UNIVERSITY OF CALIFORNIA, RIVERSIDE

BOURNS COLLEGE OF ENGINEERING

DEPARTMENT OF ELECTRICAL AND COMPUTER ENGINEERING

EE 105 Lab 3 Solution

First-order systems in Simulink

LUIS FERNANDO ENRIQUEZ-CONTRERAS

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1 Introduction

This laboratory introduces Simulink through the analysis and design of linear ordinary differential equations (ODEs). You will explore key systems concepts like transfer functions, time constants, pole locations, DC gain, and frequency response. The design process involves choosing system parameters to meet specific requirements, using transfer functions for analysis and state-space representation for simulation testing. The lab starts with fundamental concepts in first-order systems and progressively generalizes them to higher-order systems.

2 Pre-Lab

2.1 Part 1

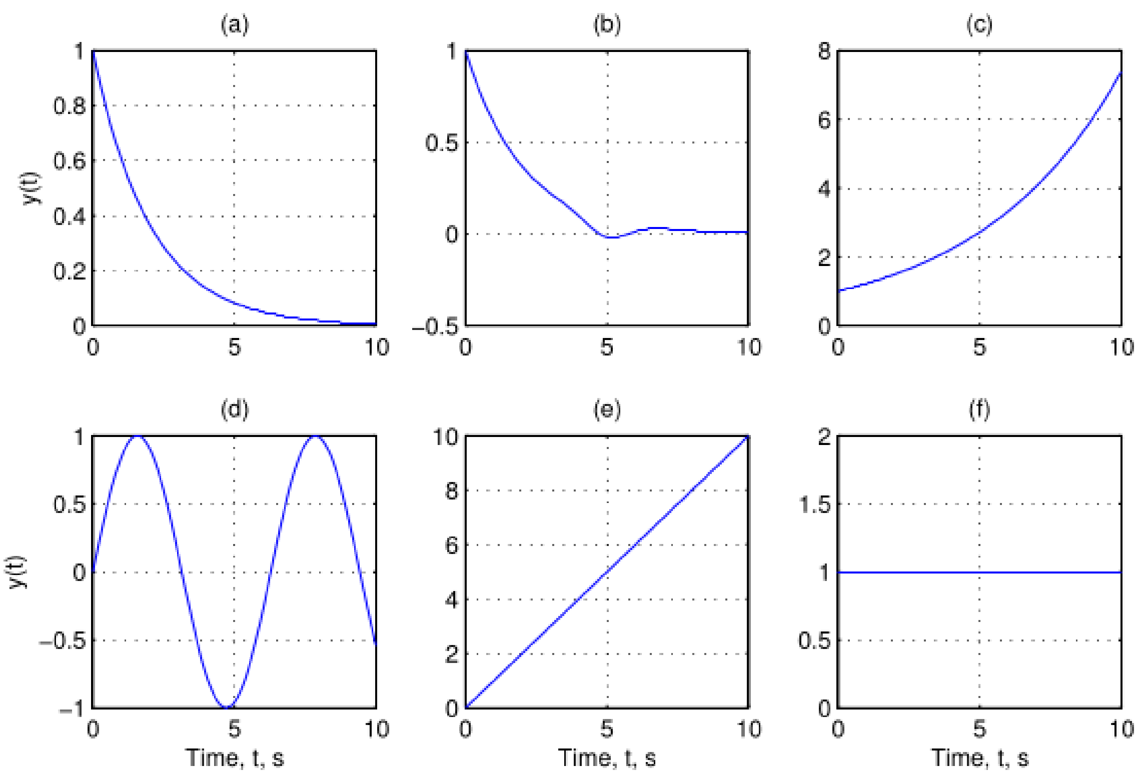

Figure 1: Figures for the Prelab Part 1

- (a) Only graphs (a), (c), and (f) from Figure 1 could correspond to a first order linear system, as none of the other graphs were exponential.
- (b) Graphs (b), (d), and (e) did not match the form of a decaying function.
- (c)
  - (f) Parameter a has the value zero, and thus never decays.
  - (c) has a positive value for its parameter a, thus the system is unstable
  - (a) has a negative value for a, thus it is stable. We can then use the initial value of that graph, y(0) = 1, a = -.460517 therefore, τ = 2.2 seconds

2.2 Part 2

$$\begin{aligned} \mathrm{H(s) = Y(s)/U(s)} &= \frac{1}{sRC+1} \\ \mathrm{H(s) = Y(s)/U(s)} &= \frac{\frac{1}{RC}}{s+\frac{1}{RC}} \end{aligned} \tag{1}$$

$$\begin{aligned} \frac{dx}{dt} &= \left[\frac{-1}{\mathrm{RC}}\right] x + \left[\frac{1}{\mathrm{RC}}\right] u \\ y &= [1]x \end{aligned} \tag{2}$$

2.3 Part 3

$$\begin{aligned} H(j\omega) &= \cancel{Y(j\omega)/U(j\omega)} = \frac{100 - j\omega * 10}{100+\omega^2} \\ |H(j\omega)| &= \frac{10}{\sqrt{100+\omega^2}} \\ \angle H(j\omega) &= \arctan(-\omega/10) \end{aligned} \tag{3}$$

Table 1: Magnitude and Phase for RC Circuit

ω, rad/s	$\lvert H(j\omega)\rvert$	$20\log\lvert H(j\omega)\rvert$	$\angle H(j\omega)$rad	$\angle H(j\omega)$ deg
0.00	1	0	0.00	$0°$
0.01	1	0	-0.001	$-0.057°$
0.10	1	0	-0.01	$-0.573°$
1.00	0.995	-0.043	-0.1	$-5.711°$
10.00	0.707	-3.01	-0.785	$-45°$
100.00	0.1	-20.43	-1.471	$-84.289°$

2.4 Part 4

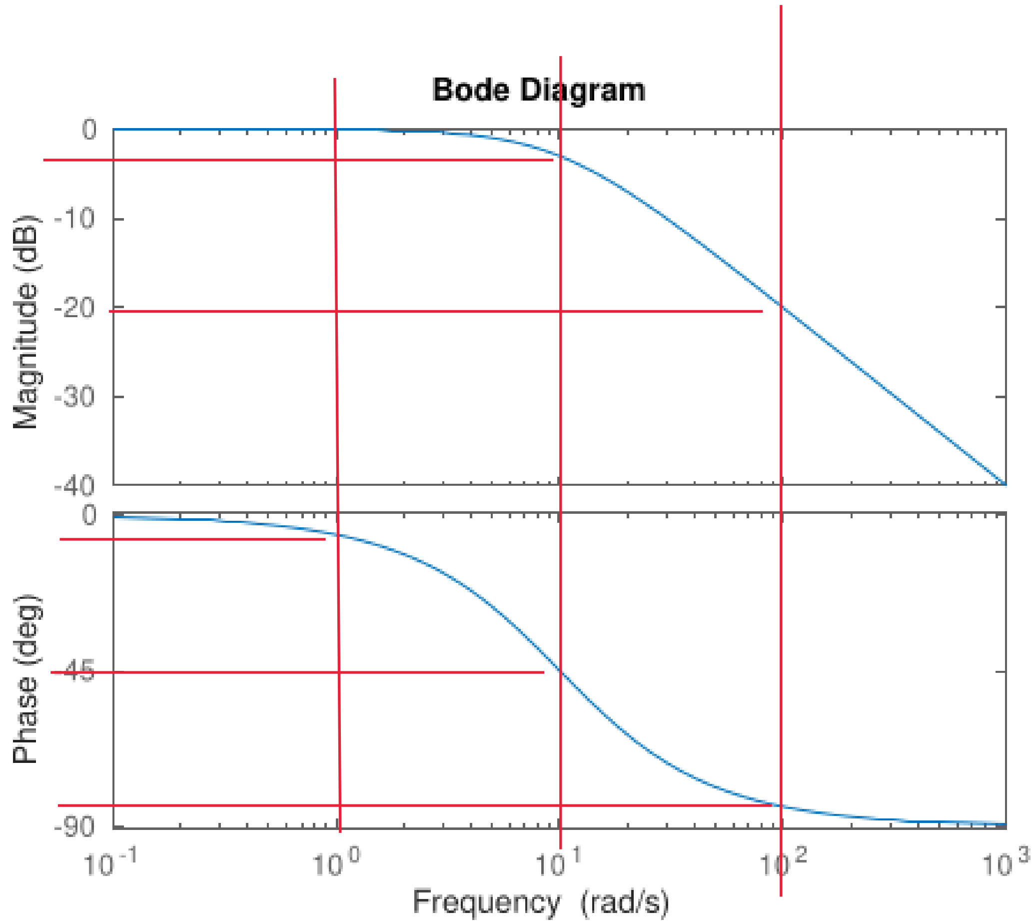

Figure 2: Bode Plot for RC Circuit

Figure 2 matches the values in Table 1.

3 Time Constant Estimation

Listing 1: Matlab Code for Time Constant Estimation

```
% Plot the .mat data
load('EE105_Lab3data.mat')
figure
plot(t,y)
title('Time Constant Estimation Plot', 'Interpreter', 'latex');
xlabel('$t$', 'Interpreter', 'latex');
ylabel('$y$', 'Interpreter', 'latex');

%First method
y_tau = 0.37*y(1);
index = find(abs(y_tau-y)==min(abs(y_tau-y)),1);
tau_1 = t(index);

%Second method
%Compute dy/dt
dydt = (y(2:101)-y(1:100))./(t(2:101)-t(1:100));
a = dydt./y(1:100);
%You may check a, all the same numbers
tau_2 = 1/(-a(1));
fig = gcf; % Obtains current graphic in matlab
exportgraphics(fig, 'Fig/time_constant_plot.pdf', 'ContentType','vector');
```

τ from both methods is ≈ 0.15.

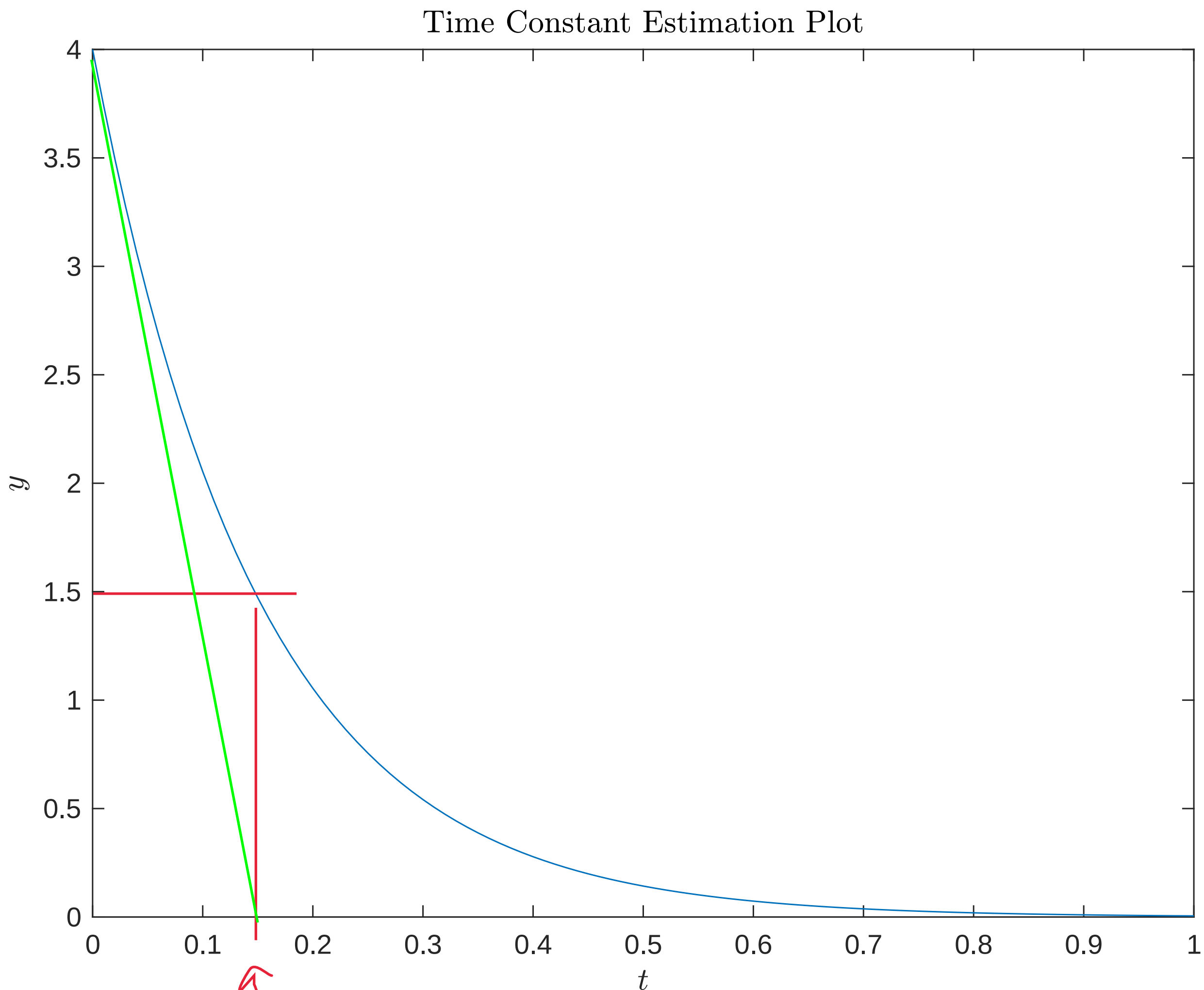

Figure 3: Time Constant Estimation Plot

0.37 × 4 i≈ 1.5, so t is ≈ 0.15.

τ

4 Simulation with Simulink

4.1 Zero Input Response

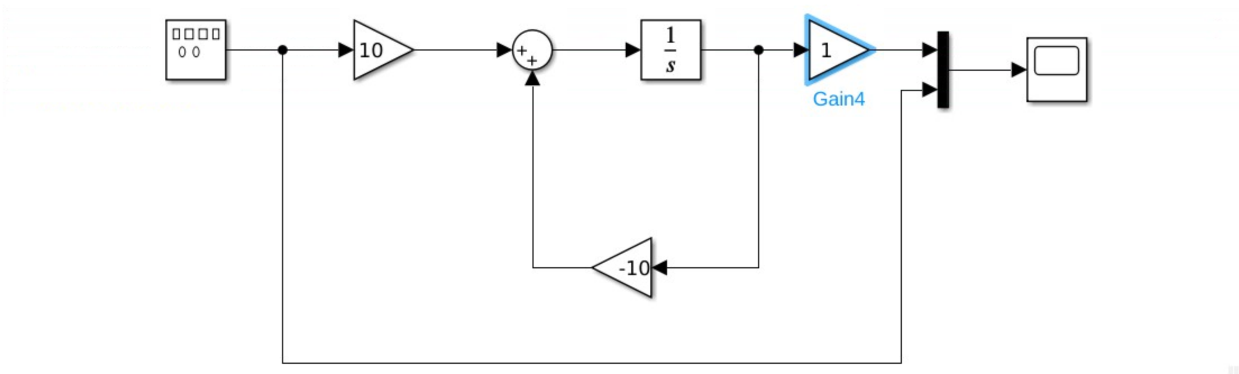

Figure 4: Simulink Diagram for Zero Input Response

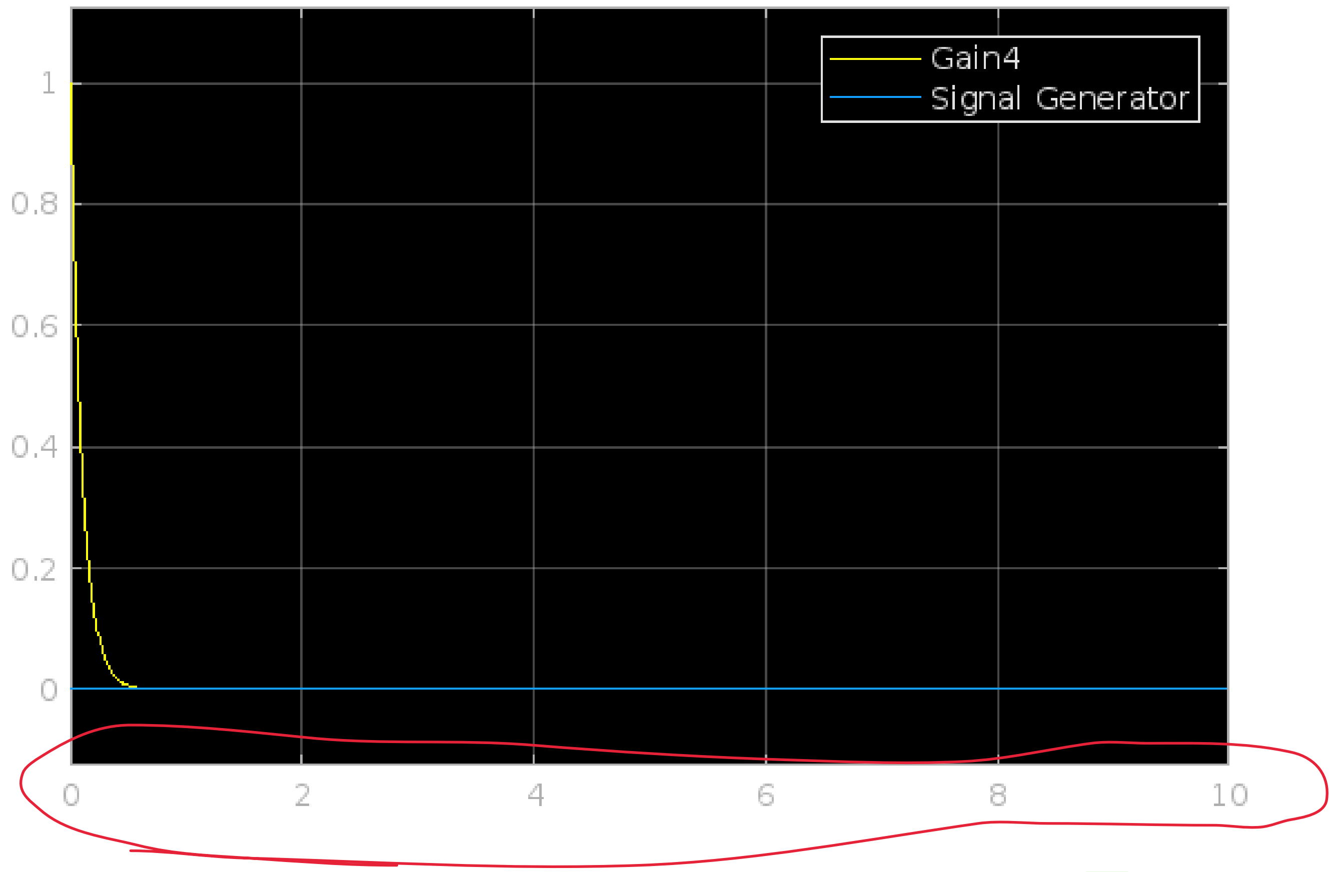

Figure 5: Oscilloscope Output of Zero Input Response

Figure 5 is similar to Figure 3, and its time constant.

4.2 Forced Response: Step input

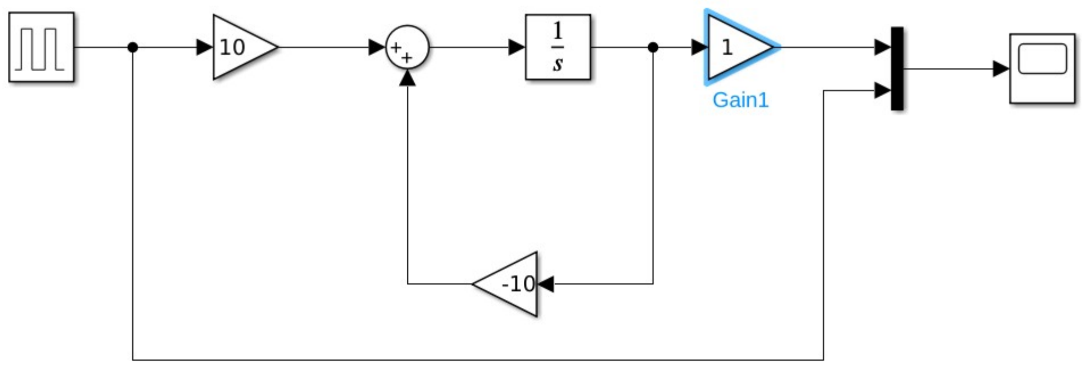

Figure 6: Simulink Diagram for Step Input Response

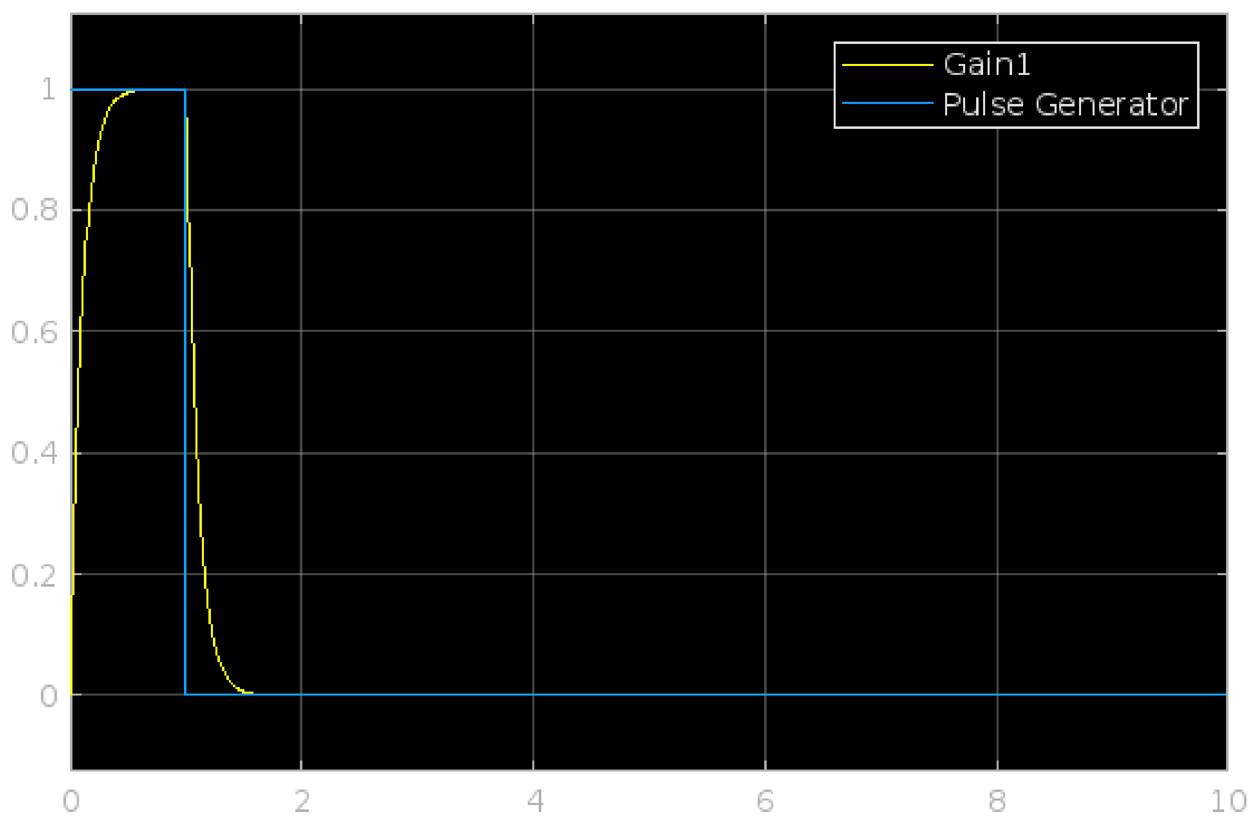

Figure 7: Oscilloscope Output of Step Input Response

4.3 Forced Response: Sinusoidal Input

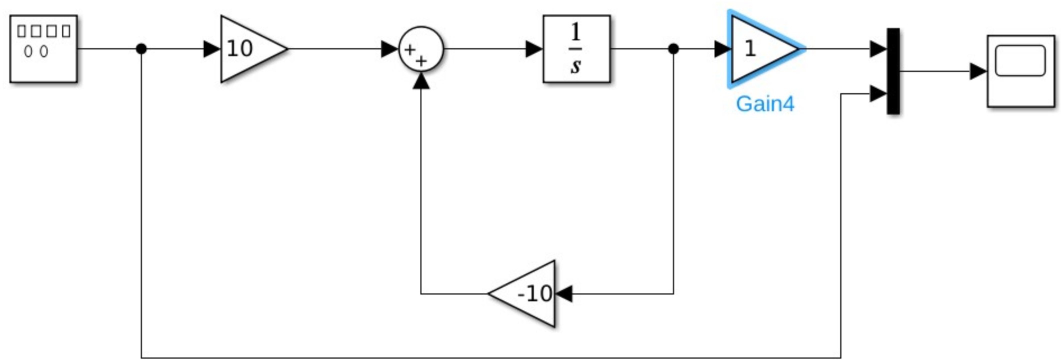

Figure 8: Simulink Diagram for Sinusoidal Input Response

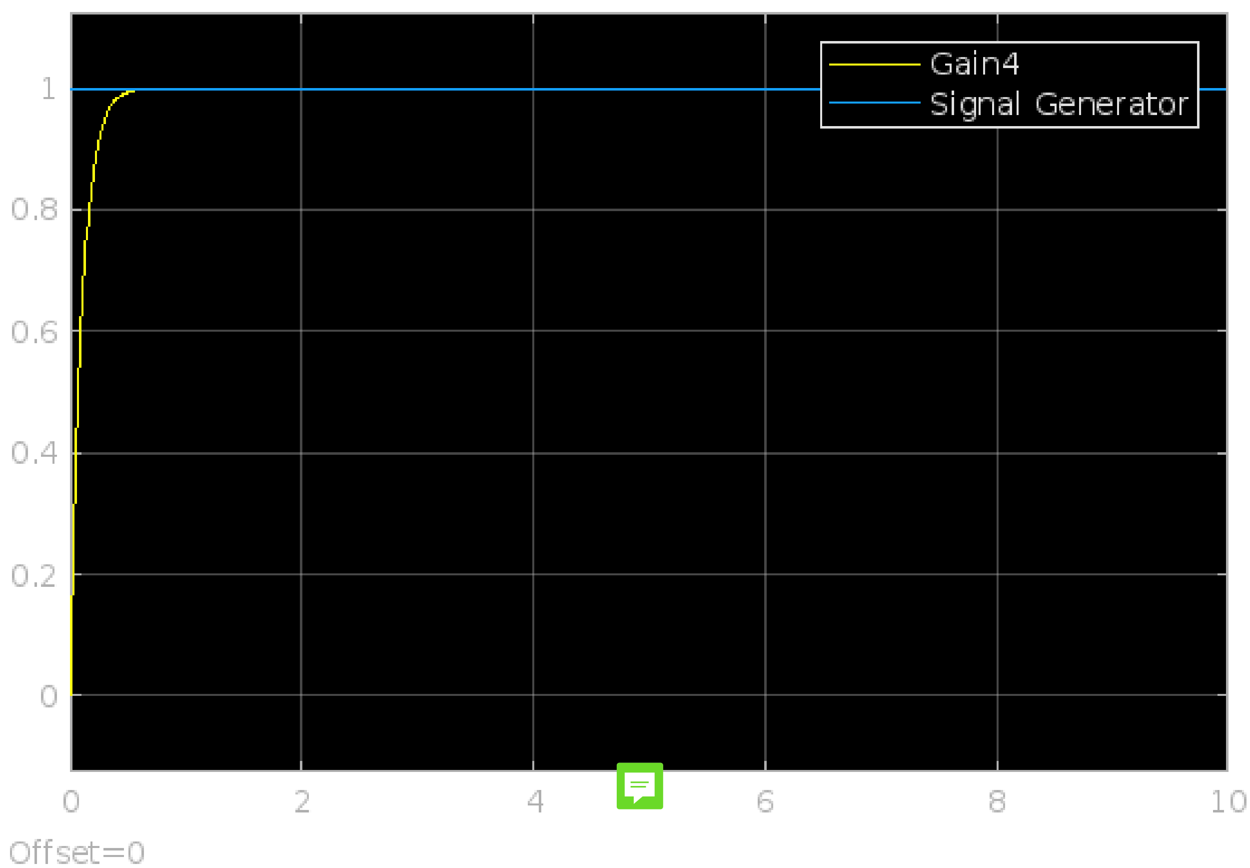

Figure 9: Oscilloscope Output of Sinusoidal Input Response $\omega = 0.00$

Magnitude and Phase are near identical.

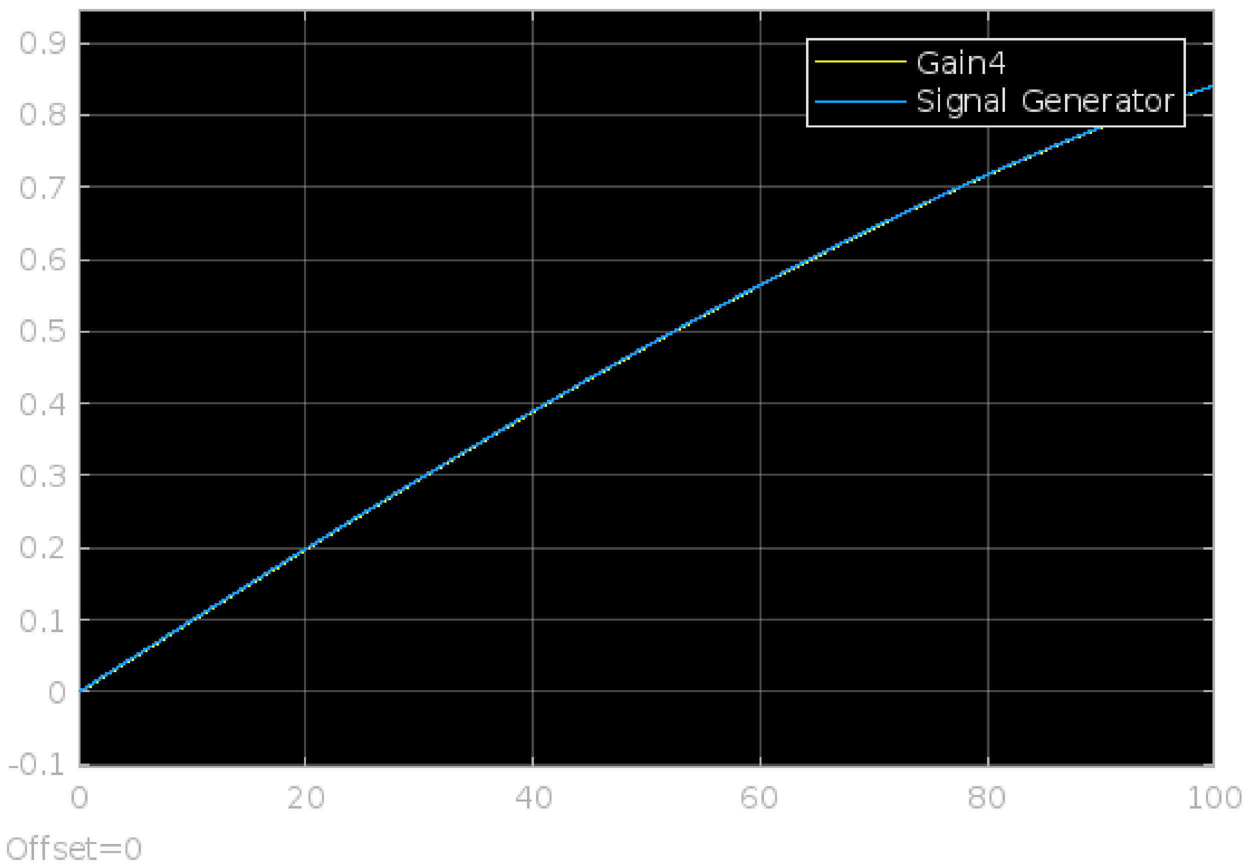

Figure 10: Oscilloscope Output of Sinusoidal Input Response $\omega = 0.01$

Magnitude and Phase are near identical.

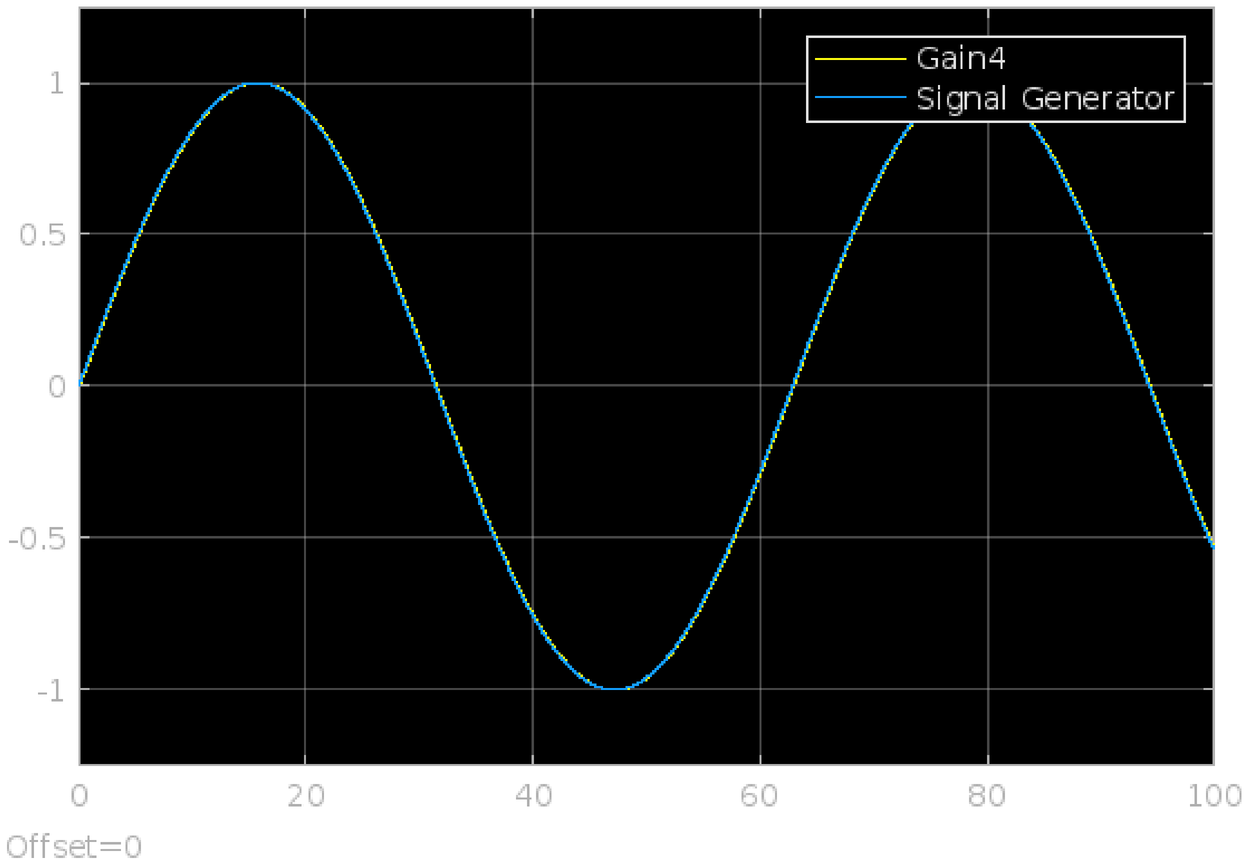

Figure 11: Oscilloscope Output of Sinusoidal Input Response $\omega = 0.10$

Magnitude and Phase are near identical.

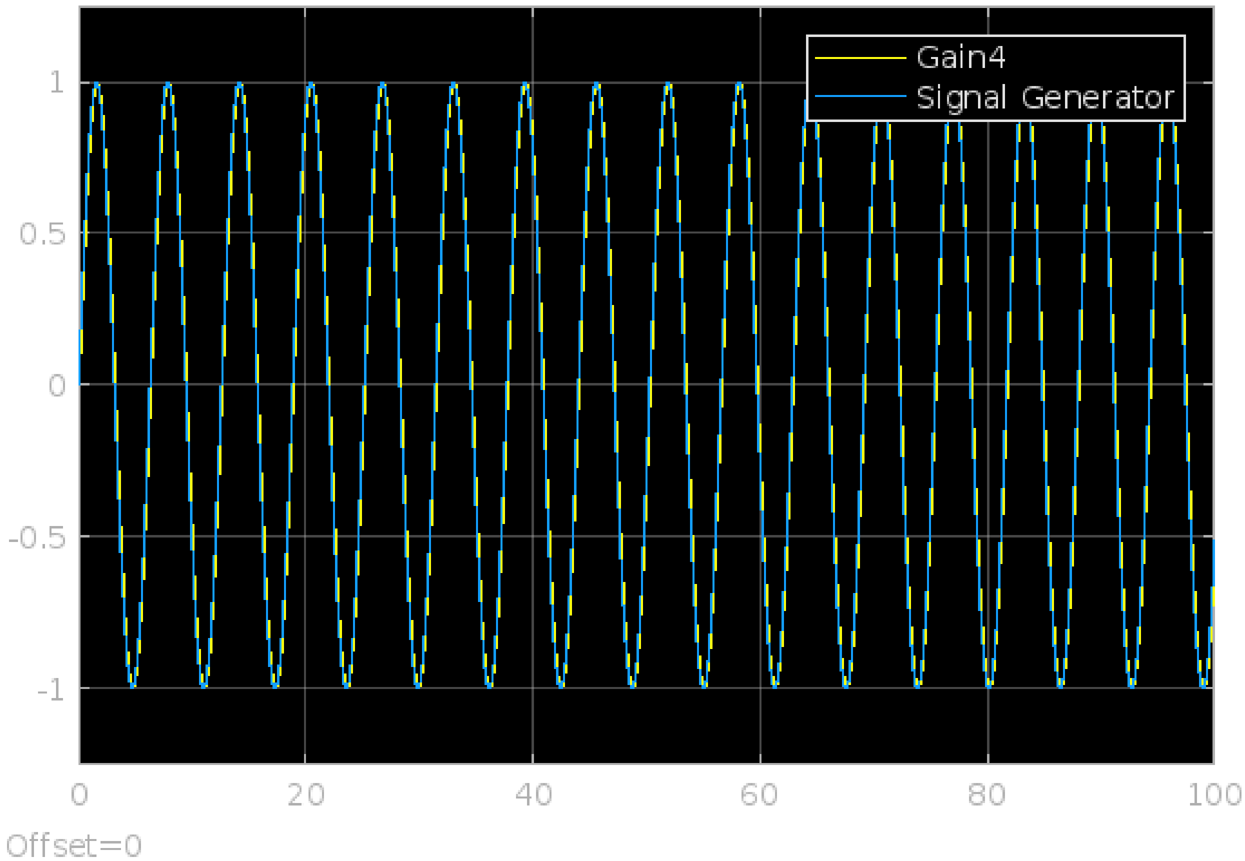

Figure 12: Oscilloscope Output of Sinusoidal Input Response $\omega = 1.00$

Magnitude and Phase are near identical.

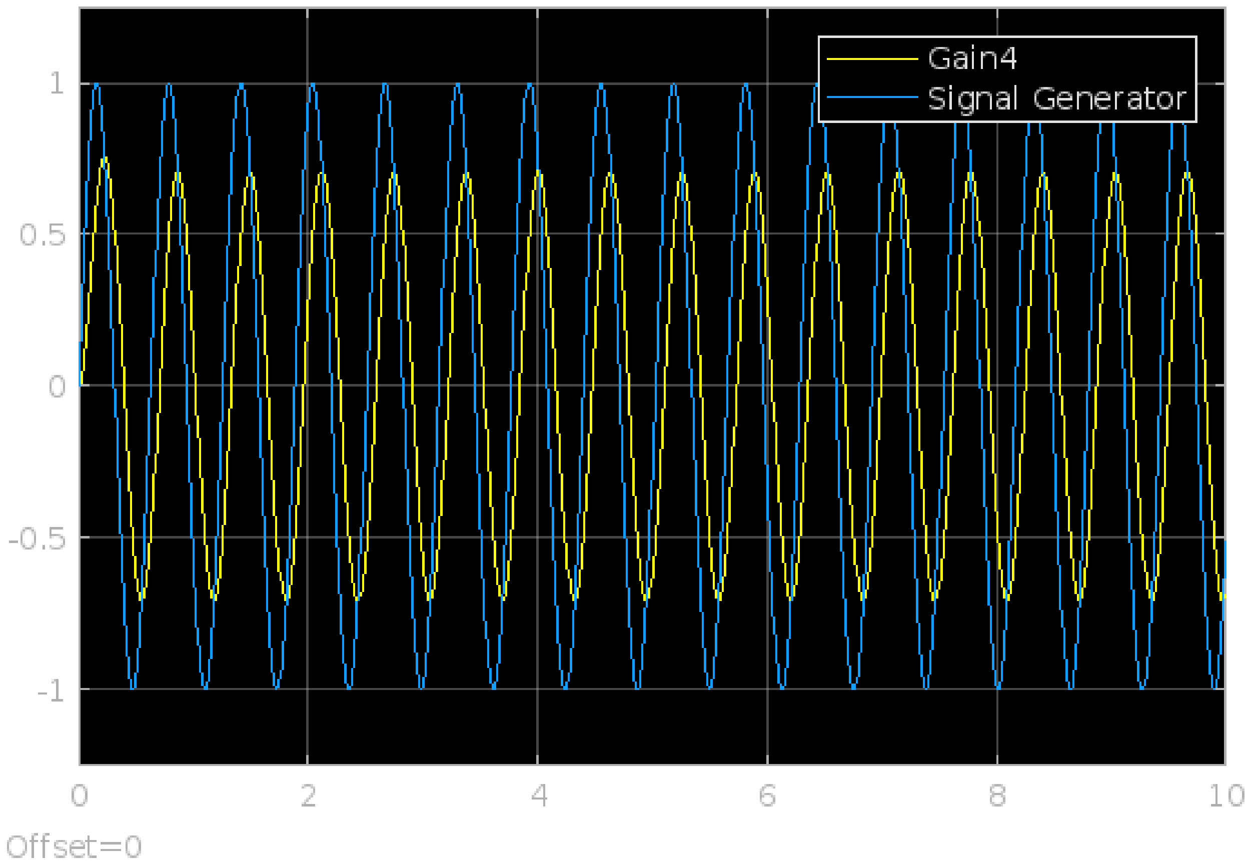

Figure 13: Oscilloscope Output of Sinusoidal Input Response $\omega = 10.00$

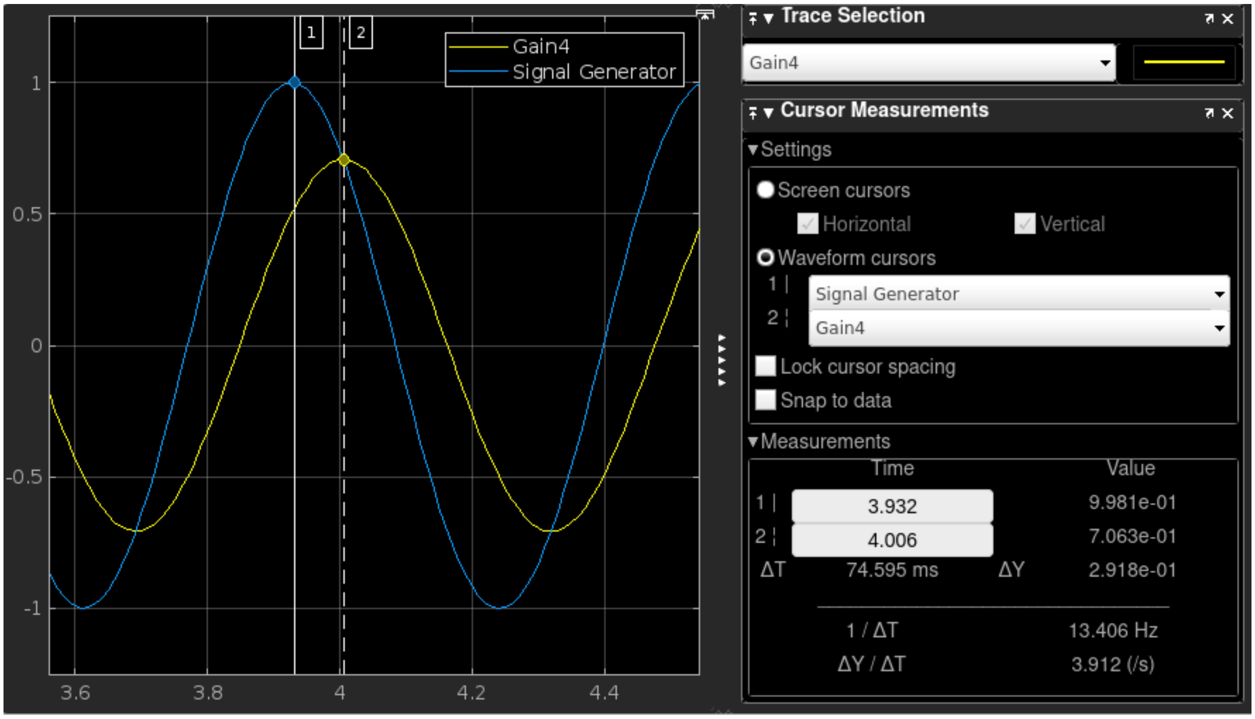

Figure 14: Oscilloscope Magnitude and Phase Shift of Sinusoidal Input Response $\omega = 10.00$

The magnitude difference is ≈ .0708 and the phase shift is ≈ -0.746 rad.

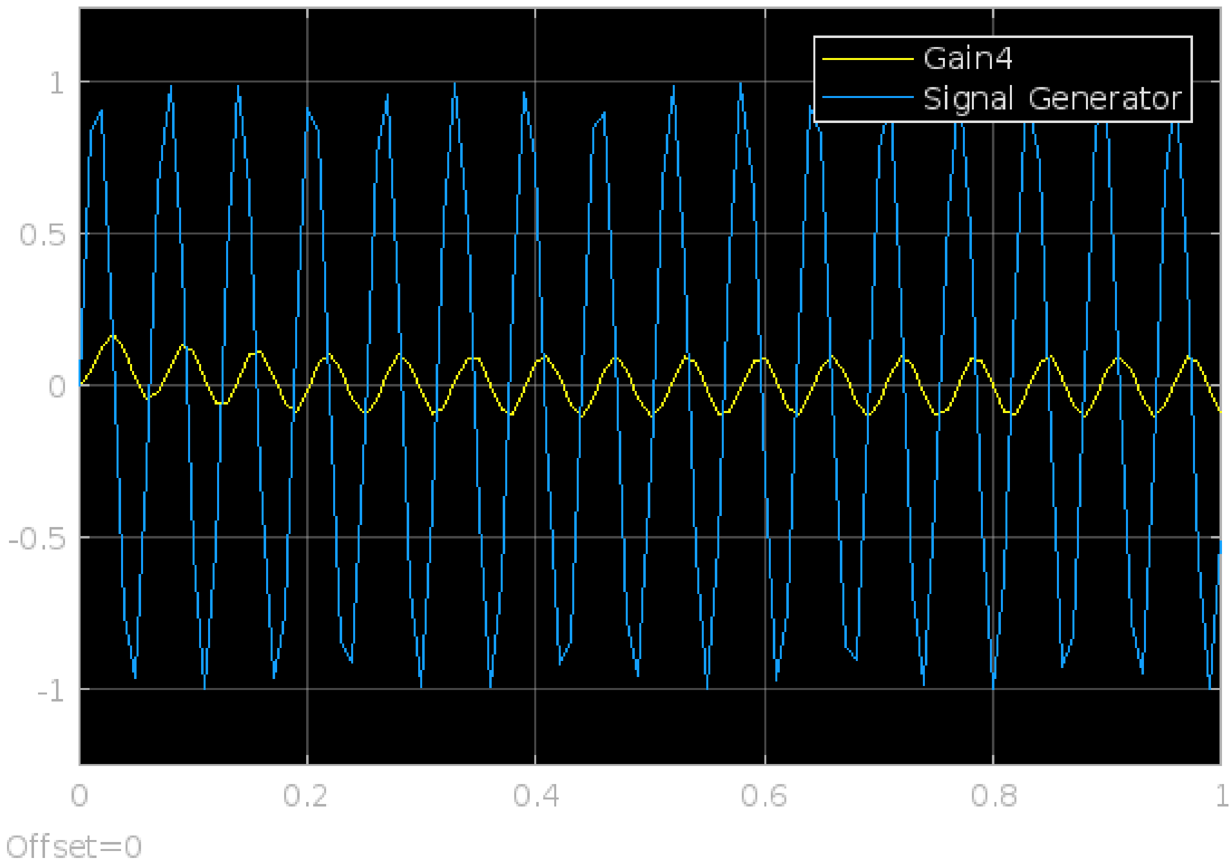

Figure 15: Oscilloscope Output of Sinusoidal Input Response $\omega = 100.00$

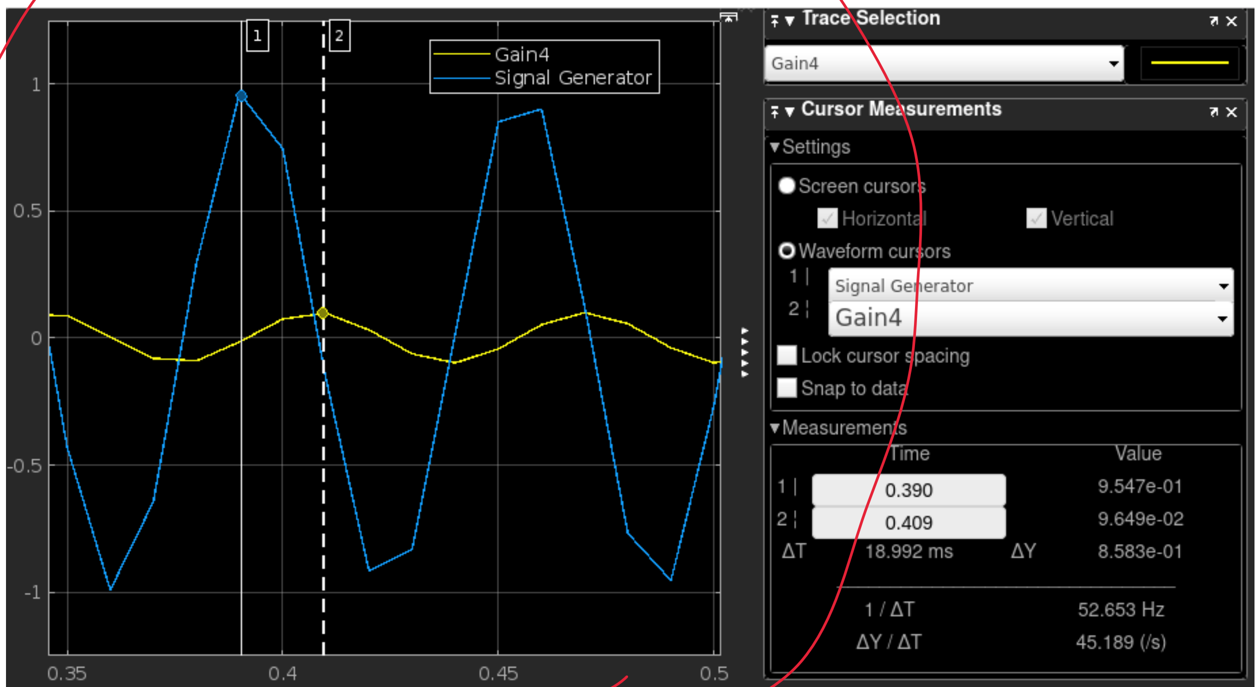

Figure 16: Oscilloscope Magnitude and Phase Shift of Sinusoidal Input Response $\omega = 100.00$

The magnitude difference is ≈ 0.102 and the phase shift is ≈ -1.9rad.
The frequency and phase are similar to those predicted in Table 1 and Figure 2. Only Figure 16 was slight inaccurately since the plot was somewhat low resolution

5 Conclusion

This lab successfully modeled a first order RC circuit using matlab and simulink to simulate the circuit. At very low frequencies the circuits normal decay behavior, but at higher frequency the capacitor will start change the magnitude and shift the phase of an input signal. This circuit behaves as a low pass that has almost nor distortion with $\omega \leq 1$ and basically filter out sin gals where $\omega > 100$.