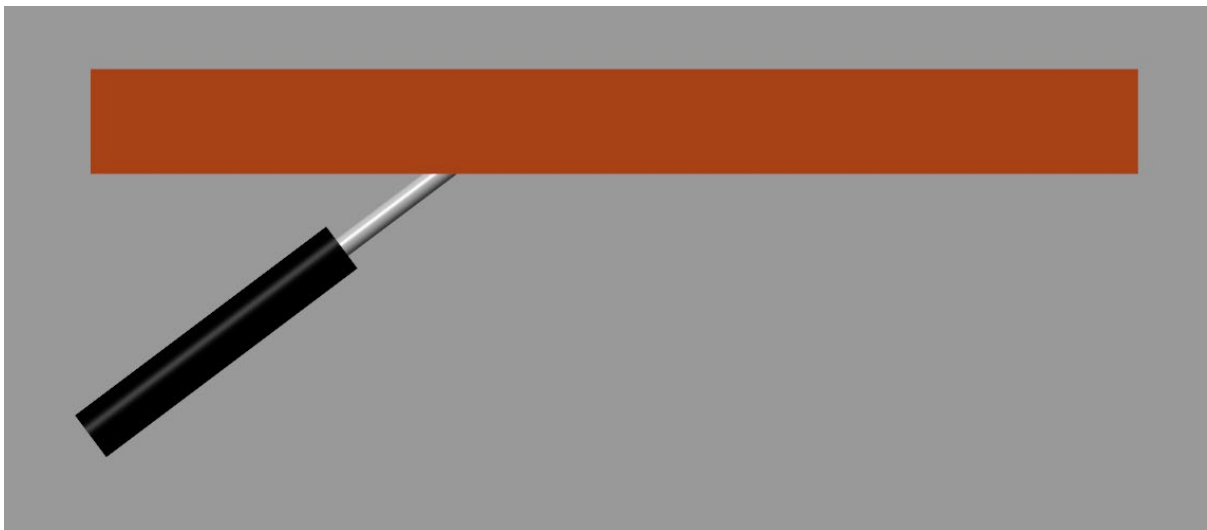# Multibody Dynamics

Introduction to 3D mechanics with MATLAB/Simulink and Simscape Multibody

Morten H. Rudolfsen

This tutorial provides an introduction to assembling a simple 3D mechanical system using Simscape Multibody. The system comprises two components: a straight boom and a cylinder.

Ultimately, this tutorial will connect the mechanical system to the simulated hydraulic system from the Simscape Fluids tutorial, enabling control of mechanical movements.

Contents

Initialization

This tutorial is made with MATLAB R2024b, and with the following packages.

- Simulink
- Simscape Multibody
- Simscape Fluids

When a new Simulink model has been opened, locate the following blocks in the library browser, or using the search function.

- **Solver Configuration** - Solver for the simulation
- **World Frame** – a refence point to build from
- **Mechanism Configuration** – Settings for gravitational force and other mechanism settings

Mechanism Configuration
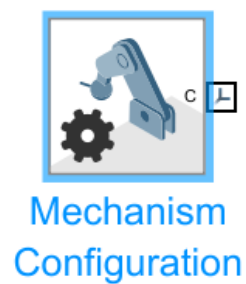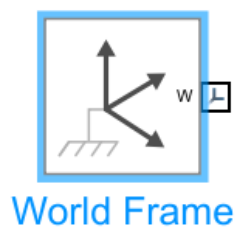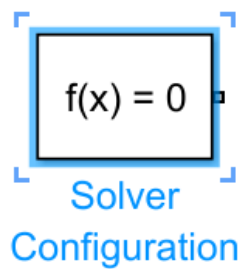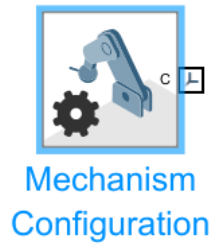
Block Parameters: Mechanism Configuration ✕

Mechanism Configuration ☑ Auto Apply ❓

Settings	Description

NAME	VALUE		
∨ **Uniform Gravity**	Constant		∨
Gravity	[0 0 -9.81]	m/s^2 ∨	Compile-time ∨
Linearization Delta	0.001		
› **Joint Mode Transition**			

Pendulum Modeling

We begin by modeling a pendulum swinging in 2D. This involves:

- Adding a Revolute Joint to allow rotation around the z-axis.
- Adjusting the rotation angles to simulate a 90-degree motion around the x-axis and back to the starting position.

Revolute Joint

In Simscape Multibody, every joint is defined relative to a local coordinate system that is attached to the connected components.

By convention, the z-axis is used as the axis of motion because it aligns with the principal axis of rotation or translation in the underlying physics engine. This ensures consistency across simulations.
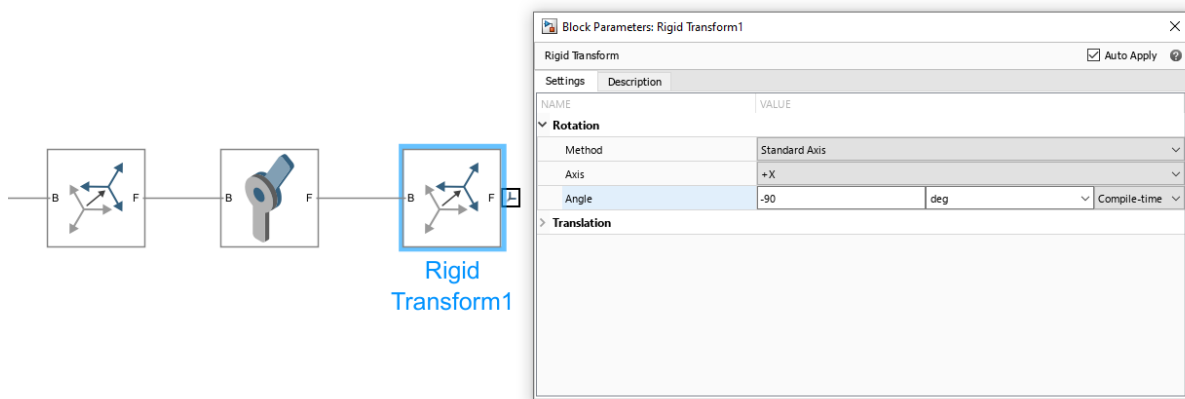
By convention, Simscape Multibody follows a **right-handed coordinate system** where the z-axis is designated for dynamic movements. This provides a standardized approach for integrating multiple components without conflicts in directionality.
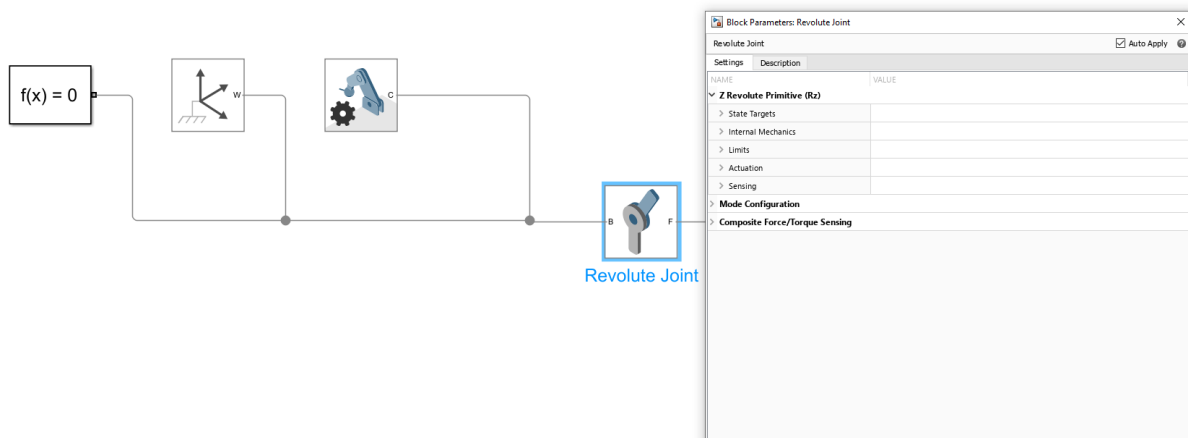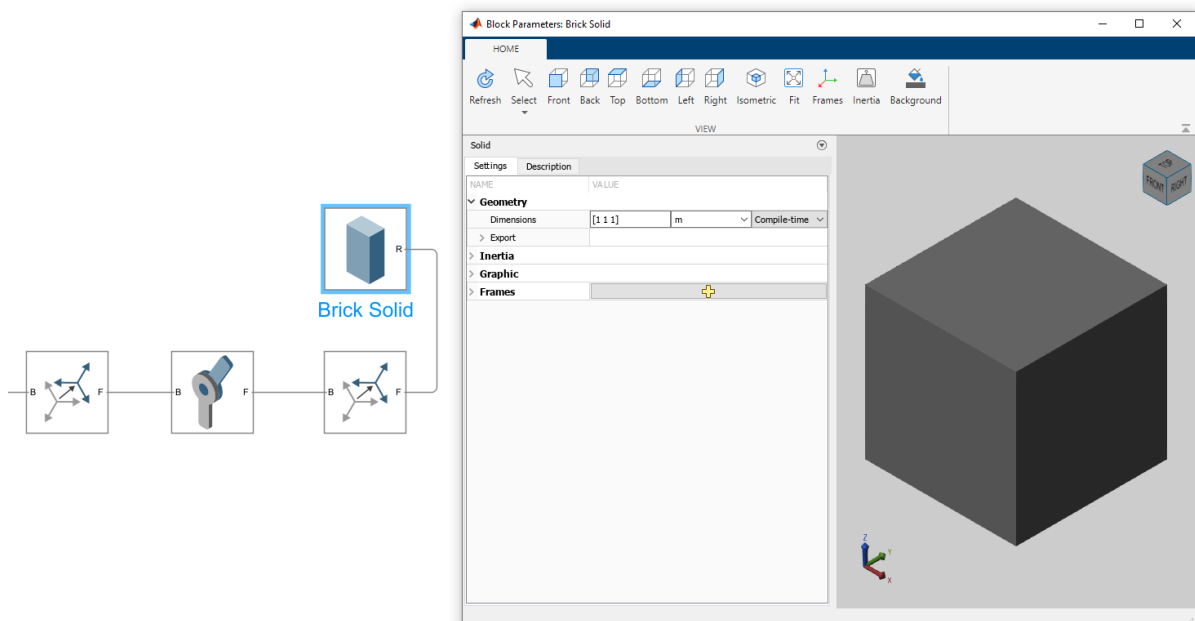

90 degree rotation about the x-axis
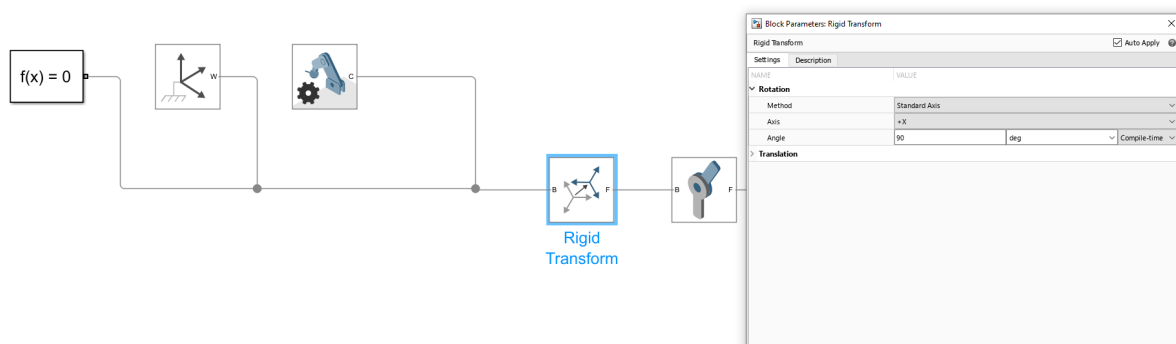
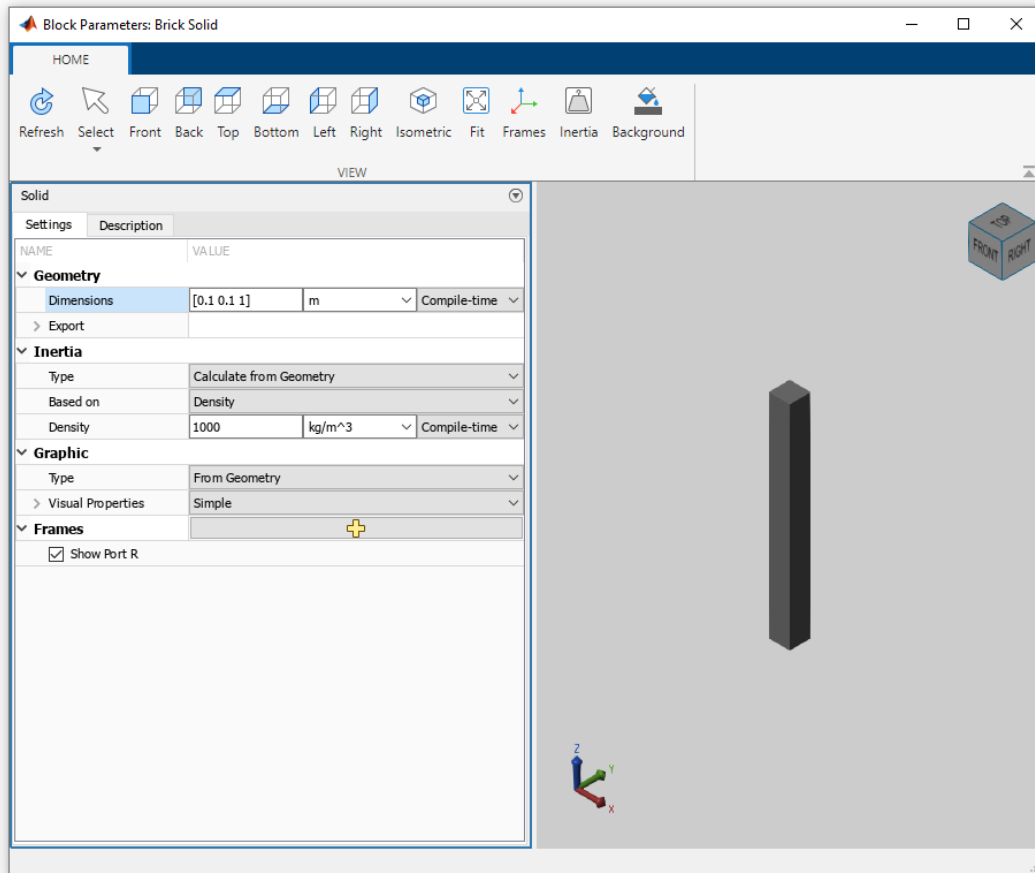And 90 degrees back again to the original orientation.

Connecting a Mass

The next step is to attach a mass to the pendulum. For this:

- Insert a rigid body.
- Adjust the mass properties (density, volume, and geometry).
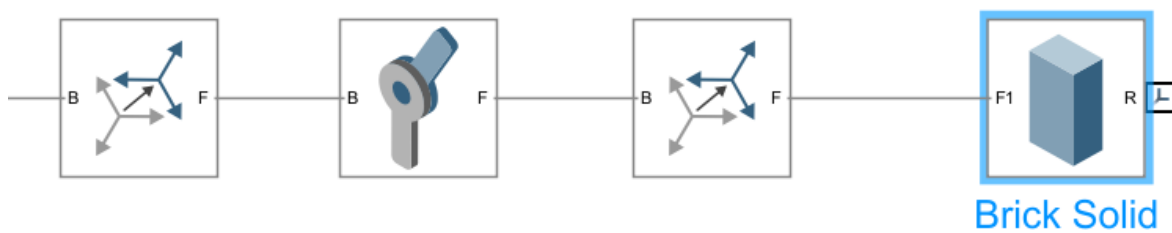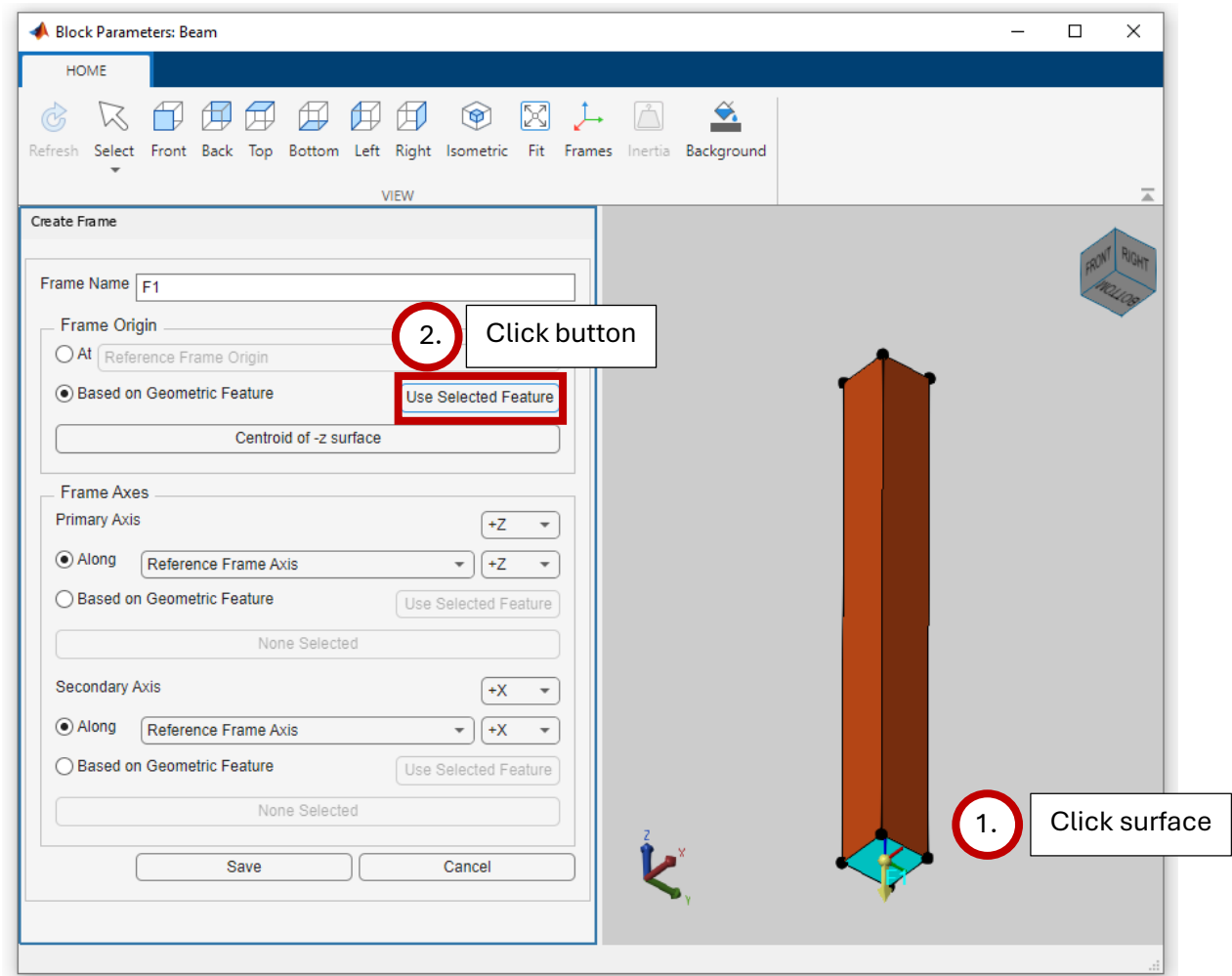- Make connections intuitive using Simscape Multibody's drag-and-drop functionality.

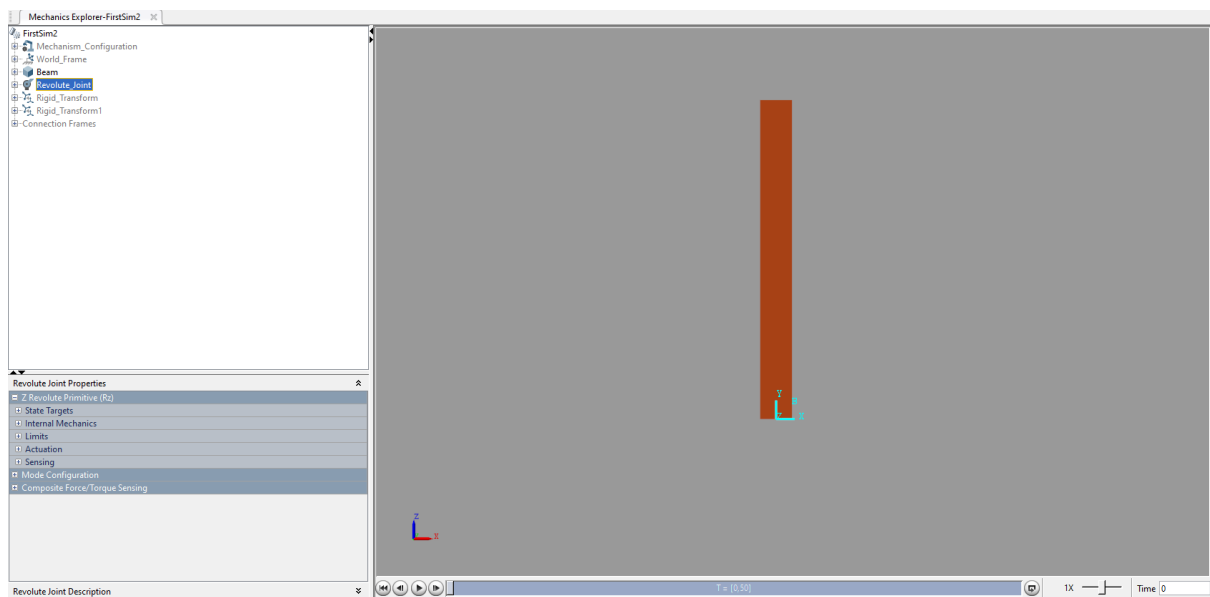# Mass Property Adjustments

Intuitive Connections

Adding new frames

Running the Simulation

Once the setup is complete, the simulation can be run. Key aspects to observe include:

- Position and orientation of coordinate systems.
- Dynamics of the joints, including rotations and translations.
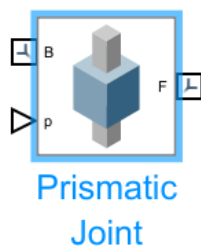
Setting Initial States

Result

Mechanical Cylinder

Prismatic Joint

We add a cylinder to enable linear motion using:

- Prismatic Joints to allow movement along one axis.
- Actuation and sensing settings to monitor and control position and force.

Settings for Actuation:
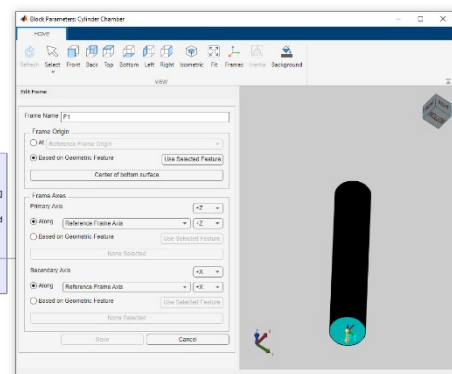
Settings for Sensing:

Prismatic Joint1

Prismatic Joint with Revolute Joints
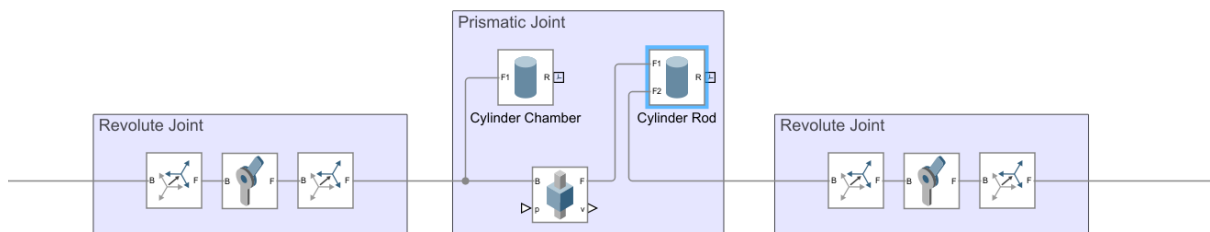
Geometry and Frames of the Cylinder

Cylinder Housing
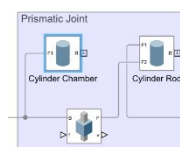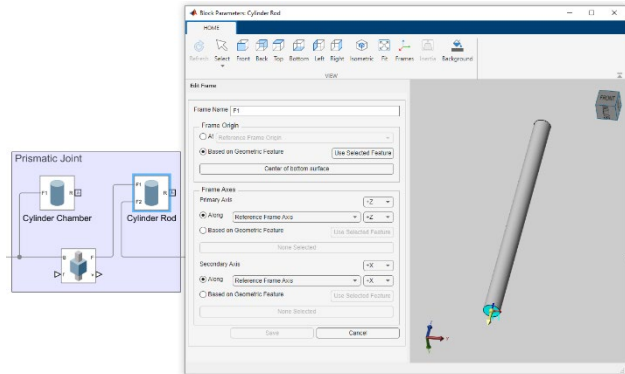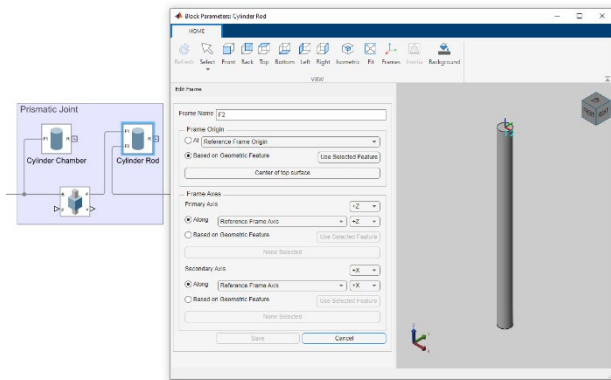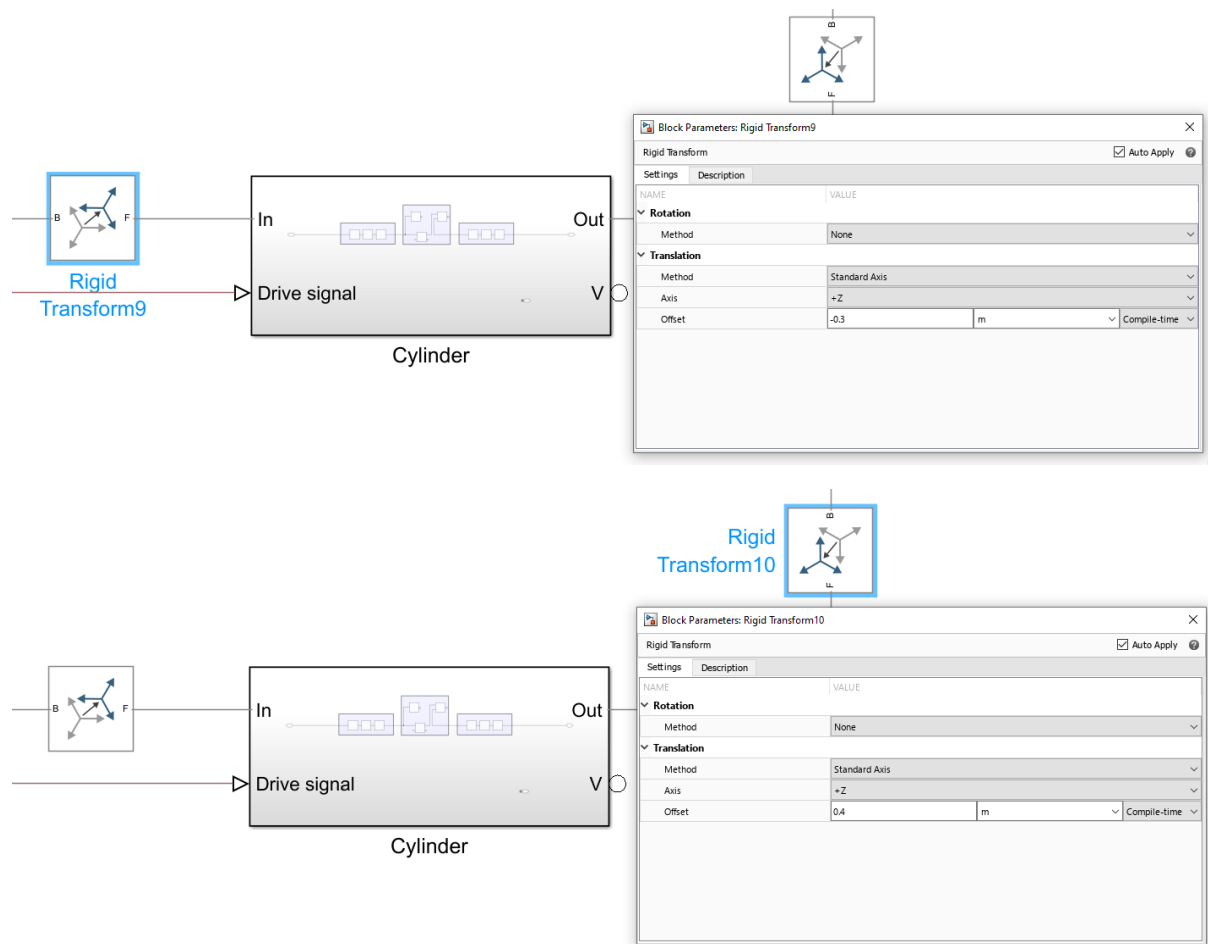
Cylinder Rod

Setting Initial States
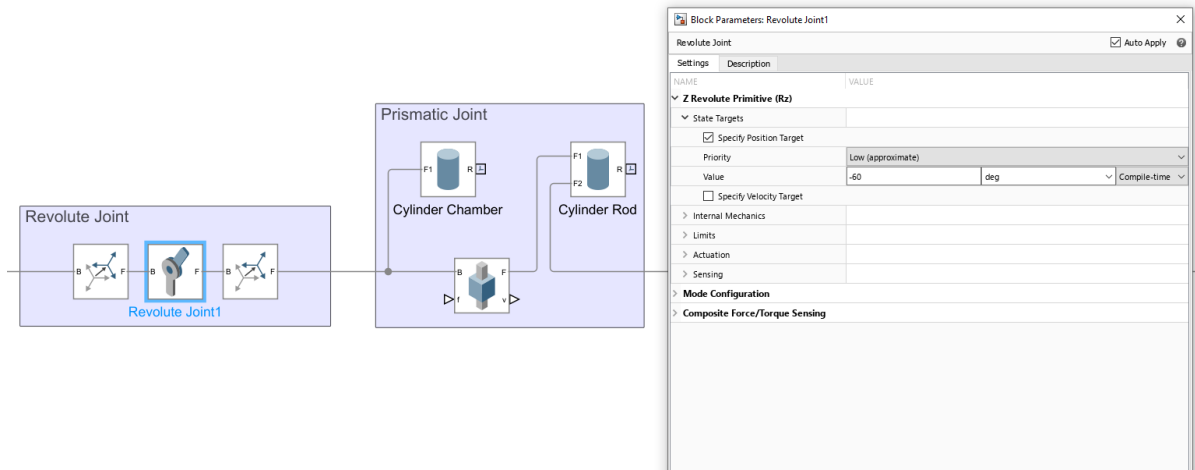
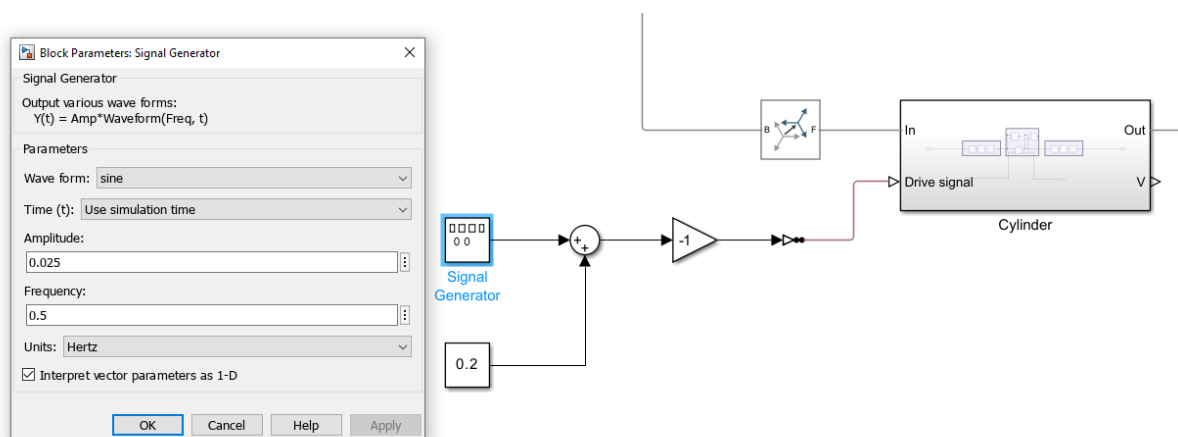## Creating a Sub System for the Cylinder
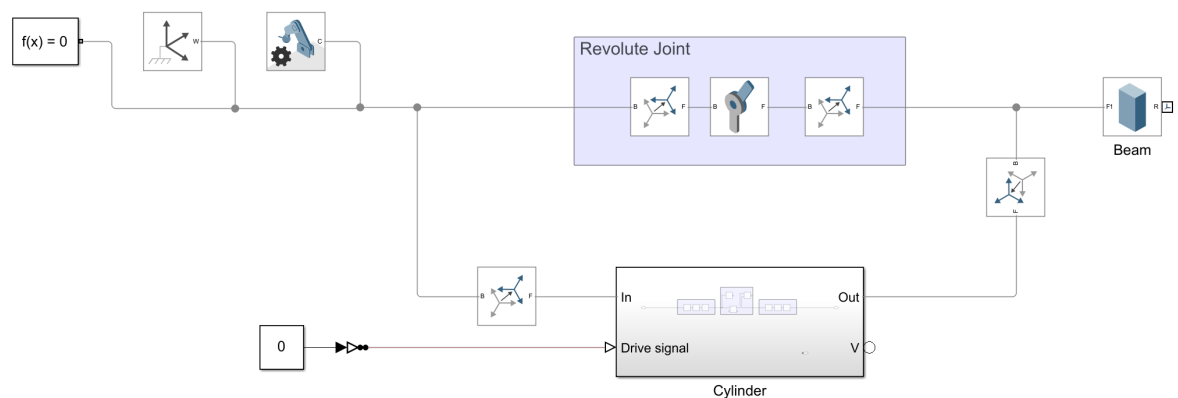
Moving the contact points of the cylinders

The marked transformations in the image above are translations only, moving the endpoints of the cylinder.
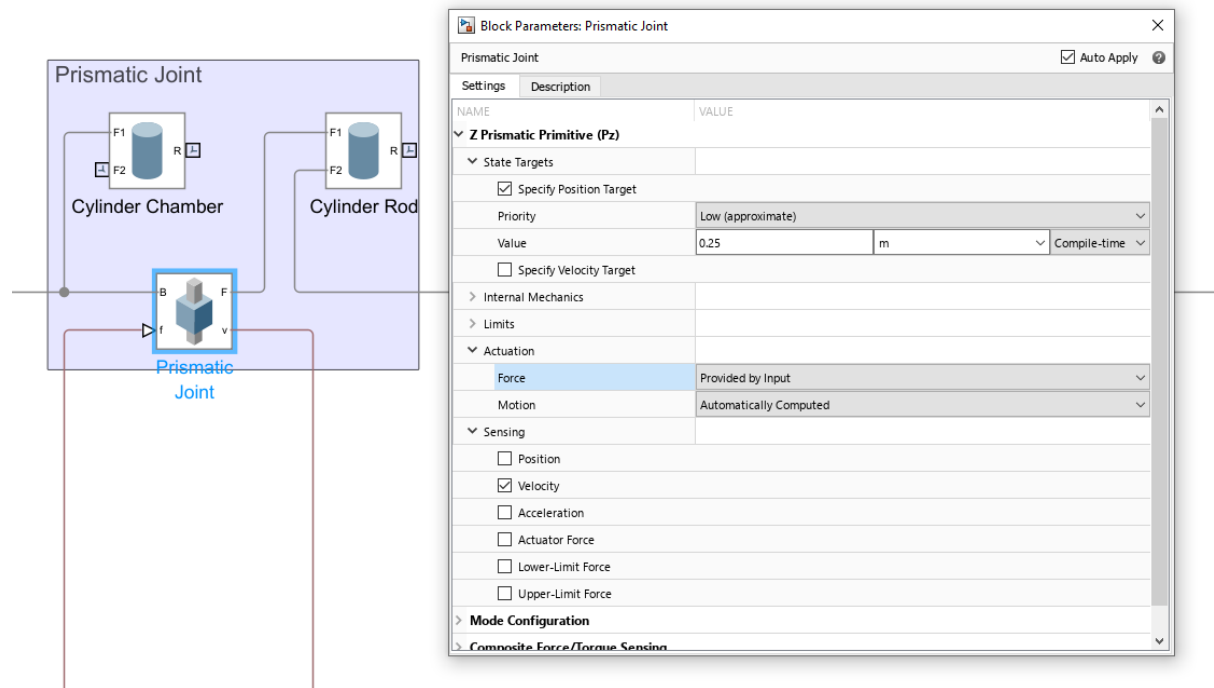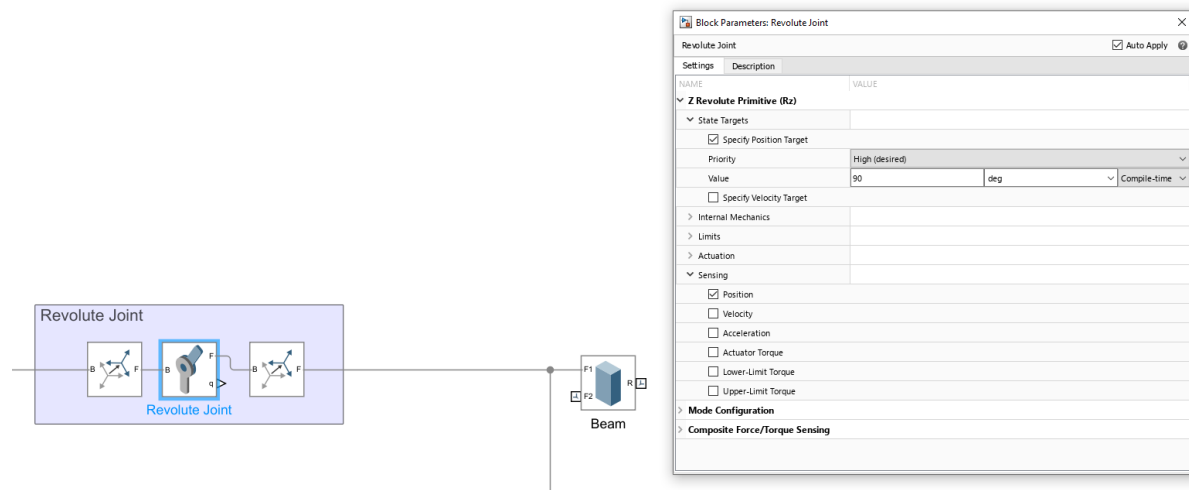

Controlling the Piston Position
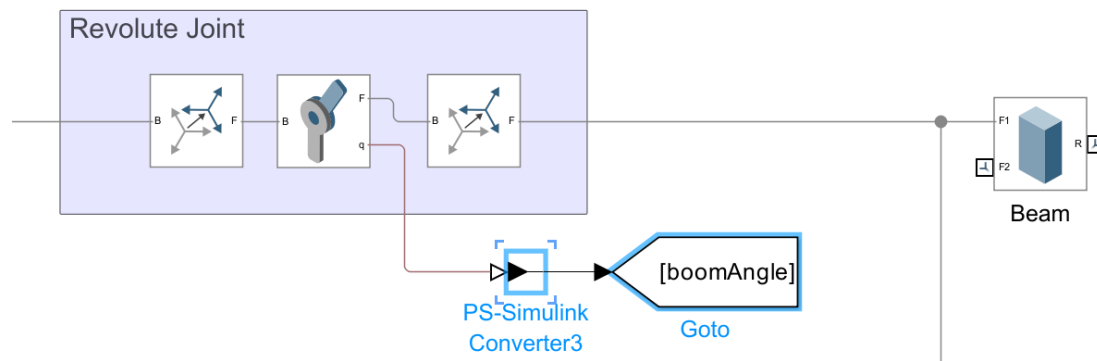
Closed Loop Force Control

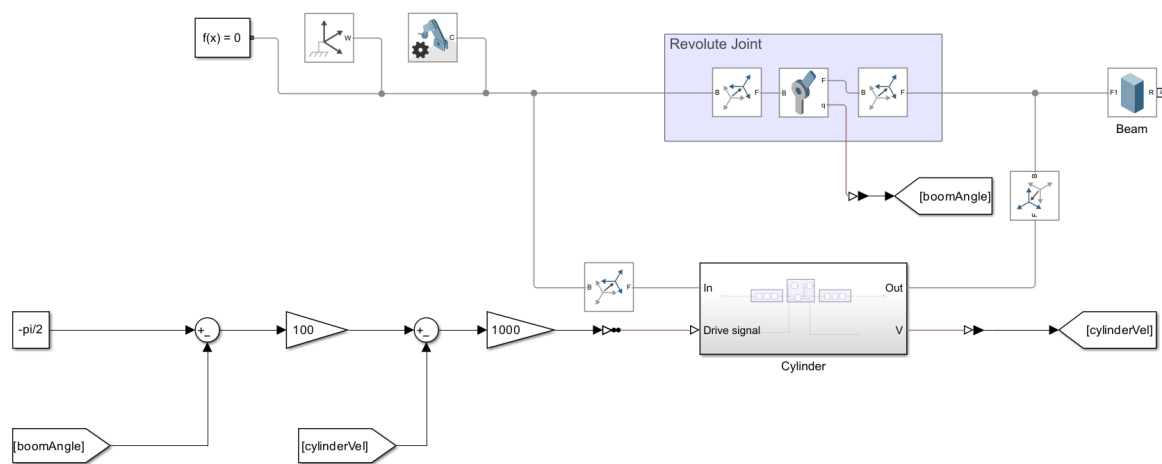## Changing the Control Signal and Feedback of the Cylinder
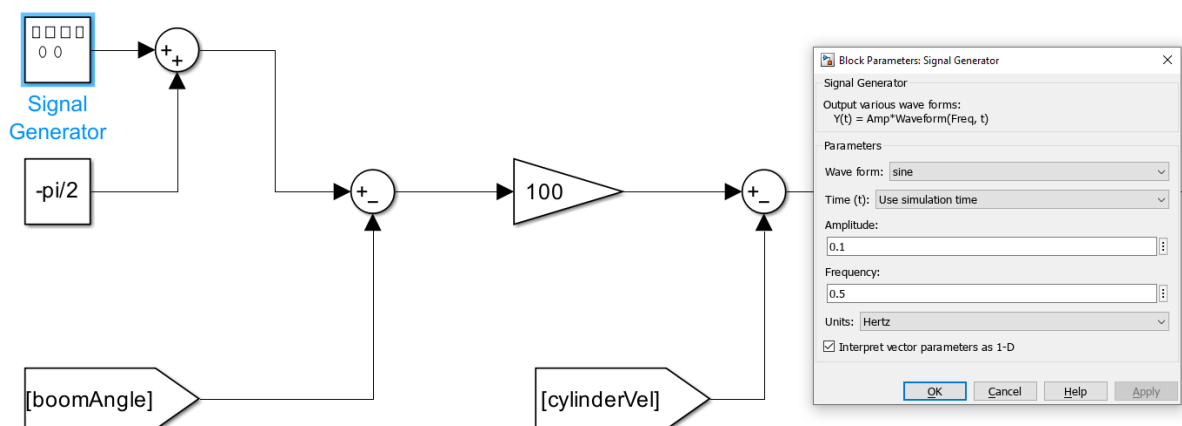

Sensing the Boom Angle

Converting signal and GoTo function to transmit signals
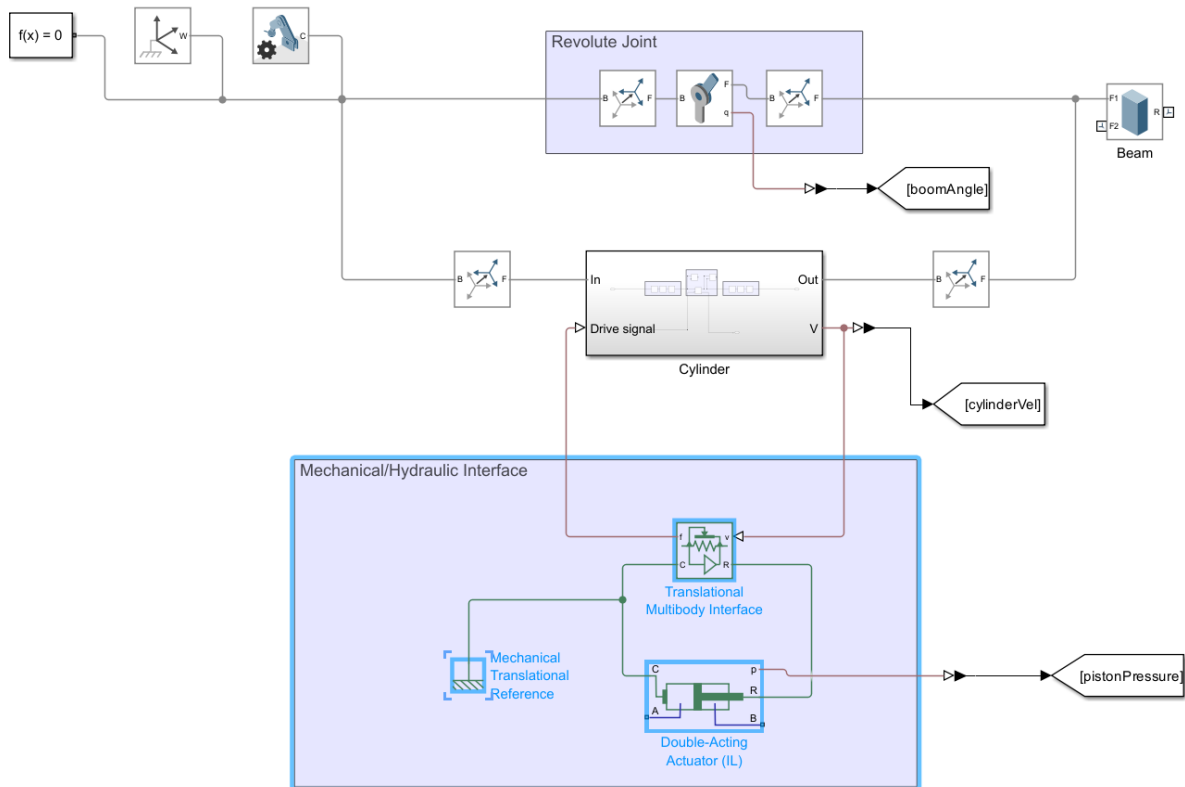

Closed Loop Control
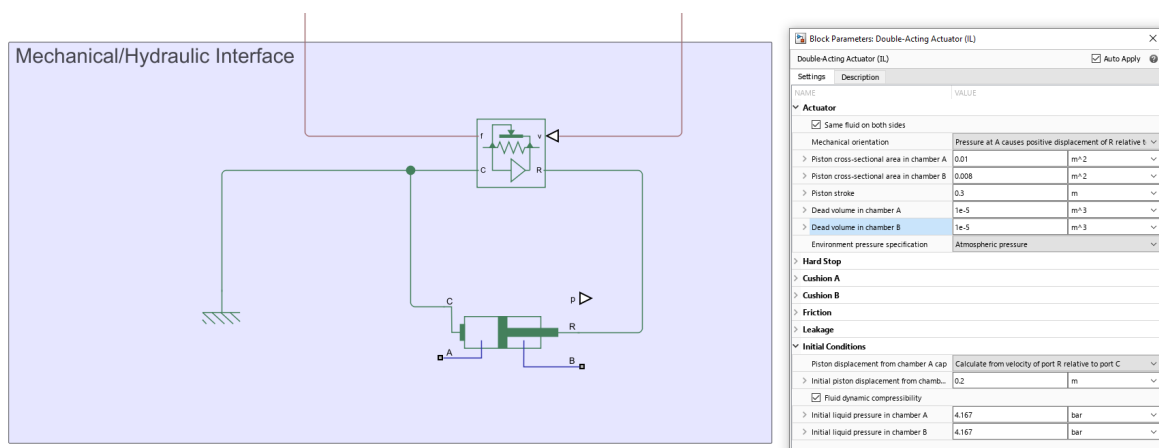

Using a Signal Generator
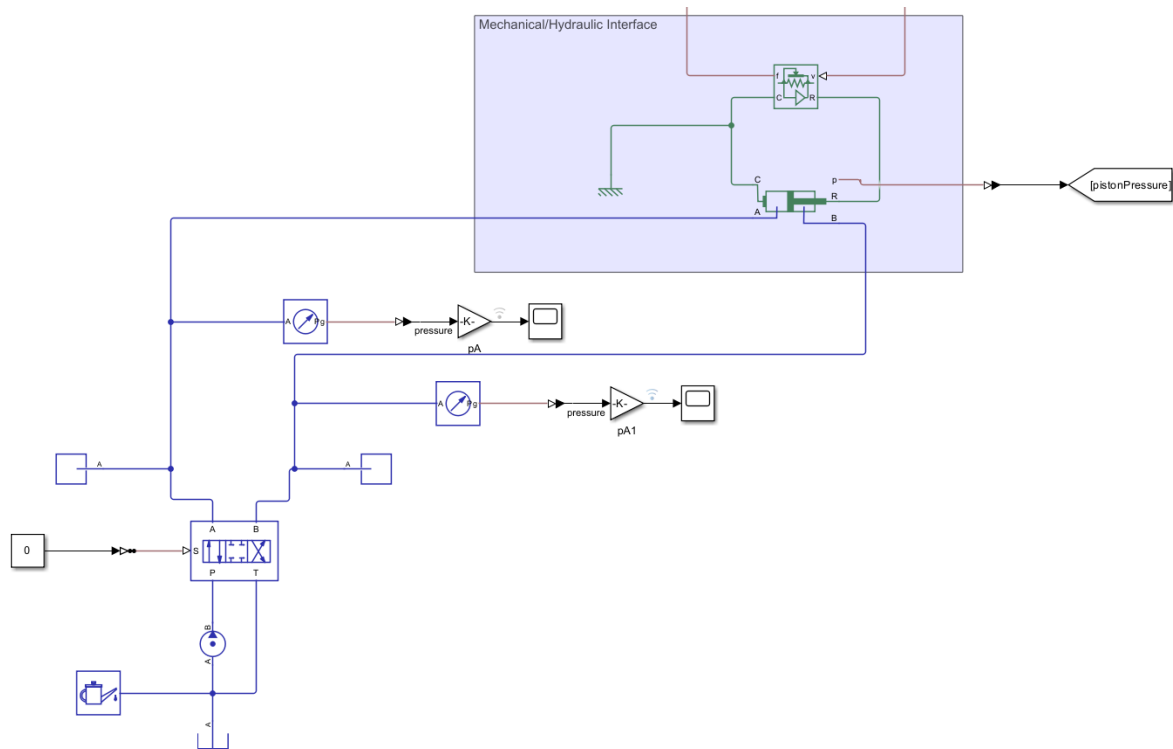
Connecting Hydraulics

The components we need to connect the mechanical system to the hydraulic system from the Fluids tutorial is listed in the "Mechanical/Hydraulic Interface" section in the figure below.
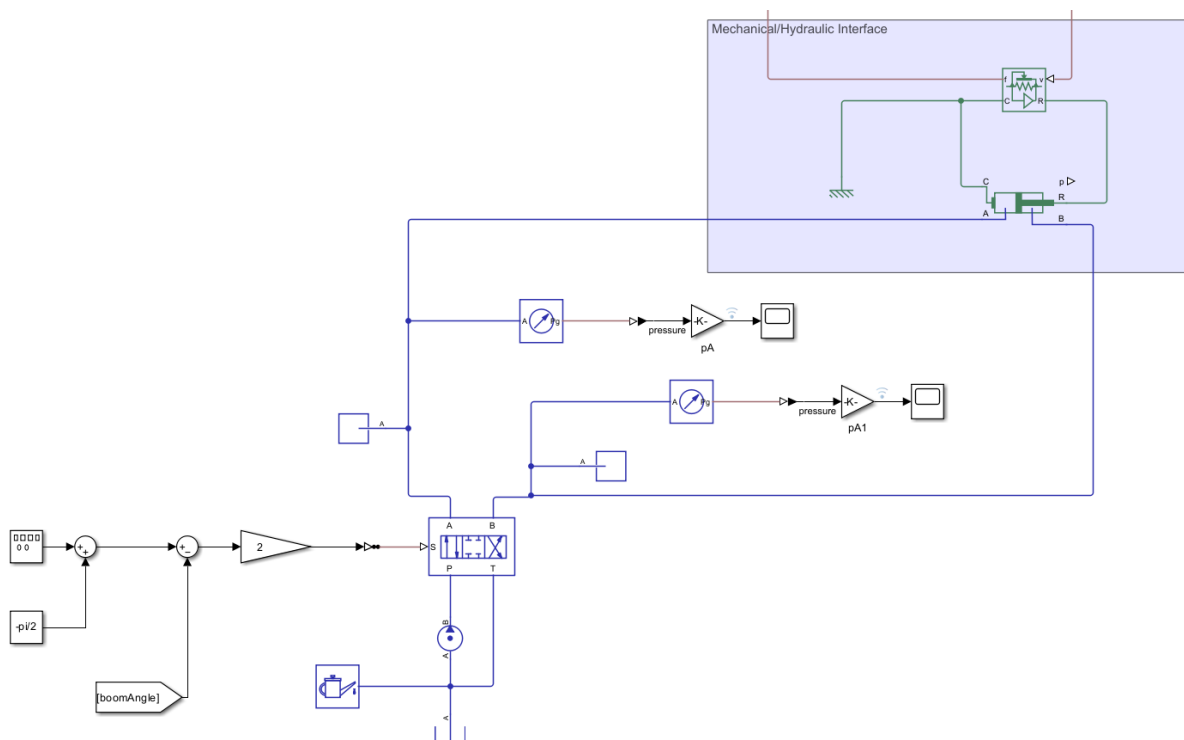

Parameters of the Cylinder

Connecting the Hydraulic System

Initial Condition

Measure the hydraulic pressure at the A port of the cylinder at steady state to set the correct initial pressure in the cylinder.

Hydraulic Closed Loop Control

Results