Simscape Fluids exercise

Simscape is an environment for modeling and simulating multidomain physical systems within Matlab/Simulink. More than 10 physical domains, including mechanical, electrical and hydraulic (Simscape Fluids) are covered. In this assignment both the **Simscape Fluids** and **Simulink** domains are mostly utilized.

With Simscape physical component models can be generated based on physical connections by using physical units for both parameters and variables. All unit conversions are handled automatically.



Cylinder piston's position can be controlled in open and closed loop by using directional proportional control valve. System includes

- Differential cylinder with inertia load (mass)
- Directional proportional control valve
- Pressure compensated pump (constant pressure)
- Control system for position control

(Presure relief valve)
Hydraulic actuator force needed only for mass acceleration and deceleration since there is no mechanical friction in this system.
In the assignment the cylinder piston is moved a) into – direction and b) into + direction both by using a) open loop and b) closed loop control.

The hydraulic system to be modeled

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 to specify the solver parameters for your model
 - Simulink-PS Converter and PS-Simulink Converter blocks for data transfer between Simscape and Simulink domains
- Foundation library

Simulink area



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



Open loop control – assignment phase 1

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.
- 1. Open Hydraulic Fluid block by double clicking it.
- 2. Change the Hydraulic Fluid from Skydrol LD-4 to ISO VG 32 (ESSO UNIVIS N 32).
- 3. Keep the other fluid parameters the same.

Skydrol is fire-resistant aviation hydraulic fluid: http://skydrol-ld4.com/technical bulletin skydrol 4.pdf.

- Connect the **Solver Configuration** (f(x)=0) 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.

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

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



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



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

Block

From Sublibrary

Hydraulic Constant Pressure SourceFoundation Library > Hydraulic > Hydraulic SourcesHydraulic ReferenceFoundation 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.



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

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

• From the **Simscape** > **Foundation** > **Mechanical** > **Translational** library, add a **Mechanical Translational Reference** block

and connect it as shown in the figure below.



• 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 sensors



for measuring cylinder chamber pressures.

- From the **Simscape > Foundation** library bring **Hydraulic > Hydraulic Sensors** > **Hydraulic Pressure Sensor** block. Make a copy of it (Ctrl-C and Ctrl-V) and connect those
 - between Hydraulic Cylinder's A interface and Hydraulic Reference (B interface)
 - between Hydraulic Cylinder's B interface and Hydraulic Reference (B interface)



• Connect both of the **Hydraulic Pressure Sensor(s)** to **Scope(s)** by using a **PS-Simulink Converter** as follows. You can use the existing converter and make a copy of it.



Signal inputs

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

Step block \Rightarrow clone it (Ctrl-C and Ctrl-V) to get **4 blocks** together.

Constant block



Construction
 C

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. At first set the **Constant** value to **0**.

Adjust that parameter later to keep cylinder still during zero input signal.

The **Step** blocks are used for step input commands for the proportional control valve. These parameters values will also be set later.

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!** Remember that you can rotate blocks by using Crtl-R keyboard command.



System Parameters

Double click blocks to open

Set system parameters as follows.

Step blocks for timing of the valve commands (usable voltage area: -10 V ... 0 ... +10 V).







Block Parameters:	Step			×
Step				
Output a step.				
Parameters				
Step time:				
2				:
Initial value:				
0				:
Final value:				
-2				:
Sample time:				
0				:
✓ Interpret vector	parameters as	1-D		
Enable zero-cros	sing detection			
0	OK	Cancel	Help	Apply

Set Time and Final value

Step block 1 parameters

Block Parameters: Step1 ×	
Step	
Output a step.	
Parameters	
Step time:	
4	
Initial value:	
0	
Final value:	
2	
Sample time:	
0	
☑ Interpret vector parameters as 1-D	
☑ Enable zero-crossing detection	
5	
OK Cancel Help Apply	Set Ti

Set Time and Final value

Step block 2 parameters

MEC-E5004 - Fluid Power Systems

Block Parameters: Step2	х	
Step	~	
Output a step.		
Parameters		
Step time:		
6	:	
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 a

Step block 3 parameters

Block Parameters: Step3	×
Step	
Output a step.	
Parameters	
Step time:	
8	E
Initial value:	
0	
Final value:	
-2	I
Sample time:	
0	
☑ Interpret vector parameters as 1-D	
☑ Enable zero-crossing detection	
-	
OK Cancel Help	PPly Set Time and Final w

Step block 4 parameters

Constant (named U_0) block represents the valve's zero point parameter. Run the simulation (after setting other parameters) and adjust that parameter to keep cylinder still during zero input.

Valve Actuator

📔 Block Parameters: Valve Ac	tuator			×
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.				
Positive signal at the input	causes the output to	move in positive direct	ion.	
Settings				
Parameters				
Valve stroke:	0.005		m	~
Time constant:	0.002		S	~
Actuator gain:	5e-4		m	~
		OK Ca	ncel H	elp 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 or in theory 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: Hyd	draulic Constant Pressure Sou	urce		×
- Hydraulic Constant Pr	essure Source			
The block represents pressure difference re ports P and T is speci source inlet and outle <u>Source code</u>	an ideal source of hydrau gardless of the flow rate fied with the block param t ports respectively. The l	lic energy that is powe through the source. The eter. Block connection block positive direction	rful enough to maintain ne pressure difference be s T and P correspond to is from port P to port T.	specified etween the
Settings				
Parameters				
Pressure:	120e5		Ра	~
		ОК С	Cancel Help	Apply

- ideal pump with constant pressure of 120 bar (120.10⁵ [Pa] in Matlab: 120e5 [Pa])

4-Way Directional Valve (proportional valve)

For a narrow (mainly turbulent flow) orifice the flow rate is

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

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

If we know

- nominal flow rate (q_v) ,
- nominal pressure drop (Δp) ,
- fluid density (ρ) and
- flow coefficient (C_q)

the corresponding flow area can be calculated as follows

For leakage of a certain proportional control valve

$q_{ m v}$	0.45 l/min =	⇒ 0.45/60000 m ³ /s
Δp	50 bar \Rightarrow 50	$10^5 \mathrm{Pa}$
ρ	844.4 kg/m ³	(from Hydraulic fluid block for ISO VG 32 hydraulic fluid at 60°C)
C_{q}	0.7	(for turbulent region)

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

MEC-E5004 - Fluid Power Systems

Block Parameters: 4-Way Directional Valve Way Directional Valve This block models the basic option of the 4-way directional valve in a hydraulic network. To parameterize the block, 3 options are available: (1) maximum area and control member stroke, (2) the table of valve area vs. control member displacement, and (3) the pressure-flow rate characteristics. Ports P, T, A and B are hydraulic conserving ports associated with the valve inlet, outlet, and actuator terminals, respectively. The control member displacement is set by the physical signal input S. A positive displacement opens the connections between ports P-A and B-T and closes the connections between ports P-B and A-T. Settings Basic Parameters Model Parametrization Valve Opening Offsets Area characteristics: Identical for all flow paths v Model parameterization: Maximum area and opening v Flow discharge coefficient: 0.7 Leakage area: 0.45/60000/(0.7*sqrt(2*50e5/844.4))) m^2 v						
4-Way Directional Valve This block models the basic option of the 4-way directional valve in a hydraulic network. To parameterize the block, 3 options are available: (1) maximum area and control member stroke, (2) the table of valve area vs. control member displacement, and (3) the pressure-flow rate characteristics. Ports P, T, A and B are hydraulic conserving ports associated with the valve inlet, outlet, and actuator terminals, respectively. The control member displacement is set by the physical signal input S. A positive displacement opens the connections between ports P-A and B-T and closes the connections between ports P-B and A-T. Settings Basic Parameters Model Parametrization Valve Opening Offsets Area characteristics: Identical for all flow paths · Model parameterization: Maximum area and opening · Flow discharge coefficient: 0.7 Leakage area: 0.45/60000/(0.7*sqrt(2*50e5/844.4))) m^2 Laminar transition Pressure ratio ·	🛅 Block Parameters: 4-Way Dire	ectional Valve X				
This block models the basic option of the 4-way directional valve in a hydraulic network. To parameterize the block, 3 options are available: (1) maximum area and control member stoke, (2) the table of valve area vs. control member displacement, and (3) the pressure-flow rate characteristics. Ports P, T, A and B are hydraulic conserving ports associated with the valve inlet, outlet, and actuator terminals, respectively. The control member displacement is set by the physical signal input S. A positive displacement opens the connections between ports P-A and B-T and closes the connections between ports P-B and A-T. Settings Basic Parameters Basic Parameters Model Parametrization Valve Opening Offsets Area characteristics: Identical for all flow paths Flow discharge coefficient: 0.7 Leakage area: 0.45/60000/(0.7*sqrt(2*50e5/844.4))) m^2 2 Laminar transition specification: Pressure ratio	4-Way Directional Valve					
Settings Basic Parameters Model Parametrization Valve Opening Offsets Area characteristics: Identical for all flow paths Model parameterization: Maximum area and opening Flow discharge coefficient: 0.7 Affective coefficient: Valve Opening Offsets Identical for all flow paths Identical for all flow paths Identical for a	This block models the basic option of the 4-way directional valve in a hydraulic network. To parameterize the block, 3 options are available: (1) maximum area and control member stroke, (2) the table of valve area vs. control member displacement, and (3) the pressure-flow rate characteristics. Ports P, T, A and B are hydraulic conserving ports associated with the valve inlet, outlet, and actuator terminals, respectively. The control member displacement is set by the physical signal input S. A positive displacement opens the connections between ports P-A and B-T and closes the connections between ports P-B and A-T.					
Basic Parameters Model Parametrization Valve Opening Offsets Area characteristics: Identical for all flow paths • Model parameterization: Maximum area and opening • Flow discharge coefficient: 0.7 • Leakage area: 0.45/60000/(0.7*sqrt(2*50e5/844.4)) m^2 Laminar transition specification: Pressure ratio •	Settings					
Area characteristics: Identical for all flow paths Model parameterization: Maximum area and opening Flow discharge coefficient: 0.7 Afficient 	Basic Parameters Mode	l Parametrization Valve Opening Offsets				
Model parameterization: Maximum area and opening • Flow discharge coefficient: 0.7 Leakage area: 0.45/60000/(0.7*sqrt(2*50e5/844.4)) m^2 Laminar transition specification: Pressure ratio •	Area characteristics:	Identical for all flow paths				
Flow discharge coefficient: 0.7 Leakage area: 0.45/60000/(0.7*sqrt(2*50e5/844.4)) Image: Comparison of the second com	Model parameterization:	Maximum area and opening				
Leakage area: 0.45/60000/(0.7*sqrt(2*50e5/844.4)) m^2 Laminar transition specification: •	Flow discharge coefficient:	0.7				
Laminar transition Pressure ratio	Leakage area:	0.45/60000/(0.7*sqrt(2*50e5/844.4)) m^2 ~				
	Laminar transition specification:	Pressure ratio •				
Laminar flow pressure ratio: 0.999	Laminar flow pressure ratio	o: 0.999				
OK Cancel Heln Anniv		OK Cancel Help Apply				

Set the Leakage area parameter as follows.

Leakage area parameter (0.45 l/min @ Δp = 50 bar over each control edge), use Copy+Paste.

0.45/60000/(0.7*sqrt(2*50e5/844.4))

In Model Parametrization page

Maximum opening parameter 0.005 m

Maximum opening area parameter, use Copy+Paste

Actual flow area (40 l/min @ 35 bar) + Leakage area

40/60000/(0.7*sqrt(2*35e5/844.4))+0.45/60000/(0.7*sqrt(2*50e5/844.4))

ł	Block Parameters: 4-\	Nay Direction	nal Valve			×	
	4-Way Directional Va	lve					
	4-Way Directional Valve This block models the basic option of the 4-way directional valve in a hydraulic network. To parameterize the block, 3 options are available: (1) maximum area and control member stroke, (2) the table of valve area vs. control member displacement, and (3) the pressure-flow rate characteristics. Ports P, T, A and B are hydraulic conserving ports associated with the valve inlet, outlet, and actuator terminals, respectively. The control member displacement is set by the physical signal input S. A positive displacement opens the connections between ports P-A and B-T and closes the connections between ports.						
	Settings						
	Basic Parameters	Model Pa	rametrization	Valve Opening Offsets			
	Maximum opening:		0.005		m	~	
	Maximum opening a	area:	.4))+0.45/600	00/(0.7*sqrt(2*50e5/844.4))	m^2	~	
				<u>Q</u> K <u>C</u> ancel	<u>H</u> elp App	oly	

Simscape's way of modeling orifice area

$$A_{\text{orifice}} = \frac{A_{\text{maximum}}}{h_{\text{maximum}}}h + A_{\text{leakage}}$$

h orifice opening [m]

+

 h_{maximum} maximum orifice opening [m]

 A_{maximum} maximum orifice area [m²]

 A_{leakage} leakage orifice area $[m^2]$

Leakage orifice area is for a "closed orifice".

Double-Acting Hydraulic Cylinder (Simple)

🚡 Block Parameters: Double-Actir	ng Hydraulic Cylinder (Simple)	
Double-Acting Hydraulic Cylind	der (Simple)	
The block is a model of a dout basic cylinder functionality mur- reasons, factors such as fluid hard stops are assumed to be stroke. The model is suitable fr Connections R and C are mech and cylinder clamping structur. A is connected to chamber A a divitable with the Quider Q	ple-acting hydraulic cylinder developed fo st be reproduced in exchange for better i compressibility, friction, and leakages are fully inelastic to eliminate any possible or or real time or HIL simulation if such sim hanical translational conserving ports corr e, respectively. Connections A and B are ind port B is connected to chamber B. The circlation property.	r applications in which only th numerical efficiency. For these assumed to be negligible. Th scillations at the end of the plifications are acceptable. responding to the cylinder rod hydraulic conserving ports. Pc he block directionality is
adustable with the Cylinder O	rientation barameter.	
adjustable war are cymaer of		
Settings		
Settings Parameters		
Settings Parameters Piston area A:	pi/4*0.032^2	m^2 ~~
Settings Parameters Piston area A: Piston area B:	pi/4*0.032^2 pi/4*0.032^2-pi/4*0.020^2	m^2 ~~ m^2 ~~
Parameters Piston area A: Piston area B: Piston stroke:	pi/4*0.032^2 pi/4*0.032^2-pi/4*0.020^2	m^2 ~ m^2 ~
Parameters Piston area A: Piston area B: Piston stroke: Piston initial distance from cap A:	pi/4*0.032^2 pi/4*0.032^2-pi/4*0.020^2 1 0.8	m^2 ~ m^2 ~ m ~ m ~
Settings Parameters Piston area A: Piston area B: Piston stroke: Piston stroke: Piston initial distance from cap A: Penetration coefficient:	pi/4*0.032^2 pi/4*0.032^2-pi/4*0.020^2 1 0.8 1e12	m^2 ~ m^2 ~ m ~ m ~ s*N/m^2 ~

- OK Cancel Help Apply
- *D* cylinder diameter 32 mm
- *d* rod diameter 20 mm
- Piston area A: pi/4*0.032^2
- Piston area B: pi/4*0.032^2- pi/4*0.020^2
- Piston stroke: 1 m
- Piston initial distance from cap A: 0.8 m

Mass

皆 Block Parameters: Mass		×				
Mass						
The block represents an ideal m	nechanical 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. <u>Source code</u>						
Settings						
Parameters Variables						
Mass:	[234] kg ~					
	OK Cancel Help Apply	,				

 $(A_{A} = \pi/4D^{2})$ $(A_{B} = A_{A} - \pi/4d^{2})$ (maximum stroke) (initial position of piston)

Pipe parameters

Update parameters

- Pipe internal diameter \Rightarrow 0.012 m
- Pipe length $\Rightarrow 0.75 \text{ m}$

🚹 Block Parameters: Hydraulic Pipel	ine		×
Hydraulic Pipeline			^
This block models hydraulic pipe for friction loss along the pipe le an intermediate place between t not account for fluid inertia. The building blocks.	lines with circular and noncircular cross sectio ngth and for fluid compressibility, and by exte he Resistive Tube and the Segmented Pipeline model is built of Resistive Tube and Constant	ns. The block accounts nt of idealization it take blocks. The block does Volume Chamber	S
Connections A and B are hydrau B. This means that the flow rate determined as $p = p_A - p_B$.	lic conserving ports. The block positive direction is positive if fluid flows from A to B, and the p	on is from port A to por pressure loss is	1
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 Tr	anslational Motion Sen	ISOF	×
Ideal Translational Motior	1 Sensor		
The block represents an id an across variable measur proportional to velocity ar delays, energy consumpti	deal mechanical trar red between two me nd position. The sensi on, and so on.	Islational motion sensor, that is, a devic echanical translational nodes into a cont sor is ideal since it does not account for	e that converts rol signal inertia, friction,
Connections R and C are physical signal output por port R to port C. <u>Source code</u>	mechanical translati ts for velocity and p	onal conserving ports and connections osition, respectively. The block positive	/ and P are direction is from
Settings			
Parameters			
Initial position:	0.8	m	~
		OK Cancel He	alp Apply



Your model should be ready for 10 s simulation. Use scopes

- X
- p_A
- p_B

for piston position [m], A chamber pressure [Pa] and B chamber pressure [Pa].

You can also test if the input commands are correct by placing a **Scope** between **Add** block and **Simulink-PS Converter.**

Assignment for phase 1 – Open loop control

Make a short document (Word- > pdf)

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 above6. 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

Closed loop control – assignment phase 2

Remove blocks **Step 2** and **U_0**.

Open block Add block change the List of signs to +-.

	Block Parameters: Error	×
	Sum	
	Add or subtract inputs. Specify one of the following: a) character vector containing + or - for each input port, for spacer between ports (e.g. ++ - ++) b) scalar, >= 1, specifies the number of input ports to be summed. When there is only one input port, add or subtract elements over all dimensions or one specified dimension	
	Main Signal Attributes	
	Icon shape: rectangular	-
	List of signs:	
(+-	
	OK Cancel Help App	y

Rename the block to Error. Delete Step blocks 2, 3, and 4. Delete Constant block (U_0).

Open Step 1 block. Rename it as Step and update the parameter values as in the figure below.

	Block Parameters: Step	\times
	Step	
	Output a step.	
	Deve en el com	
	Parameters	
	Step time:	
	3	:
	Initial value:	
1		
V	0	:
	Final value:	
(1	:
~	sample time:	
		:
	Interpret vector parameters as 1-D	
	Enable zero-crossing detection	
	-	
	Cancel Heip App.	у

Update cylinder parameters

Double click **Double-Acting Hydraulic Cylinder (Simple)** to open it. Update **Piston stroke** and **Piston distance from cap A** as follows. Click **OK**.

Piston area A:	pi/4*0.032^2	m^2 ~
Piston area B:	pi/4*0.032^2-pi/4*0.020^2	
Piston stroke:	1.2	
Piston initial distance from cap A:	0	m ~
Penetration coefficient:	1e12	s*N/m^2 ~
Cylinder orientation:	Acts in positive direction	•

Update also Ideal Translational Motion Sensor. Set Initial position to 0.

Tutated acceletory	0	1	
Initial position:	U	m	

From the **Simulink > Math operations** bring **Gain** block. Place it between **Error** and **Simulink-PS Converter** as in the figure below. Name it as **P gain**. This is the system's P controller (**P**ID).



Branch (mouse right button) and connect **Piston displacement signal** wire from block **PS-Simulink Converter**



to **Error block's** second interface. The difference between the values tells you how far the actual position is from the target position.



From **Simulink > Signal routing** library bring **Mux** (multiplexer) block.

Connect Scope block to it and name it for example as Piston Displacement - Command and Position.

Connect wire from **Step** block to the first interface and **Piston displacement** signal to the second interface.

From: Step From: Piston displacement (x)



From **Simulink > Sinks** library bring **To Workspace** block. Connect wire from **Mux** signal(s) to its interface.



Double click to open **To Workspace** block. Adjust the parameter(s) as follows > **Variable name** > **x**. Click **OK**.

🛅 Block Parameters: To Workspace	×
To Workspace	
Write input to specified timeseries, array, or structure in a workspac For menu-based simulation, data is written in the MATLAB base workspace. Data is not available until the simulation is stopped or paused.	e.
To log a bus signal, use "Timeseries" save format.	
Parameters	
Variable name:	
x	
Limit data points to last:	
inf	:
Decimation:	
1	:
Save format: Timeseries	•
☑ Log fixed-point data as a fi object	
Sample time (-1 for inherited):	
-1	:
OK Cancel Help Ap	ply

Add also a **Scope** for valve command voltage U between **P Gain** and **Simulink-PS Converter**.



Your system should look (something like) this.



Plotting of variables **File > Model properties > Model properties > Callbacks > StopFcn**

Main Callbacks History Description Data Model callbacks PreLoadFcn Simulation stop function: Close all PostLoadFcn figure InitFcn StartFcn plot(x.Time-3,x.Data(:,1)) PauseFcn plot(x.Time-3,x.Data(:,2)) plot(x.Time-3,0.95+0*x.Time) plot(x.Time-3,1.05+0*x.Time) PostSaveFcn plot(x.Time-3,1.05+0*x.Time) plot(x.Time) plot(x.Time)
Model callbacks Simulation stop function: PretLoadFcn InitFcn PostLoadFcn figure InitFcn plot(x.Time-3,x.Data(:,1)) PauseFcn plot(x.Time-3,x.Data(:,2)) PostSaveFcn plot(x.Time-3,0.95+0*x.Time) PostSaveFcn plot(x.Time-3,1.05+0*x.Time) IcloseFcn plot(x.Time-3,1.05+0*x.Time)
OK Cancel Help Apply

Add the following **code** to **StopFcn**

close all figure plot(x.Time-3,x.Data(:,1)) hold on plot(x.Time-3,x.Data(:,2)) %plot(x.Time-3,1+0*x.Time) plot(x.Time-3,0.95+0*x.Time) plot(x.Time-3,1.05+0*x.Time) legend('command','x','95%','105%','Location','southeast')

Click **OK** to confirm the changes.

Run the model.

You should get also a **Figure** like this.



Can be also here (depending on Matlab version)

Use Zoom (In or Out) and Data Cursor tools for finding detailed information.



Check from the **Figure** or from **Scope Piston Displacement - Command and Position** how well the actuator follows the command.

If the performance is poor increase the **P** Gain value. Raise the value boldly (decades). This is only a simulator!

Notice that the **Piston displacement** signal starts to oscillate if the **P Gain** value is too high. More specified servo tuning instructions below (**Tuning the P controller according to Ziegler-Nichols**).

Tuning the P controller according to Ziegler-Nichols

- Increase **P** Gain parameter value until the system starts to oscillate continuously. Use zooming!
- This minimum value of P Gain (parameter K_P) is so called critical gain K_{P, crit}. Store this value!
- (To implement controllers as PI or PID you should also estimate the time period of oscillation T_{crit} corresponding this gain. This can be identified from the response \Rightarrow time between two successive peaks).
- P controller's gain according to Ziegler-Nichols tuning rules is now simply 0.5·KP, crit.

Assignment for phase 2

Continue with your short document (Word -> pdf) for Phase 1

Documentation Format:

Assigments

- Finalize the simulation model
 - Paste a Figure of the updated simulation model to your document
 - Edit > Copy Current View to Clipboard > Metafile or Bitmap
- Test the system with **critical gain** and two different values for the **P gain**
 - \circ P_{gain, 0}= **K**_{P, crit} (critical gain according to Ziegler-Nichols tuning rule)
 - \circ P_{gain, 1}= **0.5·K**_{P, crit} (tuned according to Ziegler-Nichols tuning rule)
 - \circ P_{gain, 2}= **0.25·K**_{P, crit} (smaller gain for comparison)
- Plot the **Piston Displacement** signals for
 - P_{gain, 0} (critical)
 - 1. overall displacement Figure
 - 2. zoomed Figure to see the performance near the target position
 - Pgain, 1
 - 3. overall displacement Figure
 - 4. zoomed Figure to see the performance near the target position
 - Pgain, 2
 - 1. overall displacement Figure
 - 2. zoomed Figure to see the performance near the target position

Analyze the plots and add information to these tables. Check the following page for **Performance** analysis.

P controller parameters

KP, crit	V/m
0.5·KP, crit	V/m
0.25·K _{P, crit}	V/m

Performance of P control for Pgain, 1 parameter value (0.5·KP, crit)

Overshoot	%
Rise time 95%	S
Settling time 5%	S
Steady state error	m

Performance of P control Pgain, 2 for parameter value (0.25·KP, crit)

Overshoot	%
Rise time 95%	S
Settling time 5%	S
Steady state error	m



Overshoot

The ratio of difference between output y's first maximum and its new steady-state value to its new steady-state value (= a/b in Figure above). Sometimes this characteristic is marked with $M_{\rm p}$, maximum percentual overshoot.

Rise time (95%)

Time it takes for the response to rise from zero to 95% of the steady-state response.

Damping ratio

The ratio of difference between output y's first maximum and its new steady-state value to the difference between output y's second maximum and its new steady-state value (= c/a in Figure above).

Settling time *t*s

The time that after a stepwise change in system's setting value *w* is required for the process output *y* to reach and remain inside a band whose width is equal to ± 5 % of the total change in *y* (sometimes also other bandwidths are used, e.g., ± 1 %, ± 2 %).

Time period *T*

The time between output y's two successive peaks (e.g., first and second maximum) or valleys.

Oscillation frequency f

The frequency that the system oscillated with (= 1/T).

Steady state error est

The constant deviation between system's setting value *w* and actual output value *y*.