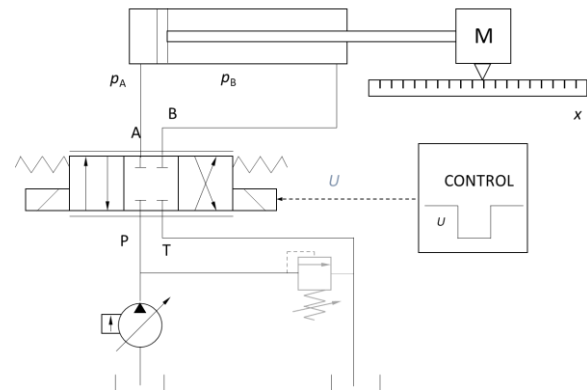


## Simscape Fluids exercise



Open **Matlab**.

Open the **Simscape** model template for your Simscape Fluids models.

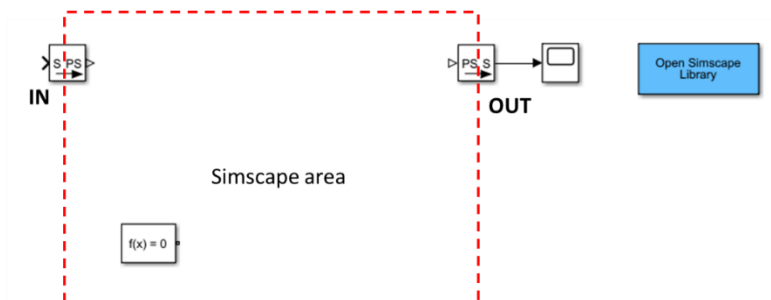
For opening give Matlab command

```
ssc_new
```

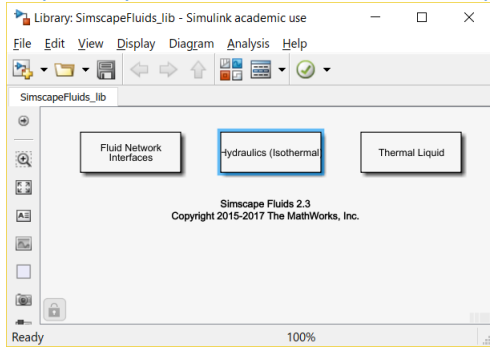
This will open the

- **model template** with
  - **Solver Configuration** block
  - and **Simulink-PS Converter** and **PS-Simulink Converter** blocks
- **Foundation library**

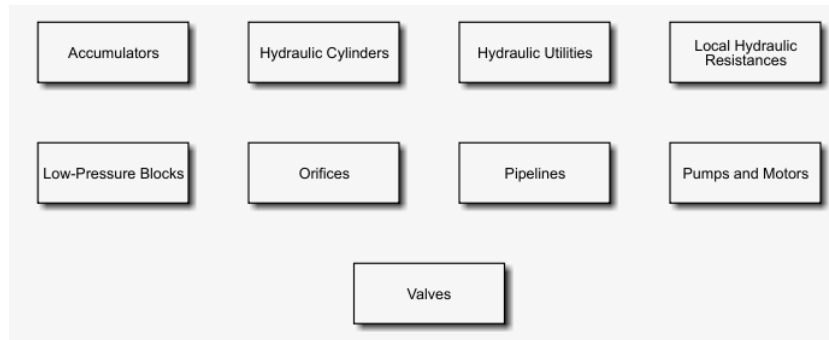
Simulink area



You can enter **Matlab** command `SimscapeFluids_lib` for Simscape Fluids block library.



Library: SimscapeFluids\_lib



Library: SimscapeFluids\_lib > Hydraulics (Isothermal)



Model canvas

Find **Hydraulics (Isothermal) > Hydraulic Utilities** library, open it (double clicking) and use the mouse to drag a **Hydraulic Fluid** block to your new model canvas.

With this block you can determine the physical properties of the hydraulic fluid.

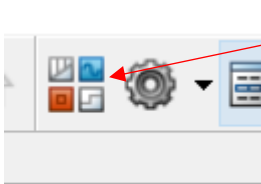
- density,
  - viscosity, and
  - bulk modulus.
- Connect the **Solver Configuration** and **Hydraulic Fluid** blocks.
    - With left mouse button draw a wire between blocks' terminals.
    - **OR**
    - Click on the first block with the left button of your mouse
    - Press **Ctrl** button of your keyboard
    - Click on the second block
    - Connection (Wire) will be formed automatically.



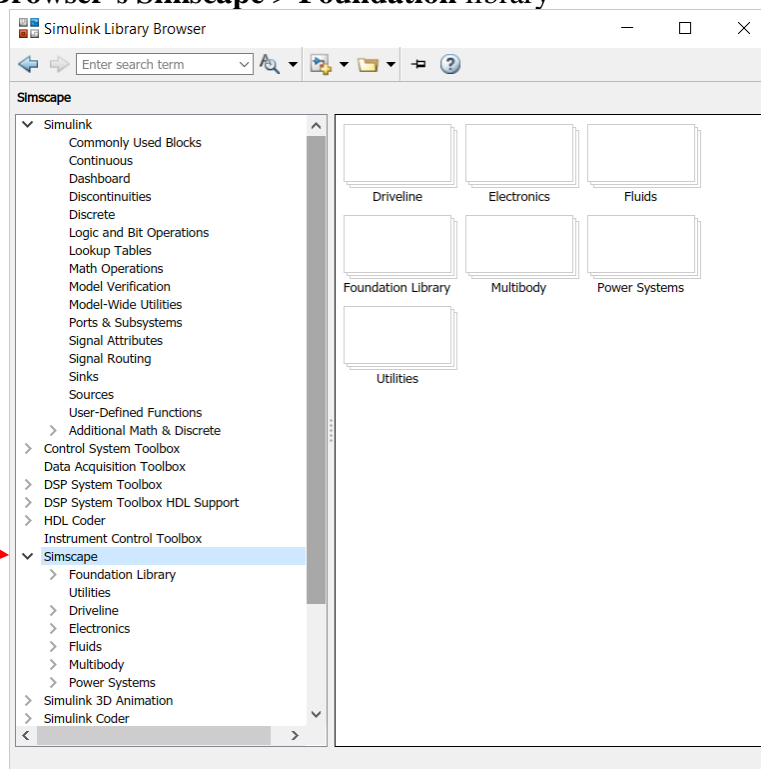
## Solver Configuration Hydraulic Fluid

The Solver Configuration block defines solver settings for your model.

In your canvas window click **Library Browser** button to open **Simulink Library Browser**.



From the **Library Browser's** **Simscape** > **Foundation** library



Pick the next two blocks and drag them to the model canvas.

**Block**

**Sublibrary**

Hydraulic Constant Pressure Source **Foundation Library > Hydraulic > Hydraulic Sources**

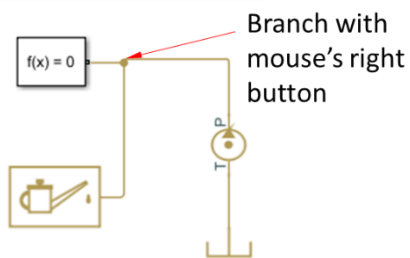
Hydraulic Reference **Foundation Library > Hydraulic > Hydraulic Elements**



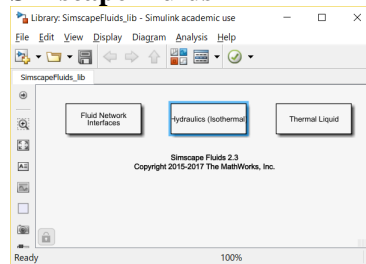
## Hydraulic Constant Pressure Source and Hydraulic Reference

The Hydraulic Reference block represents a connection to atmospheric pressure.

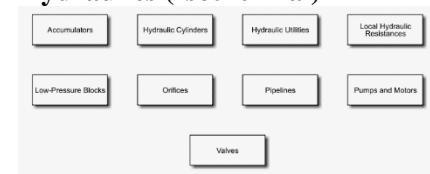
Connect these elements on the canvas. To make the branch use mouse's right button.



### Simscape Fluids



### Hydraulics (Isothermal)



From the **Simscape** > **Fluids** library, pick and drag three blocks to the model canvas.

#### Block

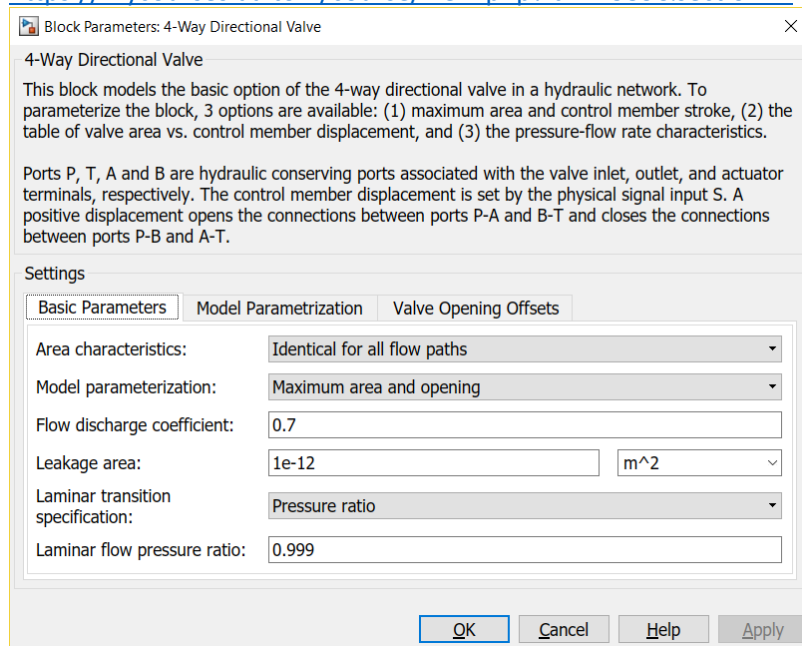
Double-Acting  
Hydraulic Cylinder  
(Simple)

#### Sublibrary

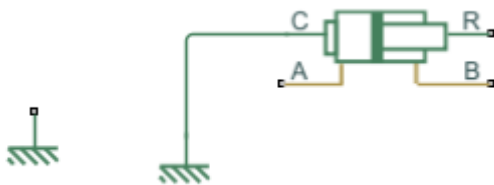
**Hydraulics (Isothermal) > Hydraulic Cylinders**

4-Way Directional Valve **Hydraulics (Isothermal) > Valves**

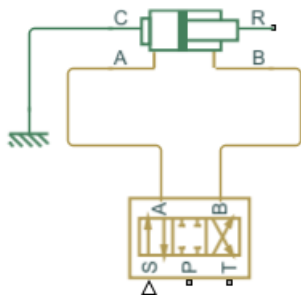
- The block connections represent the physical connections between the actual components. The cylinder connects to the valve, which connects to the pump, which in turn connects to the fluid reservoir.
- Open the **4-Way Directional Valve** block dialog box by double clicking.



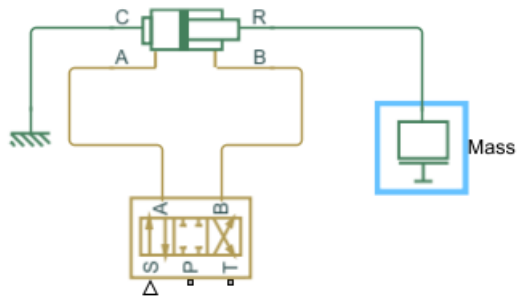
- From the **Simscape** > **Foundation** > **Mechanical** > **Translational** library, add a Mechanical Translational Reference block and connect it as shown in the figure.



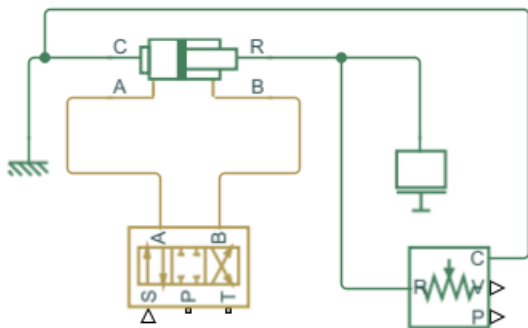
- Connect the **4-way Directional Valve** to the **Double-Acting Hydraulic Cylinder** as follows.



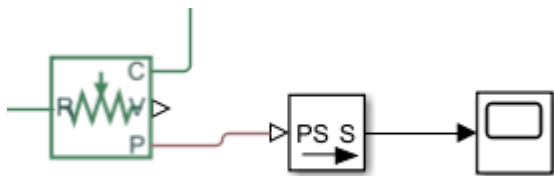
- From the **Simscape** > **Foundation** > **Mechanical** > **Translational Elements** library, add a **Mass** block and connect it as shown in the figure below.



- From the **Simscape** > **Foundation** > **Mechanical** > **Mechanical Sensors** library bring an **Ideal Translational Motion Sensor** block and connect it as in the figure below (both **C** and **R** terminals).



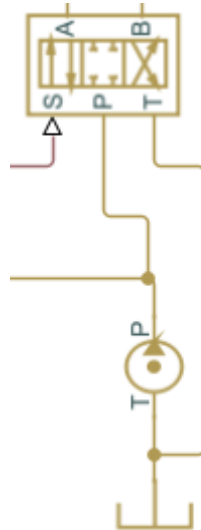
- Connect the **Ideal Translational Motion Sensor** block to **PS-Simulink Converter** and **Scope** as follows.



- From the **Hydraulics (Isothermal)** > **Valves** > **Valve Actuators** library bring a **Valve Actuator** block and connect it to **Simulink-PS Converter** and **4-Way Directional Valve** as in the figure below.



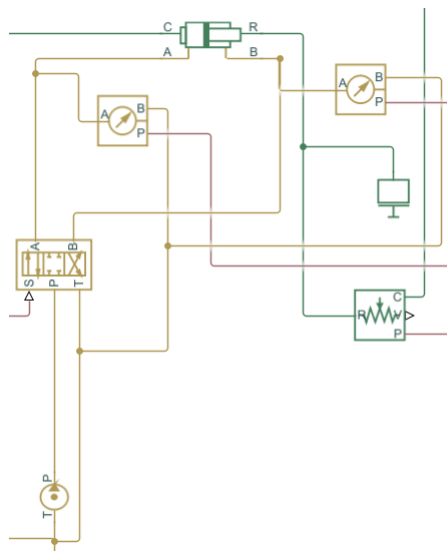
- Connect the **4-Way Directional Valve** to **Hydraulic Constant Pressure Source block** and to the **Hydraulic Reference block** as in the figure below.



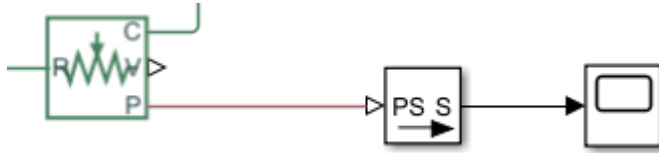
### Pressure sensor



- From the **Simscape > Foundation** library bring **Hydraulic > Hydraulic Sensors > Hydraulic Pressure Sensor** block. Make a copy of it and connect those two to **Hydraulic Cylinder's A and B** interfaces as well as the **Hydraulic Reference** (tank pressure) as in the figure below.



- Connect both of the **Hydraulic Pressure Sensor(s)** to **Scope(s)** by using a **PS-Simulink Converter** as follows.



### Signal inputs

From the **Simulink Library Browser** > **Sources** bring

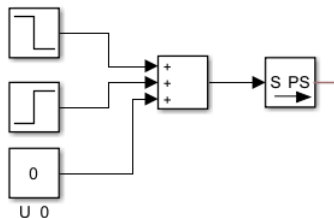
**Step** block ⇒ clone it (Ctrl-C and Ctrl-V) to get another block.

### Constant block

From the **Simulink Library Browser** > **Math Operations** bring

**Add** block

Connect the blocks with **Simulink-PS Converter** block as follows.



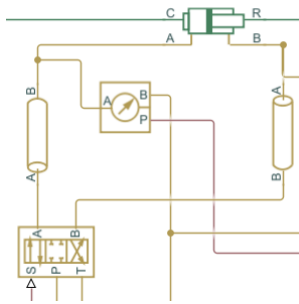
**Constant** (named U\_0) block represents the valve's zero point parameter. Adjust that parameter to keep cylinder still during zero input signal.

### Pipes

From the Library: **Simscape** > **Fluids** > **Hydraulics (Isothermal)** > **Pipelines** bring **Hydraulic Pipeline** block. Make a copy of it and connect those two to **Hydraulic Cylinder's** A and B interfaces and corresponding A and B interfaces of **4-Way Directional Valve** as in the figure below.

**Attention!** You can rotate blocks by using Ctrl-R keyboard command.

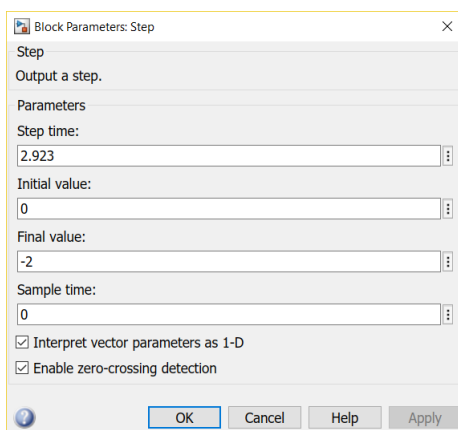
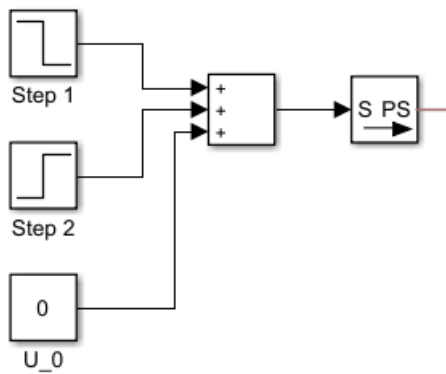




## System Parameters – Double click blocks to open

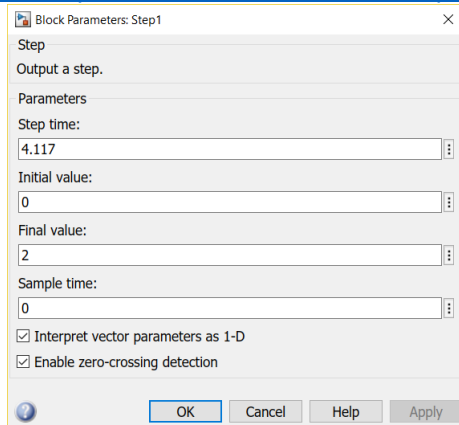
Set system parameters as follows.

### Step blocks



Set **Time** and **Final value**

### Step block 1 parameters



Block Parameters: Step

Step  
Output a step.

Parameters

Step time:  
4.117

Initial value:  
0

Final value:  
2

Sample time:  
0

☒ Interpret vector parameters as 1-D  
☒ Enable zero-crossing detection

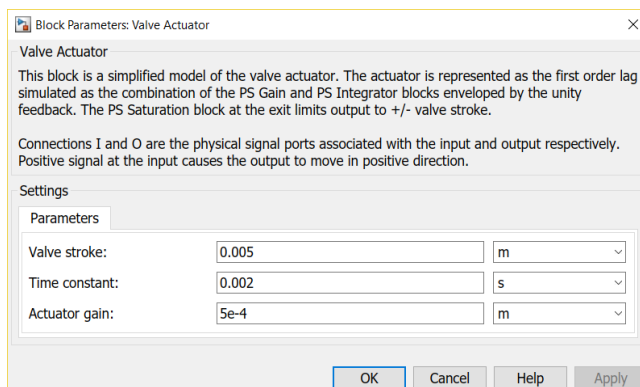
OK Cancel Help Apply

Set Time and Final value

### Step block 2 parameters

**Constant** (named U\_0) block represents the valve's zero point parameter. Adjust that parameter to keep cylinder still during zero input.

### Valve Actuator



Block Parameters: Valve Actuator

Valve Actuator

This block is a simplified model of the valve actuator. The actuator is represented as the first order lag simulated as the combination of the PS Gain and PS Integrator blocks enveloped by the unity feedback. The PS Saturation block at the exit limits output to +/- valve stroke.

Connections I and O are the physical signal ports associated with the input and output respectively. Positive signal at the input causes the output to move in positive direction.

Settings

Parameters

Valve stroke: 0.005 m

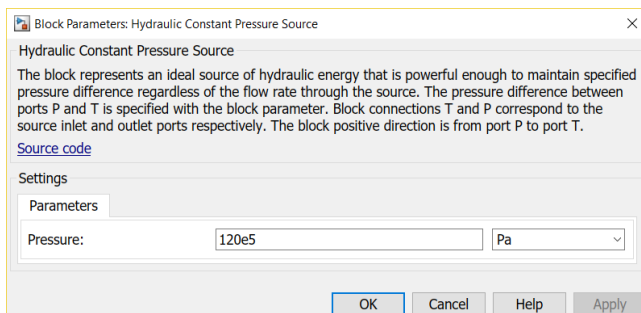
Time constant: 0.002 s

Actuator gain: 5e-4 m

OK Cancel Help Apply

- maximum **Valve stroke** 0.005 m (5 mm)
- by applying 10 V input the Actuator reaches full 5 mm stroke
- therefore the **Actuator gain** is 0.005/10 [m/V]
- the value for the **Time constant** can be 0.002 s (2 ms)

### Hydraulic Constant Pressure Source (ideal constant pressure pump)



Block Parameters: Hydraulic Constant Pressure Source

Hydraulic Constant Pressure Source

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

[Source code](#)

Settings

Parameters

Pressure: 120e5 Pa

OK Cancel Help Apply

- ideal pump with constant pressure of 120 bar (in Matlab 120e5 [Pa])

**4-Way Directional Valve** (proportional valve)

For an orifice the flow rate is

If we know

$$q_v = C_q A \sqrt{\frac{2\Delta p}{\rho}}$$

- nominal flow rate ( $q_v$ ),
- nominal pressure drop ( $\Delta p$ ),
- fluid density ( $\rho$ ) and
- flow coefficient ( $C_q$ )

the corresponding flow are can be calculated as follows

$$A = \frac{q_v}{C_q \sqrt{\frac{2\Delta p}{\rho}}}$$

**For leakage of a certain proportional control valve**

$$q_v \quad 0.45 \text{ l/min} \Rightarrow 0.45/60000 \text{ m}^3/\text{s}$$

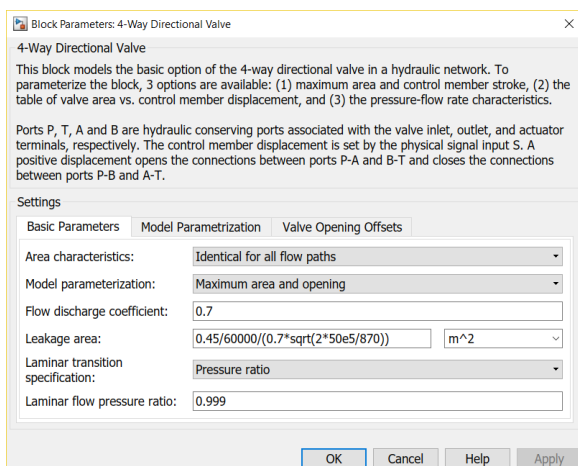
$$\Delta p \quad 50 \text{ bar} \Rightarrow 50 \cdot 10^5 \text{ Pa}$$

$$\rho \quad 961.873 \text{ kg/m}^3 \text{ (from **Hydraulic fluid** block)}$$

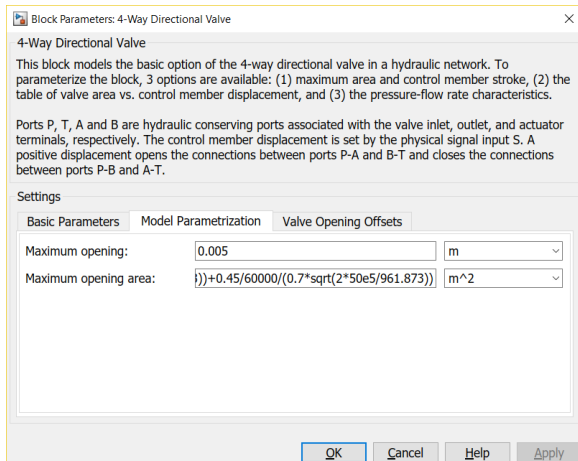
$$C_q \quad 0.7$$

**Leakage area** parameter

$$0.45/60000/(0.7 \cdot \sqrt{2 \cdot 50 \cdot 10^5 / 961.873}))$$

**Maximum opening** parameter 0.005 m

## Maximum opening area



## Maximum opening area parameter

leakage area + actual flow area (40 l/min @ 35 bar)

$$40/60000/((0.7*\sqrt{2*35e5/961.873}))+0.45/60000/((0.7*\sqrt{2*50e5/961.873}))$$

## Double-Acting Hydraulic Cylinder (Simple)

**Block Parameters: Double-Acting Hydraulic Cylinder (Simple)**

Double-Acting Hydraulic Cylinder (Simple)

The block is a model of a double-acting hydraulic cylinder developed for applications in which only the basic cylinder functionality must be reproduced in exchange for better numerical efficiency. For these reasons, factors such as fluid compressibility, friction, and leakages are assumed to be negligible. The hard stops are assumed to be fully inelastic to eliminate any possible oscillations at the end of the stroke. The model is suitable for real time or HIL simulation if such simplifications are acceptable.

Connections R and C are mechanical translational conserving ports corresponding to the cylinder rod and cylinder clamping structure, respectively. Connections A and B are hydraulic conserving ports. Port A is connected to chamber A and port B is connected to chamber B. The block directionality is adjustable with the Cylinder Orientation parameter.

**Settings**

**Parameters**

Piston area A:	$\pi/4 \cdot 0.032^2$	m <sup>2</sup>
Piston area B:	$\pi/4 \cdot 0.032^2 - \pi/4 \cdot 0.020^2$	m <sup>2</sup>
Piston stroke:	1	m
Piston initial distance from cap A:	0.8	m
Penetration coefficient:	1e12	s*N/m <sup>2</sup>
Cylinder orientation:	Acts in positive direction	

OK Cancel Help Apply

- $D$  cylinder diameter 32 mm
- $d$  rod diameter 20 mm
- maximum stroke 1 m
- initial position of piston 0.8 m
- $A_A = \pi/4 D^2$
- $A_B = A_A - \pi/4 d^2$

## Mass

**Block Parameters: Mass**

Mass

The block represents an ideal mechanical translational mass.

The block has one mechanical translational conserving port. The block positive direction is from its port to the reference point. This means that the inertia force is positive if mass is accelerated in positive direction.

[Source code](#)

**Settings**

**Parameters** **Variables**

Mass:	234	kg
-------	-----	----

OK Cancel Help Apply

## Pipe parameters

## Update parameters

- Pipe internal diameter  $\Rightarrow 0.012$  m
- Pipe length  $\Rightarrow 0.75$  m

**Block Parameters: Hydraulic Pipeline**

**Hydraulic Pipeline**

This block models hydraulic pipelines with circular and noncircular cross sections. The block accounts for friction loss along the pipe length and for fluid compressibility, and by extent of idealization it takes an intermediate place between the Resistive Tube and the Segmented Pipeline blocks. The block does not account for fluid inertia. The model is built of Resistive Tube and Constant Volume Chamber building blocks.

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

**Settings**

**Parameters**

Pipe cross section type: Circular

Pipe internal diameter: 0.012 m

Geometrical shape factor: 64

Pipe length: 0.75 m

Aggregate equivalent length of local resistances: 1 m

Internal surface roughness height: 15e-6 m

Laminar flow upper Reynolds number limit: 2000

Turbulent flow lower Reynolds number limit: 4000

OK Cancel Help Apply

## Ideal Translational Motion Sensor

### Update parameter **Initial position** $\Rightarrow 0.8$ m

**Block Parameters: Ideal Translational Motion Sensor**

**Ideal Translational Motion Sensor**

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

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

[Source code](#)

**Settings**

**Parameters**

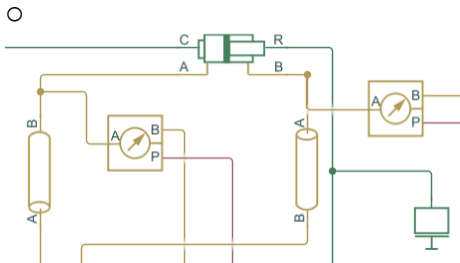
Initial position: 0.8 m

OK Cancel Help Apply

## Hydraulic Pressure Sensors

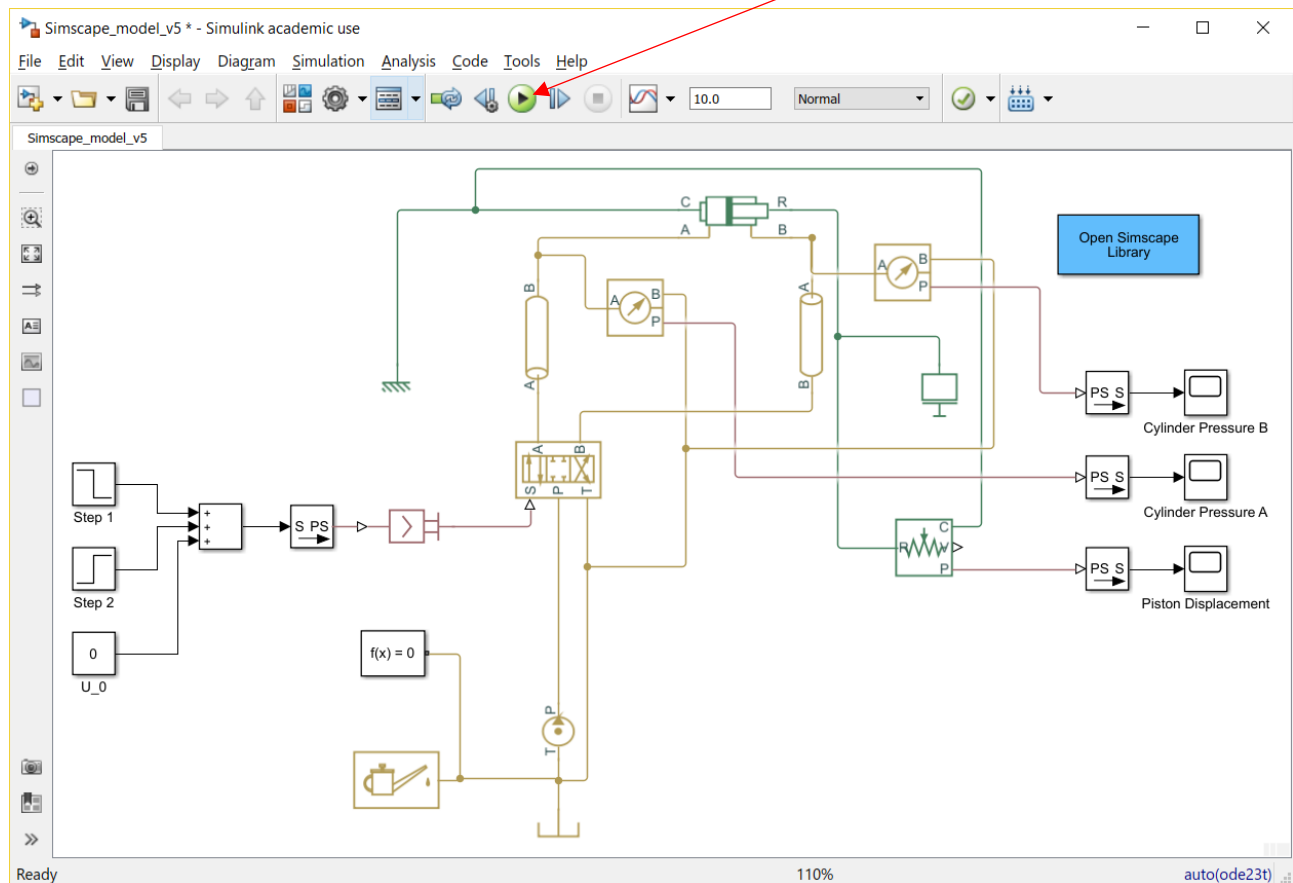
From the **Library Browser's Simscape > Foundation library > Hydraulic > Hydraulic Sensors** bring **Hydraulic Pressure Sensor**, make a copy of it and connect those two

- between **Hydraulic Cylinder's A interface** and **Hydraulic Reference (B interface)**
- between **Hydraulic Cylinder's B interface** and **Hydraulic Reference (B interface)**
- connect **P** interfaces to **PS-Simulink Converter(s)**
- connect **PS-Simulink Converter(s)** to **Scopes**



Your system should look like this.

**Start simulation**



## Assignment for phase 1

### Make a short document (Word)

Documentation Format:

#### Your name

#### Assignments

1. Finalize the simulation model
  - a. Document **part 1**
    - i. Paste a **Figure of the System Model** to your document
    - ii. **Edit > Copy Current View to Clipboard > Metafile or Bitmap**
2. Tune the system with valve's zero point parameter (U\_0). Adjust that parameter to keep cylinder still during zero input.
  - a. Document **part 2**
    - i. Give the proper parameter value for U\_0
3. Plot the **Piston Displacement** signal
  - a. Document **part 3**
    - i. Copy the Scope plot and paste it into your document
    - ii. **File > Copy to Clipboard (Ctrl-C) OR**
    - iii. (File > Print to Figure) OR
    - iv. Configuration Properties > Logging > Log data to Workspace
      1. Variable name x
      2. Save format: Array
      3. In Matlab workspace
        - a. figure
        - b. `plot(x(:,1),x(:,2);`
4. Plot the **Cylinder Pressure A** signal
  - a. Document **part 4**
    - i. Copy the Scope plot and paste it into your document
    - ii. **File > Copy to Clipboard (Ctrl-C) OR** the options presented above
5. Plot the **Cylinder Pressure B** signal
  - a. Document **part 5**
    - i. Copy the Scope plot and paste it into your document
    - ii. **File > Copy to Clipboard (Ctrl-C) OR** the options presented above
6. Improvement suggestions to this Tutorial document
  - a. Actual errors or misprints (page and location)
  - b. Missing information
  - c. Actual improvements

#### Additional material

Getting started

<https://se.mathworks.com/help/physmod/hydro/getting-started-with-simhydraulics.html>

Simple actuator model tutorial

<https://se.mathworks.com/help/physmod/hydro/ug/creating-a-simple-model.html>