SIGNALS AND SYSTEMS LABORATORY
(EEU33C01)

SUBMITTED TO:
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STUDENT NUMBER: 21355131

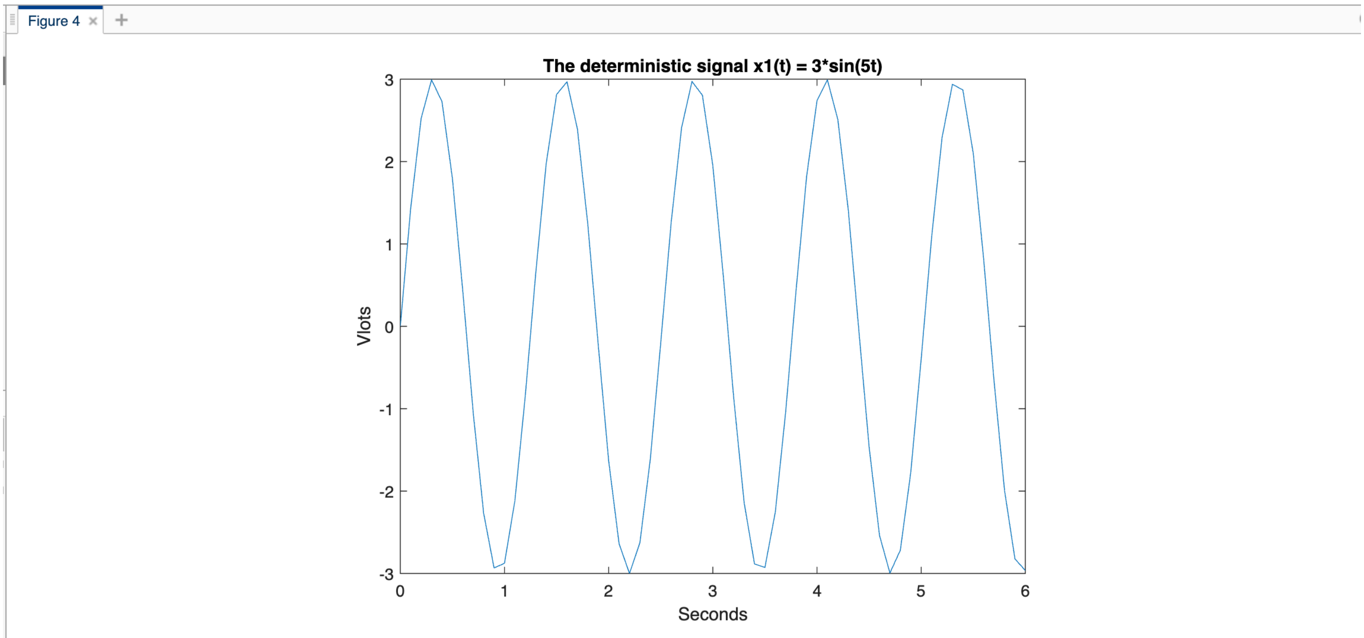
SIGNED:

DATE: 21.11.2021

2. Signals

2.1. The Sine wave: a deterministic signal

1. Plotting the deterministic signal x1 = 3sin5t where t ranges from 0 to 6 seconds



Command Window

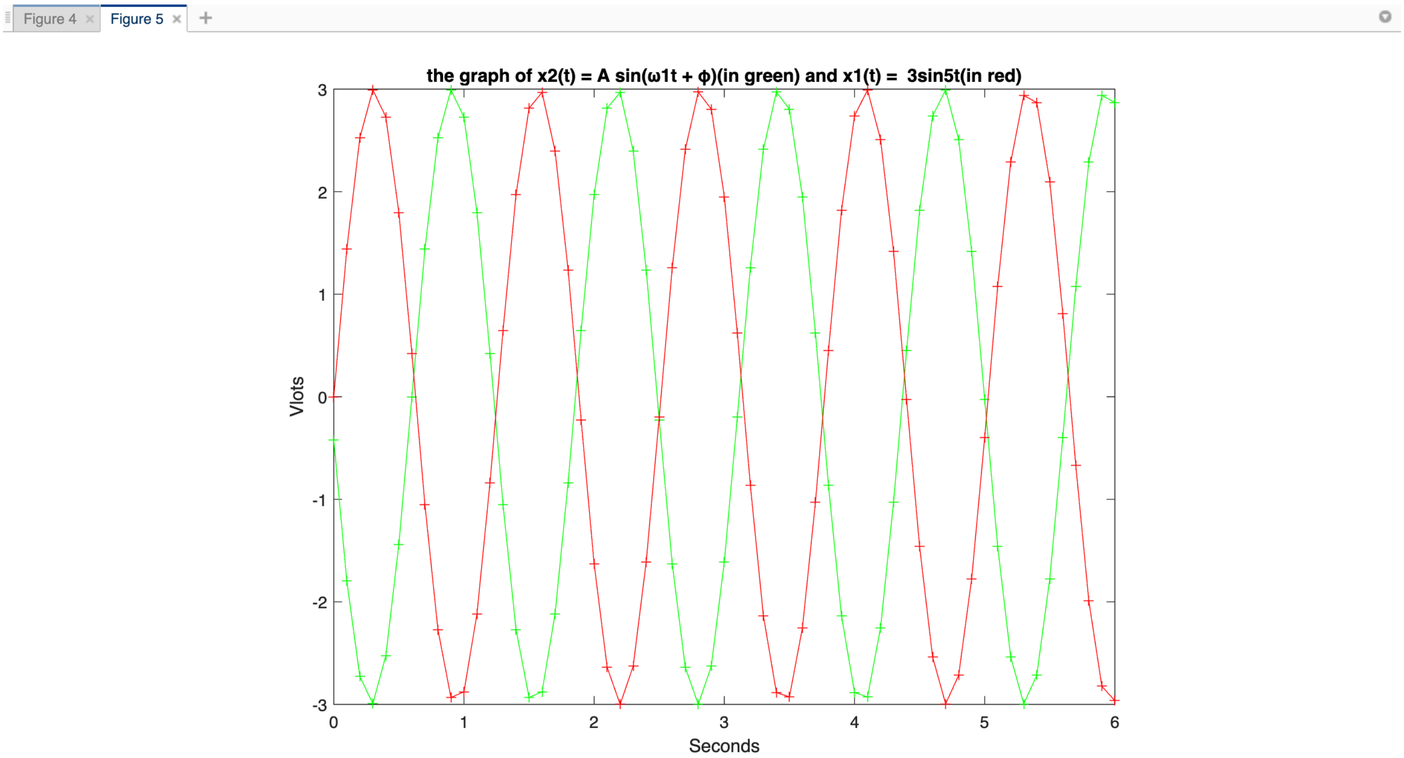
```
>> t = (0:0.1:6);
>> x1 = 3*sin(5*t);
>> figure(4); plot(t, x1);title('The deterministic signal x1(t) = 3*sin(5t)');xlabel('Seconds');ylabel('Vlots');
```

2. Maximum value of sinusoid (in Volts): 2.9925
   Minimum value of sinusoid (in Volts): -3.0000
   The frequency of the sinusoid (in Hertz): 0.796 (5/2π)
   The period of the wave (in seconds): 1.257 (2π/5)

3. Plotting x2(t) = A sin(ω1t + ϕ) and x1 in same graph

Command given:

```
figure(5); plot(t,x1,'g-+',t,x2,'r+-');title('the graph of x2(t) = A sin(ω1t + ϕ)(in green) and x1(t) =  3sin5t(in red)');xlabel('Seconds');ylabel('Vlots');
```



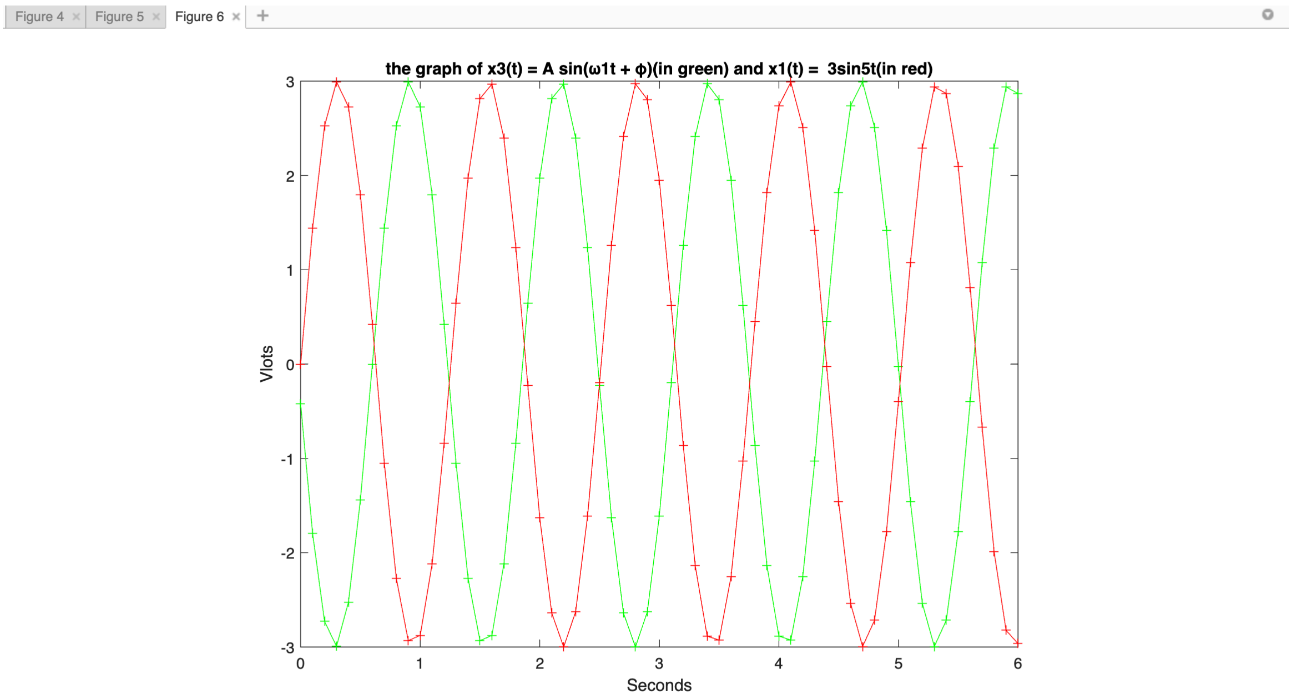
Frequency of sinusoid x2 is 0.796 (5/2π).
The difference between x1 and x2 is that both signals are *phase lagged* where x2 is *delayed* with respect to x1.

4. x2 is delayed by 0.6 seconds with respect to x1
Points used to calcite the delay: 0.61, 1.21
phase lag (in seconds) = ω/ϕ

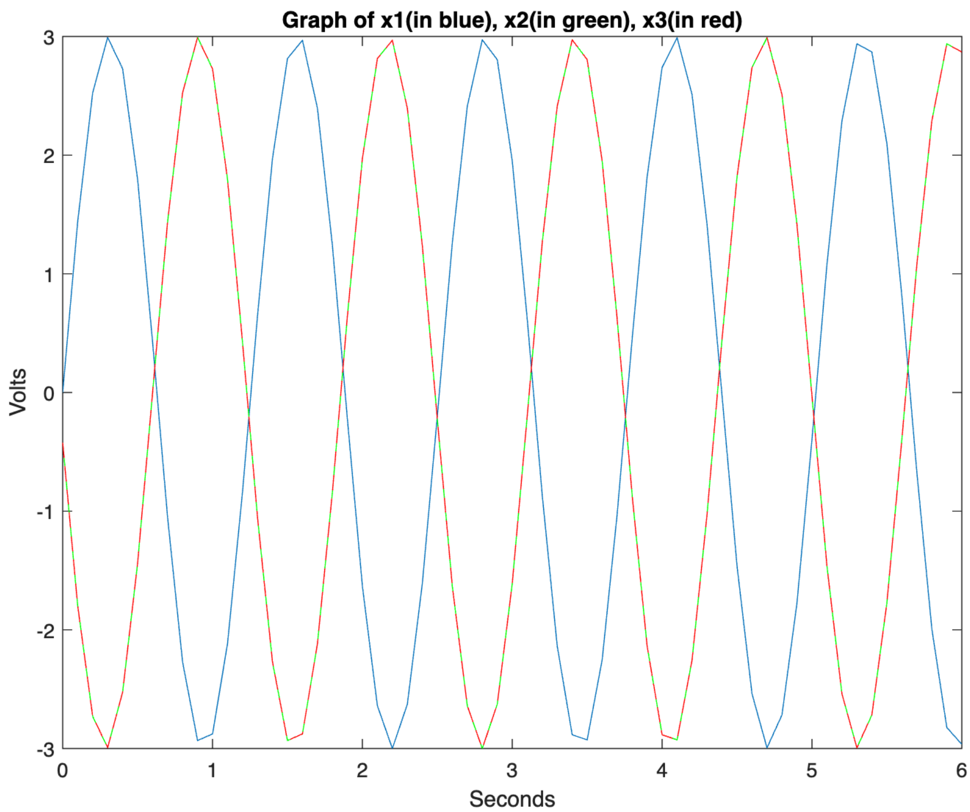
5. Graph for graph of x3(t) = A sin(ω1t + ϕ)

<u>Command given</u> :

figure(6); plot(t,x3,'g-+',t,x1,'r+-');title('the graph of x3(t) = A sin(ω1t + ϕ)(in green) and x1(t) = 3sin5t(in red)’);xlabel(‘Seconds');ylabel('Volts');

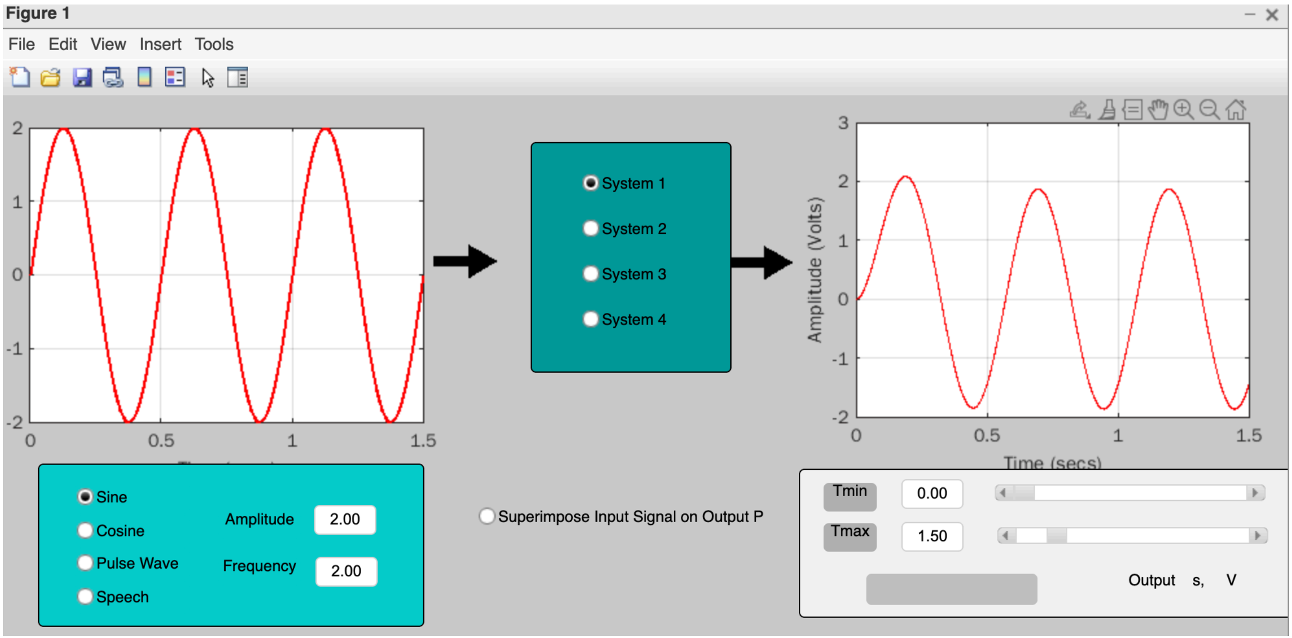


x3 is *delayed* by 0.6 seconds with respect to x1 which is equal to offset term divided by ω

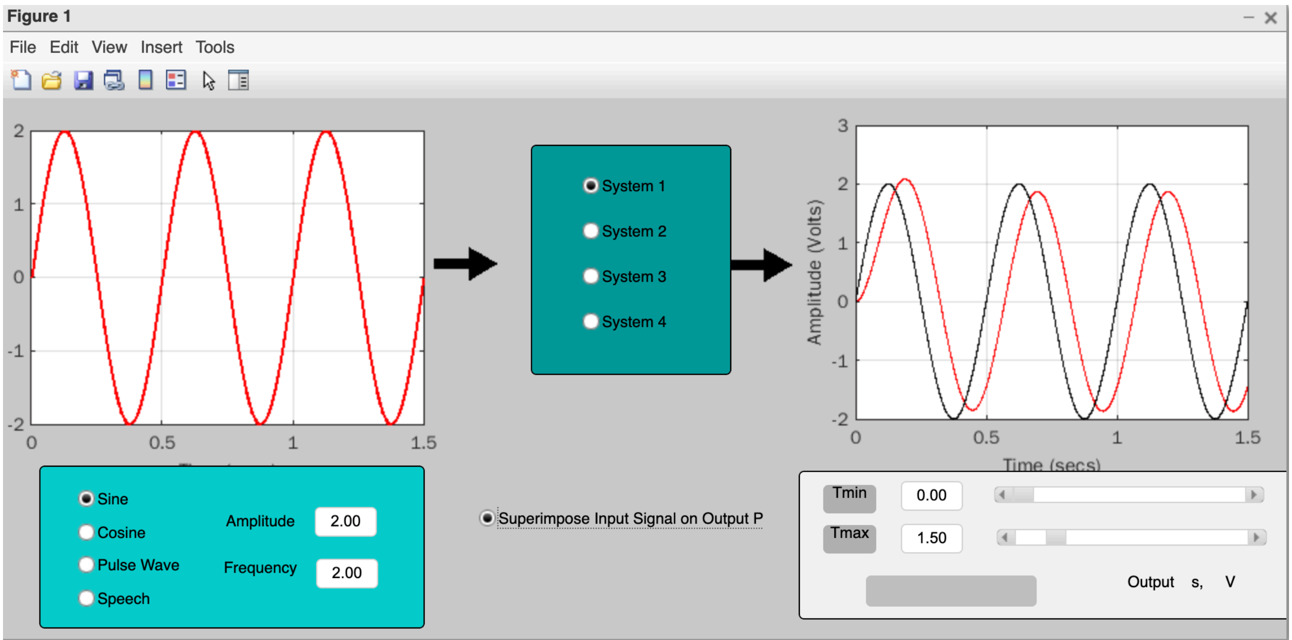


In terms of sine function x3 and x2 are same because sin(x+2π) = sin(x). There is a *phase lag of 2π* between x2 and x3.

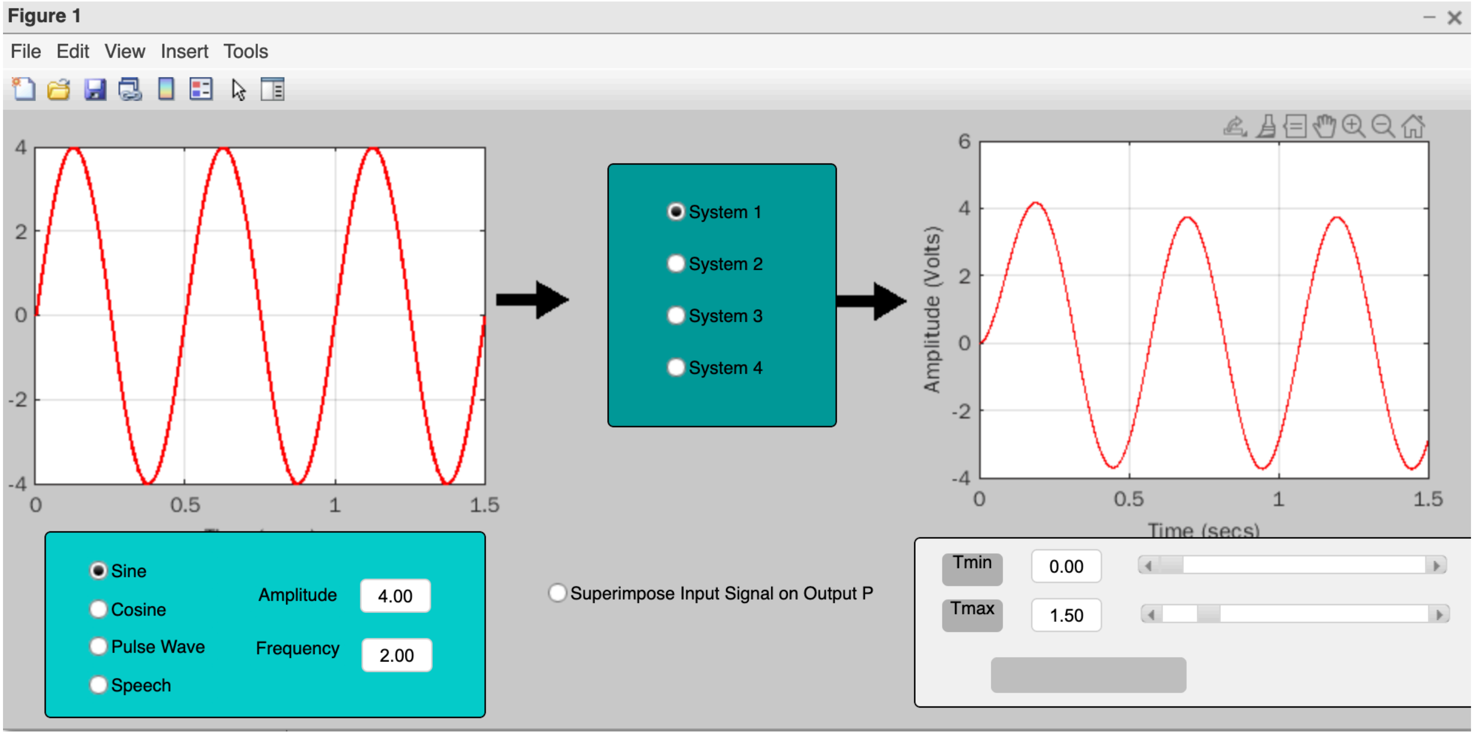
3. Linear Time Invariant Systems



1. Output signal is a *sine wave* (from above figure).



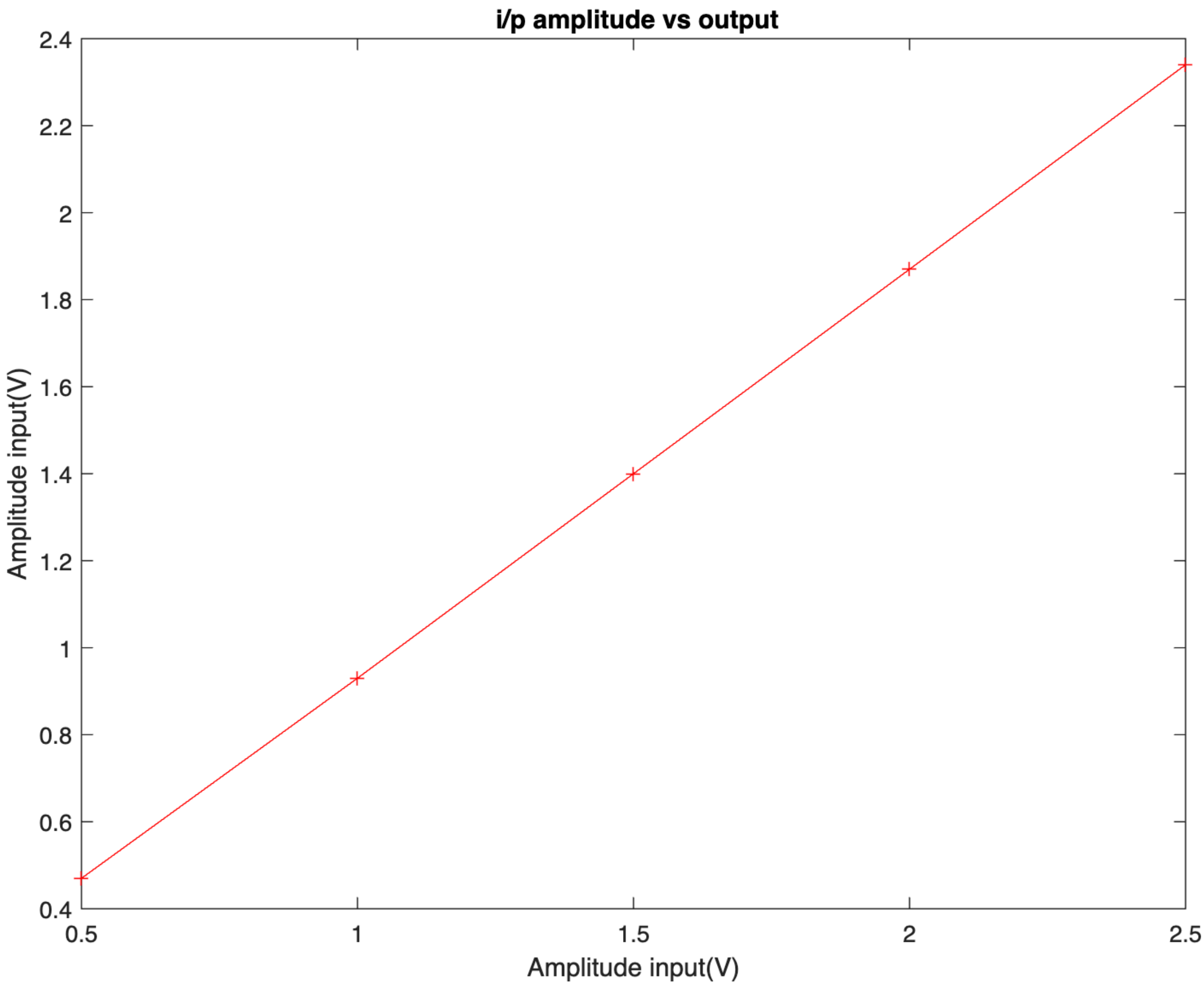
2. From above figure we can say that the output signal is *shifted to the right* with respect to the input signal. Similarity is that both the signals are sine waves with *same frequency and same amplitude*.



3. From the above figure we can say that the increase in amplitude of the output signal is same as input signal i.e. as we double the amplitude of input signal the amplitude of *output signal* also *doubles*. It takes 0.5 seconds for the system to settle to a steady state.

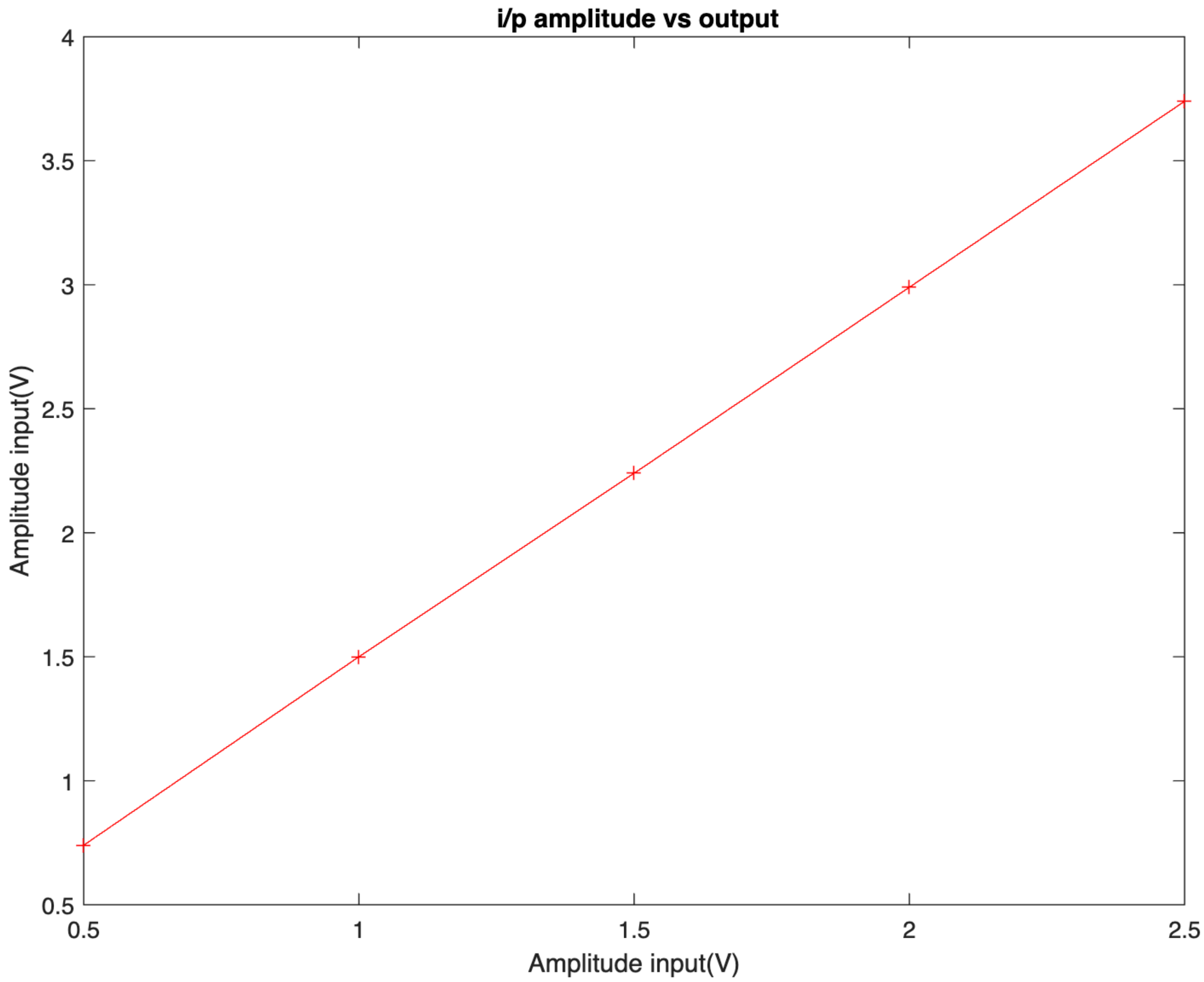
4. Graph of i/p amplitude vs output

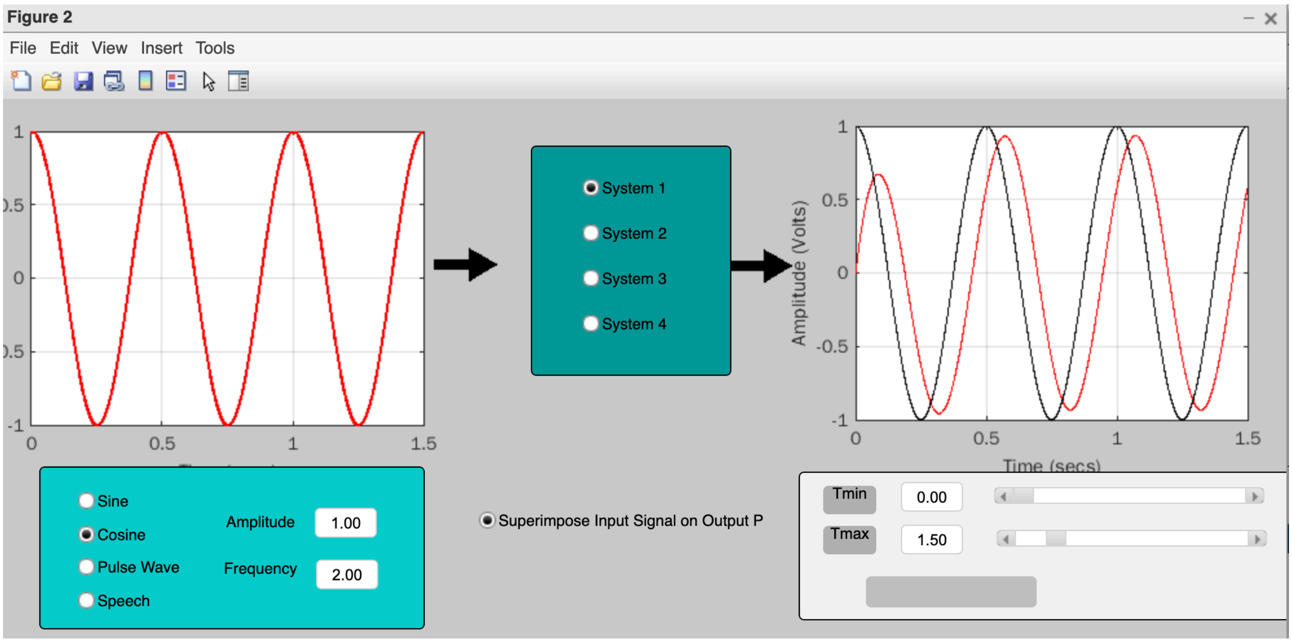
Amplitude (in Volts)	
INPUT	OUTPUT
0.5	0.47
1.0	0.93
1.5	1.40
2.0	1.87
2.5	2.34



5. Same experiment with Pulse Wave with frequency 0.8Hz

Amplitude (in Volts)	
INPUT	OUTPUT
0.5	0.74
1.0	1.50
1.5	2.24
2.0	2.99
2.5	3.74





6. The difference between input and output signal is that input wave is cosine wave whereas *output wave is sine wave* whereas the *time period* of both signals is same.

7. Sine wave
   - Input signal: 2sin(4πt)
   - Output signal: 1.87sin(4πt - 0.264π)

   Cosine wave
   - Input signal: 2cos(4πt)
   - Output signal: 1.87cos(4πt - 0.288π)

8.

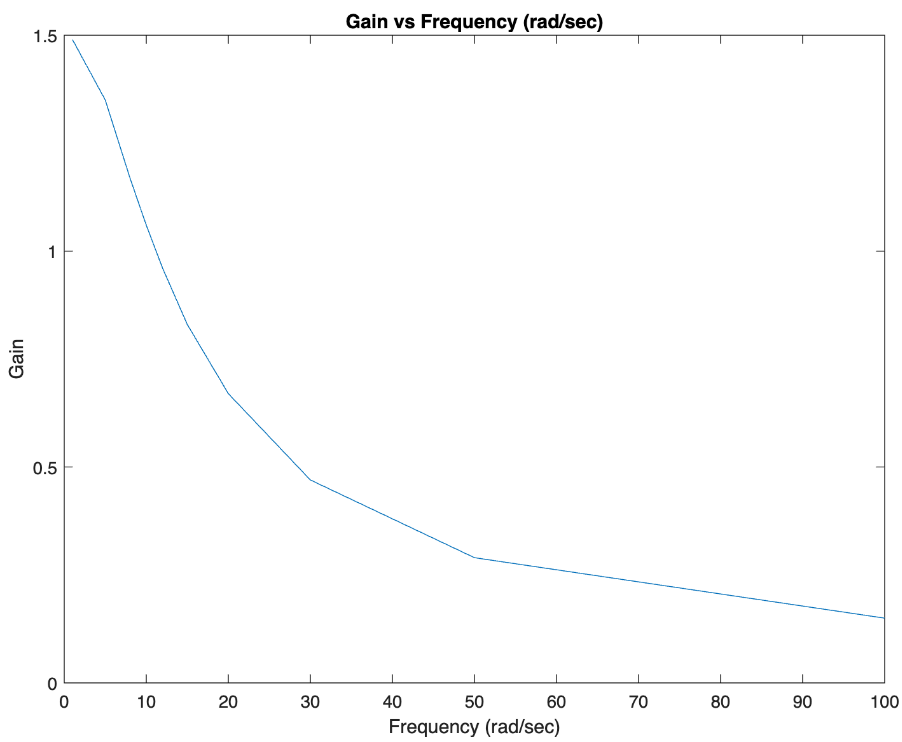
System 1	Linear
System 2	Linear
System 3	Non-linear
System 4	Linear

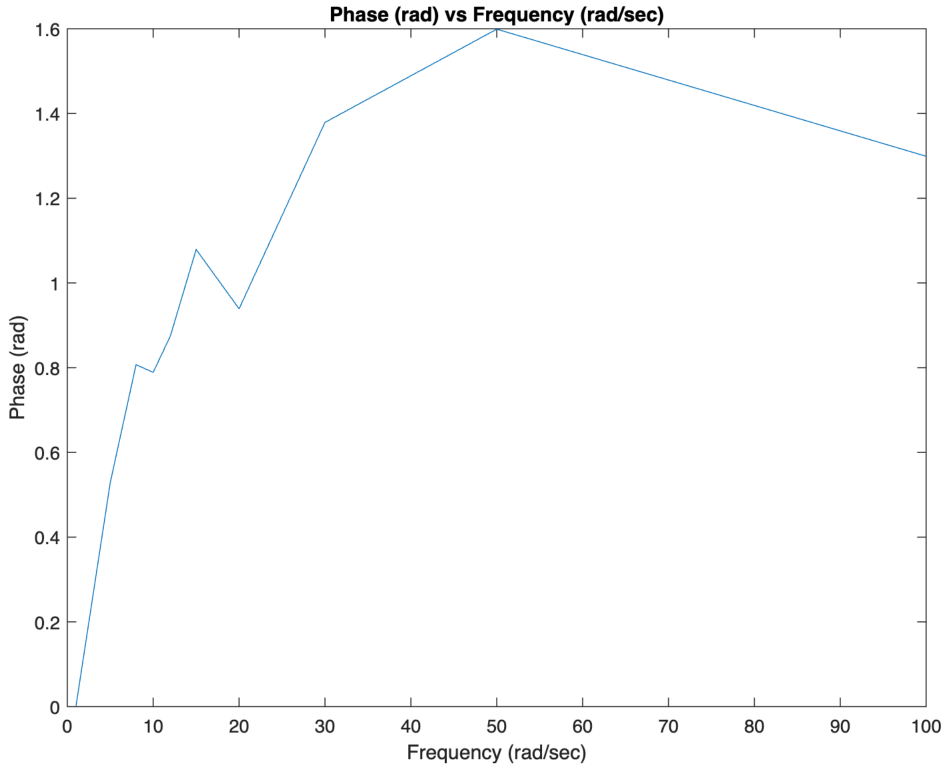
3.1 Gain and Phase as a function of frequency

1. The table below for the Sine input at various frequencies using system 1

INPUT			OUTPUT				
Frequency (rad/sec)	Frequency (Hz)	Amplitude (x)	Frequency (rad/sec)	Amplitude (y)	Pase Lag (sec)	Phase Lag (rad)	Gain (y/x)
1	0.159	1	1	1.49	0.000	0.000	1.49
5	0.796	1	5	1.35	0.016	0.529	1.35
8	1.273	1	8	1.17	0.101	0.807	1.17
10	1.591	1	10	1.06	0.079	0.789	1.06
12	1.909	1	12	0.96	0.073	0.875	0.96
15	2.387	1	15	0.83	0.072	1.079	0.83
20	3.183	1	20	0.67	0.047	0.939	0.67
30	4.774	1	30	0.47	0.046	1.379	0.47
50	7.957	1	50	0.29	0.032	1.599	0.29
100	15.915	1	100	0.15	0.013	1.299	0.15

2. Graph of Gain vs Frequency (rad/sec) and Phase (rad) vs Frequency (rad/sec) for system 1



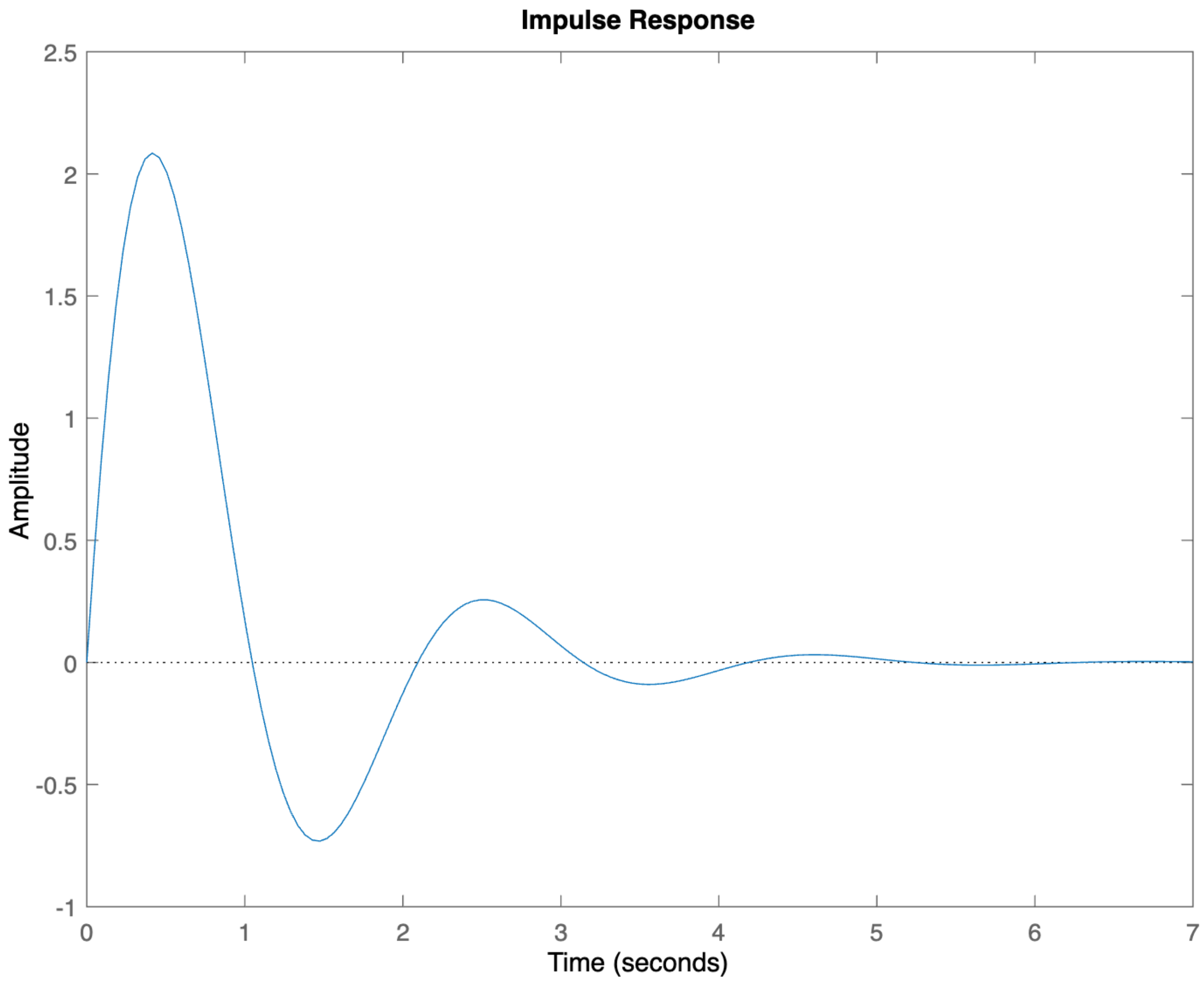


3. Effect on system is as follows:
   As *frequency* of system *increases* the *amplitude* of output *decreases*.

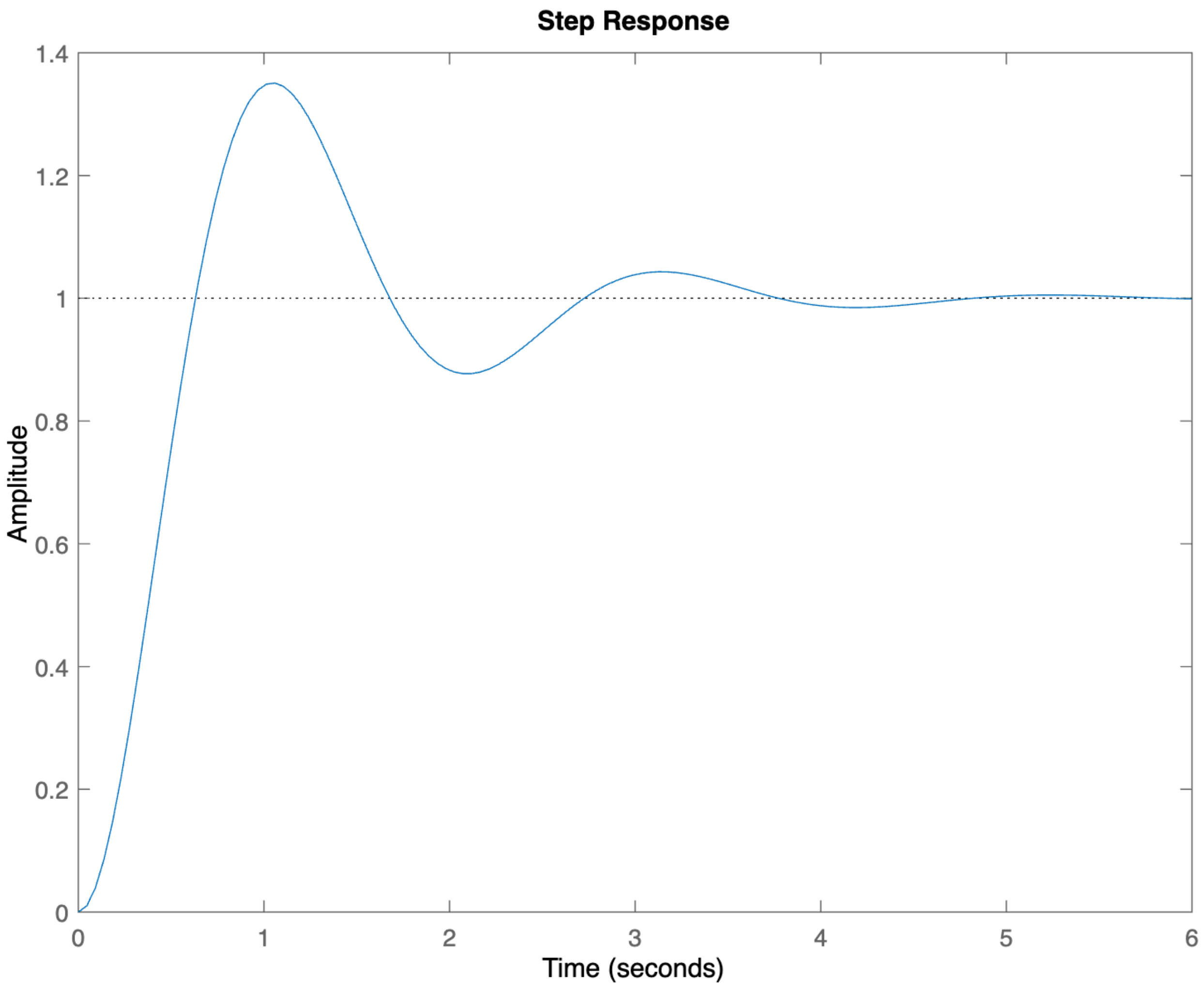
4. *Pulse wave amplitude increases* by 0.438 in output signal as compared to input signal whereas the *speech signal remains same*.

3.2 Characterising the Transient Responses of a System

1. Impulse response



Step response



2. Using the plots generated previously, following are the values for all of the parameters listed above.

$$H(s) = \frac{10(s+3)}{(s+1)(s+2)}$$

Impulse Response

- Peak time: 0.414 seconds
- Peak value: 0.29
- Settling time: 3.95 seconds

Step Response

- Steady state value: 1
- Rise time: 0.426
- Percent overshoot: 35.1%
- Settling time: 3.45 seconds

3. The poles and zeros of the transfer function shown in Fig. 2 are as follows

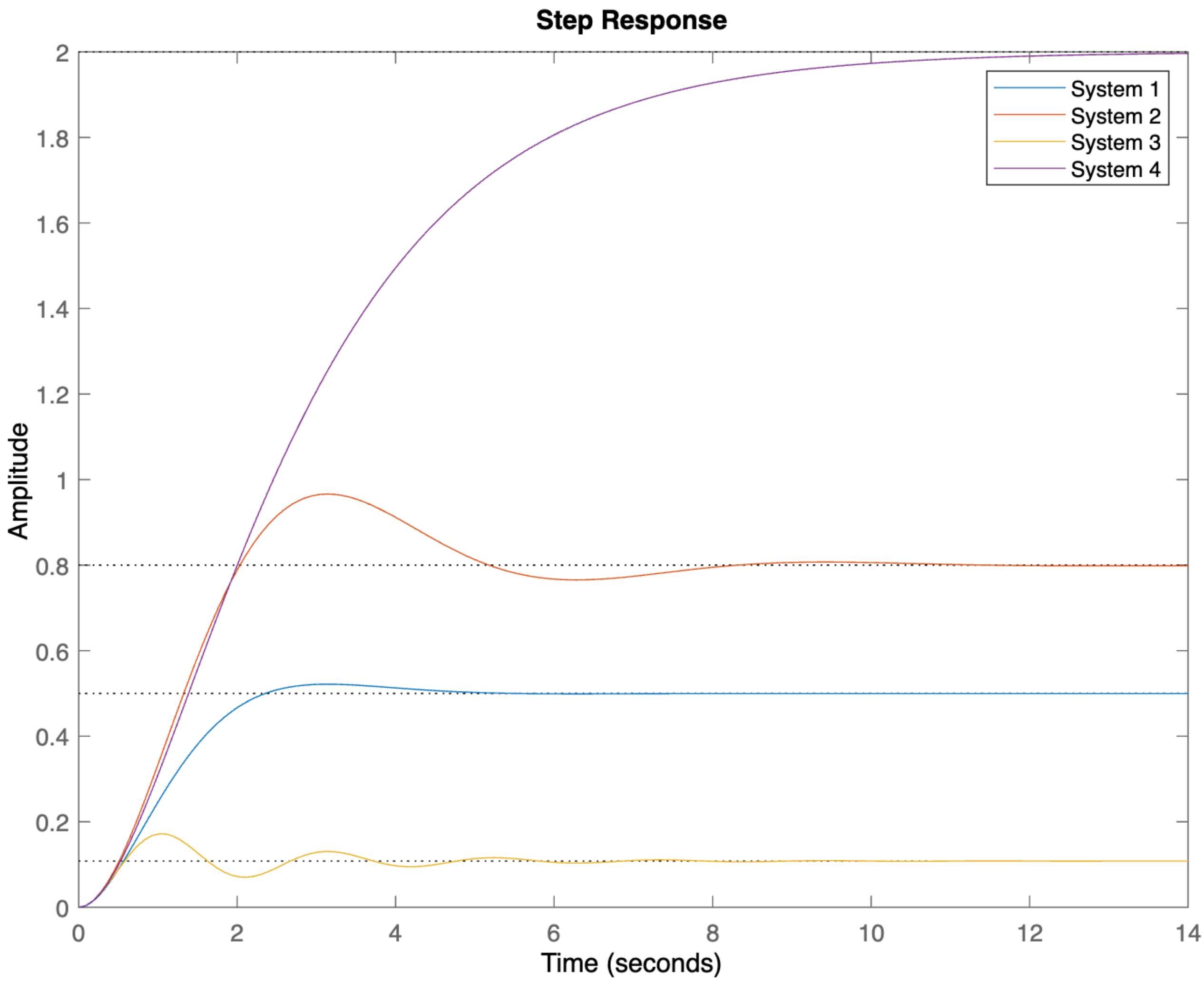
    Poles:
    - -1+3*i*
    - -1-3*i*

    Zeros: None

```
>> the_sys_Hs = zpk([], [-1+3i -1-3i], [10])


the_sys_Hs =

         10
  ---------------
  (s^2 + 2s + 10)

Continuous-time zero/pole/gain model.
```

4. 2nd order systems systems, each having a gain of 1, no zeros in the transfer function, and with the poles specified below:

- System 1 - poles at s = –1 + j, s = –1 – j
- System 2 - poles at s = –0.5 – j, s = –0.5 + j
- System 3 - poles at s = –0.5 + 3j, s = –0.5 – 3j
- System 4 - poles at s = –1, s = –0.5



Observations from above graph:

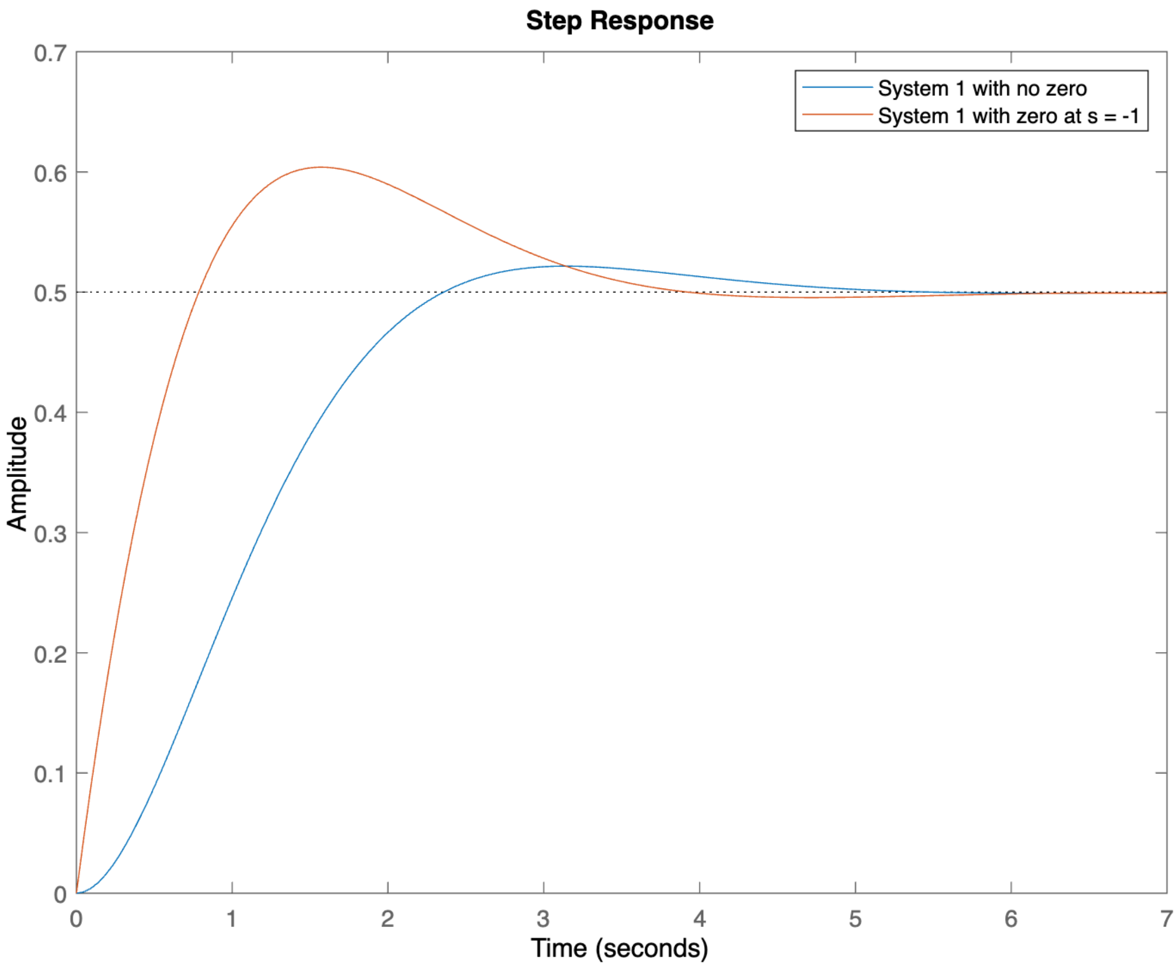
1. System 1 has slight oscillations with a settling time of 5.4 seconds
2. System 2 has single oscillations with a settling time of 8.3 seconds
3. System 3 has multiple oscillations with a settling time of 9.8 seconds
4. System 4 has no oscillations with a settling time of 13.4 seconds

Looking at the graph and above observations we can say the following things:

- *Increase* in *real* part results in *increase* in *frequency*
- *Increase* in *imaginary* part results in *increase* in *settling* time.
- The system with *real* poles has *no oscillations* and does *not overshoot* like the systems with complex conjugate do.

5. Following is the graph of following signals

```
>> sys1 = zpk([], [-1+i -1-i], [1])

sys1 =

        1
  --------------
  (s^2 + 2s + 2)

Continuous-time zero/pole/gain model.

>> sys1_new = zpk([-1], [-1+i -1-i], [1])

sys1_new =

      (s+1)
  --------------
  (s^2 + 2s + 2)

Continuous-time zero/pole/gain model.
```



Observations:
- There is a *sudden increase in peak value* when zero is introduced to system 1. It incensed from0.52V to 0.604V
- *Settling time* was *reduced* from 5.2 s[1]econds to 3.92 seconds