

1909756

by Joshua Rees

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Task 1

I selected suitable component values for the circuit in figure 1.

$L = 0.2\text{H}$

$R = 20\Omega$

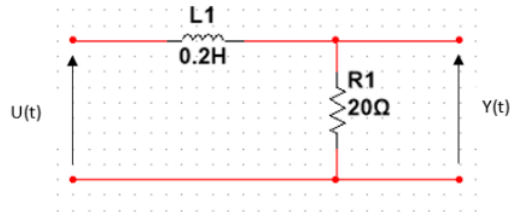


Figure 1

This is the calculation for time constant.

$$T = \frac{L}{R} = 0.01\text{s}$$

Below is the laplass module with the transfer function.

$$H(S) = \frac{1}{Ts + 1} = \frac{1}{0.01s + 1}$$

Time response.

$$Y(t) = 1 \left(1 - e^{-\frac{t}{T}} \right) = 1 - e^{-1} = 0.632$$

Figure 2 shows the matlab model program with the transient response. The cursor is also placed on the point for time response calculated previously.

```
>> num = [1];
>> den = [0.01 1];
>> step(num,den);
>>
```

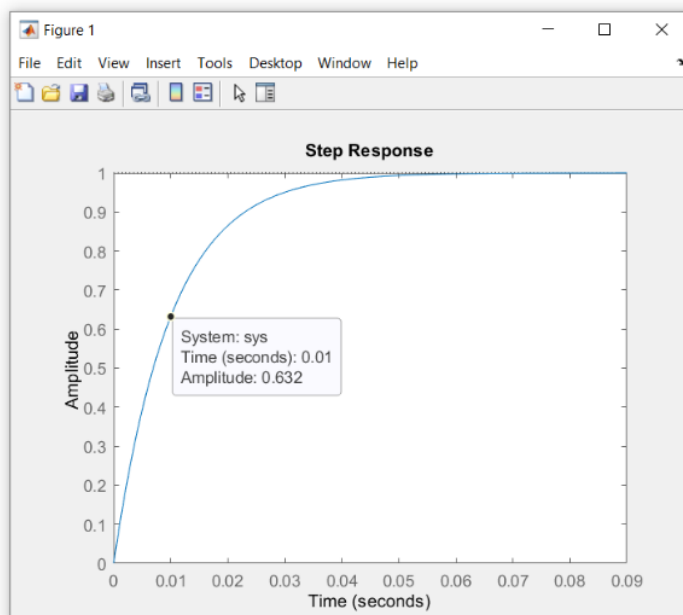


Figure 2

Table 1

Task 1	Calculated	Simulated
T	0.01	0.01

The results in the comparison table show that the calculated result is the same as the simulated, the time response equation gave the calculation for the 0.632 to relate to where on the graph to measure for the growth. This proved to be correct.

Task 2

I selected suitable component values for the circuit in figure 3.

$R = 100\Omega$

$C = 20\mu F$

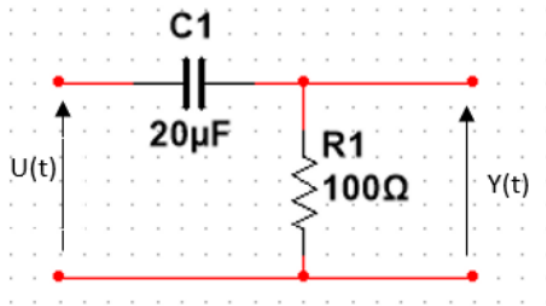


Figure 3

This is the calculation for time constant.

$$T = R \times C = 100 \times 20\mu = 0.002s$$

Below is the laplass module with the transfer function.

$$H(S) = \frac{Ts}{Ts + 1} = \frac{0.002}{0.002s + 1}$$

Time response.

$$Y(t) = -e^{-\frac{t}{T}} = -e^{-1} = 0.368$$

Figure 4 shows the matlab model program with the transient response. The cursor is also placed on the point for time response calculated previously.

```
>> num = [0.002 0];
>> den = [0.002 1];
>> step(num,den)
>>
```

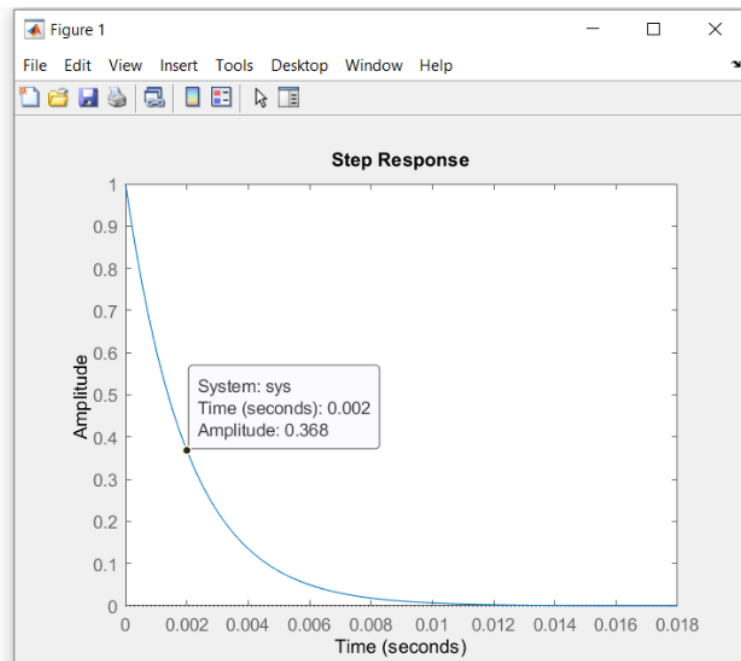


Figure 4

Table 2

Task 2	Calculated	Simulated
T	0.002	0.002

The calculated result is the same as the simulated, the time response equation which showed 0.368 to relate to where on the graph to measure for the decay. This proved to be correct as shown in the table.

Task 3

This is the transfer function in terms of the cut off frequency

$$H(S) = \frac{1}{Ts + 1}$$

$$H(S) = \frac{1}{\frac{1}{wc}s + 1}$$

$$H(S) = \frac{wc}{s + wc}$$

$$wc = \frac{R}{L} = \frac{20}{0.2} = 100$$

$$H(S) = \frac{1}{0.01s + 1} = \frac{100}{s + 100}$$

Figure 5 is the low pass matlab model program.

```
>> num = [100];
>> den = [1 100];
>> bode(num,den);
>>
```

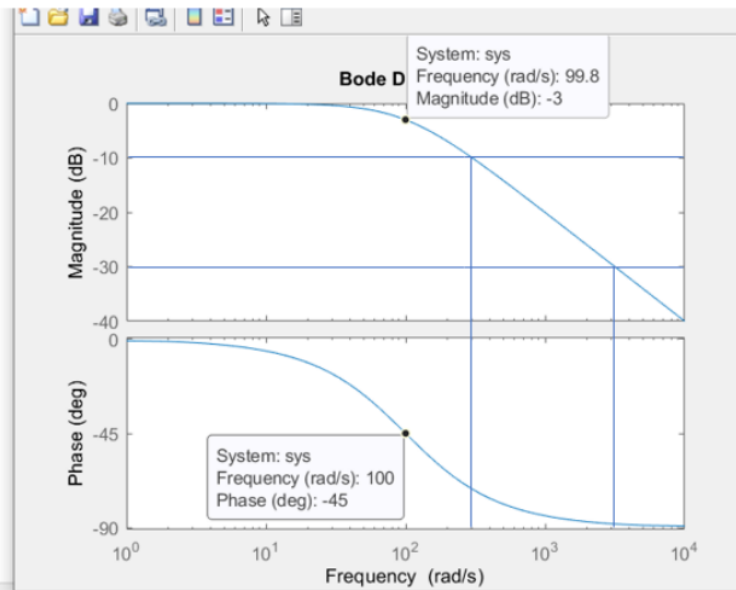


Figure 5

This is the matlab model program for high pass in figure 6.

$$H(S) = \frac{0.01s}{0.01s + 1} = \frac{s}{s + 100}$$

7

```
. num = [1 0];
. den = [1 100];
. bode(num,den);
```

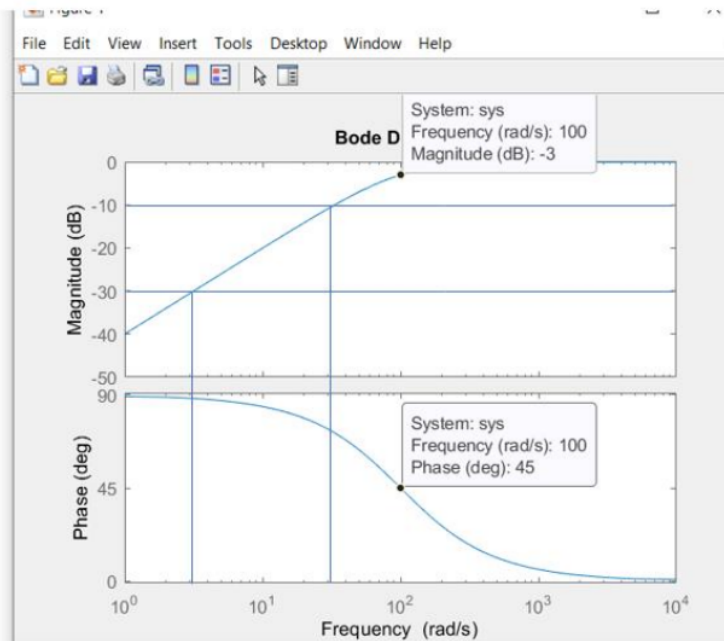


Figure 6

Table 3

RL	Low pass	High pass
Roll-off	20 dB/decade	20 dB/decade
ω_c	99.8 rad/s	100 rad/s
Phase shift	-45 deg	45 deg

From the graphs in figures 5 and 6 along with the table comparison in table 3 it is clear that the cut off frequency at -3dB comes out at 100 rad/s for both the low pass and high pass. With the low pass having a negative phase shift of -45 degrees and the high pass having a positive phase shift of 45 degrees. Each has a roll-off of 20db per decade.

Task 4

This is the transfer function in terms of the cut off frequency

$$H(S) = \frac{1}{Ts + 1}$$

$$H(S) = \frac{1}{\frac{1}{\omega_c} s + 1}$$

$$H(S) = \frac{\omega_c}{s + \omega_c}$$

$$\omega_c = \frac{1}{RC} = \frac{1}{20\mu \times 100} = 500$$

$$H(S) = \frac{500}{s + 500}$$

Figure 7 is the matlab model program for low pass.

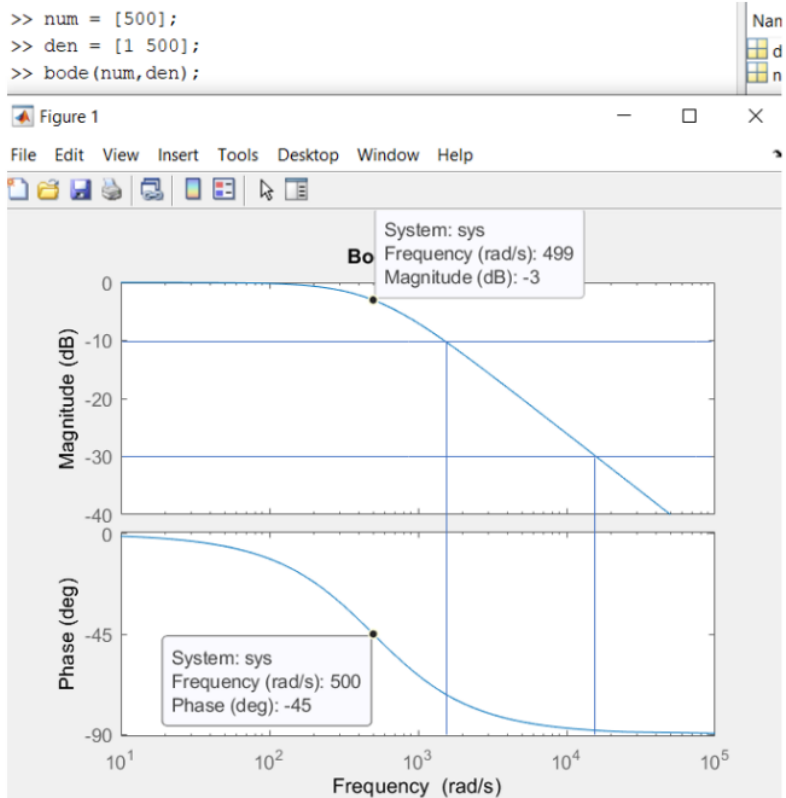


Figure 7

Figure 8 is the matlab model program for high pass.

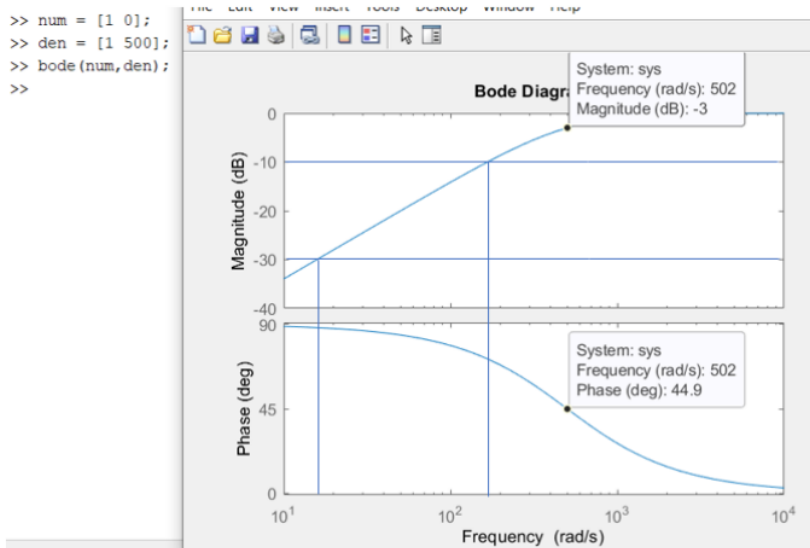


Figure 8

Table 4

RC	Low pass	High pass 10
Roll-off	20 dB/decade	20 dB/decade
ω_c	499 rad/s	502 rad/s
Phase shift	-45 deg	44.9 deg

From the graphs in figures 7 and 8 along with the table comparison in table 4 it is clear that the cut off frequency at -3dB comes out at around 500 rad/s for both the low pass and high pass. With the low pass having a negative phase shift of -45 degrees and the high pass having a positive phase shift of 45 degrees. Each has a roll-off of 20db per decade.

Task 5

Component values for the circuit in figure 9

R = 10 Ohms

L = 0.2H

C = 58uF

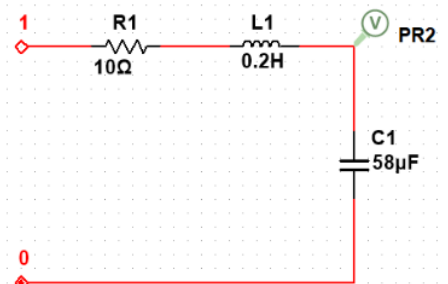


Figure 9

Transfer function

$$H(S) = \frac{\frac{1}{LC}}{s^2 + s\frac{R}{L} + \frac{1}{LC}}$$

Standard form 11

K = 1

$$\omega_n = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.2 \times 58 \times 10^{-6}}} = 293.61 \text{ rad/s}$$

$$Z = \frac{R}{2} \times \sqrt{\frac{C}{L}} = \frac{10}{2} \times \sqrt{\frac{58 \times 10^{-6}}{0.2}} = 0.085 \text{ underdamped}$$

$$H(S) = \frac{K\omega_n^2}{s^2 + 2z\omega_n s + \omega_n^2}$$

$$H(S) = \frac{86206.83}{s^2 + 49.91s + 86206.83}$$

Matlab model program is shown in figure 10 which shows underdamping.

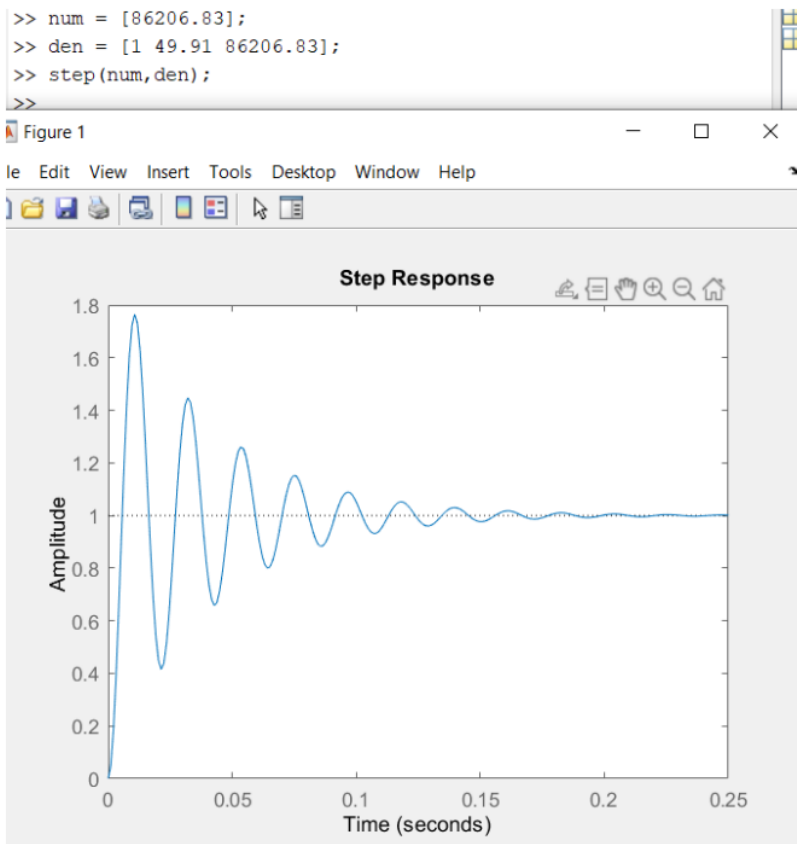


Figure 10

Rearranged formula to get values for $z = 1$ and $z = 0$

$$Z = \frac{R}{2} \times \sqrt{\frac{C}{L}}$$

$$R = \frac{Z}{\sqrt{\frac{C}{L}}} \times 2 = \frac{1.6}{\sqrt{\frac{58 \times 10^{-6}}{0.2}}} \times 2 = 187.91 \text{ Ohms}$$

$$Z = \frac{R}{2} \times \sqrt{\frac{C}{L}} = \frac{187.91}{2} \times \sqrt{\frac{58 \times 10^{-6}}{0.2}} = 1.6 \text{ overdamped}$$

$$H(s) = \frac{K\omega_n^2}{s^2 + 2z\omega_n s + \omega_n^2}$$

$$H(s) = \frac{86206.83}{s^2 + 939.552s + 86206.83}$$

Overdamping is shown in figure 11.

You have worked this out correctly, well

```
>> num = [86206.83];
>> den = [1 939.552 86206.83];
>> step(num,den);
```

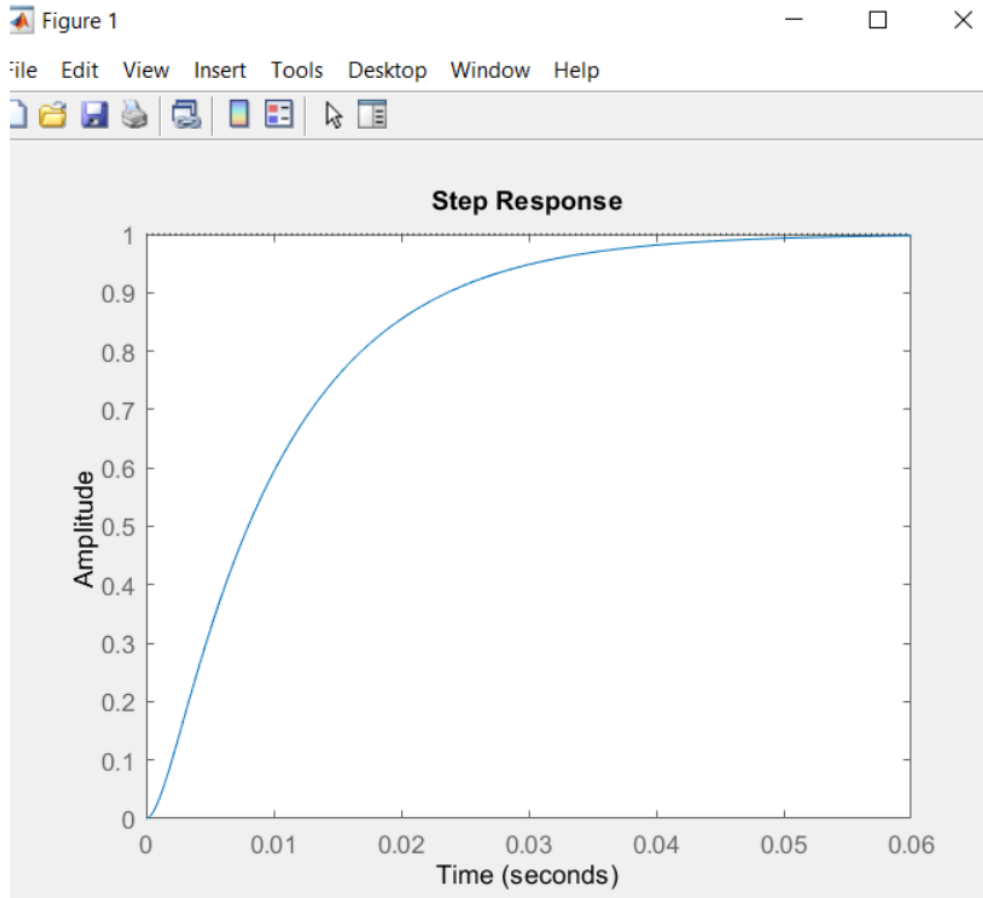


Figure 11

You have worked this out correctly, well

$$R = \frac{Z}{\sqrt{\frac{C}{L}}} X2 = \frac{1}{\sqrt{\frac{58 \times 10^{-6}}{0.2}}} X2 = 117.44 \text{ Ohms}$$

$$Z = \frac{R}{2} X \sqrt{\frac{C}{L}} = \frac{117.44}{2} X \sqrt{\frac{58 \times 10^{-6}}{0.2}} = 1 \text{ critically damped}$$

$$H(S) = \frac{Kwn^2}{s^2 + 2zwns + wn^2}$$

$$H(S) = \frac{86206.83}{s^2 + 587.22s + 86206.83}$$

Critically damped is shown in figure 12.

```
>> num = [86206.83];
>> den = [1 587.22 86206.83];
>> step(num,den);
>>
```

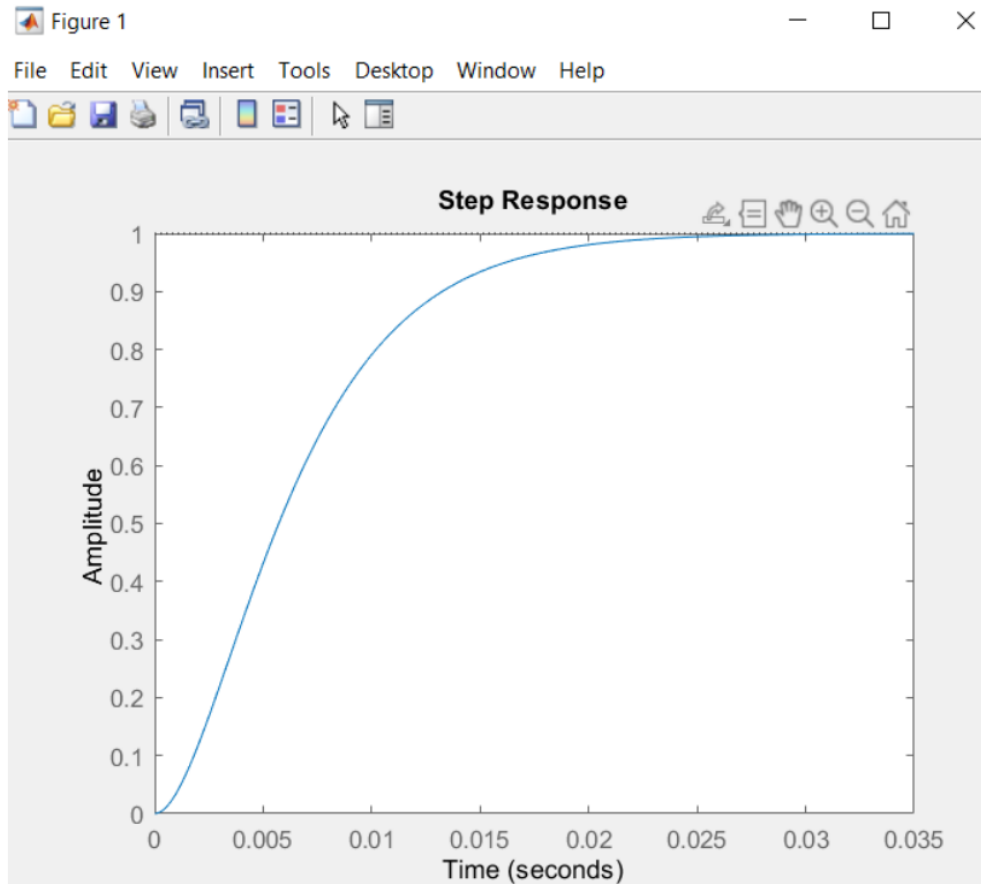


Figure 12

$$R = \frac{Z}{\sqrt{\frac{C}{L}}} X2 = \frac{0}{\sqrt{\frac{58 \times 10^{-6}}{0.2}}} X2 = 0 \text{ Ohms}$$

$$Z = \frac{R}{2} X \sqrt{\frac{C}{L}} = \frac{0}{2} X \sqrt{\frac{58 \times 10^{-6}}{0.2}} = 0 \text{ nondamped}$$

$$H(S) = \frac{K\omega n^2}{s^2 + 2z\omega n s + \omega n^2}$$

$$H(S) = \frac{86206.83}{s^2 + 0s + 86206.83}$$

You have worked this out correctly, well

Nondamping is shown in figure 13.

```
>> num = [86206.83];
>> den = [1 0 86206.83];
>> step(num,den);
>>
```

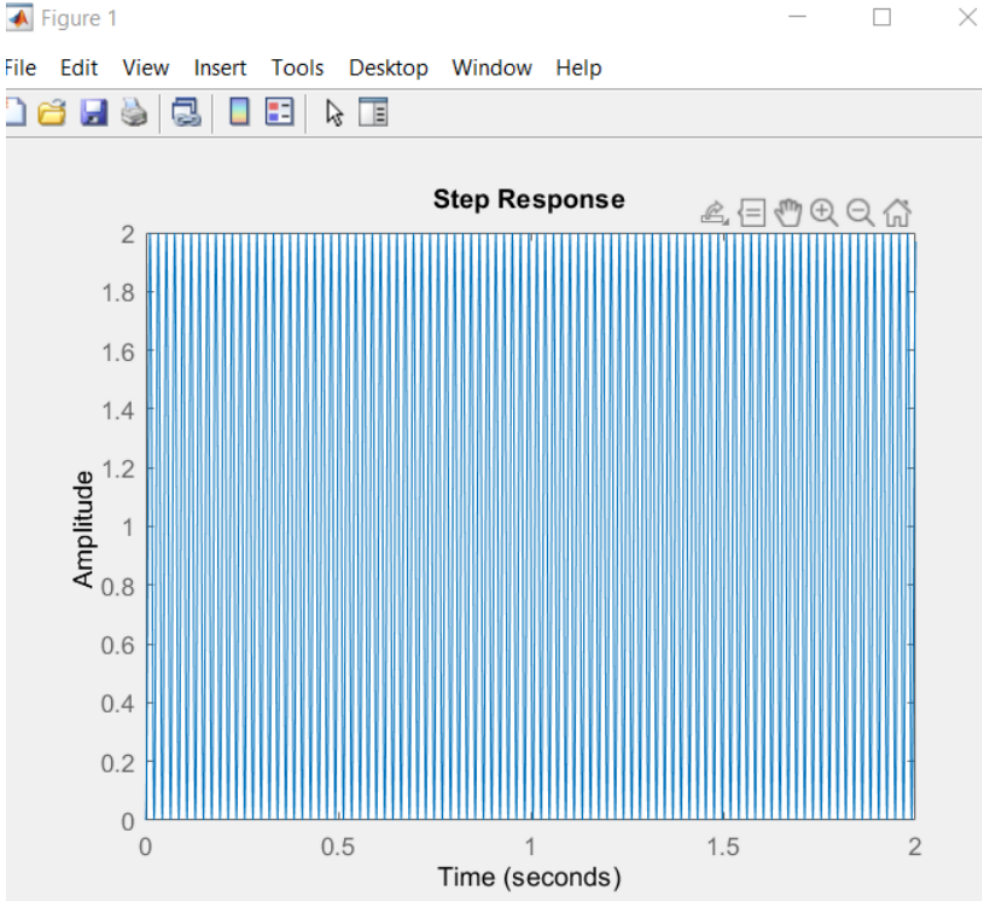


Figure 13

Table 5

Resistor Ω	Z sigma	Result
10	0.085	Underdamped
187.91	1.6	Overdamped
117.44	1	Critically damped
0	0	Non damped

From the table of results it is clear that the resistance in the circuit determines how damped it is. When the resistance in the circuit is 0Ω then the response is non damped which is shown in the graph as the amplitude goes up and down to the same points. When increasing the resistance to 10Ω the sigma is 0.085 and as it is under 1 this makes it underdamped, on

the graph it shows the amplitude shoots over and comes back down and takes 0.25 seconds before settling down. When the resistance is raised to 187.91Ω the sigma is 1.6 which is overdamped which is shown in the graph as the response is a slow curve up to the point. At 117.44Ω the sigma is 1, this is critically damped which is the best as it doesn't overshoot and the curve to the point is quick.

Task 6

Component values

$R = 80 \text{ Ohms}$

$L = 0.4\text{H}$

$C = 40\mu\text{F}$

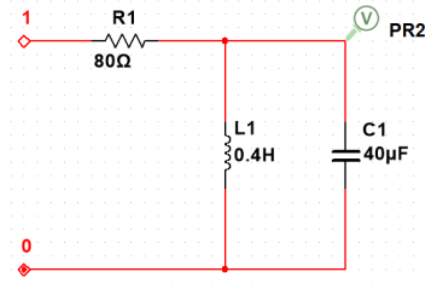


Figure 14

Transfer function

$$H(S) = \frac{s \frac{1}{RC}}{s^2 + s \frac{1}{RC} + \frac{1}{LC}}$$

$$H(S) = \frac{312.5s + 0}{s^2 + 312.5s + 62500}$$

Standard form

$K = 1$

$$\omega_n = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.4 \times 40 \times 10^{-6}}} = 250 \text{ rad/s}$$

$$Z = \frac{1}{2R} \times \sqrt{\frac{L}{C}} = \frac{1}{2 \times 80} \times \sqrt{\frac{0.4}{40 \times 10^{-6}}} = 0.625 \text{ underdamped}$$

$$H(S) = \frac{K\omega_n^2}{s^2 + 2z\omega_n s + \omega_n^2}$$

$$H(S) = \frac{62500s + 0}{s^2 + 312.5s + 62500}$$

Figure 15 shows the underdamping

Lacks essential detail

```
>> num = [62500 0];
>> den= [1 315.5 62500];
>> step(num,den);
```

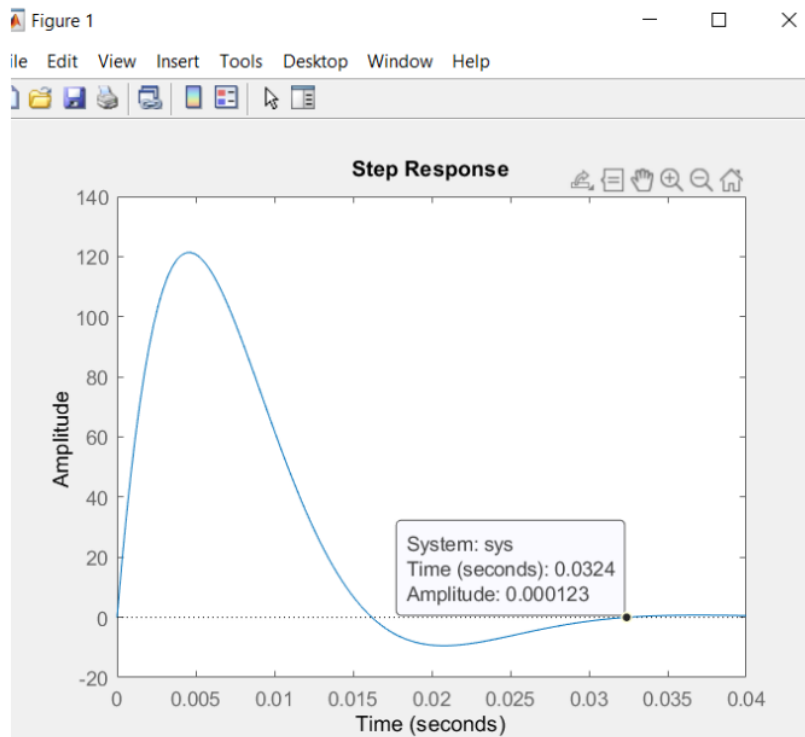


Figure 15

$$F = 1/T = 1/0.0324 = 30.86 \text{ Hz}$$

$$\omega_n = 2\pi F = 193.90 \text{ rad/s}$$

Rearrange:

$$Z = \frac{1}{2R} X \sqrt{\frac{L}{C}}$$

$$2RZ = \sqrt{\frac{L}{C}}$$

$$R = \frac{\sqrt{\frac{L}{C}}}{2Z}$$

Transfer function

$$H(S) = \frac{s \frac{1}{RC}}{s^2 + s \frac{1}{RC} + \frac{1}{LC}}$$

$$H(S) = \frac{781.25s + 0}{s^2 + 781.25s + 62500}$$

Standard form

$$Z = \frac{1}{2R} X \sqrt{\frac{L}{C}} = \frac{1}{2 \times 32} X \sqrt{\frac{0.4}{40 \times 10^{-6}}} = 1.5625 \text{ overdamped}$$

$$H(S) = \frac{K\omega_n^2}{s^2 + 2z\omega_n s + \omega_n^2}$$

$$H(S) = \frac{62500s + 0}{s^2 + 781.25s + 62500}$$

Figure 16 shows the overdamping.

```
>> num = [625000 0];
>> den = [1 781.25 62500];
>> step(num,den);
```

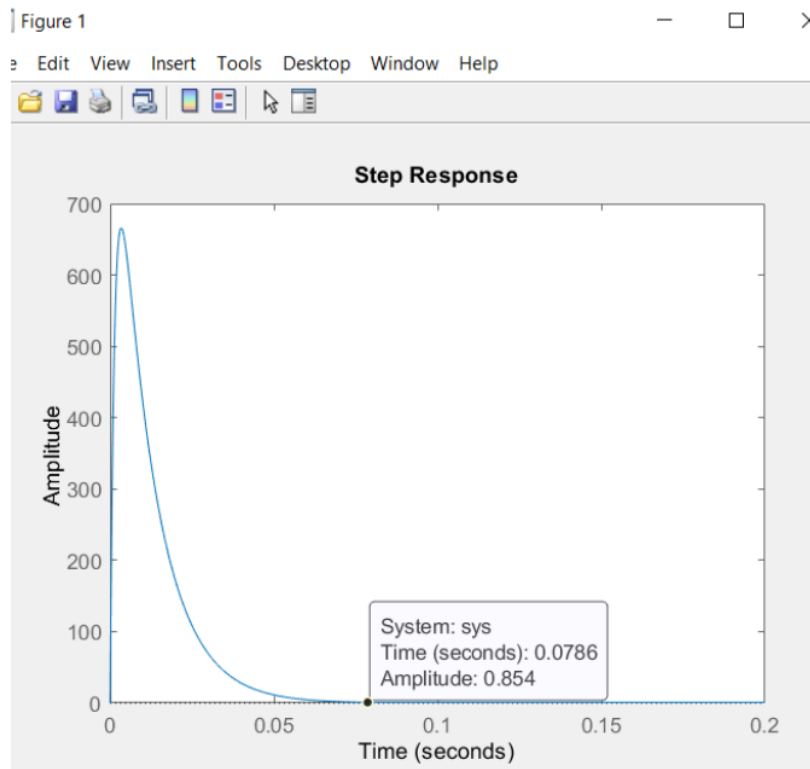


Figure 16

Transfer function

$$H(S) = \frac{s \frac{1}{RC}}{s^2 + s \frac{1}{RC} + \frac{1}{LC}}$$

$$H(S) = \frac{500s + 0}{s^2 + 500s + 62500}$$

Standard form

$$Z = \frac{1}{2R} X \sqrt{\frac{L}{C}} = \frac{1}{2 \times 50} X \sqrt{\frac{0.4}{40 \times 10^{-6}}} = 1 \text{ critically damped}$$

$$H(S) = \frac{Kwn^2}{s^2 + 2zwn s + wn^2}$$

$$H(S) = \frac{62500s + 0}{s^2 + 500s + 62500}$$

Figure 17 shows the critically damping.

```
>> num = [62500 0];
>> den = [1 500 62500];
>> step(num,den);
```

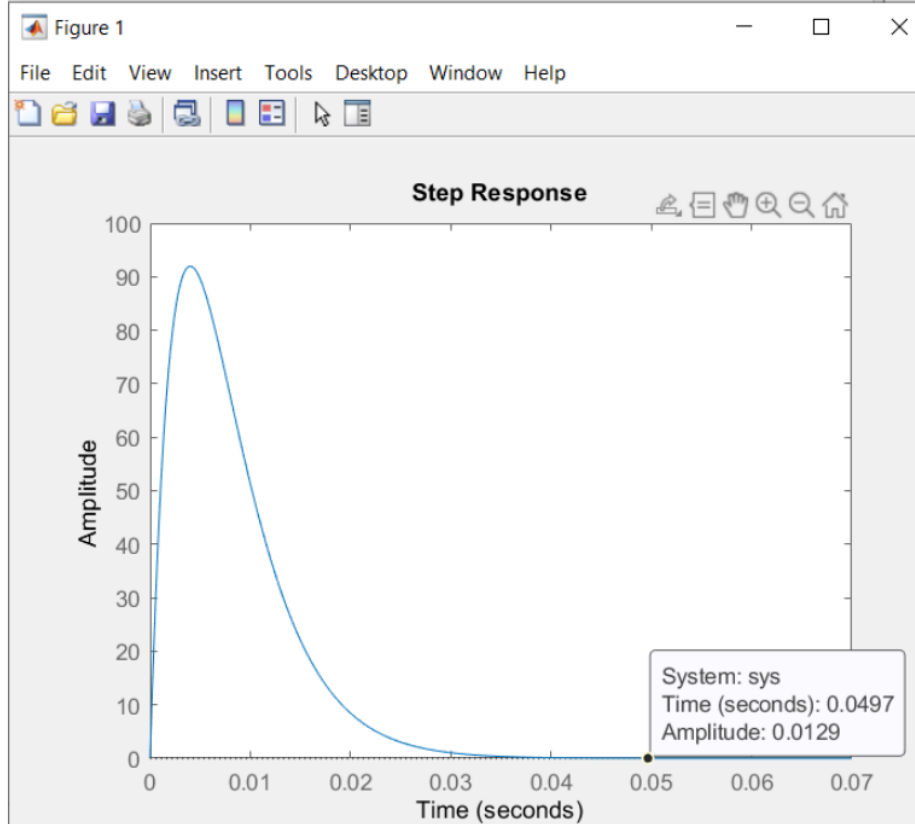


Figure 17

Task 7

Component values

R = 10 Ohms

L = 0.2H

C = 58uF

Transfer function

$$H(S) = \frac{\frac{1}{LC}}{s^2 + s\frac{R}{L} + \frac{1}{LC}}$$

$$H(S) = \frac{86206.89}{s^2 + 50s + 86206.89}$$

$$\omega_n = \sqrt{\frac{1}{LC} - \frac{1}{2} \left(\frac{R}{L}\right)^2} = \sqrt{\frac{1}{0.2 \times 58 \times 10^{-6}} - \frac{1}{2} \left(\frac{10}{0.2}\right)^2} = 291.47 \text{ rad/s}$$

$$Q = \frac{1}{R} \times \sqrt{\frac{L}{C}} = \frac{1}{10} \times \sqrt{\frac{0.2}{58 \times 10^{-6}}} = 5.872$$

$$\omega_o = \frac{1}{\sqrt{LC}} = 293.61 \text{ rad/s}$$

Standard forms

$$Z = \frac{R}{2} \times \sqrt{\frac{C}{L}} = \frac{10}{2} \times \sqrt{\frac{58 \times 10^{-6}}{0.2}} = 0.085 \text{ underdamped}$$

$$H(S) = \frac{K\omega_n^2}{s^2 + 2z\omega_n s + \omega_n^2}$$

$$H(S) = \frac{86206.83}{s^2 + 50s + 86206.83}$$

$$Z = \frac{R}{2} \times \sqrt{\frac{C}{L}} = \frac{187.91}{2} \times \sqrt{\frac{58 \times 10^{-6}}{0.2}} = 1.6 \text{ overdamped}$$

$$H(S) = \frac{K\omega_n^2}{s^2 + 2z\omega_n s + \omega_n^2}$$

$$H(S) = \frac{86206.83}{s^2 + 939.552s + 86206.83}$$

$$Z = \frac{R}{2} \times \sqrt{\frac{C}{L}} = \frac{117.44}{2} \times \sqrt{\frac{58 \times 10^{-6}}{0.2}} = 1 \text{ underdamped}$$

$$H(S) = \frac{K\omega_n^2}{s^2 + 2z\omega_n s + \omega_n^2}$$

$$H(S) = \frac{86206.83}{s^2 + 587.22s + 86206.83}$$

$$Z = \frac{R}{2} \times \sqrt{\frac{C}{L}} = \frac{0}{2} \times \sqrt{\frac{58 \times 10^{-6}}{0.2}} = 0 \text{ non damped}$$

$$H(S) = \frac{Kwn^2}{s^2 + 2zwns + wn^2}$$

$$H(S) = \frac{86206.83}{s^2 + 0s + 86206.83}$$

Figure 18 shows the matlab code.

```
>> num = [86206.89];
>> den = [1 50 86206.89];
>> bode(num,den);
>> grid
>> hold on
>> den = [1 939.552 86206.83];
>> bode(num,den);
>> hold on
>> den = [1 587.22 86206.83];
>> bode(num,den);
>> hold on
>> den = [1 0 86206.83];
>> bode(num,den);
>> hold on
>> |
```

Figure 18

Figure 19 and 20 shows the results of the bode plot. This including the roll off per decade, its magnitude at frequency and phase angle at frequency.

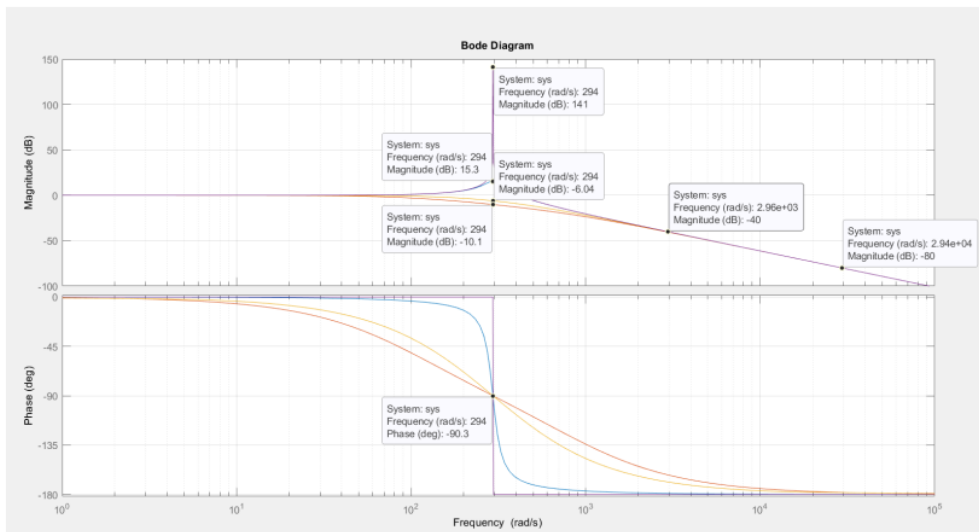


Figure 19

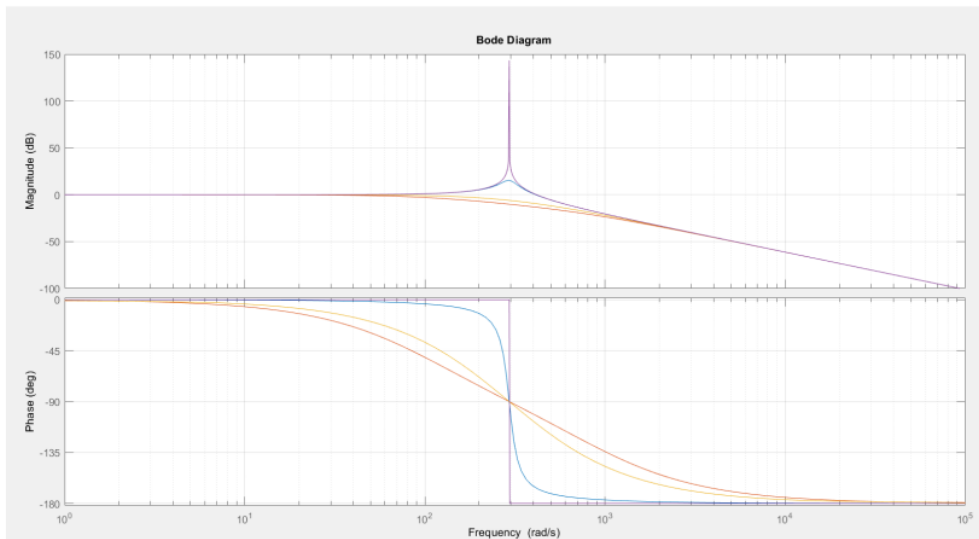


Figure 20

14

Task 8

Component values

$R = 80 \text{ Ohms}$

$L = 0.4 \text{ H}$

$C = 40 \mu\text{F}$

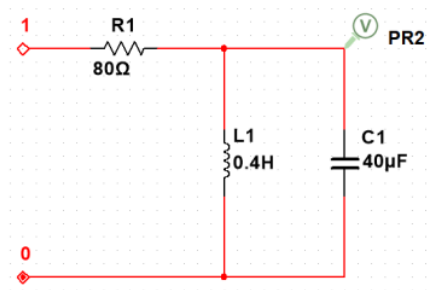


Figure 21

Transfer function.

$$H(S) = \frac{s \frac{1}{RC}}{s^2 + s \frac{1}{RC} + \frac{1}{LC}}$$

$$H(S) = \frac{312.5s + 0}{s^2 + 312.5s + 62500}$$

Compare transfer function with

$$\frac{SB}{S^2 + SB + w_o}$$

$$W_o = \sqrt{62500} = 250 \text{ rad/s}$$

Matlab Program is shown in figure 22.

```
>> clear all
>> num = [312.5 0];
>> den = [1 312.5 62500];
>> bode(num,den);
grid
>> |
```

Figure 22

Figure 23 shows the result of the bode plot.

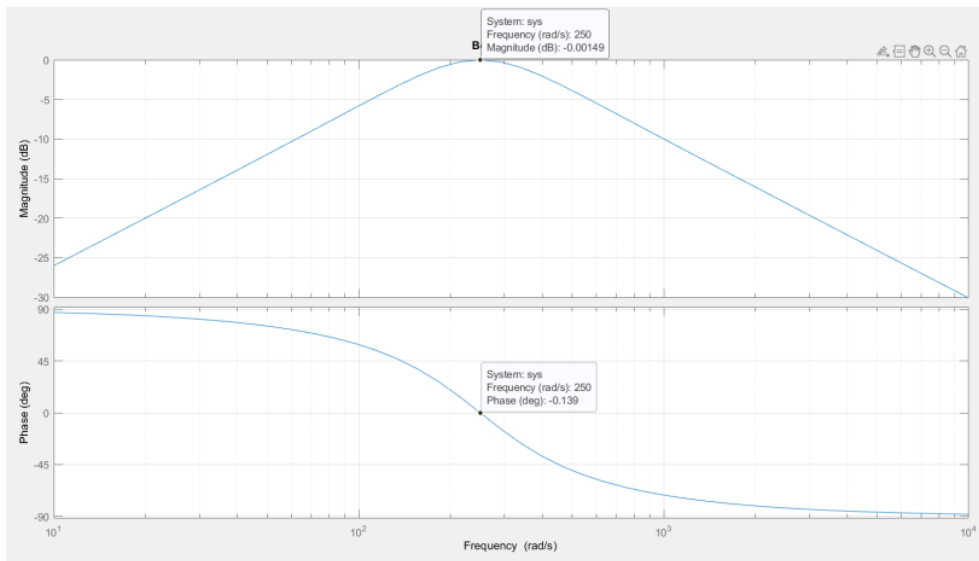


Figure 23

Table 6

	Calculated value	Matlab value
Resonant Frequency (Wo)	250rad/s	250/rad/s
Phase shift	0 degree	0 degree

15

Task 9

Component values.

R1 = 1K

R2 = 2K

C = 650nf

K = 2000/1000 = 2

Transfer function and standard form

$$wc = \frac{1}{CR2} = \frac{1}{650 \times 10^{-9} \times 2000} = 769.23 \text{ rad/s}$$

$$H(S) = -K \left[\frac{wc}{S + wc} \right] = -2 \left[\frac{769.23}{S + 769.23} \right] = \frac{-1538.46}{S + 769.23}$$

Gain

$$20 \log_{10}(2) = 6.02 \text{ dB}$$

Cut off point

$$6.02 - 3 = 3.02 \text{ dB}$$

Figure 24 shows the matlab code for the bode plot.

```
>> num = [-1538.46];
>> den = [1 769.23];
>> bode(num,den);
>> grid
```

Figure 24

You have worked this out correctly, well

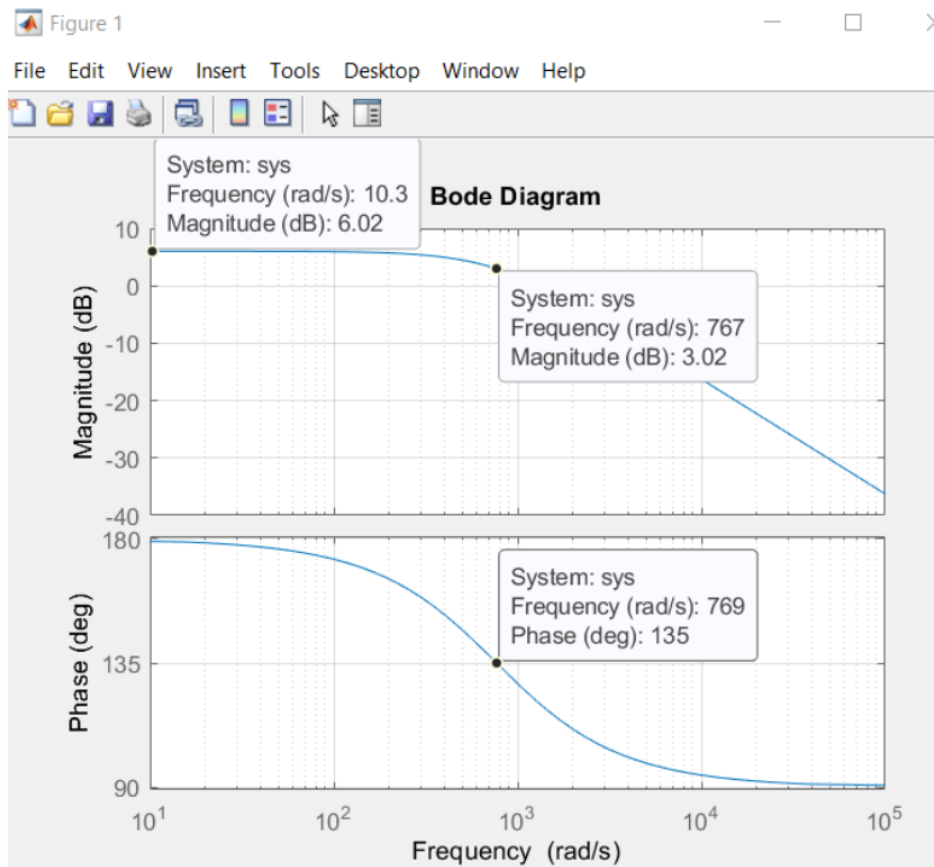


Figure 25

Figure 25 shows the bode plot result which is then analysed in table 6.

Table 7

	Calculated	Matlab
<u>W_c</u> at cut off point	769.23	767
Gain	6.02	6.02
<u>Phase deg at w_c</u>	135	135

1st order therefore slope is -20Db/dec

As shown in table 4 the results are the same as what was previously calculated although there is a slight discrepancy. As this is a first order filter there is a roll-off of 20db per decade.

Task 10

Component values.

R1 = 1K

R2 = 2K

C = 650nf

K = 2000/1000 = 2

Transfer function and standard form

$$\omega_c = \frac{1}{CR1} = \frac{1}{650 \times 10^{-9} \times 1000} = 1538.46 \text{ rad/s}$$

$$H(S) = -K \left[\frac{S}{S + \omega_c} \right] = -2 \left[\frac{S}{S + 1538.46} \right] = \frac{-2}{S + 1538.46}$$

Gain

$$20 \log_{10}(2) = 6.02 \text{ dB}$$

Cut off point

$$6.02 - 3 = 3.02 \text{ dB}$$

Figure 26 shows the matlab code for the bode plot.

```
>> num = [-2 0];  
>> den = [1 1538.46];  
>> bode(num,den);  
>> grid  
>>
```

You have worked this out correctly, well

Figure 26

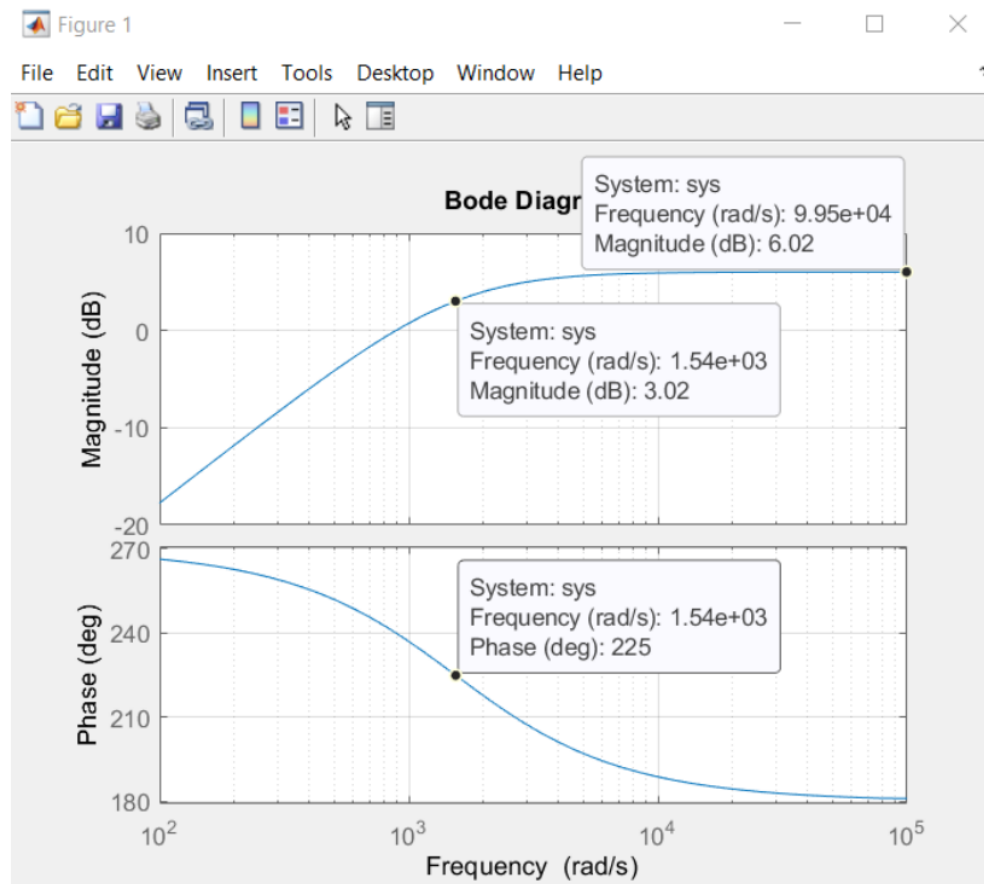


Figure 27

Table 8

	Calculated	Matlab
Wc at cut off point	1538.46	15400
Gain	6.02	6.02
Phase deg at wc	225	225

1st order therefore slope is -20Db/dec

From figure 27 and the comparison in table 7 its clear that the results are the same as what was previously calculated. And as this is a first order the slope is 20db per decade.

Task 11

Transfer function and standard form

$$H(S) = \frac{K Wc^2}{S^2 + 2WcS + Wc^2}$$

17

$$Wc = \frac{1}{R2C} = \frac{1}{20000 \times 100 \times 10^{-9}} = 500 \text{ rad/s}$$

$$K = 3$$

$$H(S) = \frac{3 \times 500^2}{S^2 + 2 \times 500S + 500^2} = \frac{750000}{S^2 + 1000S + 250000}$$

Figure 28 shows the matlab code for the bode plot

```
>> clear all
>> num1 = [-1500];
>> den1 = [1 500];
>> bode(num1,den1);
>> grid on
>> hold on
>> num2 = [750000];
>> den2 = [1 1000 250000];
>> bode(num2,den2);
>> hold on
>> num3 = [-375000000];
>> den3 = [1 1500 750000 125000000];
>> bode(num3,den3);
>> hold on
>> num4 = [187500000000];
>> den4 = [1 2000 1500000 500000000 625000000000];
>> bode(num4,den4);
>> |
```

Figure 28

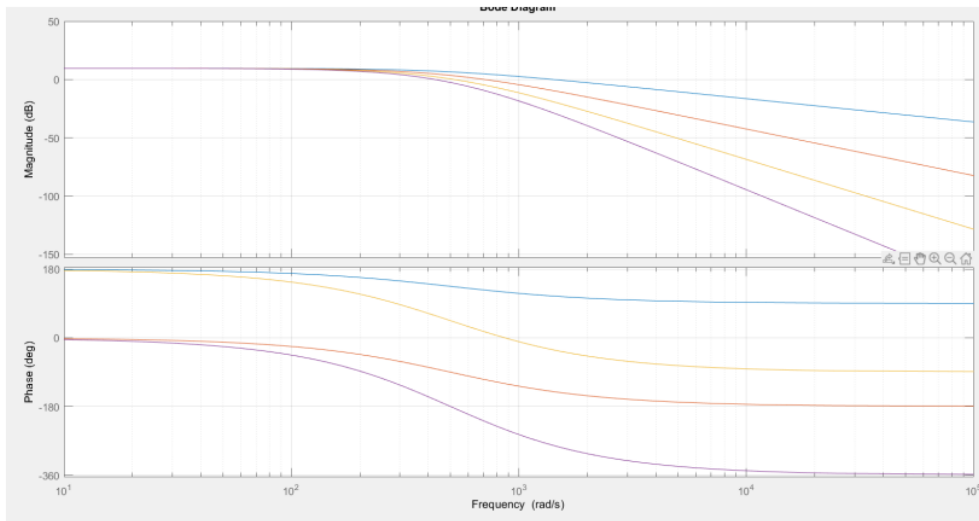


Figure 29

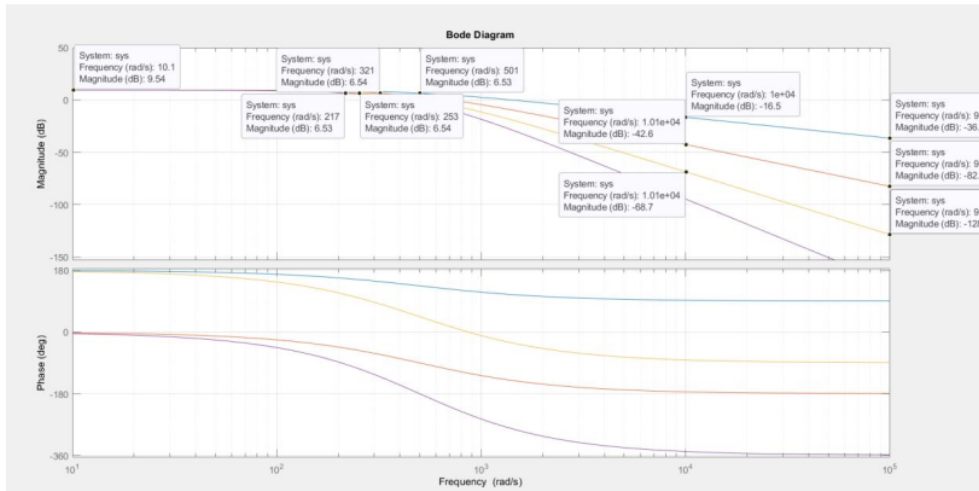


Figure 30

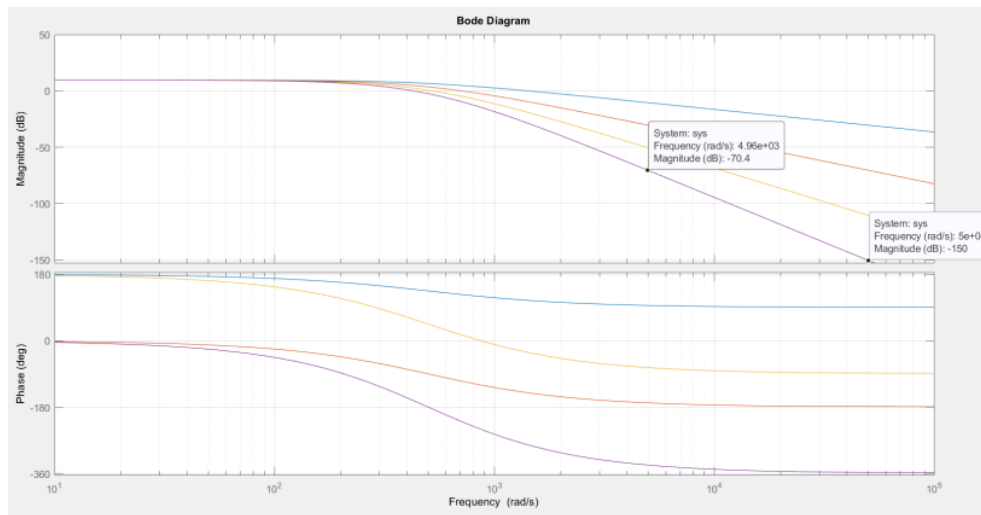


Figure 31

Table 9

Filter order	F(rad/s) at 6.54db	Db per decade
First	501	20
Second	321	40
Third	253	60
fourth	217	80

Figures 29,30, 31 and table 8 show the results of the bode plot the four order system. With the results in table it shows that as the filter order goes up the db per decade increases by 20 db per decade. Although the frequency is dropping as the order increases.

MODIFIED DESIGN

The design can be modified to have the same frequency as the first order by using scaling factors as calculated below.

$$W_{cn} = \sqrt[n]{\sqrt{2} - 1} \times w_c$$

$$N=2$$

$$W_{c2} = \sqrt[2]{\sqrt{2} - 1} = 0.6436$$

You have worked this out correctly, well

$$\text{Scaling factor of } 1/0.6436 = 1.554$$

$$500 \times 1.554 = 777 \text{ rad/s}$$

$$N=3$$

$$W_{c3} = \sqrt[3]{\sqrt{2} - 1} = 0.5098$$

Scaling factor of $1/0.5098 = 1.962$

$500 \times 1.962 = 981 \text{ rad/s}$

$N=4$

$$Wc4 = \sqrt[4]{2} - 1 = 0.435$$

Scaling factor of $1/0.435 = 2.299$

$500 \times 2.299 = 1149.5 \text{ rad/s}$

Figure 32 is the updated modified code.

```
>> wc1 = 500;
>> wc = wc1;
>> k = 3;
>> num1 = [-k*wc];
>> den1 = [1 wc];
>> bode(num1,den1);
grid on
>> hold on
>> wc = wc1*1.554;
>> num2 = [k*wc^2];
>> den2 = [1 2*wc wc^2];
>> bode(num2,den2);
>> hold on
>> wc = wc1*1.962;
>> num3 = [-k*wc^3];
>> den3 = [1 3*wc 3*wc^2 wc^3];
>> bode(num,den);
Unrecognized function or variable 'num'.

>> bode(num3,den3);
>> hold on
>> wc = wc1*2.299;
>> num4 = [k*wc^4];
>> den4 = [1 4*wc 6*wc^2 4*wc^3 wc^4];
>> bode(num4,den4);
>> |
```

Figure 32

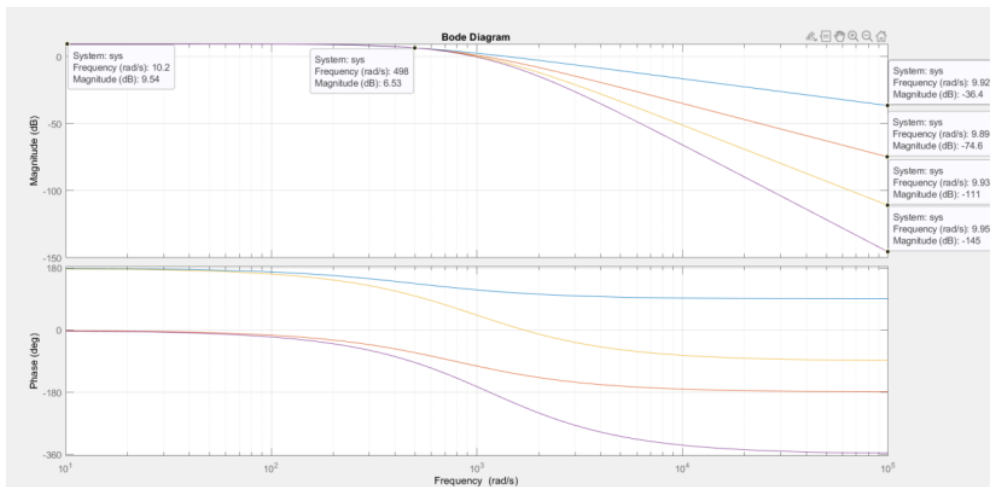


Figure 33

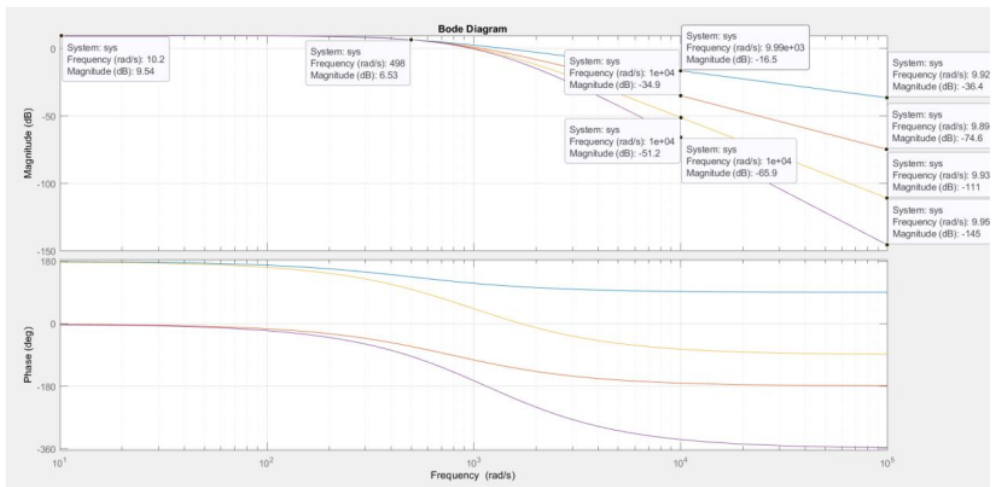


Figure 34

Table 10

Filter order	F(rad/s) at 6.54db	Db per decade
First	498	20
Second	498	40
Third	498	60
fourth	498	80

As shown in the results in figures 33, 34 and table 9, the frequency is the same through all the orders which shows that the scaling factor has worked to make the following orders the same as the first order along with the db per decade increase by 20 after each order.

Task 12

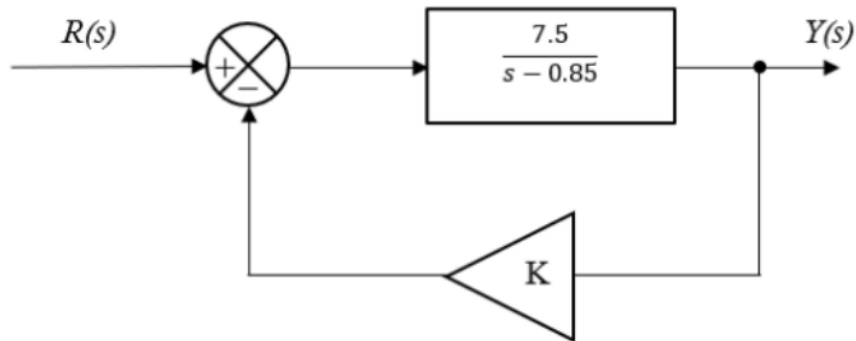


Figure 35

From using the transfer function in figure 35 the systems stability can be determined.

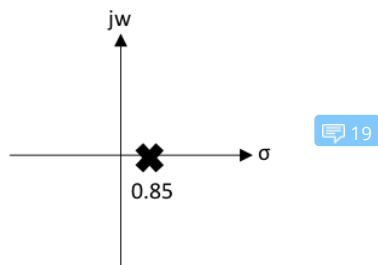


Figure 36

$$T.F = \frac{G(S)}{1 + G(S)H(S)}$$

$$T.F = \frac{\frac{7.5}{s - 0.85}}{1 + \frac{7.5}{s - 0.85} K}$$

Multiply by (s - 0.85)

$$T.F = \frac{7.5}{s - 0.85 + 7.5K} = \frac{7.5}{s + (K + 6.65)} = \frac{7.5}{s + 6.65}$$

Incorrect

From the below argand diagram it shows that with a gain of 1 that it is stable as its on the left-hand side.

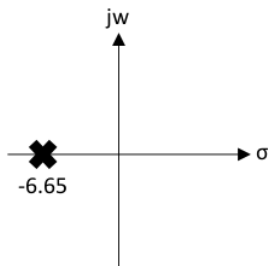


Figure 37

Pole lies at $S + (7.5K - 0.85) = 0$

$S = -(7.5K - 0.85) = -6.65$

$0.85/7.5 = 0.113$ this is the calculated minimum value of K

This is proven in the figure below by a root locus plot to show the minimum gain required for a stable system. As shown in figure 38 the same value as the previous calculation.

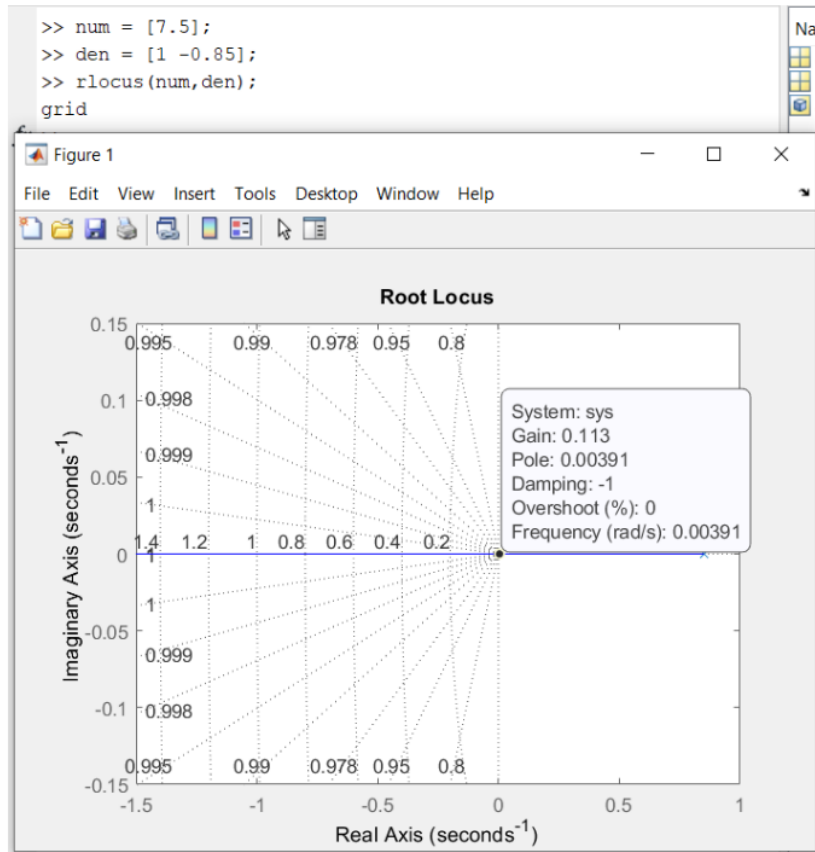


Figure 38

The system was built on matlab with the minium gain being used, the graph shows the response of the the circuit.

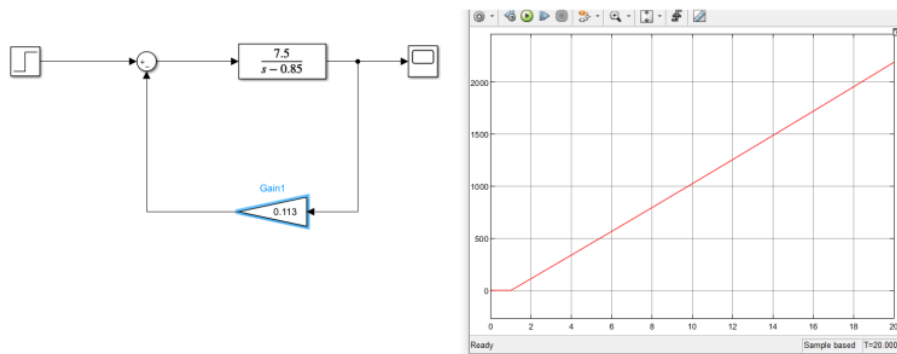


Figure 39

A separate value of 0.05 was then used for the gain with the response looking like the graph below.

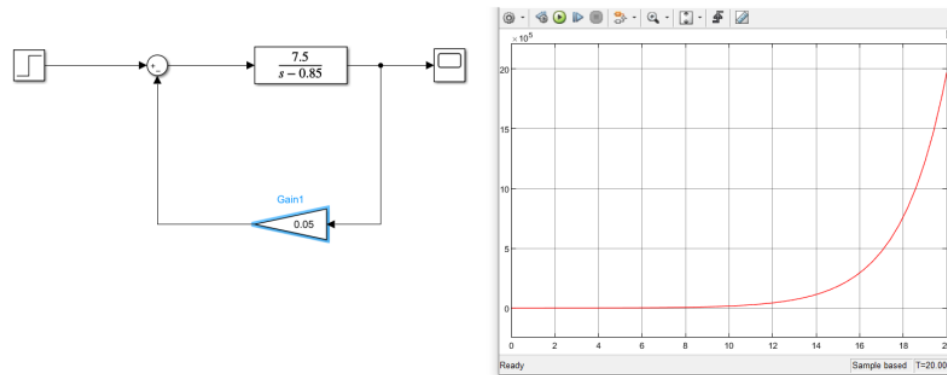


Figure 40

Another value of 0.4 was used for the gain for this response.

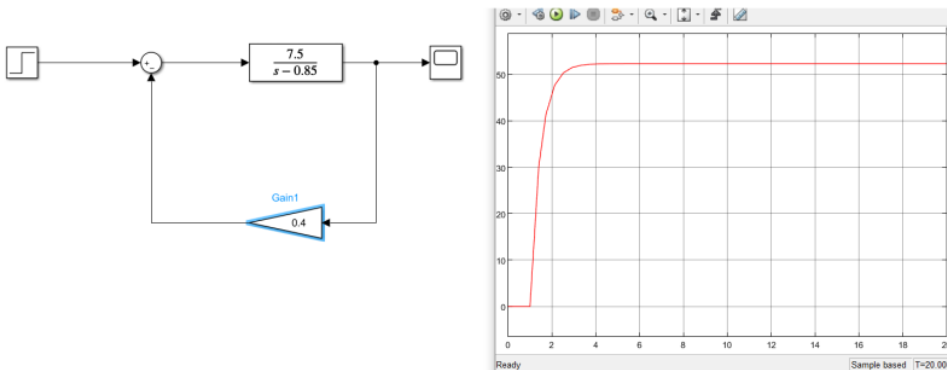


Figure 41

Table 11

Value of K	Stability
0.113	Minimum value of stability
0.05	Unstable
0.4	Stable

Figures 39, 40 and 41 show the results along with an analysis in table 10. As shown the minimum value of K is 0.113 for a stable system as the graph is linear. When the gain is less than this value the system goes unstable as shown in figure 40. And when the value of k is greater than 0.113 then the system is more stable as shown in figure 41.

Task 13

Transfer function

$$G(S) = \frac{Kt/LaJ}{s^2 + s(\frac{b}{J} + \frac{Ra}{La} + \frac{RaB}{LaJ} + (KtKe)/(LaJ))}$$

20

Time constant

$$Te = \frac{La}{Ra} = \frac{0.165}{1.5} = 0.11s$$

Standard form compare to transfer function

$$\frac{Kwn^2}{s^2 + 2zwns + wn^2}$$

$$Wn^2 = \frac{RaB}{LaJ} + \frac{KtKe}{LaJ} = \frac{1.5 \times 4.6 \times 10^{-6}}{0.165 \times 0.00042} + \frac{0.062 \times 0.063}{0.165 \times 0.00042} = 56.46 \text{ rad/s}$$

$$Wn = \sqrt{56.46} = 7.51 \text{ rad/s}$$

$$2zwn = \frac{B}{J} + \frac{Ra}{La} = \frac{4.6 \times 10^{-6}}{0.00042} + \frac{1.5}{0.165} = 9.1$$

$$z = \frac{2zwn}{2wn} = \frac{9.1}{2 \times 7.51} = 0.606 \text{ underdamped}$$

Stall torque and friction less no load speed

$$T_{stall} = \frac{KtVa}{Ra} = \frac{0.062 \times 15}{1.5} = 0.62 \text{ NM}$$

$$\Omega_{NL} = \frac{Va}{Ke} = \frac{15}{0.063} = 238.1 \text{ rad/s}$$

Load speed

$$\Omega_L = \frac{Va - \frac{RaXTl}{Kt}}{\frac{RaXb}{Kt} + Ke} = \frac{15 - \frac{1.5 \times 0.03}{0.062}}{\frac{1.5 \times 4.6 \times 10^{-6}}{0.062} + 0.063} = 226.17 \text{ rad/s}$$

Torque

$$\Omega = \frac{KtVa}{bRa + KtKe} = \frac{0.062 \times 15}{1.5 \times 4.6 \times 10^{-6} + 0.062 \times 0.063} = 237.68$$

$$Tm = 237.68 \times 4.6 \times 10^{-6} = 1.093 \times 10^{-3} \text{ Nm}$$

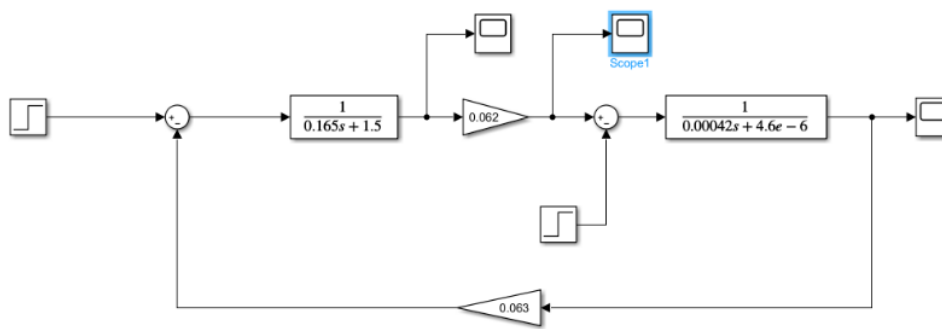


Figure 42

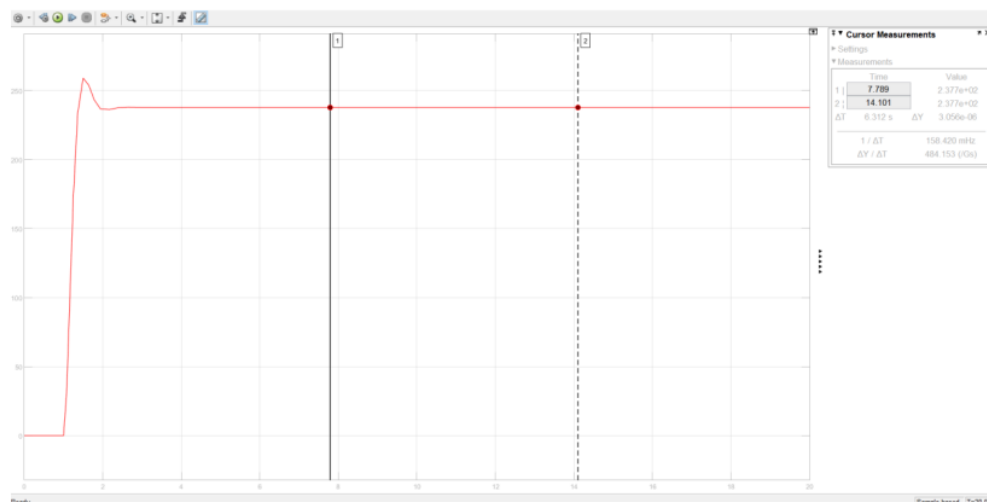


Figure 43

Disturbance of 0.03Nm

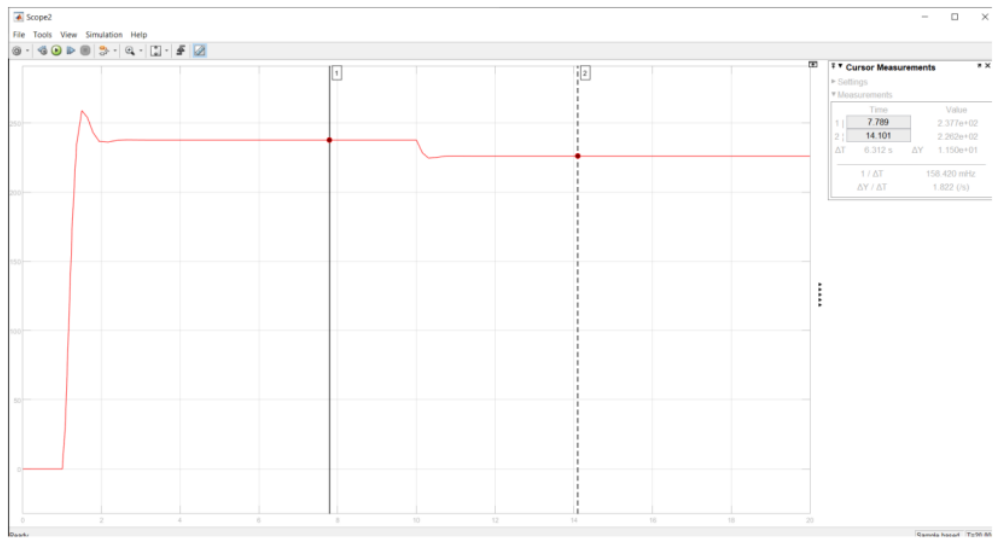


Figure 44

Torque response with no disturbance.

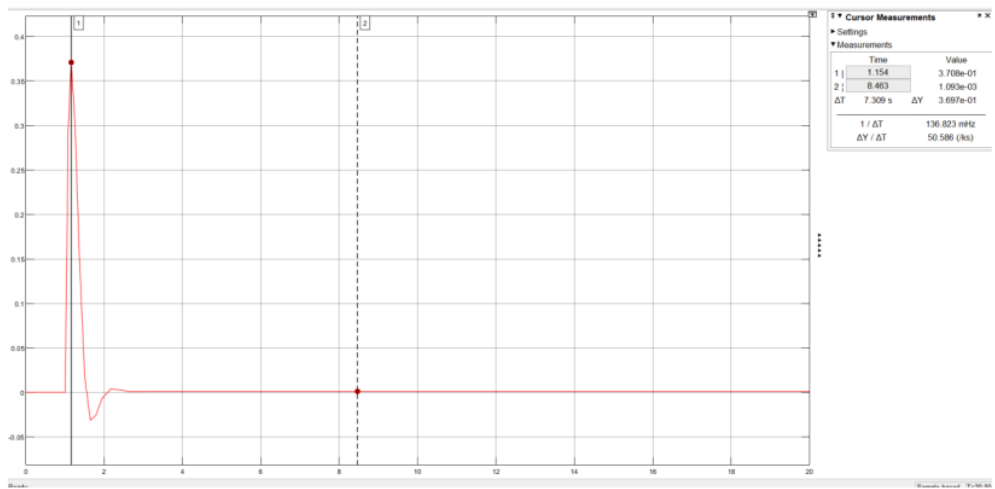


Figure 45

Torque response with disturbance of 0.03.

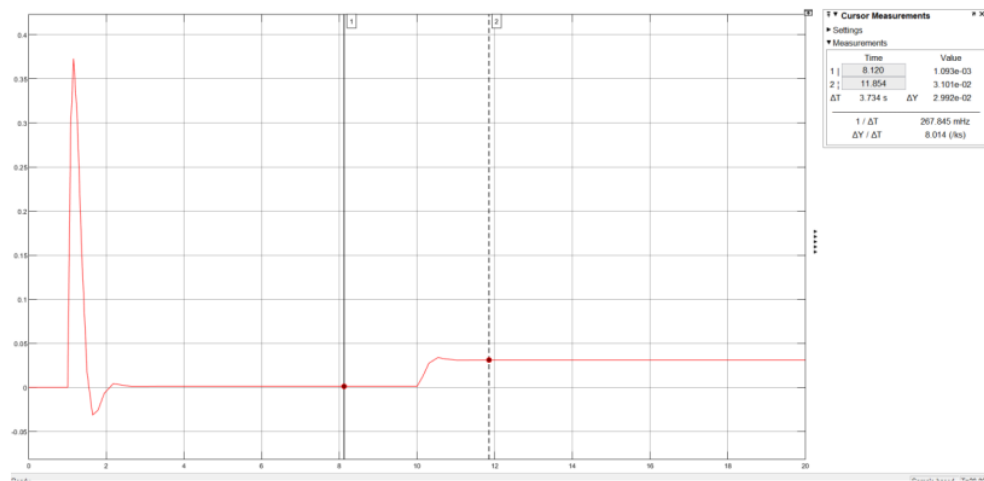


Figure 46

Table 12

	Calculated	Matlab
No load speed	238.1 rad/s	237.7 rad/s
torque	1.093×10^{-6} Nm	1.093×10^{-6} Nm
Speed with 0.03 disturbance	226.17	226.2 rad/s

Task 14

4 substations were created with the k_p values being 0.12 for first, 0.1 for second and then 0.3 for third, the fourth is a PID showing what it should look like. The substations are placed on order going downwards in the below diagram.

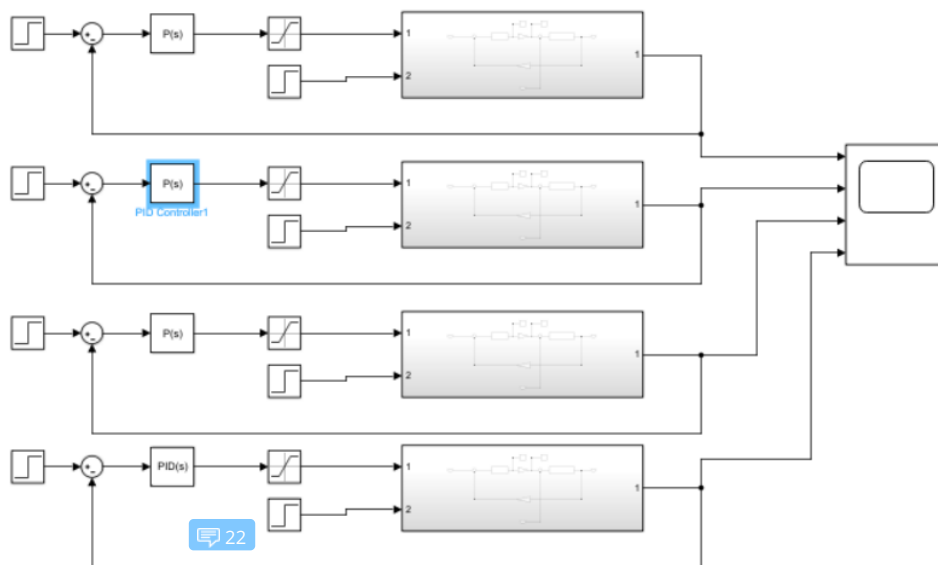


Figure 47

Steady state is 140 – cursor 1 value.

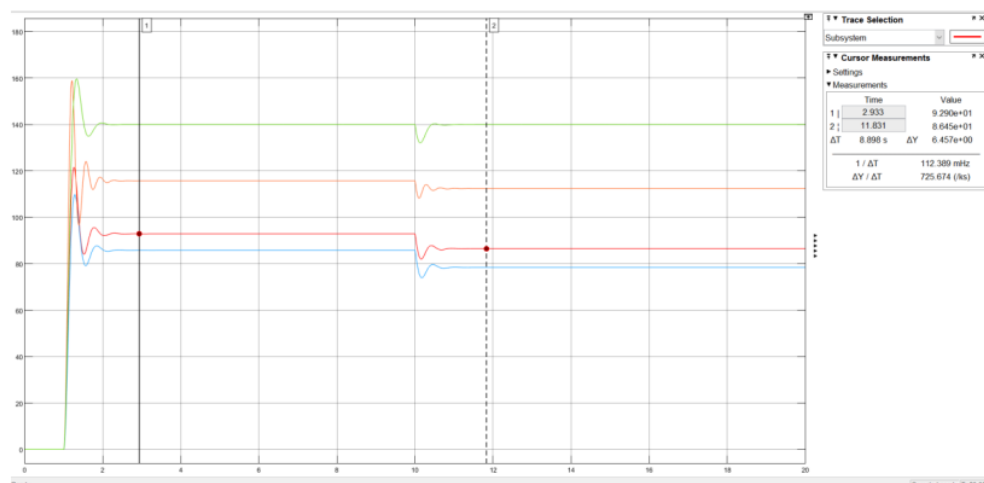


Figure 48

Overshoot % is cursor 1 divide by cursor 2 times by 100.

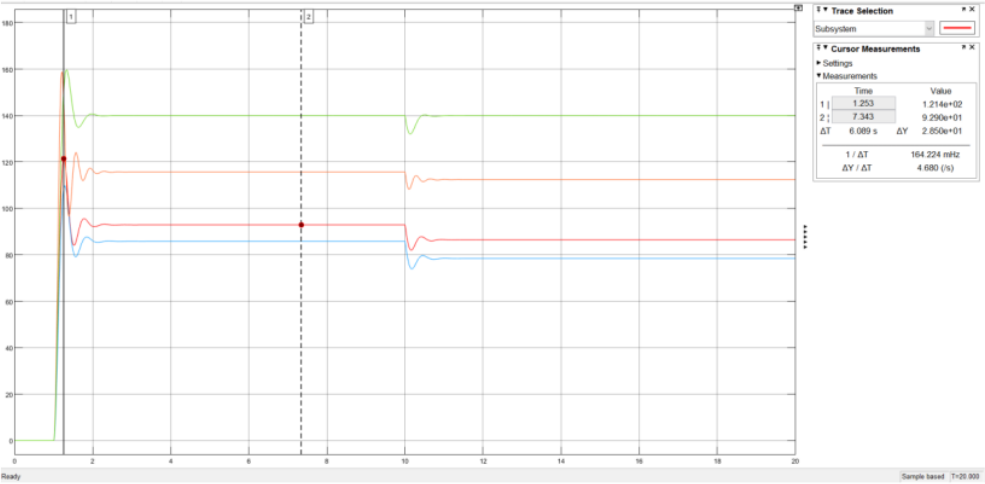


Figure 49

Time settled cursors 2-1

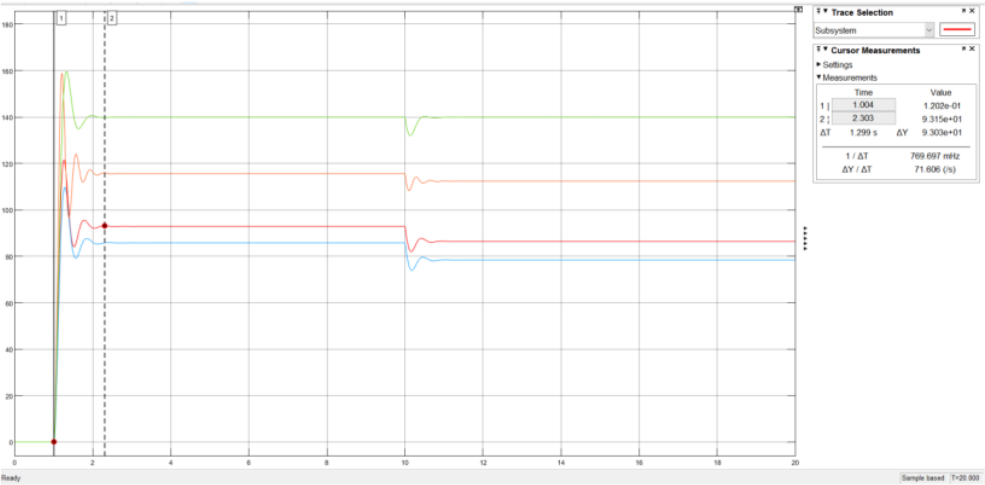
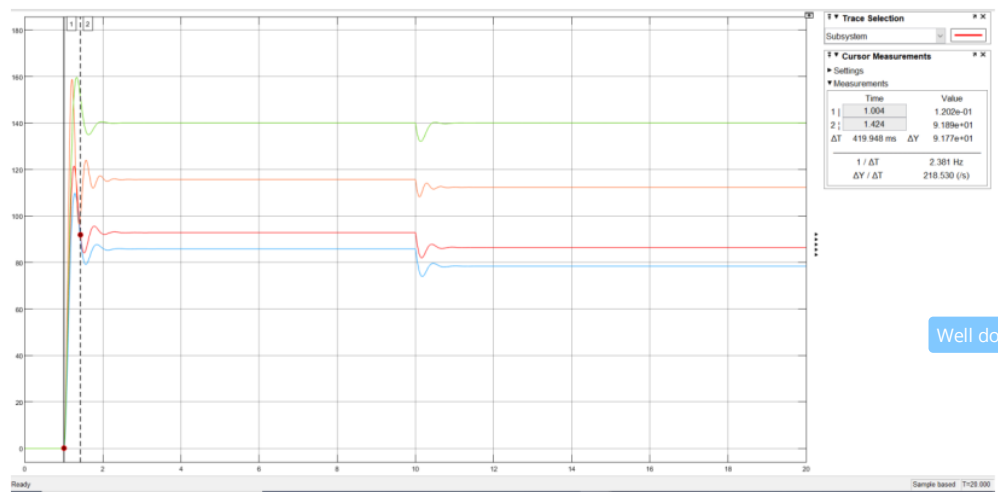


Figure 50

Rise time cursors 2-1



Well done

Figure 51

Table 13

Red	Model 1
Blue	Model 2
Orange	Model 3
Green	PID

Table 14

	Model 1	Model 2	Model 3
K_p	0.12	0.1	0.3
Time settled	1.299	1.142	1.378
Steady state error	47.1	54.17	24.3
Overshoot%	130%	127.8%	137%
Rise time	0.42	0.446	0.315

When the value of K_p is increased the settling time increases but the rise time decreases, this is because of the overshoot that happens when increasing the value. The steady state error is less when value of k_p is increased.

You have worked this out correctly, well

Task 15

The system from task 14 was changed to PI controllers to see the difference as shown below. All k_p values were the same with k_i being changed from 0.3 in the first, to 0.2 in the second and 0.4 in the third.

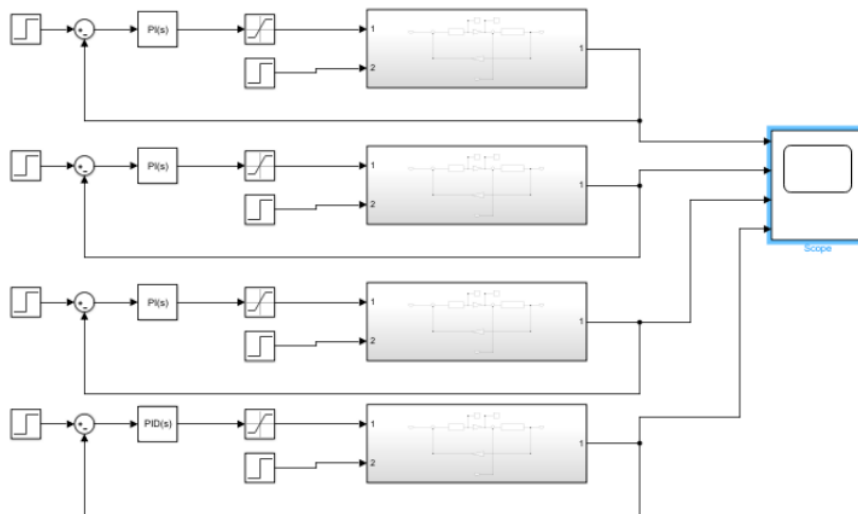


Figure 52

Steady state error

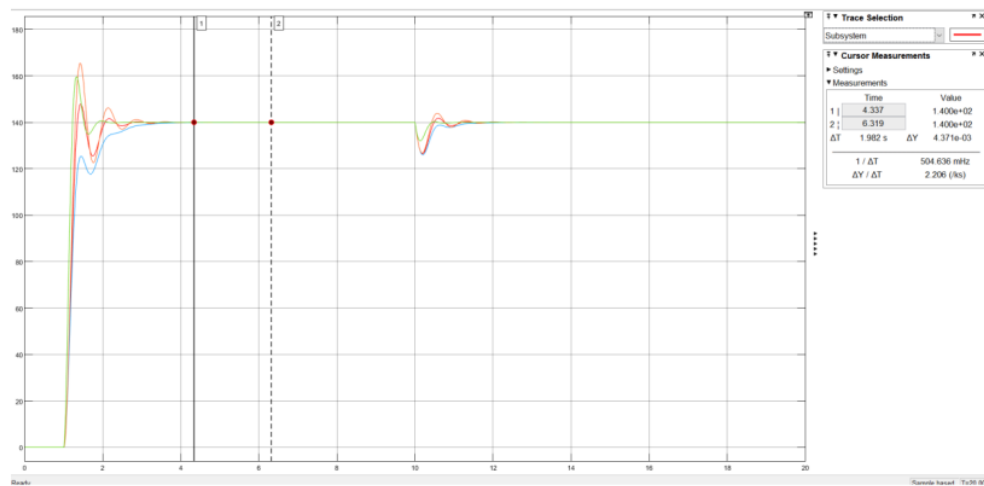


Figure 53

Overshoot%

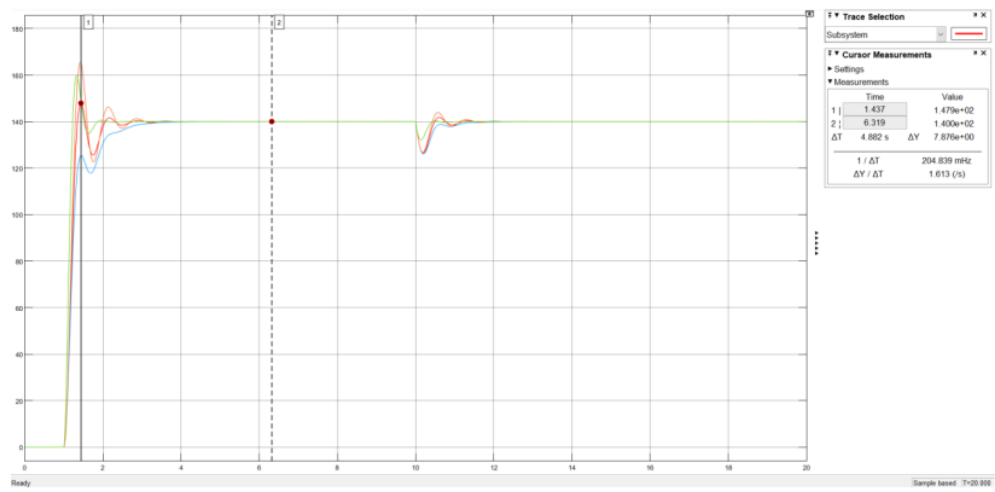


Figure 54

Rise time

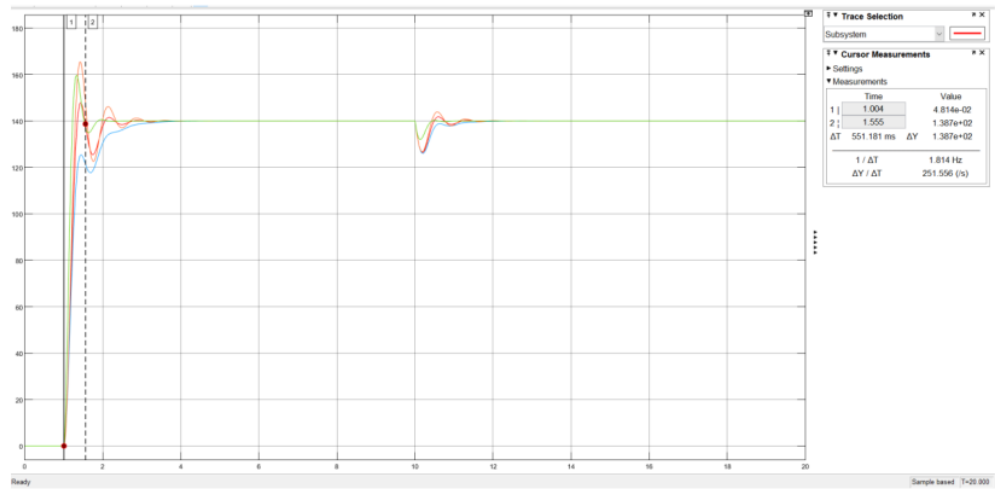


Figure 55

Time settled

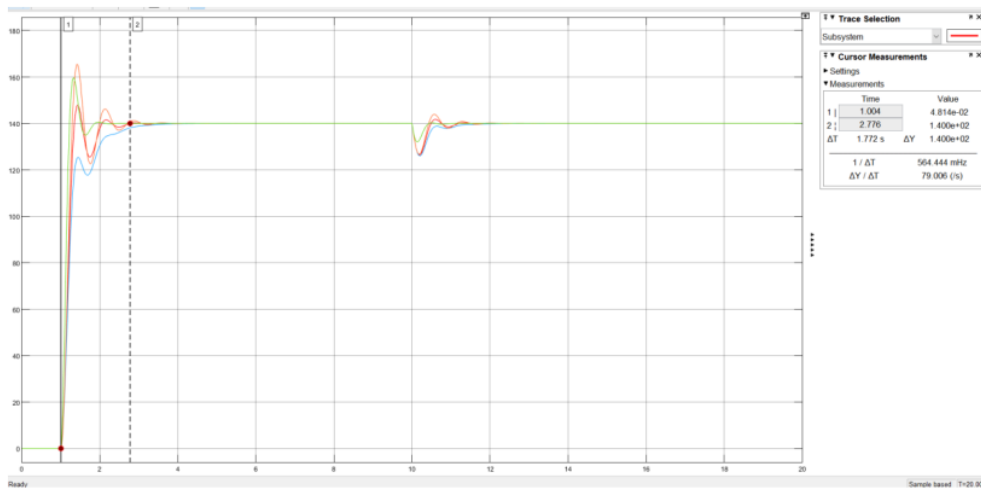


Figure 56

Table 15

Red	Model 1
Blue	Model 2
Orange	Model 3
Green	PID

Table 16

	Model 1	Model 2	Model 3
Ki	0.3	0.2	0.4
Time settled	1.772	2.281	2.311
Steady state error	0	0	0
Overshoot%	105.6%	89.6%	117.7%
Rise time	0.551	2.165	0.59

You have worked this out correctly, well

As can be seen by the graphs by adding the integral part it reduced the steady state error to 0. By looking at the table of results it's clear that changing k_i affects the time and there's an optimum value, too little increases the time and too much increases the time.

Task 16

The system from task 15 was changed to PID controllers to see the difference as shown below. All k_p and k_i values were the same with k_d being changed from 0.006 in the first, to 0.004 in the second and 0.01 in the third.

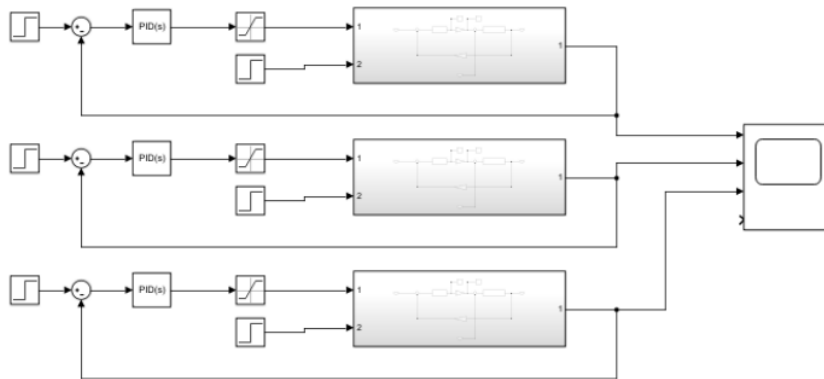


Figure 57

Steady state error

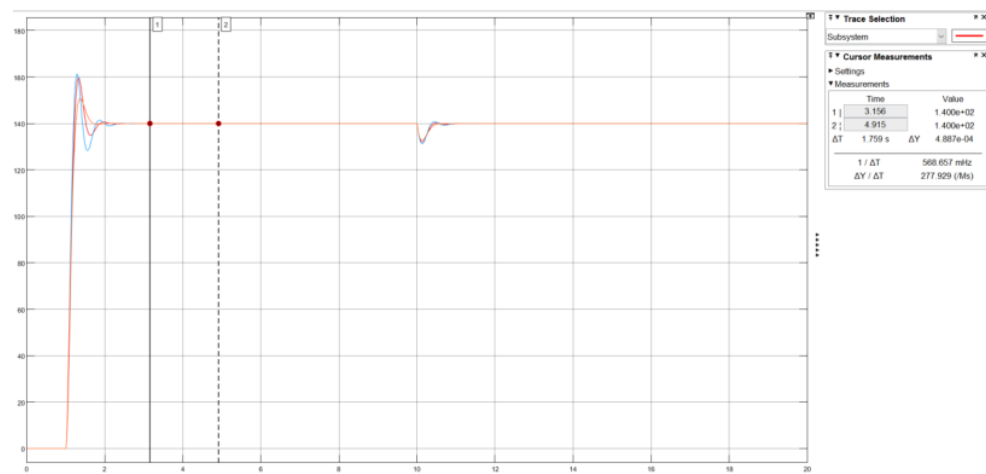


Figure 58

Overshoot %

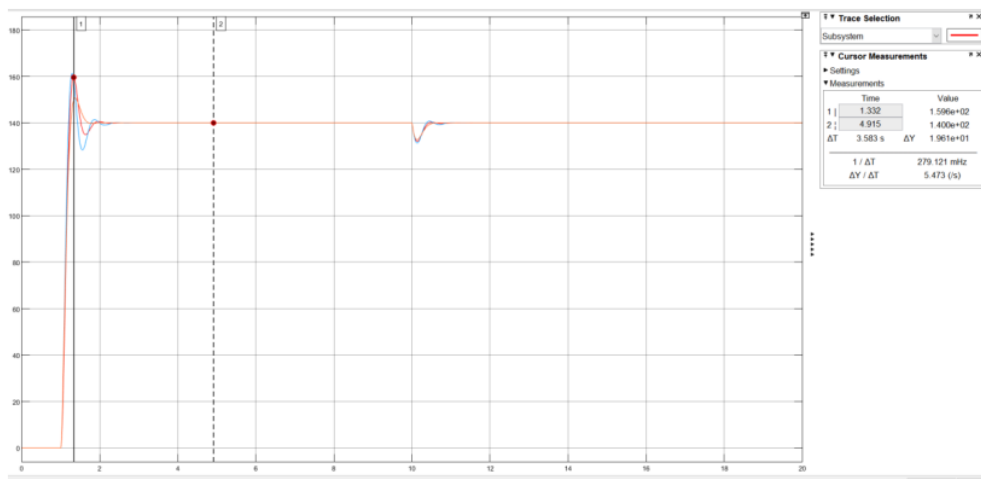


Figure 59

Rise time

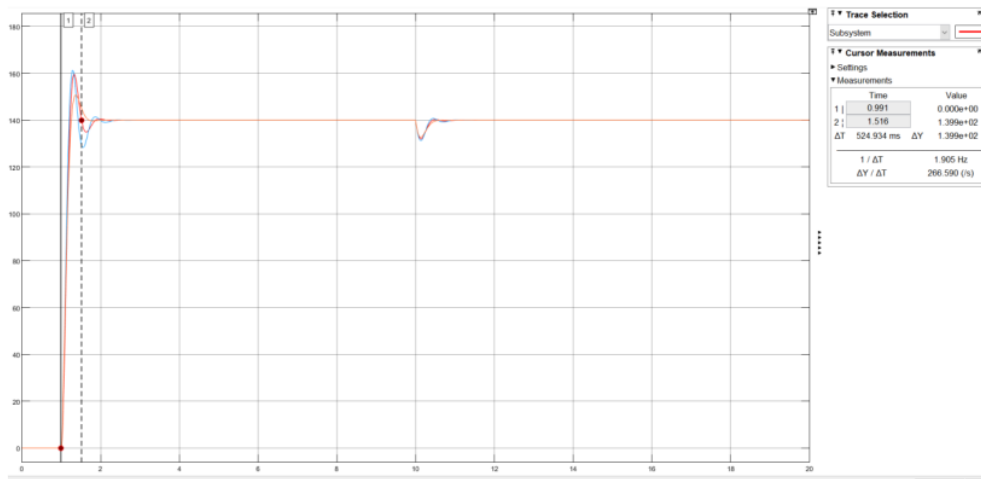


Figure 60

Settling time

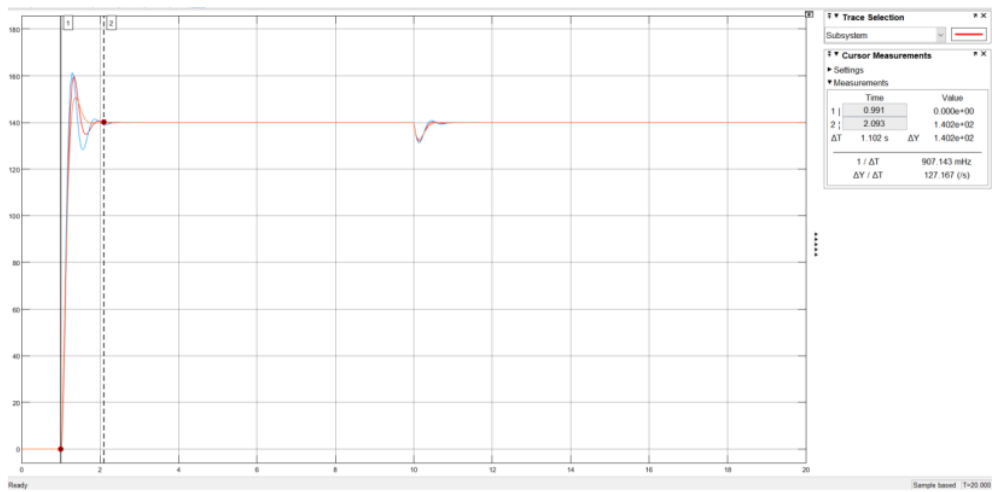


Figure 61

Table 17

Red	Model 1
Blue	Model 2
Orange	Model 3

Table 18

	Model 1	Model 2	Model 3
<u>Kd</u>	0.006	0.004	0.1
Time settled	1.102	1.22	0.787
Steady state error	0	0	0
Overshoot%	114%	115.1%	107.6%
Rise time	0.525	0.433	0.708

You have worked this out

As shown in the results adjusting the kd value upwards decreases the settling time. It does this by having less of an overshoot although this will increase the rise time as its less sharp.

Task 17

This system has 3 subsystems with the first being a P controller, the second being a PI controller and the third being a PID controller as shown in the figure below. The same values were used through each subsystem with P being 0.1290, I being 0.6224, and D being 0.0066.

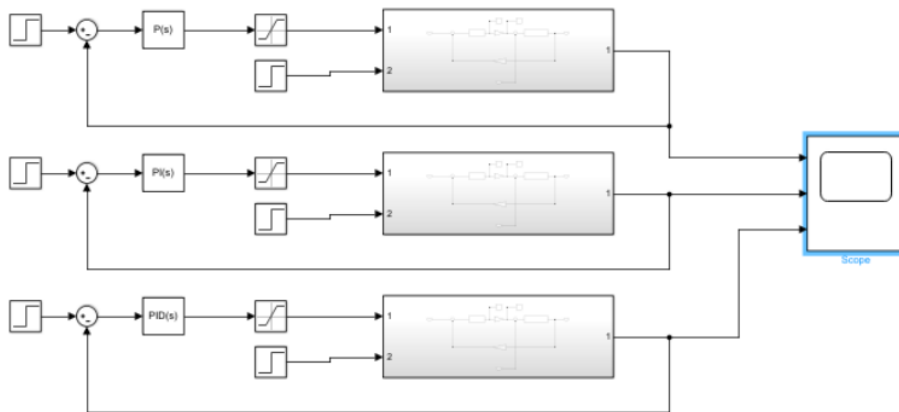


Figure 62

Steady state error

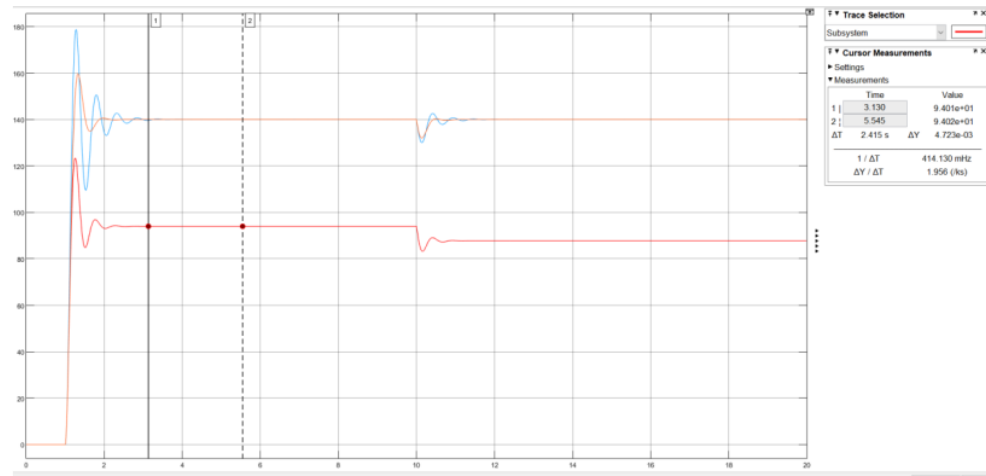


Figure 63

Overshoot %

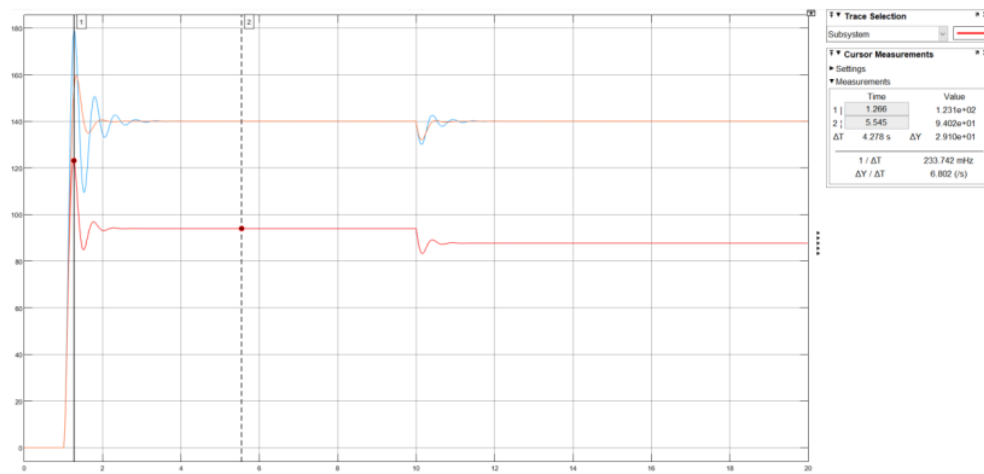


Figure 64

Rise time

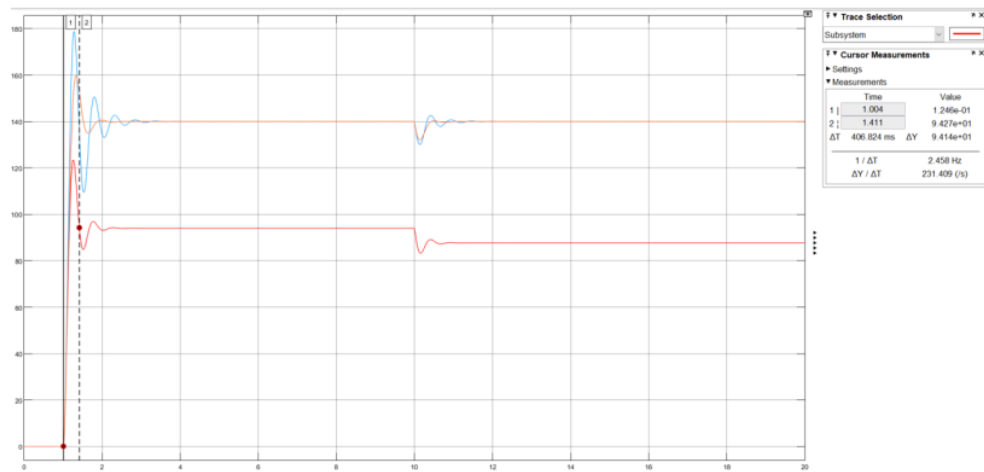


Figure 65

Settling time

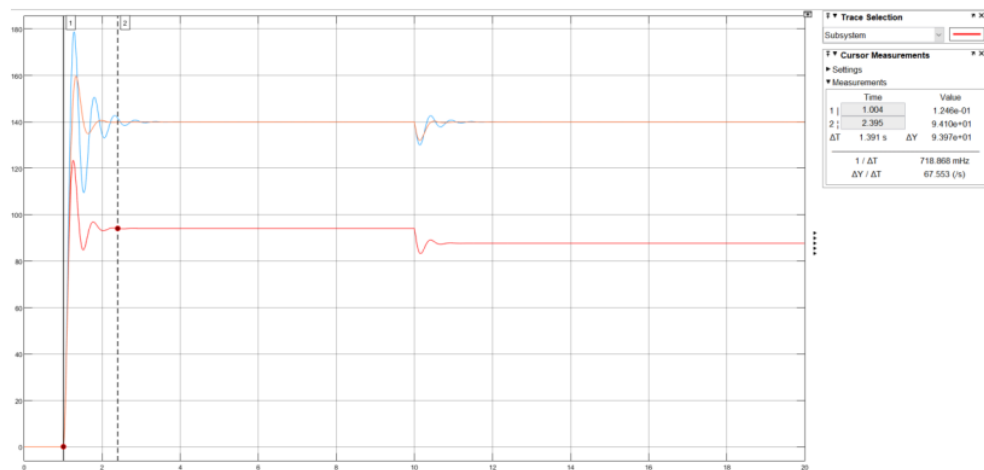


Figure 66

Table 19

Red	Model 1
Blue	Model 2
Orange	Model 3

Table 20

	Model 1	Model 2	Model 3
K_p	0.1290	0.1290	0.1290
K_i	n/a	0.6224	0.6224
K_d	n/a	n/a	0.0066
Time settled	1.391	2.349	1.207
Steady state error	45.99	0	0
Overshoot%	131.3%	127.6%	114%
Rise time	0.407	0.394	0.512

By looking at the table it shows that by adding I control to the P it eliminates the steady state error. The rise time decreases but with this the settling time increases because of the sharp gain. By adding the D control it evens the rise time and settling time out, the rise time is longer which brings down the settling time.

Task 18

This assignment showed how organisation and values of components effect a circuit. By organising components in a certain way a circuit can become a high pass or a low pass as shown previously. Adjusting values can change characteristics of a circuit such as adjusting the resistance changes the damping of the circuit this is the sharpness of the step response. A step response is an important characteristic as too sharp will overshoot and make the settling time longer. And too little will increase the rise time. The tasks also showed how changing the order of a filter has an effect such as the roll-off per decade increases with each order. At cut-off frequency the phase angle should be 45° in a RC circuit as the capacitor gives it a positive phase shift. An inductor would be -45° as it is 90° out of phase with a capacitor.

When controlling a speed of a motor it is important to get the PID control correct to optimize the characteristics. As shown when auto tuning through the tasks, with just the P control there is an obvious steady state error. By adding in the I control it eliminates the steady state error. And the D control is used to change the rise time and settling time. Adjusting the values of each control will have an effect on the results as shown in previous tasks.



1909756

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

63/100

PAGE 1

PAGE 2



Comment 1

give more meaningful titles

PAGE 3

PAGE 4

PAGE 5



Comment 2

Sp



Comment 3

explain how to get this, pot divider rule etc



Comment 4

needs a bit more explaining i.e. at $t=T$

PAGE 6



Comment 5

see comments for task 1

PAGE 7



Comment 6

state circuit you are analysing

PAGE 8



Comment 7

needs more explanation, you are jumping about, makes it hard to follow

PAGE 9



Comment 8

task 3 is LPF only



Comment 9

need circuit arrangement

PAGE 10

PAGE 11



Comment 10

task 4 is HPF only



Comment 11

show standard form, state circuit type

PAGE 12



You have worked this out correctly, well

PAGE 13



You have worked this out correctly, well

PAGE 14



You have worked this out correctly, well

PAGE 15

PAGE 16



Comment 12

no need to repeat tabulated values, rather look for trends or an overall conclusion of effects of changing R



Lacks essential detail

Lacks detail

PAGE 17

PAGE 18

PAGE 19



Comment 13

tabulate results and analyse.....

PAGE 20

PAGE 21

PAGE 22



Comment 14

where is the analysis? LPF with resonant point, what about Q factor and effect on max gain frequency moving to ω_n ?

PAGE 23

PAGE 24



Comment 15

Analysis missing, changes in R effects.....?



You have worked this out correctly, well

PAGE 25



Comment 16

units missing

PAGE 26



You have worked this out correctly, well



Comment 17

you must explain what you are doing? circuit, TF etc



You have worked this out correctly, well



Comment 18

vague, what has remained constant when scaled?



Comment 19

explain this argand diagram



Incorrect

You have worked this out wrongly. It is not correct, check work more carefully.



You have worked this out correctly, well



Comment 20

you must explain what you are doing, why is this the TF?



You have worked this out correctly, well



Comment 21

subsystems?



Comment 22

P only for this task



Well done

Well done



You have worked this out correctly, well



You have worked this out correctly, well



You have worked this out correctly, well



You have worked this out correctly, well



Comment 23

Too brief

GRADING FORM: NEW CSG-RUBRIC

JOSHUA REES

63

1. ENGAGEMENT WITH LITERATURE



NA

2. KNOWLEDGE AND UNDERSTANDING



Mostly good explanations as your calculations are correct, however, in a lot of cases you did not explain your methods, and there is essential information missing. 17/30

17

3. COGNITIVE AND INTELLECTUAL



Mostly good analysis in particular the control systems, however, in a lot of cases you did not analyse results, and there is essential information missing. 17/30

17

4. PRACTICAL APPLICATION



Excellent application of testing for matlab and simulink, showed high levels of practical application skills. 22/30

22

5. TRANSFERABLE SKILLS



Very good report overall. 7/10

7