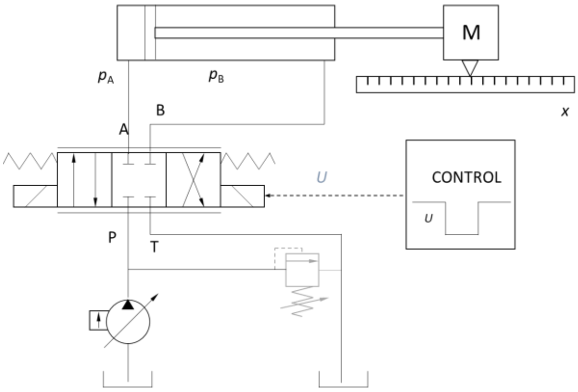
MEC-E5004 - Fluid Power Systems
Aalto university
https://mycourses.aalto.fi/course/view.php?id=21959&section=1

Simscape Fluids exercise



Open **Matlab.**

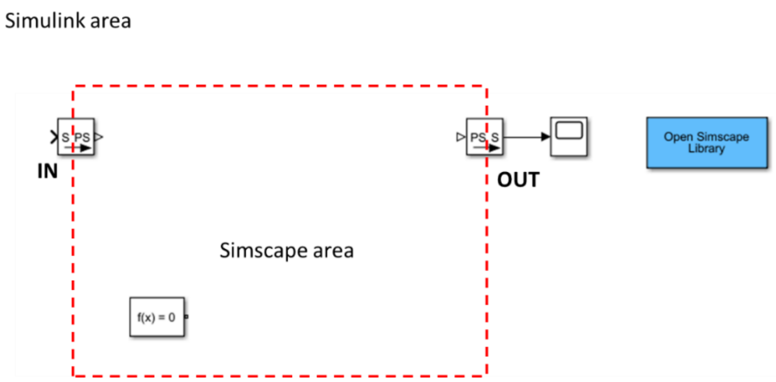
Open the **Simscape** model template for your Simscape Fluids models.

For opening give Matlab command

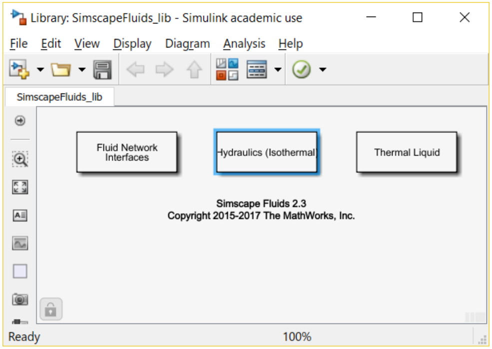
```
ssc_new
```

This will open the

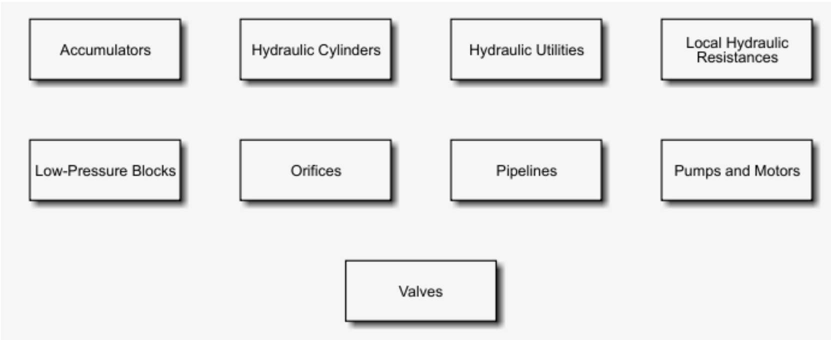
- **model template** with
  - **Solver Configuration** block
  - and **Simulink-PS Converter** and **PS-Simulink Converter** blocks
- **Foundation library**



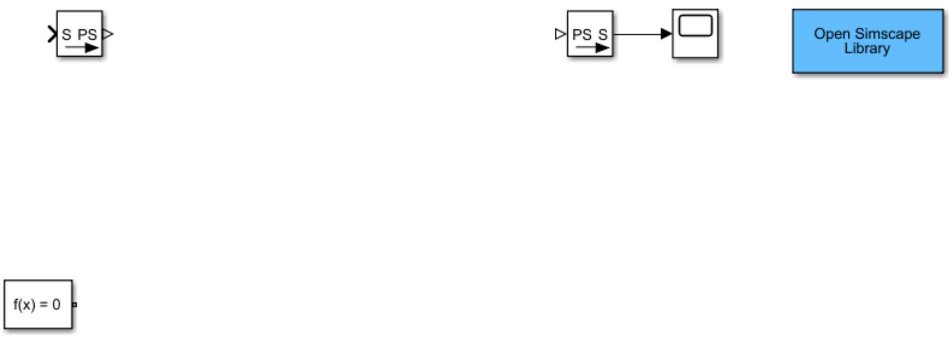
You can enter **Matlab** command `SimscapeFluids_lib` for Simscape Fluids block library.



Library: SimscapeFluids_lib



Library: SimscapeFluids_lib > Hydraulics (Isothermal)



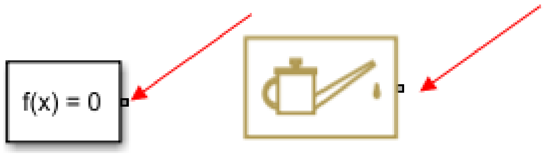
Model canvas

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.

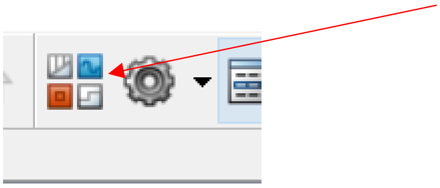
  - With left mouse button draw a wire between blocks' terminals.
  - **OR**
  - Click on the first block with the left button of your mouse
  - Press **Ctrl** button of your keyboard
  - Click on the second block
  - Connection (Wire) will be formed automatically.



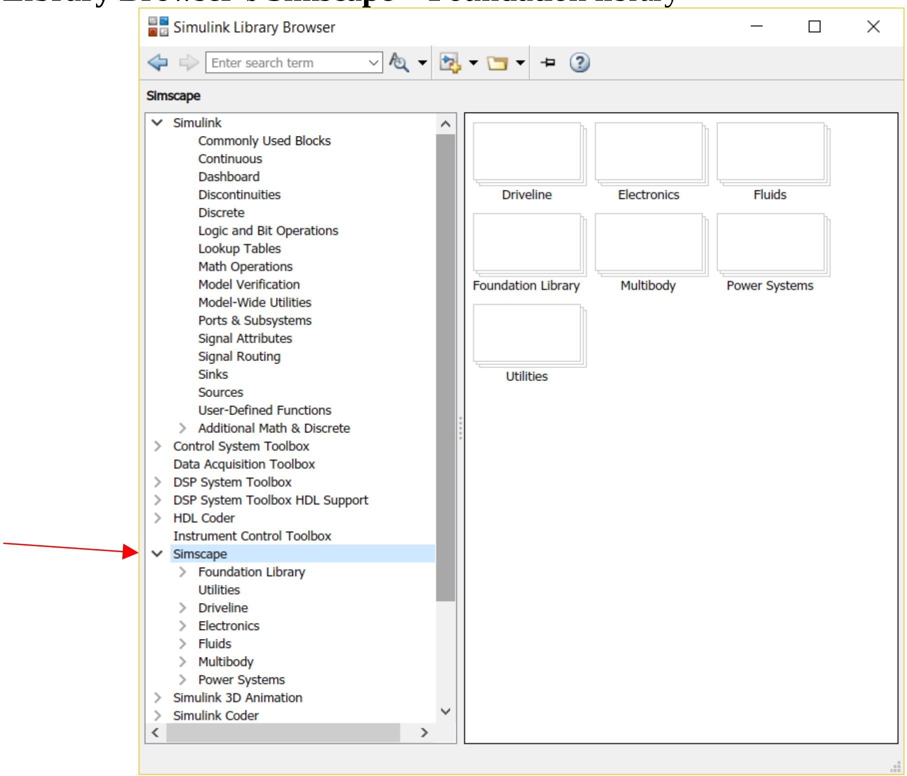
Solver Configuration Hydraulic Fluid

The Solver Configuration block defines solver settings for your model.

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

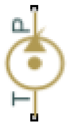


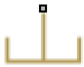
From the **Library Browser's Simscape** > **Foundation** library



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**

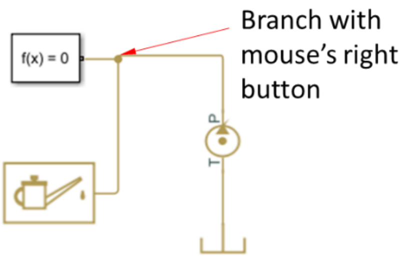




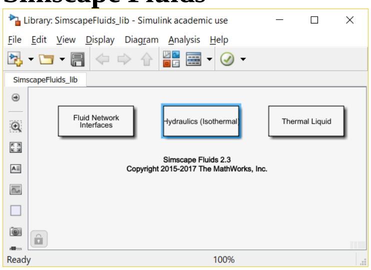
Hydraulic Constant Pressure Source and
Hydraulic Reference

The Hydraulic Reference block represents a connection to atmospheric pressure.

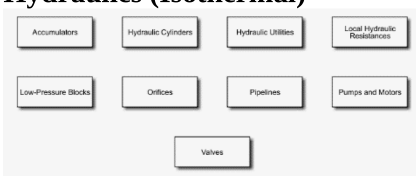
Connect these elements on the canvas. To make the branch use mouse's right button.



Simscape Fluids



Hydraulics (Isothermal)

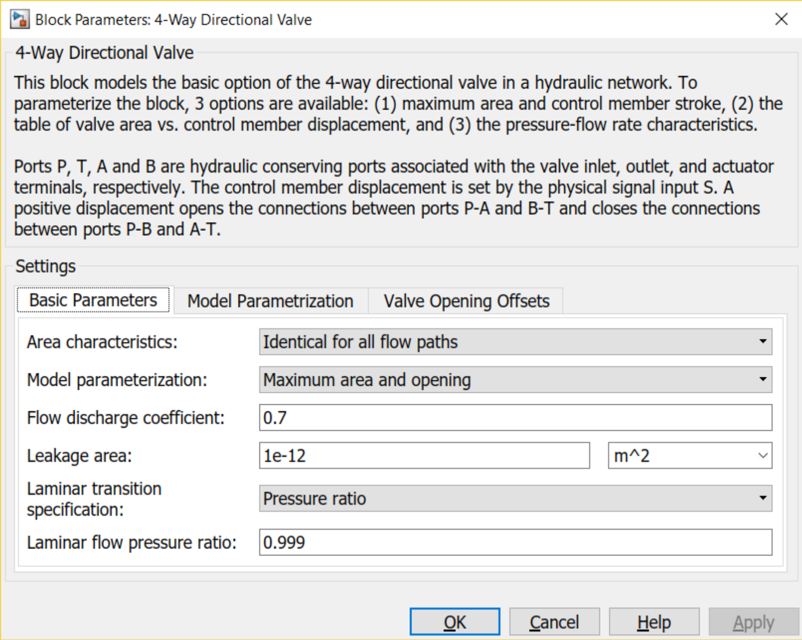


From the **Simscape** > **Fluids** library, pick and drag three blocks to the model canvas.

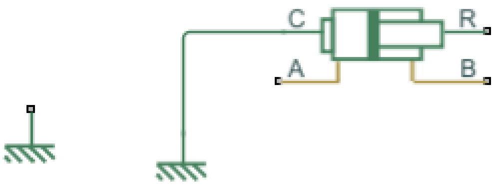
Block	Sublibrary
Double-Acting Hydraulic Cylinder (Simple)	**Hydraulics (Isothermal)** > **Hydraulic Cylinders**
4-Way Directional Valve	**Hydraulics (Isothermal)** > **Valves**

- 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.

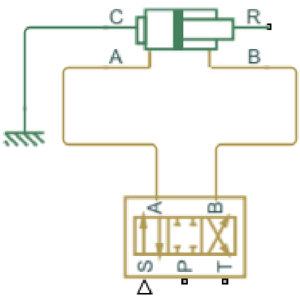
- Open the **4-Way Directional Valve** block dialog box by double clicking.



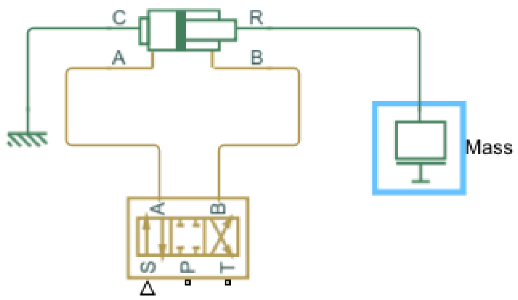
- From the **Simscape** > **Foundation** > **Mechanical** > **Translational** library, add a Mechanical Translational Reference block and connect it as shown in the figure.



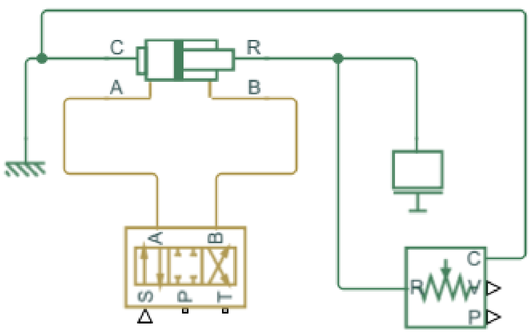
- Connect the **4-way Directional Valve** to the **Double-Acting Hydraulic Cylinder** as follows.



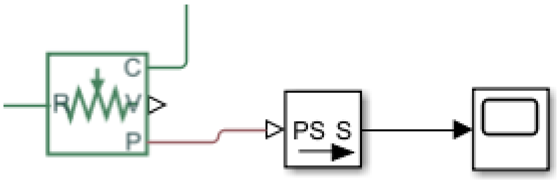
- From the **Simscape** > **Foundation** > **Mechanical** > **Translational Elements** library, add a **Mass** block and connect it as shown in the figure below.



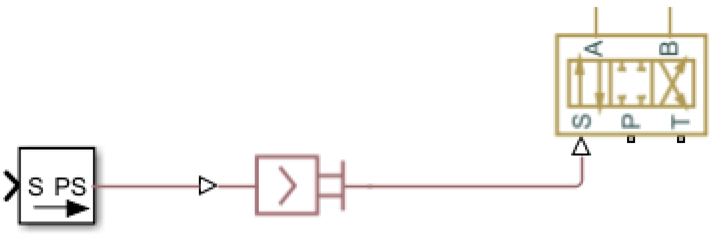
- From the **Simscape** > **Foundation** > **Mechanical** > **Mechanical Sensors** library bring an **Ideal Translational Motion Sensor** block and connect it as in the figure below (both **C** and **R** terminals).



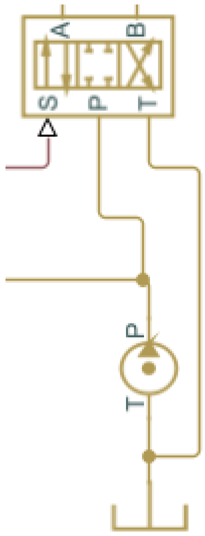
- Connect the **Ideal Translational Motion Sensor** block to **PS-Simulink Converter** and **Scope** as follows.



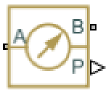
- From the **Hydraulics (Isothermal)** > **Valves** > **Valve Actuators** library bring a **Valve Actuator** block and connect it to **Simulink-PS Converter** and **4-Way Directional Valve** as in the figure below.



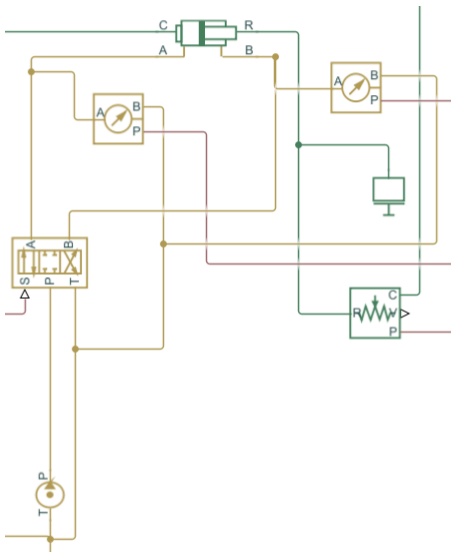
- Connect the **4-Way Directional Valve** to **Hydraulic Constant Pressure Source block** and to **the Hydraulic Reference block** as in the figure below.



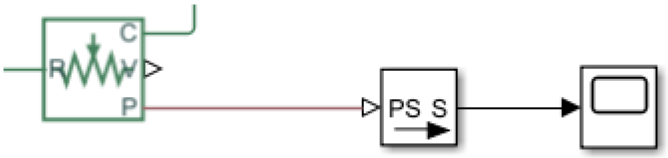
Pressure sensor



- 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

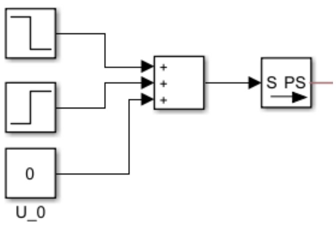
Step block ⇒ clone it (Ctrl-C and Ctrl-V) to get another block.

Constant block

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

Add block

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

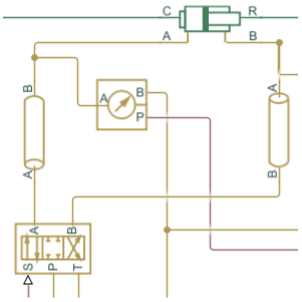


Constant (named U_0) block represents the valve's zero point parameter. Adjust that parameter to keep cylinder still during zero input signal.

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.

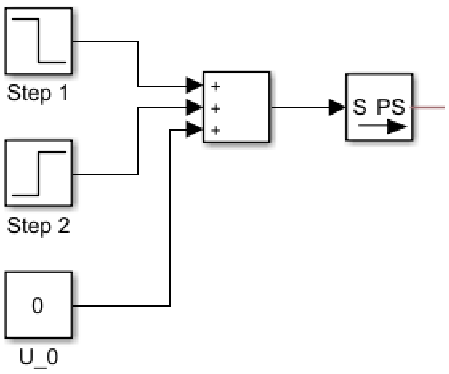
Attention! You can rotate blocks by using Crtl-R keyboard command.

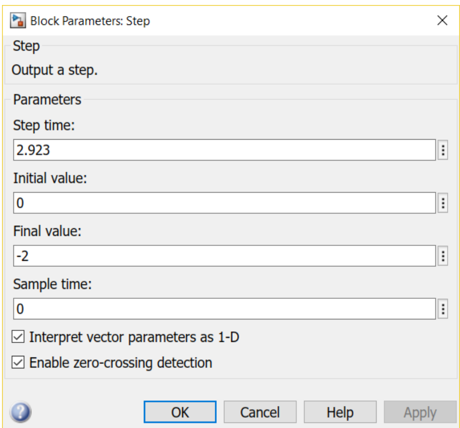


System Parameters – Double click blocks to open

Set system parameters as follows.

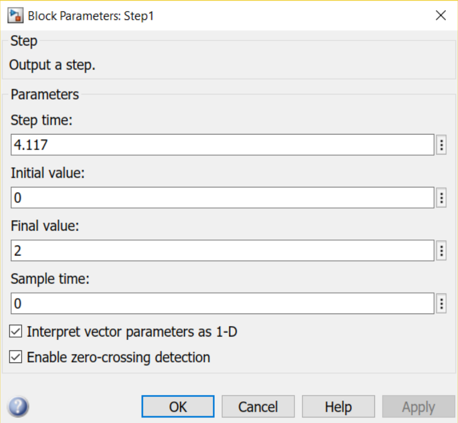
Step blocks





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

Step block 1 parameters

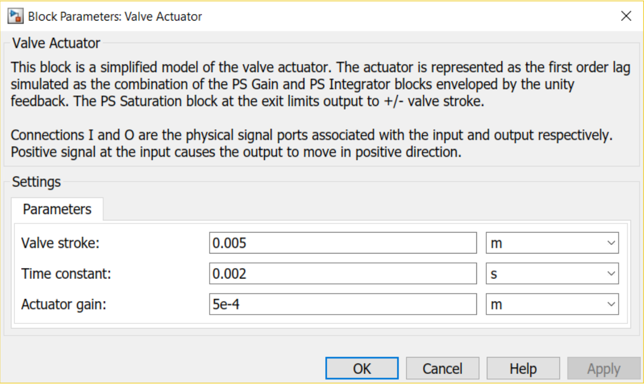


Set **Time** and **Final value**

Step block 2 parameters

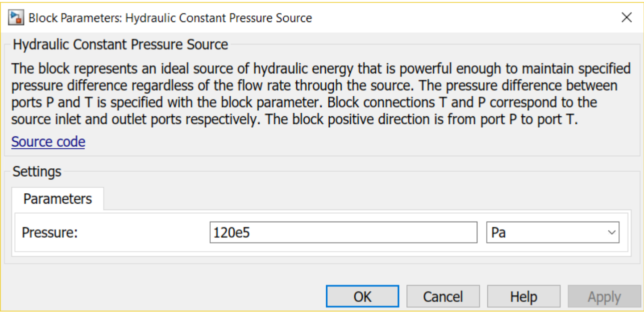
Constant (named U_0) block represents the valve's zero point parameter. Adjust that parameter to keep cylinder still during zero input.

Valve Actuator



- 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)



- 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

$$q_{\mathrm{v}} = C_{\mathrm{q}} A \sqrt{\frac{2\Delta p}{\rho}}$$

If we know

- nominal flow rate (q_{v}),
- nominal pressure drop (Δp),
- fluid density (ρ) and
- flow coefficient (C_{q})

the corresponding flow are can be calculated as follows

$$A = \frac{q_{\mathrm{v}}}{C_{\mathrm{q}}\sqrt{\frac{2\Delta p}{\rho}}}$$

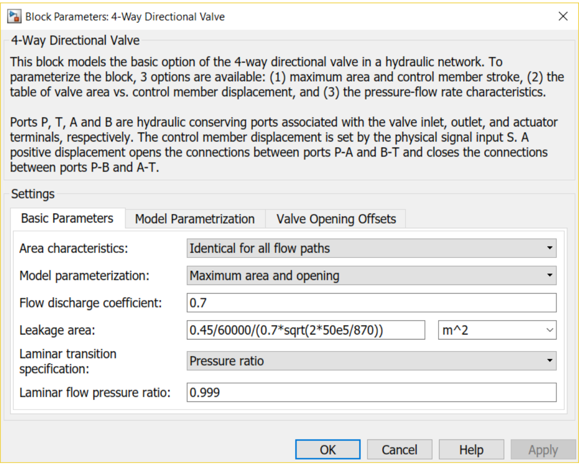
For leakage of a certain proportional control valve

q_{v}	0.45 l/min $\Rightarrow$ 0.45/60000 m^3/s
Δp	50 bar $\Rightarrow$ $50 \cdot 10^5$ Pa
ρ	961.873 $\mathrm{kg/m}^3$ (from **Hydraulic fluid** block)
C_{q}	0.7

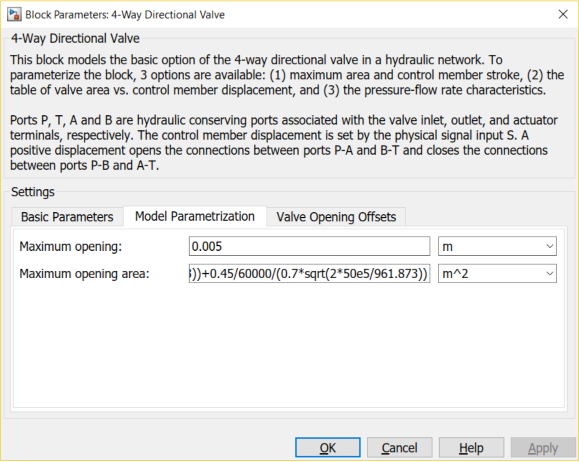
Leakage area parameter

0.45/60000/(0.7*sqrt(2*50e5/961.873))

Maximum opening parameter 0.005 m



Maximum opening area

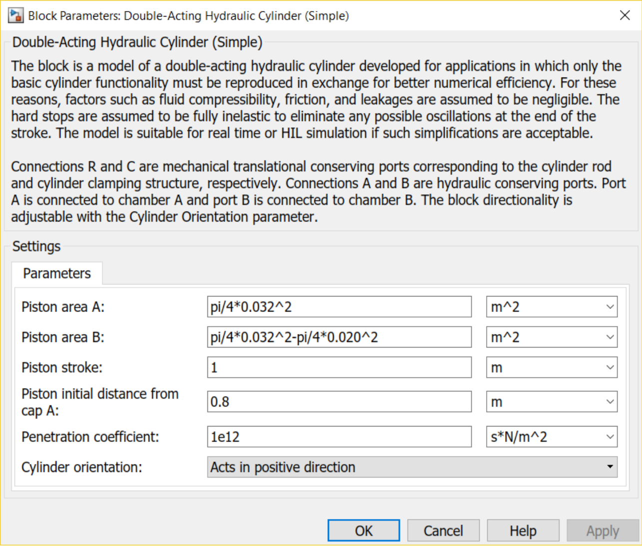


Maximum opening area parameter

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

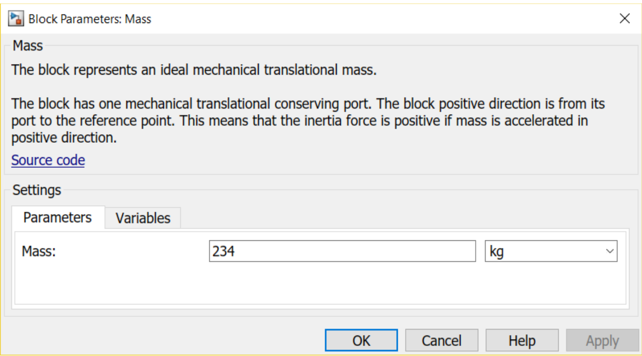
40/60000/(0.7*sqrt(2*35e5/961.873))+0.45/60000/(0.7*sqrt(2*50e5/961.873))

Double-Acting Hydraulic Cylinder (Simple)



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

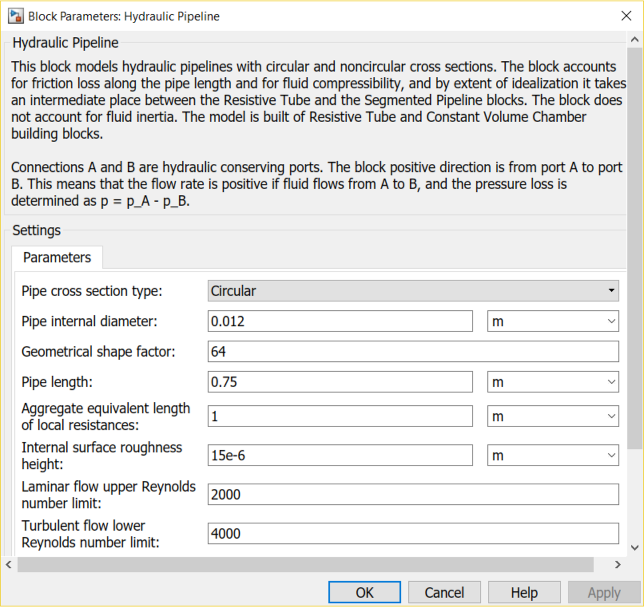
Mass



Pipe parameters

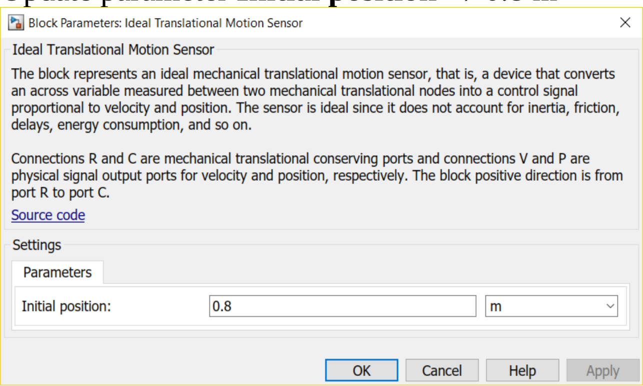
Update parameters

- Pipe internal diameter ⇒ 0.012 m
- Pipe length ⇒ 0.75 m



Ideal Translational Motion Sensor

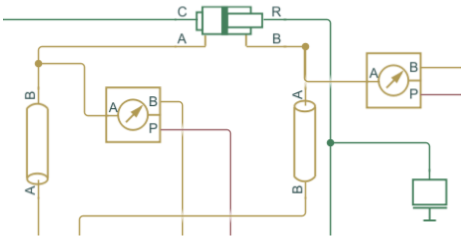
Update parameter **Initial position** ⇒ 0.8 m



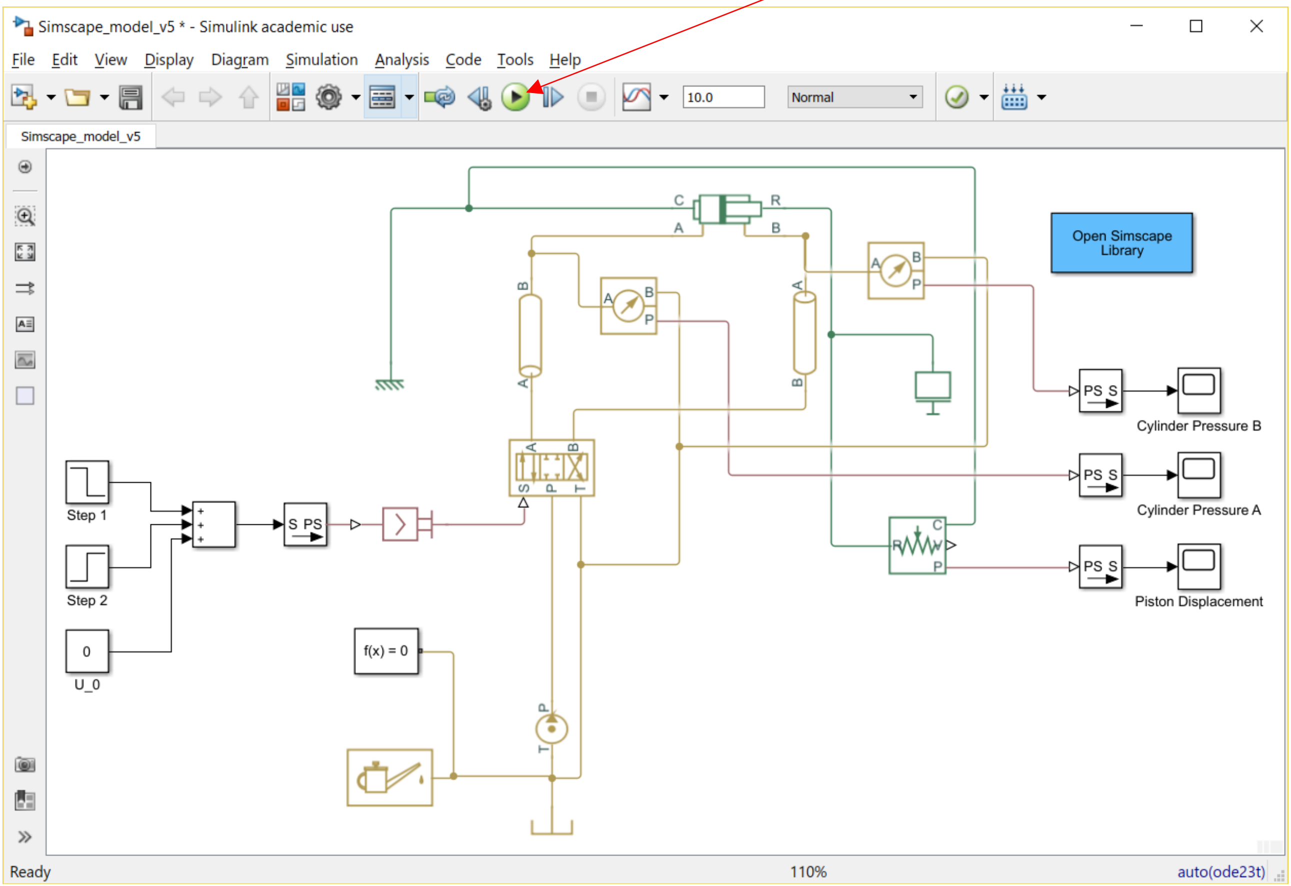
Hydraulic Pressure Sensors

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
Assigments

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