frame. This frame is coincident with the X Prismatic Primitive (Px) follower frame.

2 Rotation:

   • About the Z axis of the Z Revolute Primitive (Rz) base frame. This frame is coincident with the Y Prismatic Primitive (Py) follower frame.

The figure shows the sequence in which the joint transformations occur at a given simulation time step. The resulting frame of each transformation serves as the base frame for the following transformation.

Joint Transformation Sequence

A set of optional state targets guide assembly for each joint primitive. Targets include position and velocity. A priority level sets the relative importance of the state targets. If two targets are incompatible, the priority level determines which of the targets to satisfy.

Internal mechanics parameters account for energy storage and dissipation at each joint primitive. Springs act as energy storage elements, resisting any attempt to displace the joint primitive from its equilibrium position. Joint dampers act as energy dissipation elements. Springs and dampers are strictly linear.

Each joint primitive has a set of optional actuation and sensing ports. Actuation ports accept physical signal inputs that drive the joint primitives. These inputs can be forces and torques or a desired joint trajectory. Sensing ports provide physical signal outputs

that measure joint primitive motion as well as actuation forces and torques. Actuation modes and sensing types vary with joint primitive.

Dialog Box and Parameters

Planar Joint : Planar Joint

Description

Represents a planar joint between two frames. This joint has two translational and one rotational degrees of freedom represented by two prismatic primitives and one revolute primitive along a set of three mutually orthogonal axes. This joint constrains the z-axes of the base and follower frames to be aligned and prohibits relative translation along that axis. It allows translation of the follower origin in the base xy-plane and rotation of the follower frame around its z-axis.

In the expandable nodes under Properties, specify the state, actuation method, sensing capabilities, and internal mechanics of the primitives of this joint. After you apply these settings, the block displays the corresponding physical signal ports.

Ports B and F are frame ports that represent the base and follower frames, respectively. The joint direction is defined by motion of the follower frame relative to the base frame.

Properties

- ■ X Prismatic Primitive (Px)
  - ⊞ State Targets
  - ⊞ Internal Mechanics
  - ⊞ Actuation
  - ⊞ Sensing
- ⊞ Y Prismatic Primitive (Py)
- ⊞ Z Revolute Primitive (Rz)
- ⊞ Composite Force/Torque Sensing

OK Cancel Help Apply

Prismatic Primitive: State Targets

Specify the prismatic primitive state targets and their priority levels. A state target is the desired value for one of the joint state parameters—position and velocity. The priority level is the relative importance of a state target. It determines how precisely the target must be met. Use the Model Report tool in Mechanics Explorer to check the assembly status for each joint state target.

Specify Position Target

Select this option to specify the desired joint primitive position at time zero. This is the relative position, measured along the joint primitive axis, of the follower frame origin with respect to the base frame origin. The specified target is resolved in the base frame. Selecting this option exposes priority and value fields.

Specify Velocity Target

Select this option to specify the desired joint primitive velocity at time zero. This is the relative velocity, measured along the joint primitive axis, of the follower frame origin with respect to the base frame origin. It is resolved in the base frame. Selecting this option exposes priority and value fields.

Priority

Select state target priority. This is the importance level assigned to the state target. If all state targets cannot be simultaneously satisfied, the priority level determines which targets to satisfy first and how closely to satisfy them. This option applies to both position and velocity state targets.

Priority Level	Description
High (desired)	Satisfy state target precisely
Low (approximate)	Satisfy state target approximately

Note: During assembly, high-priority targets behave as exact guides. Low-priority targets behave as rough guides.

Value

Enter the state target numerical value. The default is 0. Select or enter a physical unit. The default is m for position and m/s for velocity.

Prismatic Primitive: Internal Mechanics

Specify the prismatic primitive internal mechanics. Internal mechanics include linear spring forces, accounting for energy storage, and damping forces, accounting for energy dissipation. You can ignore internal mechanics by keeping spring stiffness and damping coefficient values at 0.

Equilibrium Position

Enter the spring equilibrium position. This is the distance between base and follower frame origins at which the spring force is zero. The default value is 0. Select or enter a physical unit. The default is m.

Spring Stiffness

Enter the linear spring constant. This is the force required to displace the joint primitive by a unit distance. The default is 0. Select or enter a physical unit. The default is N/m.

Damping Coefficient

Enter the linear damping coefficient. This is the force required to maintain a constant joint primitive velocity between base and follower frames. The default is 0. Select or enter a physical unit. The default is N/(m/s).

Prismatic Primitive: Actuation

Specify actuation options for the prismatic joint primitive. Actuation modes include **Force** and **Motion**. Selecting Provided by Input from the drop-down list for an actuation mode adds the corresponding physical signal port to the block. Use this port to specify the input signal. Actuation signals are resolved in the base frame.

Force

Select an actuation force setting. The default setting is None.

Actuation Force Setting	Description
None	No actuation force.
Provided by Input	Actuation force from physical signal input. The signal provides the force acting on the follower frame with respect to the base frame along the joint primitive axis. An equal and opposite force acts on the base frame.

Actuation Force Setting	Description
`Automatically computed`	Actuation force from automatic calculation. Simscape Multibody computes and applies the actuation force based on model dynamics.

Motion

Select an actuation motion setting. The default setting is `Automatically Computed`.

Actuation Motion Setting	Description
`Provided by Input`	Joint primitive motion from physical signal input. The signal provides the desired trajectory of the follower frame with respect to the base frame along the joint primitive axis.
`Automatically computed`	Joint primitive motion from automatic calculation. Simscape Multibody computes and applies the joint primitive motion based on model dynamics.

Prismatic Primitive: Sensing

Select the variables to sense in the prismatic joint primitive. Selecting a variable exposes a physical signal port that outputs the measured quantity as a function of time. Each quantity is measured for the follower frame with respect to the base frame. It is resolved in the base frame. You can use the measurement signals for analysis or as input in a control system.

Position

Select this option to sense the relative position of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Velocity

Select this option to sense the relative velocity of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Acceleration

Select this option to sense the relative acceleration of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Actuator Force

Select this option to sense the actuation force acting on the follower frame with respect to the base frame along the joint primitive axis.

Revolute Primitive: State Targets

Specify the revolute primitive state targets and their priority levels. A state target is the desired value for one of the joint state parameters—position and velocity. The priority level is the relative importance of a state target. It determines how precisely the target must be met. Use the Model Report tool in Mechanics Explorer to check the assembly status for each joint state target.

Specify Position Target

Select this option to specify the desired joint primitive position at time zero. This is the relative rotation angle, measured about the joint primitive axis, of the follower frame with respect to the base frame. The specified target is resolved in the base frame. Selecting this option exposes priority and value fields.

Specify Velocity Target

Select this option to specify the desired joint primitive velocity at time zero. This is the relative angular velocity, measured about the joint primitive axis, of the follower frame with respect to the base frame. It is resolved in the base frame. Selecting this option exposes priority and value fields.

Priority

Select state target priority. This is the importance level assigned to the state target. If all state targets cannot be simultaneously satisfied, the priority level determines which targets to satisfy first and how closely to satisfy them. This option applies to both position and velocity state targets.

Priority Level	Description
High (desired)	Satisfy state target precisely
Low (approximate)	Satisfy state target approximately

Note: During assembly, high-priority targets behave as exact guides. Low-priority targets behave as rough guides.

Value

> Enter the state target numerical value. The default is 0. Select or enter a physical unit. The default is deg for position and deg/s for velocity.

Revolute Primitive: Internal Mechanics

Specify the revolute primitive internal mechanics. Internal mechanics include linear spring torques, accounting for energy storage, and linear damping torques, accounting for energy dissipation. You can ignore internal mechanics by keeping spring stiffness and damping coefficient values at 0.

Equilibrium Position

> Enter the spring equilibrium position. This is the rotation angle between base and follower frames at which the spring torque is zero. The default value is 0. Select or enter a physical unit. The default is deg.

Spring Stiffness

> Enter the linear spring constant. This is the torque required to rotate the joint primitive by a unit angle. The default is 0. Select or enter a physical unit. The default is N*m/deg.

Damping Coefficient

> Enter the linear damping coefficient. This is the torque required to maintain a constant joint primitive angular velocity between base and follower frames. The default is 0. Select or enter a physical unit. The default is N*m/(deg/s).

Revolute Primitive: Actuation

Specify actuation options for the revolute joint primitive. Actuation modes include **Torque** and **Motion**. Selecting Provided by Input from the drop-down list for an actuation mode adds the corresponding physical signal port to the block. Use this port to specify the input signal. Input signals are resolved in the base frame.

Torque

> Select an actuation torque setting. The default setting is None.

Actuation Torque Setting	Description
None	No actuation torque.

Actuation Torque Setting	Description
`Provided by Input`	Actuation torque from physical signal input. The signal provides the torque acting on the follower frame with respect to the base frame about the joint primitive axis. An equal and opposite torque acts on the base frame.
`Automatically computed`	Actuation torque from automatic calculation. Simscape Multibody computes and applies the actuation torque based on model dynamics.

Motion

Select an actuation motion setting. The default setting is `Automatically Computed`.

Actuation Motion Setting	Description
`Provided by Input`	Joint primitive motion from physical signal input. The signal provides the desired trajectory of the follower frame with respect to the base frame along the joint primitive axis.
`Automatically computed`	Joint primitive motion from automatic calculation. Simscape Multibody computes and applies the joint primitive motion based on model dynamics.

Revolute Primitive: Sensing

Select the variables to sense in the revolute joint primitive. Selecting a variable exposes a physical signal port that outputs the measured quantity as a function of time. Each quantity is measured for the follower frame with respect to the base frame. It is resolved in the base frame. You can use the measurement signals for analysis or as input in a control system.

Position

Select this option to sense the relative rotation angle of the follower frame with respect to the base frame about the joint primitive axis.

Velocity

Select this option to sense the relative angular velocity of the follower frame with respect to the base frame about the joint primitive axis.

Acceleration

Select this option to sense the relative angular acceleration of the follower frame with respect to the base frame about the joint primitive axis.

Actuator Torque

Select this option to sense the actuation torque acting on the follower frame with respect to the base frame about the joint primitive axis.

Composite Force/Torque Sensing

Select the composite, or joint-wide, forces and torques to sense. These are forces and torques that act not at individual joint primitives but at the whole joint. Options include constraint and total forces and torques.

During simulation, the block computes the selected composite forces and torques acting between the base and follower port frames. It outputs these variables using physical signal output ports. Check the port labels to identify the output variables at different ports.

Direction

Forces and torques acting at joints do so in pairs. Newton's third law of motion requires that every action be accompanied by an equal and opposite reaction. If the base frame of a joint exerts a force or torque on the follower frame, then the follower frame must exert an equal and opposite force or torque on the base frame.

Select whether to sense the composite forces and torques exerted by the base frame on the follower frame or vice versa. The force and torque vector components are positive if they point along the positive X, Y, and Z axes of the selected resolution frame.

Resolution Frame

You can resolve a vector quantity into Cartesian components in different frames. If the resolution frames have different orientations, then the measured components are themselves different—even though the vector quantity remains the same.

Select the frame in which to resolve the sensed force and torque variables. Possible resolution frames include `Base` and `Follower`. The block outputs the Cartesian components of the sensed force and torque vectors as observed in this frame.

Constraint Force

Joint blocks with fewer than three translational degrees of freedom forbid motion along one or more axes. For example, the Gimbal Joint block forbids translation along all axes. To prevent translation along an axis, a joint block applies a constraint force between its base and follower port frames. Constraint forces are orthogonal to joint translation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint force vector [fc_x, fc_y, fc_z] acting at the joint. Only constraint force components that are orthogonal to the joint translational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port fc.

Constraint Torque

Joint blocks with fewer than three rotational degrees of freedom forbid motion about one or more axes. For example, the Cartesian Joint block forbids rotation about all axes. To prevent rotation about an axis, a joint block applies a constraint torque between its base and follower port frames. Constraint torques are orthogonal to joint rotation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint torque vector [tc_x, tc_y, tc_z] acting at the joint. Only constraint torque components that are orthogonal to the joint rotational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port tc.

Total Force

A joint block generally applies various forces between its port frames:

- Actuation forces that drive prismatic joint primitives.
- Internal spring and damper forces that resist motion at prismatic joint primitives.
- Constraint forces that forbid motion in directions orthogonal to prismatic joint primitives.

The net sum of the different force components equals the total force acting between the joint port frames. Select the check box to compute and output the 3-D total force vector [ft_x, ft_y, ft_z]. Selecting this option causes the block to expose physical signal port ft.

Total Torque

A joint block generally applies various torques between its port frames:

- Actuation torques that drive revolute or spherical joint primitives.

- Internal spring and damper torques that resist motion at revolute or spherical joint primitives.
- Constraint torques that forbid motion in directions orthogonal to the revolute or spherical joint primitive axes.

The net sum of the different torque components equals the total torque acting at a joint. Select the check box to compute and output the 3-D total torque vector [tt_x, tt_y, tt_z]. Selecting this option causes the block to expose physical signal port tt.

Ports

This block has two frame ports. It also has optional physical signal ports for specifying actuation inputs and sensing dynamical variables such as forces, torques, and motion. You expose an optional port by selecting the sensing check box corresponding to that port.

Frame Ports

- B — Base frame
- F — Follower frame

Actuation Ports

The prismatic joint primitives provide the following actuation ports:

- fx, fy — Actuation forces acting on the X and Y prismatic joint primitives
- px, py — Desired trajectories of the X and Y prismatic joint primitives

The revolute joint primitive provides the following actuation ports:

- tz — Actuation torque acting on the Z revolute joint primitive
- qz — Desired rotation of the Z revolute joint primitive

Sensing Ports

The prismatic joint primitives provide the following sensing ports:

- px, py — Positions of the X and Y prismatic joint primitives
- vx, vy — Velocities of the X and Y prismatic joint primitives
- ax, ay — Accelerations of the X and Y prismatic joint primitives
- fx, fy — Actuator forces acting on the X and Y prismatic joint primitives

The revolute joint primitive provides the following sensing ports:

- qz — Angular position of the Z revolute joint primitive
- wz — Angular velocity of the Z revolute joint primitive
- bz — Angular acceleration of the Z revolute joint primitive
- tz — Actuation torque acting on the Z revolute joint primitive

The following sensing ports provide the composite forces and torques acting on the joint:

- fc — Constraint force
- tc — Constraint torque
- ft — Total force
- tt — Total torque

See Also
Prismatic Joint | Rectangular Joint | Revolute Joint

More About
- "Actuating and Sensing with Physical Signals"
- "Motion Sensing"
- "Rotational Measurements"
- "Translational Measurements"

Point On Curve Constraint

Kinematic constraint between a frame origin and a curved path

Library

Constraints

Description

This block represents a kinematic constraint between a point and a curve. The constraint allows the follower frame origin to translate only along the curve connected to the base geometry port. The follower frame is free to rotate depending on other constraints in the model. Use this block to model point-on-curve constraints, such as that between a roller coaster and a track or a cam follower and a cam.
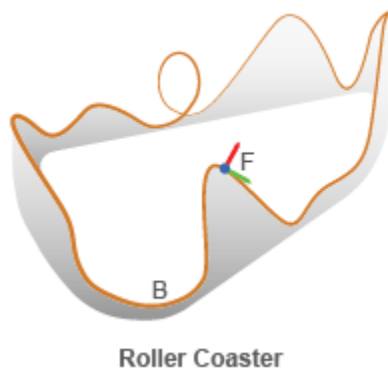
Examples of Point-on-Curve Constraints

Specify the constraint curve by connecting a curve block to the base geometry port. As a best practice, always use the curve block as part of a rigid body, for example, by keeping

it inside a rigid body subsystem. This enables you to quickly switch, for example, between different cams or roller coaster tracks. Avoid curves with sharp changes in slope, as these can cause simulation issues.

Dialog Box and Parameters
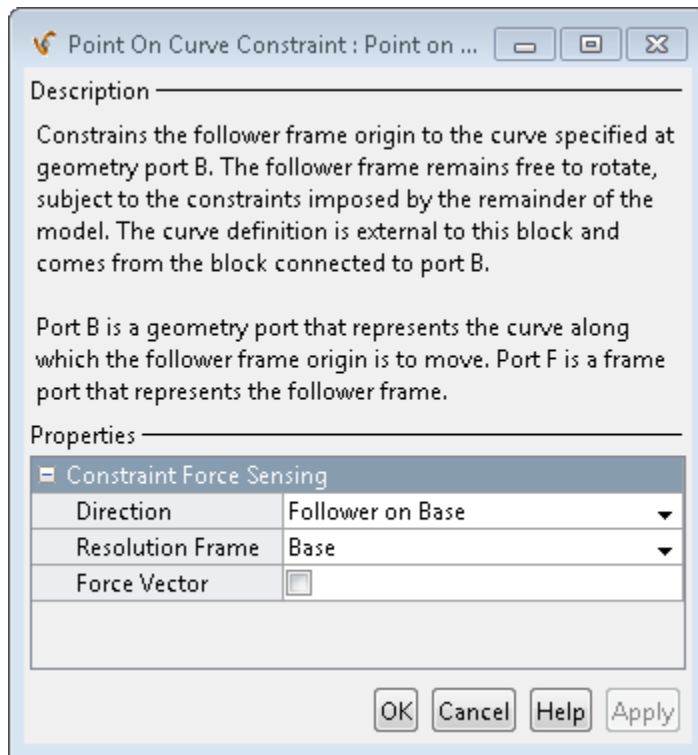
Constraint Force Sensing

Direction

Select the force in the constraint action-reaction force pair to sense. You can sense the force that the follower frame exerts on the base curve or vice-versa. The default setting is `Follower on Base`.

Resolution Frame

Select the frame to resolve the constraint force measurement in. You can select the base or follower frame. The default setting is `Base`.

Force Vector

Select the check box to sense the constraint force. The block exposes physical signal output port f, which outputs the force measurement as a three-dimensional vector, $[F_\mathrm{x}, F_\mathrm{y}, F_\mathrm{z}]$.

Ports

The block contains two ports:

- B — Base geometry port representing the constraint curve
- F — Follower frame port representing the constrained point

An optional port appears when you select constraint force sensing:

- f — Physical signal with the constraint force components $[F_\mathrm{x}, F_\mathrm{y}, F_\mathrm{z}]$

See Also

Angle Constraint | Bevel Gear Constraint | Common Gear Constraint | Distance Constraint | Rack and Pinion Constraint | Spline

Related Examples

- sm_cam_flapping_wing

Prismatic Joint

Joint with one prismatic primitive
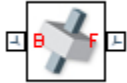
Library

Joints

Description

This block represents a joint with one translational degree of freedom. One prismatic primitive provides the translational degree of freedom. The base and follower frames remain parallel during simulation.
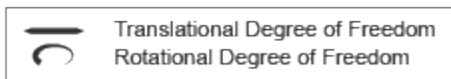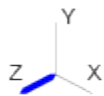
Joint Degrees of Freedom

The joint block represents motion between the base and follower frames as a single time-varying transformation. The Z prismatic primitive (Pz) applies this transformation, which causes the follower frame to translate with respect to the base frame along the common Z axis.

Joint Transformation

A set of optional state targets guide assembly for each joint primitive. Targets include position and velocity. A priority level sets the relative importance of the state targets. If two targets are incompatible, the priority level determines which of the targets to satisfy.

Internal mechanics parameters account for energy storage and dissipation at each joint primitive. Springs act as energy storage elements, resisting any attempt to displace the joint primitive from its equilibrium position. Joint dampers act as energy dissipation elements. Springs and dampers are strictly linear.

Each joint primitive has a set of optional actuation and sensing ports. Actuation ports accept physical signal inputs that drive the joint primitives. These inputs can be forces and torques or a desired joint trajectory. Sensing ports provide physical signal outputs that measure joint primitive motion as well as actuation forces and torques. Actuation modes and sensing types vary with joint primitive.

Dialog Box and Parameters

Prismatic Primitive: State Targets

Specify the prismatic primitive state targets and their priority levels. A state target is the desired value for one of the joint state parameters—position and velocity. The

priority level is the relative importance of a state target. It determines how precisely the target must be met. Use the Model Report tool in Mechanics Explorer to check the assembly status for each joint state target.

Specify Position Target

Select this option to specify the desired joint primitive position at time zero. This is the relative position, measured along the joint primitive axis, of the follower frame origin with respect to the base frame origin. The specified target is resolved in the base frame. Selecting this option exposes priority and value fields.

Specify Velocity Target

Select this option to specify the desired joint primitive velocity at time zero. This is the relative velocity, measured along the joint primitive axis, of the follower frame origin with respect to the base frame origin. It is resolved in the base frame. Selecting this option exposes priority and value fields.

Priority

Select state target priority. This is the importance level assigned to the state target. If all state targets cannot be simultaneously satisfied, the priority level determines which targets to satisfy first and how closely to satisfy them. This option applies to both position and velocity state targets.

Priority Level	Description
High (desired)	Satisfy state target precisely
Low (approximate)	Satisfy state target approximately

Note: During assembly, high-priority targets behave as exact guides. Low-priority targets behave as rough guides.

Value

Enter the state target numerical value. The default is 0. Select or enter a physical unit. The default is m for position and m/s for velocity.

Prismatic Primitive: Internal Mechanics

Specify the prismatic primitive internal mechanics. Internal mechanics include linear spring forces, accounting for energy storage, and damping forces, accounting for energy

dissipation. You can ignore internal mechanics by keeping spring stiffness and damping coefficient values at 0.

Equilibrium Position

Enter the spring equilibrium position. This is the distance between base and follower frame origins at which the spring force is zero. The default value is 0. Select or enter a physical unit. The default is m.

Spring Stiffness

Enter the linear spring constant. This is the force required to displace the joint primitive by a unit distance. The default is 0. Select or enter a physical unit. The default is N/m.

Damping Coefficient

Enter the linear damping coefficient. This is the force required to maintain a constant joint primitive velocity between base and follower frames. The default is 0. Select or enter a physical unit. The default is N/(m/s).

Prismatic Primitive: Actuation

Specify actuation options for the prismatic joint primitive. Actuation modes include **Force** and **Motion**. Selecting Provided by Input from the drop-down list for an actuation mode adds the corresponding physical signal port to the block. Use this port to specify the input signal. Actuation signals are resolved in the base frame.

Force

Select an actuation force setting. The default setting is None.

Actuation Force Setting	Description
None	No actuation force.
Provided by Input	Actuation force from physical signal input. The signal provides the force acting on the follower frame with respect to the base frame along the joint primitive axis. An equal and opposite force acts on the base frame.
Automatically computed	Actuation force from automatic calculation. Simscape Multibody computes and applies the actuation force based on model dynamics.

Motion

Select an actuation motion setting. The default setting is `Automatically Computed`.

Actuation Motion Setting	Description
`Provided by Input`	Joint primitive motion from physical signal input. The signal provides the desired trajectory of the follower frame with respect to the base frame along the joint primitive axis.
`Automatically computed`	Joint primitive motion from automatic calculation. Simscape Multibody computes and applies the joint primitive motion based on model dynamics.

Prismatic Primitive: Sensing

Select the variables to sense in the prismatic joint primitive. Selecting a variable exposes a physical signal port that outputs the measured quantity as a function of time. Each quantity is measured for the follower frame with respect to the base frame. It is resolved in the base frame. You can use the measurement signals for analysis or as input in a control system.

Position

Select this option to sense the relative position of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Velocity

Select this option to sense the relative velocity of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Acceleration

Select this option to sense the relative acceleration of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Actuator Force

Select this option to sense the actuation force acting on the follower frame with respect to the base frame along the joint primitive axis.

Composite Force/Torque Sensing

Select the composite, or joint-wide, forces and torques to sense. These are forces and torques that act not at individual joint primitives but at the whole joint. Options include constraint and total forces and torques.

During simulation, the block computes the selected composite forces and torques acting between the base and follower port frames. It outputs these variables using physical signal output ports. Check the port labels to identify the output variables at different ports.

Direction

Forces and torques acting at joints do so in pairs. Newton's third law of motion requires that every action be accompanied by an equal and opposite reaction. If the base frame of a joint exerts a force or torque on the follower frame, then the follower frame must exert an equal and opposite force or torque on the base frame.

Select whether to sense the composite forces and torques exerted by the base frame on the follower frame or vice versa. The force and torque vector components are positive if they point along the positive X, Y, and Z axes of the selected resolution frame.

Resolution Frame

You can resolve a vector quantity into Cartesian components in different frames. If the resolution frames have different orientations, then the measured components are themselves different—even though the vector quantity remains the same.

Select the frame in which to resolve the sensed force and torque variables. Possible resolution frames include `Base` and `Follower`. The block outputs the Cartesian components of the sensed force and torque vectors as observed in this frame.

Constraint Force

Joint blocks with fewer than three translational degrees of freedom forbid motion along one or more axes. For example, the Gimbal Joint block forbids translation along all axes. To prevent translation along an axis, a joint block applies a constraint force between its base and follower port frames. Constraint forces are orthogonal to joint translation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint force vector [fc_x, fc_y, fc_z] acting at the joint. Only constraint force components that are orthogonal to the

joint translational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port fc.

Constraint Torque

Joint blocks with fewer than three rotational degrees of freedom forbid motion about one or more axes. For example, the Cartesian Joint block forbids rotation about all axes. To prevent rotation about an axis, a joint block applies a constraint torque between its base and follower port frames. Constraint torques are orthogonal to joint rotation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint torque vector [tc_x, tc_y, tc_z] acting at the joint. Only constraint torque components that are orthogonal to the joint rotational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port tc.

Total Force

A joint block generally applies various forces between its port frames:

- Actuation forces that drive prismatic joint primitives.
- Internal spring and damper forces that resist motion at prismatic joint primitives.
- Constraint forces that forbid motion in directions orthogonal to prismatic joint primitives.

The net sum of the different force components equals the total force acting between the joint port frames. Select the check box to compute and output the 3-D total force vector [ft_x, ft_y, ft_z]. Selecting this option causes the block to expose physical signal port ft.

Total Torque

A joint block generally applies various torques between its port frames:

- Actuation torques that drive revolute or spherical joint primitives.
- Internal spring and damper torques that resist motion at revolute or spherical joint primitives.
- Constraint torques that forbid motion in directions orthogonal to the revolute or spherical joint primitive axes.

The net sum of the different torque components equals the total torque acting at a joint. Select the check box to compute and output the 3-D total torque vector [tt_x, tt_y, tt_z]. Selecting this option causes the block to expose physical signal port tt.

Ports

This block has two frame ports. It also has optional physical signal ports for specifying actuation inputs and sensing dynamical variables such as forces, torques, and motion. You expose an optional port by selecting the sensing check box corresponding to that port.

Frame Ports

- B — Base frame
- F — Follower frame

Actuation Ports

The prismatic joint primitive provides the following actuation ports:

- fz — Actuation force acting on the Z prismatic joint primitive
- pz — Desired trajectory of the Z prismatic joint primitive

Sensing Ports

The prismatic joint primitive provides the following sensing ports:

- pz — Position of the Z prismatic joint primitive
- vz — Velocity of the Z prismatic joint primitive
- az — Acceleration of the Z prismatic joint primitive
- fz — Actuation force acting on the Z prismatic joint primitive

The following sensing ports provide the composite forces and torques acting on the joint:

- fc — Constraint force
- tc — Constraint torque
- ft — Total force
- tt — Total torque

See Also
`Revolute Joint` | `Spherical Joint`

More About

- "Actuating and Sensing with Physical Signals"
- "Motion Sensing"
- "Translational Measurements"

Rack and Pinion Constraint

Kinematic constraint for converting between rotation and translation

Library

Gears and Couplings/Gears

Description

This block represents a kinematic constraint between a rack and a pinion. The constraint converts rotation of the pinion into translation of the rack and vice-versa. The pinion, which connects to the base port frame, spins about the base Z axis. The rack, which connects to the follower port frame, translates along the follower Z axis.

Kinematic constraints in the remainder of the model must hold the base and follower frames at the correct distance and with the proper alignment. These constraints might be due to rigid transforms, joints, and model topology. Assembly conditions include:

- Base and follower Z axes must be mutually orthogonal. This condition ensures that the pinion rotation axis sits at a right angle to the rack translation axis. You can rotate frames using the `Rigid Transform` block.

- Base and follower frame origins must be apart by a distance equal to the **Pinion Radius** parameter. This condition ensures that the rack and pinion cogs are at the correct distance for engagement. You can translate frames using the `Rigid Transform` block.

The figure shows the distance and alignment of the base and follower frames in the zero configuration. This is the primary configuration that Simscape Multibody attempts to achieve during model assembly.
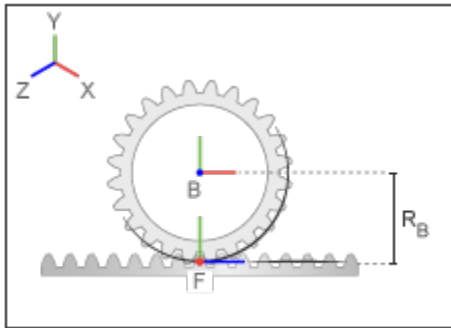
In the zero configuration, the pinion rotation angle and the rack translation distance are both zero. To achieve this configuration, Simscape Multibody:

- Aligns the base and follower Y axes.
- Positions the follower frame origin along the negative Y axis of the base frame.

Joint blocks provide the base and follower frames with the proper internal degrees of freedom. These degrees of freedom must support rotation about the base Z axis and translation along the follower Z axis. You can achieve these degrees of freedom using different joint block combinations. For example, you can connect the pinion to a `Revolute Joint` block and the rack to a `Prismatic Joint` block.

During simulation, a positive pinion rotation about the base Z axis corresponds to a positive rack translation along the follower Z axis. By definition, the translational velocity of the rack is equal to the tangential velocity at a point in the pinion pitch circle, an imaginary circle that intersects the rack and pinion cogs at the mutual contact point.

The figure shows the relative motion of the base and follower frames due to the rack and pinion constraint.
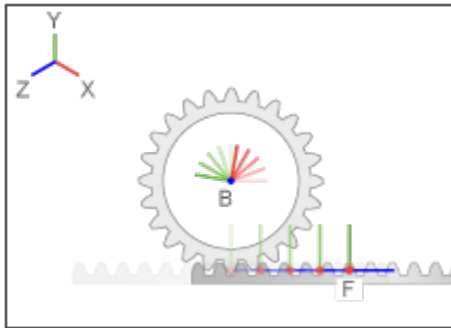
Dialog Box and Parameters
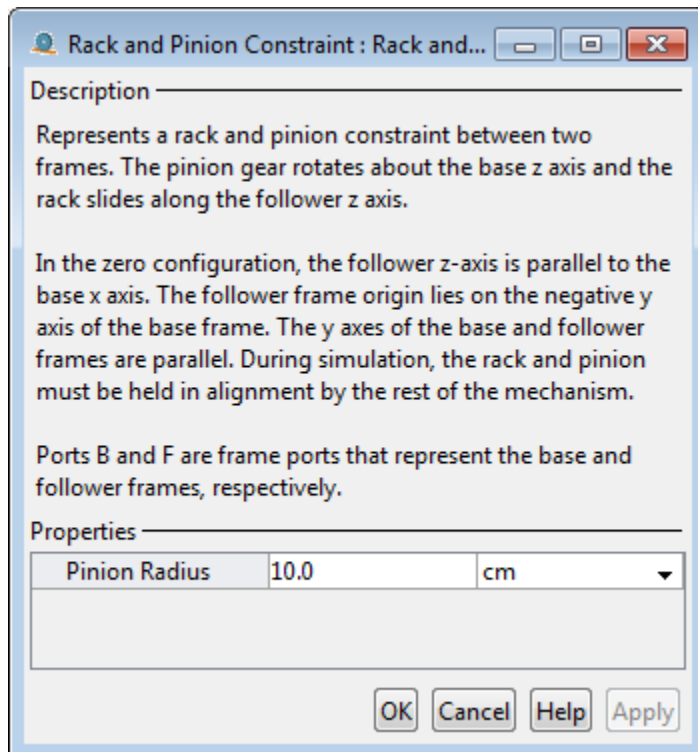
Pinion Radius

> Distance between the pinion center and pitch circle. This circle contains the instantaneous contact point between a pair of rack and pinion cogs. The pinion radius must equal the actual distance between the base and follower frames as specified by the remainder of the model. The default value is 10 cm.

Ports

The block contains frame ports B and F, representing base and follower frames, respectively.

See Also
Bevel Gear Constraint | Common Gear Constraint

Rectangular Joint

Joint with two prismatic primitives

Library

Joints

Description

This block represents a joint with two translational degrees of freedom. Two prismatic primitives provide the two translational degrees of freedom. The base and follower frames remain parallel during simulation.

Joint Degrees of Freedom

The joint block represents motion between the base and follower frames as a sequence of time-varying transformations. Each joint primitive applies one transformation in this sequence. The transformation translates or rotates the follower frame with respect to the

joint primitive base frame. For all but the first joint primitive, the base frame coincides with the follower frame of the previous joint primitive in the sequence.

At each time step during the simulation, the joint block applies the sequence of time-varying frame transformations in this order:

1   Translation:

   a   Along the X axis of the X Prismatic Primitive (Px) base frame.

   b   Along the Y axis of the Y Prismatic Primitive (Py) base frame. This frame is coincident with the X Prismatic Primitive (Px) follower frame.

The figure shows the sequence in which the joint transformations occur at a given simulation time step. The resulting frame of each transformation serves as the base frame for the following transformation.

Joint Transformation Sequence

A set of optional state targets guide assembly for each joint primitive. Targets include position and velocity. A priority level sets the relative importance of the state targets. If two targets are incompatible, the priority level determines which of the targets to satisfy.

Internal mechanics parameters account for energy storage and dissipation at each joint primitive. Springs act as energy storage elements, resisting any attempt to displace the joint primitive from its equilibrium position. Joint dampers act as energy dissipation elements. Springs and dampers are strictly linear.

Each joint primitive has a set of optional actuation and sensing ports. Actuation ports accept physical signal inputs that drive the joint primitives. These inputs can be forces and torques or a desired joint trajectory. Sensing ports provide physical signal outputs that measure joint primitive motion as well as actuation forces and torques. Actuation modes and sensing types vary with joint primitive.

Dialog Box and Parameters

Rectangular Joint : Rectangular Joint

Description

Represents a rectangular joint between two frames. This joint has two translational degrees of freedom represented by two prismatic primitives along a set of two mutually orthogonal axes. This joint constrains the z-axes of the base and follower frames to be aligned and prohibits relative translation along that axis.

In the expandable nodes under Properties, specify the state, actuation method, sensing capabilities, and internal mechanics of the primitives of this joint. After you apply these settings, the block displays the corresponding physical signal ports.

Ports B and F are frame ports that represent the base and follower frames, respectively. The joint direction is defined by motion of the follower frame relative to the base frame.

Properties

- ⊟ X Prismatic Primitive (Px)
  - ⊞ State Targets
  - ⊞ Internal Mechanics
  - ⊞ Actuation
  - ⊞ Sensing
- ⊞ Y Prismatic Primitive (Py)
- ⊞ Composite Force/Torque Sensing

OK   Cancel   Help   Apply

Prismatic Primitive: State Targets

Specify the prismatic primitive state targets and their priority levels. A state target is the desired value for one of the joint state parameters—position and velocity. The priority level is the relative importance of a state target. It determines how precisely the target must be met. Use the Model Report tool in Mechanics Explorer to check the assembly status for each joint state target.

Specify Position Target

Select this option to specify the desired joint primitive position at time zero. This is the relative position, measured along the joint primitive axis, of the follower frame origin with respect to the base frame origin. The specified target is resolved in the base frame. Selecting this option exposes priority and value fields.

Specify Velocity Target

Select this option to specify the desired joint primitive velocity at time zero. This is the relative velocity, measured along the joint primitive axis, of the follower frame origin with respect to the base frame origin. It is resolved in the base frame. Selecting this option exposes priority and value fields.

Priority

Select state target priority. This is the importance level assigned to the state target. If all state targets cannot be simultaneously satisfied, the priority level determines which targets to satisfy first and how closely to satisfy them. This option applies to both position and velocity state targets.

Priority Level	Description
`High (desired)`	Satisfy state target precisely
`Low (approximate)`	Satisfy state target approximately

Note: During assembly, high-priority targets behave as exact guides. Low-priority targets behave as rough guides.

Value

Enter the state target numerical value. The default is `0`. Select or enter a physical unit. The default is `m` for position and `m/s` for velocity.

Prismatic Primitive: Internal Mechanics

Specify the prismatic primitive internal mechanics. Internal mechanics include linear spring forces, accounting for energy storage, and damping forces, accounting for energy dissipation. You can ignore internal mechanics by keeping spring stiffness and damping coefficient values at 0.

Equilibrium Position

Enter the spring equilibrium position. This is the distance between base and follower frame origins at which the spring force is zero. The default value is 0. Select or enter a physical unit. The default is m.

Spring Stiffness

Enter the linear spring constant. This is the force required to displace the joint primitive by a unit distance. The default is 0. Select or enter a physical unit. The default is N/m.

Damping Coefficient

Enter the linear damping coefficient. This is the force required to maintain a constant joint primitive velocity between base and follower frames. The default is 0. Select or enter a physical unit. The default is N/(m/s).

Prismatic Primitive: Actuation

Specify actuation options for the prismatic joint primitive. Actuation modes include **Force** and **Motion**. Selecting Provided by Input from the drop-down list for an actuation mode adds the corresponding physical signal port to the block. Use this port to specify the input signal. Actuation signals are resolved in the base frame.

Force

Select an actuation force setting. The default setting is None.

Actuation Force Setting	Description
None	No actuation force.
Provided by Input	Actuation force from physical signal input. The signal provides the force acting on the follower frame with respect to the base frame along the joint primitive axis. An equal and opposite force acts on the base frame.

Actuation Force Setting	Description
`Automatically computed`	Actuation force from automatic calculation. Simscape Multibody computes and applies the actuation force based on model dynamics.

Motion

Select an actuation motion setting. The default setting is `Automatically Computed`.

Actuation Motion Setting	Description
`Provided by Input`	Joint primitive motion from physical signal input. The signal provides the desired trajectory of the follower frame with respect to the base frame along the joint primitive axis.
`Automatically computed`	Joint primitive motion from automatic calculation. Simscape Multibody computes and applies the joint primitive motion based on model dynamics.

Prismatic Primitive: Sensing

Select the variables to sense in the prismatic joint primitive. Selecting a variable exposes a physical signal port that outputs the measured quantity as a function of time. Each quantity is measured for the follower frame with respect to the base frame. It is resolved in the base frame. You can use the measurement signals for analysis or as input in a control system.

Position

Select this option to sense the relative position of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Velocity

Select this option to sense the relative velocity of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Acceleration

Select this option to sense the relative acceleration of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Actuator Force

Select this option to sense the actuation force acting on the follower frame with respect to the base frame along the joint primitive axis.

Composite Force/Torque Sensing

Select the composite, or joint-wide, forces and torques to sense. These are forces and torques that act not at individual joint primitives but at the whole joint. Options include constraint and total forces and torques.

During simulation, the block computes the selected composite forces and torques acting between the base and follower port frames. It outputs these variables using physical signal output ports. Check the port labels to identify the output variables at different ports.

Direction

Forces and torques acting at joints do so in pairs. Newton's third law of motion requires that every action be accompanied by an equal and opposite reaction. If the base frame of a joint exerts a force or torque on the follower frame, then the follower frame must exert an equal and opposite force or torque on the base frame.

Select whether to sense the composite forces and torques exerted by the base frame on the follower frame or vice versa. The force and torque vector components are positive if they point along the positive X, Y, and Z axes of the selected resolution frame.

Resolution Frame

You can resolve a vector quantity into Cartesian components in different frames. If the resolution frames have different orientations, then the measured components are themselves different—even though the vector quantity remains the same.

Select the frame in which to resolve the sensed force and torque variables. Possible resolution frames include `Base` and `Follower`. The block outputs the Cartesian components of the sensed force and torque vectors as observed in this frame.

Constraint Force

Joint blocks with fewer than three translational degrees of freedom forbid motion along one or more axes. For example, the Gimbal Joint block forbids translation along all axes. To prevent translation along an axis, a joint block applies a constraint

force between its base and follower port frames. Constraint forces are orthogonal to joint translation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint force vector [fc_x, fc_y, fc_z] acting at the joint. Only constraint force components that are orthogonal to the joint translational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port fc.

Constraint Torque

Joint blocks with fewer than three rotational degrees of freedom forbid motion about one or more axes. For example, the Cartesian Joint block forbids rotation about all axes. To prevent rotation about an axis, a joint block applies a constraint torque between its base and follower port frames. Constraint torques are orthogonal to joint rotation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint torque vector [tc_x, tc_y, tc_z] acting at the joint. Only constraint torque components that are orthogonal to the joint rotational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port tc.

Total Force

A joint block generally applies various forces between its port frames:

- Actuation forces that drive prismatic joint primitives.
- Internal spring and damper forces that resist motion at prismatic joint primitives.
- Constraint forces that forbid motion in directions orthogonal to prismatic joint primitives.

The net sum of the different force components equals the total force acting between the joint port frames. Select the check box to compute and output the 3-D total force vector [ft_x, ft_y, ft_z]. Selecting this option causes the block to expose physical signal port ft.

Total Torque

A joint block generally applies various torques between its port frames:

- Actuation torques that drive revolute or spherical joint primitives.
- Internal spring and damper torques that resist motion at revolute or spherical joint primitives.
- Constraint torques that forbid motion in directions orthogonal to the revolute or spherical joint primitive axes.

The net sum of the different torque components equals the total torque acting at a joint. Select the check box to compute and output the 3-D total torque vector [tt_x, tt_y, tt_z]. Selecting this option causes the block to expose physical signal port tt.

Ports

This block has two frame ports. It also has optional physical signal ports for specifying actuation inputs and sensing dynamical variables such as forces, torques, and motion. You expose an optional port by selecting the sensing check box corresponding to that port.

Frame Ports

- B — Base frame
- F — Follower frame

Actuation Ports

The prismatic joint primitives provide the following actuation ports:

- fx, fy — Actuation forces acting on the X and Y prismatic joint primitives
- px, py — Desired trajectories of the X and Y prismatic joint primitives

Sensing Ports

The prismatic joint primitives provide the following sensing ports:

- px, py — Positions of the X and Y prismatic joint primitives
- vx, vy — Velocities of the X and Y prismatic joint primitives
- ax, ay — Accelerations of the X and Y prismatic joint primitives
- fx, fy — Actuation forces acting on the X and Y prismatic joint primitives

The following sensing ports provide the composite forces and torques acting on the joint:

- fc — Constraint force
- tc — Constraint torque

- ft — Total force
- tt — Total torque

See Also
`Planar Joint` | `Prismatic Joint`

More About
- "Actuating and Sensing with Physical Signals"
- "Motion Sensing"
- "Translational Measurements"

Reference Frame

Non-inertial reference frame

Library

Frames and Transforms

Description

This block represents a reference frame with respect to which you can define other frames. The reference frame is generally non-inertial. It can accelerate with respect to the World frame. This block is optional in a model.

Dialog Box and Parameters
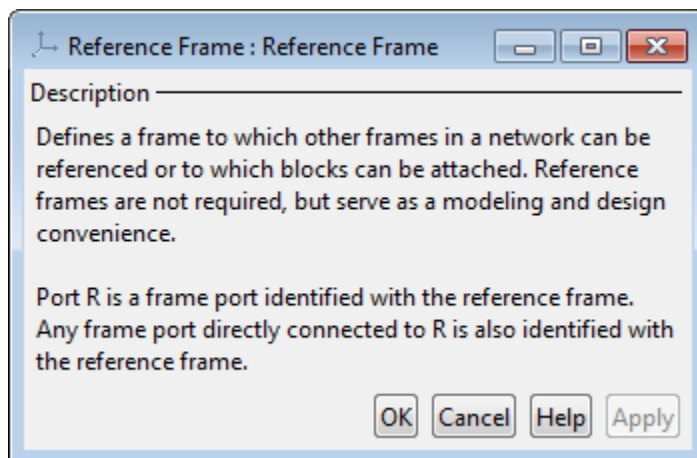
Ports

This block contains frame port R, representing the reference frame.

See Also

`World Frame`

Revolute Joint

Joint with one revolute primitive
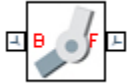
Library

Joints

Description

This block represents a joint with one rotational degree of freedom. One revolute primitive provides the rotational degree of freedom. The base and follower frame origins remain coincident during simulation.
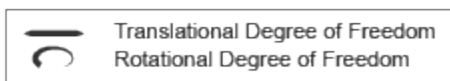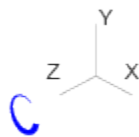
Joint Degrees of Freedom

The joint block represents motion between the base and follower frames as a single time-varying transformation. The Z revolute primitive (Pz) applies this transformation, which causes the follower frame to rotate with respect to the base frame about the common Z axis.

Joint Transformation

A set of optional state targets guide assembly for each joint primitive. Targets include position and velocity. A priority level sets the relative importance of the state targets. If two targets are incompatible, the priority level determines which of the targets to satisfy.

Internal mechanics parameters account for energy storage and dissipation at each joint primitive. Springs act as energy storage elements, resisting any attempt to displace the joint primitive from its equilibrium position. Joint dampers act as energy dissipation elements. Springs and dampers are strictly linear.

Each joint primitive has a set of optional actuation and sensing ports. Actuation ports accept physical signal inputs that drive the joint primitives. These inputs can be forces and torques or a desired joint trajectory. Sensing ports provide physical signal outputs that measure joint primitive motion as well as actuation forces and torques. Actuation modes and sensing types vary with joint primitive.

Dialog Box and Parameters

Revolute Primitive: State Targets

Specify the revolute primitive state targets and their priority levels. A state target is the desired value for one of the joint state parameters—position and velocity. The priority level is the relative importance of a state target. It determines how precisely the target must be met. Use the Model Report tool in Mechanics Explorer to check the assembly status for each joint state target.

Specify Position Target

Select this option to specify the desired joint primitive position at time zero. This is the relative rotation angle, measured about the joint primitive axis, of the follower frame with respect to the base frame. The specified target is resolved in the base frame. Selecting this option exposes priority and value fields.

Specify Velocity Target

Select this option to specify the desired joint primitive velocity at time zero. This is the relative angular velocity, measured about the joint primitive axis, of the follower frame with respect to the base frame. It is resolved in the base frame. Selecting this option exposes priority and value fields.

Priority

Select state target priority. This is the importance level assigned to the state target. If all state targets cannot be simultaneously satisfied, the priority level determines which targets to satisfy first and how closely to satisfy them. This option applies to both position and velocity state targets.

Priority Level	Description
High (desired)	Satisfy state target precisely
Low (approximate)	Satisfy state target approximately

Note: During assembly, high-priority targets behave as exact guides. Low-priority targets behave as rough guides.

Value

Enter the state target numerical value. The default is 0. Select or enter a physical unit. The default is deg for position and deg/s for velocity.

Revolute Primitive: Internal Mechanics

Specify the revolute primitive internal mechanics. Internal mechanics include linear spring torques, accounting for energy storage, and linear damping torques, accounting for energy dissipation. You can ignore internal mechanics by keeping spring stiffness and damping coefficient values at 0.

Equilibrium Position

Enter the spring equilibrium position. This is the rotation angle between base and follower frames at which the spring torque is zero. The default value is 0. Select or enter a physical unit. The default is deg.

Spring Stiffness

Enter the linear spring constant. This is the torque required to rotate the joint primitive by a unit angle. The default is 0. Select or enter a physical unit. The default is N*m/deg.

Damping Coefficient

Enter the linear damping coefficient. This is the torque required to maintain a constant joint primitive angular velocity between base and follower frames. The default is 0. Select or enter a physical unit. The default is N*m/(deg/s).

Revolute Primitive: Actuation

Specify actuation options for the revolute joint primitive. Actuation modes include **Torque** and **Motion**. Selecting Provided by Input from the drop-down list for an actuation mode adds the corresponding physical signal port to the block. Use this port to specify the input signal. Input signals are resolved in the base frame.

Torque

Select an actuation torque setting. The default setting is None.

Actuation Torque Setting	Description
None	No actuation torque.
Provided by Input	Actuation torque from physical signal input. The signal provides the torque acting on the follower frame with respect to the base frame about the joint primitive axis. An equal and opposite torque acts on the base frame.

Actuation Torque Setting	Description
Automatically computed	Actuation torque from automatic calculation. Simscape Multibody computes and applies the actuation torque based on model dynamics.

Motion

Select an actuation motion setting. The default setting is Automatically Computed.

Actuation Motion Setting	Description
Provided by Input	Joint primitive motion from physical signal input. The signal provides the desired trajectory of the follower frame with respect to the base frame along the joint primitive axis.
Automatically computed	Joint primitive motion from automatic calculation. Simscape Multibody computes and applies the joint primitive motion based on model dynamics.

Revolute Primitive: Sensing

Select the variables to sense in the revolute joint primitive. Selecting a variable exposes a physical signal port that outputs the measured quantity as a function of time. Each quantity is measured for the follower frame with respect to the base frame. It is resolved in the base frame. You can use the measurement signals for analysis or as input in a control system.

Position

Select this option to sense the relative rotation angle of the follower frame with respect to the base frame about the joint primitive axis.

Velocity

Select this option to sense the relative angular velocity of the follower frame with respect to the base frame about the joint primitive axis.

Acceleration

Select this option to sense the relative angular acceleration of the follower frame with respect to the base frame about the joint primitive axis.

Actuator Torque

Select this option to sense the actuation torque acting on the follower frame with respect to the base frame about the joint primitive axis.

Composite Force/Torque Sensing

Select the composite, or joint-wide, forces and torques to sense. These are forces and torques that act not at individual joint primitives but at the whole joint. Options include constraint and total forces and torques.

During simulation, the block computes the selected composite forces and torques acting between the base and follower port frames. It outputs these variables using physical signal output ports. Check the port labels to identify the output variables at different ports.

Direction

Forces and torques acting at joints do so in pairs. Newton's third law of motion requires that every action be accompanied by an equal and opposite reaction. If the base frame of a joint exerts a force or torque on the follower frame, then the follower frame must exert an equal and opposite force or torque on the base frame.

Select whether to sense the composite forces and torques exerted by the base frame on the follower frame or vice versa. The force and torque vector components are positive if they point along the positive X, Y, and Z axes of the selected resolution frame.

Resolution Frame

You can resolve a vector quantity into Cartesian components in different frames. If the resolution frames have different orientations, then the measured components are themselves different—even though the vector quantity remains the same.

Select the frame in which to resolve the sensed force and torque variables. Possible resolution frames include `Base` and `Follower`. The block outputs the Cartesian components of the sensed force and torque vectors as observed in this frame.

Constraint Force

Joint blocks with fewer than three translational degrees of freedom forbid motion along one or more axes. For example, the Gimbal Joint block forbids translation along all axes. To prevent translation along an axis, a joint block applies a constraint

force between its base and follower port frames. Constraint forces are orthogonal to joint translation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint force vector [fc_x, fc_y, fc_z] acting at the joint. Only constraint force components that are orthogonal to the joint translational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port fc.

Constraint Torque

Joint blocks with fewer than three rotational degrees of freedom forbid motion about one or more axes. For example, the Cartesian Joint block forbids rotation about all axes. To prevent rotation about an axis, a joint block applies a constraint torque between its base and follower port frames. Constraint torques are orthogonal to joint rotation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint torque vector [tc_x, tc_y, tc_z] acting at the joint. Only constraint torque components that are orthogonal to the joint rotational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port tc.

Total Force

A joint block generally applies various forces between its port frames:

- Actuation forces that drive prismatic joint primitives.
- Internal spring and damper forces that resist motion at prismatic joint primitives.
- Constraint forces that forbid motion in directions orthogonal to prismatic joint primitives.

The net sum of the different force components equals the total force acting between the joint port frames. Select the check box to compute and output the 3-D total force vector [ft_x, ft_y, ft_z]. Selecting this option causes the block to expose physical signal port ft.

Total Torque

A joint block generally applies various torques between its port frames:

- Actuation torques that drive revolute or spherical joint primitives.
- Internal spring and damper torques that resist motion at revolute or spherical joint primitives.
- Constraint torques that forbid motion in directions orthogonal to the revolute or spherical joint primitive axes.

The net sum of the different torque components equals the total torque acting at a joint. Select the check box to compute and output the 3-D total torque vector [tt_x, tt_y, tt_z]. Selecting this option causes the block to expose physical signal port tt.

Ports

This block has two frame ports. It also has optional physical signal ports for specifying actuation inputs and sensing dynamical variables such as forces, torques, and motion. You expose an optional port by selecting the sensing check box corresponding to that port.

Frame Ports

- B — Base frame
- F — Follower frame

Actuation Ports

The revolute joint primitive provides the following actuation ports:

- tz — Actuation torque acting on the Z revolute joint primitive
- qz — Desired rotation of the Z revolute joint primitive

Sensing Ports

The revolute joint primitive provides the following sensing ports:

- qz — Angular position of the Z revolute joint primitive
- wz — Angular velocity of the Z revolute joint primitive
- bz — Angular acceleration of the Z revolute joint primitive
- tz — Actuation torque acting on the Z revolute joint primitive

The following sensing ports provide the composite forces and torques acting on the joint:

- fc — Constraint force
- tc — Constraint torque

- ft — Total force
- tt — Total torque

See Also

`Prismatic Joint` | `Spherical Joint`

More About

- "Actuating and Sensing with Physical Signals"
- "Motion Sensing"
- "Rotational Measurements"

Rigid Transform

Fixed spatial relationship between frames

Library

Frames and Transforms

Description

This block applies a time-invariant transformation between two frames. The transformation rotates and translates the follower port frame (F) with respect to the base port frame (B). Connecting the frame ports in reverse causes the transformation itself to reverse. The frames remain fixed with respect to each other during simulation, moving only as a single unit. Combine Rigid Transform and Solid blocks to model compound rigid bodies.

Dialog Box and Parameters
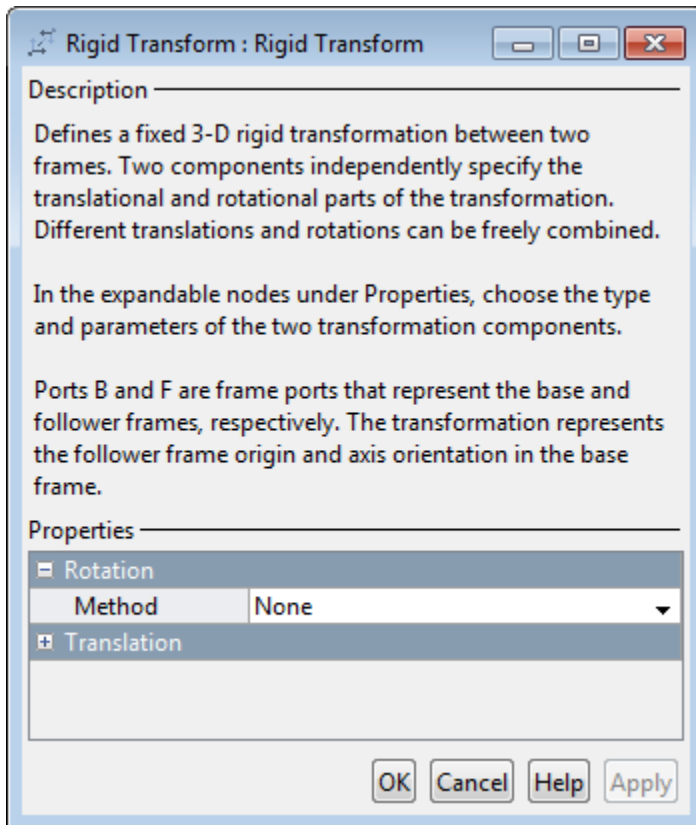
Rotation: Method

Select the method to use to specify rotation. The default is None.

Method	Description
None	Constrain the base and follower frames to share the same orientation.
Aligned Axes	Set frame rotation by aligning two follower frame axes with two base frame axes.

Method	Description
Standard Axis	Specify frame rotation as an angle about a standard axis (*x*, *y*, or *z*).
Arbitrary Axis	Specify frame rotation as an angle about a general [*x*, *y*, *z*] axis.
Rotation Sequence	Specify frame rotation as a sequence of three elementary rotations.
Rotation Matrix	Specify frame rotation as a right-handed orthogonal rotation matrix.

Aligned Axes

Select two pairs of base-follower frame axes.

Parameter	Description
Pair 1	First pair of base-follower frame axes to align.
Pair 2	Second pair of base-follower frame axes to align. Axis choices depend on **Pair 1** axis selections.

Standard Axis

Select a standard rotation axis, resolved in the base frame, and specify the follower frame rotation angle.

Parameter	Description
Axis	Standard rotation axis (X, Y, or Z) resolved in the base frame.
Angle	Follower frame rotation angle about the rotation axis with respect to the base frame.

Arbitrary Axis

Select a general 3-D rotation axis, resolved in the base frame, and specify the follower frame rotation angle.

Parameter	Description
Axis	General rotation axis [X Y Z] resolved in the base frame.
Angle	Follower frame rotation angle about the rotation axis with respect to the base frame.

Rotation Sequence

Specify a sequence of three elementary rotations about the selected permutation of x, y, and z axes. These rotation sequences are also known as Euler and Tait-Bryan sequences. The rotations are those of the follower frame relative to the frame selected in the **Rotate About** parameter.

If you set the **Rotate About** parameter to Follower Frame, the follower frame rotates about its own axes. These axes change orientation with each successive rotation. If you set the **Rotate About** parameter to Base Frame, the follower frame rotates about the fixed base frame axes.

Parameter	Description
Rotation About	Frame whose axes to rotate the follower frame about.
Sequence	Sequence of axes about which to apply the elementary rotations.
Angles	Three-element vector with elementary rotation angles about the axes specified in the **Sequence** parameter.

Rotation Matrix

Specify the 3×3 transformation matrix of a proper rotation between the base and follower frames. The matrix must be orthogonal and have determinant +1. The default matrix is [1 0 0; 0 1 0; 0 0 1].

Translation: Method

Select the method to use to specify translation. The default is None.

Method	Description
None	Make base and follower frames coincident. This method requires no parameters.
Cartesian	Specify a 3-D translation in terms of Cartesian coordinates
Standard Axis	Specify a 1-D translation along the X, Y, or Z axis
Cylindrical	Specify a 3-D translation in terms of cylindrical coordinates

Cartesian Axis

Specify the **Offset** of the follower frame with respect to the base frame. This is the 3-D translation vector that brings the base frame into coincidence with the follower frame. Select or enter a physical unit.

Standard Axis

Specify the offset of the follower frame with respect to the base frame along the base frame X, Y, or Z axis. Select or enter a physical unit.

Parameter	Description
Axis	Axis the follower frame translates along
Offset	Translation of the follower frame with respect to the base frame along the specified axis

Cylindrical

Specify in cylindrical coordinates the translation that brings the base frame into coincidence with the follower frame. Select or enter a physical unit.

Parameter	Description
Radius	Distance between the origin of the follower frame and the Z axis of the base frame. This is the cylindrical radius coordinate.

Parameter	Description
Theta	Rotation angle of the line connecting base and follower frame origins with respect to the base frame X axis. This is the cylindrical azimuth coordinate.
Z Offset	Distance between base and follower frame origins along the base frame Z axis. This is the cylindrical length coordinate.

Ports

Frame ports B and F represent the base and follower frames.

See Also
Solid

Solid

Solid element with geometry, inertia, and color
Library: Body Elements

Description

The Solid block adds a solid element with geometry, inertia, and color to the attached frame. The solid element can be a simple rigid body or part of a compound rigid body—a group of rigidly connected solids, often separated in space through rigid transformations. Combine `Solid` and `Rigid Transform` blocks to model a compound rigid body.

Geometry parameters include shape and size. You can choose from a list of preset shapes or import a custom shape from an external file in STL or STEP format. By default, for all but STL-derived shapes, the block automatically computes the solid inertia from the specified geometry and mass or mass density. You can change this setting in the **Inertia** > **Type** block parameter.

A reference frame encodes the position and orientation of the solid. In the default configuration, the block provides only the reference frame. A frame-creation interface provides the means to define additional frames based on solid geometry features. You access this interface by selecting the Create button in the **Frames** expandable area.

The block dialog box contains a collapsible visualization pane. This pane provides instant visual feedback on the solid you are modeling. Use it to find and fix any issues with the shape and color of the solid. You can examine the solid from different perspectives by selecting a standard view or by rotating, panning, and zooming the solid.

Visualization Pane

Select the Update Visualization button to view the latest changes to the solid geometry in the visualization pane. Select **Apply** or **OK** to commit your changes to the

solid. Closing the block dialog box without first selecting **Apply** or **OK** causes the block to discard those changes.

A — Show/Hide Visualization Pane
B — Update Visualization
C — Select | Rotate | Pan | Zoom | Zoom to Region | Fit to View
D — Front | Back | Top | Bottom | Left | Right | Isometric Views
E — Show/Hide Frame
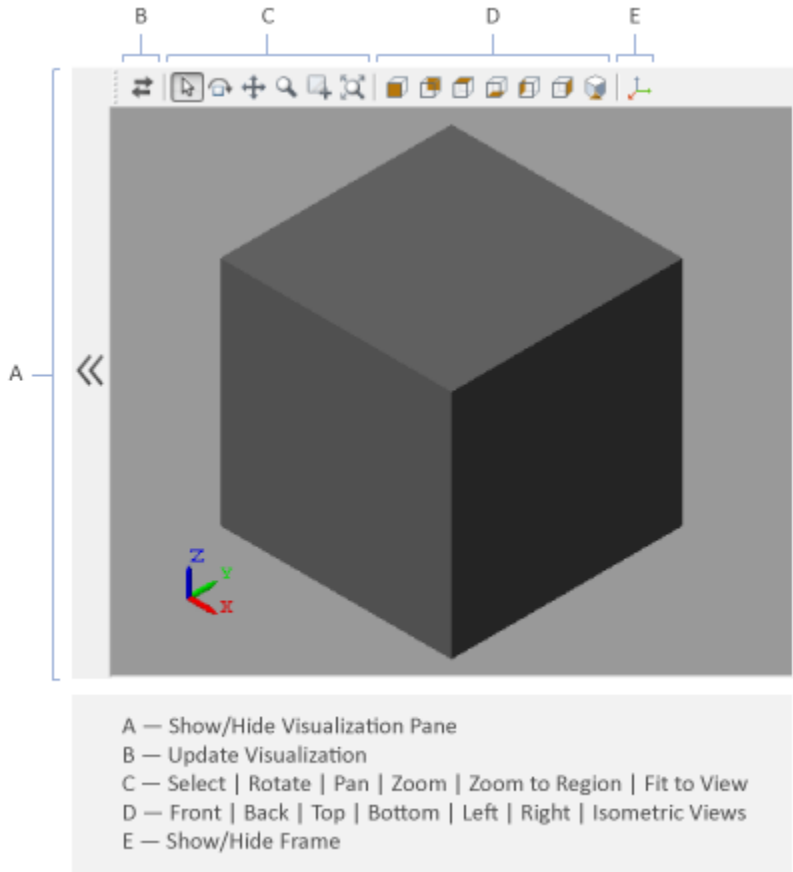
Solid Visualization Pane

Right-click the visualization pane to access the visualization context-sensitive menu. This menu provides additional options so that you can change the background color, split the visualization pane into multiple tiles, and modify the view convention from the default **+Z up (XY Top)** setting.

Ports

Frame

R — Reference frame
frame

Local reference frame of the solid element. Connect to a frame line or frame port to define the relative position and orientation of the solid.

Parameters

Geometry

Shape — Geometrical shape of the solid element
Brick (default) | Cylinder | Sphere | Ellipsoid | Regular Extrusion | General Extrusion | Revolution | From File

Geometrical shape of the solid element:

- Cylinder — Cylindrical shape with geometry center coincident with the reference frame origin and symmetry axis coincident with the reference frame z axis.
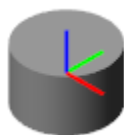
- Sphere — Spherical shape with geometry center coincident with the reference frame origin.
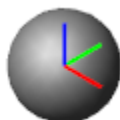
- `Brick` — Prismatic shape with geometry center coincident with the reference frame origin and prismatic surfaces normal to the reference frame x, y, and z axes.

- `Ellipsoid` — Three-dimensional extension of the ellipse with geometry center coincident with the reference frame origin and semi-principal axes coincident with the reference frame x, y, and z axes.
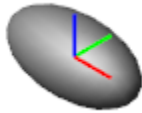
- `Regular Extrusion` — Translational sweep of a regular polygon cross section with geometry center coincident with the reference frame origin and extrusion axis coincident with the reference frame z axis.
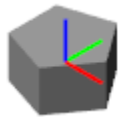
- `General Extrusion` — Translational sweep of a general cross section with geometry center coincident with the [0 0] coordinate on the cross-sectional XY plane and extrusion axis coincident with the reference frame z axis.

- `Revolution` — Rotational sweep of a general cross section with geometry center coincident with the [0 0] coordinate on the cross-sectional XZ plane and revolution axis coincident with the reference frame z axis.
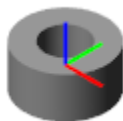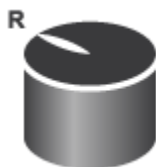
- `From File` — Imported custom shape with geometry center and orientation as defined in STL or STEP geometry file.
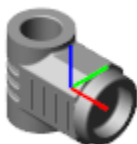
`Cylinder: Radius` — Radial distance from the longitudinal axis to the curved surface
1 m (default)

Distance R in the figure, specified as a scalar in terms of the selected physical units.

`Cylinder: Length` — Longitudinal distance between the cylinder flat ends
1 m (default)

Distance L in the figure, specified as a scalar in terms of the selected physical units.

**Sphere: Radius — Distance from the origin of the sphere to its surface**
1 m (default)

Distance R in the figure, specified as a scalar in terms of the selected physical units.

Brick: Dimensions — Brick dimensions along the reference frame x, y, and z axes
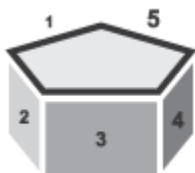[1 1 1] m (default)

Dimensions x, y, and z in the figure, specified in this order as a three-element vector in terms of the selected physical units.
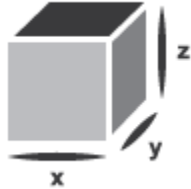
Ellipsoid: Radii — Ellipsoid dimensions along the x, y, and z semi-principal axes
[1,1,1] m (default)

Dimensions x, y, and z in the figure, specified in this order as a three-element vector in terms of the selected physical units. The ellipsoid reduces to a sphere when all three radii have the same have.

Regular Extrusion: `Number of Sides` — Number of edges in the regular polygon cross section

3 (default)

Edge count of the polygon cross section, specified as a scalar number greater than 2. The default value of 3 corresponds to a triangle, the polygon with the lowest possible number of sides. The figure shows a regular extrusion with a pentagon for cross section.

Regular Extrusion: `Outer Radius` — Radial distance from the polygon center to a polygon vertex

1 m (default)

Distance R in the figure, specified as a scalar in terms of the selected physical units. The enveloping circle highlights the relationship between the outer circle radius and the polygon center-to-vertex distance.

Regular Extrusion: `Length` — Longitudinal distance between the extrusion terminal ends

1 m (default)

Distance L in the figure, specified as a scalar in terms of the selected physical units.

General Extrusion: `Cross-section` — Cross-section coordinates specified on the XY plane
[1 1; -1 1; -1 -1; 1 -1] (default)

Cross-sectional shape specified as an [x,y] coordinate matrix, with each row corresponding to a point on the cross-sectional profile. The coordinates specified must define a closed loop with no self-intersecting segments.

The coordinates must be arranged such that from one point to the next the solid region always lies to the left. The block extrudes the cross-sectional shape specified along the z axis to obtain the extruded solid.
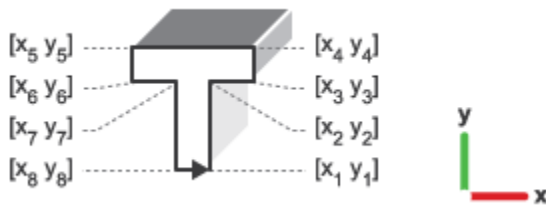
General Extrusion: `Length` — Sweep angle of the general extrusion
1 m (default)

Distance to sweep the extrusion cross section by. The block extrudes the cross section by half the extrusion length along the +z axis and by half along the -z axis.
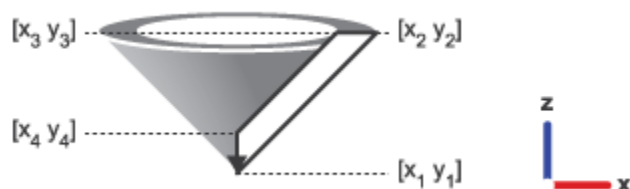
Revolution: `Cross-section` — Cross-section coordinates specified on the XZ plane

[1 1; 1 -1; 2 -1; 2 1] m (default)

Cross-sectional shape specified as an [x,z] coordinate matrix, with each row corresponding to a point on the cross-sectional profile. The coordinates specified must define a closed loop with no self-intersecting segments.

The coordinates must be arranged such that from one point to the next the solid region always lies to the left. The block revolves the cross-sectional shape specified about the reference frame z axis to obtain the revolved solid.

Revolution: `Extent of Revolution` — Choice of full or partial revolution sweeps

Full (default) | Custom

Type of revolution sweep to use. Use the default setting of `Full` to revolve the cross-sectional shape by the maximum 360 degrees. Select `Custom` to revolve the cross-sectional shape by a lesser angle.
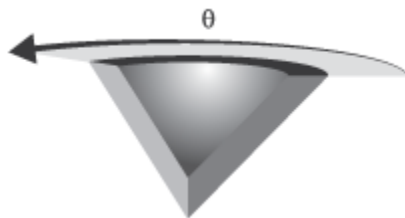
Revolution: `Revolution Angle` — Sweep angle of a partial revolution

180 (default) | Scalar number in the specified units

Angle to sweep a partial revolution cross section by. The block revolves the specified cross section by half the revolution angle in the clockwise direction and by half in the counterclockwise direction.

`From File: File Type` — Geometry file type to import
STEP (default) | STL

Geometry file type to import. The block provides automatic inertia calculation from geometry for STEP files only. For STL geometry files, you must manually enter the solid inertia using the `Custom` or `Point Mass` parameterization.

`From File: File Name` — Geometry file name
Character vector with the geometry file name

Geometry file name, complete with path and extension—e.g., 'C:/Users/Jdoe/Documents/myShape.STEP'

`From File: Units` — STL file unit of length
m (default) | cm | mm | km | in | ft | yd | mi

Unit of length for STL file coordinates.

Inertia

`Type` — Inertia parameterization to use
Calculate from Geometry (default) | Point Mass | Custom

Inertia parameterization to use. Select `Point Mass` to model a concentrated mass with negligible rotational inertia. Select `Custom` to model a distributed mass with the specified moments and products of inertia. The default setting, `Calculate from Geometry`, enables the block to automatically calculate the rotational inertia properties from the solid geometry and specified mass or mass density.

`Based on` — Parameter to base inertia calculation on
Density (default) | Mass

Parameter to use in inertia calculation. The block obtains the inertia tensor from the solid geometry and the parameter selected. Use `Density` if the material properties are known. Use `Mass` if the total solid mass if known.

`Density` — Mass per unit volume of material
1000 kg/m^3 (default)

Mass per unit volume of material. The mass density can take on a positive or negative value. Specify a negative mass density to model the effects of a void or cavity in a solid body.

`Mass` — Aggregate mass of the solid
1 kg (default)

Aggregate mass of the solid. The mass can be a positive or negative value. Specify a negative mass to model the aggregate effect of voids and cavities in a compound body.

`Custom: Center of Mass` — Center-of-mass coordinates
[0 0 0] m (default)

[x y z] coordinates of the center of mass relative to the block reference frame. The center of mass coincides with the center of gravity in uniform gravitational fields only.

`Custom: Moments of Inertia` — Diagonal elements of inertia tensor
[1 1 1] kg*m^2 (default)

Three-element vector with the $[I_{xx}\ I_{yy}\ I_{zz}]$ moments of inertia specified relative to a frame with origin at the center of mass and axes parallel to the block reference frame. The moments of inertia are the diagonal elements of the inertia tensor

$$\begin{pmatrix} I_{xx} & & \\ & I_{yy} & \\ & & I_{zz} \end{pmatrix},$$

where:

- $I_{xx} = \int\limits_V \left(y^2 + z^2 \right) dm$

- $I_{yy} = \int\limits_V \left(x^2 + z^2 \right) dm$

- $I_{zz} = \int\limits_V \left(x^2 + y^2 \right) dm$

`Custom: Products of Inertia` — Off-diagonal elements of inertia tensor
[0 0 0] kg*m^2 (default)

Three-element vector with the $[I_{yz}\ I_{zx}\ I_{xy}]$ products of inertia specified relative to a frame with origin at the center of mass and axes parallel to the block reference frame. The products of inertia are the off-diagonal elements of the inertia tensor

$$\begin{pmatrix} & I_{xy} & I_{zx} \\ I_{xy} & & I_{yz} \\ I_{zx} & I_{yz} & \end{pmatrix},$$

where:

- $I_{yz} = -\int_V yz\, dm$

- $I_{zx} = -\int_V zx\, dm$

- $I_{xy} = -\int_V xy\, dm$

Graphic

Type — Solid visualization setting
From Geometry (default) | Marker | None

Visualization setting for this solid. Use the default setting, From Geometry, to show the solid geometry. Select Marker to show a graphic marker such as a sphere or frame. Select None to disable visualization for this solid.

Marker: Shape — Shape of the graphic marker.
Sphere (default) | Cube | Frame

Geometrical shape of the graphic marker. Mechanics Explorer shows the marker using the selected shape.

Marker: Size — Pixel size of the graphic marker
10 (default)

Absolute size of the graphic marker in screen pixels. The marker size is invariant with zoom level.

Visual Properties — Parameterizations for color and opacity
Simple (default) | Advanced

Parameterization for specifying visual properties. Select `Simple` to specify color and opacity. Select `Advanced` to add specular highlights, ambient shadows, and self-illumination effects.

Simple: Color — True color as [R,G,B] vector on 0–1 scale

[0.5 0.5 0.5] (default)

RGB color vector with red (R), green (G), and blue (B) color amounts specified on a 0–1 scale. A color picker provides an alternative interactive means of specifying a color. If you change the **Visual Properties** setting to `Advanced`, the color specified in this parameter becomes the **Diffuse Color** vector.

Simple: Opacity — Surface opacity as scalar number on 0–1 scale

1.0 (default)

Graphic opacity specified on a scale of 0–1. An opacity of 0 corresponds to a completely transparent graphic and an opacity of 1 to a completely opaque graphic.

Advanced: Diffuse Color — True color as [R,G,B,A] vector on 0–1 scale

[0.5 0.5 0.5] (default)

True color under direct white light specified as an [R,G,B] or [R,G,B,A] vector on a 0–1 scale. An optional fourth element specifies the color opacity also on a scale of 0–1. Omitting the opacity element is equivalent to specifying a value of 1.

Advanced: Specular Color — Highlight color as [R,G,B,A] vector on 0–1 scale

[0.5 0.5 0.5 1.0] (default)

Color of specular highlights specified as an [R,G,B] or [R,G,B,A] vector on a 0–1 scale. The optional fourth element specifies the color opacity. Omitting the opacity element is equivalent to specifying a value of 1.

Advanced: Ambient Color — Shadow color as [R,G,B,A] vector on 0–1 scale

[0.5 0.5 0.5 1.0] (default)

Color of shadow areas in diffuse ambient light, specified as an [R,G,B] or [R,G,B,A] vector on a 0–1 scale. The optional fourth element specifies the color opacity. Omitting the opacity element is equivalent to specifying a value of 1.

Advanced: Emissive Color — Self-illumination color as [R,G,B] vector on 0–1 scale

[0.5 0.5 0.5 1.0] (default)

Surface color due to self illumination, specified as an [R,G,B] or [R,G,B,A] vector on a 0–1 scale. The optional fourth element specifies the color opacity. Omitting the opacity element is equivalent to specifying a value of 1.

Advanced: Shininess — Highlight sharpness as scalar number on 0–128 scale
75 (default)

Sharpness of specular light reflections, specified as a scalar number on a 0–128 scale. Increase the shininess value for smaller but sharper highlights. Decrease the value for larger but smoother highlights.

Frames

Show Port R — Show the reference frame port for connection to other blocks
Checked (default) | Cleared

Clear the check box to hide the reference frame port in the Solid block. Hiding the reference frame port suppresses the frame visualization in Mechanics Explorer. You must expose the reference frame port if the block has no custom frames.

New Frame — Create a custom frame for connection to other blocks
Empty (default)

Select the Create button 🟨 to define a new frame using the frame-creation interface. Each new frame appears on a row above the **New Frame** parameter. To edit an existing frame, select the Edit button 🖊. To delete an existing frame, select the Delete button ✖.

Frame Creation Interface

Frame Name — MATLAB® string used to identify the custom frame
Custom name

Frame identifier specified as a MATLAB string. This string identifies the frame port in the block diagram and in the tree view pane of Mechanics Explorer. Keep the frame name short to ensure it fits in the block icon width.

Frame Origin — Position of the custom frame origin
At Reference Frame Origin (default) | At Center of Mass | Based on Geometric Feature

Select the location of the frame origin. Options include:

- **At Reference Frame Origin** — Make the new frame origin coincident with the reference frame origin. This is the default option.

- **At Center of Mass** — Make the new frame origin coincident with the solid center of mass. The reference frame origin is located at the center of mass in symmetrical shapes such as spheres and bricks but not in certain extrusions or revolutions.

- **Based on Geometric Feature** — Place the new frame origin at the center of the selected geometry feature. Valid geometry features include surfaces, lines, and points. You must select a geometry feature from the visualization pane and then select the **Use Selected Feature** button. The name of the selected geometry feature appears in the field below this option.

Frame Axes: Primary Axis — Axis used to constrain the possible directions of the remaining frame axes

Along Reference Frame Axis (default) | Along Principal Inertia Axis | Based on Geometric Feature

Select the axis of the new frame that you want to set as the primary axis. The primary axis constrains the possible orientations of the remaining two axes. Specify the orientation of the primary axis by selecting from the following options:

- **Along Reference Frame Axis** — Align the primary axis with the selected axis of the reference frame.

- **Along Principal Inertia Axis** — Align the primary axis with the selected principal inertia axis. The principal inertia axes are those about which the products of inertia are zero.

- **Based on Geometric Feature** — Align the primary axis with the vector associated with the selected geometric feature. Valid geometric features include surfaces and lines.

Frame Axes: Secondary Axis — Axis used to constrain the possible directions of the remaining frame axis

Along Reference Frame Axis (default) | Along Principal Inertia Axis | Based on Geometric Feature

Select the axis of the new frame that you want to set as the secondary axis. The secondary axis is the projection of the selected direction onto the normal plane of the primary axis. Select the direction to project from the following options:

- **Along Reference Frame Axis** — Project the selected reference frame axis onto the normal plane of the primary axis. Align the secondary axis with the projection.

- **Along Principal Inertia Axis** — Project the selected principal inertia axis onto the normal plane of the primary axis. Align the secondary axis with the projection. The principal inertia axes are those about which the products of inertia are zero.

- **Based on Geometric Feature** — Project the vector associated with the selected geometry feature onto the normal plane of the primary axis. Align the secondary axis with the projection. Valid geometry features include surfaces and lines. You must select a geometry feature from the visualization pane and then select the **Use Selected Feature** button.

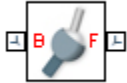## More About

- "Solid Inertia"

See Also

Graphic | Solid | Spline

Introduced in R2012a

Spherical Joint

Joint with one spherical primitive

Library

Joints

Description

This block represents a joint with three rotational degrees of freedom. One spherical primitive provides the three rotational degrees of freedom. The base and follower frame origins remain coincident during simulation.

	Translational Degree of Freedom
	Rotational Degree of Freedom
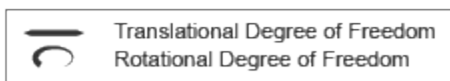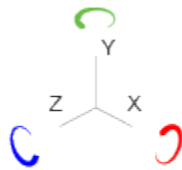
Joint Degrees of Freedom

The joint block represents motion between the base and follower frames as a single time-varying transformation. The spherical primitive (S) applies this transformation, which causes the follower frame to rotate with respect to the base frame about an arbitrary 3-D axis. This joint primitive is not susceptible to gimbal lock.

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Joint Transformation

A set of optional state targets guide assembly for each joint primitive. Targets include position and velocity. A priority level sets the relative importance of the state targets. If two targets are incompatible, the priority level determines which of the targets to satisfy.

Internal mechanics parameters account for energy storage and dissipation at each joint primitive. Springs act as energy storage elements, resisting any attempt to displace the joint primitive from its equilibrium position. Joint dampers act as energy dissipation elements. Springs and dampers are strictly linear.

Each joint primitive has a set of optional actuation and sensing ports. Actuation ports accept physical signal inputs that drive the joint primitives. These inputs can be forces and torques or a desired joint trajectory. Sensing ports provide physical signal outputs that measure joint primitive motion as well as actuation forces and torques. Actuation modes and sensing types vary with joint primitive.

Dialog Box and Parameters

Spherical Primitive: State Targets

Specify the spherical primitive state targets and their priority levels. A state target is the desired value for one of the joint state parameters—position and velocity. The priority level is the relative importance of a state target. It determines how precisely the target must be met. Use the Model Report tool in Mechanics Explorer to check the assembly status for each joint state target.

Specify Position Target

Select this option to specify the desired joint primitive position at time zero. This is the relative rotation of the follower frame with respect to the base frame. It is resolved in the base frame. Selecting this option exposes priority and value fields.

Priority

Select state target priority. This is the importance level assigned to the state target. If all state targets cannot be simultaneously satisfied, the priority level determines which targets to satisfy first and how closely to satisfy them. This option applies to both position and velocity state targets.

Priority Level	Description
High (desired)	Satisfy state target precisely
Low (approximate)	Satisfy state target approximately

Note: During assembly, high-priority targets behave as exact guides. Low-priority targets behave as rough guides.

Value

Select a method to specify the joint primitive state target.

Method	Description
None	Constrain the base and follower frames to share the same orientation.
Aligned Axes	Set frame rotation by aligning two follower frame axes with two base frame axes.

Method	Description
Standard Axis	Specify frame rotation as an angle about a standard axis (*x*, *y*, or *z*).
Arbitrary Axis	Specify frame rotation as an angle about a general [*x*, *y*, *z*] axis.
Rotation Sequence	Specify frame rotation as a sequence of three elementary rotations.
Rotation Matrix	Specify frame rotation as a right-handed orthogonal rotation matrix.

Aligned Axes

Select two pairs of base-follower frame axes.

Parameter	Description
Pair 1	First pair of base-follower frame axes to align.
Pair 2	Second pair of base-follower frame axes to align. Axis choices depend on **Pair 1** axis selections.

Standard Axis

Select a standard rotation axis, resolved in the base frame, and specify the follower frame rotation angle.

Parameter	Description
Axis	Standard rotation axis (X, Y, or Z) resolved in the base frame.
Angle	Follower frame rotation angle about the rotation axis with respect to the base frame.

Arbitrary Axis

Select a general 3-D rotation axis, resolved in the base frame, and specify the follower frame rotation angle.

Parameter	Description
Axis	General rotation axis [X Y Z] resolved in the base frame.
Angle	Follower frame rotation angle about the rotation axis with respect to the base frame.

Rotation Sequence

Specify a sequence of three elementary rotations about the selected permutation of x, y, and z axes. These rotation sequences are also known as Euler and Tait-Bryan sequences. The rotations are those of the follower frame relative to the frame selected in the **Rotate About** parameter.

If you set the **Rotate About** parameter to Follower Frame, the follower frame rotates about its own axes. These axes change orientation with each successive rotation. If you set the **Rotate About** parameter to Base Frame, the follower frame rotates about the fixed base frame axes.

Parameter	Description
Rotation About	Frame whose axes to rotate the follower frame about.
Sequence	Sequence of axes about which to apply the elementary rotations.
Angles	Three-element vector with elementary rotation angles about the axes specified in the **Sequence** parameter.

Rotation Matrix

Specify the 3×3 transformation matrix of a proper rotation between the base and follower frames. The matrix must be orthogonal and have determinant +1. The default matrix is [1 0 0; 0 1 0; 0 0 1].

Specify Velocity Target

Select this option to specify the desired joint primitive velocity at time zero. This is the relative angular velocity of the follower frame with respect to the base frame. It is resolved in the base frame. Selecting this option exposes priority and value fields. The priority field is identical to that used for the position state target.

Value

Enter a three element vector with the angular velocity components of the follower frame with respect to the base frame. Select a physical unit. The default is `deg/s` (degree/second).

Resolution Frame

From the drop-down list, select a resolution frame. This is the frame in which the state target is resolved. It identifies the axes the velocity vector components apply to. The default is `Follower`.

Spherical Primitive: Internal Mechanics

Specify the spherical primitive internal mechanics. This includes linear spring and damping forces, accounting for energy storage and dissipation, respectively. To ignore internal mechanics, keep spring stiffness and damping coefficient values at the default value of `0`.

Equilibrium Position

Select a method to specify the spring equilibrium position. The equilibrium position is the rotation angle between base and follower port frames at which the spring torque is zero.

Method	Description
None	Constrain the base and follower frames to share the same orientation.
Aligned Axes	Set frame rotation by aligning two follower frame axes with two base frame axes.
Standard Axis	Specify frame rotation as an angle about a standard axis (*x*, *y*, or *z*).
Arbitrary Axis	Specify frame rotation as an angle about a general [*x*, *y*, *z*] axis.
Rotation Sequence	Specify frame rotation as a sequence of three elementary rotations.
Rotation Matrix	Specify frame rotation as a right-handed orthogonal rotation matrix.

Aligned Axes

Select two pairs of base-follower frame axes.

Parameter	Description
Pair 1	First pair of base-follower frame axes to align.
Pair 2	Second pair of base-follower frame axes to align. Axis choices depend on **Pair 1** axis selections.

Standard Axis

Select a standard rotation axis, resolved in the base frame, and specify the follower frame rotation angle.

Parameter	Description
Axis	Standard rotation axis (X, Y, or Z) resolved in the base frame.
Angle	Follower frame rotation angle about the rotation axis with respect to the base frame.

Arbitrary Axis

Select a general 3-D rotation axis, resolved in the base frame, and specify the follower frame rotation angle.

Parameter	Description
Axis	General rotation axis [X Y Z] resolved in the base frame.
Angle	Follower frame rotation angle about the rotation axis with respect to the base frame.

Rotation Sequence

Specify a sequence of three elementary rotations about the selected permutation of x, y, and z axes. These rotation sequences are also known as Euler and Tait-Bryan

sequences. The rotations are those of the follower frame relative to the frame selected in the **Rotate About** parameter.

If you set the **Rotate About** parameter to `Follower Frame`, the follower frame rotates about its own axes. These axes change orientation with each successive rotation. If you set the **Rotate About** parameter to `Base Frame`, the follower frame rotates about the fixed base frame axes.

Parameter	Description
Rotation About	Frame whose axes to rotate the follower frame about.
Sequence	Sequence of axes about which to apply the elementary rotations.
Angles	Three-element vector with elementary rotation angles about the axes specified in the **Sequence** parameter.

Rotation Matrix

Specify the 3×3 transformation matrix of a proper rotation between the base and follower frames. The matrix must be orthogonal and have determinant +1. The default matrix is [1 0 0; 0 1 0; 0 0 1].

Spring Stiffness

Enter the linear spring constant. This is the torque required to displace the joint primitive by a unit angle. The term linear refers to the mathematical form of the spring equation. The default is 0. Select a physical unit. The default is `N*m/deg`.

Damping Coefficient

Enter the linear damping coefficient. This is the torque required to maintain a constant joint primitive angular velocity between base and follower frames. The default is 0. Select a physical unit. The default is `N*m/(deg/s)`.

Spherical Primitive: Actuation

Specify actuation options for the spherical joint primitive. Actuation modes include **Torque** only. Selecting a torque input adds the corresponding physical signal port to the block. Use this port to specify the actuation torque signal.

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Torque

Select a source for the actuation torque. The default setting is `None`.

Actuation Torque Setting	Description
None	Apply no actuation torque.
Provided by Input	Apply an actuation torque based on a physical signal. The signal specifies the torque acting on the follower frame with respect to the base frame. An equal and opposite torque acts on the base frame. Selecting this option exposes additional parameters.

Torque (X), Torque (Y), Torque (Z)

Select in order to actuate the spherical joint primitive about each standard Cartesian axis (X, Y, Z) separately. The block exposes the corresponding physical signal ports. Use these ports to specify the actuation torque signals. The signals must be scalar values.

Torque (XYZ)

Select in order to actuate the spherical joint primitive about an arbitrary axis [X Y Z]. The block exposes the corresponding physical signal port. Use this port to specify the actuation torque signal. The signal must be a 3-D vector.

Frame

Select the frame to resolve the actuation torque signal in. The axes of this frame establish the directions of the X, Y, and Z torque components. The default setting is `Base`.

Spherical Primitive: Sensing

Select the motion variables to sense in the spherical joint primitive. The block adds the corresponding physical signal ports. Use these ports to output the numerical values of the motion variables.

The block measures each motion variable for the follower frame with respect to the base frame. It resolves that variable in the resolution frame that you select from the **Frame** drop-down list.

Motion Variables	Description
Position	Quaternion describing follower frame rotation with respect to base frame. The quaternion coefficients are $$\left[\cos\left(\frac{\theta}{2}\right), n_x \sin\left(\frac{\theta}{2}\right), n_y \sin\left(\frac{\theta}{2}\right), n_z \sin\left(\frac{\theta}{2}\right)\right].$$ The measurement is the same in all measurement frames.
Velocity (X), **Velocity (Y)**, **Velocity (Z)**	Angular velocity components about X, Y, and Z axes.
Velocity	3–D angular velocity vector with components about X, Y, and Z axes.
Acceleration (X), **Acceleration (Y)**, **Acceleration (Z)**	Angular acceleration components about X, Y, and Z axes.
Acceleration	3–D angular acceleration vector with components about X, Y, and Z axes.

Frame

Select the frame to resolve the measurement in. The axes of this frame establish the directions of X, Y, and Z vector components. The default setting is Base.

Composite Force/Torque Sensing

Select the composite, or joint-wide, forces and torques to sense. These are forces and torques that act not at individual joint primitives but at the whole joint. Options include constraint and total forces and torques.

During simulation, the block computes the selected composite forces and torques acting between the base and follower port frames. It outputs these variables using physical signal output ports. Check the port labels to identify the output variables at different ports.

Direction

Forces and torques acting at joints do so in pairs. Newton's third law of motion requires that every action be accompanied by an equal and opposite reaction. If the base frame of a joint exerts a force or torque on the follower frame, then the follower frame must exert an equal and opposite force or torque on the base frame.

Select whether to sense the composite forces and torques exerted by the base frame on the follower frame or vice versa. The force and torque vector components are positive if they point along the positive X, Y, and Z axes of the selected resolution frame.

Resolution Frame

You can resolve a vector quantity into Cartesian components in different frames. If the resolution frames have different orientations, then the measured components are themselves different—even though the vector quantity remains the same.

Select the frame in which to resolve the sensed force and torque variables. Possible resolution frames include `Base` and `Follower`. The block outputs the Cartesian components of the sensed force and torque vectors as observed in this frame.

Constraint Force

Joint blocks with fewer than three translational degrees of freedom forbid motion along one or more axes. For example, the Gimbal Joint block forbids translation along all axes. To prevent translation along an axis, a joint block applies a constraint force between its base and follower port frames. Constraint forces are orthogonal to joint translation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint force vector [fc_x, fc_y, fc_z] acting at the joint. Only constraint force components that are orthogonal to the joint translational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port fc.

Constraint Torque

Joint blocks with fewer than three rotational degrees of freedom forbid motion about one or more axes. For example, the Cartesian Joint block forbids rotation about all axes. To prevent rotation about an axis, a joint block applies a constraint torque between its base and follower port frames. Constraint torques are orthogonal to joint rotation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint torque vector [tc_x, tc_y, tc_z] acting at the joint. Only constraint torque components that are orthogonal to the joint rotational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port tc.

Total Force

A joint block generally applies various forces between its port frames:

- Actuation forces that drive prismatic joint primitives.

- Internal spring and damper forces that resist motion at prismatic joint primitives.
- Constraint forces that forbid motion in directions orthogonal to prismatic joint primitives.

The net sum of the different force components equals the total force acting between the joint port frames. Select the check box to compute and output the 3-D total force vector [ft_x, ft_y, ft_z]. Selecting this option causes the block to expose physical signal port ft.

Total Torque

A joint block generally applies various torques between its port frames:

- Actuation torques that drive revolute or spherical joint primitives.
- Internal spring and damper torques that resist motion at revolute or spherical joint primitives.
- Constraint torques that forbid motion in directions orthogonal to the revolute or spherical joint primitive axes.

The net sum of the different torque components equals the total torque acting at a joint. Select the check box to compute and output the 3-D total torque vector [tt_x, tt_y, tt_z]. Selecting this option causes the block to expose physical signal port tt.

Ports

This block has two frame ports. It also has optional physical signal ports for specifying actuation inputs and sensing dynamical variables such as forces, torques, and motion. You expose an optional port by selecting the sensing check box corresponding to that port.

Frame Ports

- B — Base frame
- F — Follower frame

Actuation Ports

The spherical joint primitive provides the following actuation ports:

- t — Actuation torque vector [*tx*, *ty*, *tz*] acting on the spherical joint primitive
- tx, ty, tz — X, Y, and Z components of the actuation torque acting on the spherical joint primitive

Sensing Ports

The spherical primitive provides the following sensing ports:

- Q — Orientation of the spherical joint primitive in quaternion form
- wx, wy, wz — X, Y, and Z angular velocity components of the spherical joint primitive
- w — Angular velocity [*wx*, *wy*, *wz*] of the spherical joint primitive
- bx, by, bz — X, Y, and Z angular acceleration components of the spherical joint primitive
- b — Angular acceleration [*bx*, *by*, *bz*] of the spherical joint primitive

The following sensing ports provide the composite forces and torques acting on the joint:

- fc — Constraint force
- tc — Constraint torque
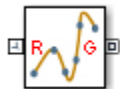- ft — Total force
- tt — Total torque

See Also
`6-DOF Joint` | `Bushing Joint` | `Gimbal Joint` | `Revolute joint`

More About
- "Motion Sensing"
- "Measurement Frames"
- "Actuating and Sensing with Physical Signals"

Spline

Cubic interpolating plane or space curve
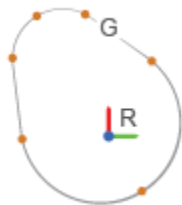

Library

Curves and Surfaces

Description

This block represents a continuous spline curve based on cubic interpolation between the points specified. The curve can be two-dimensional, such as a planar cam profile, or three-dimensional, such as a roller coaster track. Depending on the end conditions selected, the curve can be either open or closed.

Cam profile — An Example of a 2-D Spline Curve

Whether a spline curve is two- or three-dimensional depends solely on the coordinate matrix dimensions. A two-column matrix specifies a two-dimensional curve in the xy plane. Each row in this matrix provides the [x, y] coordinates of a point. A three-column matrix specifies a three-dimensional curve. Each row in this matrix provides the [x, y, z] coordinates of a point. All coordinates are resolved in the local reference frame of the block.

The spline curve is a piecewise function of third-order polynomial segments connected end-to-end. The curve is built such that adjacent polynomial segments have the same first and second derivatives at the shared end point. If the curve is periodic, an additional curve segment connects the last point specified to the first point. The first and second derivatives of this segment matches those of the adjacent segments at the shared end point.

Dialog Box and Parameters
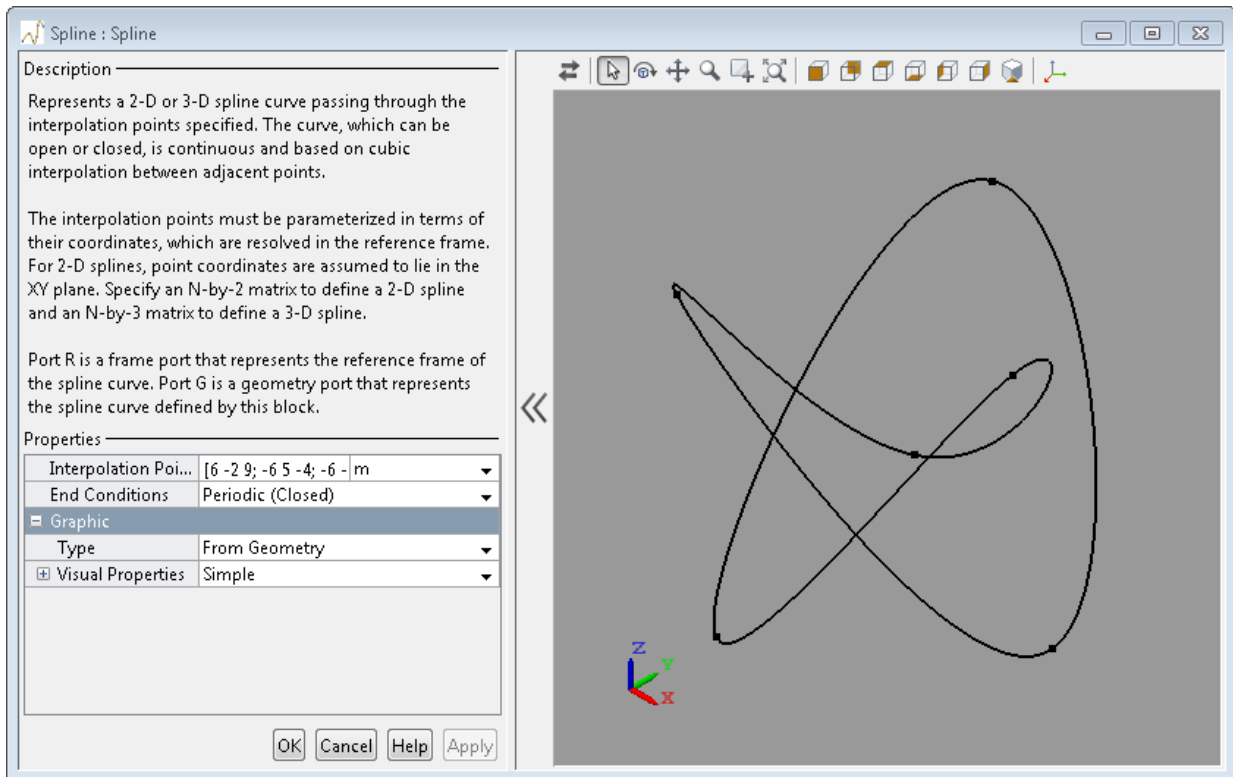
Interpolation Points

> Enter the coordinates of the interpolation points as an [x, y] matrix for a 2-D curve or [x, y, x] matrix for a 3-D curve. Coordinates are resolved in the reference frame of the block. The default input is a 6×3 matrix representing a 3-D curve.

If you set the end conditions to `Periodic (Closed)`, the block joins the first and last data points with an additional spline segment. Like all spline segments, the additional segment and its first two derivatives are continuous at the shared point.

Each data point in the coordinate matrix must be unique. If the curve is closed, ensure the first and last data points are not the same.

End Conditions

Select the end conditions to use. Periodic end conditions correspond to a closed curve. Natural end conditions correspond to an open curve. The default setting is `Periodic (Closed)`.

Graphic

Type

Select a method to represent the shape in Mechanics Explorer. The default is `From Geometry`.

Type	Description
From Geometry	Shape specified in **Geometry** section
Marker	Simple icon such as `Sphere`, `Cube`, or `Frame`
None	No visualization

Marker: Shape

Geometric shape of the graphic marker. Options include `Cube`, `Frame`, and `Sphere`. The default setting is `Sphere`.

Marker: Size

Absolute size of the graphic marker in pixels. Changing the zoom level in the model visualization pane has no effect on the apparent marker size. The default value is `10`.

Visual Properties

Color specification type. Options include `Simple` and `Advanced`. Select `Simple` to specify only the base color and opacity of your shape. Select `Advanced` to add lighting effects such as specular reflections and light emission.

Simple: Color

[R G B] color vector. This vector contains the red (R), green (G), and blue (B) contents of the specified color on a scale of 0–1. The default vector is `[0.5 0.5 0.5]`. A color picker provides an alternative means of specifying color.

`Simple`: **Opacity**

Degree to which your shape obscures model components positioned behind it. The opacity value can range from 0 to 1. An opacity of 0 makes the shape completely translucent, while an opacity of 1 makes it completely opaque. The default value is `1.0`.

`Advanced`: **Diffuse Color**

[R G B] or [R G B A] diffuse color vector. The diffuse color is the apparent color of the specified shape under direct white light. The color vector contains the red (R), green (G), and blue (B) contents of the diffuse color on a scale of 0–1. It can include an optional opacity value (A), also on a scale of 0–1. The default vector is `[0.5 0.5 0.5]`.

`Advanced`: **Specular Color**

[R G B] or [R G B A] specular color vector. The specular color is the color of the glossy highlights on the periphery of the specified shape. The color vector contains the red (R), green (G), and blue (B) contents of the specular color on a scale of 0–1. It can include an optional opacity value (A), also on a scale of 0–1. The default vector is `[0.5 0.5 0.5 1.0]`.

`Advanced`: **Ambient Color**

[R G B] or [R G B A] ambient color vector. The ambient color is the apparent color of the specified shape under indirect ambient light. The color vector contains the red (R), green (G), and blue (B) contents of the ambient color on a scale of 0–1. It can include an optional opacity value (A), also on a scale of 0–1. The default vector is `[0.15 0.15 0.15 1.0]`.

`Advanced`: **Emissive Color**

[R G B] or [R G B A] emissive color vector. The emissive color is the color of light the specified shape generates. The sun is an example of a body with emissive color. The color vector contains the red (R), green (G), and blue (B) contents of the emissive color on a scale of 0–1. It can include an optional opacity value (A), also on a scale of 0–1. The default vector is `[0.0 0.0 0.0 1.0]`.

`Advanced`: **Shininess**

Sharpness of the specular highlights on the periphery of the specified shape. The shininess value can range from 0 to 128. A low shininess value produces large specular highlights with a gradual falloff in intensity. A large shininess value

produces small specular highlights with a sharp falloff in intensity. The default value is 75.

Ports

The block contains frame port R, representing a local reference frame, and geometry port G, representing the specified spline curve.

See Also

Graphic | Point On Curve Constraint | Solid

Spring and Damper Force

Force proportional to the distance and relative velocity between two frame origins

Library

Forces and Torques

Description

This block represents a linear spring and damper force pair acting reciprocally between base and follower frame origins. The two forces in the pair have equal magnitude but opposite directions. One force acts on the base frame origin, along the vector connecting follower to base frame origins. The other force acts on the follower frame origin, along the vector connecting base to follower frame origins.

The magnitude of the spring force component is proportional to the distance between base and follower frame origins. This distance is the length of the straight line segment connecting the two origins. The magnitude of the damper force component is proportional to the relative velocity of the follower frame origin with respect to the base frame.

Dialog Box and Parameters
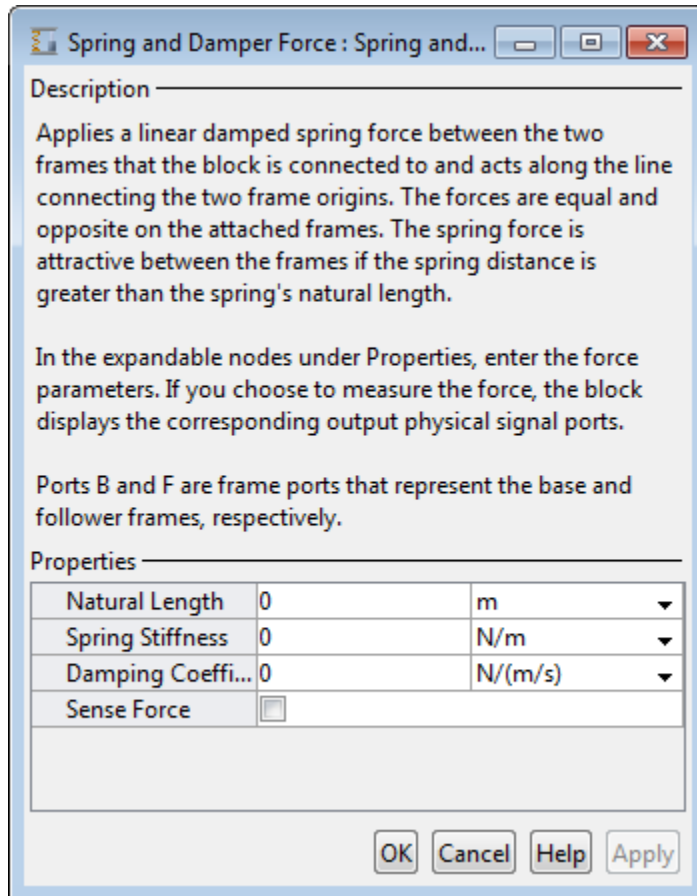
Natural Length

>   Enter the equilibrium distance between the base and follower frame origins. This is the distance at which the magnitude of the spring force is zero. The default value is 0. Select or enter a physical unit.

Spring Stiffness

>   Enter the value of the linear spring constant. The value must be greater than or equal to zero. The default value is zero. Select or enter a physical unit.

Damping Coefficient

Enter the value of the linear damping coefficient. The value must be greater than or equal to zero. The default value is zero. Select or enter a physical unit.

Sense Force

Select to sense the signed magnitude of the spring and damper force acting between the two frame origins. The block exposes an additional physical signal port to output the force signal. The output signal is a scalar value. This value is positive if the force is repulsive; it is negative if the force is attractive.

Ports

The block contains frame ports B and F, representing base and follower frames, respectively.

Selecting the **Sense Force** check box in the block dialog box adds a physical signal port, **fm**.

See Also

External Force and Torque | Internal Force | Inverse Square Law Force

More About

· "Actuating and Sensing with Physical Signals"

Telescoping Joint

Joint with one prismatic and one spherical joint primitive

Library

Joints

Description

This block represents a joint with one translational and three rotational degrees of freedom. One prismatic primitive provides the translational degree of freedom. One spherical primitive provides the three rotational degrees of freedom.
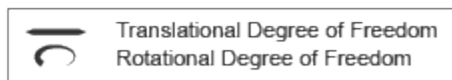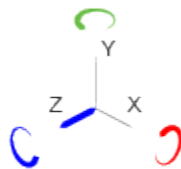
Joint Degrees of Freedom

The joint block represents motion between the base and follower frames as a sequence of time-varying transformations. Each joint primitive applies one transformation in this sequence. The transformation translates or rotates the follower frame with respect to the joint primitive base frame. For all but the first joint primitive, the base frame coincides with the follower frame of the previous joint primitive in the sequence.

At each time step during the simulation, the joint block applies the sequence of time-varying frame transformations in this order:

1 Rotation:

- About an arbitrary 3-D axis resolved in the Spherical Primitive (S) base frame.

2 Translation:

- Along the Z axis of the Z Prismatic Primitive (Pz) base frame. This frame is coincident with the Spherical Primitive (S) follower frame.

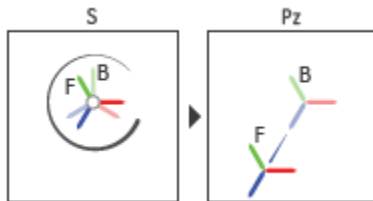The figure shows the sequence in which the joint transformations occur at a given simulation time step. The resulting frame of each transformation serves as the base frame for the following transformation. Because 3-D rotation occurs as a single rotation about an arbitrary 3-D axis (as opposed to three separate rotations about the X, Y, Z axes), gimbal lock does not occur.

Joint Transformation Sequence

A set of optional state targets guide assembly for each joint primitive. Targets include position and velocity. A priority level sets the relative importance of the state targets. If two targets are incompatible, the priority level determines which of the targets to satisfy.

Internal mechanics parameters account for energy storage and dissipation at each joint primitive. Springs act as energy storage elements, resisting any attempt to displace the joint primitive from its equilibrium position. Joint dampers act as energy dissipation elements. Springs and dampers are strictly linear.

Each joint primitive has a set of optional actuation and sensing ports. Actuation ports accept physical signal inputs that drive the joint primitives. These inputs can be forces and torques or a desired joint trajectory. Sensing ports provide physical signal outputs that measure joint primitive motion as well as actuation forces and torques. Actuation modes and sensing types vary with joint primitive.

Dialog Box and Parameters

Telescoping Joint : Telescoping Joint

Description

Represents a telescoping joint between two frames. This joint has three rotational and one translational degrees of freedom represented by one spherical primitive and one prismatic primitive. The follower frame first rotates freely around the common frame origins as the pivot. The follower origin then translates along the follower z-axis.

In the expandable nodes under Properties, specify the state, actuation method, sensing capabilities, and internal mechanics of the primitives of this joint. After you apply these settings, the block displays the corresponding physical signal ports.

Ports B and F are frame ports that represent the base and follower frames, respectively. The joint direction is defined by motion of the follower frame relative to the base frame.

Properties

- Spherical Primitive (S)
  - State Targets
  - Internal Mechanics
  - Actuation
  - Sensing
- Z Prismatic Primitive (Pz)
- Composite Force/Torque Sensing

OK Cancel Help Apply

Spherical Primitive: State Targets

Specify the spherical primitive state targets and their priority levels. A state target is the desired value for one of the joint state parameters—position and velocity. The priority level is the relative importance of a state target. It determines how precisely the target must be met. Use the Model Report tool in Mechanics Explorer to check the assembly status for each joint state target.

Specify Position Target

> Select this option to specify the desired joint primitive position at time zero. This is the relative rotation of the follower frame with respect to the base frame. It is resolved in the base frame. Selecting this option exposes priority and value fields.

Priority

> Select state target priority. This is the importance level assigned to the state target. If all state targets cannot be simultaneously satisfied, the priority level determines which targets to satisfy first and how closely to satisfy them. This option applies to both position and velocity state targets.

Priority Level	Description
High (desired)	Satisfy state target precisely
Low (approximate)	Satisfy state target approximately

Note: During assembly, high-priority targets behave as exact guides. Low-priority targets behave as rough guides.

Value

> Select a method to specify the joint primitive state target.

Method	Description
None	Constrain the base and follower frames to share the same orientation.
Aligned Axes	Set frame rotation by aligning two follower frame axes with two base frame axes.

Method	Description
`Standard Axis`	Specify frame rotation as an angle about a standard axis (*x*, *y*, or *z*).
`Arbitrary Axis`	Specify frame rotation as an angle about a general [*x*, *y*, *z*] axis.
`Rotation Sequence`	Specify frame rotation as a sequence of three elementary rotations.
`Rotation Matrix`	Specify frame rotation as a right-handed orthogonal rotation matrix.

Aligned Axes

Select two pairs of base-follower frame axes.

Parameter	Description
Pair 1	First pair of base-follower frame axes to align.
Pair 2	Second pair of base-follower frame axes to align. Axis choices depend on **Pair 1** axis selections.

Standard Axis

Select a standard rotation axis, resolved in the base frame, and specify the follower frame rotation angle.

Parameter	Description
Axis	Standard rotation axis (X, Y, or Z) resolved in the base frame.
Angle	Follower frame rotation angle about the rotation axis with respect to the base frame.

Arbitrary Axis

Select a general 3-D rotation axis, resolved in the base frame, and specify the follower frame rotation angle.

Parameter	Description
Axis	General rotation axis [X Y Z] resolved in the base frame.
Angle	Follower frame rotation angle about the rotation axis with respect to the base frame.

Rotation Sequence

Specify a sequence of three elementary rotations about the selected permutation of x, y, and z axes. These rotation sequences are also known as Euler and Tait-Bryan sequences. The rotations are those of the follower frame relative to the frame selected in the **Rotate About** parameter.

If you set the **Rotate About** parameter to `Follower Frame`, the follower frame rotates about its own axes. These axes change orientation with each successive rotation. If you set the **Rotate About** parameter to `Base Frame`, the follower frame rotates about the fixed base frame axes.

Parameter	Description
Rotation About	Frame whose axes to rotate the follower frame about.
Sequence	Sequence of axes about which to apply the elementary rotations.
Angles	Three-element vector with elementary rotation angles about the axes specified in the **Sequence** parameter.

Rotation Matrix

Specify the 3×3 transformation matrix of a proper rotation between the base and follower frames. The matrix must be orthogonal and have determinant +1. The default matrix is [1 0 0; 0 1 0; 0 0 1].

Specify Velocity Target

Select this option to specify the desired joint primitive velocity at time zero. This is the relative angular velocity of the follower frame with respect to the base frame. It is resolved in the base frame. Selecting this option exposes priority and value fields. The priority field is identical to that used for the position state target.

Value

Enter a three element vector with the angular velocity components of the follower frame with respect to the base frame. Select a physical unit. The default is `deg/s` (degree/second).

Resolution Frame

From the drop-down list, select a resolution frame. This is the frame in which the state target is resolved. It identifies the axes the velocity vector components apply to. The default is `Follower`.

Spherical Primitive: Internal Mechanics

Specify the spherical primitive internal mechanics. This includes linear spring and damping forces, accounting for energy storage and dissipation, respectively. To ignore internal mechanics, keep spring stiffness and damping coefficient values at the default value of `0`.

Equilibrium Position

Select a method to specify the spring equilibrium position. The equilibrium position is the rotation angle between base and follower port frames at which the spring torque is zero.

Method	Description
None	Constrain the base and follower frames to share the same orientation.
Aligned Axes	Set frame rotation by aligning two follower frame axes with two base frame axes.
Standard Axis	Specify frame rotation as an angle about a standard axis (*x*, *y*, or *z*).
Arbitrary Axis	Specify frame rotation as an angle about a general [*x*, *y*, *z*] axis.
Rotation Sequence	Specify frame rotation as a sequence of three elementary rotations.
Rotation Matrix	Specify frame rotation as a right-handed orthogonal rotation matrix.

Aligned Axes

Select two pairs of base-follower frame axes.

Parameter	Description
Pair 1	First pair of base-follower frame axes to align.
Pair 2	Second pair of base-follower frame axes to align. Axis choices depend on **Pair 1** axis selections.

Standard Axis

Select a standard rotation axis, resolved in the base frame, and specify the follower frame rotation angle.

Parameter	Description
Axis	Standard rotation axis (X, Y, or Z) resolved in the base frame.
Angle	Follower frame rotation angle about the rotation axis with respect to the base frame.

Arbitrary Axis

Select a general 3-D rotation axis, resolved in the base frame, and specify the follower frame rotation angle.

Parameter	Description
Axis	General rotation axis [X Y Z] resolved in the base frame.
Angle	Follower frame rotation angle about the rotation axis with respect to the base frame.

Rotation Sequence

Specify a sequence of three elementary rotations about the selected permutation of x, y, and z axes. These rotation sequences are also known as Euler and Tait-Bryan

sequences. The rotations are those of the follower frame relative to the frame selected in the **Rotate About** parameter.

If you set the **Rotate About** parameter to `Follower Frame`, the follower frame rotates about its own axes. These axes change orientation with each successive rotation. If you set the **Rotate About** parameter to `Base Frame`, the follower frame rotates about the fixed base frame axes.

Parameter	Description
Rotation About	Frame whose axes to rotate the follower frame about.
Sequence	Sequence of axes about which to apply the elementary rotations.
Angles	Three-element vector with elementary rotation angles about the axes specified in the **Sequence** parameter.

Rotation Matrix

Specify the 3×3 transformation matrix of a proper rotation between the base and follower frames. The matrix must be orthogonal and have determinant +1. The default matrix is [1 0 0; 0 1 0; 0 0 1].

Spring Stiffness

Enter the linear spring constant. This is the torque required to displace the joint primitive by a unit angle. The term linear refers to the mathematical form of the spring equation. The default is 0. Select a physical unit. The default is N*m/deg.

Damping Coefficient

Enter the linear damping coefficient. This is the torque required to maintain a constant joint primitive angular velocity between base and follower frames. The default is 0. Select a physical unit. The default is N*m/(deg/s).

Spherical Primitive: Actuation

Specify actuation options for the spherical joint primitive. Actuation modes include **Torque** only. Selecting a torque input adds the corresponding physical signal port to the block. Use this port to specify the actuation torque signal.

Torque

Select a source for the actuation torque. The default setting is `None`.

Actuation Torque Setting	Description
None	Apply no actuation torque.
Provided by Input	Apply an actuation torque based on a physical signal. The signal specifies the torque acting on the follower frame with respect to the base frame. An equal and opposite torque acts on the base frame. Selecting this option exposes additional parameters.

Torque (X), Torque (Y), Torque (Z)

Select in order to actuate the spherical joint primitive about each standard Cartesian axis (X, Y, Z) separately. The block exposes the corresponding physical signal ports. Use these ports to specify the actuation torque signals. The signals must be scalar values.

Torque (XYZ)

Select in order to actuate the spherical joint primitive about an arbitrary axis [X Y Z]. The block exposes the corresponding physical signal port. Use this port to specify the actuation torque signal. The signal must be a 3-D vector.

Frame

Select the frame to resolve the actuation torque signal in. The axes of this frame establish the directions of the X, Y, and Z torque components. The default setting is `Base`.

Spherical Primitive: Sensing

Select the motion variables to sense in the spherical joint primitive. The block adds the corresponding physical signal ports. Use these ports to output the numerical values of the motion variables.

The block measures each motion variable for the follower frame with respect to the base frame. It resolves that variable in the resolution frame that you select from the **Frame** drop-down list.

Motion Variables	Description
Position	Quaternion describing follower frame rotation with respect to base frame. The quaternion coefficients are $$\left[\cos\left(\frac{\theta}{2}\right), n_x \sin\left(\frac{\theta}{2}\right), n_y \sin\left(\frac{\theta}{2}\right), n_z \sin\left(\frac{\theta}{2}\right)\right].$$ The measurement is the same in all measurement frames.
Velocity (X), **Velocity (Y)**, **Velocity (Z)**	Angular velocity components about X, Y, and Z axes.
Velocity	3–D angular velocity vector with components about X, Y, and Z axes.
Acceleration (X), **Acceleration (Y)**, **Acceleration (Z)**	Angular acceleration components about X, Y, and Z axes.
Acceleration	3–D angular acceleration vector with components about X, Y, and Z axes.

Frame

Select the frame to resolve the measurement in. The axes of this frame establish the directions of X, Y, and Z vector components. The default setting is `Base`.

Prismatic Primitive: State Targets

Specify the prismatic primitive state targets and their priority levels. A state target is the desired value for one of the joint state parameters—position and velocity. The priority level is the relative importance of a state target. It determines how precisely the target must be met. Use the Model Report tool in Mechanics Explorer to check the assembly status for each joint state target.

Specify Position Target

Select this option to specify the desired joint primitive position at time zero. This is the relative position, measured along the joint primitive axis, of the follower frame origin with respect to the base frame origin. The specified target is resolved in the base frame. Selecting this option exposes priority and value fields.

Specify Velocity Target

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Select this option to specify the desired joint primitive velocity at time zero. This is the relative velocity, measured along the joint primitive axis, of the follower frame origin with respect to the base frame origin. It is resolved in the base frame. Selecting this option exposes priority and value fields.

Priority

Select state target priority. This is the importance level assigned to the state target. If all state targets cannot be simultaneously satisfied, the priority level determines which targets to satisfy first and how closely to satisfy them. This option applies to both position and velocity state targets.

Priority Level	Description
High (desired)	Satisfy state target precisely
Low (approximate)	Satisfy state target approximately

Note: During assembly, high-priority targets behave as exact guides. Low-priority targets behave as rough guides.

Value

Enter the state target numerical value. The default is 0. Select or enter a physical unit. The default is m for position and m/s for velocity.

Prismatic Primitive: Internal Mechanics

Specify the prismatic primitive internal mechanics. Internal mechanics include linear spring forces, accounting for energy storage, and damping forces, accounting for energy dissipation. You can ignore internal mechanics by keeping spring stiffness and damping coefficient values at 0.

Equilibrium Position

Enter the spring equilibrium position. This is the distance between base and follower frame origins at which the spring force is zero. The default value is 0. Select or enter a physical unit. The default is m.

Spring Stiffness

Enter the linear spring constant. This is the force required to displace the joint primitive by a unit distance. The default is 0. Select or enter a physical unit. The default is N/m.

Damping Coefficient

Enter the linear damping coefficient. This is the force required to maintain a constant joint primitive velocity between base and follower frames. The default is `0`. Select or enter a physical unit. The default is `N/(m/s)`.

Prismatic Primitive: Actuation

Specify actuation options for the prismatic joint primitive. Actuation modes include **Force** and **Motion**. Selecting `Provided by Input` from the drop-down list for an actuation mode adds the corresponding physical signal port to the block. Use this port to specify the input signal. Actuation signals are resolved in the base frame.

Force

Select an actuation force setting. The default setting is `None`.

Actuation Force Setting	Description
None	No actuation force.
Provided by Input	Actuation force from physical signal input. The signal provides the force acting on the follower frame with respect to the base frame along the joint primitive axis. An equal and opposite force acts on the base frame.
Automatically computed	Actuation force from automatic calculation. Simscape Multibody computes and applies the actuation force based on model dynamics.

Motion

Select an actuation motion setting. The default setting is `Automatically Computed`.

Actuation Motion Setting	Description
Provided by Input	Joint primitive motion from physical signal input. The signal provides the desired trajectory of the follower frame with respect to the base frame along the joint primitive axis.

Actuation Motion Setting	Description
`Automatically computed`	Joint primitive motion from automatic calculation. Simscape Multibody computes and applies the joint primitive motion based on model dynamics.

Prismatic Primitive: Sensing

Select the variables to sense in the prismatic joint primitive. Selecting a variable exposes a physical signal port that outputs the measured quantity as a function of time. Each quantity is measured for the follower frame with respect to the base frame. It is resolved in the base frame. You can use the measurement signals for analysis or as input in a control system.

Position

Select this option to sense the relative position of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Velocity

Select this option to sense the relative velocity of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Acceleration

Select this option to sense the relative acceleration of the follower frame origin with respect to the base frame origin along the joint primitive axis.

Actuator Force

Select this option to sense the actuation force acting on the follower frame with respect to the base frame along the joint primitive axis.

Composite Force/Torque Sensing

Select the composite, or joint-wide, forces and torques to sense. These are forces and torques that act not at individual joint primitives but at the whole joint. Options include constraint and total forces and torques.

During simulation, the block computes the selected composite forces and torques acting between the base and follower port frames. It outputs these variables using physical signal output ports. Check the port labels to identify the output variables at different ports.

Direction

Forces and torques acting at joints do so in pairs. Newton's third law of motion requires that every action be accompanied by an equal and opposite reaction. If the base frame of a joint exerts a force or torque on the follower frame, then the follower frame must exert an equal and opposite force or torque on the base frame.

Select whether to sense the composite forces and torques exerted by the base frame on the follower frame or vice versa. The force and torque vector components are positive if they point along the positive X, Y, and Z axes of the selected resolution frame.

Resolution Frame

You can resolve a vector quantity into Cartesian components in different frames. If the resolution frames have different orientations, then the measured components are themselves different—even though the vector quantity remains the same.

Select the frame in which to resolve the sensed force and torque variables. Possible resolution frames include `Base` and `Follower`. The block outputs the Cartesian components of the sensed force and torque vectors as observed in this frame.

Constraint Force

Joint blocks with fewer than three translational degrees of freedom forbid motion along one or more axes. For example, the Gimbal Joint block forbids translation along all axes. To prevent translation along an axis, a joint block applies a constraint force between its base and follower port frames. Constraint forces are orthogonal to joint translation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint force vector [fc_x, fc_y, fc_z] acting at the joint. Only constraint force components that are orthogonal to the joint translational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port fc.

Constraint Torque

Joint blocks with fewer than three rotational degrees of freedom forbid motion about one or more axes. For example, the Cartesian Joint block forbids rotation about all axes. To prevent rotation about an axis, a joint block applies a constraint torque between its base and follower port frames. Constraint torques are orthogonal to joint rotation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint torque vector [tc_x, tc_y, tc_z] acting at the joint. Only constraint torque components that are orthogonal to the

joint rotational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port tc.

Total Force

A joint block generally applies various forces between its port frames:

- Actuation forces that drive prismatic joint primitives.
- Internal spring and damper forces that resist motion at prismatic joint primitives.
- Constraint forces that forbid motion in directions orthogonal to prismatic joint primitives.

The net sum of the different force components equals the total force acting between the joint port frames. Select the check box to compute and output the 3-D total force vector $[ft_x, ft_y, ft_z]$. Selecting this option causes the block to expose physical signal port ft.

Total Torque

A joint block generally applies various torques between its port frames:

- Actuation torques that drive revolute or spherical joint primitives.
- Internal spring and damper torques that resist motion at revolute or spherical joint primitives.
- Constraint torques that forbid motion in directions orthogonal to the revolute or spherical joint primitive axes.

The net sum of the different torque components equals the total torque acting at a joint. Select the check box to compute and output the 3-D total torque vector $[tt_x, tt_y, tt_z]$. Selecting this option causes the block to expose physical signal port tt.

Ports

This block has two frame ports. It also has optional physical signal ports for specifying actuation inputs and sensing dynamical variables such as forces, torques, and motion. You expose an optional port by selecting the sensing check box corresponding to that port.

Frame Ports

- B — Base frame

- F — Follower frame

Actuation Ports

The prismatic joint primitive provides the following actuation ports:

- fz — Actuation force of the Z prismatic joint primitive
- pz — Desired trajectory of the Z prismatic joint primitive

The spherical joint primitive provides the following actuation ports:

- t — Actuation torque vector [tx, ty, tz] acting on the spherical joint primitive
- tx, ty, tz — X, Y, and Z components of the actuation torque acting on the spherical joint primitive

Sensing Ports

The prismatic primitive provides the following sensing ports:

- pz — Position of the Z prismatic joint primitive
- vz — Velocity of the Z prismatic joint primitive
- az — Acceleration of the Z prismatic joint primitive
- fz — Actuation force acting on the Z prismatic joint primitive

The spherical primitive provides the following sensing ports:

- Q — Orientation of the spherical joint primitive in quaternion form
- wx, wy, wz — X, Y, and Z angular velocity components of the spherical joint primitive
- w — Angular velocity [wx, wy, wz] of the spherical joint primitive
- bx, by, bz — X, Y, and Z angular acceleration components of the spherical joint primitive
- b — Angular acceleration [bx, by, bz] of the spherical joint primitive

The following sensing ports provide the composite forces and torques acting on the joint:

- fc — Constraint force
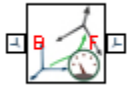- tc — Constraint torque
- ft — Total force

- tt — Total torque

See Also

`Prismatic Joint` | `Spherical Joint`

Transform Sensor

Sensor that measures the spatial relationship between two frames
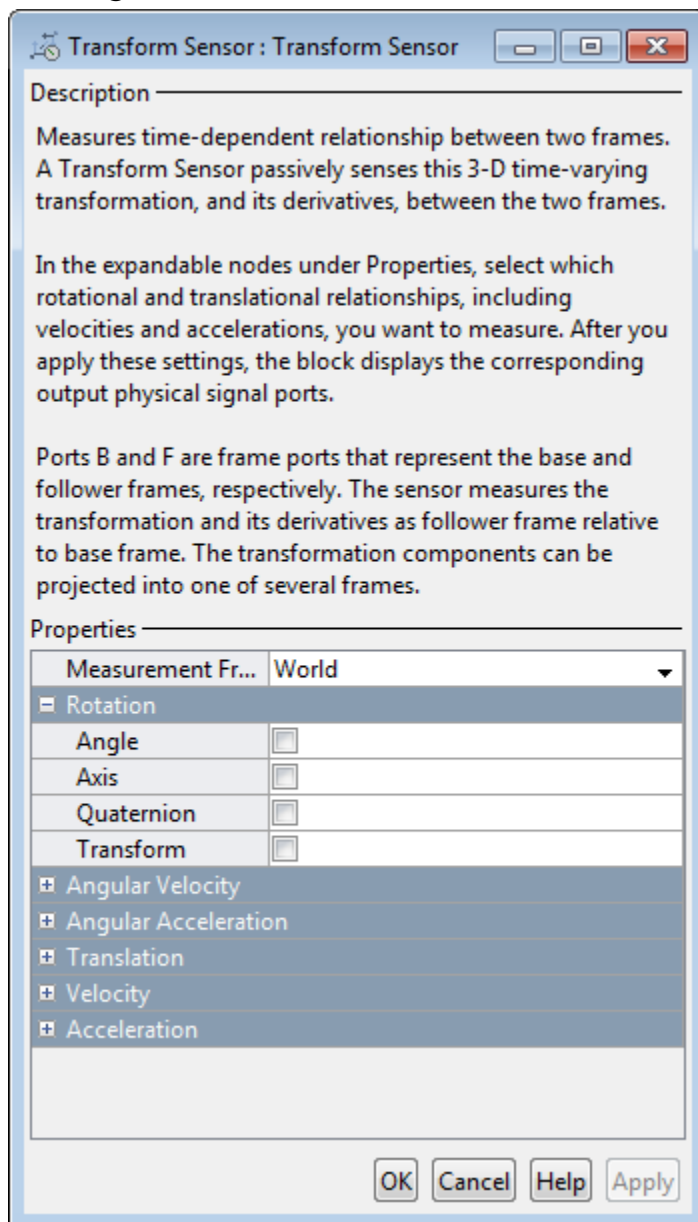

Library

Frames and Transforms

Description

This block represents a sensor that measures the spatial relationship between two frames. Parameters that this sensor measures include rotational and translational position, velocity, and acceleration. The sensor can measure these parameters between any two frames in a model. This block provides the broadest motion sensing capability in Simscape Multibody.

Each measurement provides the value of a parameter for the follower frame with respect to the base frame, resolved in the **Measurement Frame** that you choose. Measurement frames include World as well as rotating and non-rotating base and follower frames.

To output a parameter, the block provides a set of optional physical signal ports. Ports remain hidden until you select the corresponding parameters in the dialog box. Each port outputs a parameter as a time-varying physical signal. By default, measurements are in SI units. If connecting to Simulink® blocks, you can use the `PS-Simulink Converter` block to select a different physical unit.

Dialog Box and Parameters

Transform Sensor : Transform Sensor

Description

Measures time-dependent relationship between two frames. A Transform Sensor passively senses this 3-D time-varying transformation, and its derivatives, between the two frames.

In the expandable nodes under Properties, select which rotational and translational relationships, including velocities and accelerations, you want to measure. After you apply these settings, the block displays the corresponding output physical signal ports.

Ports B and F are frame ports that represent the base and follower frames, respectively. The sensor measures the transformation and its derivatives as follower frame relative to base frame. The transformation components can be projected into one of several frames.

Properties

Measurement Fr...	World
▬ Rotation	
Angle	☐
Axis	☐
Quaternion	☐
Transform	☐
▣ Angular Velocity	
▣ Angular Acceleration	
▣ Translation	
▣ Velocity	
▣ Acceleration	

OK   Cancel   Help   Apply

Measurement Frame

Select a frame in which to resolve the selected spatial measurements. The choice of measurement frame affects the expression of a vector quantity in terms of its X, Y, and Z components. Some quantities, such as **Angle**, are not affected by the choice of measurement frame. For more information, see "Measurement Frames". The default is `World`.

Rotation

Select the rotation parameters to sense. These parameters encode the rotation operation required to bring the base frame into coincidence with the follower frame. Rotation observes the right-hand rule: with the rotation axis pointing out of the screen, counterclockwise motion defines positive rotation, while clockwise motion defines negative rotation.

Non-vector quantities require no measurement frame for resolution; these quantities are unaffected by measurement frame choice. Vector quantities, such as **Axis**, are *always* resolved in either base or follower measurement frames; the `World` measurement frame does not apply.

Angle

3–D rotation angle of the follower frame with respect to the base frame. Selecting **Angle** exposes physical signal port **q**.

Axis

Vector components of the normalized rotation axis. The output is a three-element vector with the X, Y, and Z axis components resolved in the measurement frame. Selecting **Axis** exposes physical signal port **axs**.

Quaternion

Unit quaternion that describes the pure rotation of the follower frame with respect to the base frame. The output is a four-element vector with the scalar (S) and vector (V_x, V_y, V_z) quaternion coefficients. The vector provides the coefficients in the order [S V_x V_y V_z]. Selecting **Quaternion** exposes physical signal port **Q**.

Transform

Transform matrix that describes the pure rotation of the follower frame with respect to the base frame. The output is a nine-element, 3×3 matrix. Selecting **Transform** exposes physical signal port **R**.

Angular Velocity

Select the angular velocity parameters to sense. The parameters encode the angular velocity of the follower frame with respect to the base frame, resolved in the measurement frame. Rotation observes the right-hand rule: with the rotation axis pointing out of the screen, counterclockwise motion defines positive rotation, while clockwise motion defines negative rotation.

Omega X/Omega Y/Omega Z

Relative angular velocities about the X, Y, and Z axes of the base frame. Selecting **Omega X**, **Omega Y**, and **Omega Z** exposes physical signal ports **wx**, **wy**, and **wz**.

Quaternion

Unit quaternion that describes the angular velocity of the follower frame with respect to the base frame. The output is a four-element vector with the scalar (S) and vector (V_x, V_y, V_z) quaternion coefficients. The vector provides the coefficients in the order [S V_x V_y V_z]. Selecting **Quaternion** exposes physical signal port **Qd**.

Transform

Transform matrix that describes the angular velocity of the follower frame with respect to the base frame. The output is a nine-element, 3×3 matrix. Selecting **Transform** exposes physical signal port **Rd**.

Angular Acceleration

Select the angular acceleration parameters to sense. The parameters encode the angular acceleration of the follower frame with respect to the base frame, resolved in the measurement frame. Rotation observes the right-hand rule: with the rotation axis pointing out of the screen, counterclockwise motion defines positive rotation, while clockwise motion defines negative rotation.

Alpha X/Alpha Y/Alpha Z

Relative angular accelerations about the X, Y, and Z axes of the base frame. Selecting **Alpha X**, **Alpha Y**, and **Alpha Z** exposes physical signal ports **bx**, **by**, and **bz**.

Quaternion

Unit quaternion that describes the angular acceleration of the follower frame with respect to the base frame. The output is a four-element vector with the scalar (S) and vector (V_x, V_y, V_z) quaternion coefficients. The vector provides the coefficients in the order [S V_x V_y V_z]. Selecting **Quaternion** exposes physical signal port **Qdd**.

Transform

> Transform matrix that describes the angular acceleration of the follower frame with respect to the base frame. The output is a nine-element, 3×3 matrix. Selecting **Transform** exposes physical signal port **Rdd**.

Translation

Select the translation parameters to sense. The parameters encode the translation of the follower frame with respect to the base frame, resolved in the measurement frame.

X/Y/Z

> Offset vector from the base frame origin to the follower frame origin along the X, Y, and Z axes. Selecting **X**, **Y**, and **Z** exposes physical signal ports **x**, **y**, and **z**.

Radius

> Standard radius coordinate found in cylindrical coordinate systems. This radius is the shortest distance from the base frame Z axis to the follower frame origin. The value of the radius is always greater than or equal to zero. Selecting **Radius** exposes physical signal port **rad**.
>
> The figure shows the cylindrical translation parameters **Z**, **Radius**, and **Azimuth**.
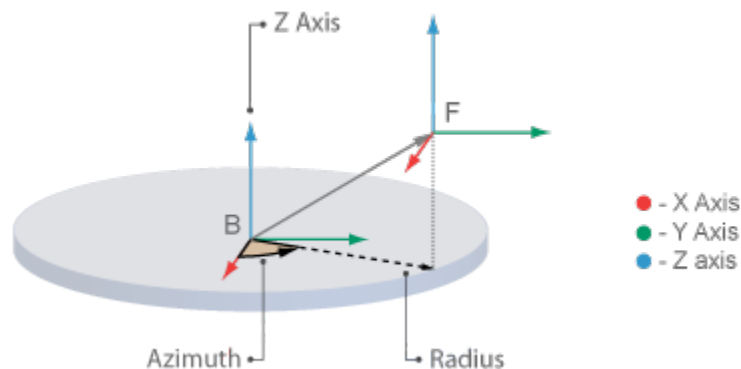
Azimuth

> Standard azimuth coordinate found in cylindrical and spherical coordinate systems. The azimuth is the angle from the base frame +X axis to the projection of the ray

connecting base to follower frame origins onto the base frame XY plane. The angle measurement observes the right-hand rule. The azimuth falls in the range [-180°, +180°]. If base and follower frame origins coincide with each other, the azimuth is undefined. Selecting **Azimuth** exposes sensing port **azm**.

Distance

Standard radius found in spherical coordinate systems. This is the distance from the origin of the base frame to the origin of the follower frame. This distance is always equal to or greater than zero. Selecting **Distance** exposes sensing port **dst**.

The figure shows the spherical translation parameters **Azimuth**, **Distance**, and **Inclination**.
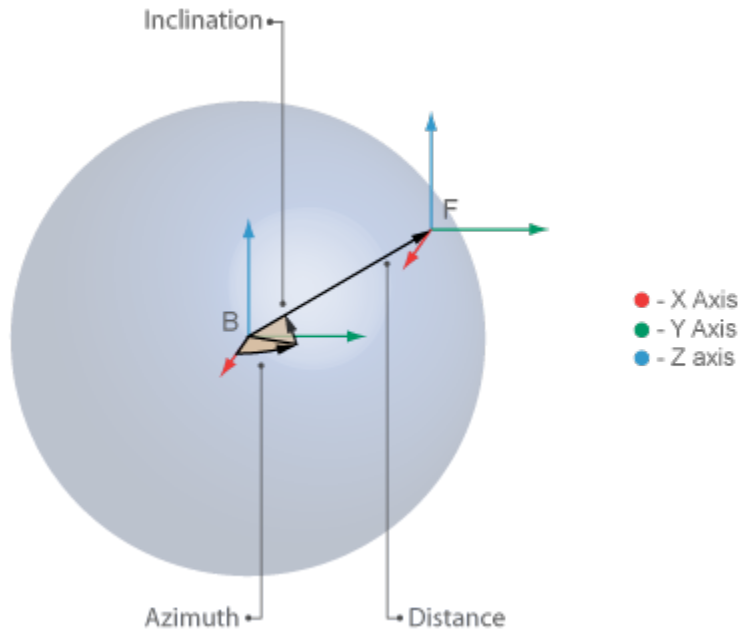
Inclination

Standard inclination found in spherical coordinate systems. The inclination is the angle of the ray connecting base to follower frame origins with respect to the projection of this ray onto the base frame XY plane. The angle measurement observes the right-hand rule. The inclination falls in the range [-90°, +90°]. If base

and follower frame origins coincide with each other, the inclination is undefined. Selecting **Inclination** exposes sensing port **inc**.

Velocity

Select the linear velocity parameters to sense. The parameters encode the linear velocity of the follower frame with respect to the base frame, resolved in the measurement frame. Differentiation of a translation parameter occurs in measurement coordinates, after that parameter is resolved in the chosen measurement frame.

X/Y/Z

Relative linear velocities along the X, Y, and Z axes. Selecting **X**, **Y**, and **Z** exposes physical signal ports **vx**, **vy**, and **vz**.

Radius

Time rate of change of the **Radius** coordinate defined under **Translation**. Selecting **Radius** exposes physical signal port **vrad**.

Azimuth

Time rate of change of the **Azimuth** coordinate defined under **Translation**. Selecting **Azimuth** exposes physical signal port **vazm**.

Distance

Time rate of change of the **Distance** coordinate defined under **Translation**. Selecting **Distance** exposes physical signal port **vdst**.

Inclination

Time rate of change of the **Inclination** coordinate defined under **Translation**. Selecting **Inclination** exposes physical signal port **vinc**.

Acceleration

Select the linear acceleration parameters to sense. The parameters encode the linear acceleration of the follower frame with respect to the base frame, resolved in the measurement frame. Differentiation of a translation parameter occurs in measurement coordinates, after that parameter is resolved in the chosen measurement frame.

X/Y/Z

Relative linear accelerations along the X, Y, and Z axes. Selecting **X**, **Y**, and **Z** exposes physical signal ports **ax**, **ay**, and **az**.

Radius

Second time-derivative of the **Radius** coordinate defined under **Translation**. Selecting **Radius** exposes physical signal port **arad**.

Azimuth

Second time-derivative of the **Azimuth** coordinate defined under **Translation**. Selecting **Azimuth** exposes physical signal port **aazm**.

Distance

Second time-derivative of the **Distance** coordinate defined under **Translation**. Selecting **Distance** exposes physical signal port **adst**.

Inclination

Second time-derivative of the **Inclination** coordinate defined under **Translation**. Selecting **Inclination** exposes physical signal port **ainc**.

Ports

The block contains frame ports B and F, representing base and follower frames, respectively.

See Also
```
Rigid Transform
```

More About
· "Motion Sensing"
· "Representing Frames"

Universal Joint
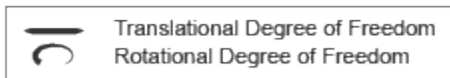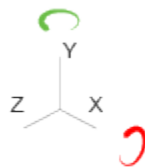
Joint with two revolute primitives
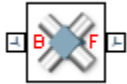
Library

Joints

Description

This block represents a joint with two rotational degrees of freedom. Two revolute primitives provide the two rotational degrees of freedom. The base and follower frame origins remain coincident during simulation.

Joint Degrees of Freedom

The joint block represents motion between the base and follower frames as a sequence of time-varying transformations. Each joint primitive applies one transformation in this sequence. The transformation translates or rotates the follower frame with respect to the
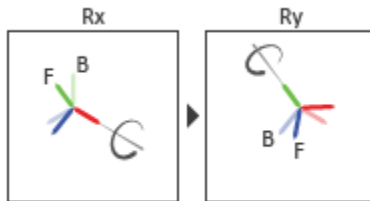
joint primitive base frame. For all but the first joint primitive, the base frame coincides with the follower frame of the previous joint primitive in the sequence.

At each time step during the simulation, the joint block applies the sequence of time-varying frame transformations in this order:

1 Rotation:

    a About the X axis of the X Revolute Primitive (Rx) base frame.

    b About the Y axis of the Y Revolute Primitive (Ry) base frame. This frame is coincident with the X Revolute Primitive (Rx) follower frame.

The figure shows the sequence in which the joint transformations occur at a given simulation time step. The resulting frame of each transformation serves as the base frame for the following transformation.
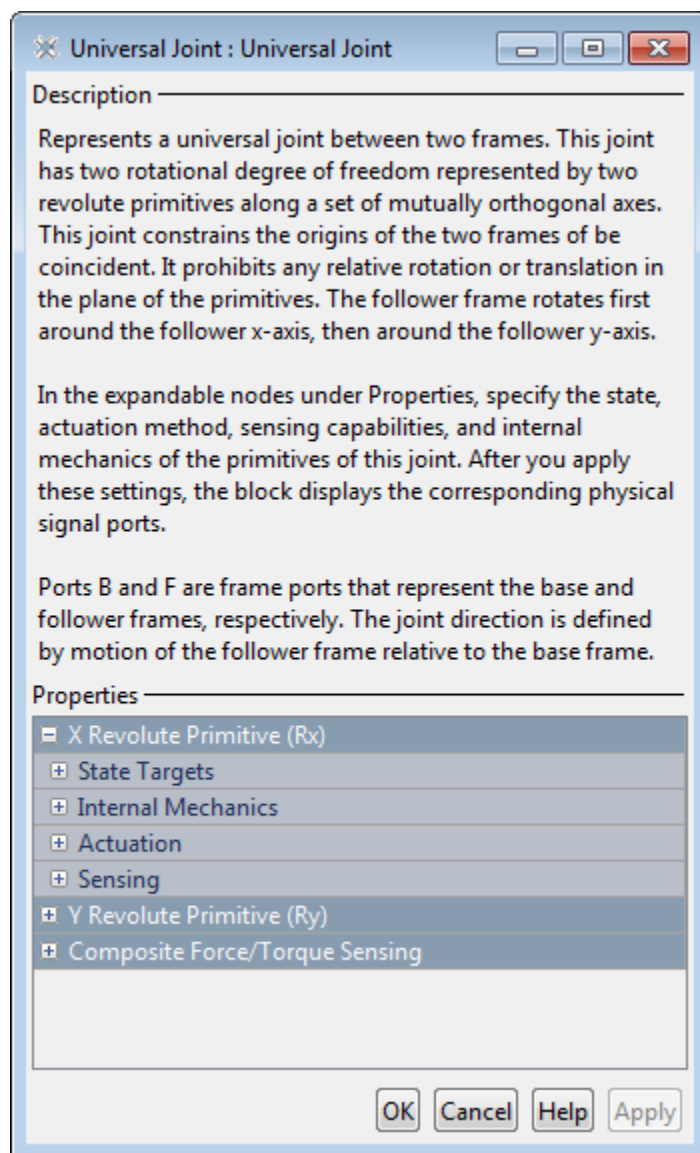

Joint Transformation Sequence

A set of optional state targets guide assembly for each joint primitive. Targets include position and velocity. A priority level sets the relative importance of the state targets. If two targets are incompatible, the priority level determines which of the targets to satisfy.

Internal mechanics parameters account for energy storage and dissipation at each joint primitive. Springs act as energy storage elements, resisting any attempt to displace the joint primitive from its equilibrium position. Joint dampers act as energy dissipation elements. Springs and dampers are strictly linear.

Each joint primitive has a set of optional actuation and sensing ports. Actuation ports accept physical signal inputs that drive the joint primitives. These inputs can be forces and torques or a desired joint trajectory. Sensing ports provide physical signal outputs that measure joint primitive motion as well as actuation forces and torques. Actuation modes and sensing types vary with joint primitive.

Dialog Box and Parameters

Universal Joint : Universal Joint

Description

Represents a universal joint between two frames. This joint has two rotational degree of freedom represented by two revolute primitives along a set of mutually orthogonal axes. This joint constrains the origins of the two frames of be coincident. It prohibits any relative rotation or translation in the plane of the primitives. The follower frame rotates first around the follower x-axis, then around the follower y-axis.

In the expandable nodes under Properties, specify the state, actuation method, sensing capabilities, and internal mechanics of the primitives of this joint. After you apply these settings, the block displays the corresponding physical signal ports.

Ports B and F are frame ports that represent the base and follower frames, respectively. The joint direction is defined by motion of the follower frame relative to the base frame.

Properties

- X Revolute Primitive (Rx)
  - State Targets
  - Internal Mechanics
  - Actuation
  - Sensing
- Y Revolute Primitive (Ry)
- Composite Force/Torque Sensing

OK   Cancel   Help   Apply

Revolute Primitive: State Targets

Specify the revolute primitive state targets and their priority levels. A state target is the desired value for one of the joint state parameters—position and velocity. The priority level is the relative importance of a state target. It determines how precisely the target must be met. Use the Model Report tool in Mechanics Explorer to check the assembly status for each joint state target.

Specify Position Target

Select this option to specify the desired joint primitive position at time zero. This is the relative rotation angle, measured about the joint primitive axis, of the follower frame with respect to the base frame. The specified target is resolved in the base frame. Selecting this option exposes priority and value fields.

Specify Velocity Target

Select this option to specify the desired joint primitive velocity at time zero. This is the relative angular velocity, measured about the joint primitive axis, of the follower frame with respect to the base frame. It is resolved in the base frame. Selecting this option exposes priority and value fields.

Priority

Select state target priority. This is the importance level assigned to the state target. If all state targets cannot be simultaneously satisfied, the priority level determines which targets to satisfy first and how closely to satisfy them. This option applies to both position and velocity state targets.

Priority Level	Description
High (desired)	Satisfy state target precisely
Low (approximate)	Satisfy state target approximately

Note: During assembly, high-priority targets behave as exact guides. Low-priority targets behave as rough guides.

Value

Enter the state target numerical value. The default is 0. Select or enter a physical unit. The default is deg for position and deg/s for velocity.

Revolute Primitive: Internal Mechanics

Specify the revolute primitive internal mechanics. Internal mechanics include linear spring torques, accounting for energy storage, and linear damping torques, accounting for energy dissipation. You can ignore internal mechanics by keeping spring stiffness and damping coefficient values at 0.

Equilibrium Position

Enter the spring equilibrium position. This is the rotation angle between base and follower frames at which the spring torque is zero. The default value is 0. Select or enter a physical unit. The default is deg.

Spring Stiffness

Enter the linear spring constant. This is the torque required to rotate the joint primitive by a unit angle. The default is 0. Select or enter a physical unit. The default is N*m/deg.

Damping Coefficient

Enter the linear damping coefficient. This is the torque required to maintain a constant joint primitive angular velocity between base and follower frames. The default is 0. Select or enter a physical unit. The default is N*m/(deg/s).

Revolute Primitive: Actuation

Specify actuation options for the revolute joint primitive. Actuation modes include **Torque** and **Motion**. Selecting Provided by Input from the drop-down list for an actuation mode adds the corresponding physical signal port to the block. Use this port to specify the input signal. Input signals are resolved in the base frame.

Torque

Select an actuation torque setting. The default setting is None.

Actuation Torque Setting	Description
None	No actuation torque.
Provided by Input	Actuation torque from physical signal input. The signal provides the torque acting on the follower frame with respect to the base frame about the joint primitive axis. An equal and opposite torque acts on the base frame.

Actuation Torque Setting	Description
`Automatically computed`	Actuation torque from automatic calculation. Simscape Multibody computes and applies the actuation torque based on model dynamics.

Motion

Select an actuation motion setting. The default setting is `Automatically Computed`.

Actuation Motion Setting	Description
`Provided by Input`	Joint primitive motion from physical signal input. The signal provides the desired trajectory of the follower frame with respect to the base frame along the joint primitive axis.
`Automatically computed`	Joint primitive motion from automatic calculation. Simscape Multibody computes and applies the joint primitive motion based on model dynamics.

Revolute Primitive: Sensing

Select the variables to sense in the revolute joint primitive. Selecting a variable exposes a physical signal port that outputs the measured quantity as a function of time. Each quantity is measured for the follower frame with respect to the base frame. It is resolved in the base frame. You can use the measurement signals for analysis or as input in a control system.

Position

Select this option to sense the relative rotation angle of the follower frame with respect to the base frame about the joint primitive axis.

Velocity

Select this option to sense the relative angular velocity of the follower frame with respect to the base frame about the joint primitive axis.

Acceleration

Select this option to sense the relative angular acceleration of the follower frame with respect to the base frame about the joint primitive axis.

Actuator Torque

Select this option to sense the actuation torque acting on the follower frame with respect to the base frame about the joint primitive axis.

Composite Force/Torque Sensing

Select the composite, or joint-wide, forces and torques to sense. These are forces and torques that act not at individual joint primitives but at the whole joint. Options include constraint and total forces and torques.

During simulation, the block computes the selected composite forces and torques acting between the base and follower port frames. It outputs these variables using physical signal output ports. Check the port labels to identify the output variables at different ports.

Direction

Forces and torques acting at joints do so in pairs. Newton's third law of motion requires that every action be accompanied by an equal and opposite reaction. If the base frame of a joint exerts a force or torque on the follower frame, then the follower frame must exert an equal and opposite force or torque on the base frame.

Select whether to sense the composite forces and torques exerted by the base frame on the follower frame or vice versa. The force and torque vector components are positive if they point along the positive X, Y, and Z axes of the selected resolution frame.

Resolution Frame

You can resolve a vector quantity into Cartesian components in different frames. If the resolution frames have different orientations, then the measured components are themselves different—even though the vector quantity remains the same.

Select the frame in which to resolve the sensed force and torque variables. Possible resolution frames include `Base` and `Follower`. The block outputs the Cartesian components of the sensed force and torque vectors as observed in this frame.

Constraint Force

Joint blocks with fewer than three translational degrees of freedom forbid motion along one or more axes. For example, the Gimbal Joint block forbids translation along all axes. To prevent translation along an axis, a joint block applies a constraint

force between its base and follower port frames. Constraint forces are orthogonal to joint translation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint force vector [fc_x, fc_y, fc_z] acting at the joint. Only constraint force components that are orthogonal to the joint translational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port fc.

Constraint Torque

Joint blocks with fewer than three rotational degrees of freedom forbid motion about one or more axes. For example, the Cartesian Joint block forbids rotation about all axes. To prevent rotation about an axis, a joint block applies a constraint torque between its base and follower port frames. Constraint torques are orthogonal to joint rotation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint torque vector [tc_x, tc_y, tc_z] acting at the joint. Only constraint torque components that are orthogonal to the joint rotational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port tc.

Total Force

A joint block generally applies various forces between its port frames:

- Actuation forces that drive prismatic joint primitives.
- Internal spring and damper forces that resist motion at prismatic joint primitives.
- Constraint forces that forbid motion in directions orthogonal to prismatic joint primitives.

The net sum of the different force components equals the total force acting between the joint port frames. Select the check box to compute and output the 3-D total force vector [ft_x, ft_y, ft_z]. Selecting this option causes the block to expose physical signal port ft.

Total Torque

A joint block generally applies various torques between its port frames:

- Actuation torques that drive revolute or spherical joint primitives.
- Internal spring and damper torques that resist motion at revolute or spherical joint primitives.
- Constraint torques that forbid motion in directions orthogonal to the revolute or spherical joint primitive axes.

The net sum of the different torque components equals the total torque acting at a joint. Select the check box to compute and output the 3-D total torque vector [tt_x, tt_y, tt_z]. Selecting this option causes the block to expose physical signal port tt.

Ports

This block has two frame ports. It also has optional physical signal ports for specifying actuation inputs and sensing dynamical variables such as forces, torques, and motion. You expose an optional port by selecting the sensing check box corresponding to that port.

Frame Ports

- B — Base frame
- F — Follower frame

Actuation Ports

The revolute joint primitives provide the following actuation ports:

- tx, ty — Actuation torques acting on the X and Y revolute joint primitives
- qx, qy — Desired rotations of the X and Y revolute joint primitives

Sensing Ports

The revolute joint primitives provide the following sensing ports:

- qx, qy — Angular positions of the X and Y revolute joint primitives
- wx, wy — Angular velocities of the X and Y revolute joint primitives
- bx, by — Angular accelerations of the X and Y revolute joint primitives
- tx, ty — Actuation torques acting on the X and Y revolute joint primitives

The following sensing ports provide the composite forces and torques acting on the joint:

- fc — Constraint force
- tc — Constraint torque

- ft — Total force
- tt — Total torque

See Also

`Gimbal Joint` | `Revolute Joint`

More About

- "Actuating and Sensing with Physical Signals"
- "Motion Sensing"
- "Rotational Measurements"
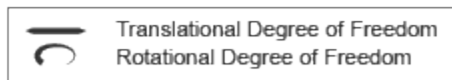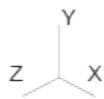
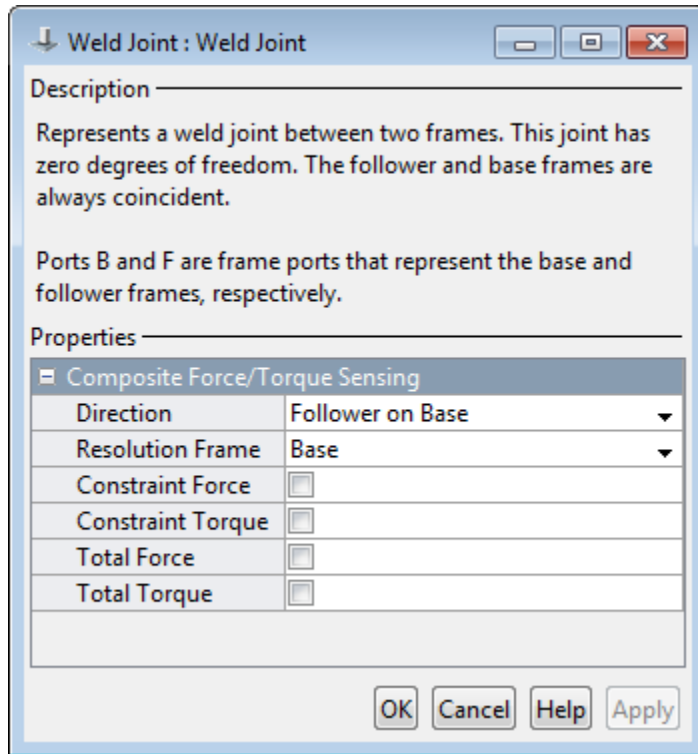# Weld Joint

Joint with zero primitives
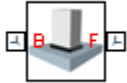
Library

Joints

Description

This block represents a joint with zero degrees of freedom. It contains no joint primitives. Base and follower frames, each connected to a separate rigid body, are coincident for all time. The block dialog box provides sensing options for constraint and total forces and torques.

Joint Degrees of Freedom

Dialog Box and Parameters

Composite Force/Torque Sensing

Select the composite, or joint-wide, forces and torques to sense. These are forces and torques that act not at individual joint primitives but at the whole joint. Options include constraint and total forces and torques.

During simulation, the block computes the selected composite forces and torques acting between the base and follower port frames. It outputs these variables using physical signal output ports. Check the port labels to identify the output variables at different ports.

Direction

Forces and torques acting at joints do so in pairs. Newton's third law of motion requires that every action be accompanied by an equal and opposite reaction. If the base frame of a joint exerts a force or torque on the follower frame, then the follower frame must exert an equal and opposite force or torque on the base frame.

Select whether to sense the composite forces and torques exerted by the base frame on the follower frame or vice versa. The force and torque vector components are positive if they point along the positive X, Y, and Z axes of the selected resolution frame.

Resolution Frame

You can resolve a vector quantity into Cartesian components in different frames. If the resolution frames have different orientations, then the measured components are themselves different—even though the vector quantity remains the same.

Select the frame in which to resolve the sensed force and torque variables. Possible resolution frames include `Base` and `Follower`. The block outputs the Cartesian components of the sensed force and torque vectors as observed in this frame.

Constraint Force

Joint blocks with fewer than three translational degrees of freedom forbid motion along one or more axes. For example, the Gimbal Joint block forbids translation along all axes. To prevent translation along an axis, a joint block applies a constraint force between its base and follower port frames. Constraint forces are orthogonal to joint translation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint force vector [fc_x, fc_y, fc_z] acting at the joint. Only constraint force components that are orthogonal to the joint translational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port fc.

Constraint Torque

Joint blocks with fewer than three rotational degrees of freedom forbid motion about one or more axes. For example, the Cartesian Joint block forbids rotation about all axes. To prevent rotation about an axis, a joint block applies a constraint torque between its base and follower port frames. Constraint torques are orthogonal to joint rotation axes and therefore do no work.

Select the check box to compute and output the 3-D constraint torque vector [tc_x, tc_y, tc_z] acting at the joint. Only constraint torque components that are orthogonal to the joint rotational degrees of freedom have nonzero values. Selecting this option causes the block to expose physical signal port tc.

Total Force

A joint block generally applies various forces between its port frames:

- Actuation forces that drive prismatic joint primitives.
- Internal spring and damper forces that resist motion at prismatic joint primitives.
- Constraint forces that forbid motion in directions orthogonal to prismatic joint primitives.

The net sum of the different force components equals the total force acting between the joint port frames. Select the check box to compute and output the 3-D total force vector $[ft_x, ft_y, ft_z]$. Selecting this option causes the block to expose physical signal port ft.

Total Torque

A joint block generally applies various torques between its port frames:

- Actuation torques that drive revolute or spherical joint primitives.
- Internal spring and damper torques that resist motion at revolute or spherical joint primitives.
- Constraint torques that forbid motion in directions orthogonal to the revolute or spherical joint primitive axes.

The net sum of the different torque components equals the total torque acting at a joint. Select the check box to compute and output the 3-D total torque vector $[tt_x, tt_y, tt_z]$. Selecting this option causes the block to expose physical signal port tt.

Ports

This block has two frame ports. It also has optional physical signal ports for sensing dynamical variables such as forces, torques, and motion. You expose an optional port by selecting the sensing check box corresponding to that port.

Frame Ports

- B — Base frame
- F — Follower frame

Sensing Ports

The following sensing ports provide the composite forces and torques acting on the joint:

- fc — Constraint force
- tc — Constraint torque
- ft — Total force
- tt — Total torque

See Also

`Rigid Transform`
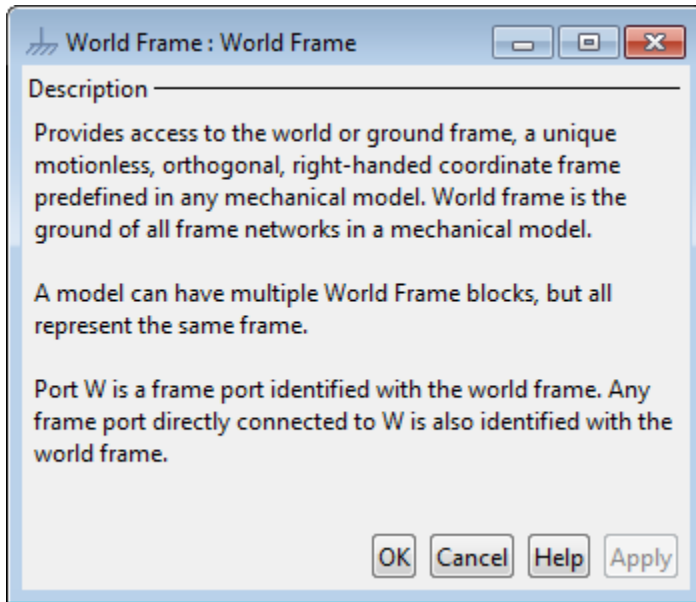
World Frame

Inertial reference frame

Library

Frames and Transforms

Description

This block represents the global reference frame in a model. This frame is inertial and at absolute rest. Rigidly connecting a frame to the World frame makes that frame inertial. Frame axes are orthogonal and arranged according to the right-hand rule.

In a frame network, the World frame is the ultimate reference frame. Directly or indirectly, all other frames are defined with respect to the World frame. If multiple World Frame blocks connect to the same frame network, those blocks identify the same frame. If no World Frame block connects to a frame network, a copy of an existing frame, frozen in its initial position and orientation, serves as the World frame.

Dialog Box and Parameters

Ports

This block contains frame port W, representing the World frame.

See Also
`Reference Frame` | `Rigid Transform`

More About
- "World and Reference Frames"
- "Representing Frames"

2

Configuration Parameters

Simscape Multibody Pane: General

The SimMechanics Second Generation (2G) configuration parameters are arranged into the following sections :

Diagnostics

This section contains configurable diagnostic messages. The messages can be configured to be ignored or to be reported as warnings or errors. Errors will prevent simulation while warnings will allow simulation to proceed. The Mechanics Explorer (if selected) will be opened and visualization shown in all cases.

Explorer

This section contains parameters that configure the Mechanics Explorer.

Simscape Multibody Pane Overview

Configure the mechanical settings for an entire Simscape Multibody model.

Configuration

- This pane appears only if your model contains at least one block from the Simscape product or a product based on the Simscape product, such as the Simscape Multibody product.

- The settings in this pane are saved only if your model contains at least one Simscape Multibody block.

Simscape Multibody Pane: Diagnostics

In this section...

Invalid visual properties

Select the diagnostic action to take if the application detects an improperly specified color vector.

Settings

Default: `warning`

`none`

    The application does not check for this situation.

`warning`

    When the application detects this situation, it displays a warning.

`error`

    When the application detects this situation, it terminates the simulation and displays an error message.

Command-Line Information

Parameter: `SimMechanicsInvalidVisualProperty`
Type: string
Value: `none` | `warning` | `error`
Default: `warning`

Repeated vertices in a cross-section

Select the diagnostic action to take if the application detects repeated vertices in a cross-section.

Settings

Default: `warning`

`none`

> The application does not check for this situation.

`warning`

> When the application detects this situation, it displays a warning.

`error`

> When the application detects this situation, it terminates the simulation and displays an error message.

Command-Line Information

Parameter: `SimMechanicsCrossSectionNullEdge`
Type: string
Value: `none` | `warning` | `error`
Default: `warning`

Unconnected frame port

Select the diagnostic action to take if the application detects an unconnected frame port.

Settings

Default: `Warning`

`none`

> The application does not check for this situation.

`warning`

> When the application detects this situation, it displays a warning.

`error`

> When the application detects this situation, it terminates the simulation and displays an error message.

Command-Line Information
Parameter: `SimMechanicsUnconnectedFramePorts`
Type: string
Value: `none` | `warning` | `error`
Default: `warning`

Unconnected Geometry port

Select the diagnostic action to take if the application detects an unconnected geometry port.

Settings

Default: `Warning`

`none`

> The application does not check for this situation.

`warning`

> When the application detects this situation, it displays a warning.

`error`

> When the application detects this situation, it terminates the simulation and displays an error message.

Command-Line Information
Parameter: SimMechanicsUnconnectedGeometryPorts
Type: string
Value: none | warning | error
Default: warning

Redundant block

Select the diagnostic action to take if the application detects a redundant block in the model.

Settings

Default: `warning`

`none`

   The application does not check for this situation.

`warning`

   When the application detects this situation, it displays a warning.

`error`

   When the application detects this situation, it terminates the simulation and displays an error message.

Command-Line Information

Parameter: `SimMechanicsRedundantBlock`
Type: string
Value: `none` | `warning` | `error`
Default: `warning`

Conflicting reference frames

Select the diagnostic action to take if the application detects conflicting reference frames in the model.

Settings

Default: `warning`

`none`

> The application does not check for this situation.

`warning`

> When the application detects this situation, it displays a warning.

`error`

> When the application detects this situation, it terminates the simulation and displays an error message.

Command-Line Information
Parameter: `SimMechanicsConflictingReferenceFrames`
Type: string
Value: `none` | `warning` | `error`
Default: `warning`

Rigidly constrained block

Select the diagnostic action to take if the application detects a rigidly constrained block in the model.

Settings

Default: `warning`

`none`

    The application does not check for this situation.

`warning`

    When the application detects this situation, it displays a warning.

`error`

    When the application detects this situation, it terminates the simulation and displays an error message.

Command-Line Information

Parameter: `SimMechanicsRigidlyBoundBlock`
Type: string
Value: `none` | `warning` | `error`
Default: `error`

Unsatisfied high priority state targets

Select the diagnostic action to take if the application detects targets with unsatisfied desired states in the model.

Settings

Default: `warning`

`none`

    The application does not check for this situation.

`warning`

    When the application detects this situation, it displays a warning.

`error`

    When the application detects this situation, it terminates the simulation and displays an error message.

Command-Line Information

Parameter: `SimMechanicsUnsatisfiedHighPriorityTargets`
Type: string
Value: `none` | `warning` | `error`
Default: `warning`

Overspecified targets in kinematic loops

Select the diagnostic action to take if the application detects overspecified targets contained in kinematic loops in the model.

Settings

Default: `warning`

`none`

> The application does not check for this situation.

`warning`

> When the application detects this situation, it displays a warning.

`error`

> When the application detects this situation, it terminates the simulation and displays an error message.

Command-Line Information

Parameter: `SimMechanicsJointTargetOverSpecification`
Type: string
Value: `none` | `warning` | `error`
Default: `error`

Simscape Multibody Pane: Explorer

☑ Open Mechanics Explorer on model update or simulation

Open Mechanics Explorer on model update or simulation

Start Mechanics Explorer when model is updated or simulated.

Settings

Default: on

☑ On

Model Explorer starts when model is updated or simulated.

☐ Off

Model Explorer does not start when model is updated or simulated.

Tip

If you clear this check box, you can start Model Explorer by selecting **Desktop** > **Mechanics Explorers** from the MATLAB Command Window.

Command-Line Information
Parameter: `SimMechanicsOpenEditorOnUpdate`
Type: string
Value: `'on'` | `'off'`
**Default:** `'on'`

Multibody Visualization

Mechanics Explorer

Visualize and explore multibody models

Description

Mechanics Explorer is a Simscape Multibody tool based on the Silicon Graphics OpenGL®
API that lets you visualize and explore your multibody models. The tool comprises a
visualization pane to view the model, a tree view pane to explore the model hierarchy,
and a properties pane to examine the individual component parameters.

Tree View Pane   Properties Pane   Visualization Pane
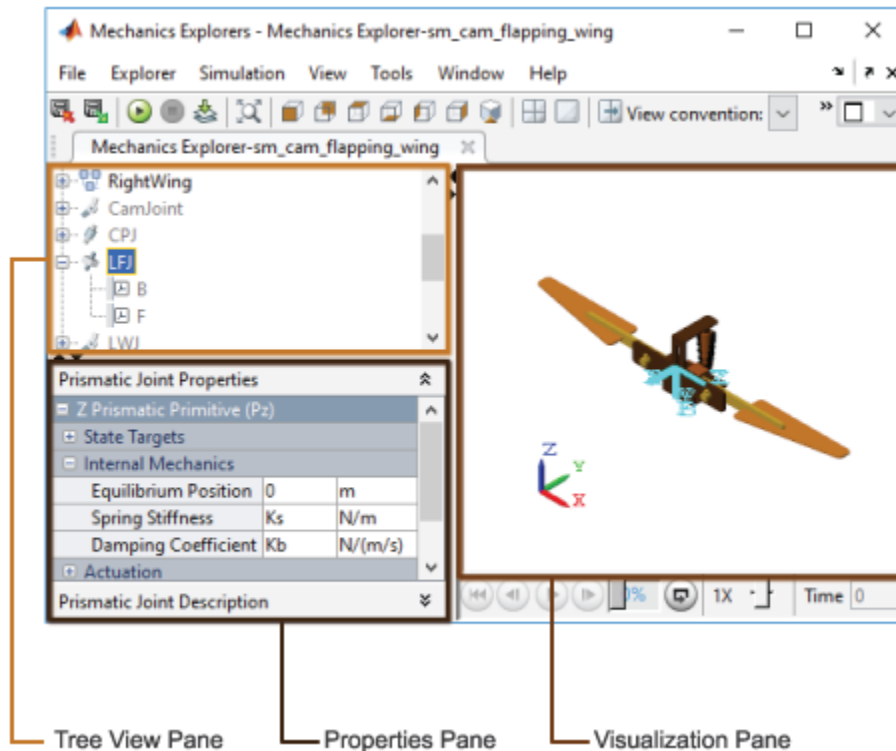
The visualization pane is interactive and allows you to manipulate the model viewpoint.
You can rotate, roll, pan, and zoom the model to more clearly view its components. You

can also select from a list of preset viewpoints that includes isometric, front, side, and top views. To access the view manipulation tools, use the Mechanics Explorer **View** menu.

For more information on view manipulation, see "Manipulate the Visualization Viewpoint".

A Camera Manager tool allows you to create, edit, and delete dynamic cameras with moving viewpoints. You can interactively set the camera views at discrete playback times (`Keyframes` mode) or constrain the camera to coordinate frames in your model (`Tracking` mode). To open Camera Manager, in the Mechanics Explorer menu bar, select **Tools** > **Camera Manager**.

For more information on dynamic cameras, see "Create a Dynamic Camera".

A Video Creator tool allows you to configure and create videos from your multibody animations. You can set the video frame rate, frame size, playback speed ratio, and file format. Video Creator captures the model animation as shown in the active visualization tile the moment you click the **Create** button. To open Video Creator, in the Mechanics Explorer menu bar, select **Tools** > **Video Creator**.

For more information on video creation, see "Create a Model Animation Video".

Open the Mechanics Explorer App

Update or simulate the model you want to visualize. By default, Mechanics Explorer opens automatically with the corresponding model visualization. The visualization shows the initial model configuration on model update and a dynamic animation during model simulation. If Mechanics Explorer fails to open, check that automatic model visualization is enabled:

1 In the Simulink menu bar, select **Simulation** > **Model Configuration Parameters**.
2 In the Model Configuration Parameters window, select **Simscape Multibody** > **Explorer**.
3 Select the **Open Mechanics Explorer on model update or simulation** check box.

Examples

• "Manipulate the Visualization Viewpoint"

- "Create a Dynamic Camera"
- "Selectively Show and Hide Model Components"
- "Visualize Simscape Multibody Frames"
- "Go to a Block from Mechanics Explorer"
- "Create a Model Animation Video"

Introduced in R2012a

Camera Manager

Create, edit, and delete dynamic cameras

Description

Camera Manager is a Mechanics Explorer tool that lets you create, edit, and delete cameras with dynamic viewpoints.

You can constrain the camera trajectories using keyframe and tracking modes. Use the keyframe mode to set the camera viewpoints at specific playback times and apply smooth interpolation between them. Use the tracking mode to fix the camera position and aim to coordinate frames and follow them during playback.

The cameras that you create appear in the cameras list shown in the visualization context-sensitive menu. To select a camera, right-click the visualization pane and select **Camera**. If the visualization pane is split into tiles, you can assign a different camera to each tile. All dynamic cameras use a perspective projection to capture the visualization contents.

Open the Camera Manager App

From the Mechanics Explorer menu bar, select **Tools** > **Camera Manager**. To open the camera definition pane, click the ⊞ button in the **New Camera** field or the ✎ button in an existing camera field. Use the camera definition pane to set the camera mode and trajectory constraints.

Parameters

`Camera Name` — Name of the camera
MATLAB string

Label used to identify the camera in the main pane of Camera Manager and in the visualization context-sensitive menu.

Mode — Dynamic camera mode
Keyframes (default) | Tracking

Select a mode for defining the camera trajectory:

- `Keyframes` — Set the camera viewpoints at specific playback times. The camera trajectory is the result of smooth interpolation applied between keyframes.
- `Tracking` — Constrain the camera position, aim, and up vector to coordinate frames in the model. The camera trajectory is the result of the constraints applied to the camera.

`Keyframes` — Set, remove, and navigate keyframes
Buttons

Use the buttons to set, remove, and navigate camera keyframes:

- **Set** — Define a keyframe with the current viewpoint shown in the active visualization tile. Click **Set** for an existing keyframe to modify its definition.
- **Remove** — Remove the currently selected keyframe from the camera trajectory definition. The location of the playback slider identifies the selected keyframe.
- **Previous** and **Next** — Jump to the previous or next defined keyframes.

Before setting keyframes, you must simulate the model and pause playback. The **Keyframes** parameter is active only when the **Mode** parameter is set to `Keyframes`.

`Position` — Fix the camera position to a frame origin
Button

Frame origin used to constrain the camera position. During simulation, the camera position follows the trajectory traced by the selected frame origin. To set the camera position:

1 In the Mechanics Explorer visualization or tree view panes, select a coordinate frame.
2 In Camera Manager, click the **Use Selected Frame** button.

Be sure to select the frame itself and not simply the solid or body it belongs to. The **Position** parameter is active only when the **Mode** parameter is set to `Tracking`.

`Aim` — Fix the camera aim to a frame origin or along a frame axis
Button

Frame origin or axis used to constrain the camera orientation. During simulation, the camera aim stays fixed on the selected frame origin or aligned along the selected frame axis. To set the camera aim:

1 In the Mechanics Explorer visualization or tree view panes, select a coordinate frame.

2 In Camera Manager, click the **Use Selected Frame** button.

3 From the adjacent drop-down list, select the frame origin or axis to constrain the camera aim to.

Be sure to select the frame itself and not simply the solid or body it belongs to. The **Aim** parameter is active only when the **Mode** parameter is set to `Tracking`.

Up Vector — Fix the camera up direction along a frame axis
Button

Frame axis used to constrain the camera up direction. During simulation, the up direction stays aligned with the selected axis. To set the camera up direction:

1 In the Mechanics Explorer visualization or tree view panes, select a coordinate frame.

2 In Camera Manager, click the **Use Selected Frame** button.

3 From the adjacent drop-down list, select the frame axis to align the camera up direction with.

Be sure to select the frame itself and not simply the solid or body it belongs to. This parameter is active only when the **Mode** parameter is set to `Tracking`.

More About

· "Visualization Cameras"
· "Create a Dynamic Camera"

Introduced in R2016a

Video Creator

Configure and create multibody animation videos

Description

Video Creator is a Mechanics Explorer tool that lets you configure and create videos of multibody animations. You can modify the video playback speed, frame rate, file format, and frame size. Click **Create** to generate a video with the specified properties. Use the `smwritevideo` function for a programmatic alternative to Video Creator.

Open the Video Creator App

From the Mechanics Explorer menu bar, select **Tools** > **Video Creator**. You must simulate the model in order to use Video Creator or the programmatic equivalent `smwritevideo` function.

Parameters

`Playback Speed Ratio` — Video playback speed relative to real time
1.0 (default)

Video playback speed relative to real time, specified as a positive number. The video plays faster than real time at values greater than 1 and slower at values smaller than 1. For example, a ratio of 2 doubles the playback speed while a ratio of 0.5 halves it.

`Frame Rate (FPS)` — Number of video frames per second
30 (default)

Number of video frames per second of playback time, specified as a positive number. Larger frame rates result in smoother video playback time but also larger file sizes.

`Video Format` — Video file format
Motion JPEG AVI (default) | Archival | Motion JPEG 2000 | MPEG-4 | Uncompressed AVI

File format to save the video in. The dropdown list provides various formats to select from, including compressed and uncompressed formats.

`Frame Size` — Video frame width and height
auto (default)

Video frame width and height, specified in pixel units as the two-element row vector [Width Height]. The frame dimensions must be positive integers. For example, the vector [800 400] sets the video frame dimensions to 800 pixels in width and 400 pixels in height. Enter the string `auto` instead to use the current dimensions of the active visualization tile in Mechanics Explorer.

See Also
smwritevideo

Introduced in R2016b

Functions—Alphabetical List

sm_lib

Open the Simscape Multibody block library

Syntax

```
sm_lib
```

Description

`sm_lib` opens the Simscape Multibody block library. Use this function to access Simscape Multibody blocks without having to wait for the Simulink and Simscape libraries to load.

Examples

Open the Simscape Multibody Block Library

Open the block library from the MATLAB command prompt

```
sm_lib
```

The Simscape Multibody block library opens in a new window.

· "Open the Simscape Multibody Model Template"

See Also
smnew

Introduced in R2012a

smimport

Generate a Simscape Multibody model from an XML import file

Syntax

```
[H,dataFileName] = smimport(xmlFileName)
[H,dataFileName] = smimport(xmlFileName,Name,Value)
```

Description

`[H,dataFileName] = smimport(xmlFileName)` generates a Simscape Multibody model and supporting data file from an XML import file. `H` is the model handle and `dataFileName` is the name of the supporting data file. By default, the model and data file are named after the XML import file.

`xmlFileName` is the name of the XML import file. The file extension is optional. You can append the full or relative file path to the file name. In the absence of a file path, the function searches for the file name on the MATLAB path. If the XML import file name violates MATLAB naming rules, the model and data file take on modified versions of the XML file name.

The XML import file details the structure and properties of the multibody model you are importing. To be valid. the file must conform to the published Simscape Multibody XML schema. If you use a supported CAD application, you can generate a valid XML import file using the Simscape Multibody Link CAD plug-in.

The plug-in exports assemblies in two formats, one for Simscape Multibody models, the other for Simscape Multibody First Generation models. The `smimport` function accepts only XML import files generate for Simscape Multibody models. For Simscape Multibody First Generation models, use `mech_import` instead.

The data file provides the numerical values of the block parameters in the form of a MATLAB data structure. Blocks in the imported model reference the MATLAB structure fields through the model workspace. The default structure name is smiData.

`[H,dataFileName] = smimport(xmlFileName,Name,Value)` adds options for specifying the import mode and various file names. Set `ImportMode` to `dataFile`

in order to generate a new data file for a previously imported model. Specify `PriorDataFile` to catch unexpected changes to the XML import file, such as part name changes or the addition and deletion of parts.

Input Arguments

`xmlFileName` — XML import file name
string

XML import file name. The XML import file provides Simscape Multibody software a detailed description of the multibody model to generate. The file extension and path are optional parts of the argument. In the absence of a file path, the function searches for the file name on the current MATLAB path. The file name must conform to the MATLAB naming conventions.

Example: `'robotto'`

Name-Value Arguments

Specify optional comma-separated pairs of `Name,Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (`'  '`). You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

`'ImportMode'` — Choice of model import or data file update function modes
`modelAndDataFile` (default) | `dataFile`

Option to generate a new model or update existing model data. Set `ImportMode` to `modelAndDataFile` to generate a new model and data file. Set `ImportMode` to `dataFile` to generate a new data file for a previously imported model. The function does not update the block diagram itself. If you do not specify `ImportMode`, the function runs in `modelAndDataFile` mode.

Example: `'dataFile'`

`'ModelName'` — Name of the multibody model to generate
string

Name of the Simscape Multibody model to generate. The model is saved in SLX format. This argument is not valid when `ImportMode` is set to `dataFile`. If you do not specify

`ModelName`, the model file is named after the XML import file. If the XML import file name is inconsistent with MATLAB naming conventions, a modified version is used instead.

Example: `'robotto'`

`'DataFileName'` — Name of the parameter data file to generate
string

Name of the supporting parameter data file. The data file is an M file with the block parameter values referenced in the imported Simscape Multibody model. If you do not specify `DataFileName`, the data file is named after the XML import file. If the XML import file name is inconsistent with MATLAB naming conventions, a modified version is used instead.

Example: `'robottos_new_data'`

`'PriorDataFile'` — Name of the last used parameter data file
string

Name of the last parameter data file associated with a previously imported model. The prior data file helps to identify changes requiring special attention, such as new physical units, added and deleted components, and model topology changes. This argument is valid only when `ImportMode` is set to `dataFile`.

Example: `'robottos_original_data'`

`'VariableName'` — Name of the MATLAB structure provided in the parameter data file
string

Name of the MATLAB data structure provided in the parameter data file. This structure contains the numerical values of all block parameters in the imported Simscape Multibody model. If you do not specify `VariableName`, the data structure is named `smiData`.

Example: `'robottosData'`

Output Arguments

`H` — Model handle
double

Model handle returned as a double. Use the model handle to get or set model parameters, for example, using the `get_param` and `set_param` functions.

`dataFileName` — Name of the parameter data file
string

Name of the parameter data file. The data file is an M file with the block parameter values referenced in the imported Simscape Multibody model.

Examples

Import Robot Model

Generate a robotic arm model from the `sm_robot.xml` import file included in your Simscape Multibody installation. At the MATLAB command prompt, enter the following code.

```
smimport('sm_robot');
```

Import Robot Model Using Custom File Names

Generate a robotic arm model from the `sm_robot.xml` import file included in your Simscape Multibody installation. Specify the model name as `robotto` and the data file name as `robottos_data_file`. At the MATLAB command prompt, enter the following code.

```
smimport('sm_robot','ModelName','robotto',...
'DataFileName','robottos_data_file');
```

Regenerate Data File for Previously Imported Model

Regenerate the data file for the previously imported robotic arm model. Specify the data file name as `robottos_new_data_file` to avoid overwriting the original data file. At the MATLAB command prompt, enter the following code.

```
smimport('sm_robot','ImportMode','dataFile','DataFileName',...
'robottos_new_data_file','PriorDataFile','robottos_data_file');
```

Point the previously generated model to the new data file and reinitialize the model workspace using the following MATLAB code.

```
hws = get_param(bdroot,'modelworkspace');
hws.DataSource = 'MATLAB File';
hws.FileName = 'robotFileData';
hws.reload;
```

You can perform the same task using Model Explorer. In the Model Workspace pane for the imported model, update the **File Name** parameter. Then, click the **Reinitialize from Source** button.

See Also

sm_lib | smnew

smnew

Open Simscape Multibody model template and block library

Syntax

```
smnew
smnew(modelName)
smnew(modelName,solverType)
```

Description

smnew opens the Simscape Multibody model template and block library. The template contains commonly used blocks and employs variable-step automatic solver selection for best performance. Simscape data logging is enabled by default, with the data history limit set to 10,000 data points.

smnew(modelName) adds an option to specify the name of the template-based model.

smnew(modelName,solverType) adds an option to specify the model Simulink solver.

Examples

Open the Simscape Multibody Model Template

Open the Simscape Multibody model template from the MATLAB command prompt:

```
smnew
```

The Simscape Multibody model template and block library open. The template is named untitled and its solver type is set to auto.

Specify the Name for the Model Template

Name the model template robotto:

```
smnew('robotto')
```

The Simscape Multibody model template and block library open. The template is named robotto.

Specify the Name and Solver for the Model Template

Name the model template robotto and set the Simulink solver type to ode15s:

```
smnew('robotto','ode15s')
```

The Simscape Multibody model template and block library open. The template is named robotto and its solver type is set to ode15s.

- "Open the Simscape Multibody Model Template"

Input Arguments

modelName — Name of the template-based model
untitled (default) | Character vector with the model name

Name of the template-based model. The model name must conform to the MATLAB naming rules. Do not include the file path in the model name. If the specified character vector is invalid, the model opens as untitled.

Example: 'robotto'

Data Types: char

solverType — Simulink solver type to use for simulation
auto (default) | Character vector with the solver name

Solver to use for model simulation. The solver type must be a valid Simulink solver, such as ode45, or ode15s. Specify a variable-step solver unless you have a specific need for a fixed-step solver.

Example: 'ode15s'

Data Types: char

See Also
sm_lib

Introduced in R2012a

smwritevideo

Configure and create multibody animation videos

Syntax

```
smwritevideo(modelIdentifier,videoName)
smwritevideo(modelIdentifier,videoName,Name,Value)
```

Description

smwritevideo(modelIdentifier,videoName) creates an animated video from the visualization results of a multibody simulation. modelIdentifier is the source model name or handle. videoName is the generated video file name and path. You can open the video file with any compatible media player.

The video properties are those specified in the Video Creator interface the moment you run the function. If the Video Creator parameters are in their default settings, the video properties are set to those defaults.

Before running smwritevideo, you must simulate the model. In addition, the model visualization results must open in a Mechanics Explorer window. If you have previously disabled model visualization, reenable it before continuing. To do this, see "Enable Mechanics Explorer".

If the model visualization pane is split into tiles, the function captures only the active tile. A colored outline identifies the active tile. Select the desired tile before creating a video.

smwritevideo(modelIdentifier,videoName,Name,Value) adds options for specifying the video properties. Use the Name,Value pair arguments to change the video file format, frame refresh rate, frame width and height, and playback speed ratio. Unused arguments are set to the latest settings specified in the Video Creator tool.

Examples

Create Video of Flapping Wing Model

Create a video named `flapping_wing_video` from the simulation results of the `sm_cam_flapping_wing` featured example. Use the video settings currently specified in the Video Creator tool.

1   Open the flapping wing featured example.
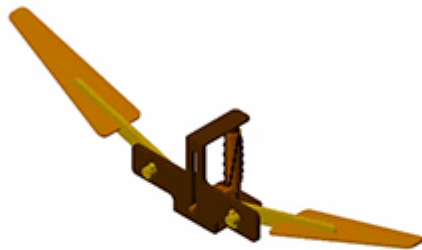
    ```
    sm_cam_flapping_wing
    ```
2   Simulate the model.

    ```
    sim('sm_cam_flapping_wing')
    ```
3   Create a video of the simulation results.

    ```
    smwritevideo('sm_cam_flapping_wing','flapping_wing_video');
    ```
    The function saves the video as `flapping_wing_video` in the current MATLAB folder. The video file format is that specified in the Video Creator tool. Open the video using your media player of choice.

Create Video of Double Wishbone Suspension Model

Create a video named `wishbone_suspension_video` from the simulation results of the `sm_double_wishbone_suspension` featured example. Change the video settings as shown in the table.

Property	Argument	Setting
Playback Speed Ratio	`PlaybackSpeedRatio`	`2.0`
Frame Rate (FPS)	`FrameRate`	`60`
Video Format	`VideoFormat`	`uncompressed avi`

1 Open the wishbone suspension featured example.

```
sm_double_wishbone_suspension
```
2 Simulate the model.

```
sim(s'm_double_wishbone_suspension')
```
3 Create a video of the simulation results.

```
smwritevideo('sm_double_wishbone_suspension', 'wishbone_suspension_video',...
'PlaybackSpeedRatio', 2.0, 'FrameRate', 60, 'VideoFormat', 'uncompressed avi');
```
The function saves the video as `wishbone_suspension_video`.mp4 in the current MATLAB folder. Open the video using your media player of choice. The video plays at twice the original speed seen in Mechanics Explorer.
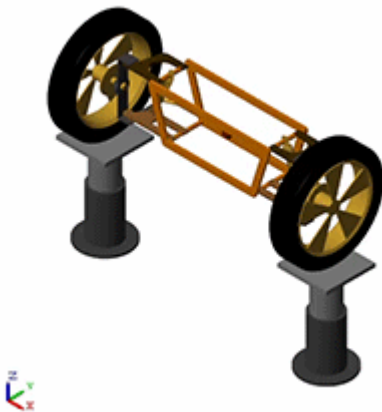
Input Arguments

`modelIdentifier` — Name or handle of the source model
Character vector with the model name or handle

Name or handle of the source model, specified as a MATLAB string. You must simulate the specified model before using this function. The model visualization window must be open in order for the function to create a video.

Example: 'sm_cam_flapping_wing'

Data Types: `string`

`videoName` — Name and path of the video file
Character vector with the desired video file name

Name and full or relative path of the video file, specified as a string. In the absence of a file path, the function saves the video file in the current MATLAB folder. The file format is determined from the video settings specified using the Video Creator tool or the `VideoFormat Name,Value` pair argument.

Example: 'flapping_wing_video'

Data Types: `string`

Name-Value Pair Arguments

Specify optional comma-separated pairs of `Name,Value` arguments. `Name` is the argument name and `Value` is the corresponding value. `Name` must appear inside single quotes (`' '`). You can specify several name and value pair arguments in any order as `Name1,Value1,...,NameN,ValueN`.

Example: 'PlaybackSpeedRatio', 2.0

`'PlaybackSpeedRatio'` — Playback speed relative to real time
1.0 (default)

Video playback speed relative to real time, specified as a positive scalar. Increase this factor for faster playback speeds. For example, a value of `2.0` doubles the video playback speed relative to the base playback speed used in Mechanics Explorer.

Data Types: `single | double | int8 | int16 | int32 | int64 | uint8 | uint16 | uint32 | uint64`

`'FrameRate'` — Number of video frames per second of playback time
30 (default)

Number of video frames per second of playback time, specified as a positive scalar. Increase this factor for smoother playback but larger video files. Small numbers may lead to choppy videos.

Data Types: `single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

`'VideoFormat'` — Video file format
motion jpeg avi (default) | archival | motion jpeg 2000 | mpeg-4 | uncompressed avi

File format to save the video in, specified as a string. Select from a list of compressed and uncompressed formats with varying quality levels and storage space requirements. Use the default format of `uncompressed jpeg avi` if file size is a concern. Use `uncompressed avi` if top video quality is a priority. The `mpeg-4` format is not supported in Linux systems.

Data Types: `string`

`'FrameSize'` — Video frame width and height
auto (default) | custom width and height

Width (W) and height (H) of the video contents, specified in pixel units as the two-element row vector [W H]. The vector elements must be positive integers. Use the default setting of `auto` to obtain the video dimensions from the Mechanics Explorer visualization pane size.

Example: [800 800]

Data Types: `single` | `double` | `int8` | `int16` | `int32` | `int64` | `uint8` | `uint16` | `uint32` | `uint64`

See Also
Video Creator

Introduced in R2016b