CONTROL SYSYTEM LAB MANUAL

Submitted by

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EXPERIMENT – 1

OBJECTIVE: Introduction to MATLAB Control System Toolbox.

SOFTWARE REQUIRED: MATLAB

THEORY:

1.1 Introduction to Control System

Control System Toolbox is a package for Matlab consisting of tools specifically developed forcontrol applications. The package offers data structures to describe common system representations such as state space models and transfer functions, as well as tools for analysis and design of control systems. There are also tools for simulation of systems.Here we will get to know the basic commands of Control System Toolbox. After completion of this experiment you should be able to understand and use Control Systems Toolbox to create and analyze linear systems. Extensive use of the Matlab help command is recommended. Student is recommended to create a script file (e.g. myscript.m) in which commands can be written and by running a script file instead of typing the commands directly at the Matlab prompt, it is quite easier to correct mistakes, and also, the work will be saved for lateruse.The system we will use, of the form

$$\dot{x} = Ax + Bu = \begin{bmatrix} 0 & 1 \\ -1 & -1 \end{bmatrix} x + \begin{bmatrix} 0 \\ 1 \end{bmatrix} u$$
$$y = Cx = \begin{bmatrix} 1 & 0 \end{bmatrix}$$

To enter a matrix in MATLAB, for example matrix A, do

$y = Cx = [1\ 0]$

To enter a matrix in MATLAB, for example matrix A, do

$A = [0\ 1; -1\ -1]$

Creation and Conversion of systems

Control System Toolbox supports several system representations of linear time invariant systems. In this exercise, we will use two of the most common representations; state space models and transfer functions.Create a state space description of the system using ss, and name it systems. Find out how to use ss by using the help function (help ss). At this stage, you should have obtained a state space description of the system.Let us now create an equivalent transfer function model of the system above. This could, as you know, be done by using the formula $G(s) = C(sI - A)-1\ B + D$. However, Matlab may also be used for the task. Use the command tf to convert the state space model to a transfer function and name it.

1.2 Introduction to Simulink

Simulink is a simulation program based upon Matlab. There are several ways to define a model. One can work graphically and connect block diagrams with predefined blocks. Alternatively one can give the mathematical description in forms of differential equations in an mfile (the format for programs written in the Matlab programming language). Matlab/Simulink supports both these representations as well as combinations. Furthermore one can use descriptions that include a hierarchy of connected subsystems.

Some useful Matlab commands:

Sl. No.	Command	Description
1	plot	Linear plot.
2	subplot	Breaks the Figure window into small axes.
3	axis	Control axis and scaling appearance.
4	hold	Hold current graph.
5	grid	Grid lines.
6	title	Graph title.
7	xlabel, ylabel	Axes labels
8	tf	Create a transfer function model.
9	tfdata	Extract numerator and denominator.
10	ss	Create a statespace
11	ssdata	Extract statespace
12	zpk	Create a zero/pole/gain/model.
13	step	Step response.
14	initial	Response of statespace model with given initial state.
15	pole	System poles.
16	zero	System zeros.
17	roots	Find polynomial roots.
18	pzmap	Polezero map.
19	eig	Compute eigenvalues and eigenvectors.
20	bode	Draw a bode frequency response.
21	lsim	Simulate time response of LTI models to arbitrary inputs.
22	simulink	Open the simulink browser.
23	sim	Use a Simulink model from a Matlab script.
24	simset	Set options for the sim command
25	linmod	Obtain the statespace linear model of the system of ordinary differential equations described in a simulink model, note that the model must contain a simulink block out from sinks and a simulink block in from sources

Using Simulink Models in Matlab Scripts

Often, it is convenient to work with Matlab scripts (mfiles), in order to save a sequence of Commands. It is possible to use Simulink models from within a Matlab script, using the Command sim. By using the command simset options for the sim command may be specified.Use the model from the previous example. Save the model, and name it “mymodel.mdl”. CreateA Matlab script named “mysim.m”, and enter the following commands:Tfinal = 300;Options = simset(’reltol’,1e-5,’refine’,10,’solver’,’ode45’);

Sim(’mymodel’,tfinal,options)
;%plot resultsFigure(1)
Clf
Subplot(211)
Plot(t,u);
Ylabel(’u’)
Subplot(212)
Plot(t,y)
Ylabel(’y’)
When you run the script, you should see a plot showing the input and the output of the transfer Function. Use the help command to learn more about how to use the simset and sim commands.

Experiment – 2

OBJECTIVE: Determine transpose, inverse value of given matrix.

SOFTWARE REQUIRED: MATLAB

PROGRAM:

TRANSPOSE OF MATRIX

```
clc;

clear all;

close all;

A = [2 3 1; 4 5 1; 2 3 1]

B = transpose(A)
```

INVERSE OF MATRIX

```
clc;

clear all;

A = [1 2; 3 4]

B = det(A)

for i = 1:2

   for j = 1:2

      D (i, j) = ((-1) ^ (i+ j)) *(A(3-i,3-j));

 E (i, j) = transpose(D(i,j))

      I (i, j) = (E (i, j)/B);

      C = I'

   end

end
```

WORKSPACE:

Workspace

Name	Value	Size	Class
A	[1,2;3,4]	2x2	double
B	-2	1x1	double
C	[-2,1;1.5000,...	2x2	double
D	[4,-3;-2,1]	2x2	double
E	[4,-3;-2,1]	2x2	double
I	[-2,1.5000;1,...	2x2	double
i	2	1x1	double
j	2	1x1	double

Workspace

Name	Value	Size	Class
A	[2,3,1;4,5,1;...	3x3	double
B	[2,4,2;3,5,3;...	3x3	double

COMMAND WINDOW:

A = 1   2

3   4

B = -2

E = 4

C = -2

E = 4   -3

C = -2.0000

1.5000

E = 4   -3

-2   0

C = -2.0000   1.0000

1.5000   0

E = 4   -3

-2   1

C = -2.0000   1.0000

1.5000   -0.5000

A = 2   3   1

4   5   1

2   3   1

B = 2   4   2

3   5   3

1   1   1

Experiment – 3

OBJECTIVE: PLOT POLE-ZERO CONFIGURATION IN S-PLANE FOR THE GIVEN TRANSFER FUNCTION USING MATLAB

SOFTWARE REQUIRED: MATLAB

PROGRAM:

```
clc;
clear all;
H = tf ([3 2 1 2 1], [6 6 2 6 2 1])
Y = zpk (1, [-2, -3], 6)
subplot (2,1,1);
pzmap (H);
grid on;
subplot (2,1,2);
pzmap(Y);
```

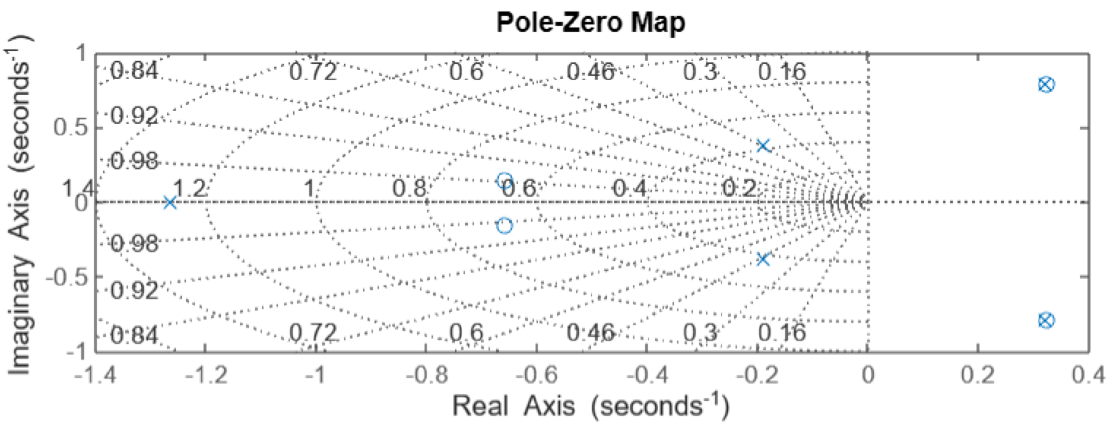
WORKSPACE:

Name	Value	Size	Class
H	*1x1 tf*	1x1	tf
Y	*1x1 zpk*	1x1	zpk

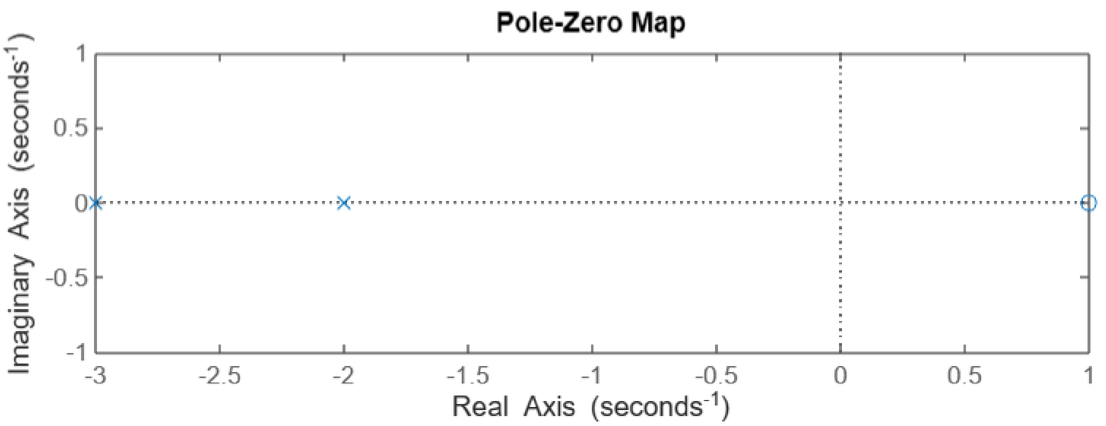
COMMAND WINDOW:

```
H = 3 s^4 + 2 s^3 + s^2 + 2 s + 1
      ---------------------------------------
     6 s^5 + 6 s^4 + 2 s^3 + 6 s^2 + 2 s + 1
Continuous-time transfer function.


Y = 6 (s-1)
     -----------
   (s+2) (s+3)Continuous-time zero/pole/gain model.
```

FIGURE:



Pole-Zero Map
Imaginary Axis (seconds-1)
Real Axis (seconds-1)



Pole-Zero Map
Imaginary Axis (seconds-1)
Real Axis (seconds-1)

Experiment – 4

OBJECTIVE: Determine the transfer function for the closed loop system in the block diagram representation.

SOFTWARE REQUIRED: MATLAB

PROGRAM:

```
clc;

close all;

clear all;

%for system1

G1 = tf ([1 0], [1 1])

H1 = tf ([1], [1 0])

G2 = tf ([1 4], [1 3 1])

H2 = tf ([1 0], [1 2])

F1 = feedback (G1, H1)

F2 = feedback (G2, H2)

A = series (F1, F2)

H = tf ([1 0], [1 3])

F3 = feedback (A, H)

f =F3(step);
```

WORKSPACE:

Name	Value	Size	Class
A	1x1 tf	1x1	tf
F1	1x1 tf	1x1	tf
F2	1x1 tf	1x1	tf
F3	1x1 tf	1x1	tf
G1	1x1 tf	1x1	tf
G2	1x1 tf	1x1	tf
H	1x1 tf	1x1	tf
H1	1x1 tf	1x1	tf
H2	1x1 tf	1x1	tf

COMMAND WINDOW:

```
G1 =   s
      -----
     s + 1

 Continuous-time transfer function.

H1 = 1
      -
      s

 Continuous-time transfer function.

G2 = s + 4
      -------------
     s^2 + 3 s + 1

 Continuous-time transfer function.

H2 = s
      -----
     s + 2

 Continuous-time transfer function.

F1 = s^2
      ---------
     s^2 + 2 s

 Continuous-time transfer function.

F2 = s^2 + 6 s + 8
      ----------------------
     s^3 + 6 s^2 + 11 s + 2

 Continuous-time transfer function.

A = s^4 + 6 s^3 + 8 s^2
     -----------------------------------
    s^5 + 8 s^4 + 23 s^3 + 24 s^2 + 4 s

 Continuous-time transfer function.
```

H = s

-----

s + 3

Continuous-time transfer function.

F3 = s^5 + 9 s^4 + 26 s^3 + 24 s^2

----

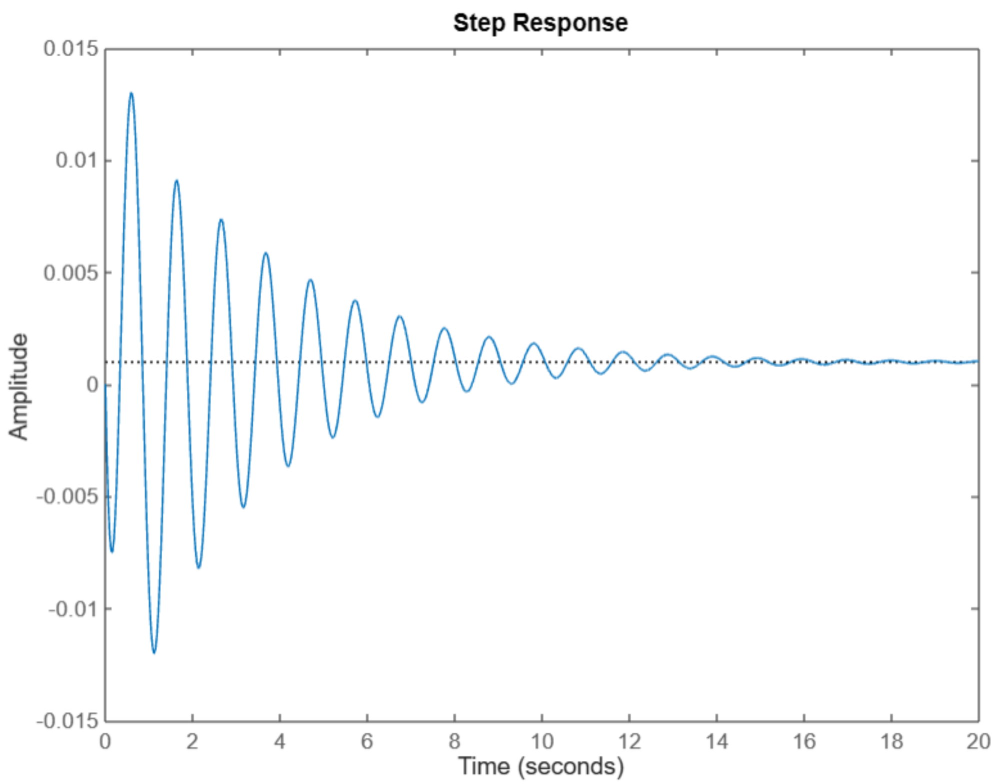
s^6 + 12 s^5 + 53 s^4 + 101 s^3 + 76 s^2 + 12 s

Continuous-time transfer function.

num = 0 -0.1022 0.0316 0.1934 -0.1795 0.1620

den = 1.0000 6.2190 50.6538 222.7866 359.5180 162.7478

FIGURE:



Experiment – 5

OBJECTIVE: Determine the time response of the given system subjected to any arbitrary input.

SOFTWARE REQUIRED: MATLAB

PROGRAM:

```
clc;
close all;
clear all;
h1 = tf ([9], [1 6 9])
t = linspace (1,15,50);
%step response
Subplot (3,2,1)
step(h1)
%impulse response
Subplot (3,2,2)
impulse(h1)
%sinusoidal
r =sin(t);
%ramp
s=2*t;
%parabolic
q = 5*(t.^2);
subplot (3,2,3);
lsim (h1, r, t);
subplot (3,2,4);
lsim (h1, s, t);
subplot (3,2,5);
lsim (h1, q, t);
```

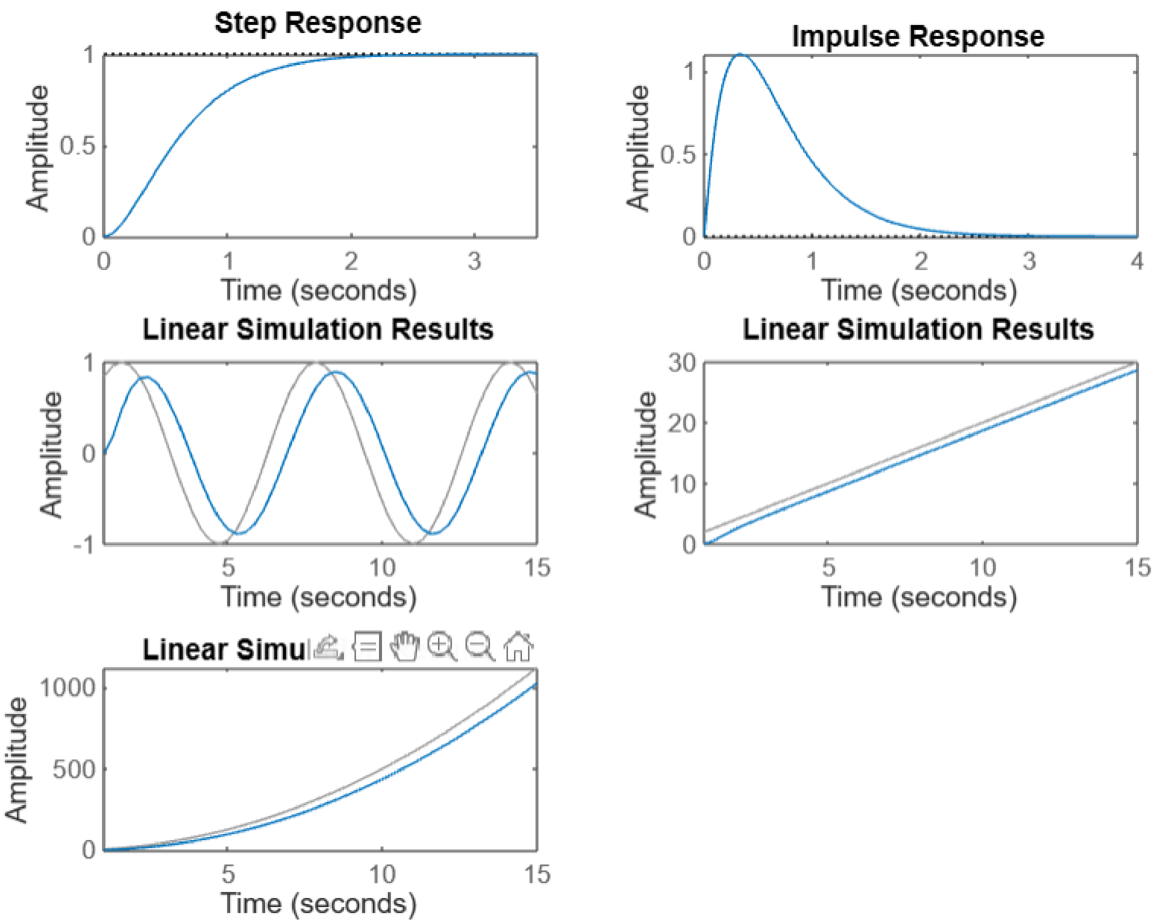
WINDOWSPACE:

Name	Value	Size	Class
h1	*1x1 tf*	1x1	tf
q	*1x50 double*	1x50	double
r	*1x50 double*	1x50	double
s	*1x50 double*	1x50	double
t	*1x50 double*	1x50	double

COMMAND WINDOW:

```
h1 =        9
     -------------
     s^2 + 6 s + 9
  Continuous-time transfer function.
```

FIGURE:



Experiment – 6

OBJECTIVE: Plot unit step response of the given transfer function and find delay time, rise time, peak time, peak time, peak overshoot and settling time.

SOFTWARE REQUIRED: MATLAB

PROGRAM:

```
clc

clear all

close all

g = tf ([25], [1 6 25])

wn = 5

zt = 6/(wn*2)

wd = wn*sqrt(1-(zt*zt))

tp =pi/wd

mp =exp((-1*zt*pi)/sqrt(1-(zt*zt)))

po = (2*pi)/wd

st = 4/(zt*wn)

a = acos(zt);

rt = (pi-a)/wd

t = 0:0.01:10;

[y, t] = step(g);

Plot (t, y)
```

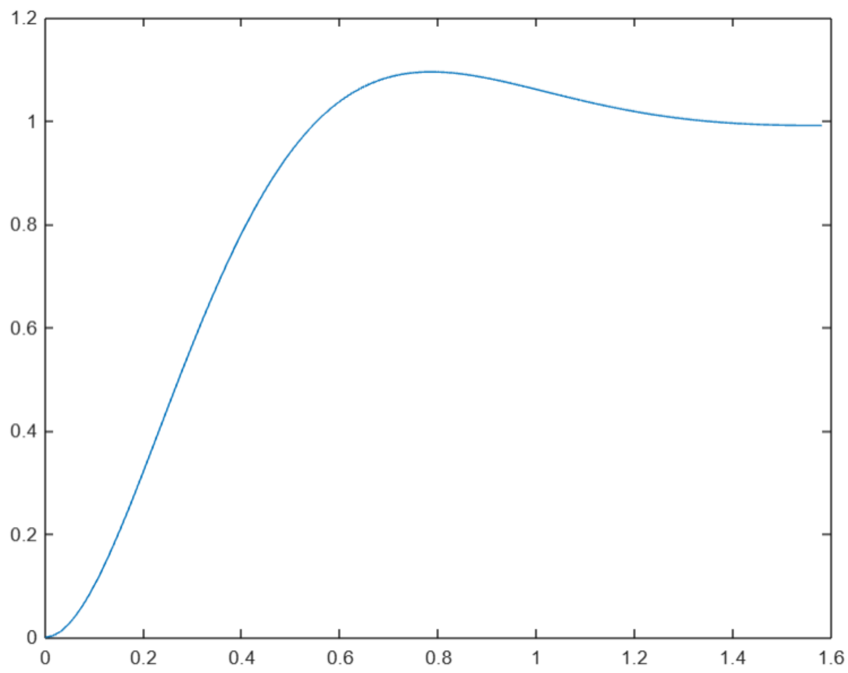
WINDOWSPACE:

Name	Value	Size	Class
a	0.9273	1x1	double
g	1x1 tf	1x1	tf
mp	0.0948	1x1	double
po	1.5708	1x1	double
rt	0.5536	1x1	double
st	1.3333	1x1	double
t	104x1 double	104x1	double
tp	0.7854	1x1	double
wd	4	1x1	double
wn	5	1x1	double
y	104x1 double	104x1	double
zt	0.6000	1x1	double

COMMAND WINDOW:

```
g =      25

       --------------

      s^2 + 6 s + 25

 Continuous-time transfer function.

wn = 5

zt = 0.6000

wd = 4

tp = 0.7854

mp = 0.0948

po = 1.5708

st = 1.3333

rt = 0.5536
```

FIGURE:



Experiment – 7

OBJECTIVE: Determine the steady state error of a given transfer function.

SOFTWARE REQUIRED: MATLAB

PROGRAM:

```
clc
close all
clear all
g = tf ([4], [1 3 4])
a = step(g);
[y, t] = step(g);
i=length(y)
z = y(i)
c = y(end)
sserror = abs(1-c)
```

WINDOWSPACE:

Name	Value	Size	Class
a	*139x1 double*	139x1	double
c	0.9999	1x1	double
g	*1x1 tf*	1x1	tf
i	139	1x1	double
sserror	1.1622e-04	1x1	double
t	*139x1 double*	139x1	double
y	*139x1 double*	139x1	double
z	0.9999	1x1	double

COMMAND WINDOW:

g = 4/ s^2 + 3 s + 4

Continuous-time transfer function.

i = 139

z = 0.9999

c = 0.9999

sserror = 1.1622e-04

Experiment – 8

OBJECTIVE: Plot root locus of a given transfer function, locate closed loop pole for the different value of K

SOFTWARE REQUIRED: MATLAB

PROGRAM:

```
%root locus plot
clc
clear all
close all
num = 1;
p = conv ([1 0], [1 4]);
den = conv (p, [1 4 13]);
G = tf (num, den);
k = linspace (1,1000,1000);
for i =1:1000:1000
 h = k(i)*G;
m = feedback(h,1);
 pzmap(m)
 hold on
 end
m = feedback(G,1)
rlocus (m)
```

WINDOWSPACE:

Name	Value	Size	Class
G	*1x1 tf*	1x1	tf
den	[1,8,29,52,0]	1x5	double
h	*1x1 tf*	1x1	tf
i	1	1x1	double
k	*1x1000 double*	1x1000	double
m	*1x1 tf*	1x1	tf
num	1	1x1	double
p	[1,4,0]	1x3	double

COMMAND WINDOW:

num = 1

p = 1 4 0

den = 1 8 29 52 0

k =

Columns 1 through 11

1 2 3 4 5 6 7 8 9 10 11

Columns 12 through 22

12 13 14 15 16 17 18 19 20 21 22

Columns 23 through 33

23 24 25 26 27 28 29 30 31 32 33

…

Columns 991 through 1,000

991 992 993 994 995 996 997 998 999 1000

m = 1

\-------------------------------

s^4 + 8 s^3 + 29 s^2 + 52 s + 1

Continuous-time transfer function.

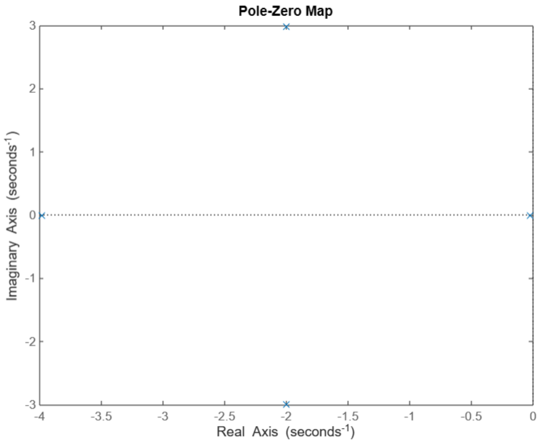
m = 1

\-------------------------------

s^4 + 8 s^3 + 29 s^2 + 52 s + 1

Continuous-time transfer function.

FIGURE:



Pole-Zero Map
Imaginary Axis (seconds^{-1})
Real Axis (seconds^{-1})
3
2
1
0
-1
-2
-3
-4
-3.5
-3
-2.5
-2
-1.5
-1
-0.5
0

Experiment – 9

OBJECTIVE: Plot root locus of a given transfer function, locate closed loop pole for the different value of K

SOFTWARE REQUIRED: MATLAB

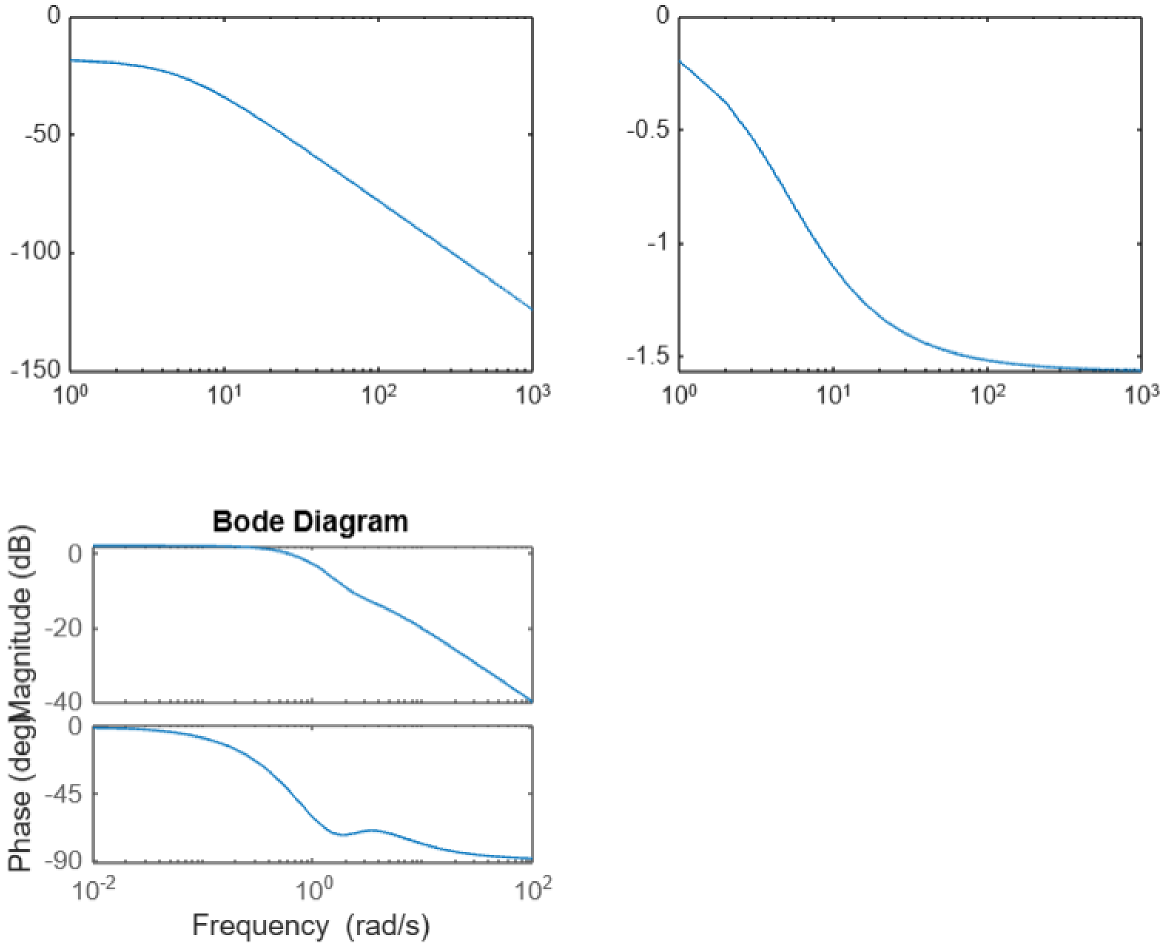
PROGRAM:

```
clc
close all
g = tf ([1 3 5], [1 5 8 4]);
w = linspace(1,1000,1000);
for i = 1:1:1000
    mag(i) = 2/sqrt(25+w(i).^2);
    magdb(i) = 20*log(mag(i));
    phase(i) = -atan(w(i)/5);
end
subplot(2,2,1)
semilogx(w,magdb)
subplot(2,2,2)
semilogx(w,phase)
subplot(2,2,3)
bodeplot(g)
```

COMMAND WINDOW:

```
g =

      s^2 + 3 s + 5
  ---------------------
  s^3 + 5 s^2 + 8 s + 4

Continuous-time transfer function.
```

FIGURE:



0
-50
-100
-150
10^0
10^1
10^2
10^3
0
-0.5
-1
-1.5
10^0
10^1
10^2
10^3
Bode Diagram
Magnitude (dB)
0
-20
-40
Phase (deg)
0
-45
-90
10^{-2}
10^0
10^2
Frequency (rad/s)