EE_105_022_23W Lab 4

Edgar Vergara Albarran

TOTAL POINTS

100 / 100

QUESTION 1

1 2.2 (a,b,c,d,e) **15 / 15**

✓ **- 0 pts** *Correct*

QUESTION 2

2 2.3 (b,c) **15 / 15**

✓ **- 0 pts** *Correct*

QUESTION 3

3 2.4 (b,c,d) **15 / 15**

✓ **- 0 pts** *Correct*

QUESTION 4

4 2.4 (e) **20 / 20**

✓ **- 0 pts** *Correct*

QUESTION 5

5 3 **10 / 10**

✓ **- 0 pts** *Correct*

QUESTION 6

6 Prelab **25 / 25**

✓ **+ 25 pts** *Full prelab presented in lab*

$$X = \begin{bmatrix} x_1 = e_b \\ x_2 = f_a \\ x_3 = f_d \\ x_4 = e_b \end{bmatrix}$$

$\dot{x}_1 = \dot{e}_b = \frac{1}{b}(x_2)$

$\dot{x}_2 = \dot{f}_a = \frac{1}{a}(e_a) = \frac{1}{a}(u - x_1 - x_4) = \frac{1}{a}x_1 - \frac{1}{a}x_4$

$n = 4 \rightarrow$ number of states

$\rightarrow p = 1$

$\rightarrow m = 1$

$y = [x_3]$

$\dot{x}_3 = \dot{f}_d$

$\frac{d i_d}{dt} = \frac{1}{d}(x_4)$

$\dot{x}_4 = \dot{e}_b$

$\dot{x}_4 = \frac{1}{b}(f_b) = \frac{1}{b}\left(x_2 - x_3 - \frac{x_4}{R_L}\right)$

$$\underset{4\times4}{A} = \begin{bmatrix} 0 & \frac{1}{b} & 0 & 0 \\ -\frac{1}{a} & 0 & 0 & -\frac{1}{a} \\ 0 & 0 & 0 & \frac{1}{d} \\ 0 & \frac{1}{b} & -\frac{1}{b} & -\frac{1}{bR_C} \end{bmatrix} \qquad \underset{4\times1}{B} = \begin{bmatrix} 0 \\ 1/a \\ 0 \\ 0 \end{bmatrix}$$

$A \in R^{n\times n}$ 4×1

$B \in R^{n\times m}$

$C \in R^{p\times n}$

$D \in R^{p\times m}$

$$\underset{1\times4}{C} = \begin{bmatrix} 0 & 0 & 1 & 0 \end{bmatrix} \qquad \underset{1\times1}{D} = \begin{bmatrix} 0 \end{bmatrix}$$

Part 2

2.

```
%(a)
a = 10e-4; b = 1e-6; c = 100; d = 40e-3;    %10e-6
A = [0 1/b 0 0; -1/a 0 0 -1/a; 0 0 0 1/d; 0 1/b -1/b -1/(b*c)];
B = [0 1/a 0 0]';
C = [0 0 1 0];
D = [0];
%(b)
poles = eig(A);
%(c)
tau = 1/(min(abs(real(poles))));
Ts = 4*tau;
%(d)
sys = ss(A,B,C,D);
trans = tf(sys)
[num,den] = ss2tf(A,B,C,D);
%(e)
r = roots(num);
p = pole(sys);
```

```
The poles found here match the ones found earlier shown in the
picture below
```

Name	Value
a	1.0000e-03
A	*4x4 double*
b	1.0000e-06
B	[0;1000;0;0]
c	100
C	[0,0,1,0]
d	0.0400
D	0
den	[1,1.0000e+04,2....
num	[0,0,0,2.5000e+1...
p	[-2.5000e+03 + ...
poles	[-2.5000e+03 + ...
r	5.6401e-10
sys	*1x1 ss*
tau	4.0000e-04
trans	*1x1 tf*
Ts	0.0016

3.

B.

```
bode(num,den)
grid on;
```

Fp1 = 3.54e03 rad/s

Fp2 = 4.46e04 rad/s

1 2.2 (a,b,c,d,e) **15 / 15**

✓ **- 0 pts** *Correct*

The poles found here match the ones found earlier shown in the picture below

Name	Value
a	1.0000e-03
A	*4x4 double*
b	1.0000e-06
B	[0;1000;0;0]
c	100
C	[0,0,1,0]
d	0.0400
D	0
den	[1,1.0000e+04,2....
num	[0,0,0,2.5000e+1...
p	[-2.5000e+03 + ...
poles	[-2.5000e+03 + ...
r	5.6401e-10
sys	*1x1 ss*
tau	4.0000e-04
trans	*1x1 tf*
Ts	0.0016

3.

B.

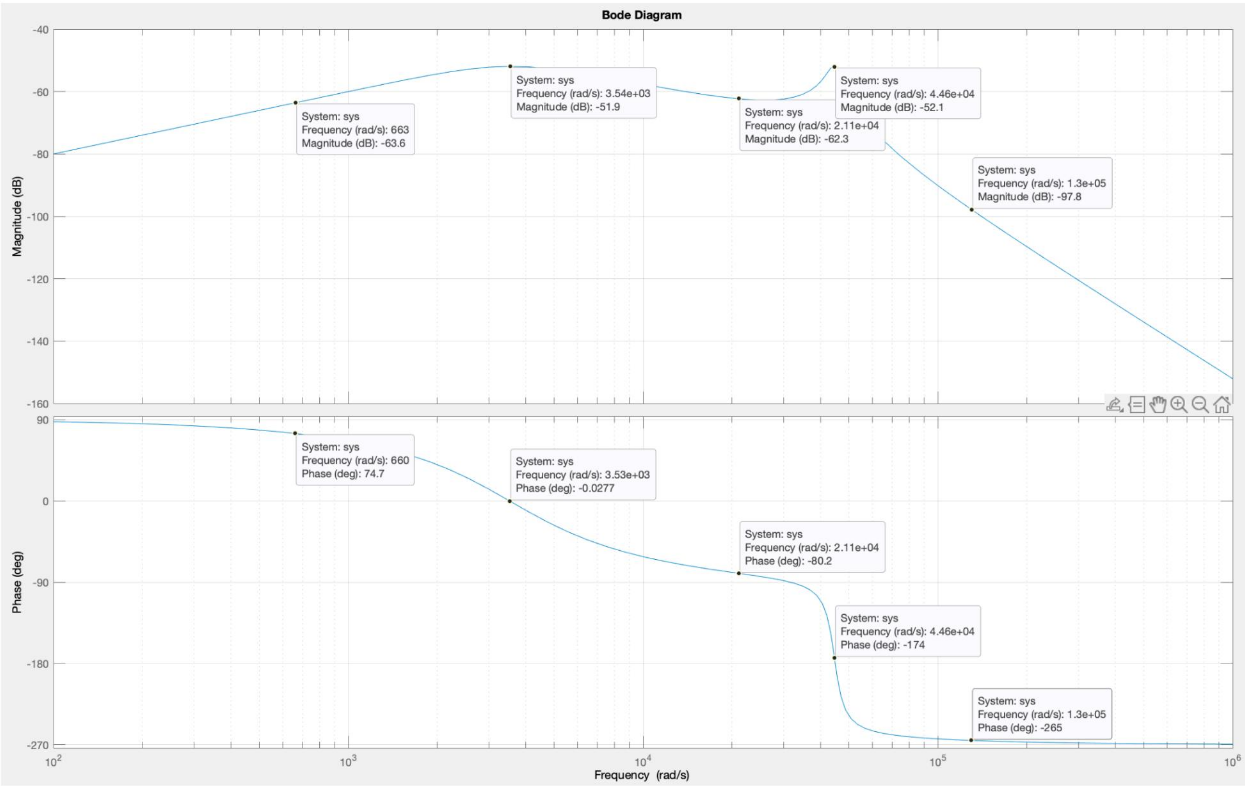
```
bode(num,den)
grid on;
```

Fp1 = 3.54e03 rad/s

Fp2 = 4.46e04 rad/s

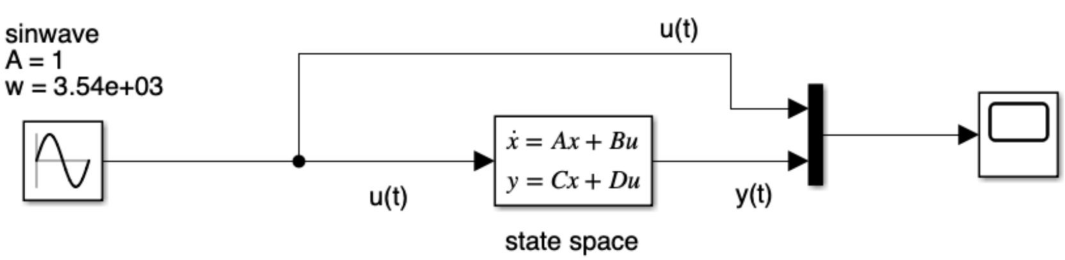
C.

F1 = 683 rad/s phase = 74.02 degrees magnitude = -63.3 db
F2 = 2.11e04 rad/s phase = -80.2 degrees magnitude = -62.3 db
F3 = 1.3e05 rad/s phase = -265 degrees magnitude = -97.8 db



4.

B.



c.

2 2.3 (b,c) **15 / 15**

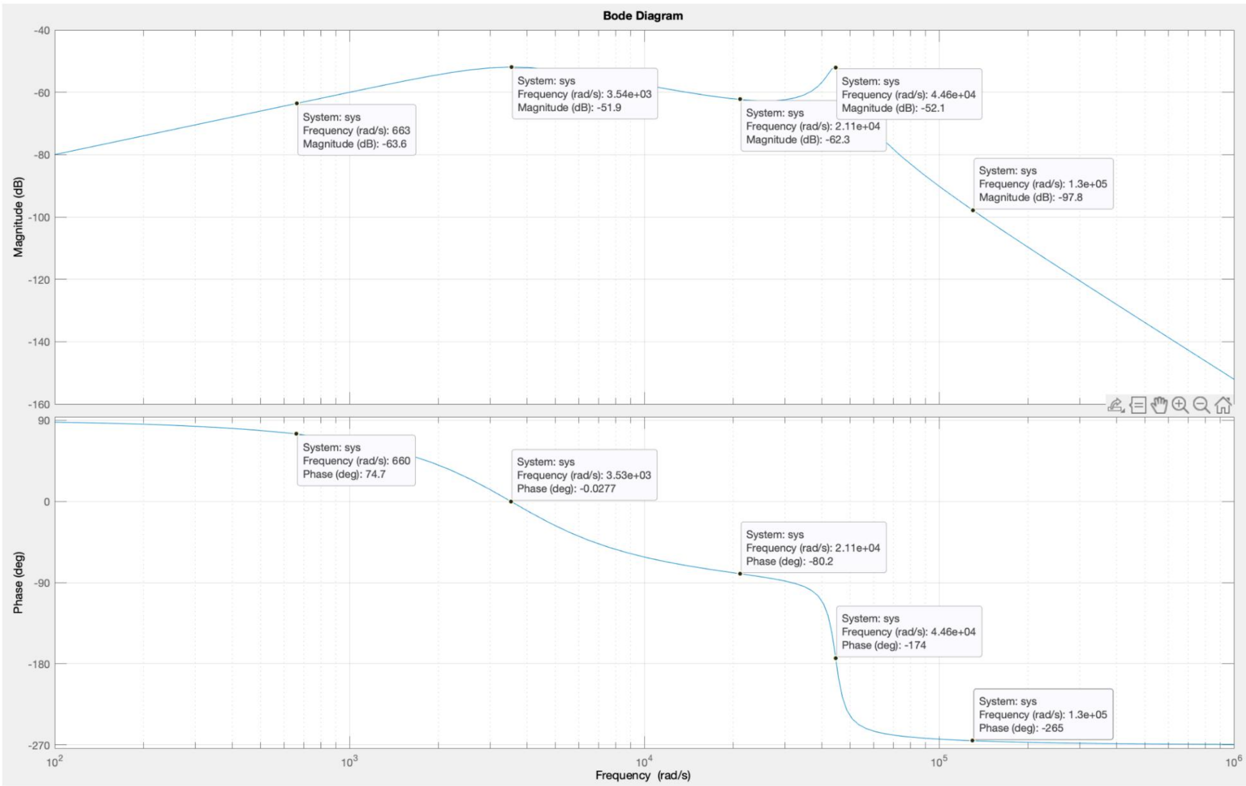
✓ **- 0 pts** *Correct*

C.

F1 = 683 rad/s		phase = 74.02 degrees		magnitude = -63.3 db

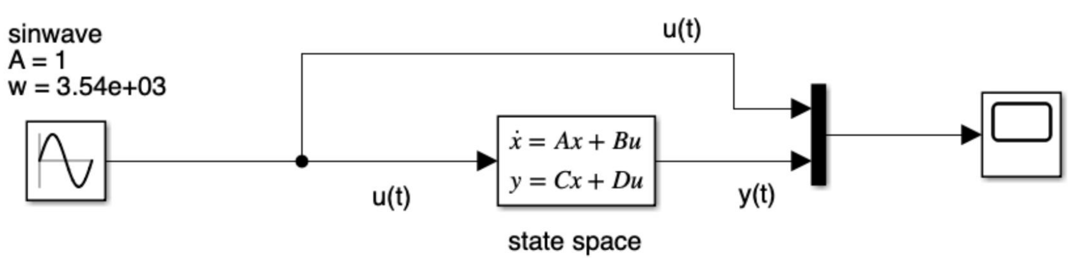
F2 = 2.11e04 rad/s	phase = -80.2 degrees		magnitude = -62.3 db

F3 = 1.3e05 rad/s	phase = -265 degrees		magnitude = -97.8 db

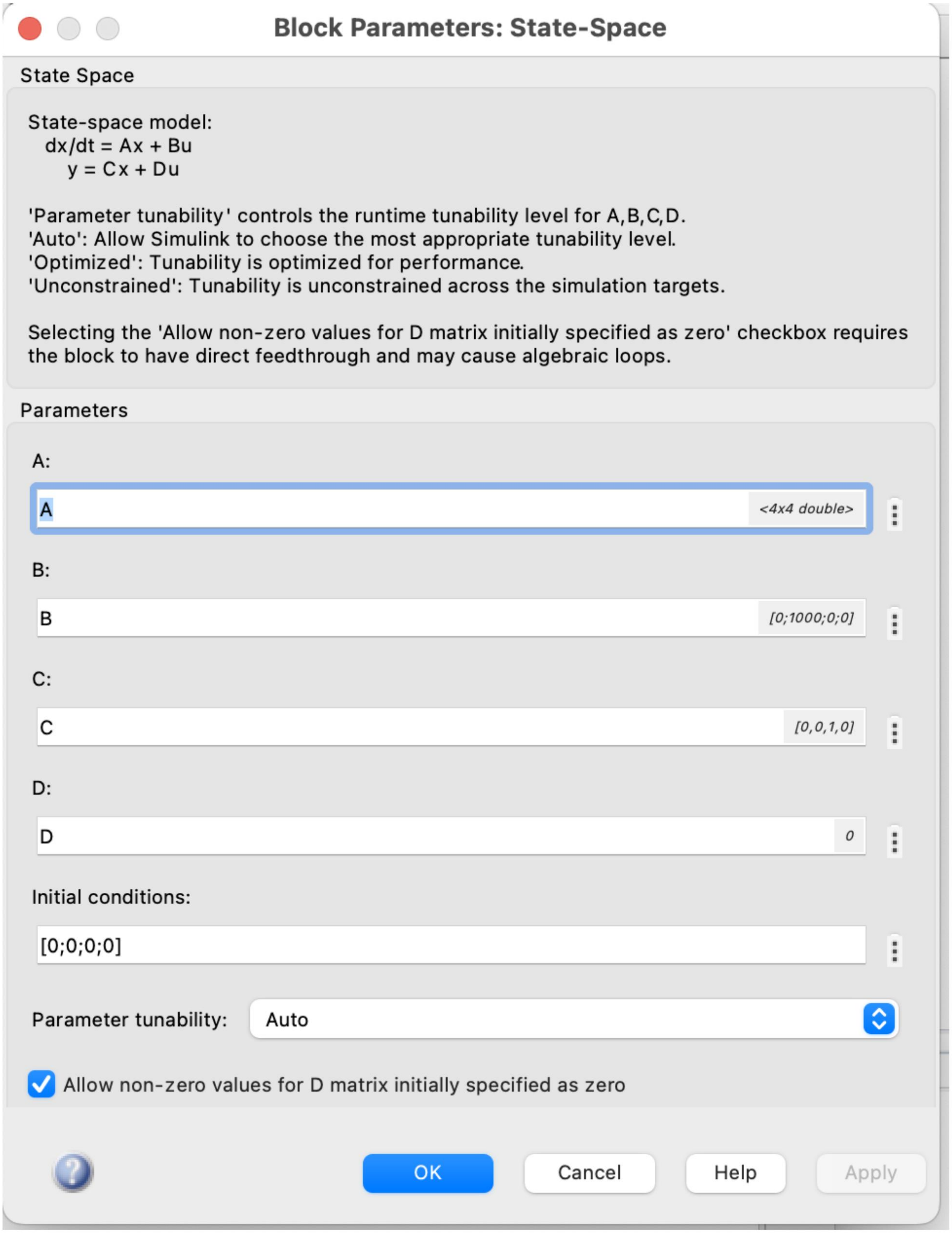


4.

B.



c.



D.

4*ts = 0.0048 second

3 2.4 (b,c,d) **15 / 15**

✓ **- 0 pts** *Correct*

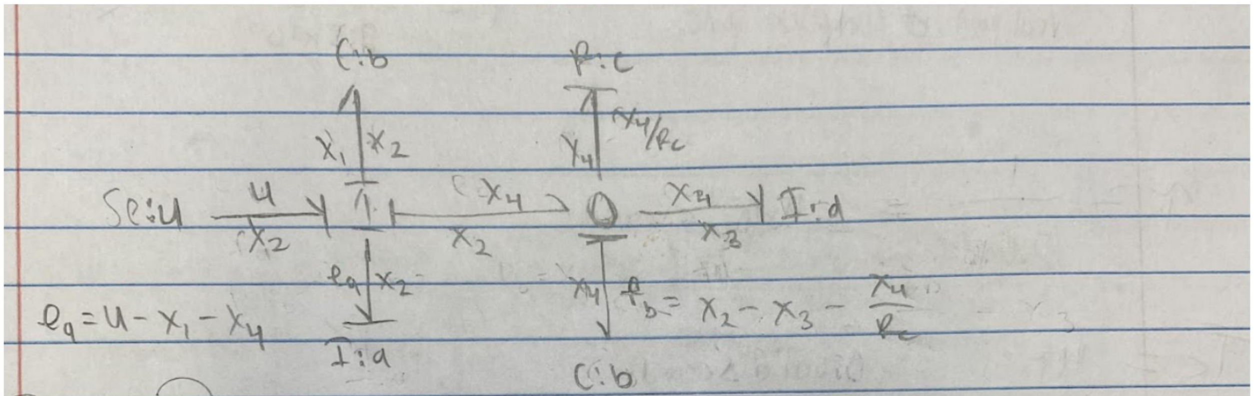
E.

	Freq (rad/s)	Theoretical T_s	Simu T_s	In Amplitude	Output Amplitude	Amp. gain	Theo. phase	Simu. phase
f1	683	4tau = 0.0016	0.00731	1	6.827e-4	6.827e-4	74.02	53.504
fp1	3.54e03	0.0016	0.0035	1	2.59e-03	2.59e-03	-0.246	-0.811
f2	2.11e04	0.0016	0.0022	1	7.423e-03	7.423e-03	-80.2	-67
fp2	4.46e4	0.0016	0.00161	1	2.44e-03	2.44e-03	-170	-191
f3	1.3e05	0.0016	0.001632	1	1.43e-05	1.43e-05	-265	-260

4 2.4 (e) **20 / 20**

✓ **- 0 pts** *Correct*

Part 3



$e_a = u - x_1 - x_4$

$f_b = x_2 - x_3 - \frac{x_4}{R_c}$

$x_1 = e_b$
$x_2 = f_a$
$x_3 = f_d$
$x_4 = e_b$

number of states

$\dot{x}_1 = e_b = \frac{1}{b}(x_2)$

$\dot{x}_2 = f_a = \frac{1}{a}(e_a) = \frac{1}{a}(u - x_1 - x_4) = -\frac{1}{a}x_1 - \frac{1}{a}x$

$X = \begin{bmatrix} x_1 = e_b \\ x_2 = f_a \\ x_3 = f_d \\ x_4 = e_b \end{bmatrix}$

$\dot{x}_1 = e_b = \frac{1}{b}(x_2)$

$\dot{x}_2 = f_a = \frac{1}{a}(e_a) = \frac{1}{a}(u - x_1 - x_4) = -\frac{1}{a}x_1 - \frac{1}{a}x_4$

$n = 4 \rightarrow$ number of states
order $\rightarrow p = 1$
inputs $\rightarrow m = 1$
$y = [x_3]$

$\dot{x}_3 = f_d$

$\frac{di_d}{dt} = \frac{1}{d}(x_4)$

$\dot{x}_4 = e_b$

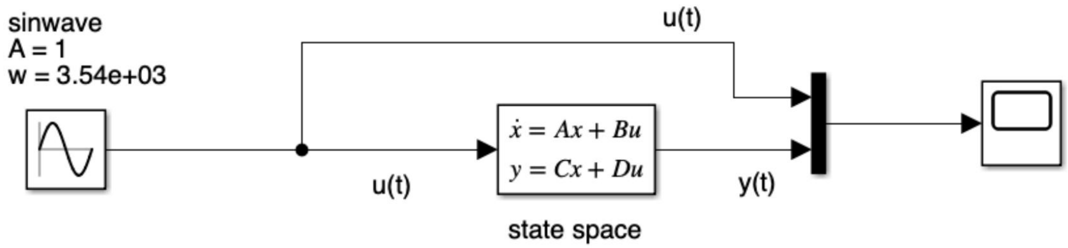
$\dot{x}_4 = \frac{1}{b}(f_b) = \frac{1}{b}\left(x_2 - x_3 - \frac{x_4}{R_c}\right)$

4x4

2.

```
a = 10e-4; b = 1e-6; c = 100; d = 40e-3;    %10e-6
A = [0 1/b 0 0; -1/a 0 0 -1/a; 0 0 0 1/d; 0 1/b -1/b -1/(b*c)];
B = [0 1/a 0 0]';
C = [0 0 1 0];
D = [0];
```

3.



4.

Figure 1

W = 3.54e03 rad/s

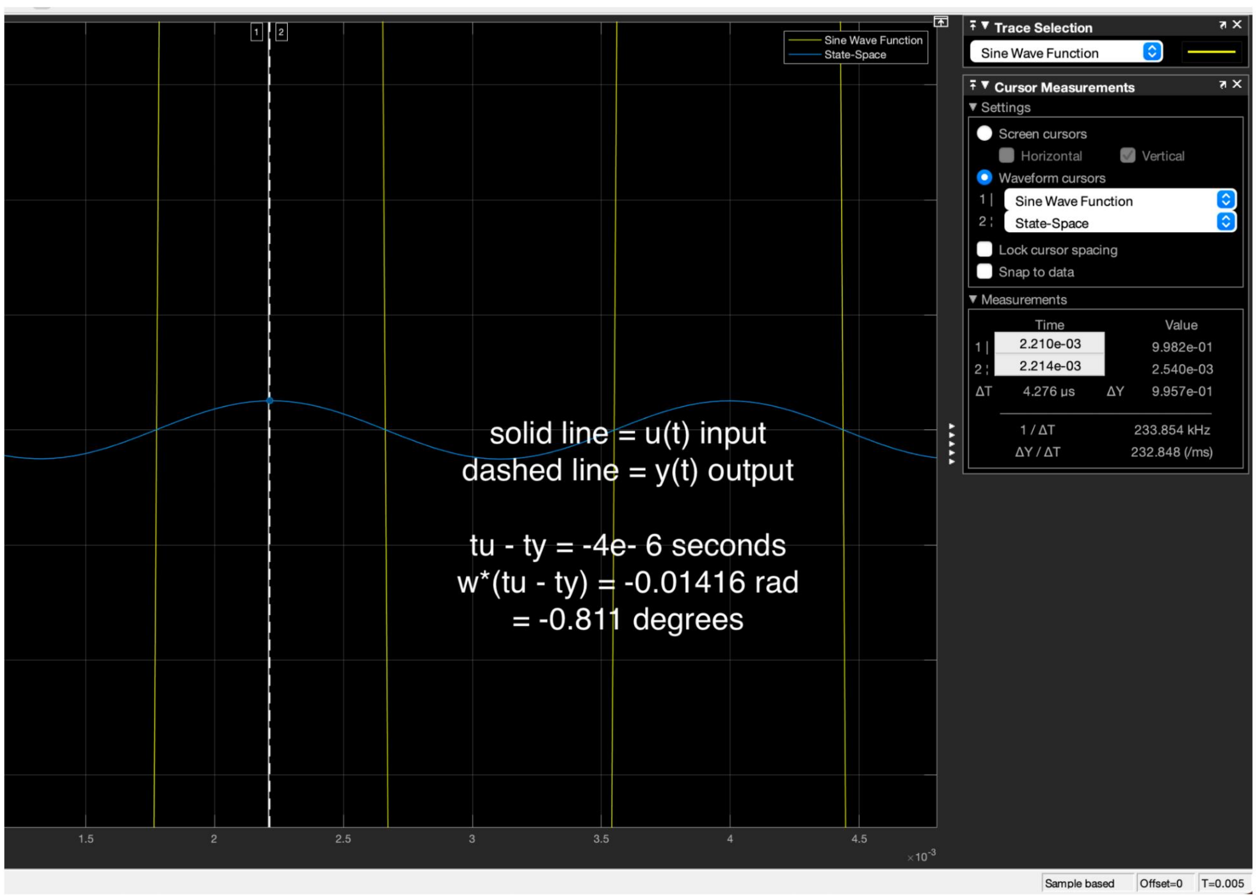
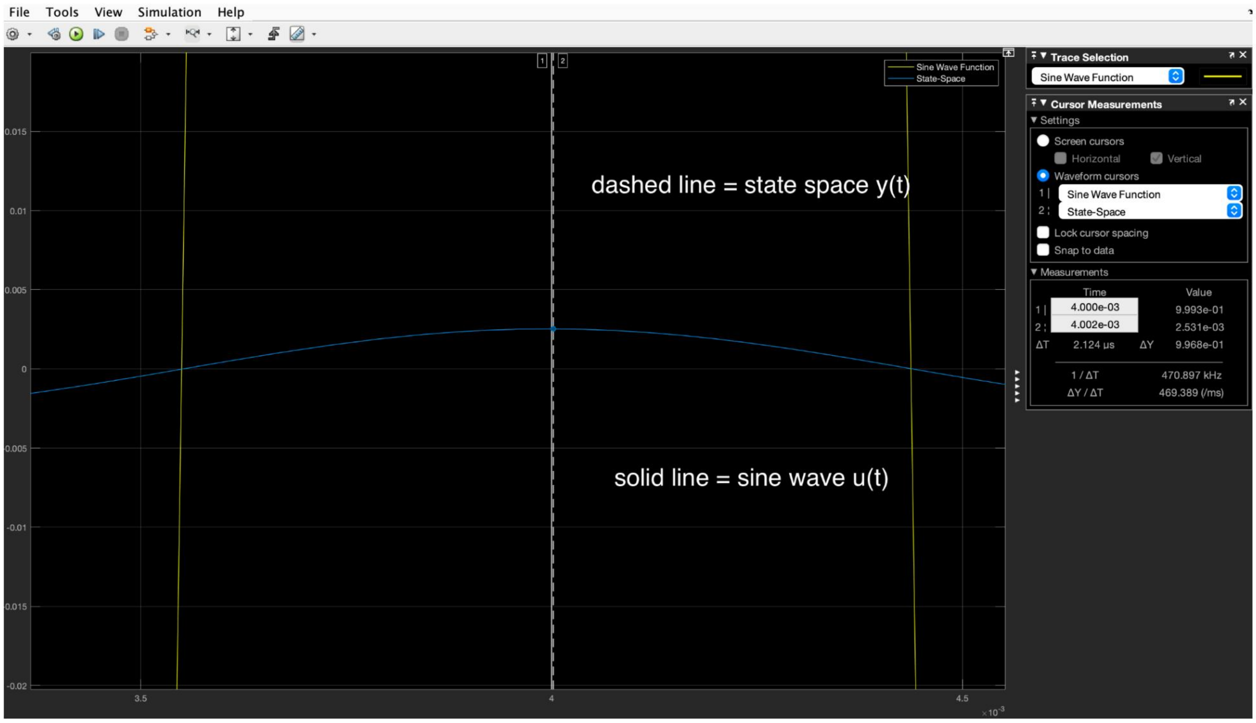
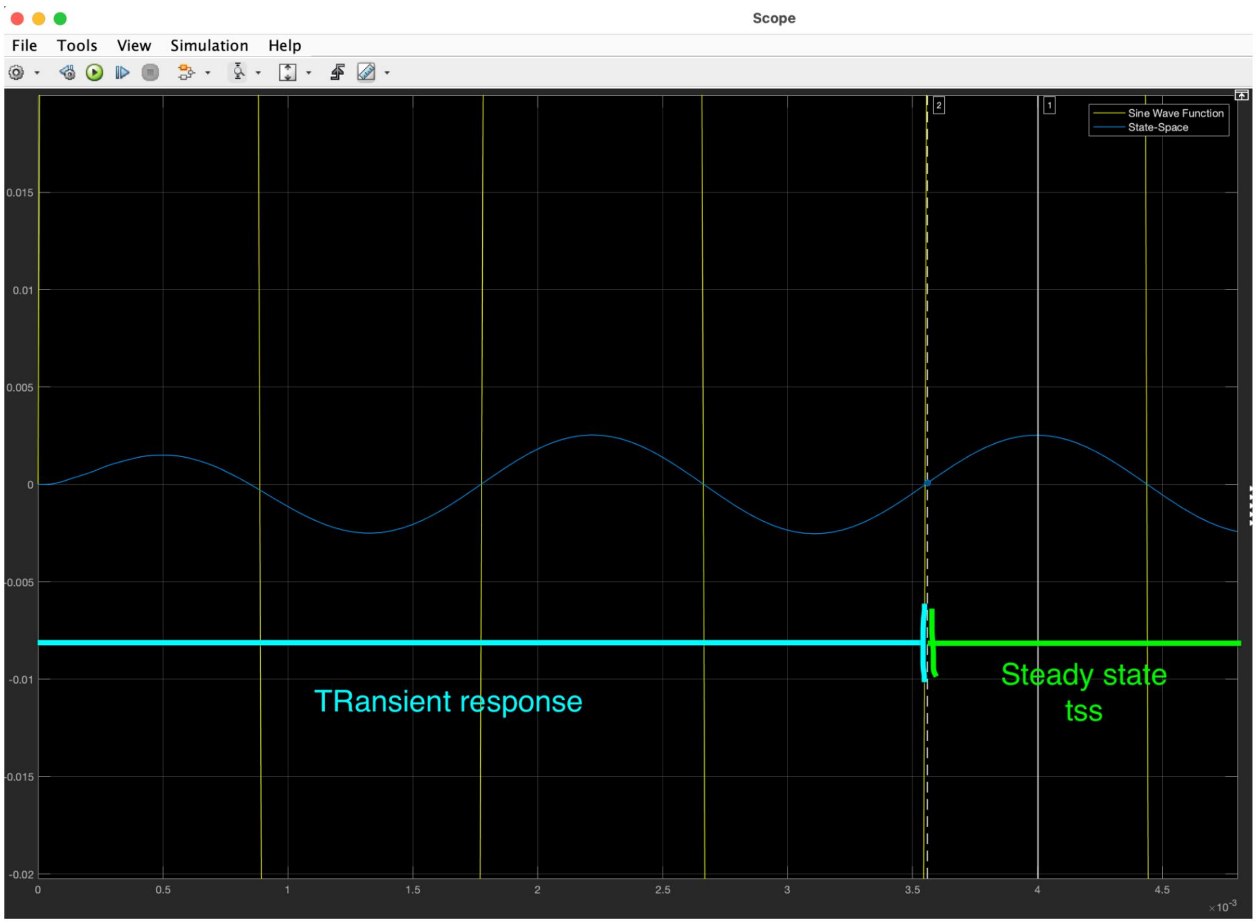


Figure 2


File
Tools
View
Simulation
Help
Sine Wave Function
State-Space
dashed line = state space y(t)
solid line = sine wave u(t)
Trace Selection
Sine Wave Function
Cursor Measurements
Settings
Screen cursors
Horizontal
Vertical
Waveform cursors
Sine Wave Function
State-Space
Lock cursor spacing
Snap to data
Measurements
Time
Value
4.000e-03
9.993e-01
4.002e-03
2.531e-03
ΔT 2.124 μs
ΔY 9.968e-01
1 / ΔT 470.897 kHz
ΔY / ΔT 469.389 (/ms)

a)
Figure 3



I selected the green part for transient response in figure 3 because at this point the state space settles to its steady state. The peaks after this point all reach the same amplitude.
When i compare the time at this point T_s to the time I calculated 4*tau = 0.0016 sec. In Figure 3 the approximate value shown is T_s = 3.5e-3 sec. This value is close to the one I calculated. They are not the same because the 0.0035 sec value is for this frequency. The one calculated at the beginning in the lab is done as a general T_s assumption for the whole system.

b) In figure 1 the amplitude shown for the sine wave is 9.982e-01 approximately 1. In figure 2 the amplitude shown for the steady space is 2.54e-03 approximately 0.00254. The ratio for the output to input is 0.00254/1 = .00254. This ratio shows the dc gain, in this case it was stepped down. I wasnt sure what to expect for the gain ratio but because this is an RLC circuit you would expect the response to be smaller than the input.

I calculated the gain from the amplitude of the peaks for both signals. I divided the amplitude of the statespace with the amplitude of the sinewave.
Sine wave amplitude = 1
State space amplitude = 2.54e-3
Gain = (2.54e-3)/1 = .00254

c)FIgure1 and Figure2 correspond to the same input frequency but figure2 is zoomed in to show the state space response y(t).

I calculate the phase at this frequency using the times at the first peak for the sine wave(u(t)) and first peak for the state space(y(t)). Both peaks are located at pi/2 rad.

$w(T_u - T_y)$ = 2.210e-4 sec - 2.214e-04 sec = (-4e-6 s)*(3.54e03 rad/s) = -0.01416 rad
-0.01416 rad * 180/pi = -0.811 degree phase shift

5.
Tau = 4e-04
Table 5.1

	Freq (rad/s)	Theoretical T_s	Simu T_s	In Amplitude	Output Amplitude	Amp. gain	Theo. phase	Simu. phase
f1	683	4tau = 0.0016	0.00731	1	6.827e-4	6.827e-4	74.02	53.504
fp1	3.54e03	0.0016	0.0035	1	2.59e-03	2.59e-03	-0.246	-0.811
f2	2.11e04	0.0016	0.0022	1	7.423e-03	7.423e-03	-80.2	-67
fp2	4.46e4	0.0016	0.00161	1	2.44e-03	2.44e-03	-170	-191
f3	1.3e05	0.0016	0.001632	1	1.43e-05	1.43e-05	-265	-260

Table 5.1 lists all the theoretical and simulated values for phase shift, T_s , and dc gain. The simulted time was the only one that got more accurate as we increased the frequency. My theoretical vs simulated phases where slightly off because of the time values i used for the input and output. They were slightly off from pinpointing the exact location in the simulation.

5 3 **10 / 10**

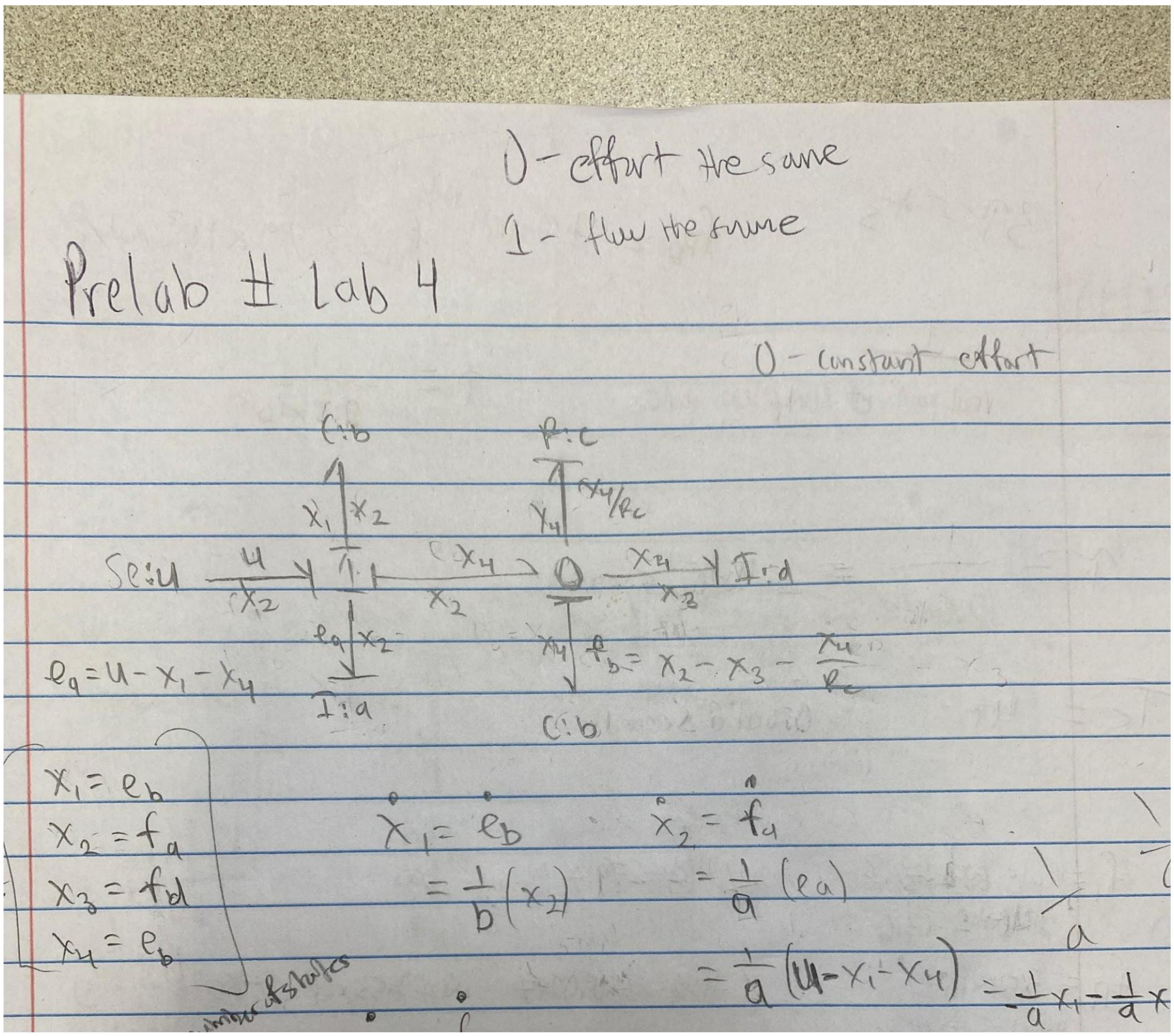
✓ **- 0 pts** *Correct*

Edgar Vergara
Section 022
Ta: Mike Stas
February 21, 2023

Lab 4: simulink lab (linear state space block)

Part 1 Prelab

1.


0 - effort the same

1 - flow the same

Prelab # Lab 4

0 - constant effort

$e_a = u - x_1 - x_4$

$f_b = x_2 - x_3 - \frac{x_4}{R_c}$

$x_1 = e_b$

$x_2 = f_a$

$x_3 = f_d$

$x_4 = e_b$

$\dot{x}_1 = \dot{e}_b = \frac{1}{b}(x_2)$

$\dot{x}_2 = \dot{f}_a = \frac{1}{a}(e_a) = \frac{1}{a}(u - x_1 - x_4) = -\frac{1}{a}x_1 - \frac{1}{a}x$

$$X = \begin{bmatrix} x_1 = e_b \\ x_2 = f_a \\ x_3 = f_d \\ x_4 = e_b \end{bmatrix}$$

$\dot{x}_1 = \dot{e}_b = \frac{1}{b}(x_2)$

$\dot{x}_2 = \dot{f}_a = \frac{1}{a}(e_a) = \frac{1}{a}(u - x_1 - x_4) = \frac{1}{a}x_1 - \frac{1}{a}x_4$

$n = 4 \rightarrow$ number of states

$\rightarrow p = 1$

$\rightarrow m = 1$

$y = [x_3]$

$\dot{x}_3 = \dot{f}_d$

$\frac{di_d}{dt} = \frac{1}{d}(x_4)$

$\dot{x}_4 = \dot{e}_b$

$\dot{x}_4 = \frac{1}{b}(f_b) = \frac{1}{b}\left(x_2 - x_3 - \frac{x_4}{R_L}\right)$

$$\underset{4\times4}{A} = \begin{bmatrix} 0 & \frac{1}{b} & 0 & 0 \\ -\frac{1}{a} & 0 & 0 & -\frac{1}{a} \\ 0 & 0 & 0 & \frac{1}{d} \\ 0 & \frac{1}{b} & -\frac{1}{b} & -\frac{1}{bR_C} \end{bmatrix} \qquad \underset{4\times1}{B} = \begin{bmatrix} 0 \\ 1/a \\ 0 \\ 0 \end{bmatrix}$$

$A \in R^{n\times n}$ 4×1

$B \in R^{n\times m}$

$C \in R^{p\times n}$

$D \in R^{p\times m}$

$$\underset{1\times4}{C} = \begin{bmatrix} 0 & 0 & 1 & 0 \end{bmatrix} \qquad \underset{1\times1}{D} = \begin{bmatrix} 0 \end{bmatrix}$$

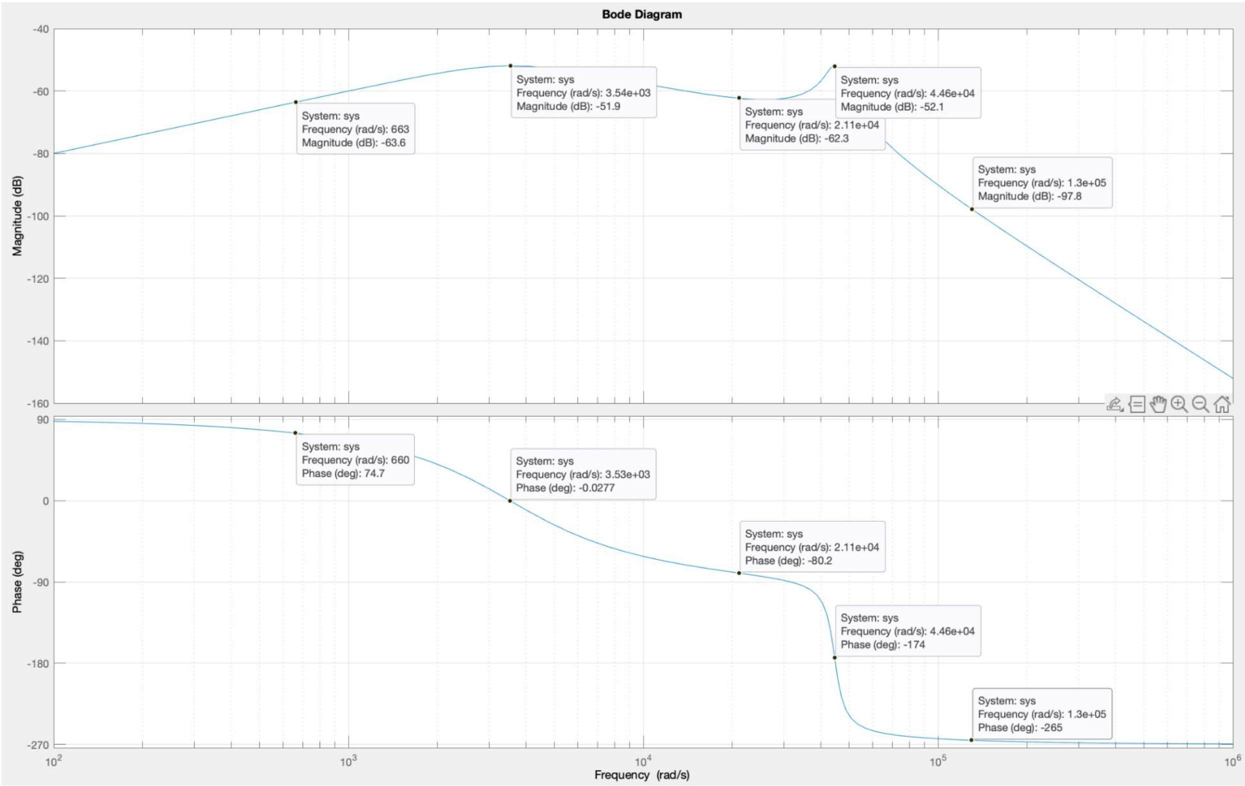
<u>Part 2</u>

2.

```
%(a)
a = 10e-4; b = 1e-6; c = 100; d = 40e-3;    %10e-6
A = [0 1/b 0 0; -1/a 0 0 -1/a; 0 0 0 1/d; 0 1/b -1/b -1/(b*c)];
B = [0 1/a 0 0]';
C = [0 0 1 0];
D = [0];
%(b)
poles = eig(A);
%(c)
tau = 1/(min(abs(real(poles))));
Ts = 4*tau;
%(d)
sys = ss(A,B,C,D);
trans = tf(sys)
[num,den] = ss2tf(A,B,C,D);
%(e)
r = roots(num);
p = pole(sys);
```

6 Prelab **25 / 25**

✓ **+ 25 pts** *Full prelab presented in lab*


Bode Diagram
Magnitude (dB)
Phase (deg)
Frequency (rad/s)
System: sys
Frequency (rad/s): 663
Magnitude (dB): -63.6
System: sys
Frequency (rad/s): 3.54e+03
Magnitude (dB): -51.9
System: sys
Frequency (rad/s): 2.11e+04
Magnitude (dB): -62.3
System: sys
Frequency (rad/s): 4.46e+04
Magnitude (dB): -52.1
System: sys
Frequency (rad/s): 1.3e+05
Magnitude (dB): -97.8
System: sys
Frequency (rad/s): 660
Phase (deg): 74.7
System: sys
Frequency (rad/s): 3.53e+03
Phase (deg): -0.0277
System: sys
Frequency (rad/s): 2.11e+04
Phase (deg): -80.2
System: sys
Frequency (rad/s): 4.46e+04
Phase (deg): -174
System: sys
Frequency (rad/s): 1.3e+05
Phase (deg): -265