



ELEC 341: Systems and Control

Lecture 21

Frequency response shaping with Matlab (Simulink simulation)

Course roadmap

Modeling

- ✓ Laplace transform
- ✓ Transfer function
- Models for systems
 - ✓ • Electrical
 - ✓ • Electromechanical
 - ✓ • Mechanical
- ✓ Linearization, delay

Analysis

- ✓ Stability
 - ✓ • Routh-Hurwitz
 - ✓ • Nyquist
- ⇨ ✓ Time response
 - ✓ • Transient
 - ✓ • Steady state
- ✓ Frequency response
 - ✓ • Bode plot

Design

- ✓ Design specs
- ✓ Root locus
- ⇨ ✓ Frequency domain
- ✓ PID & Lead-lag
- ✓ Design examples



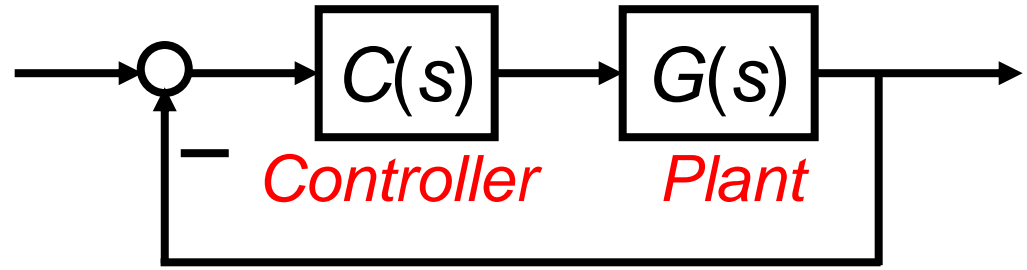
Matlab simulations

Example 1

(SISO Design Tool in Matlab)

- Consider a system

$$G(s) = \frac{4}{s(s+1)(s+2)}$$

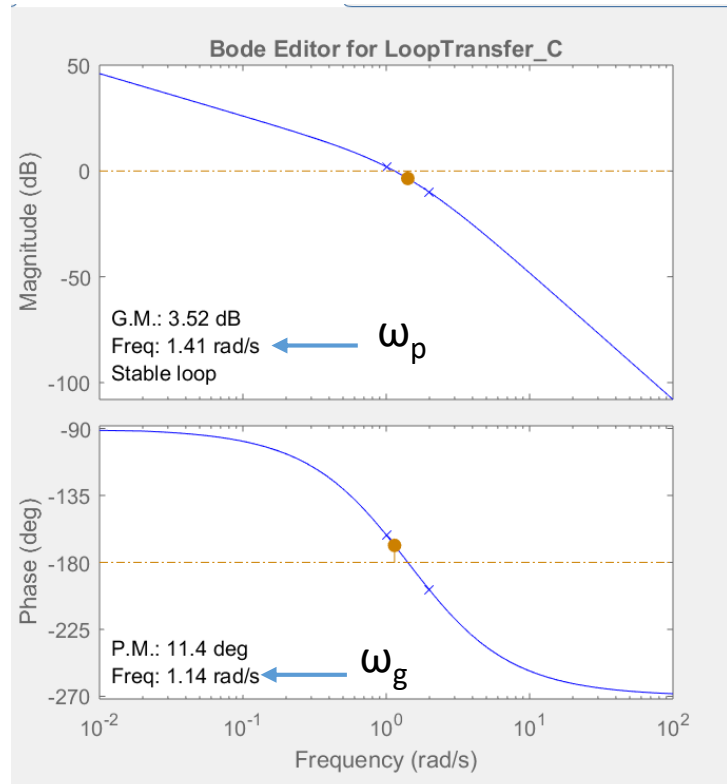


- Specs
 - Closed-loop system is stable
 - PM at least 50 deg
 - 2% Settling time < 4 s
 - Steady-state error
 - For unit step input: $e_{ss} = 0$

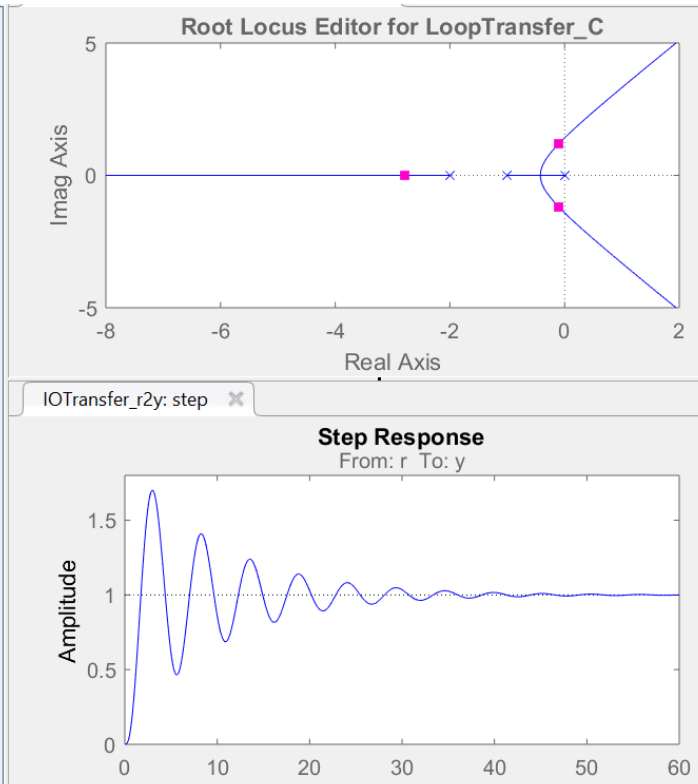


Example 1 (cont'd)

OL Bode plot



Root locus



```
>> s = tf('s')
Transfer function:
s
>> sysG = 4/s/(s+1)/(s+2)
Transfer function:
4
-----
s^3 + 3 s^2 + 2 s
>> sisotool(sysG)
```

Default setting: $C(s)=1$

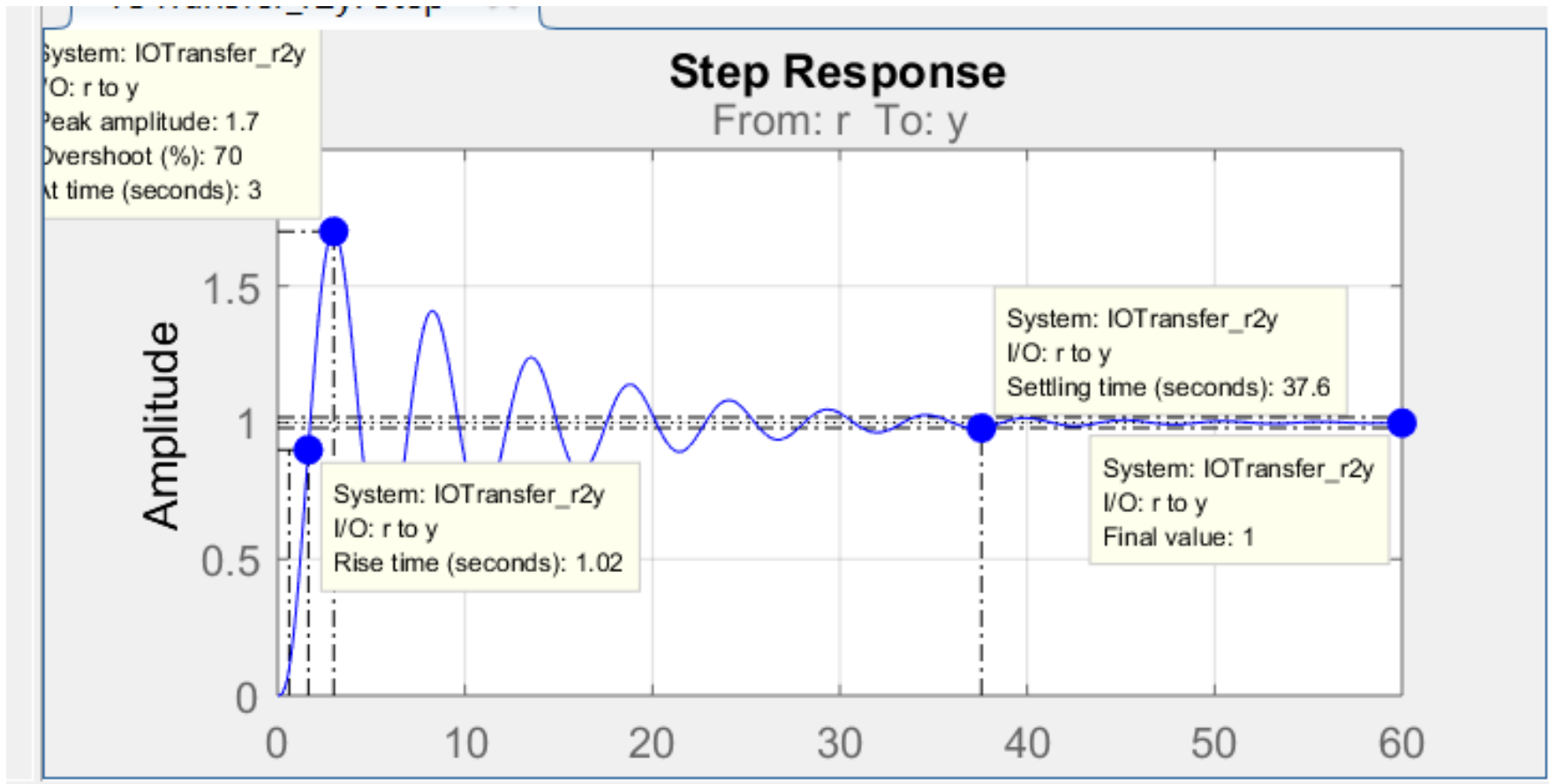
Example 1 (cont'd)

- Show settling time
 - Right click
 - Characteristic
 - Settling time





Example 1 (cont'd)



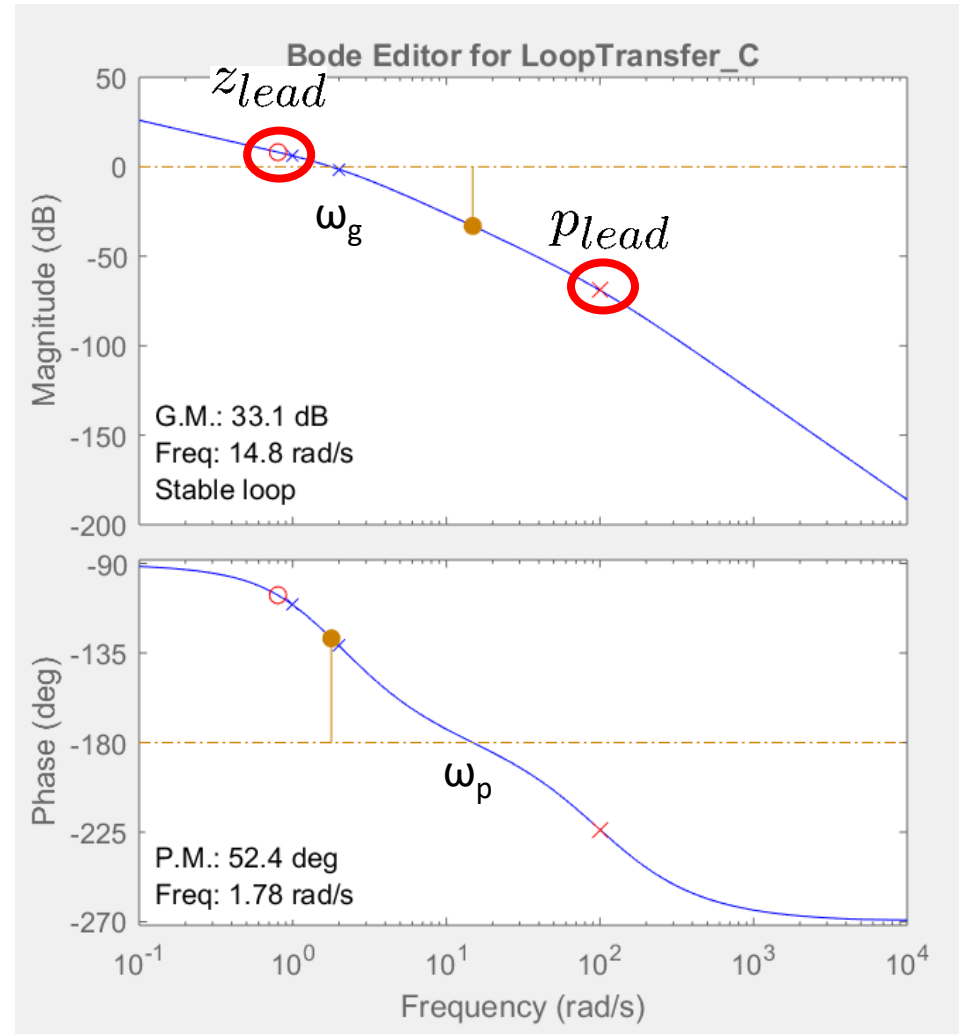
Example 1 (cont'd)

- Add a pole & a zero of a compensator:

$$C_{Lead}(s) = K \frac{s + z_{Lead}}{s + p_{Lead}}$$

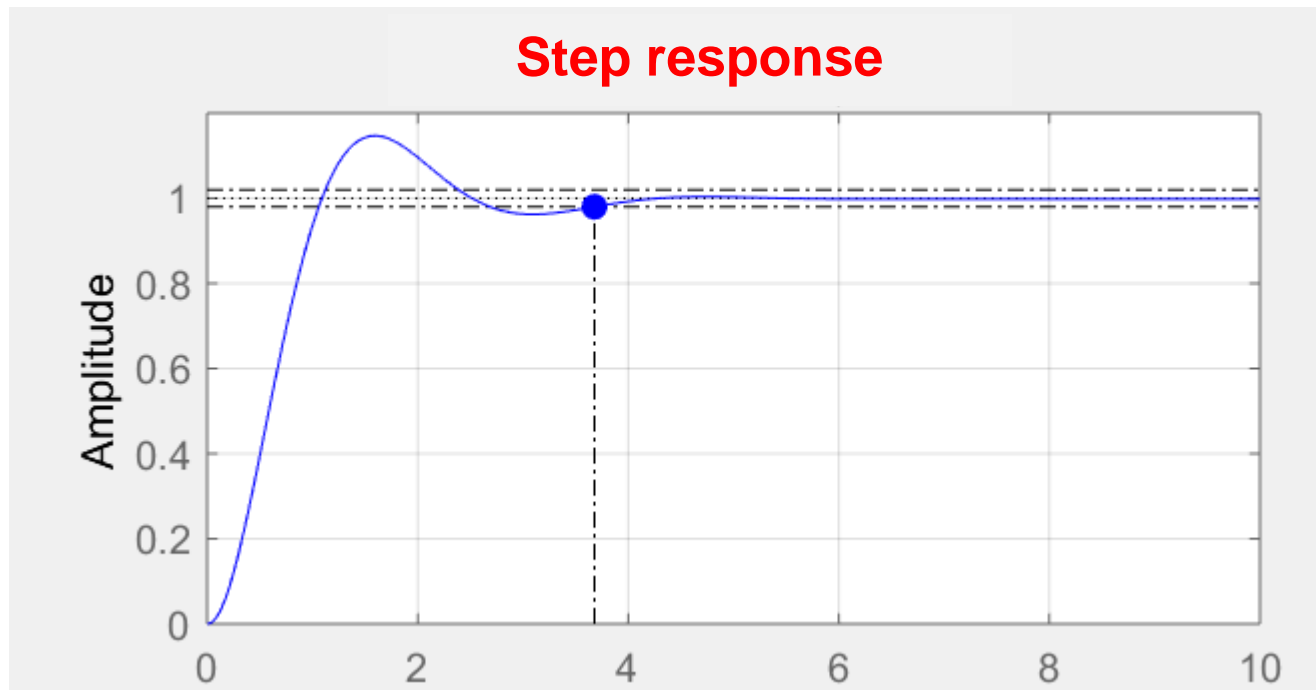
- If necessary, move the pole/zero/gain
 - by click-and-drag, or
 - *Design* → *Edit Compensator...*

```
Tunable Block
Name: C
Sample Time: 0
Value:
  125 (s+0.8)
  -----
        (s+100)
```



PM (= 52.4) > 50 degree OK!

Example 1 (cont'd)



Settling time < 4s OK!

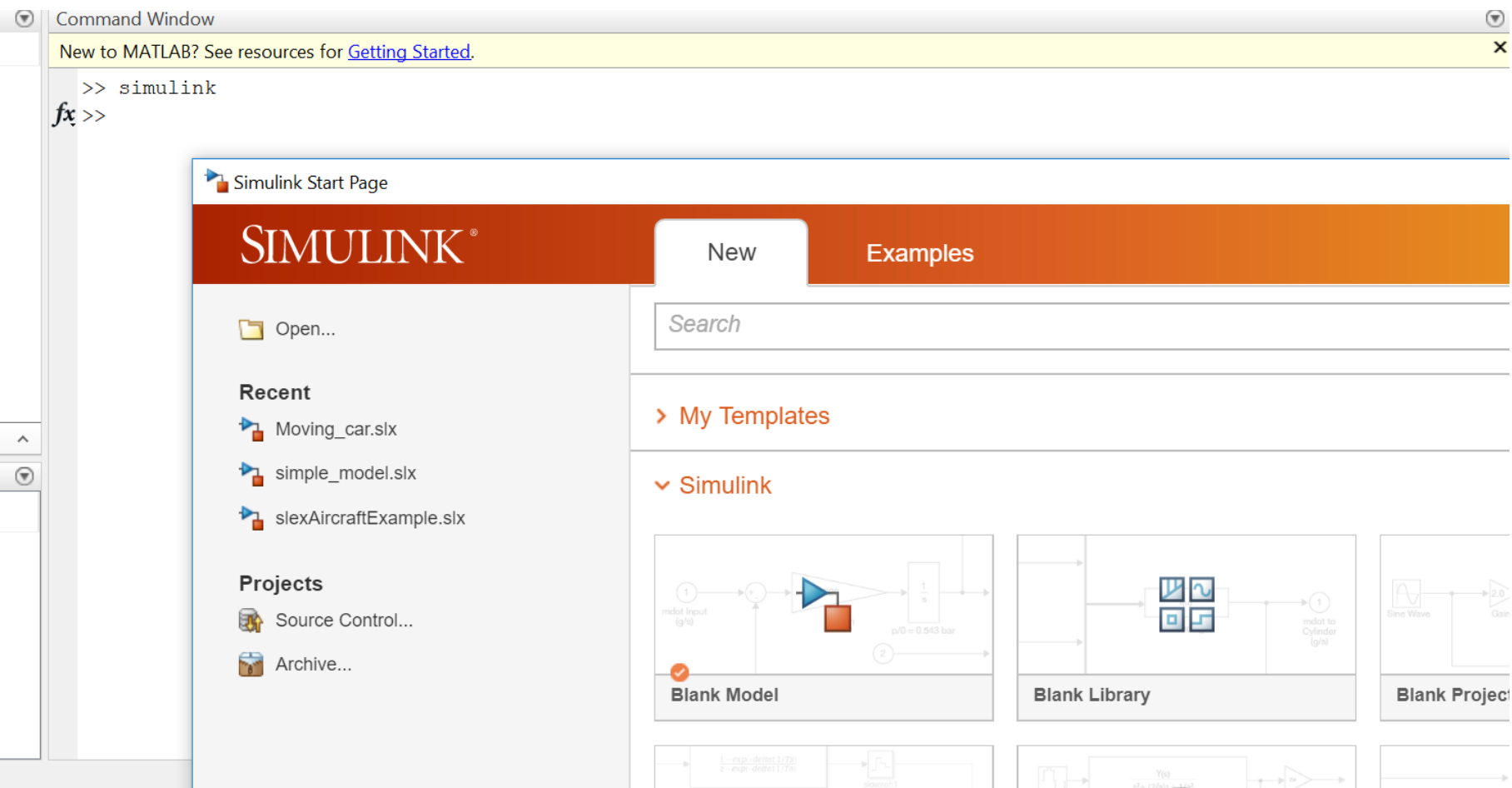
Simulink



- Simulink, developed by MathWorks, is a graphical programming environment for modeling, simulating, and analyzing dynamic systems. Its primary interface is a graphical block diagramming tool and a customizable set of block libraries. It offers tight integration with the rest of the MATLAB environment.
- It is basically a piece of software for modeling and simulating a system, as well as programming controllers.
- Engineers use Simulink to solve engineering problems in many industries, such as:
 - Automotive
 - Biomedical
 - Aerospace
 - Process industries
 - Communications
 - Industrial automation
 - Electronics
 - etc.

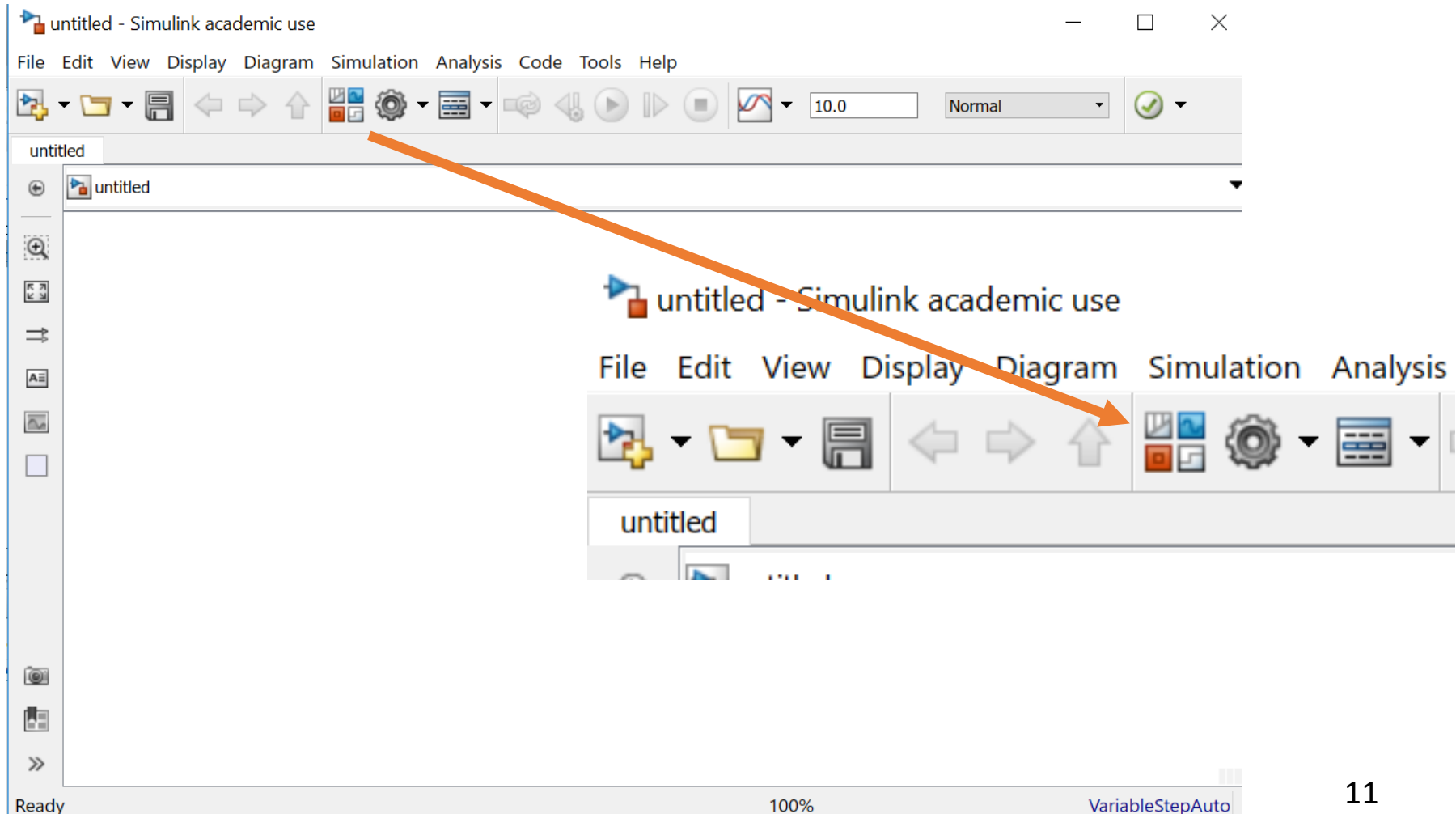
Example 2 (cont'd)

- In MATLAB prompt, type “simulink”.
- Click on Blank Model.

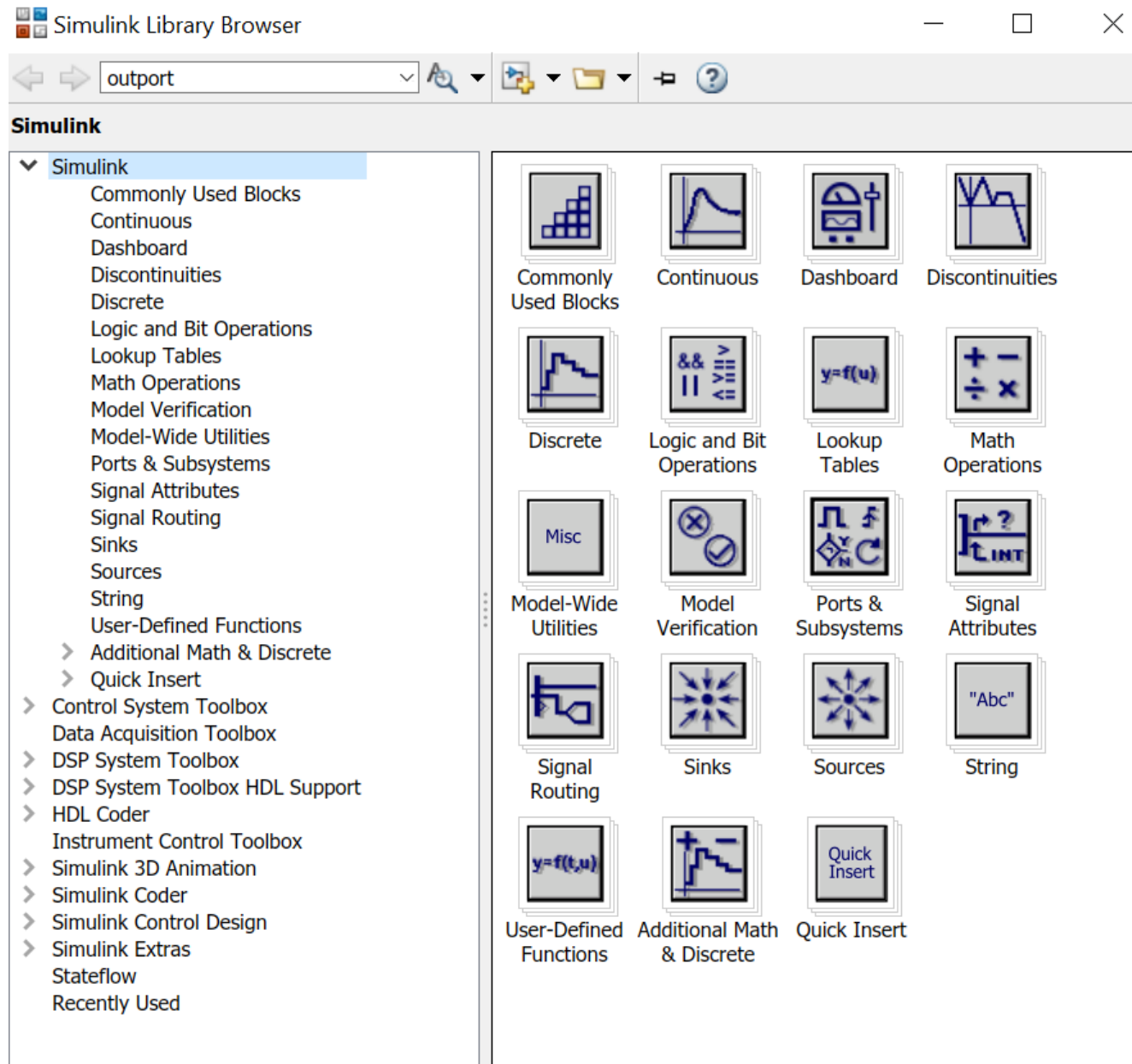


Example 2 (cont'd)

- Click on



Example 2 (cont'd)



Then, Simulink Library Browser pops up:

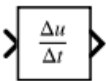
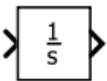
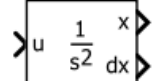
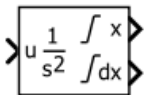

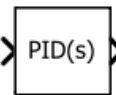
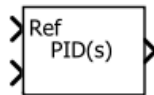
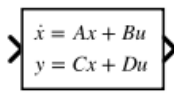
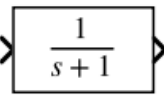
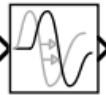

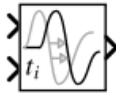
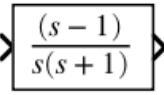
Example 2 (cont'd)

Simulink Library Browser

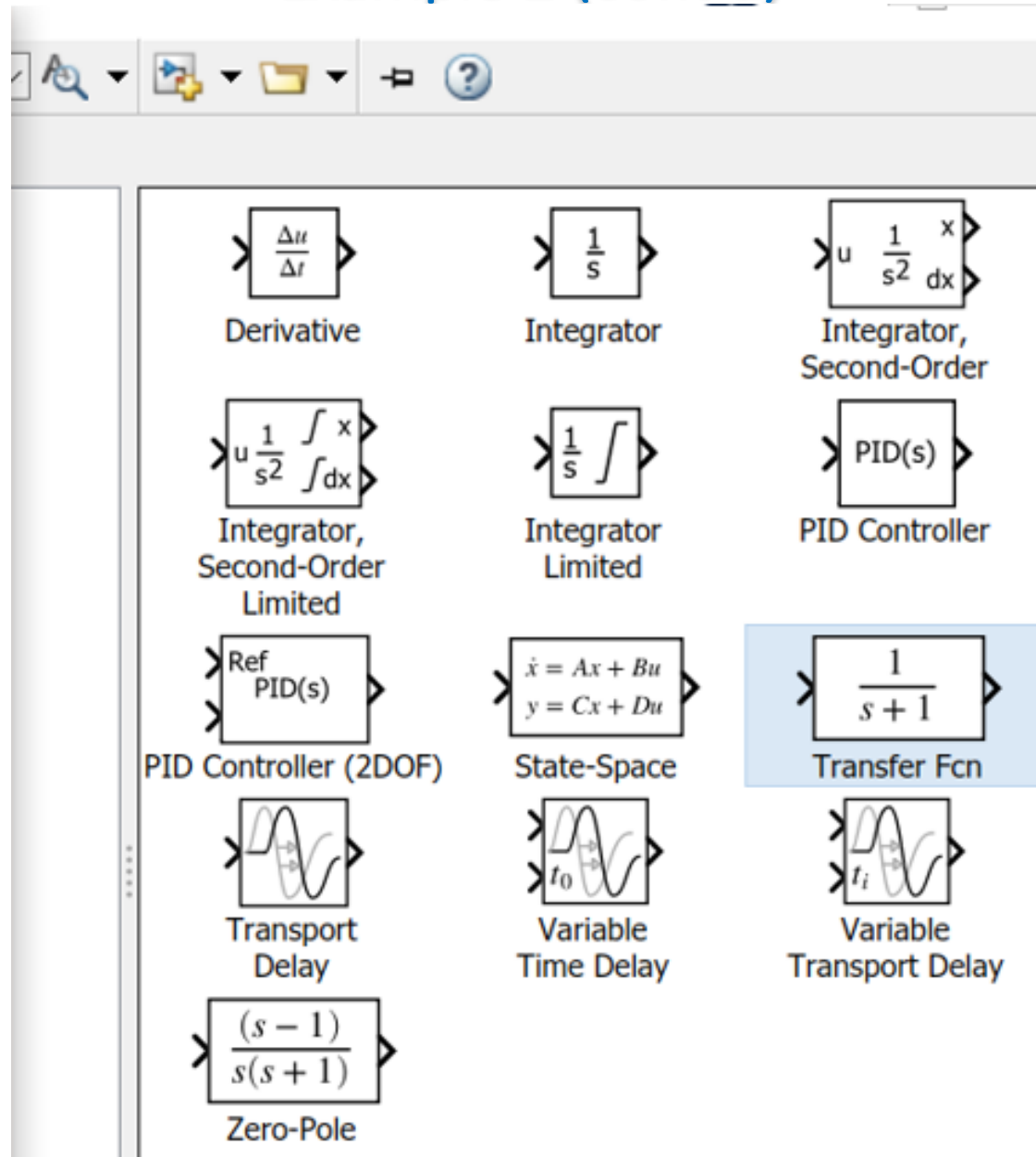
Search:

Simulink/Continuous

- Simulink
 - Commonly Used Blocks
 - Continuous**
 - Dashboard
 - Discontinuities
 - Discrete
 - Logic and Bit Operations
 - Lookup Tables
 - Math Operations
 - Model Verification
 - Model-Wide Utilities
 - Ports & Subsystems
 - Signal Attributes
 - Signal Routing
 - Sinks
 - Sources
 - String
 - User-Defined Functions
 - Additional Math & Discrete
 - Quick Insert
- Control System Toolbox
- Data Acquisition Toolbox
- DSP System Toolbox
- DSP System Toolbox HDL Support
- HDL Coder
- Instrument Control Toolbox
- Simulink 3D Animation
- Simulink Coder
- Simulink Control Design
- Simulink Extras
- Stateflow
- Recently Used

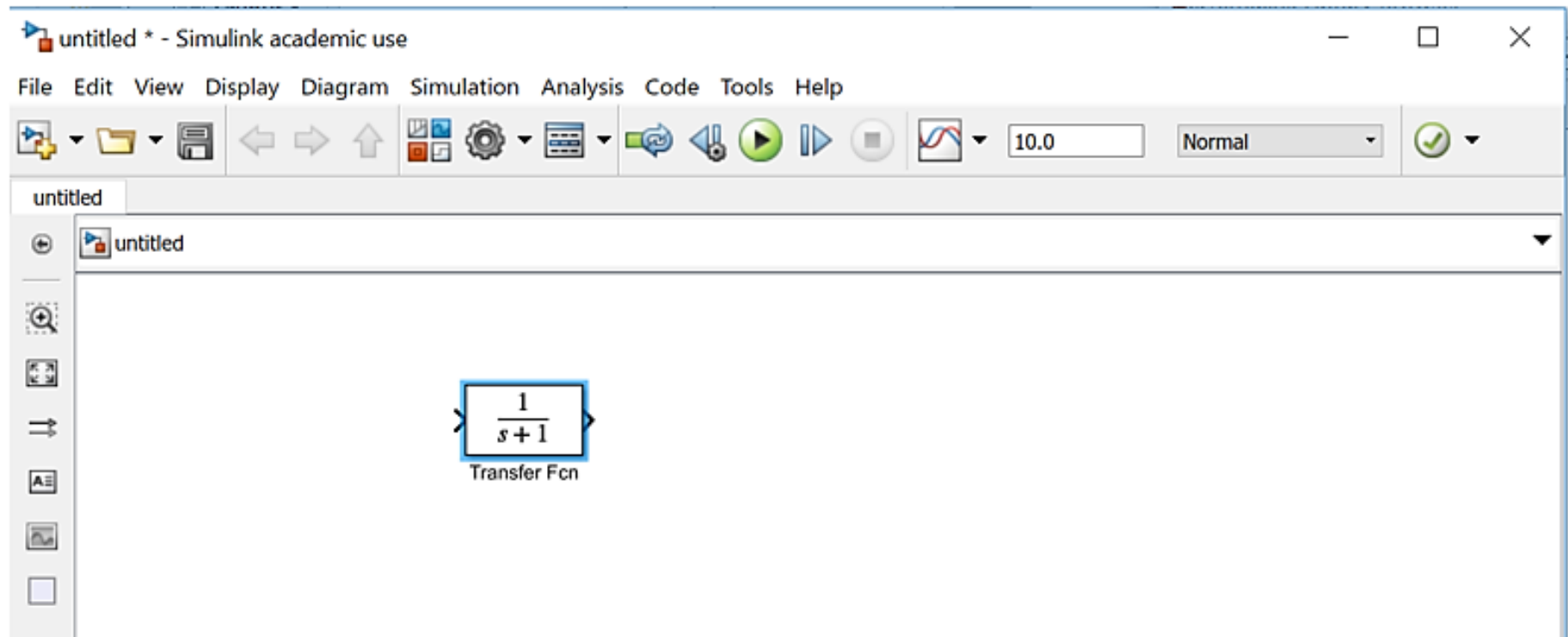
		
Derivative	Integrator	Integrator, Second-Order
		
Integrator, Second-Order Limited	Integrator Limited	PID Controller
		
PID Controller (2DOF)	State-Space	Transfer Fcn
		
Transport Delay	Variable Time Delay	Variable Transport Delay
		
Zero-Pole		

Example 2 (cont'd)





Example 2 (cont'd)



Example 2 (cont'd)

Double-click on the block to enter new numerator and denominator.



Block Parameters: Transfer Fcn

Transfer Fcn

The numerator coefficient can be a vector or matrix expression. The denominator coefficient must be a vector. The output width equals the number of rows in the numerator coefficient. You should specify the coefficients in descending order of powers of s .

Parameters

Numerator coefficients:

[1 6 10]

Denominator coefficients:

[1 7 1]

Absolute tolerance:

auto

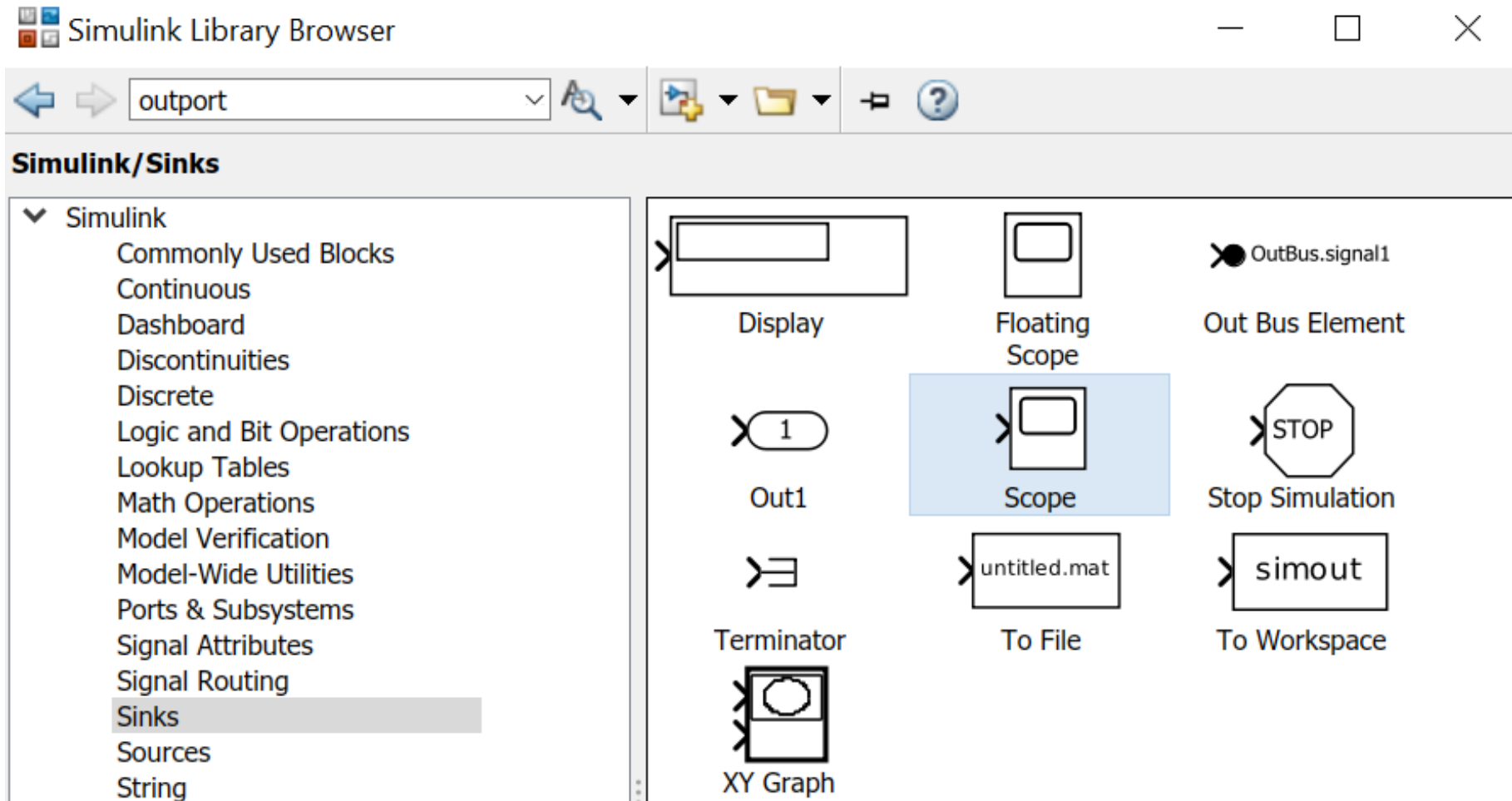
State Name: (e.g., 'position')

"

? OK Cancel Help Apply



Example 2 (cont'd)





Example 2 (cont'd)

Simulink Library Browser

Search:

Simulink/Sources

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 - > Simulink Control Design
 - > Simulink Extras
 - Stateflow

In Bus Element	In1
Pulse Generator	Ramp
Random Number	Repeating Sequence
Repeating Sequence Interpolated	Repeating Sequence Stair
Signal Builder	Signal Editor
Signal Generator	Sine Wave
Step	Uniform Random Number

Example 2 (cont'd)

Double-click on scope.

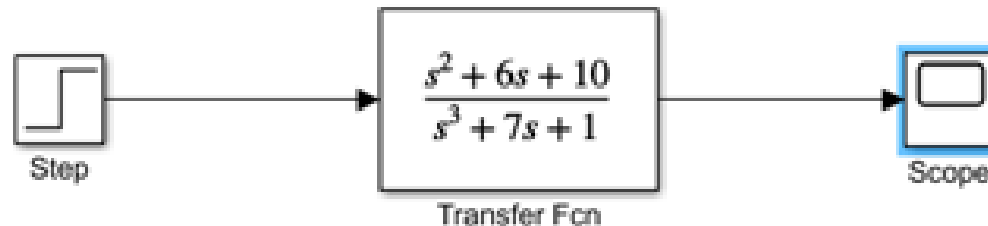
Simulink_Example_ELEC341 - Simulink academic use

File Edit View Display Diagram Simulation Analysis Code Tools Help

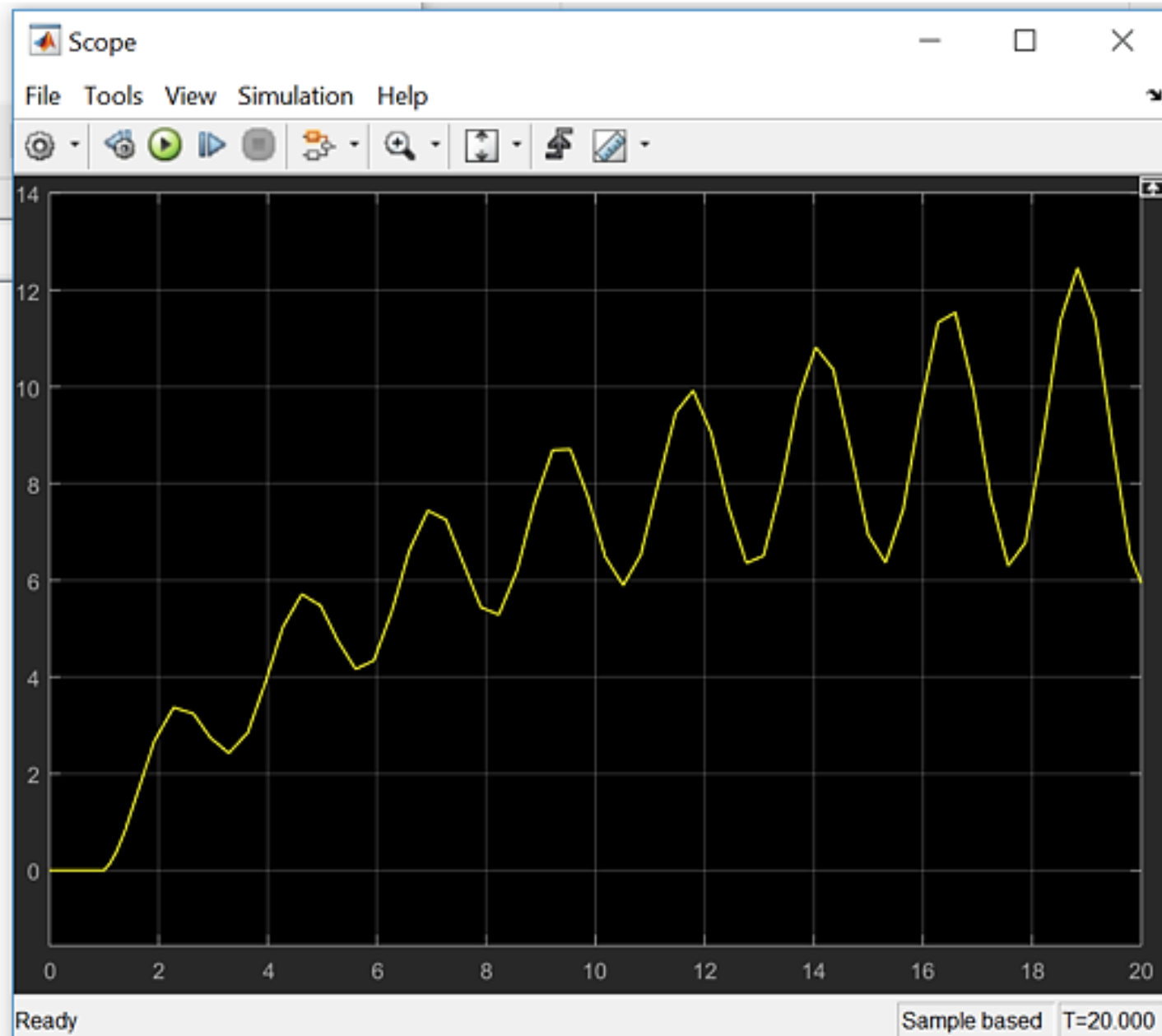


Simulink_Example_ELEC341

Simulink_Example_ELEC341



Example 2 (cont'd)





Example 2 (cont'd)

Simulink Library Browser

Search:

Link/Commonly Used Blocks

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Bus Creator	Bus Selector	Constant
Data Type Conversion	Delay	
Discrete-Time Integrator		
In1	Integrator	Logical Operator
Mux	Out1	Product
Relational Operator	Saturation	Scope
Subsystem	Sum	Switch



Example 2 (cont'd)

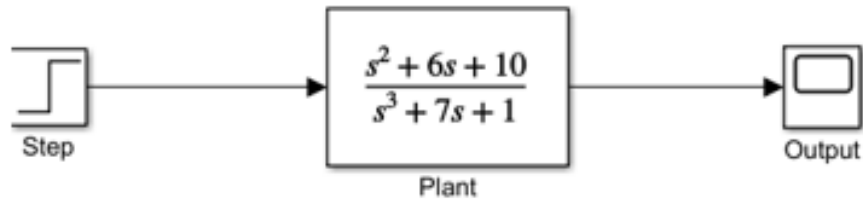
Example_ELEC341 * - Simulink academic use

File Edit View Display Diagram Simulation Analysis Code Tools Help



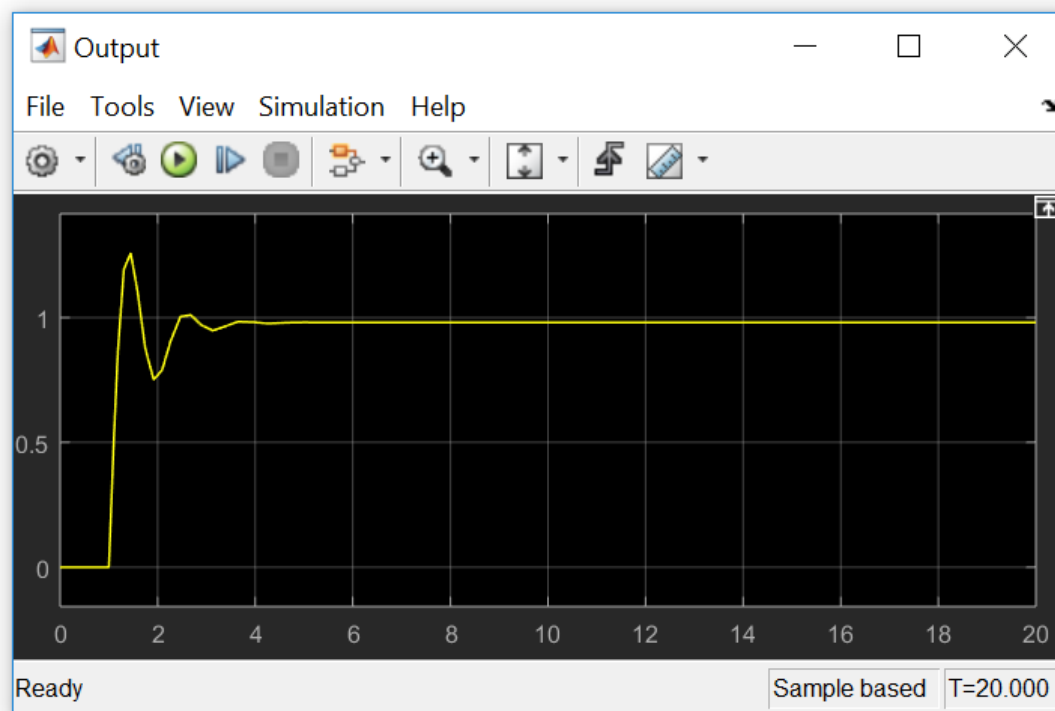
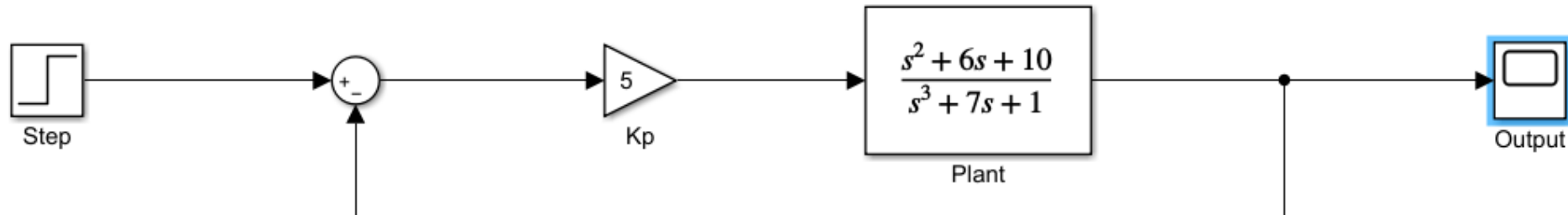
Example_ELEC341

Example_ELEC341

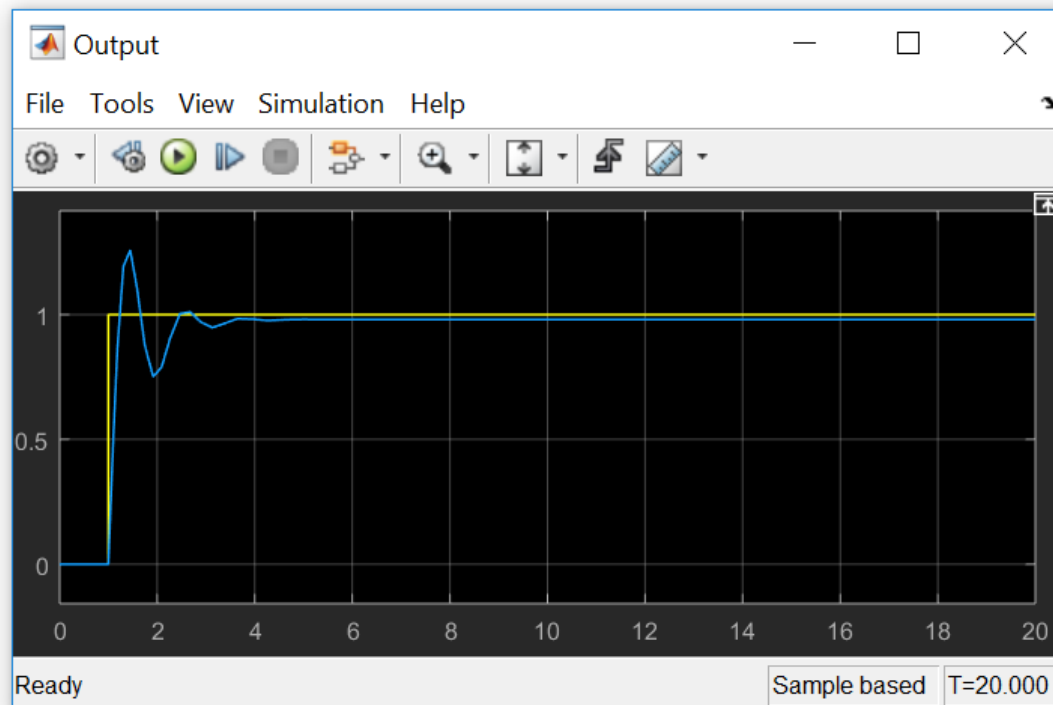
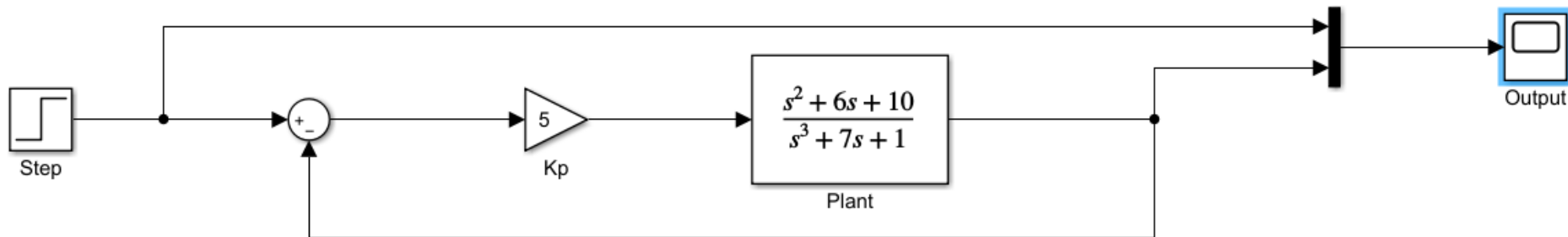




Example 2 (cont'd)



Example 2 (cont'd)



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Design

- ✓ Design specs
- ✓ Root locus
- ⇒ Frequency domain
 - ✓ PID & Lead-lag
- ✓ Design examples

✓ *Matlab simulations*

Thank You!

The End