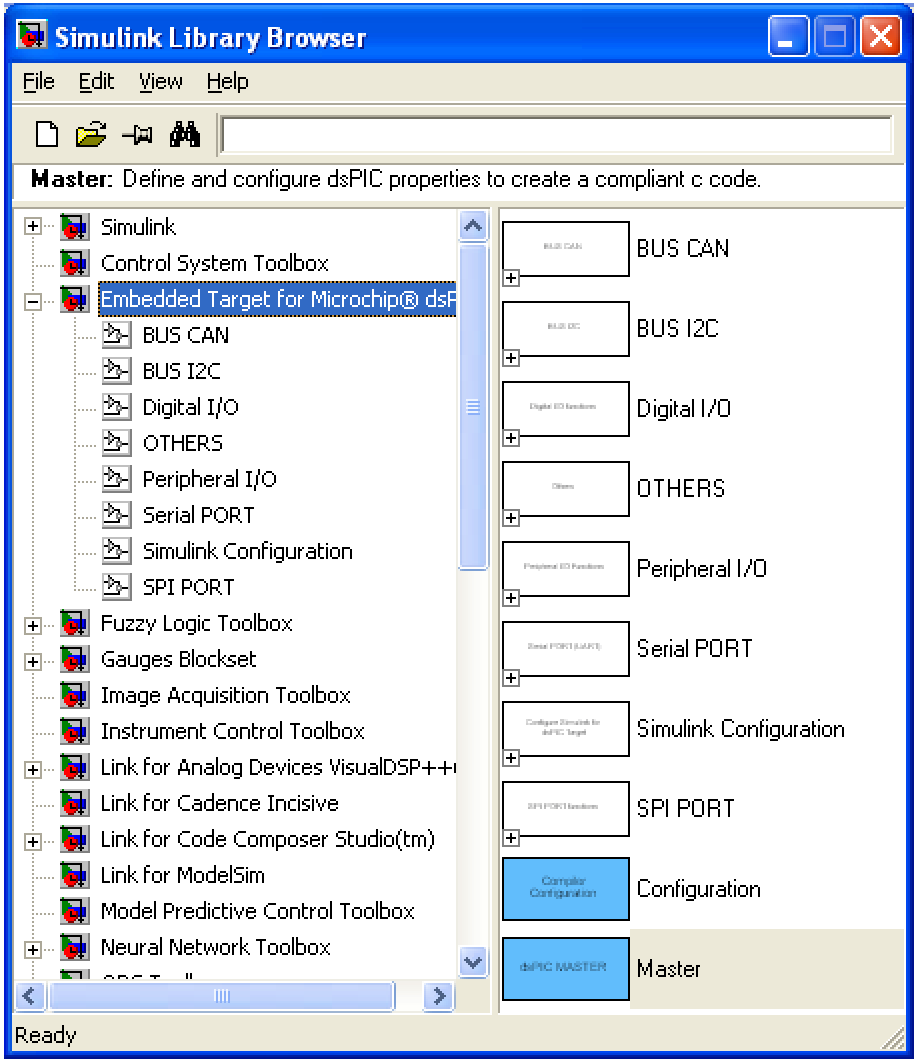
SimMechanics

What Is Simulink?

Simulink is a tool for simulating dynamic systems with a graphical interface specially developed for this purpose. Physical Modeling runs within the Simulink environment and interfaces seamlessly with the rest of Simulink and with MATLAB. Unlike other Simulink blocks, which represent mathematical operations or operate on signals, Physical Modeling blocks represent physical components or relationships directly.

simulink



Simulink Library Browser
File Edit View Help
Master: Define and configure dsPIC properties to create a compliant c code.
Simulink
Control System Toolbox
Embedded Target for Microchip® dsP
BUS CAN
BUS I2C
Digital I/O
OTHERS
Peripheral I/O
Serial PORT
Simulink Configuration
SPI PORT
Fuzzy Logic Toolbox
Gauges Blockset
Image Acquisition Toolbox
Instrument Control Toolbox
Link for Analog Devices VisualDSP++
Link for Cadence Incisive
Link for Code Composer Studio(tm)
Link for ModelSim
Model Predictive Control Toolbox
Neural Network Toolbox
BUS CAN
BUS I2C
Digital I/O
OTHERS
Peripheral I/O
Serial PORT
Simulink Configuration
SPI PORT
Configuration
Master
Ready

What Is SimMechanics?

SimMechanics is a part of Physical Modeling. Its purpose is the engineering design and simulation of mechanical systems of rigid bodies connected by joints, with the standard Newtonian dynamics of forces and torques. SimMechanics simulates translational and rotational motion in three dimensions. SimMechanics provides you with a suite of tools to specify bodies and their mass properties, their possible motions, kinematic constraints, coordinate systems, and the means of initiating and measuring motions.

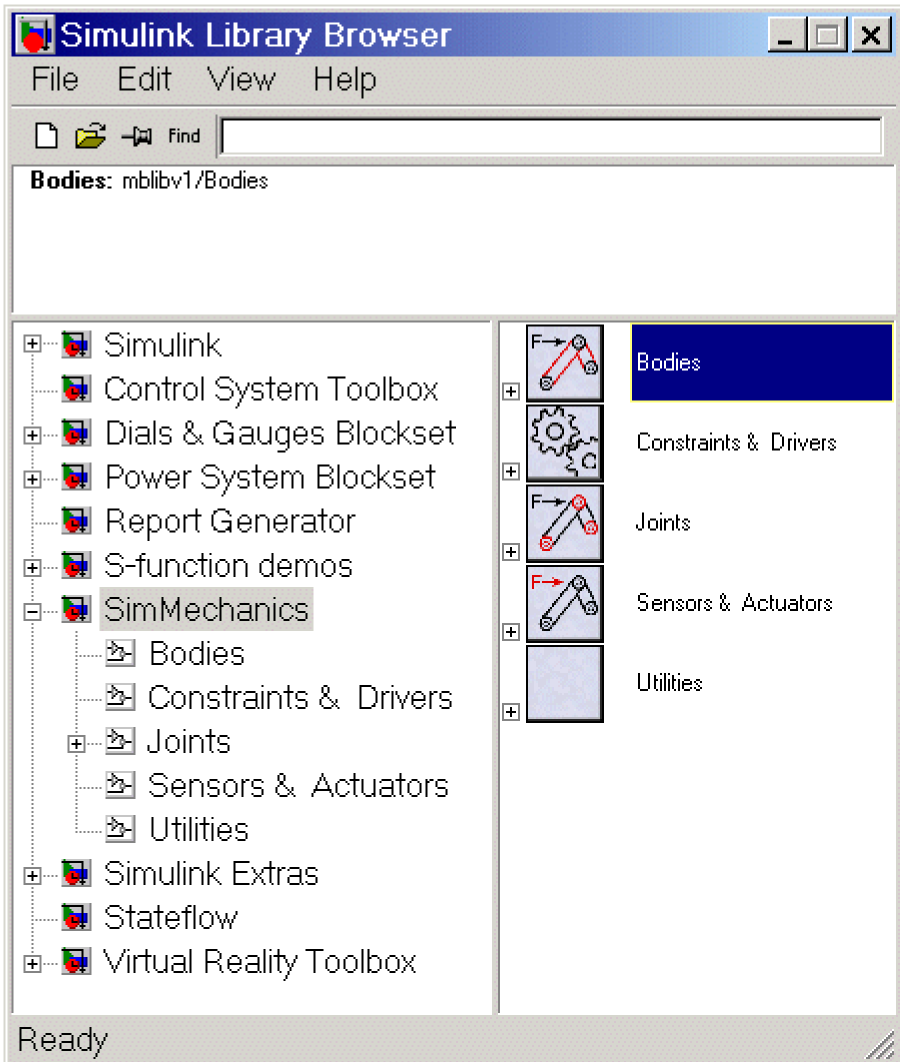
SimMechanics represents a mechanical system by a connected block diagram, like other Simulink models, and can encompass hierarchical subsystems.

Introducing the SimMechanics Block Libraries:

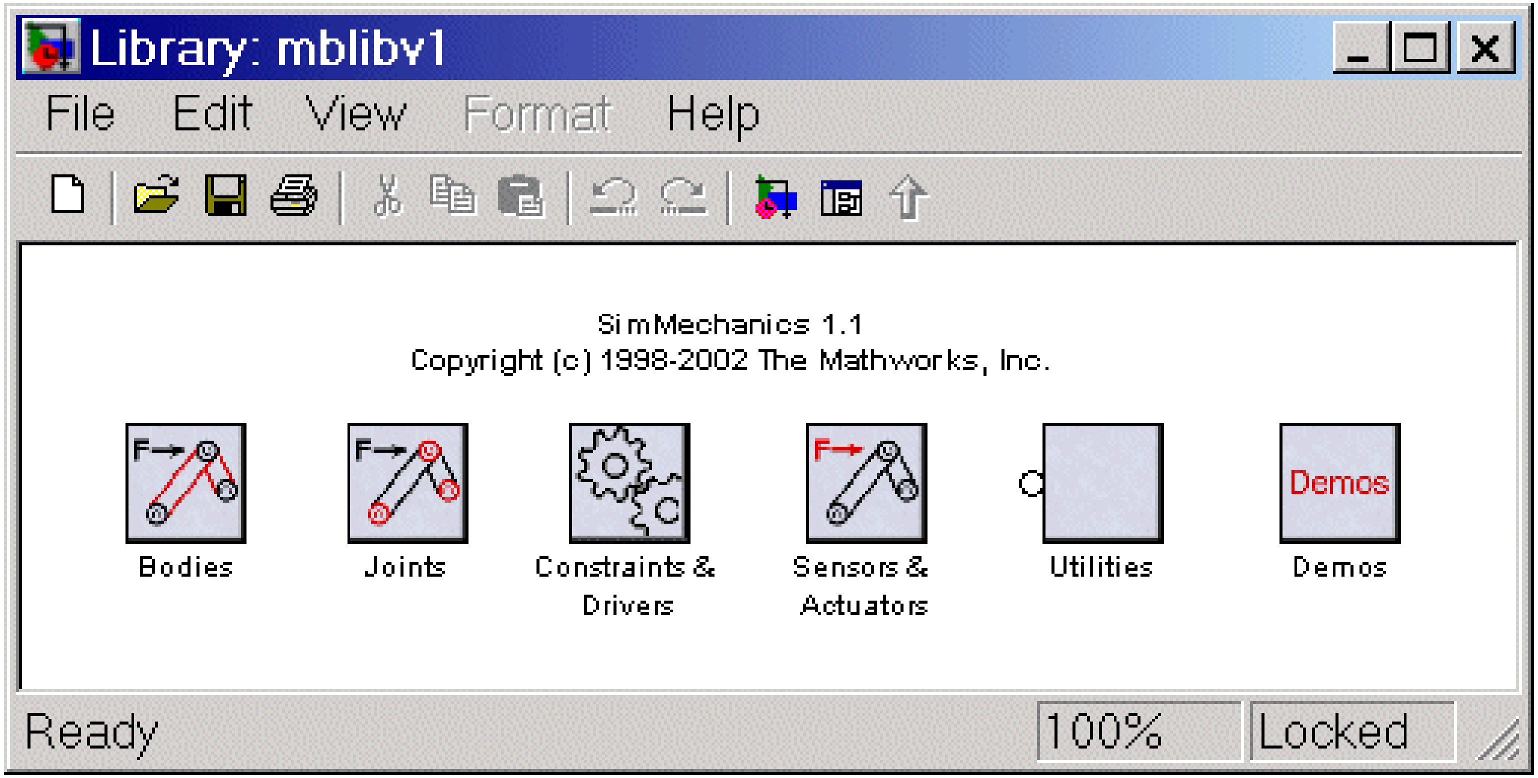
SimMechanics is organized into hierarchical libraries of closely related blocks:

- Bodies Library
- Joints Library
- Constraints & Drivers Library
- Sensors & Actuators Library
- Utilities Library
- Demos Library

SimMechanics



SimMechanics



- Bodies Library

The Bodies library provides the Body block for representing user-defined bodies by their mass properties (masses and inertia tensors), their positions and orientations, and their attached Body coordinate systems (CSs). This library also contains the Ground block representing immobile ground points, which have their own Grounded CSs.

- Joints Library

The Joints library provides the blocks to represent the relative motions between bodies as degrees of freedom (DoFs). The library is made up of assembled Joints listed individually and two sublibraries of specialized Joint blocks.

An assembled joint restricts the Body CSs on the two bodies to which it is connected. The assembled Joints are the primitive Prismatic, Revolute, and Spherical blocks and ready-made composite Joints. Unless it is explicitly labeled as disassembled, you can assume a generic Joint block is assembled.

- Constraints & Drivers Library

The Constraints & Drivers library provides blocks to specify prior restrictions on DoFs between Bodies. These restrictions can be time-independent constraints or time-dependent driving of DoFs with Simulink signals.

- Sensors & Actuators Library

The Sensors & Actuators library provides blocks for sensing and initiating the motions of joints and bodies. These blocks play a special role in connecting SimMechanics blocks to other Simulink blocks.

SimMechanics

- Utilities Library

The Utilities library contains miscellaneous blocks useful in building models.

- Demos Library

The Demos library contains prewritten Simulink demonstration models using SimMechanics and other Simulink blocks, as well as Stateflow blocks.
Double-clicking the Demos library icon calls the Help browser and displays the SimMechanics demos list.

Creating SimMechanics Models:

- Essential Steps to Build a Model
- Essential Steps to Configure and Run a Model

Essential Steps to Build a Model

Essential Steps to Build a Model:

- Select Ground, Body, and Joint blocks.
- Position and connect blocks.
- Configure Body blocks.
- Configure Joint blocks.
- Select, connect, and configure Constraint and Driver blocks.
- Select, connect, and configure Actuator and Sensor blocks.

Essential Steps to Build a Model

➢ Select Ground, Body, and Joint blocks.

From the Bodies and Joints libraries, drag and drop the Body and Joint blocks needed to represent your machine, including at least one Ground block, into a Simulink model window.

- The Machine Environment block represents your machine's mechanical settings.
- Ground blocks represent immobile ground points at rest in absolute (inertial) space.
- Body blocks represent rigid bodies.
- Joint blocks represent relative motions between the Body blocks to which they are connected.

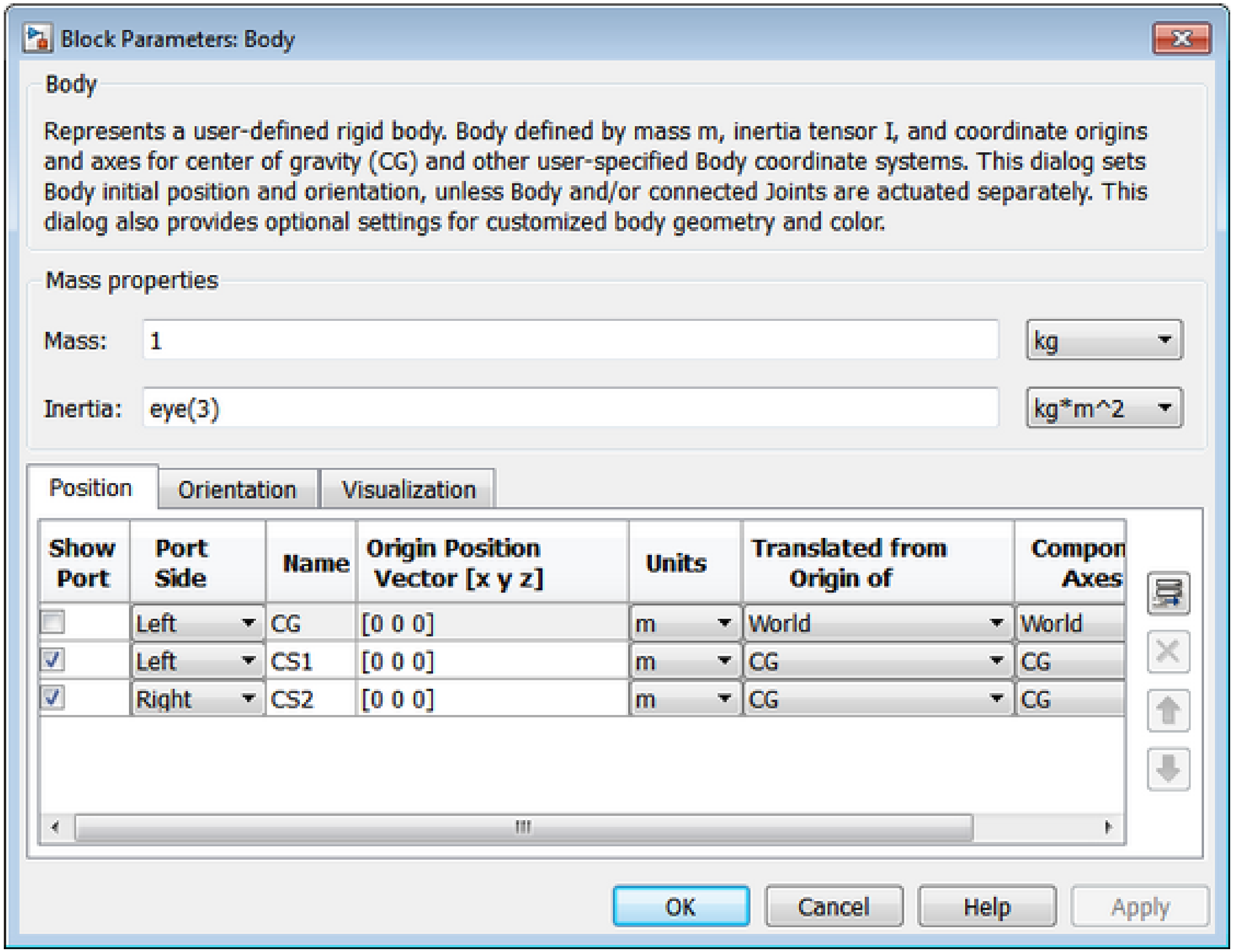
Essential Steps to Build a Model

1-Body:

Rigid body with frames, inertia and geometry

- The Body block represents a rigid body with properties you customize. The representation that you specify must include:
- The body's mass and moment of inertia tensor
- The coordinates for the body's center of gravity (CG)
- One or more Body coordinate systems (CSs)

Essential Steps to Build a Model



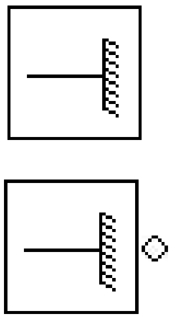
Essential Steps to Build a Model

2- Ground:

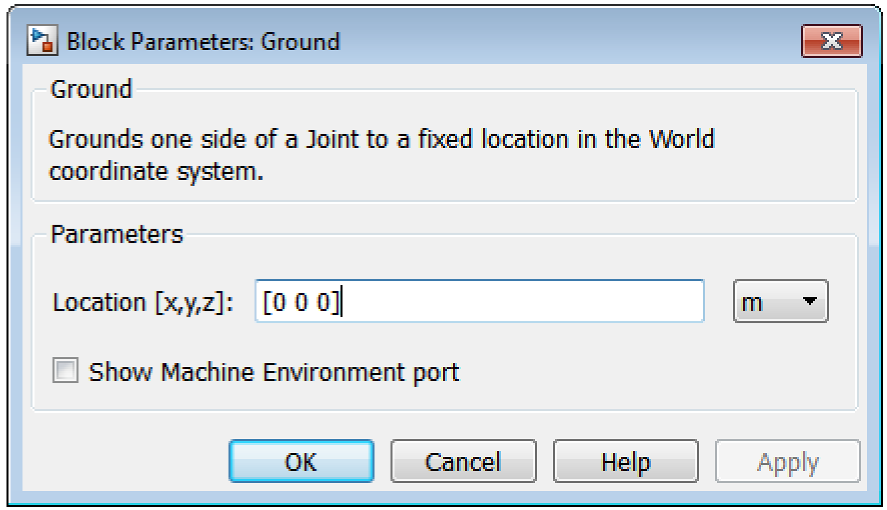
Fixed point attached to world

- Ground is a type of Body, but you can connect only one side of a Ground to a Joint block. A Ground block automatically carries a grounded coordinate system (CS). This Grounded CS is inertial, at rest in the World reference frame, with coordinate axes parallel to the World axes:
- $+x$ points right
- $+y$ points up (gravity in $-y$ direction)
- $+z$ points out of the screen, in three dimensions
- Enter the position of the ground point translated from the origin of the World CS. The position is specified as a translation vector (x,y,z), with components projected onto the fixed World CS axes. Set the Ground position units using the pull-down menu to the right. The defaults are [0 0 0] and m (meters).

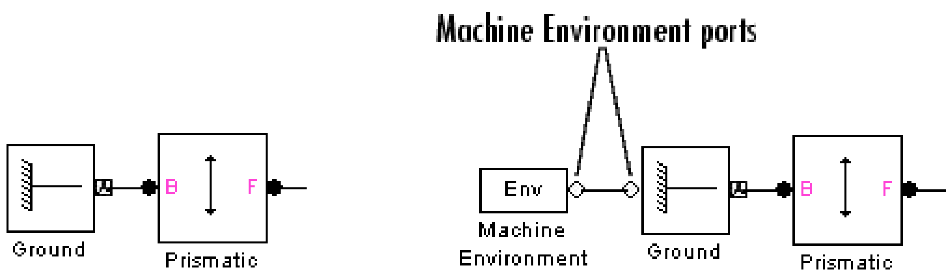
Essential Steps to Build a Model



Dialog Box and Parameters



A Ground Without and With a Connected Machine Environment Block



Essential Steps to Build a Model

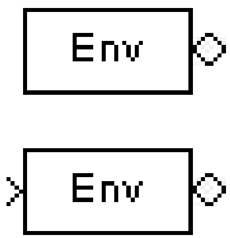
3- Machine Environment:

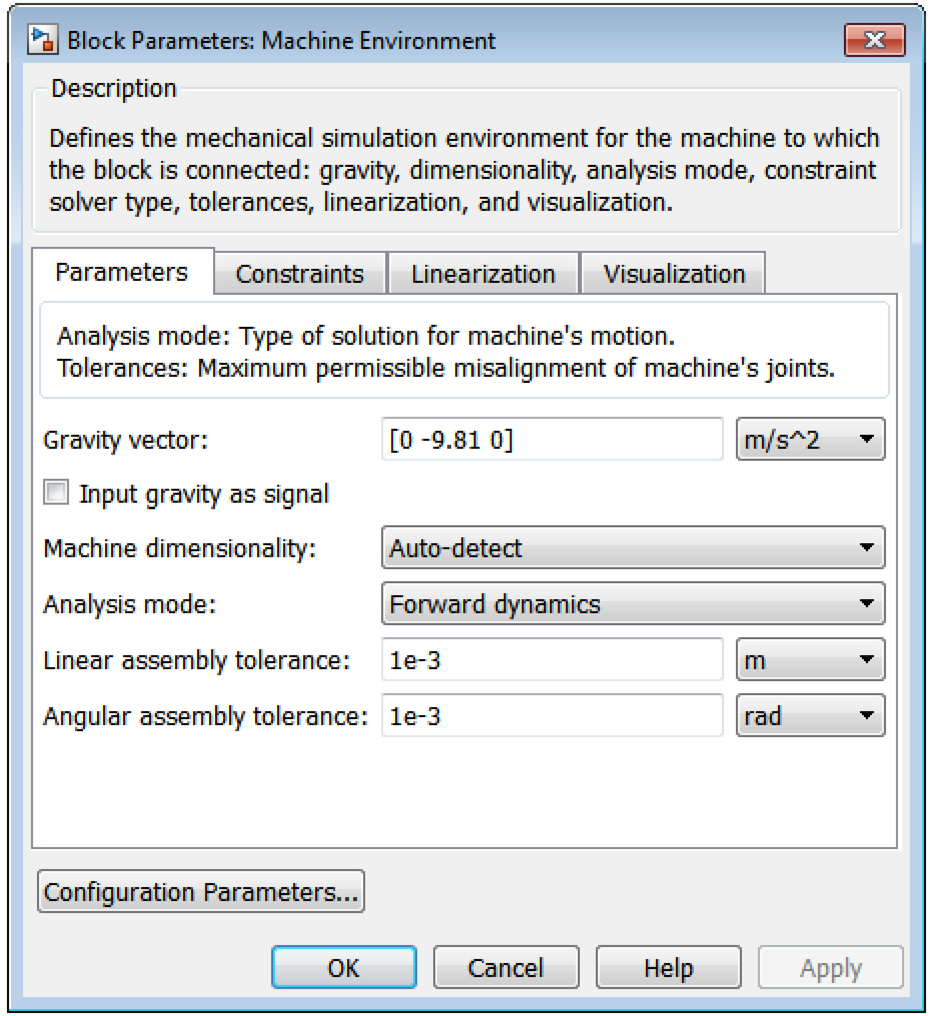
block allows you to view and change the mechanical environment settings for one machine in your model

This block determines the following settings for the machine:

- How to simulate the machine
- How to interpret mechanical constraints
- How to linearize the simulation
- Whether and how to display the machine in visualization

Essential Steps to Build a Model





Essential Steps to Build a Model

4- Assembled Joints:

Blocks

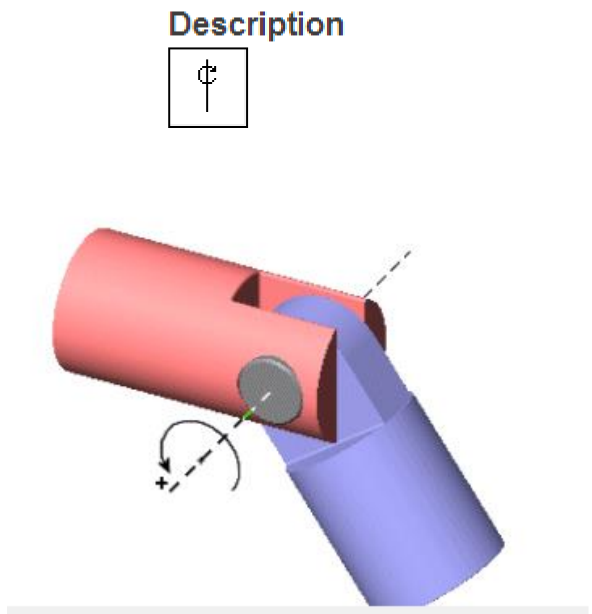
Bearing	Joint with three revolute and one prismatic joint primitives
Bushing	Joint with three revolute and three prismatic joint primitives
Custom Joint	Joint with custom combination of prismatic, revolute, and spherical joint primitives
Cylindrical	Joint with one revolute and one prismatic joint primitives
Gimbal	Joint with three revolute joint primitives
In-Plane	Joint with two coplanar prismatic joint primitives
Planar	Joint with one revolute and two prismatic joint primitives
Prismatic	Primitive joint with one translational degree of freedom
Revolute	Primitive joint with one rotational degree of freedom
Screw	Joint with coupled rotational and translational degrees of freedom
Six-DoF	Joint with three revolute and three prismatic joint primitives
Spherical	Primitive joint with three rotational degrees of freedom
Telescoping	Joint with three revolute and one prismatic joint primitives
Universal	Joint with two revolute joint primitives
Weld	Joint with zero degrees of freedom

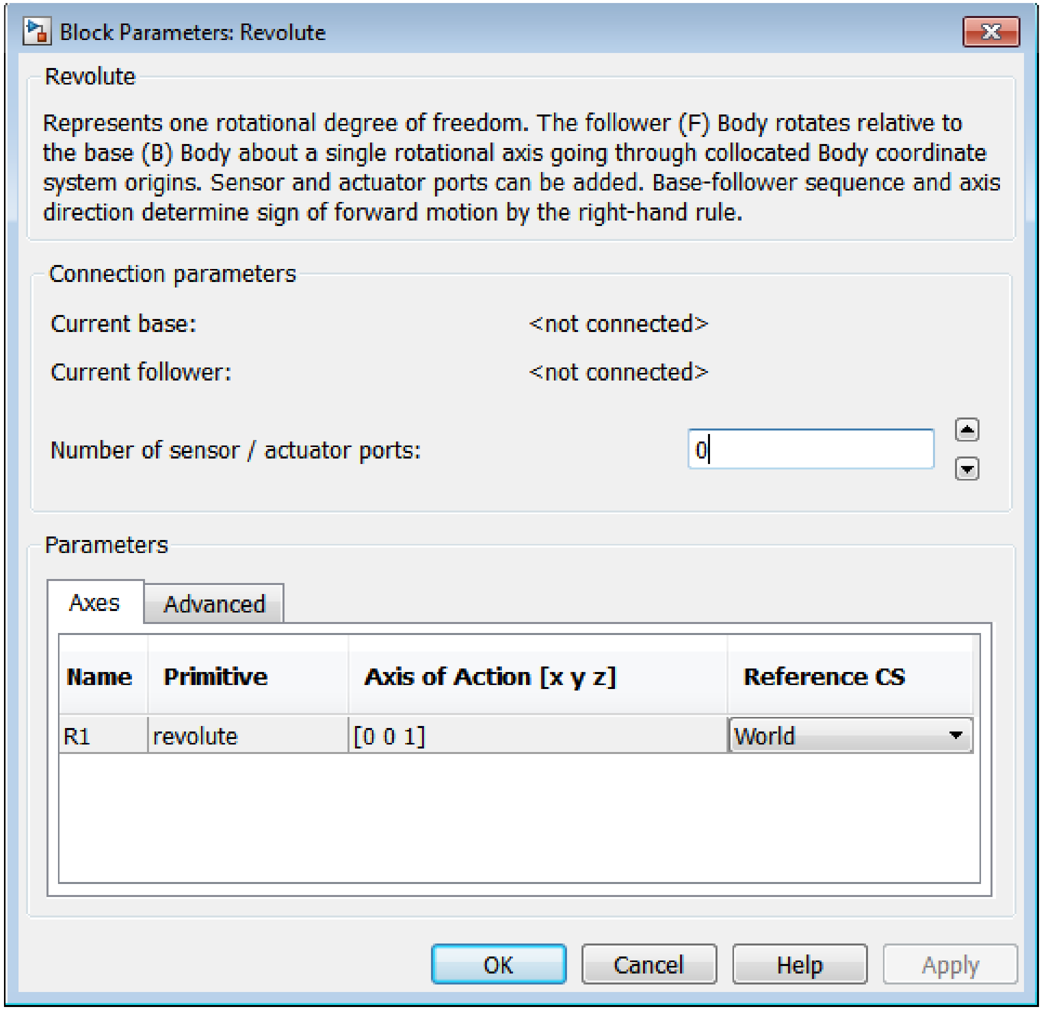
Essential Steps to Build a Model

The Revolute block:

Revolute Motion of Follower (blue)

Relative to Base (red)





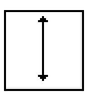
Essential Steps to Build a Model

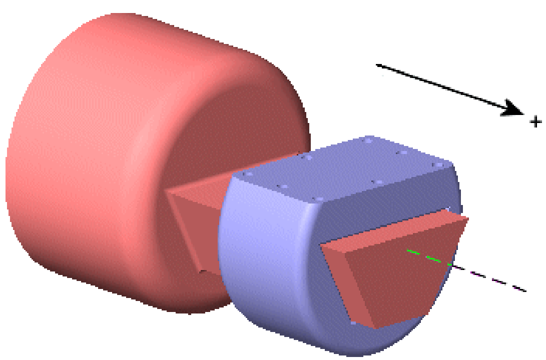
The Prismatic block:

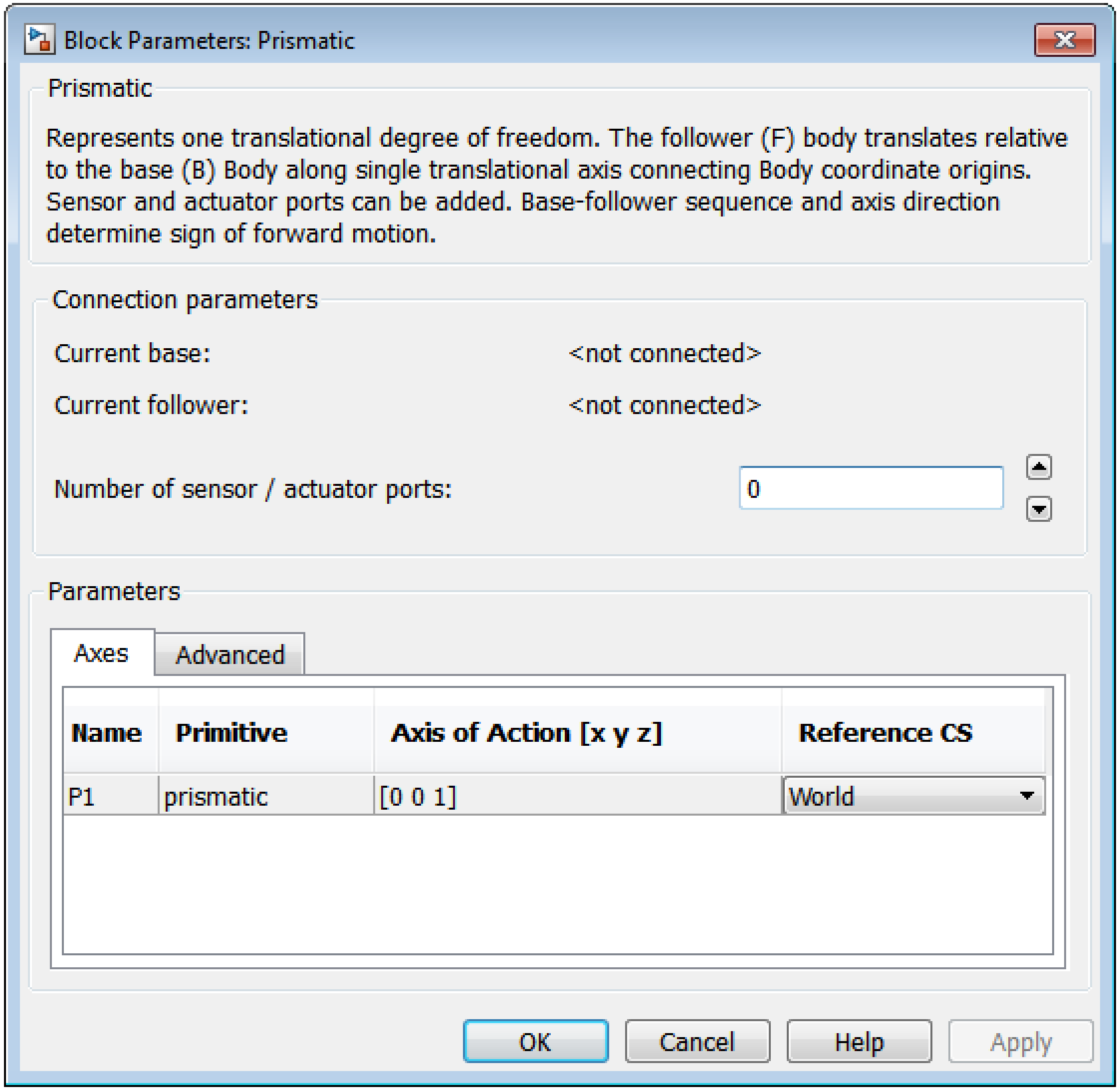
Prismatic Motion of Follower (blue)

Relative to Base (red)

Description







Essential Steps to Build a Model

5-Constraints and Drivers

Blocks

Angle Driver	Driver specifying a time-dependent angle between two body axis vectors
Distance Driver	Time-dependent distance between two body coordinate systems
Gear Constraint	Constraint that restricts body motion to rotation along tangent circles
Linear Driver	Time-dependent signal of a vector position component between two body coordinate systems
Parallel Constraint	Constant parallel relationship between two body axis vectors
Point-Curve Constraint	Constraint that restricts body motion to a specified path
Velocity Driver	Linear and angular velocity components of base and follower body coordinate systems

Essential Steps to Build a Model

Angle Driver

Driver specifying a time-dependent angle between two body axis vectors

Current base

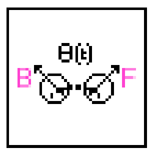
When you connect the base (B) connector port on the Angle Driver block to a Body CS Port on a Body, this parameter is automatically reset to the name of this Body CS.

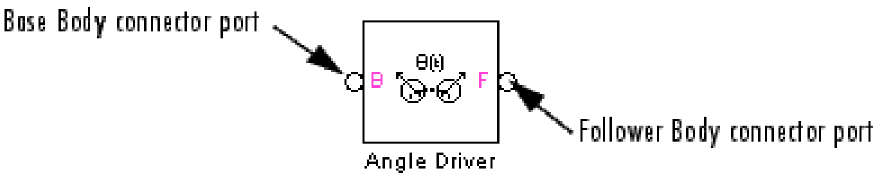
Current follower

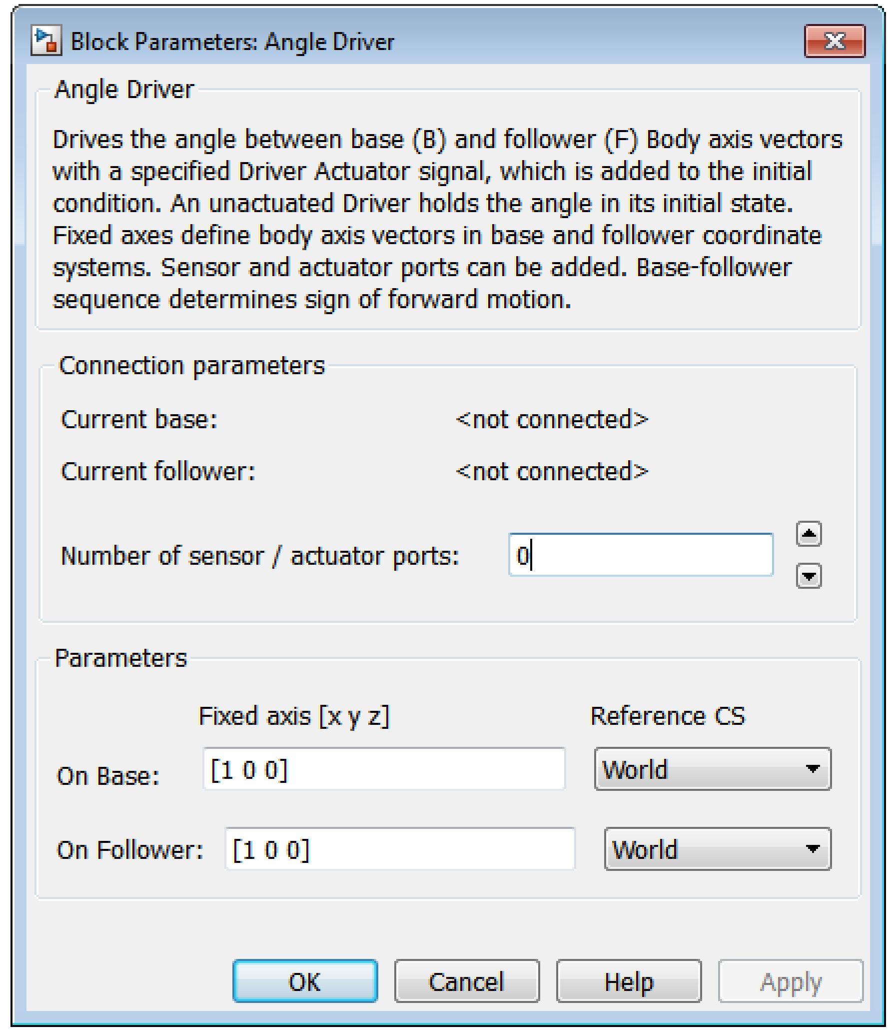
When you connect the follower (F) connector port on the Angle Driver block to a Body CS Port on a Body, this parameter is automatically reset to the name of this Body CS.

Essential Steps to Build a Model

Description





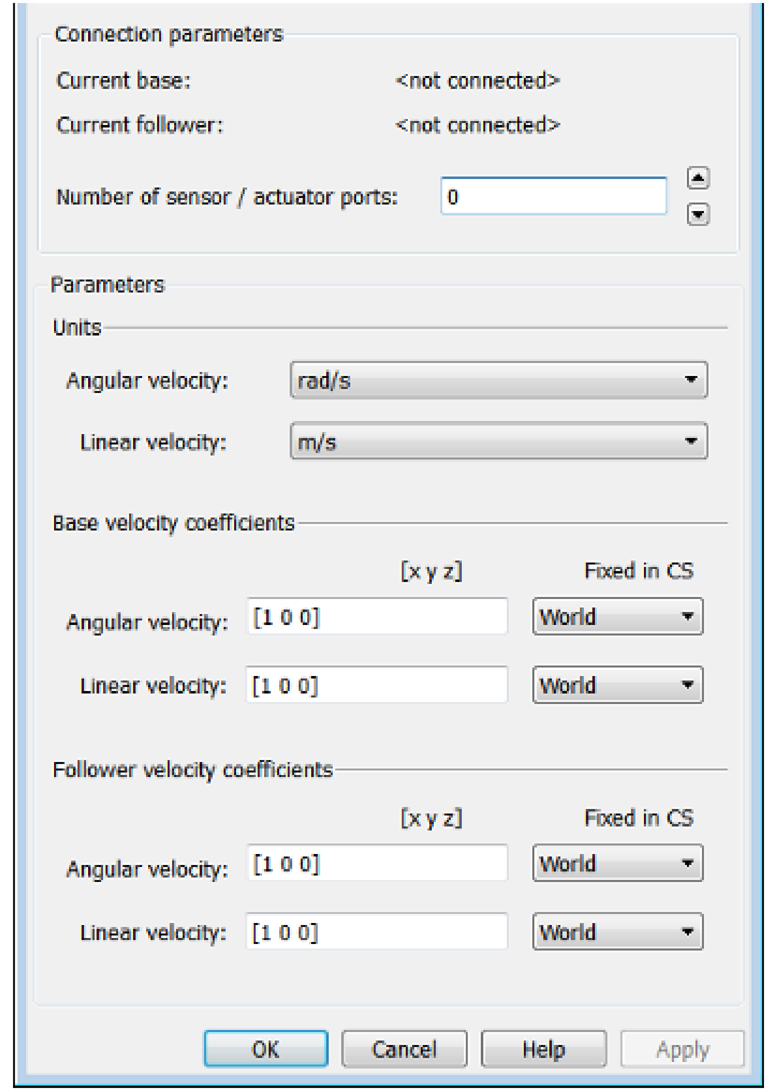


Essential Steps to Build a Model

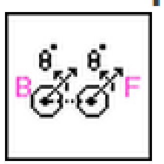
Velocity Driver:

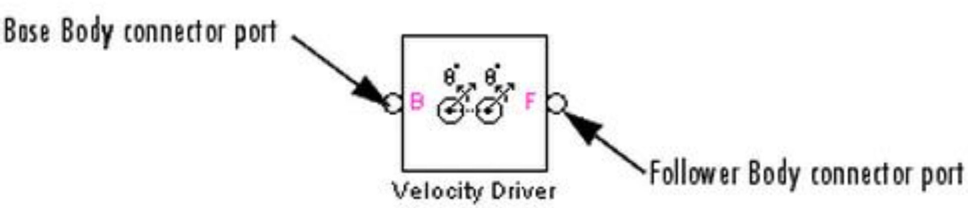
Linear and angular velocity components of base and follower body coordinate systems

The Velocity Driver block drives a linear combination of the projected translational and angular velocities of two Bodies.



Description





Essential Steps to Build a Model

6-Actuators and Sensors

Initiate, impose, and measure mechanical motion

Blocks

Body Actuator	Time-dependent force and torque used to actuate a body
Body Sensor	Body translation and rotation sensor
Constraint & Driver Sensor	Sensor used to measure the reaction force and torque between two constrained or driven bodies
Driver Actuator	Time-dependent motion input for driver blocks
Joint Actuator	Time-dependent force, torque, or motion input to a joint
Joint Initial Condition Actuator	Initial joint position and velocity
Joint Sensor	Joint force, torque, and motion sensor
Joint Stiction Actuator	Joint static and kinetic friction
Variable Mass & Inertia Actuator	Time-dependent mass and inertia parameters

Essential Steps to Build a Model

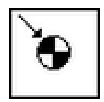
Body Actuator:

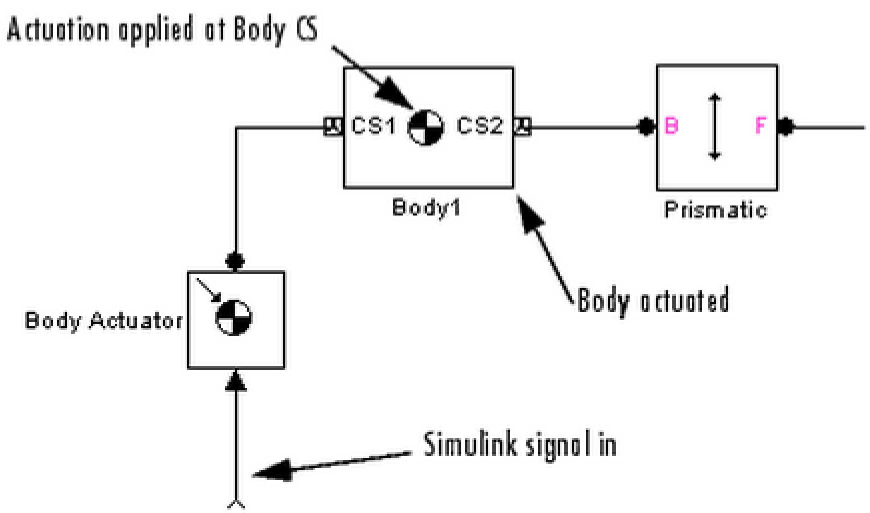
Time-dependent force and torque used to actuate a body

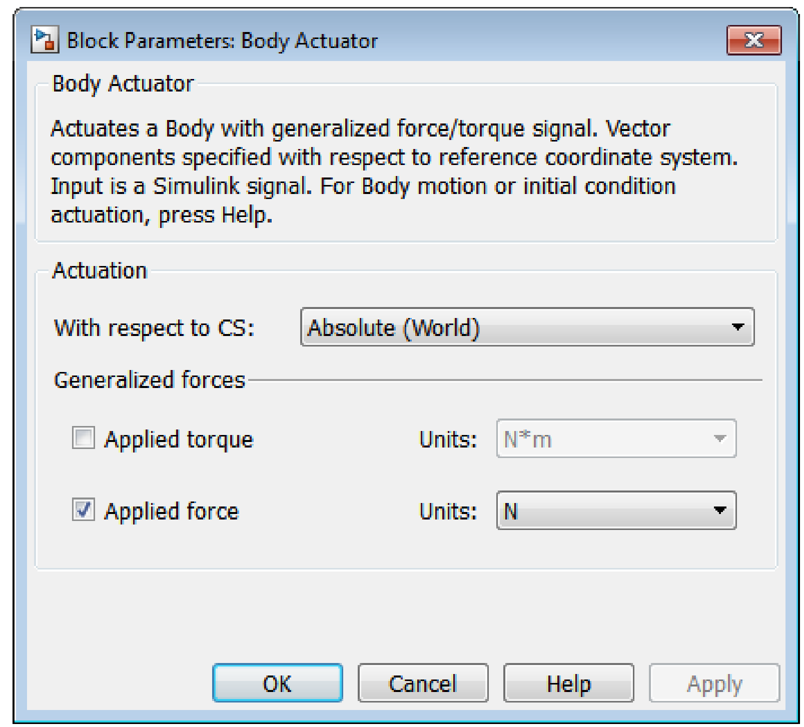
The Body Actuator block actuates a Body block with a generalized force signal, representing a force/torque applied to the body:

- Force for translational motion
- Torque for rotational motion

Description







Essential Steps to Build a Model

Joint Actuator:

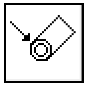
Time-dependent force, torque, or motion input to a joint

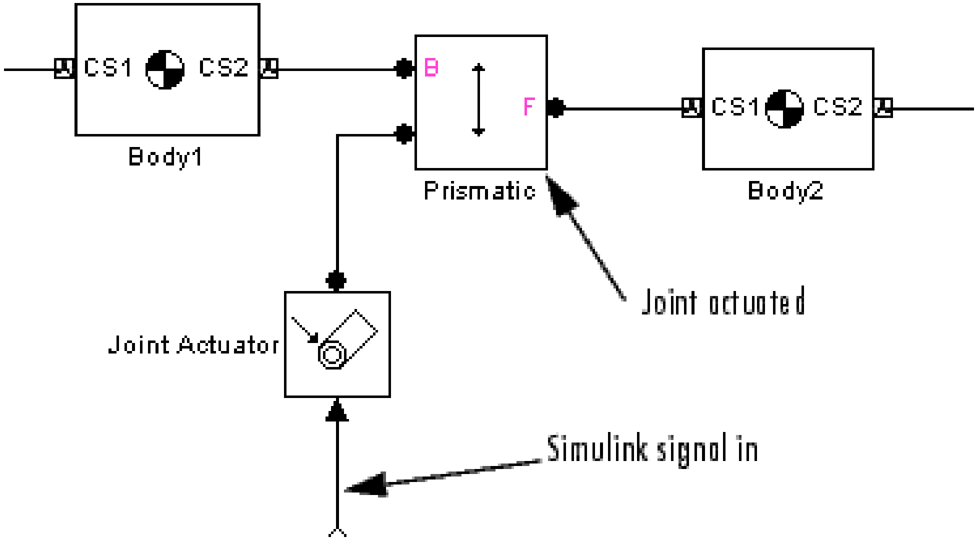
A joint between two bodies represents relative degrees of freedom (DoFs) between the bodies. The Joint Actuator block actuates a Joint block connected between two Bodies with one of these signals:

- A generalized force:
  - Force for translational motion along a prismatic joint primitive
  - Torque for rotational motion about a revolute joint primitive
- A motion:
  - Translational motion for a prismatic joint primitive, in terms of linear position, velocity, and acceleration.
  - Rotational motion for a revolute joint primitive, in terms of angular position, velocity, and acceleration.

Essential Steps to Build a Model

Description





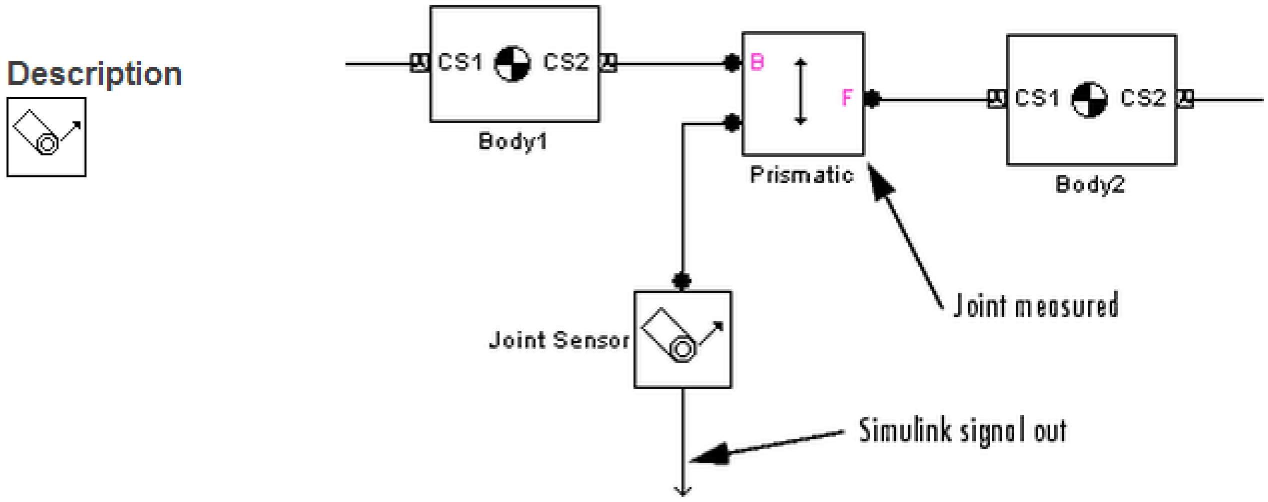
Essential Steps to Build a Model

Joint Sensor:

The Joint Sensor block measures the position, velocity, and/or acceleration of a joint primitive in a Joint block. It also measures the reaction force and torque across the Joint.

- The Joint Sensor measures the motion along/about the joint axis (or about the pivot point for a spherical primitive) in the reference coordinate system (CS) specified for that joint primitive in the Joint's dialog. The Joint connects a base and a follower Body at one body coordinate system on each body. The base-follower sequence determines the sense of the motion, which is defined as follower relative to base.

Essential Steps to Build a Model



Essential Steps to Build a Model

- Position and connect blocks.

Place Joint and Body blocks in proper relative position in the model window and connect them in the proper order. The essential result of this step is creation of a valid tree block diagram made of

Ground — Joint — Body — Joint — Body — ... — Body

with an open or closed topology and where at least one of the bodies is a Ground block.

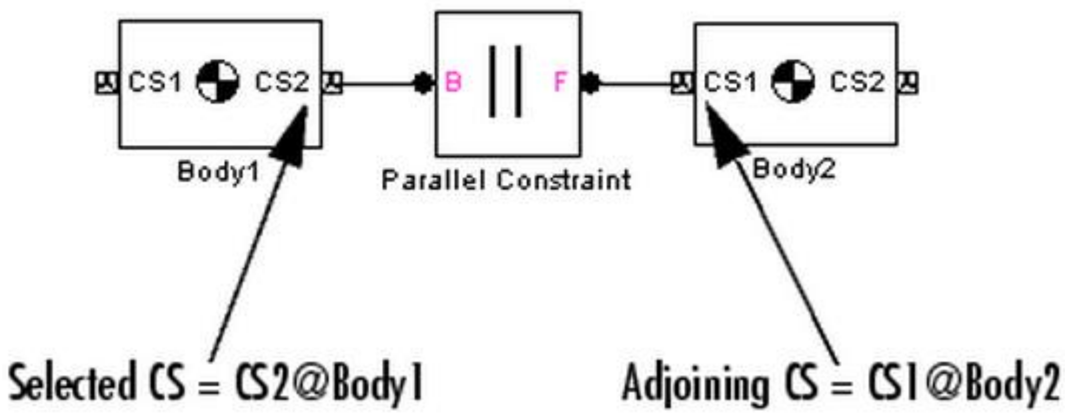
A Body can have more than two Joints attached, marking a branching of the sequence. But Joints must be attached to two and only two Bodies.

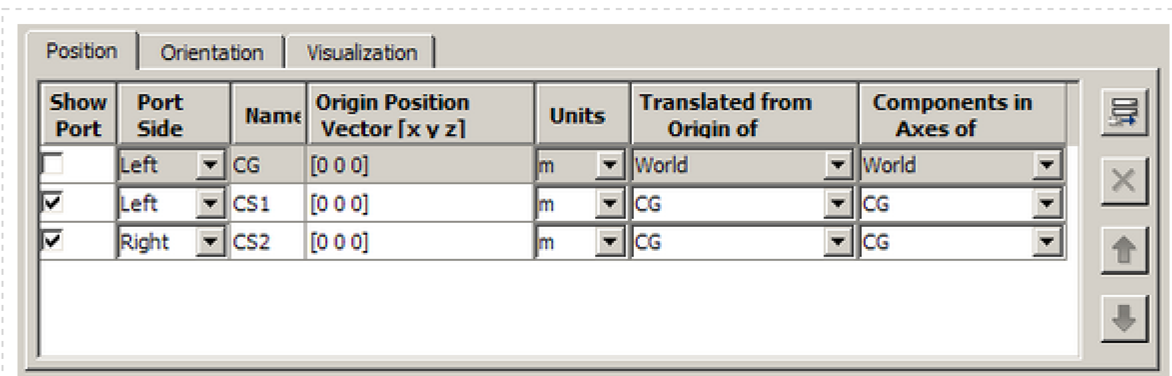
Configuring the Position Fields

- The **Position** fields for each Body CS specify the position of that CS's origin as a translation vector:
- The numerical components of the vector carry units.
- The translation vector's components are oriented with respect to another set of CS axes.
- The origin is displaced from the origin of another, pre-existing CS in your machine by this translation vector.
- Highlight each Body CS to configure it.

Essential Steps to Build a Model

Configuring the Position Fields



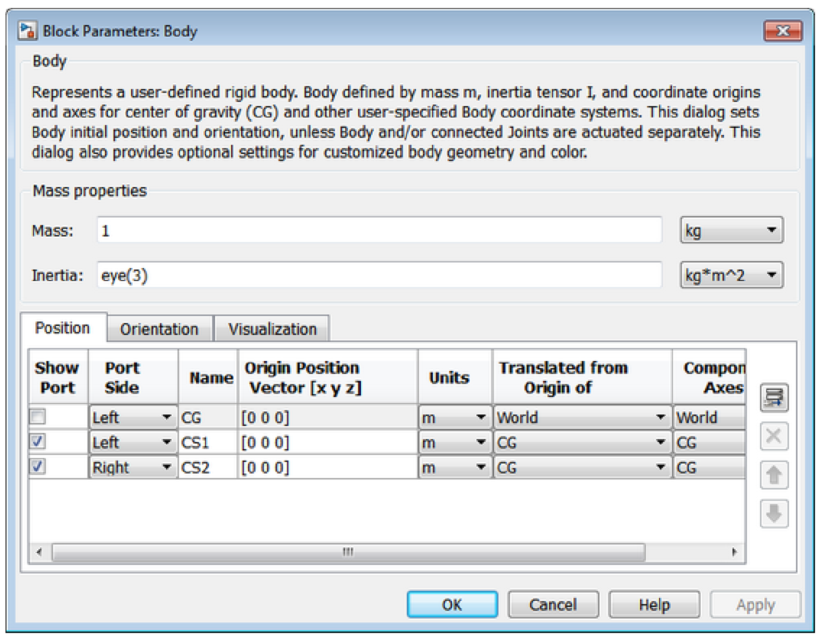


Essential Steps to Build a Model

➢ Configure Body blocks

Click the Body blocks to open their dialog boxes;

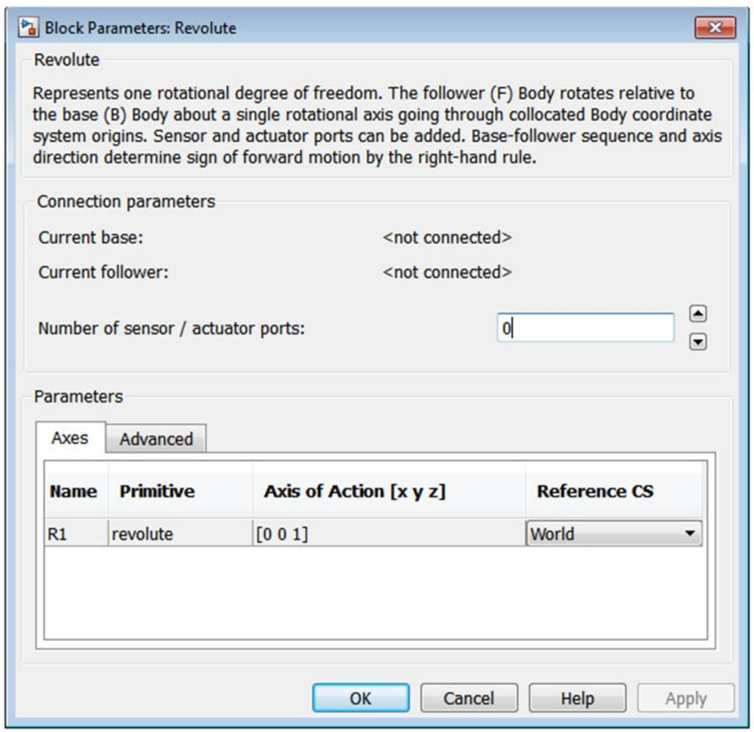
specify their mass properties (masses and moments of inertia), then position and orient the Bodies and Grounds relative to the World coordinate system (CS) or to other CSs. You set up Body CSs here.



Essential Steps to Build a Model

- Configure Joint blocks.

Click each of the Joint blocks to open its dialog box and set translation and rotation axes and spherical pivot points.



Essential Steps to Build a Model

➢ Select, connect, and configure Constraint and Driver blocks.

From the Constraints & Drivers library, drag, drop, and connect Constraint and Driver blocks in between pairs of Body blocks. Open and configure each Constraint/Driver's dialog box to restrict or drive the relative motion between the two respective bodies of each constrained/driven pair.

➢ Configure Joint blocks.

Select, connect, and configure Actuator and Sensor blocks. From the Sensors & Actuators library, drag and drop the Actuator and Sensor blocks that you need to impart and sense motion. Reconfigure Body, Joint, and Constraint/Driver blocks to accept Sensor and Actuator connections. Connect Sensor and Actuator blocks. Specify control signals (applied forces/torques or motions) through Actuators and measure motions through Sensors.

Essential Steps to Build a Model

- Select, connect, and configure Constraint and Driver blocks.

From the Constraints & Drivers library, drag, drop, and connect Constraint and Driver blocks in between pairs of Body blocks. Open and configure each Constraint/Driver’s dialog box to restrict or drive the relative motion between the two respective bodies of each constrained/driven pair.

- Configure Joint blocks.

Select, connect, and configure Actuator and Sensor blocks. From the Sensors & Actuators library, drag and drop the Actuator and Sensor blocks that you need to impart and sense motion. Reconfigure Body, Joint, and Constraint/Driver blocks to accept Sensor and Actuator connections. Connect Sensor and Actuator blocks. Specify control signals (applied forces/torques or motions) through Actuators and measure motions through Sensors.

Essential Steps to Configure and Run a Model:

- SimMechanics offers four analysis modes for running a machine model. The mode you will probably use most often, at least at first, is Forward Dynamics. But a more complete analysis of a machine makes use of the Kinematics, Inverse Dynamics, and Trimming modes as well. You can create multiple versions of the model, each with the same underlying machine, but connected to Sensors and Actuators and configured differently for different modes.

Essential Steps to Configure and Run a Model:

- You can also use the powerful visualization and animation features of SimMechanics. You can visualize your machine as you build it or after you are finished but before you start the simulation, as a tool for debugging the machine geometry. You can also animate the machine model as you simulate.
- Choose the analysis mode and configuring visualization, as well as other important settings, in the Mechanical Environment Settings dialog box. You might also need to reconfigure the Simulink Simulation Parameters dialog for SimMechanics models.