Laboratory 4

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MODELING AND SIMULATION OF DYNAMIC SYSTEMS EE 105

SECTION 023

Objective:

The purpose of this lab is an introduction to a block diagram simulation. The first part of this lab involves implementing a fourth-order Simulink flow diagram using integrators and adders. In the second part of this lab, we will be implementing a Simulink flow diagram using the state-space block.

Experimental Procedure:

2.1 Finding the Poles of the System

Find the poles of the system, using eig(A). Later in the course we will show that the poles of the transfer function are the same as the eigenvalues of the state-space matrix A.

```
a = 1;
b = 9;
c = 0.1;
d = 1;
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 0 1/c];
D = 0;
eig(A)
```

```
ans = 4×1 complex
   -0.8727 + 0.0000i
   -0.0556 + 0.3287i
   -0.0556 - 0.3287i
   -0.1273 + 0.0000i
```

2.2 Finding the Dominant Time Constant + Settling Time of the System

Find the dominant time constant of the system. How long should it take for the transient response to decay away? This is the settling time.

The dominant time constant τ is $\left|\frac{1}{0.0556}\right| \mathrm{sec} = 17.986\ \mathrm{sec}$. This means that the settling time of the system T_S is roughly equal to $\frac{4.6}{\sigma} = \frac{4.6}{0.0556\,1}\ \mathrm{sec} = 82.7338\ \mathrm{sec}$.

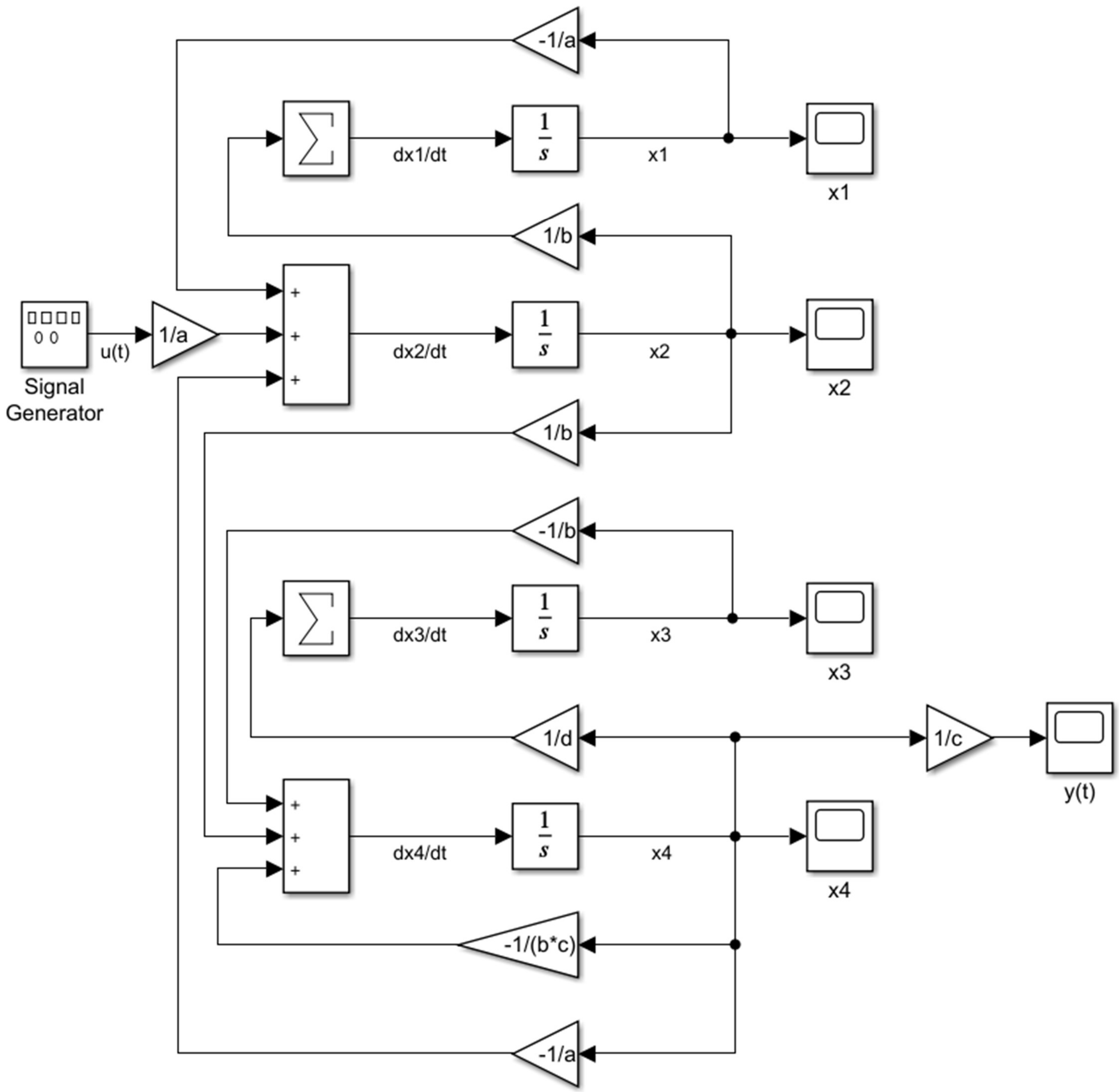
2.3 Simulating a State-Space Model Using Integrators + Summers + Gains

Implement a signal flow diagram for the system using integrators connected together by summers and gains. This approach is explained further in Appendix A of this lab.

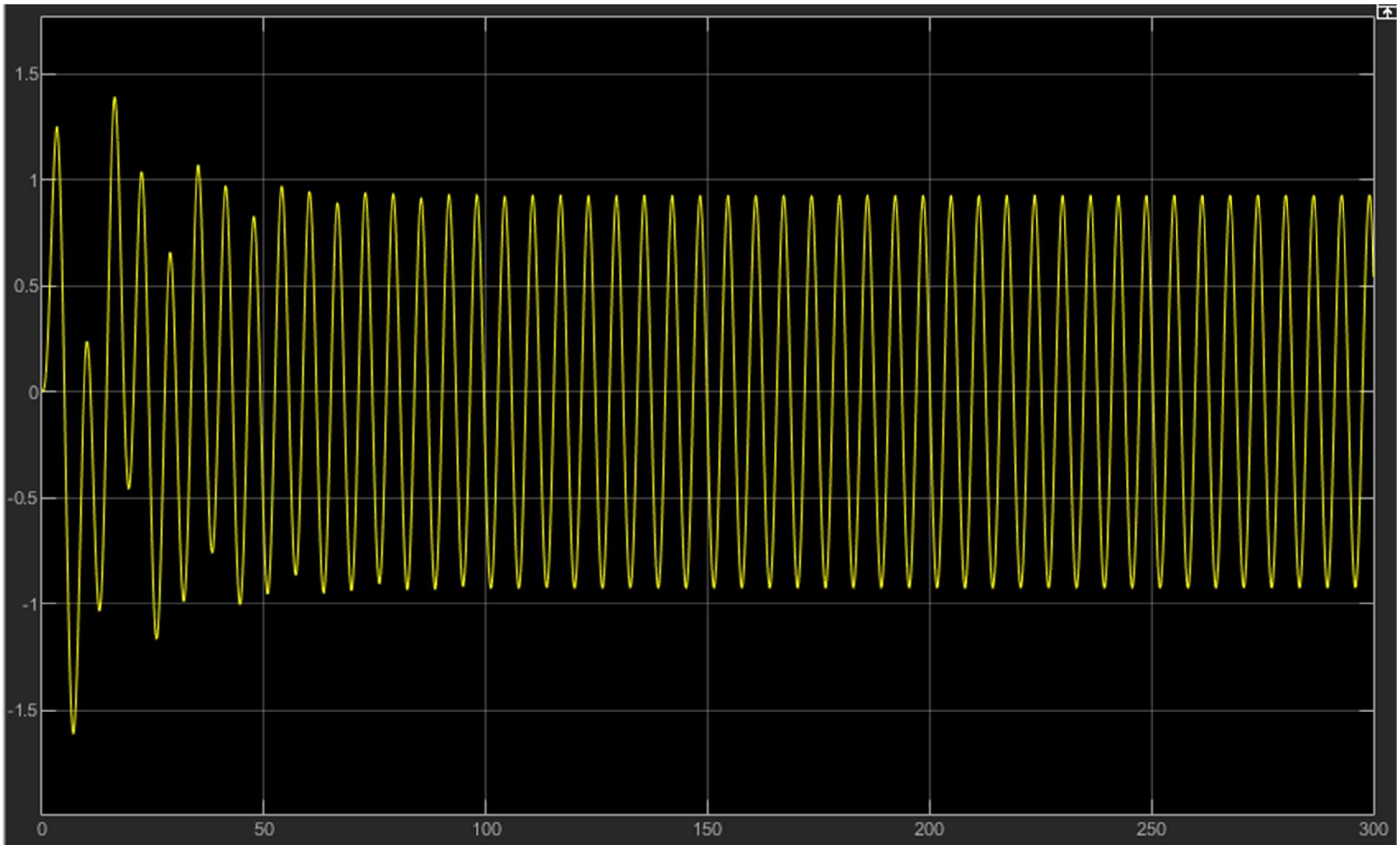
PART A

Simulate the system with a unit sinusoidal input. Ensure that your simulation is long enough in duration that the transient decays away, and at least two cycles of the steady-state response are included.

Simulink Model:



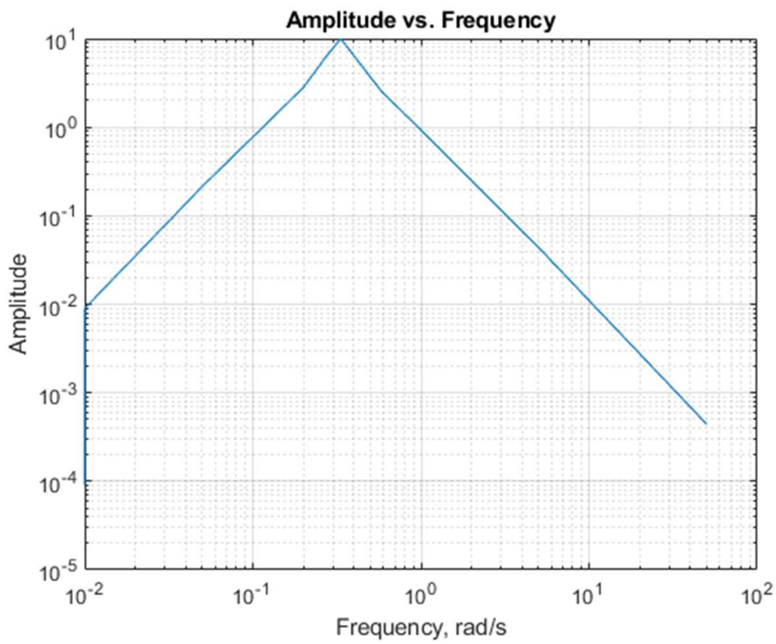
Simulink Output:



PART B

Try various frequencies for the input. Plot the amplitude of the steady-state output versus the radian frequency of the input using a loglog scale.

```
 f = [10e-3, 0.01, 0.05, 0.2, 0.27, 1/3, 0.58, 1, 5, 20, 50];
 amp = [0.00009, 0.008971, 0.2135, 2.810, 6.114, 10.000, 2.564, 0.9270, 0.04395, 0.002763,
0.0004433];
 figure
 loglog(f, amp)
 title('Amplitude vs. Frequency')
 xlabel('Frequency, rad/s')
 ylabel('Amplitude')
 grid on
```



Is there a frequency at which the output magnitude is maximum?

Yes, the frequency at which the output magnitude is the maximum is around 0.333 rad/s.

PART C

The settling-time for each input frequency should be the same. Is it?

Yes, it is the same.

2.4 Simulating a State-Space Model Using the State-Space Block

PART A

Define the A, B, C, and D matrices.

```
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 0 1/c];
D = 0;
```

PART B

Run that m file, so that the matrix variables A, B, C, and D are in memory (SKIP).

PART C

Uses the function '[n,d]=ss2tf(A,B,C,D)' to find the transfer function for the system where n is the numerator polynomial and d is the denominator polynomial.

```
[num, den] = ss2tf(A, B, C, D)
```

```
num = 1×5
         0         0    1.1111         0   -0.0000
den = 1×5
    1.0000    1.1111    0.3333    0.1235    0.0123
```

PART D

Use the `roots' function on d and n to find the poles and zeros. Confirm that the poles found here match the eigenvalues of A found earlier.

```
roots(num)
```

```
ans = 2×1
10^-8 ×
    0.2953
   -0.2953
```

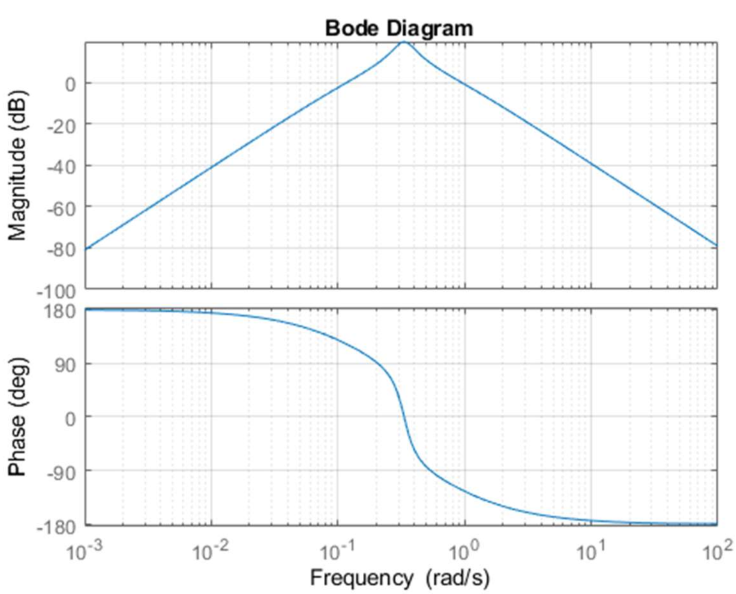
```
roots(den)
```

```
ans = 4×1 complex
  -0.8727 + 0.0000i
  -0.0556 + 0.3287i
  -0.0556 - 0.3287i
  -0.1273 + 0.0000i
```

PART E

Use the function `bode(n,d)' to plot the Bode plots for the system. The top plot is the magnitude response.

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

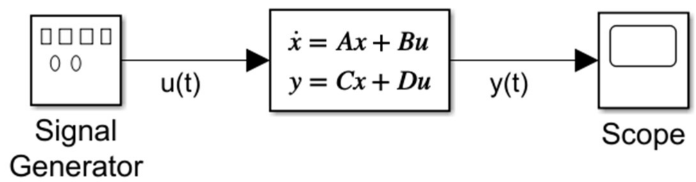


Based on the magnitude response, if you want to maximize the gain from the input to the output, what frequency of input should you apply? What will be the amplification?

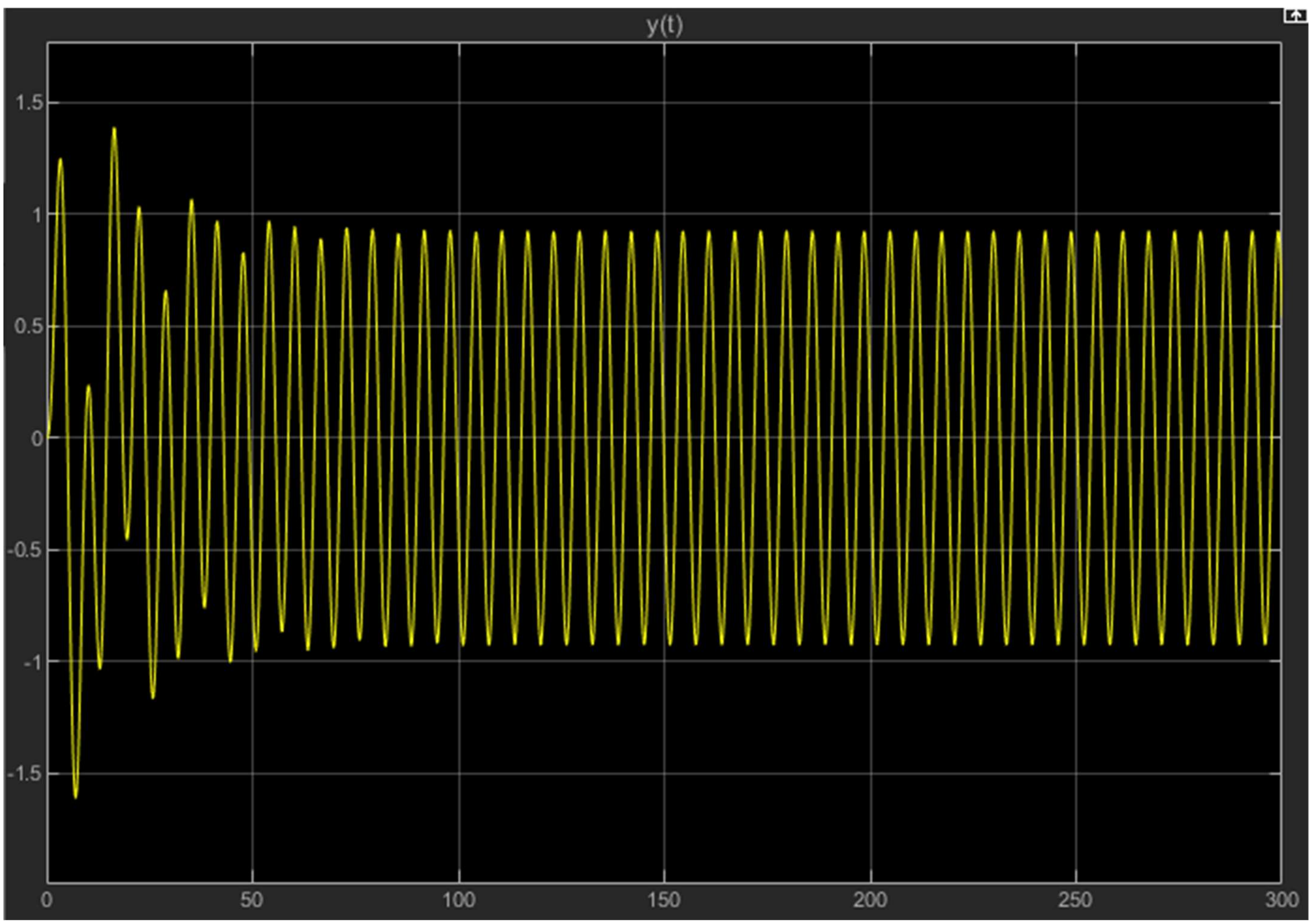
From looking at the bode plot, we can see that the maximum magnitude occurs when frequency is about 0.338 rad/s. The amplification will be 20 dB (which is equal to 10 for amplitude).

PART F-H

Simulink Model:

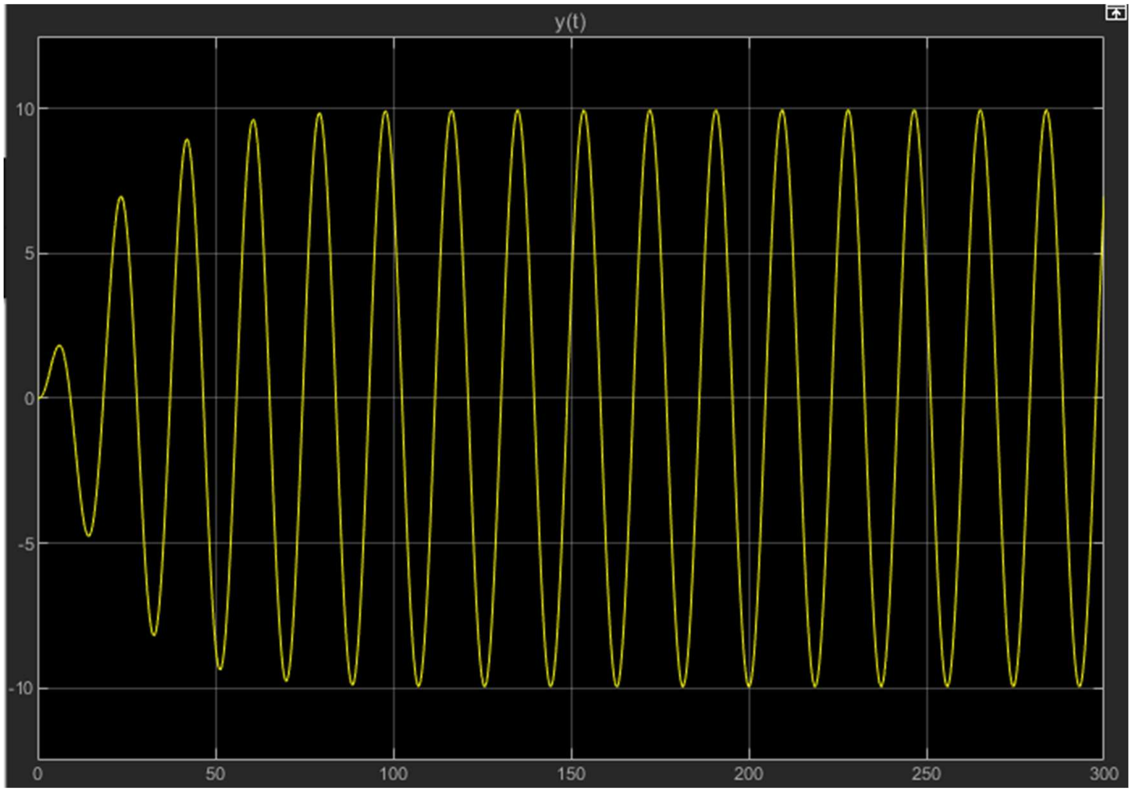


Simulink Output:



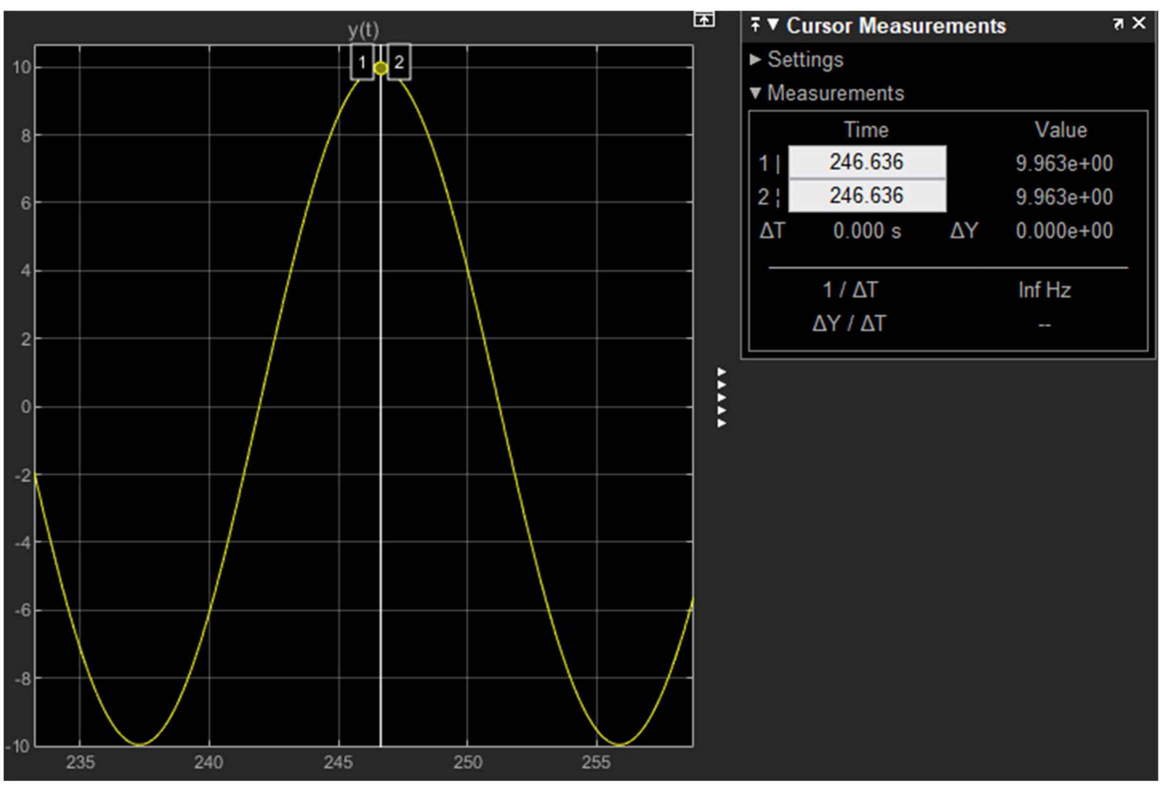
PART I

Simulate the system with the frequency of the sinusoid set equal to the value that you obtained from the magnitude response.



PART J

Compare the gain information from the Bode plot with the simulated response. They should match.



We can see that the application of the simulated response is roughly equal to 10 which matches the information from the Bode plot.

Conclusion:

Overall, the objective of this lab was accomplished. We now have a greater understanding of how to create a block diagram simulation. Throughout this lab, we were able to successfully implement a fourth-order Simulink flow diagram by using integrators and adders as well as by using the state-space block.