MATLAB Questions: Transfer Functions, Step Response, and Basic Controller Design

Q1. Understanding a First-Order Plant Using Step Response

Consider the first-order plant:

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

1. Plot the unit step response in MATLAB.
2. Using the plot or `stepinfo`, determine:
   - Time constant τ
   - Rise time t_r
   - Settling time t_s
   - Final value (using Final Value Theorem)
   - Steady-state error e_{ss}

   Shown in matlab
3. Compare MATLAB's final value with: same

$$y_{ss} = \lim_{s \to 0} s \cdot G(s) \cdot \frac{1}{s}.$$

MATLAB starter code:

```
s = tf('s');
G = 4/(s+2);
step(G), grid on
stepinfo(G)
```

Q2. System Type, Step Error, and Final Value Theorem

Given the plant:

$$G(s) = \frac{10}{s(s+5)}$$

1. Identify the **system type** (count the number of integrators). Type 1
2. Using the Final Value Theorem, find the steady-state error to a unit step:

$$e_{ss} = \lim_{s \to 0} s \left(\frac{1}{s} - G(s)\frac{1}{s} \right).$$

   Infinity for open
   0 for closed
3. Predict whether MATLAB's step response should reach 1, overshoot it, or settle below 1.

   should reach 1

Q3. Required Specifications → Modify Transfer Function

Your goal is to design a first-order system that satisfies:

$$t_s < 1.2 \text{ seconds}, \qquad e_{ss} = 0.1$$

1. Using the first-order formulas:

$$t_s \approx \frac{4}{a}, \qquad e_{ss} = \frac{1}{1+K}$$

   determine:

   - the required pole location a, 3.33
   - the required static gain K. 9

2. Construct the modified plant:

$$G_{\text{new}}(s) = \frac{K}{s+a}.$$

3. Predict the shape of the step response before running MATLAB:

   - Should it be faster or slower than Q1? Faster
   - Should the final value be higher or lower? Higher

Q4. Designing a Simple Controller to Meet Specifications

You are given the following plant:

$$G(s) = \frac{3}{s+1}$$

You must design a simple controller:

$$C(s) = K(s+z)$$

to meet these desired characteristics:

$$t_s < 2 \text{ s}, \qquad M_p < 10\%, \qquad y_{ss} = 0.8$$

1. Using formulas from the class cheat sheet:

   - Choose a zero z that reduces rise time. 1
   - Choose a gain K that sets the desired steady-state value. 1.33
   - Estimate the resulting damping ratio ζ from the overshoot requirement. 0.6

2. Write the resulting closed-loop transfer function:

0.8

$$T(s) = \frac{C(s)G(s)}{1 + C(s)G(s)}.$$

3. Before using MATLAB, **predict qualitatively**:
   - Will adding the zero increase or decrease overshoot? Slightly increase
   - Will increasing K increase or decrease y_{ss}? increase
   - Will the response be faster than the original plant? Faster

Q5. Ramp Tracking and System Type

Using the controller and closed-loop system from Q4:

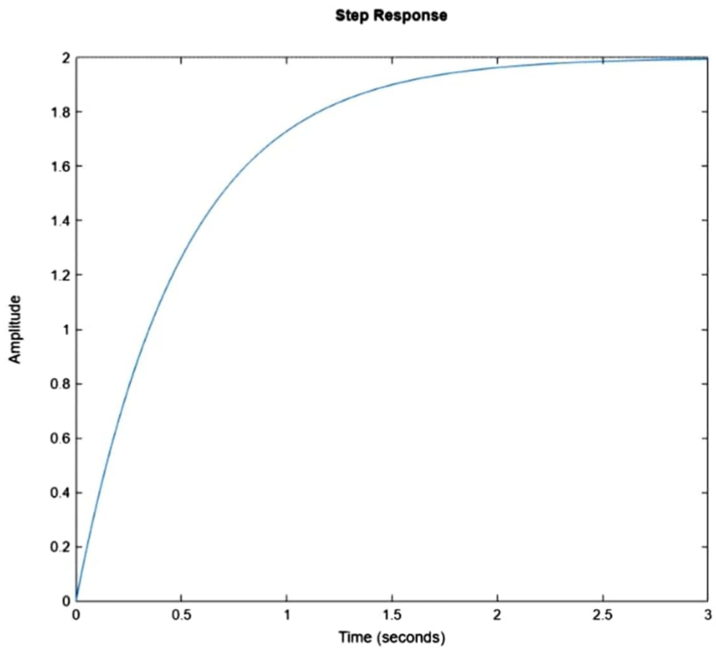
$$r(t) = t \quad \text{(unit ramp)}$$

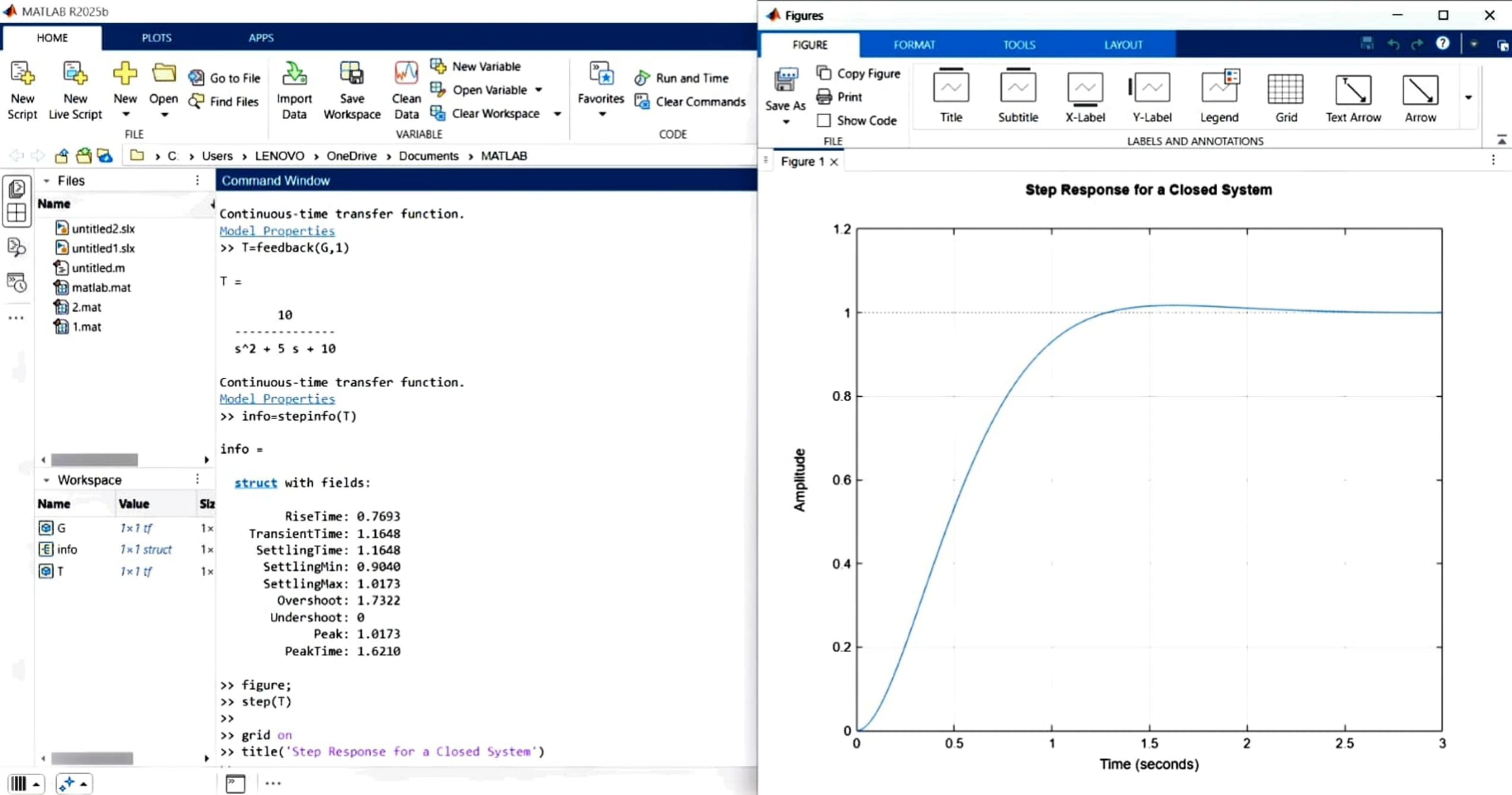
1. Determine the **system type** of the closed-loop system. Type 0
2. Using system type rules, predict whether the ramp error will be:
   - infinite,
   - finite non-zero, Infinite
   - or zero.
3. Verify using the Final Value Theorem for ramp input:

$$e_{ss}^{\text{ramp}} = \lim_{s \to 0} s \left(\frac{1}{s^2} - T(s)\frac{1}{s^2} \right).$$

4. Explain whether adding the zero at $(s + z)$ helps or hurts ramp tracking. not really help with ramp tracking ramp error still remains infinite

```
>> G = tf(4,[1 2]);

figure;
step(G);
grid on;
title('Unit Step Response');

stepinfo(G)


ans =

  struct with fields:

         RiseTime: 1.0985
    TransientTime: 1.9560
     SettlingTime: 1.9560
      SettlingMin: 1.8090
      SettlingMax: 1.9987
        Overshoot: 0
       Undershoot: 0
             Peak: 1.9987
         PeakTime: 3.6611

>> bode(G)
>> G = tf([4],[1 2])

G =

    4
  -----
  s + 2

Continuous-time transfer function.
```

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Files
Name
untitled2.slx
untitled1.slx
untitled.m
matlab.mat
2.mat
1.mat
Workspace
Name
Value
G 1×1 tf
info 1×1 struct
T 1×1 tf
Command Window
Continuous-time transfer function.
Model Properties
>> T=feedback(G,1)
T =
10
----
s^2 + 5 s + 10
Continuous-time transfer function.
Model Properties
>> info=stepinfo(T)
info =
struct with fields:
RiseTime: 0.7693
TransientTime: 1.1648
SettlingTime: 1.1648
SettlingMin: 0.9040
SettlingMax: 1.0173
Overshoot: 1.7322
Undershoot: 0
Peak: 1.0173
PeakTime: 1.6210
>> figure;
>> step(T)
>>
>> grid on
>> title('Step Response for a Closed System')
Figures
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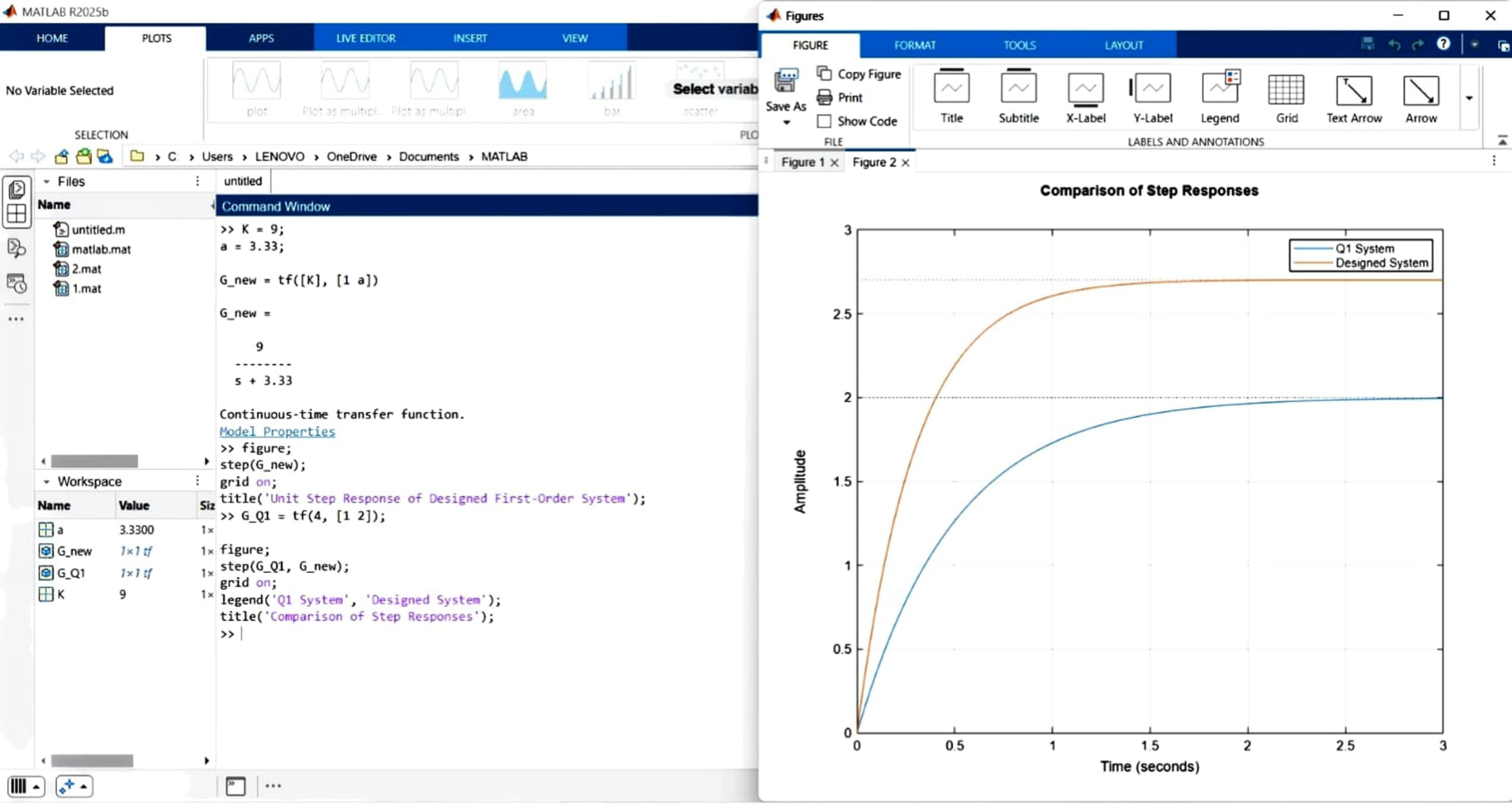
LABELS AND ANNOTATIONS
Figure 1
Step Response for a Closed System
Amplitude
Time (seconds)
0
0.2
0.4
0.6
0.8
1
1.2
0
0.5
1
1.5
2
2.5
3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Workspace
Name
Value
a
3.3300
G_new
1×1 tf
G_Q1
1×1 tf
K
9
untitled
Command Window
>> K = 9;
a = 3.33;
G_new = tf([K], [1 a])
G_new =
9
----
s + 3.33
Continuous-time transfer function.
Model Properties
>> figure;
step(G_new);
grid on;
title('Unit Step Response of Designed First-Order System');
>> G_Q1 = tf(4, [1 2]);
figure;
step(G_Q1, G_new);
grid on;
legend('Q1 System', 'Designed System');
title('Comparison of Step Responses');
>>
Figures
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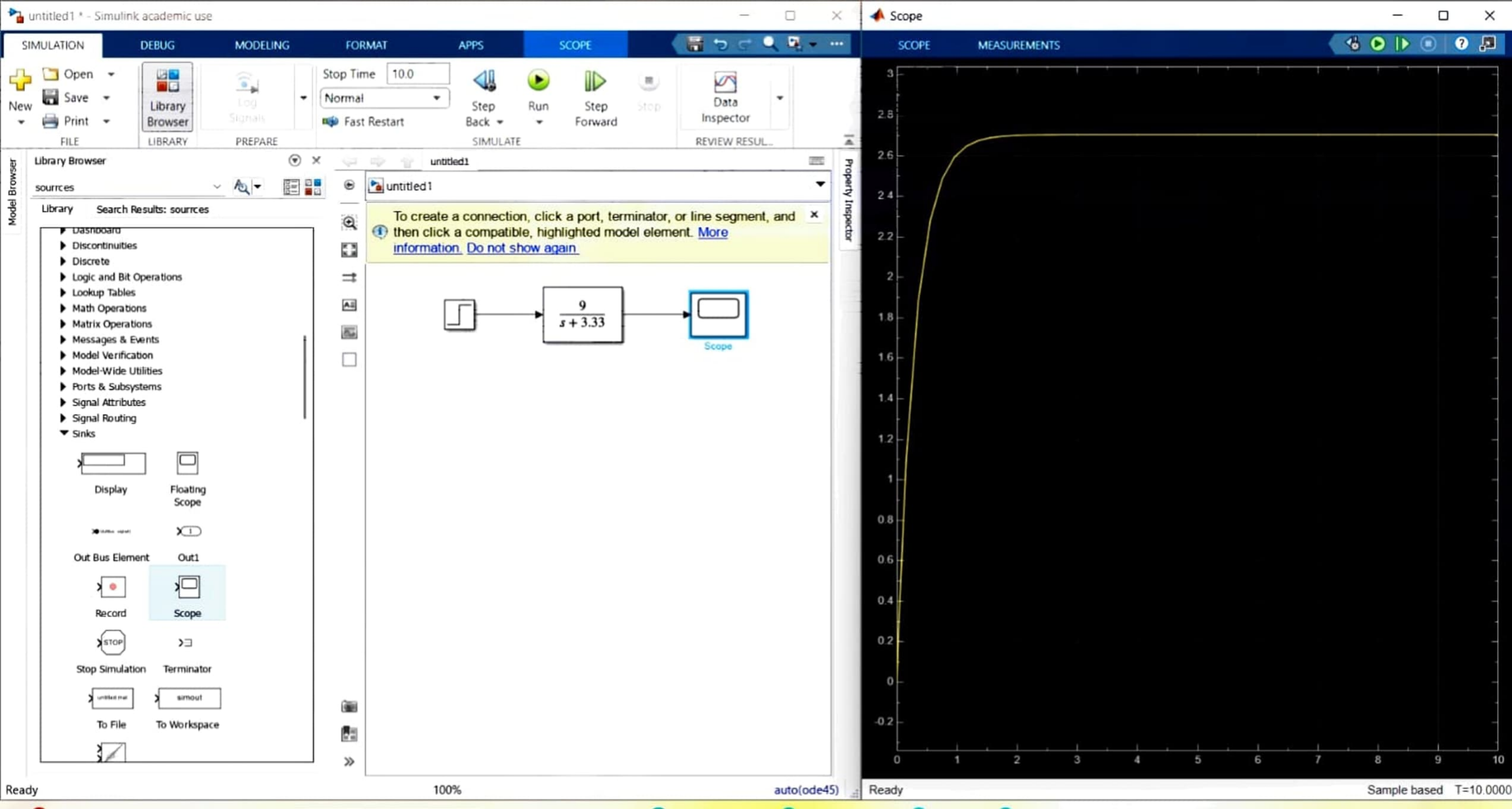
LABELS AND ANNOTATIONS
Figure 1
Figure 2
Comparison of Step Responses
Q1 System
Designed System
Amplitude
Time (seconds)
0
0.5
1
1.5
2
2.5
3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Library
Search Results: sources
Dashboard
Discontinuities
Discrete
Logic and Bit Operations
Lookup Tables
Math Operations
Matrix Operations
Messages & Events
Model Verification
Model-Wide Utilities
Ports & Subsystems
Signal Attributes
Signal Routing
Sinks
Display
Floating Scope
Out Bus Element
Out1
Record
Scope
Stop Simulation
Terminator
To File
To Workspace
simout
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To create a connection, click a port, terminator, or line segment, and then click a compatible, highlighted model element. More information. Do not show again
9
s + 3.33
Scope
Property Inspector
Ready
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auto(ode45)
Scope
SCOPE
MEASUREMENTS
3
2.8
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2
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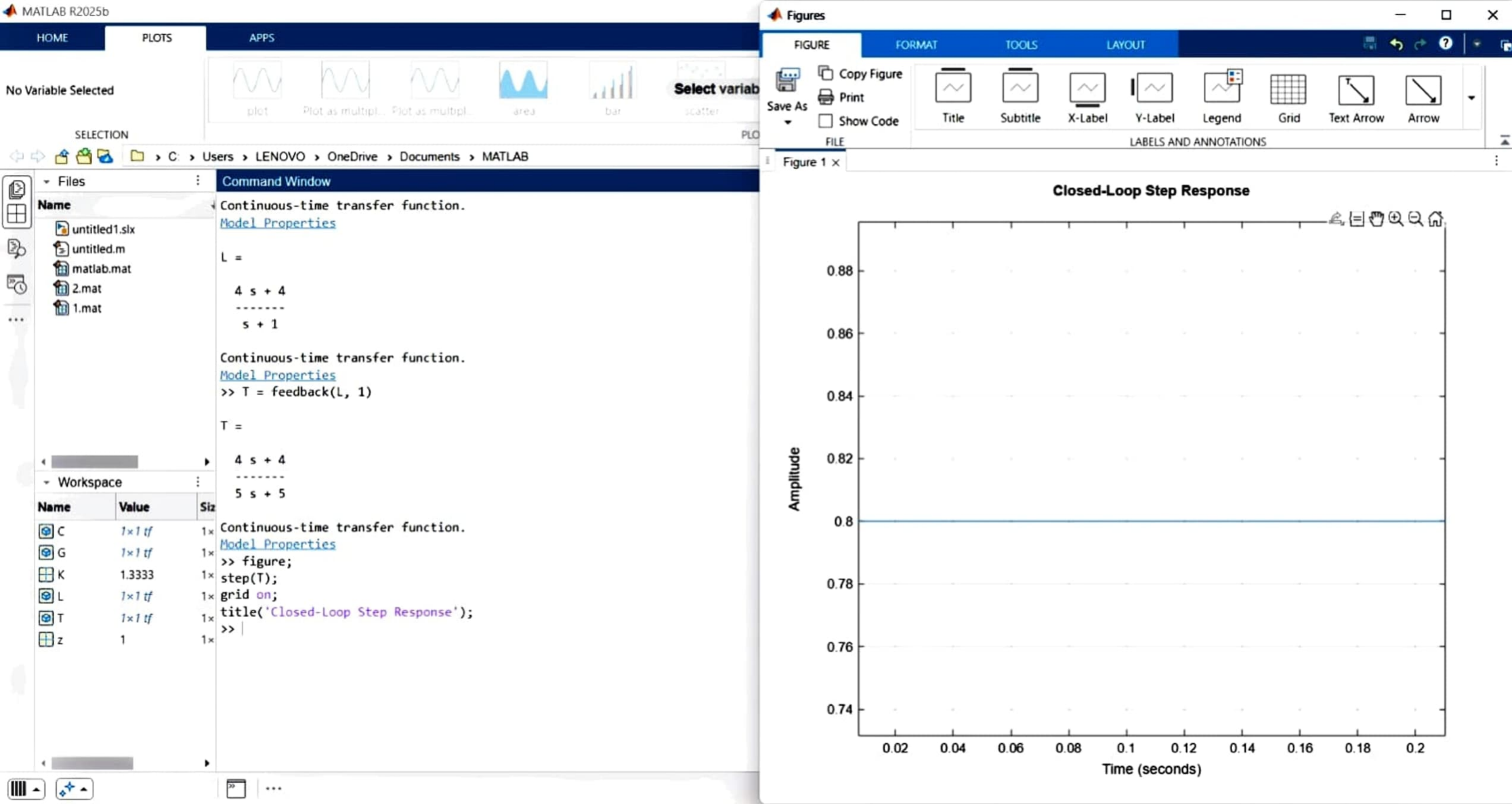
9
10
Ready
Sample based
T=10.0000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matlab.mat
2.mat
1.mat
Workspace
Name
Value
C 1×1 tf
G 1×1 tf
K 1.3333
L 1×1 tf
T 1×1 tf
z 1
Command Window
Continuous-time transfer function.
Model Properties
L =
4 s + 4
----
s + 1
Continuous-time transfer function.
Model Properties
>> T = feedback(L, 1)
T =
4 s + 4
----
5 s + 5
Continuous-time transfer function.
Model Properties
>> figure;
step(T);
grid on;
title('Closed-Loop Step Response');
>>
Figures
FIGURE
FORMAT
TOOLS
LAYOUT
Save As
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Print
Show Code
FILE
Title
Subtitle
X-Label
Y-Label
Legend
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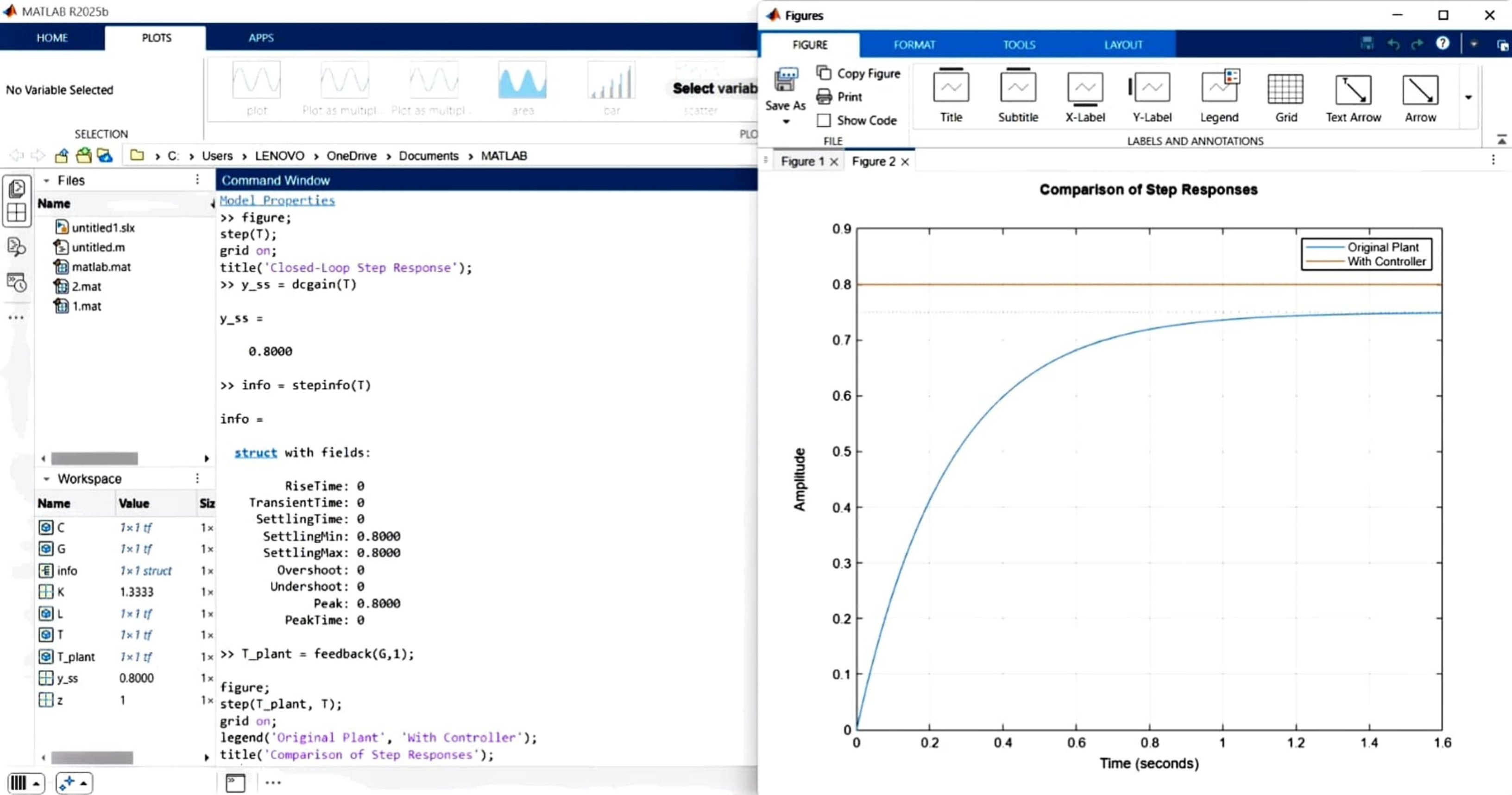
LABELS AND ANNOTATIONS
Figure 1
Closed-Loop Step Response
Amplitude
0.88
0.86
0.84
0.82
0.8
0.78
0.76
0.74
0.02
0.04
0.06
0.08
0.1
0.12
0.14
0.16
0.18
0.2
Time (seconds)


MATLAB R2025b
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PLOTS
APPS
No Variable Selected
SELECTION
plot
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Select variab
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Files
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matlab.mat
2.mat
1.mat
Workspace
Name
Value
C
1×1 tf
G
1×1 tf
info
1×1 struct
K
1.3333
L
1×1 tf
T
1×1 tf
T_plant
1×1 tf
y_ss
0.8000
z
1
Command Window
Model Properties
>> figure;
step(T);
grid on;
title('Closed-Loop Step Response');
>> y_ss = dcgain(T)
y_ss =
0.8000
>> info = stepinfo(T)
info =
struct with fields:
RiseTime: 0
TransientTime: 0
SettlingTime: 0
SettlingMin: 0.8000
SettlingMax: 0.8000
Overshoot: 0
Undershoot: 0
Peak: 0.8000
PeakTime: 0
>> T_plant = feedback(G,1);
figure;
step(T_plant, T);
grid on;
legend('Original Plant', 'With Controller');
title('Comparison of Step Responses');
Figures
FIGURE
FORMAT
TOOLS
LAYOUT
Save As
Copy Figure
Print
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FILE
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Y-Label
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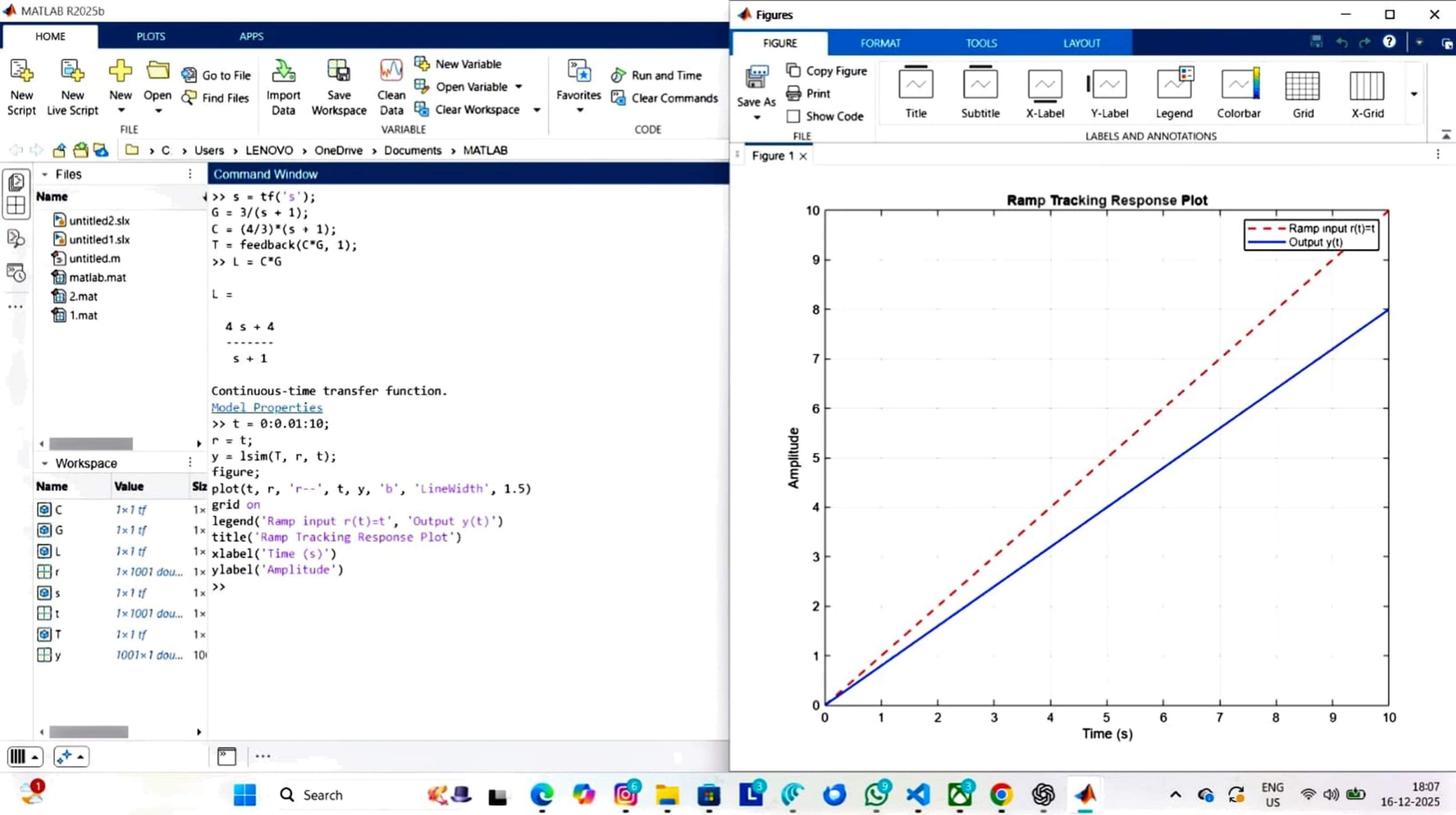
LABELS AND ANNOTATIONS
Figure 1
Figure 2
Comparison of Step Responses
Original Plant
With Controller
Amplitude
Time (seconds)
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
0
0.2
0.4
0.6
0.8
1
1.2
1.4
1.6


MATLAB R2025b
Command Window
>> s = tf('s');
G = 3/(s + 1);
C = (4/3)*(s + 1);
T = feedback(C*G, 1);
>> L = C*G
L =
4 s + 4
----
s + 1
Continuous-time transfer function.
Model Properties
>> t = 0:0.01:10;
r = t;
y = lsim(T, r, t);
figure;
plot(t, r, 'r--', t, y, 'b', 'LineWidth', 1.5)
grid on
legend('Ramp input r(t)=t', 'Output y(t)')
title('Ramp Tracking Response Plot')
xlabel('Time (s)')
ylabel('Amplitude')
>>
Ramp Tracking Response Plot
Ramp input r(t)=t
Output y(t)
Amplitude
Time (s)