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Exercises: Introduction to Simscape™

Student Competition - Physical Modeling Training

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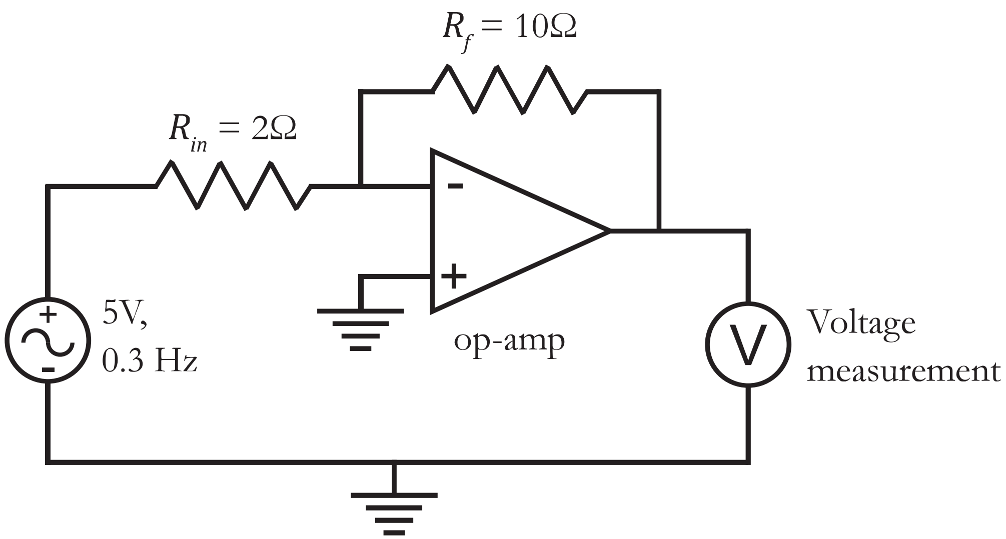
Inverting Operational Amplifier

In this exercise, you will design an inverting operational amplifier (op-amp) using blocks from the Simscape library.



An inverting operational amplifier is an electric circuit that inverts and amplifies the input voltage through negative feedback. The output voltage of an inverting amplifier is computed as follows:

where

V_{out} = Output Voltage (V)

$$V_{out} = -(R_f / R_{in}) \cdot V_{in}$$

R_f = Feedback resistance (ohms)
R_{in} = Input resistance (ohms)
V_{in} = Input Voltage (V)

To build the operational amplifier, take the following steps:

1. **Referring to the figure, drag the required blocks in the model.**

   Hint You will find a majority of the needed blocks in the Electrical domain.
2. **Connect the blocks as shown and set their respective parameters in the above figure.**

   Note that this is an inverting amplifier. Ensure that the positive terminal of the op-amp is grounded.

   Hint You need to use the appropriate Sensor block to measure the output voltage.
3. **Choose an appropriate solver, simulate the model, and view the waveforms.**

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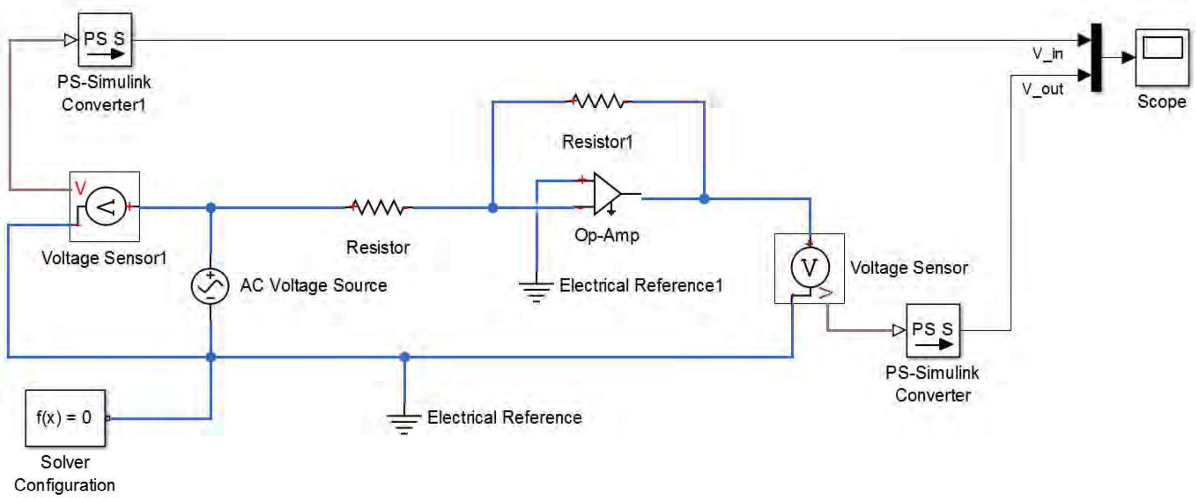
Solution: Inverting Operational Amplifier

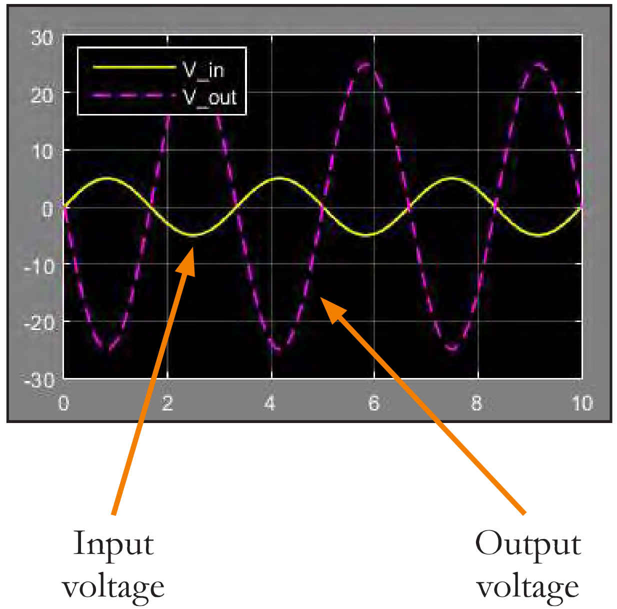
1. Drag Solver Configuration and PS-Simulink Converter blocks from the **Simscape → Utilities** library into the model.
2. Drag Op-Amp, Resistor, and Electrical Reference blocks from the **Simscape → Foundation Library → Electrical → Electrical Elements** library into the model.
3. Drag an AC Voltage Source block from the **Simscape → Foundation Library → Electrical → Electrical Sources** library into the model.
4. Drag a Voltage Sensor block from the **Simscape → Foundation Library → Electrical → Electrical Sensors** library into the model.
5. Connect the blocks as shown in the figure.
6. Set the AC voltage supply to 5V and 0.3 Hz frequency in the AC Voltage Source block.
7. Similarly, set the resistance value of the feedback resistor (R_f) to 10Ω and that of the input resistor (R_{in}) to 2Ω.

Try

```
>> invOpAmp
```

Simulate the model and view the waveforms. Observe that the output voltage is inverted and amplified with respect to the input voltage. The amplification factor (gain) for this circuit is 5. It is the ratio of the feedback resistance (R_f = 10Ω) to input resistance (R_i = 2Ω).





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Simple Hydraulic Circuit

In this exercise, you will model a hydraulic circuit using blocks from the Simscape library.

To build the hydraulic circuit, take the following steps:

1. **Referring to the figure, drag the required blocks in the model.**

   Hint You will find a majority of the needed blocks in the Hydraulic domain.
2. **Connect the blocks as shown and set their respective parameters in the diagram.**

   Refer to the diagram and parameter list on the right. Assume all other block parameters are default.

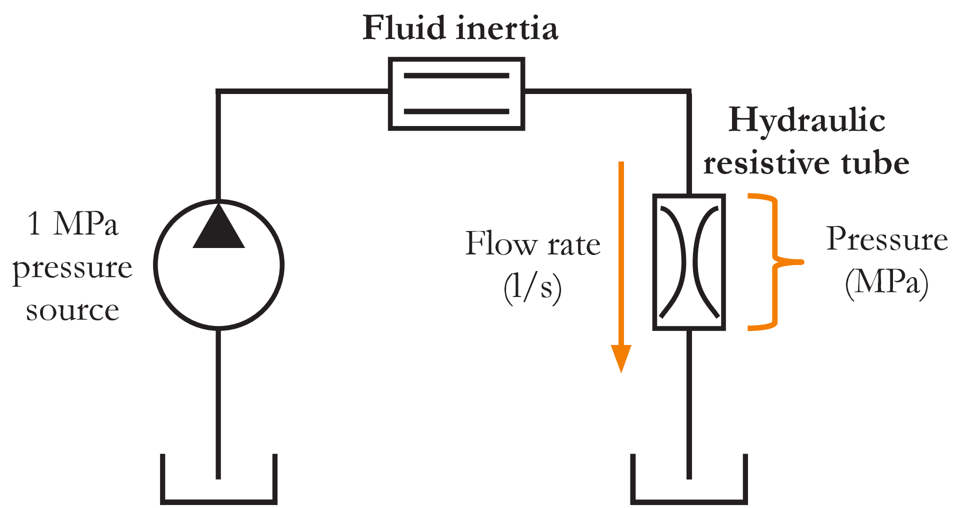
3. **Measure the physical quantities in the diagram.**

   Connect the appropriate Sensor blocks to measure the volumetric flow rate through and pressure drop across the resistive tube. Configure the output units as shown in the diagram.

Parameters

Physical parameters
Input pressure = 1 MPa
Tube internal diameter = 3 cm
Tube area (based on diameter) = 7e-4 m^2
Tube length = 1 m

Simulation parameters
Stop time = 1 s
Solver = `ode23t`



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Solution: Simple Hydraulic Circuit

1. Drag Solver Configuration and PS-Simulink Converter blocks from the **Simscape → Utilities** library into the model.
2. Drag Fluid Inertia, Hydraulic Resistive Tube, and Hydraulic Reference blocks from the **Simscape → Foundation Library → Hydraulic → Hydraulic Elements** library into the model.
3. Drag a Hydraulic Constant Pressure Source block from the **Simscape → Foundation Library → Hydraulic → Hydraulic Sources** library into the model.
4. Drag Hydraulic Flow Rare Sensor and Hydraulic Pressure Sensor blocks from the **Simscape → Foundation Library → Hydraulic → Hydraulic Sensors** library into the model.
5. Connect the blocks as shown in the figure. Note that flow rate is measured in series and pressure is measured in parallel. Configure the units in the PS-Simulink Converter blocks.
6. In the Fluid Inertia block, set the **Passage area** parameter to `7e-4 m^2`.
7. Similarly, in the Hydraulic Resistive Tube block, set the **Tube internal diameter** to `3 cm` (or `0.03 m`) and **Tube length** to `1 m`.

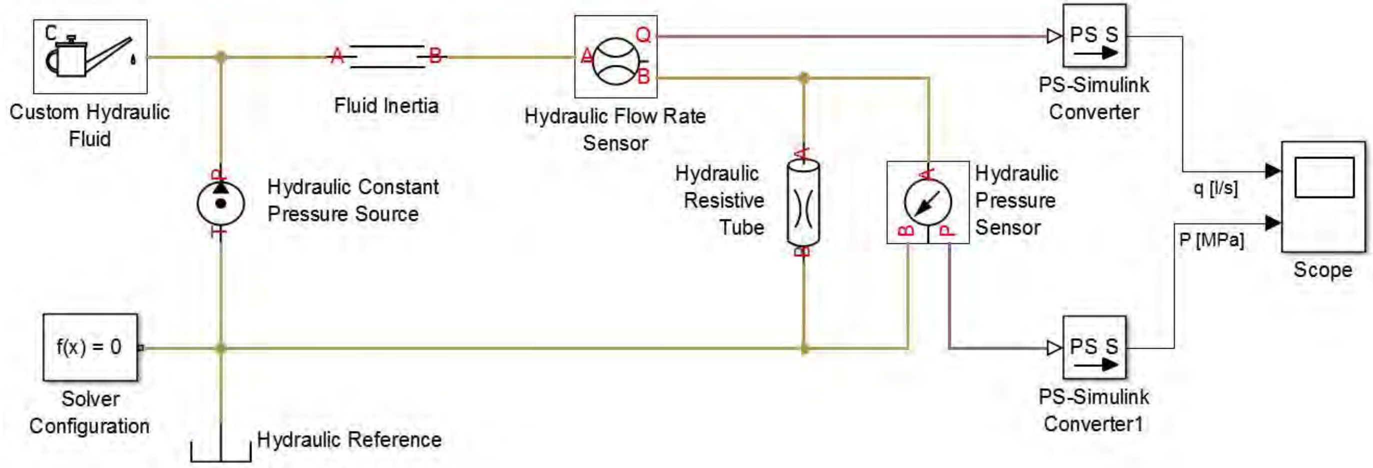
Try

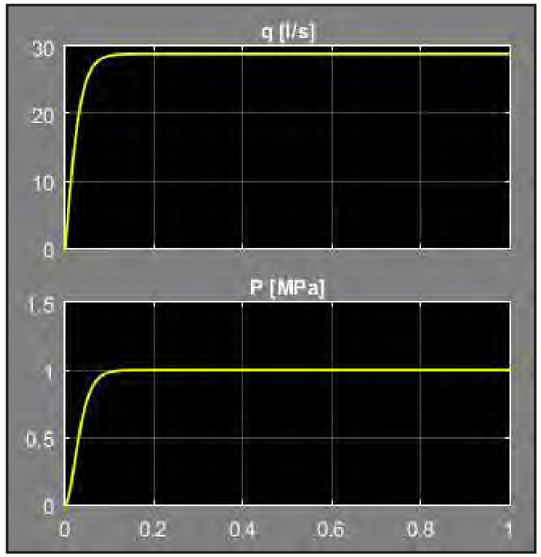
```
>> hydCircuit
```

Simulate the model and view the flow rate and pressure signals. Observe that the fluid inertia causes the pressure to rise to its steady-state value after approximately 0.15 second.

The final flow rate is almost 29 liters per minute. The final pressure is 1 MPa since at steady-state there is no pressure drop across the fluid inertia component.

Note the Custom Hydraulic Fluid block (**Simscape → Foundation Library → Hydraulic → Hydraulic Utilities** library). You can connect this block anywhere on the hydraulic network and use it to configure fluid properties such as density and viscosity.





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