

2119238

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Task 1 – Transient Analysis of a First Order RL Electrical Circuit

1.1

In order to carry out analysis of an RL electrical circuit, first component values must be selected. The selected values are:

$$R = 120\Omega$$

$$L = 0.02H$$

When t is equal to τ it is known that e^{-1} equals 0.368

Below is the calculated time constant for this circuit.

$$\tau = \frac{L}{R} = \frac{0.02}{120} = 0.16msec$$

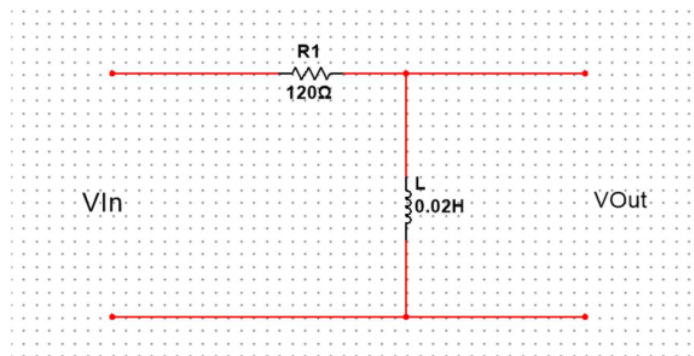


Figure 1 RL circuit multisim

1.2

$$\text{Laplace Formula} = \frac{sL}{sL+R} = \frac{0.02}{0.02+12} = 0.00016s$$

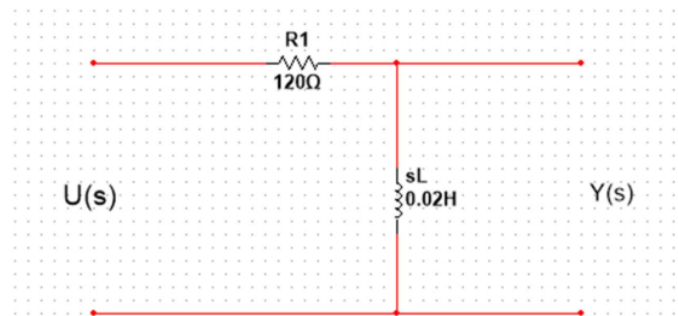


Figure 2 Laplace form for RL

1.3

Using the chosen figures, the code can now be written into MATLAB to see the response

```
1 s= tf('s');  
2 system= (0.02)*s/((0.02)*s +120);  
3 step(system);  
4 grid on
```

Figure 3 MATLAB code

The response and results are as seen below in the graph

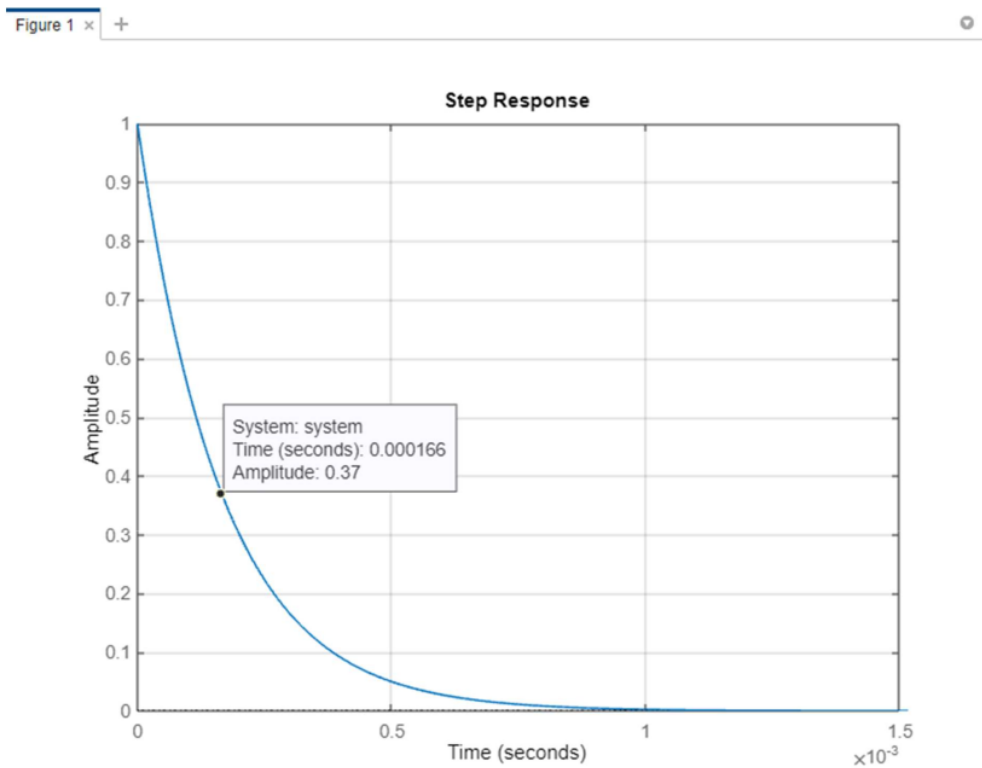


Figure 4 MATLAB response

Above given the characteristics of the circuit is the result of the MATLAB code entered, the cursor placed at 0.37 was placed here as it is as near to one time constant as possible (0.368).

1.4

Table of Results

	Calculated	Simulated	Error
Tau	0.166m	0.166m	0

1.5

Above is a table of results produced to compare the calculated and simulated results and to be able to see any discrepancies. The two results are exactly the same giving no error this is due to MATLAB being software that works off ideal values and has no outside influences.

The below formula is the reason the cursor was placed at one time constant (0.368)

$$y(t) = e^{\frac{-t}{\tau}}$$

$$y(t) = e^{\frac{-0.166}{0.166}}$$

$$y(t) = 0.368$$



Task 2 – Transient Analysis of a First Order RC Electrical Circuit

2.1

In order to carry out analysis of an RC electrical circuit, first component values must be selected. The selected values are:

$$R = 800\Omega$$

$$L = 0.03H$$

$$\tau = RC = 800 \times 0.03 = 24s$$

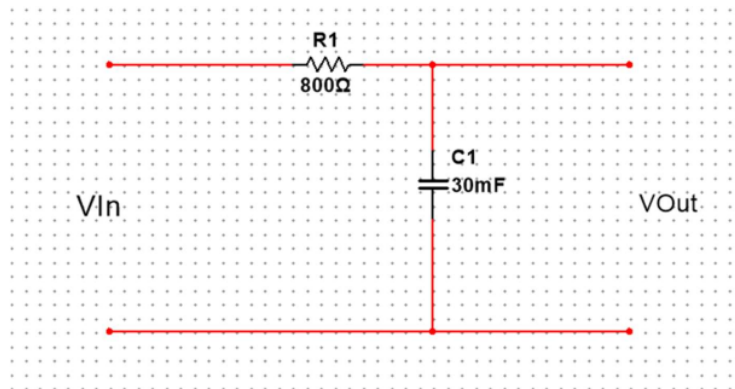


Figure 5 RC circuit multisim

2.2

$$\text{Laplace Formula} = \frac{1}{RCs+1} = \frac{1}{800 \times 0.03 + 1} = 0.04s$$

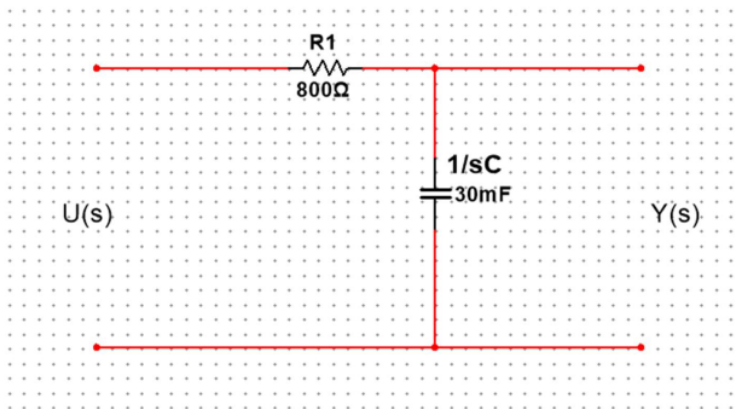


Figure 6 Laplace form for RC

2.3

Using the chosen figures, the code can now be written into MATLAB to see the response

```
1 s=tf('s');  
2 system = 1/((800)*(0.03)*s+1)  
3 step(system);  
4 grid on  
5
```

Figure 7 MATLAB code

The response to this code can be seen in the graph below

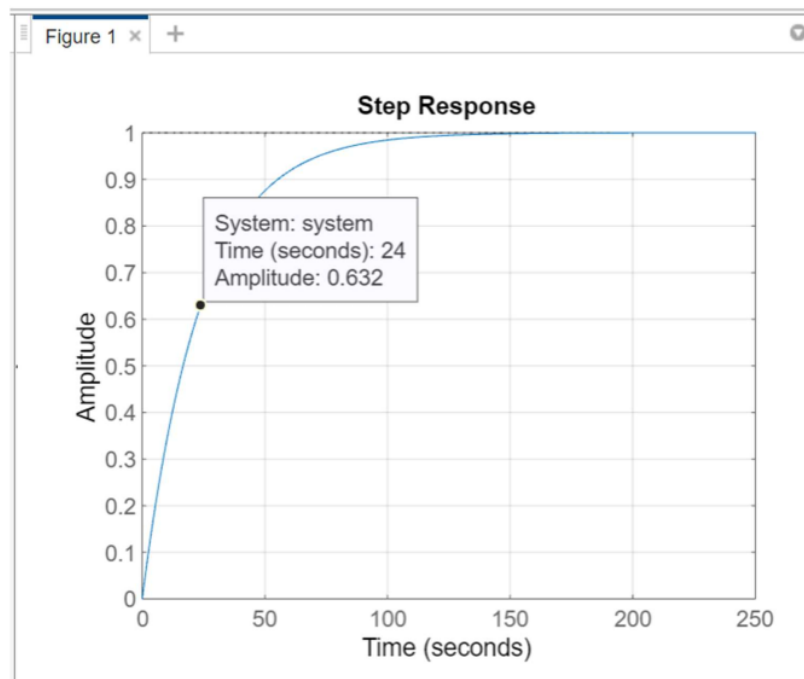


Figure 8 RC MATLAB response

Above given the characteristics of the circuit is the result of the MATLAB code entered, the cursor placed at 0.632 was placed here as it is one time constant.

2.4

	Calculated	Simulated	Error
Tau	24s	24s	0

2.5

Above is a table of results produced to compare the calculated and simulated results and to be able to see any discrepancies. The two results are the same giving no error this is due to MATLAB being software that works off ideal values and has no outside influences. As seen on the cursor on the above graph, the circuit takes 24 seconds to reach 63.2% of its final value. The proof behind this is seen in the equation below.

$$y(t) = 1 - e^{\frac{-t}{\tau}}$$

$$y(t) = 1 - e^{\frac{-24}{24}}$$

$$y(t) = 0.632$$



Task 3 – Frequency Performance Analysis of a First Order RL Electrical Circuit

3.1

The values chosen are $R = 130 \Omega$ and $L = 0.02$

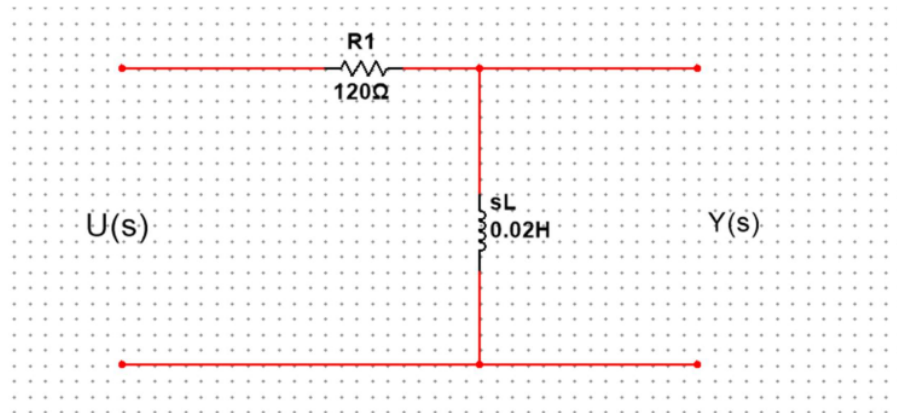


Figure 9 Laplace RL circuit

The low pass filter transfer function can be seen below

$$\tau = \frac{L}{R}$$

$$\omega_c = \frac{R}{L}$$

$$\omega_c = \frac{120}{0.02} = 6000 \text{ rad/s}$$

Where

$$H(s) = \frac{1}{\omega_c} = \frac{s}{s + \omega_c} = \frac{1}{s + 6000}$$

3.2

Using this re-arranged equation the code can now be entered into MATLAB.

```
1 s=tf('s');  
2 system = s/(s+6000);  
3 bode(system);  
4 grid on
```

Figure 10 MATLAB code for Laplace RL circuit

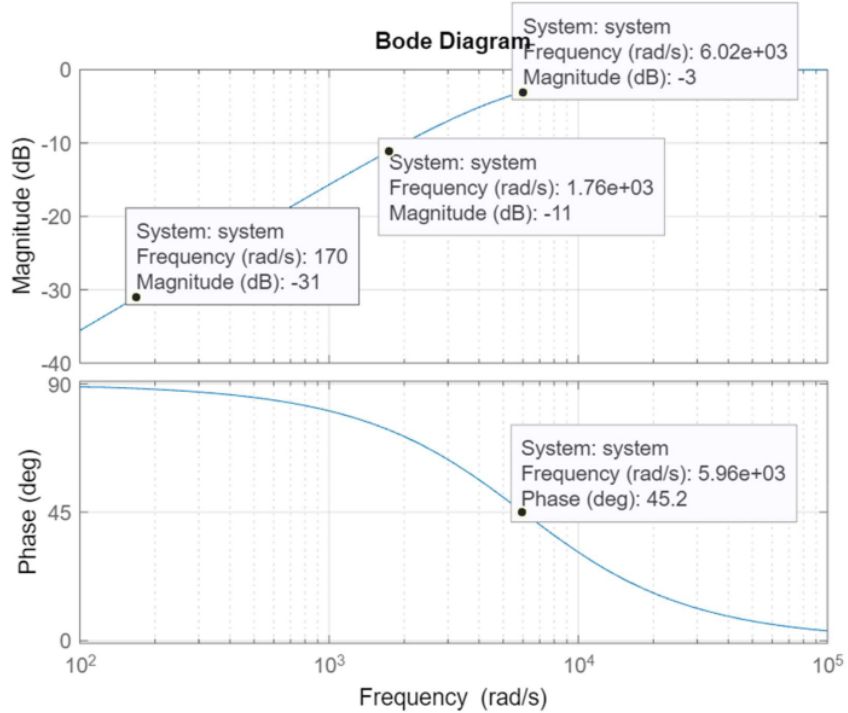


Figure 11 MATLAB response for Laplace RL circuit

3.3

The results are as found below

	Calculated	Measured
ω_c	6000	6020
Phase	45 °	45.2 °
Roll off	20 dB	28 dB

3.4



This design only allows high frequencies to pass through after the 3db point, as the component lay out makes it a high pass filter. There are very little errors seen in the result table above, therefore supporting the analysis. The roll off is 20db as it is a first order circuit, also the phase shift is at 45 degrees as it is at natural frequency.



Task 4 – Frequency Performance Analysis of a First Order RC Electrical Circuit

4.1

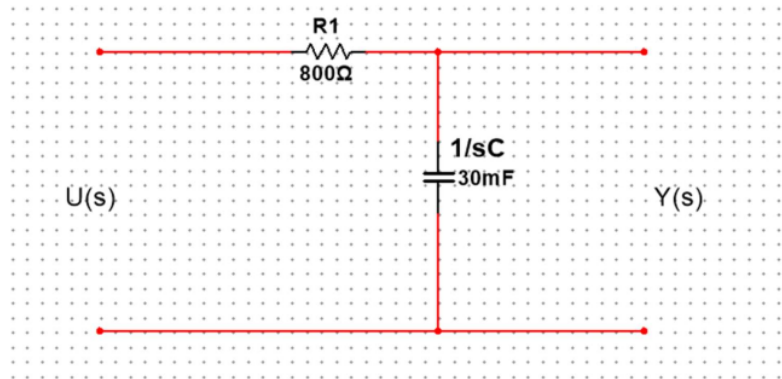


Figure 12 Laplace RC circuit

$$R = 800\Omega \quad C = 30\text{mf}$$

$$\text{Cut-off frequency} = \omega_c = \frac{1}{RC} = \frac{1}{800 \times 30 \times 10^{-3}} = 0.0416 \text{ Rad/S}$$

$$\text{Laplace formula} = H(s) = \frac{1}{\omega_c + s} = \frac{\frac{1}{\omega_c}}{\frac{1}{\omega_c} + \frac{s}{\omega_c}} = \frac{\omega_c}{s + \omega_c} = \frac{0.0416}{s + 0.0416}$$

4.2

```

1  s=tf('s');
2  system = 0.0416/(s+0.0416);
3  bode(system);
4  grid on

```

Figure 13 MALAD code for Laplace RC

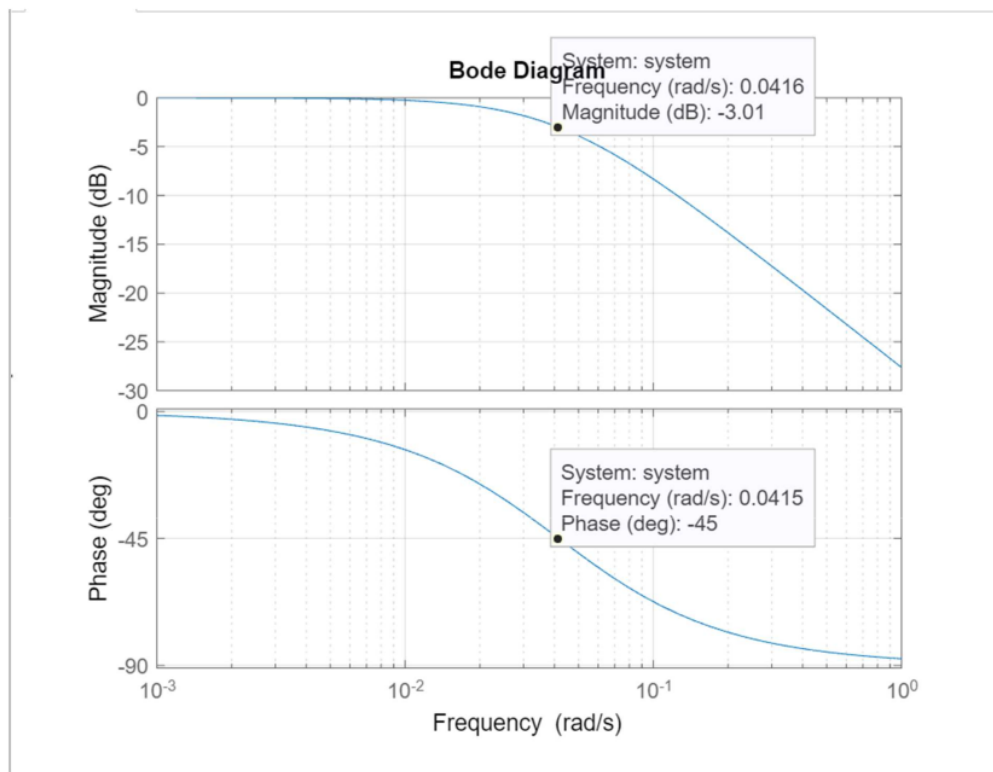


Figure 15 Phase shift and natural frequency results

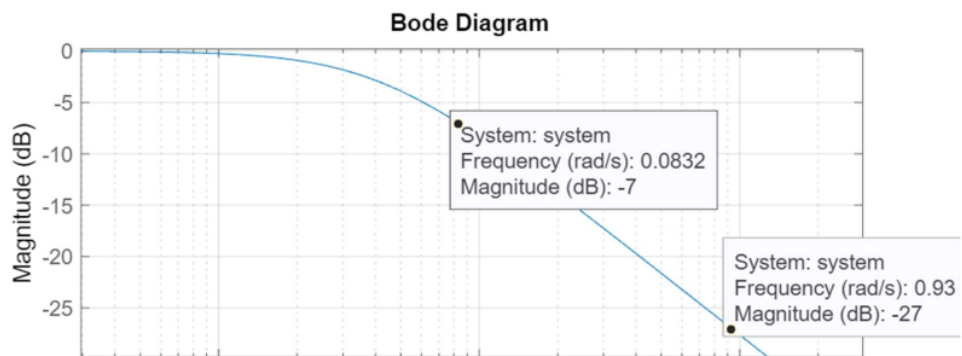


Figure 14 Roll-off results

4.3

The results are as seen below

	Calculated	Measured
ωc	0.0416 Rad/S	0.0416 Rad/S
Phase	45 degrees	45 degrees
Roll off	20 dB	20 dB

4.4

This design only allows low frequencies to pass through after the 3db point, as the component lay out makes it a low pass filter. There are very little errors seen in the result table above, therefore supporting the analysis. The roll off is 20db as it is a first order circuit, also the phase shift is at 45 degrees as it is at natural frequency.



Task 5 – Transient Performance Analysis of a Second Order Series Electrical Circuit

5.1

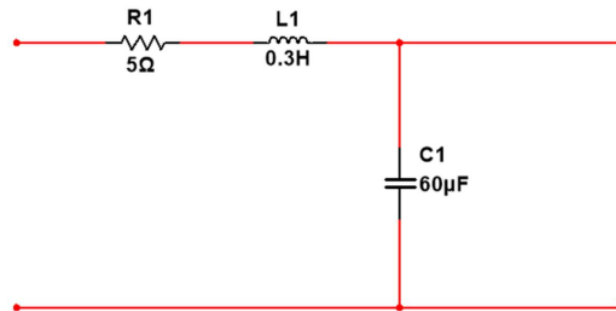


Figure 16 RLC circuit

The selected component values are

$$R = 5\Omega \quad L = 0.3 \quad C = 60\mu\text{F} \quad K = 1$$

5.2

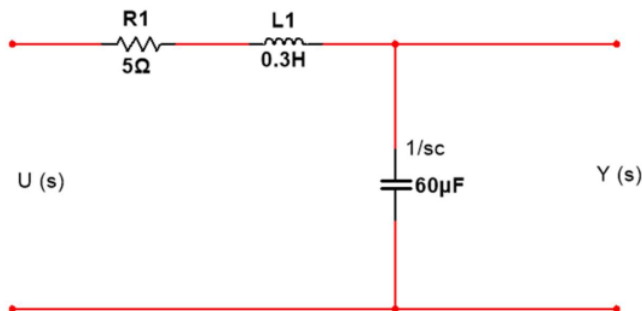


Figure 17 RLC Laplace form

$$H(s) = \frac{K W n^2}{s^2 + 2 \zeta W n s + W n^2}$$

5.3

The following equations were used to calculate the natural frequency and damping factor. The natural frequency will remain the same throughout all circuits.

$$\text{Natural frequency} = W_n = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.3 \times 60 \times 10^{-6}}} = 235.70 \text{ Rad/S}$$

$$\text{Damping factor} = \zeta = \frac{R}{2} \sqrt{\frac{C}{L}}$$

Underdamped

The under damped equations are as seen below.

R = 5 ohms

$$\text{Damping factor} = \zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{5}{2} \sqrt{\frac{60 \times 10^{-6}}{0.3}} = 0.35 < 1 \text{ under damped}$$

$$H(s) = \frac{K W_n^2}{s^2 + 2 \zeta W_n s + W_n^2} = \frac{1 \times 235.70^2}{s^2 + ((2 \times 0.35 \times 235.70) s) + 235.70^2}$$

Overdamped

The over damped equations are as seen below.

R = 290 ohms

$$\text{Damping factor} = \zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{290}{2} \sqrt{\frac{60 \times 10^{-6}}{0.3}} = 2.05 > 1 \text{ over damped}$$

$$H(s) = \frac{K W_n^2}{s^2 + 2 \zeta W_n s + W_n^2} = \frac{1 \times 235.70^2}{s^2 + ((2 \times 2.05 \times 235.70) s) + 235.70^2}$$

Critically damped

The damping factor in a critically damped circuit must equal to 1. To get it to equal 1 the damping factor equation must be rearranged, and zeta must equal 1.

$$R = \frac{2 \times \zeta}{\left(\sqrt{\frac{C}{L}}\right)} = \frac{2 \times 1}{\left(\sqrt{\frac{60 \times 10^{-6}}{0.3}}\right)} = 141.42 \text{ ohms}$$

$$\text{Damping factor} = \zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{141.42}{2} \sqrt{\frac{60 \times 10^{-6}}{0.3}} = 1 \quad \text{equal 1 critically damped}$$

$$H(s) = \frac{K W n^2}{s^2 + 2 \zeta W n s + W n^2} = \frac{1 \times 235.70^2}{s^2 + ((2 \times 1 \times 235.70) s) + 235.70^2}$$

No damping

$$R = 2 \times 10^{-6}$$

The R value was selected as this so that the damping factor would be very close to 0.

$$\text{Damping factor} = \zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{2 \times 10^{-6}}{2} \sqrt{\frac{60 \times 10^{-6}}{0.3}} = 14.14 \times 10^{-9}$$

$$H(s) = \frac{K W n^2}{s^2 + 2 \zeta W n s + W n^2} = \frac{1 \times 235.70^2}{s^2 + ((2 \times 14.14 \times 10^{-9} \times 235.70) s) + 235.70^2}$$

5.4

Under damped

```
1 s = tf('s');  
2 system = 235.70^2/(s^2+164.99*s+235.70^2);  
3 step(system);  
4 grid on;  
5
```

Figure 18 Under damped code

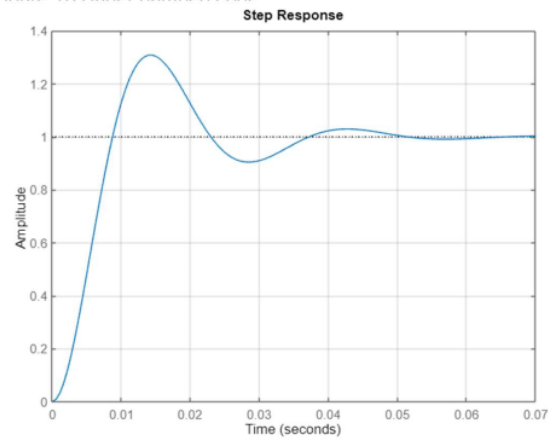


Figure 19 Under damped results

Overdamped

```
1 s = tf('s');  
2 system = 235.70^2/(s^2+966.37*s+235.70^2);  
3 step(system);  
4 grid on;
```

Figure 20 Over damped code

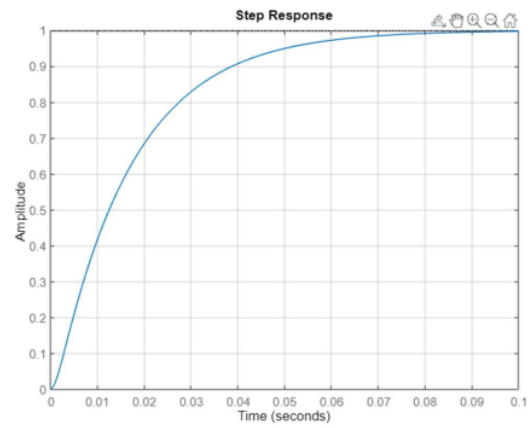


Figure 21 Under damped results

Critically damped

```

1 s = tf('s');
2 system = 235.70^2/(s^2+471.45*s+235.70^2);
3 step(system);
4 grid on;

```

Figure 22 Critically damped code

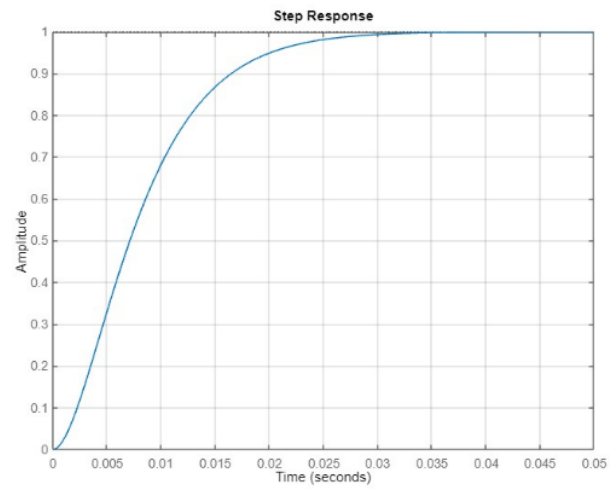
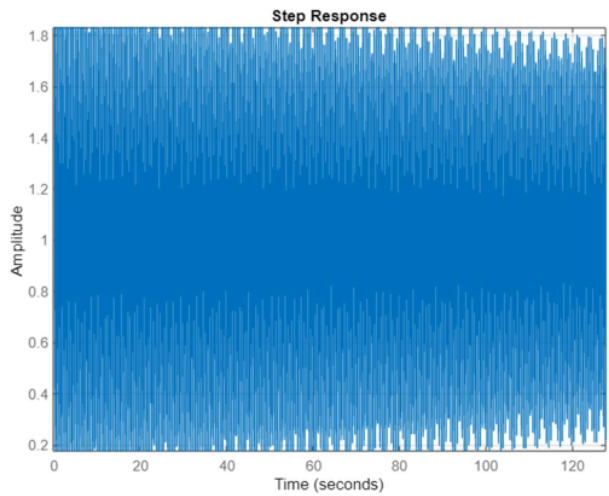


Figure 23 Critically damped results

No damping

```
Task5no4.m × +
1  s = tf('s');
2  system = 235.70^2/(s^2 + 0.0000067*s + 235.70 ^ 2);
3  step (system);
4  grid on;
```

Figure 24 No damping code



5.5

Figure 25 No damping results

Resistor values(Ω)	Damping factor(ζ)	Effect
5	0.35 ($\zeta < 1$)	Underdamping
290	2.05 ($\zeta > 1$)	Overdamping
141.42	1 ($\zeta = 1$)	Critically damped
2×10^{-6}	14.14×10^{-9} ($\zeta = 0$)	No damping

5.7

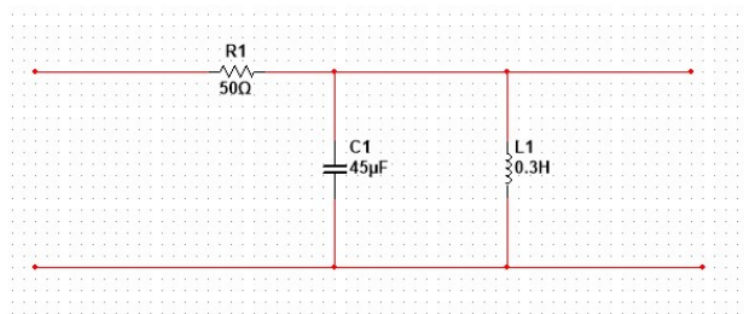
From all the graphs produced it can be seen how the R value effected each circuit and the circuits properties. The circuit being second order meant it was growing towards equilibrium. The underdamping shot quickly up to the equilibrium then overshoot before oscillating. The overdamping circuit slowly grows towards the equilibrium. Also, the critically damped grew slowly and had 0 overshoot. Finally, the no damping had major oscillations and will never reach the equilibrium.

Task 6 – Transient Performance Analysis of a Second Order Parallel Electrical Circuit

6.1

The component values selected are below and used to produce the circuit.

$$R = 50\Omega \quad L = 0.3 \quad C = 45\mu\text{F} \quad K = 1$$



6.2

Figure 26 RLC circuit

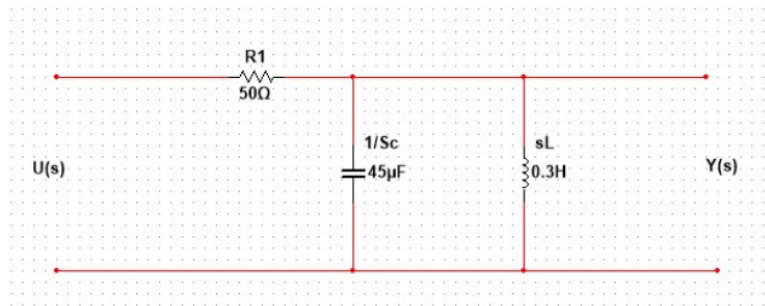


Figure 27 RLC Laplace form

$$\text{As } H(s) = \frac{s \times \frac{1}{RC}}{s^2 + \left(\frac{1}{RC} \times s\right) + \frac{1}{LC}} \quad \text{and} \quad H(s) = \frac{K W n^2}{s^2 + 2 \zeta W n s + W n^2}$$

as both are equal, the dominators will be swapped.



6.3

The following equations are used to calculate the damping factor and natural frequency. Each circuit following will have the same natural frequency.

$$\text{Damping factor} = \zeta = \frac{1}{2 \times R} \sqrt{\frac{L}{C}}$$

$$\text{Natural frequency} = \omega_n = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.3 \times 45 \times 10^{-6}}} = 272.17 \text{ Rad/S}$$

Under damped

$$R = 50\Omega$$

$$\zeta = \frac{1}{2 \times 50} \sqrt{\frac{0.3}{45 \times 10^{-6}}} = 0.82$$

$$H(s) = \frac{s \times \frac{1}{RC}}{s^2 + 2 \zeta \omega_n s + \omega_n^2} = \frac{s \times \frac{1}{50 \times 45 \times 10^{-6}}}{s^2 + (2 \times 0.82 \times 272.17 \times s) + 272.17^2}$$

Over damped

$$R = 5\Omega$$

$$\zeta = \frac{1}{2 \times 5} \sqrt{\frac{0.3}{45 \times 10^{-6}}} = 8.16$$

$$H(s) = \frac{s \times \frac{1}{RC}}{s^2 + 2 \zeta \omega_n s + \omega_n^2} = \frac{s \times \frac{1}{5 \times 45 \times 10^{-6}}}{s^2 + (2 \times 8.16 \times 272.17 \times s) + 272.17^2}$$

Critically damped

For critically damped to be attained the damping factor must equal to 1. To achieve this the damping factor equation is rearranged to find R.

$$R = \frac{1}{2} \sqrt{\frac{L}{C}} = \frac{1}{2} \sqrt{\frac{0.3}{45 \times 10^{-6}}} = 40.82\Omega$$

$$\zeta = \frac{1}{2 \times 40.82} \sqrt{\frac{0.3}{45 \times 10^{-6}}} = 1$$

$$H(s) = \frac{s \times \frac{1}{RC}}{s^2 + 2\zeta W_n s + W_n^2} = \frac{s \times \frac{1}{40.82 \times 45 \times 10^{-6}}}{s^2 + (2 \times 1 \times 272.17 \times s) + 272.17^2}$$

No damping

$$R = 320\Omega$$

$$\zeta = \frac{1}{2 \times 320} \sqrt{\frac{0.3}{45 \times 10^{-6}}} = 0.13$$

$$H(s) = \frac{s \times \frac{1}{RC}}{s^2 + 2\zeta W_n s + W_n^2} = \frac{s \times \frac{1}{320 \times 45 \times 10^{-6}}}{s^2 + (2 \times 0.13 \times 272.17 \times s) + 272.17^2}$$

6.4

Under damped

```
Task6part1.m x untitle * x +
1 s = tf('s')
2 system = (s*444.44)/(s^2+444.44*s+74074.074);
3 step(system);
4 grid on;
5
```

Figure 28 Under damped MATLAB code

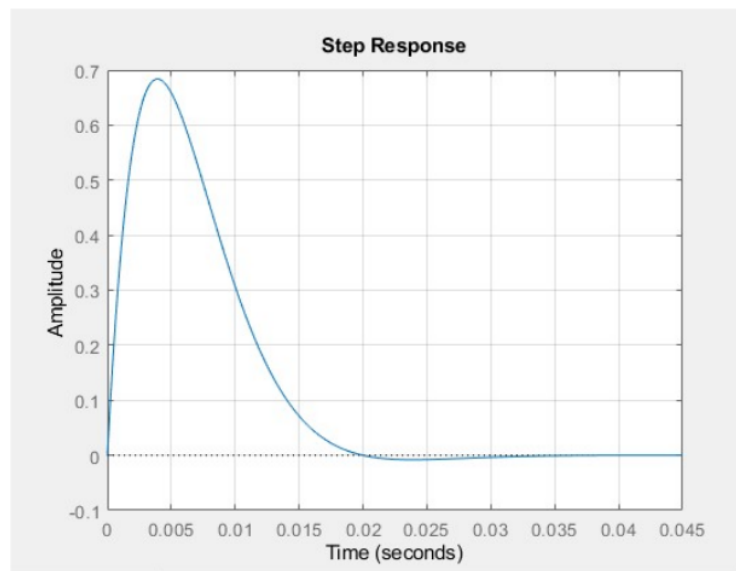


Figure 29 Under damped MATLAB results

Over damped

```
Task6part1.m  untitled *  Task6part2.m  +
1  s = tf('s')
2  system = (s*4444.4)/(s^2+4444.4*s+74074.074);
3  step (system);
4  grid on;
5
```

Figure 30 Over damped MATLAB code

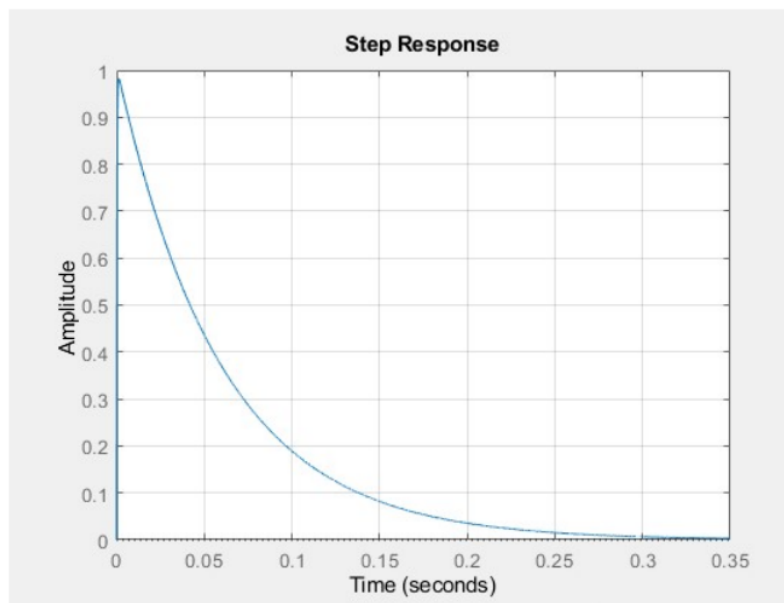


Figure 31 Over damped MATLAB results

Critical

```
Task6part1.m x untitle * x Task6part2.m x Task6part3.m x +
1      s = tf('s')
2      system = (s*544.39)/(s^2+544.39*s+74074.074);
3      step (system);
4      grid on;
```

Figure 32 Critical MATLAB code

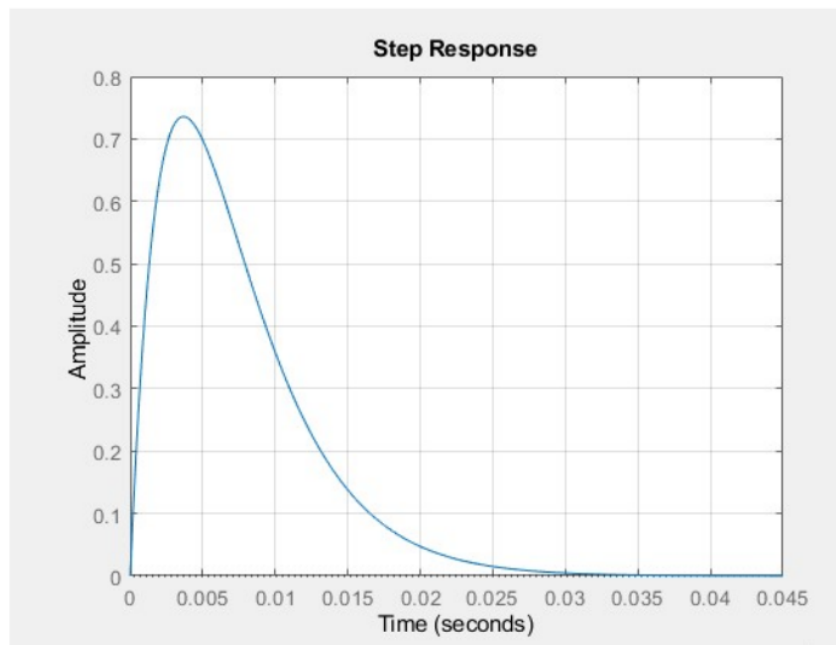


Figure 33 Critical MATLAB results

No damping

```
Task6part1.m x untitle* x Task6part2.m x Task6part3.m x Task6part4.m x
1 s = tf('s')
2 system = (s*69.4)/(s^2+69.4*s+74074.074);
3 step(system);
4 grid on;
```

Figure 35 No damping MATLAB code

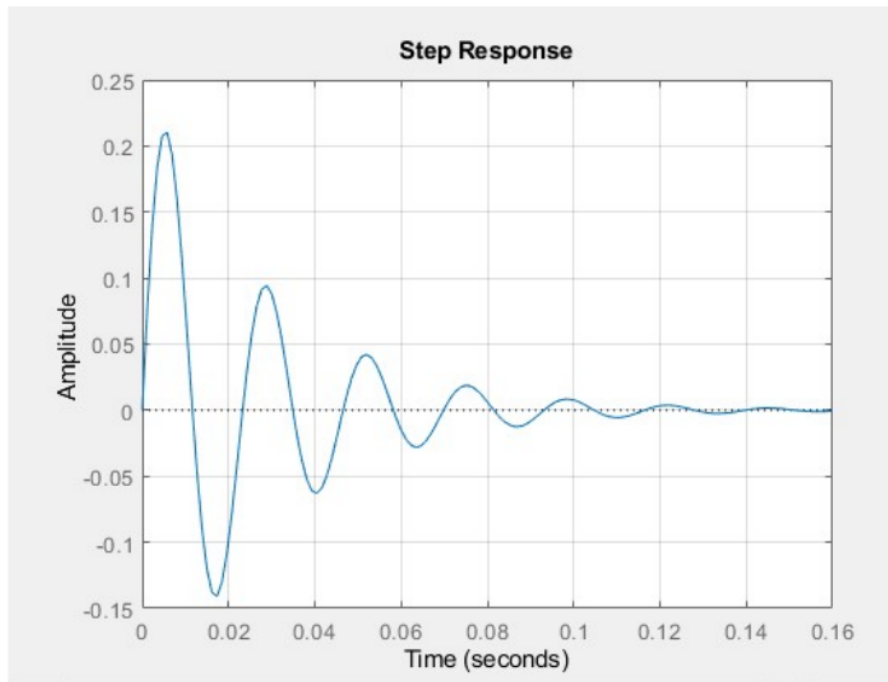


Figure 34 No damping MATLAB results

6.5

The results are as seen in the table below

Resistor values	Damping factor(ζ)	Effect (check)
50 Ω	0.82 ($\zeta < 1$)	Under damping
5 Ω	8.16 ($\zeta > 1$)	Over damping
40.82 Ω	1 ($\zeta = 1$)	Critically damped
320 Ω	0.13($\zeta = 0$)	No damping

6.6

At no damping there was major oscillation and did not reach the equilibrium. At over damping, it rises yet still does not quite reach the equilibrium. Critically damping had no overshoot due to the damping factor of 1. Under damping shots immediately up before steadily falling back down. The decaying effect seen in the results is due to it being a first order circuit. The damping factors clearly took effect on each circuits property as is displayed in the graphs from the tests above.



Task 7 – Frequency Performance Analysis of a Second Order Series

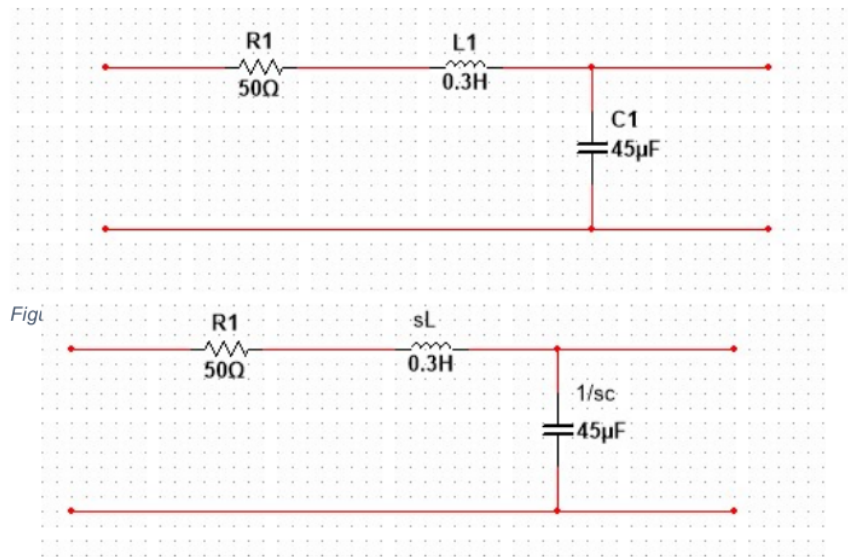


Figure 37 Second order circuit Laplace

7.1

The values below were chosen for this task

$$L=0.3 \quad C=45 \times 10^{-6}$$

$$\text{Transfer function} = H(s) = \frac{s \times \frac{1}{LC}}{s^2 + \frac{R}{L}s + \frac{1}{LC}}$$

$$\text{This is the cut-off frequency} = \omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.3 \times 45 \times 10^{-6}}} = 272.17 \text{ Rad/S}$$

$$\text{Damping factor} = \varsigma = \frac{R}{2} \sqrt{\frac{C}{L}}$$

Under damped

$$R = 50\Omega$$

$$Q = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{50} \sqrt{\frac{0.3}{45 \times 10^{-6}}} = 1.63$$

$$20 \log(1.63) = 4.24$$

$$\text{Damping factor} = \zeta = \frac{50}{2} \sqrt{\frac{45 \times 10^{-6}}{0.3}} = 0.31$$

$$H(s) = \frac{s \times \frac{1}{LC}}{s^2 + \frac{R}{L}s + \frac{1}{LC}} = \frac{s \times \frac{1}{0.3 \times 45 \times 10^{-6}}}{s^2 + \frac{50}{0.3}s + \frac{1}{0.3 \times 45 \times 10^{-6}}}$$

Over damped

$$R = 150\Omega$$

$$Q = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{150} \sqrt{\frac{0.3}{45 \times 10^{-6}}} = 0.54$$

$$20 \log(0.54) = -5.35$$

$$\text{Damping factor} = \zeta = \frac{150}{2} \sqrt{\frac{45 \times 10^{-6}}{0.3}} = 0.92$$

$$H(s) = \frac{s \times \frac{1}{LC}}{s^2 + \frac{R}{L}s + \frac{1}{LC}} = \frac{s \times \frac{1}{0.3 \times 45 \times 10^{-6}}}{s^2 + \frac{150}{0.3}s + \frac{1}{0.3 \times 45 \times 10^{-6}}}$$

Critically

To achieve critically damped it's know that;

$$\zeta = 1$$

$$R = \frac{2\zeta}{\sqrt{\frac{C}{L}}} = \frac{2(1)}{\sqrt{\frac{45 \times 10^{-6}}{0.3}}} = 163.3\Omega$$

$$Q = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{163.3} \sqrt{\frac{0.3}{45 \times 10^{-6}}} = 0.5$$

$$20 \log(0.50) = -6.02$$

$$H(s) = \frac{s \times \frac{1}{LC}}{s^2 + \frac{R}{L}s + \frac{1}{LC}} = \frac{s \times \frac{1}{0.3 \times 45 \times 10^{-6}}}{s^2 + \frac{163.3}{0.3}s + \frac{1}{0.3 \times 45 \times 10^{-6}}}$$

No damping

$$R = 5\Omega$$

$$Q = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{5} \sqrt{\frac{0.3}{45 \times 10^{-6}}} = 16.33$$

$$20 \log(16.33) = 24.26$$

$$\text{Damping factor} = \zeta = \frac{5}{2} \sqrt{\frac{45 \times 10^{-6}}{0.3}} = 0.03$$

$$H(s) = \frac{s \times \frac{1}{LC}}{s^2 + \frac{R}{L}s + \frac{1}{LC}} = \frac{s \times \frac{1}{0.3 \times 45 \times 10^{-6}}}{s^2 + \frac{5}{0.3}s + \frac{1}{0.3 \times 45 \times 10^{-6}}}$$

7.2

The MATLAB that was used is below.

```

Editor - D:\Year 4 Principles\MatLab\Task7part1.m
Task7part1.m
1  s = tf('s');
2  system1 = ((1/(0.3*0.000045))/(s^2+(50/0.3)*s+(1/(0.3*0.000045))));
3  bode (system1);
4  grid on
5  hold on
6
7  s = tf('s');
8  system2 = ((1/(0.3*0.000045))/(s^2+(150/0.3)*s+(1/(0.3*0.000045))));
9  bode (system2);
10
11 s = tf('s');
12 system3 = ((1/(0.3*0.000045))/(s^2+(163.3/0.3)*s+(1/(0.3*0.000045))));
13 bode (system3);
14
15 s = tf('s');
16 system4 = ((1/(0.3*0.000045))/(s^2+(5/0.3)*s+(1/(0.3*0.000045))));
17 bode (system4);
18
19 s = tf('s');
20 system5 = ((1/(0.3*0.000045))/(s^2+(25/0.3)*s+(1/(0.3*0.000045))));
21 bode (system5);
22
23 s = tf('s');
24 system6 = ((1/(0.3*0.000045))/(s^2+(35/0.3)*s+(1/(0.3*0.000045))));
25 bode (system6);
26

```

Figure 39 MATLAB code

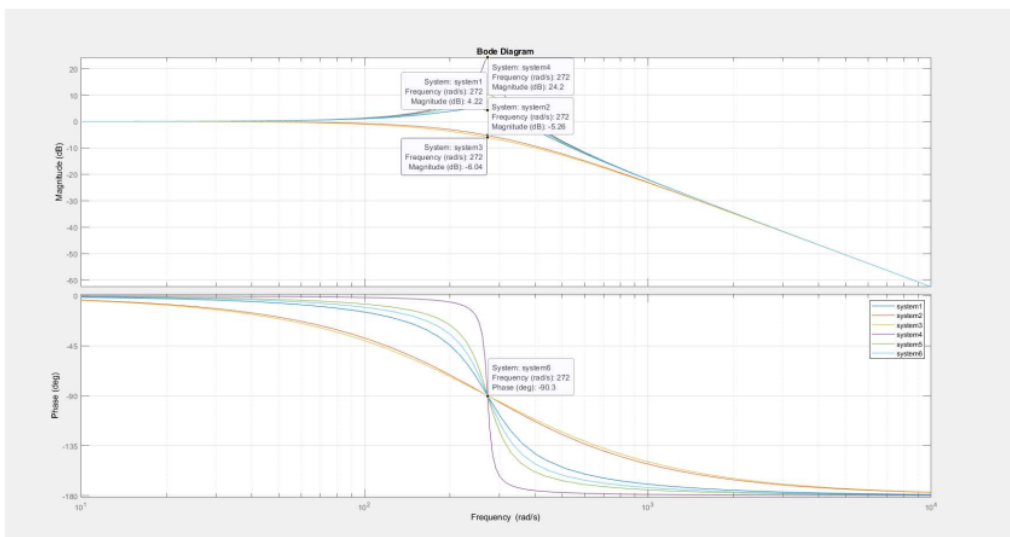


Figure 38 Phase shift and locus

The phase shift at the cut off frequency as calculated is 272rad/s

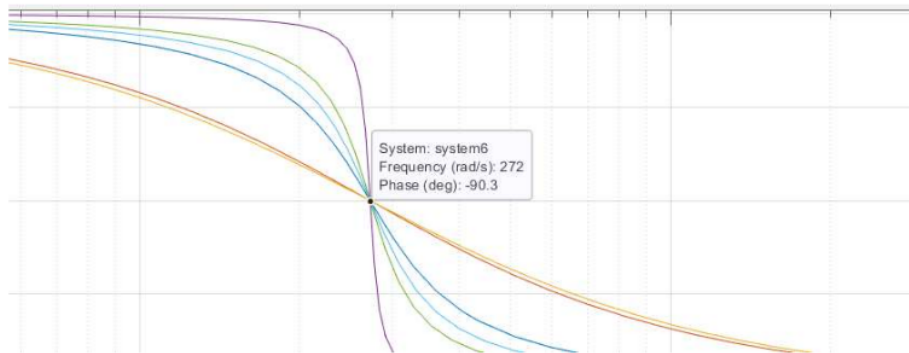


Figure 40 Phase shift

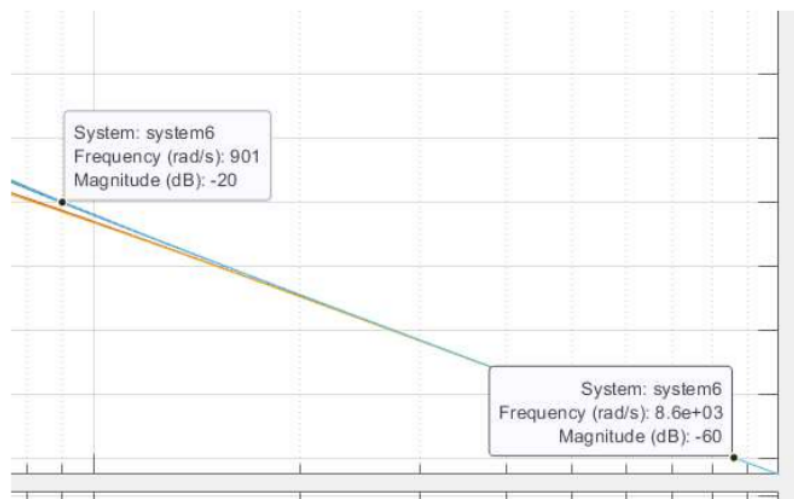


Figure 41 Roll-off

7.3

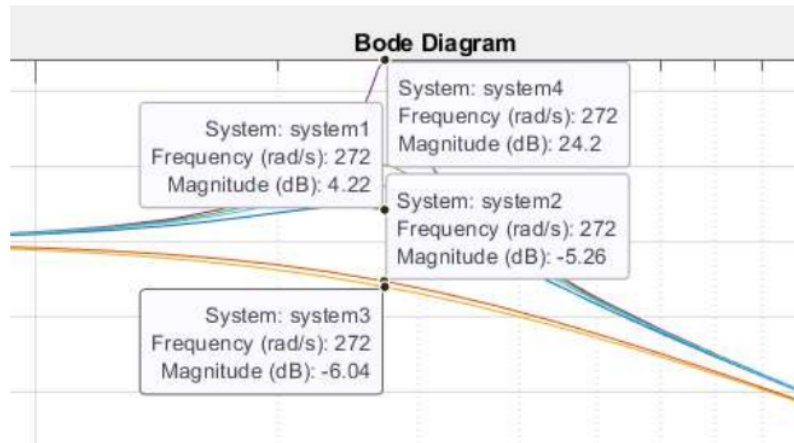


Figure 42 Gain

$\text{Log}_{10}(\dots) = \text{magnitude dB}$, these values can be found in task 7.1 with the rest of the equations.

	Measured values at the cut off frequency (magnitude Db)	Calculated values at the cut off frequency (magnitude Db)	Error
Underdamped	4.24	4.22	0.02
Overdamped	-5.35	-5.26	0.09
Critically damped	-6.02	-6.04	0.02
No damping	24.26	24.2	0.06

7.4

All calculated values were confirmed by the measured ones as seen in the table above there is marginal errors. Rounding differences may be a factor of the errors as the biggest difference is 0.09. A locus diagram was produced, as seen above, by varying the resistor values to the chosen value. The lower the value of R the higher the value of the magnitude achieved. Such frequencies can only be passed before the cut off due to this being a low pass filter.

Task 8 – Frequency Performance Analysis of a Second Order Parallel

8.1

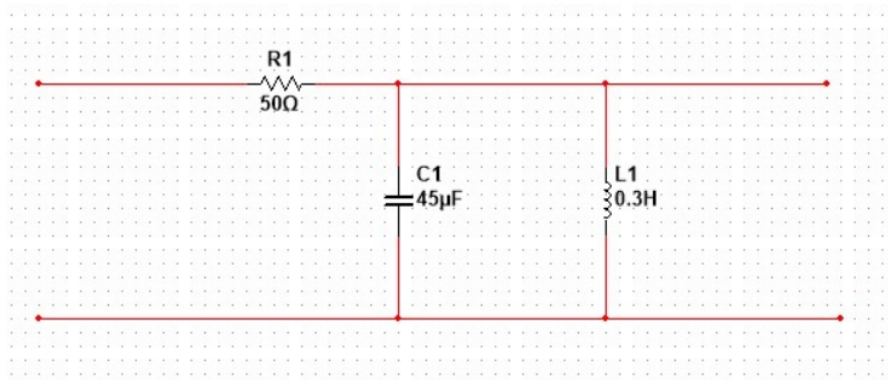


Figure 44 Second order parallel circuit

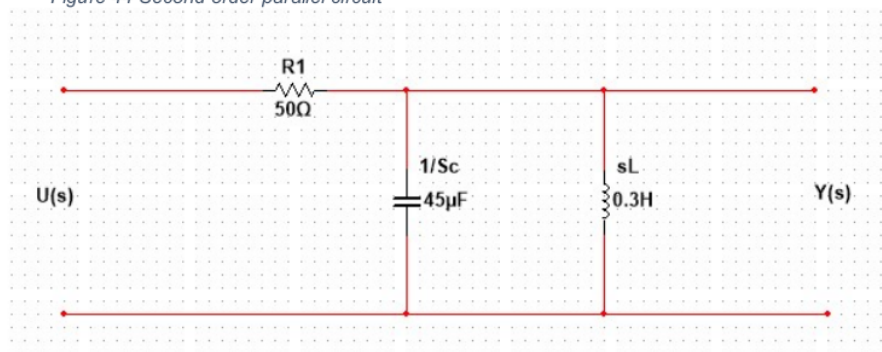


Figure 43 Second order parallel Laplace circuit

These are the selected values chosen.

$$C = 45 \times 10^{-6} \quad L = 0.3\text{H} \quad K = 1$$

$$Q = R \sqrt{\frac{C}{L}}$$

$$W_{c1} = -\frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{LC}\right)}$$

$$W_{c2} = \frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{LC}\right)}$$

$$\beta = \frac{1}{RC}$$

$$W_o = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.3 \times 45 \times 10^{-6}}} = 272.17 \text{ Rad/S}$$

$$R=50 \, \Omega$$

$$Q = 50 \sqrt{\frac{45 \times 10^{-6}}{0.3}} = 0.61$$

$$W_{c1} = -\frac{1}{2 \times 50 \times 45 \times 10^{-6}} + \sqrt{\left(\frac{1}{2 \times 50 \times 45 \times 10^{-6}}\right)^2 + \left(\frac{1}{0.3 \times 45 \times 10^{-6}}\right)} = 129.14$$

$$W_{c2} = \frac{1}{2 \times 50 \times 45 \times 10^{-6}} + \sqrt{\left(\frac{1}{2 \times 50 \times 45 \times 10^{-6}}\right)^2 + \left(\frac{1}{0.3 \times 45 \times 10^{-6}}\right)} = 573.59$$

$$\beta = \frac{1}{50 \times 45 \times 10^{-6}} = 444.4$$

$$R=5 \, \Omega$$

$$Q = 5 \sqrt{\frac{45 \times 10^{-6}}{0.3}} = 0.061$$

$$W_{c1} = -\frac{1}{2 \times 5 \times 45 \times 10^{-6}} + \sqrt{\left(\frac{1}{2 \times 5 \times 45 \times 10^{-6}}\right)^2 + \left(\frac{1}{0.3 \times 45 \times 10^{-6}}\right)} = 16.60$$

$$W_{c2} = \frac{1}{2 \times 5 \times 45 \times 10^{-6}} + \sqrt{\left(\frac{1}{2 \times 5 \times 45 \times 10^{-6}}\right)^2 + \left(\frac{1}{0.3 \times 45 \times 10^{-6}}\right)} = 4461.05$$

$$\beta = \frac{1}{5 \times 45 \times 10^{-6}} = 4444.4$$

$$R=40.82 \, \Omega$$

$$Q = 40.82 \sqrt{\frac{45 \times 10^{-6}}{0.3}} = 0.50$$

$$W_{c1} = -\frac{1}{2 \times 40.82 \times 45 \times 10^{-6}} + \sqrt{\left(\frac{1}{2 \times 40.82 \times 45 \times 10^{-6}}\right)^2 + \left(\frac{1}{0.3 \times 45 \times 10^{-6}}\right)} = 112.73$$

$$W_{c2} = \frac{1}{2 \times 40.82 \times 45 \times 10^{-6}} + \sqrt{\left(\frac{1}{2 \times 40.82 \times 45 \times 10^{-6}}\right)^2 + \left(\frac{1}{0.3 \times 45 \times 10^{-6}}\right)} = 657.12$$

$$\beta = \frac{1}{40.82 \times 45 \times 10^{-6}} = 544.4$$

$$R=320 \, \Omega$$

$$Q = 320 \sqrt{\frac{45 \times 10^{-6}}{0.3}} = 3.92$$

$$W_{c1} = -\frac{1}{2 \times 320 \times 45 \times 10^{-6}} + \sqrt{\left(\frac{1}{2 \times 320 \times 45 \times 10^{-6}}\right)^2 + \left(\frac{1}{0.3 \times 45 \times 10^{-6}}\right)} = 239.65$$

$$W_{c2} = \frac{1}{2 \times 320 \times 45 \times 10^{-6}} + \sqrt{\left(\frac{1}{2 \times 320 \times 45 \times 10^{-6}}\right)^2 + \left(\frac{1}{0.3 \times 45 \times 10^{-6}}\right)} = 309.09$$

$$\beta = \frac{1}{320 \times 45 \times 10^{-6}} = 69.4$$

8.2

$R=50\ \Omega$

```
task850.m  x  +
1  s = tf('s');
2  system1 = s * 444.4 / (s^2 + 444.4*s + 272.12^2);
3  bode (system1);
4  grid on
5  hold on
6
```

Figure 45 $R = 50$ code

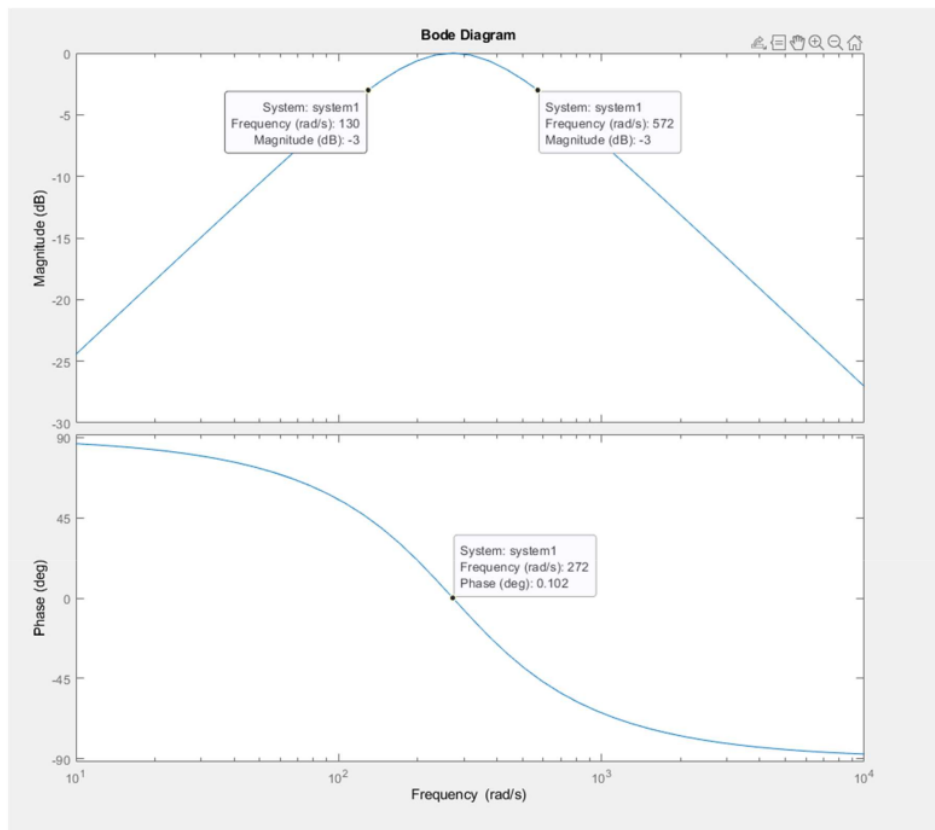


Figure 46 $R = 50$ results

$R=5\ \Omega$

```
task85.m  x  +
1      s = tf('s');
2      system1 = s * 4444.4/ (s^2 + 4444.4*s + 272.12^2);
3      bode (system1);
4      grid on
5      hold on
6
```

Figure 47 $R = 5$ code

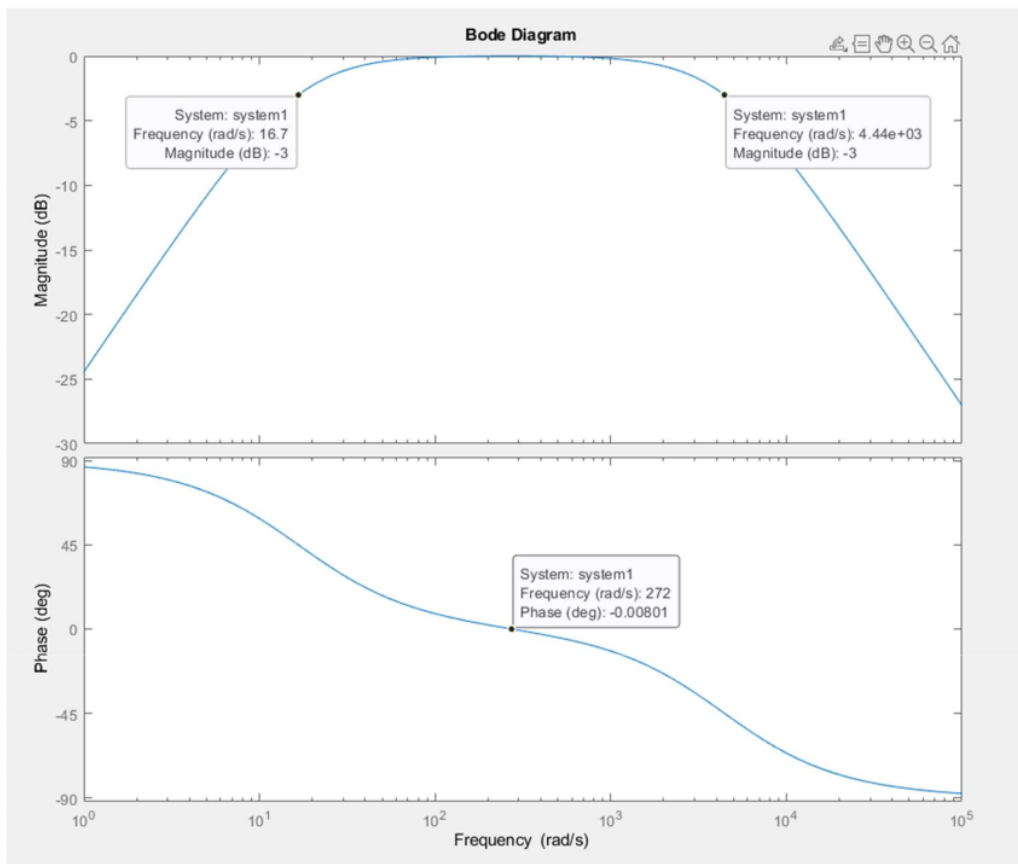


Figure 48 $R = 5$ results

$R=40.82\ \Omega$

```
task84082.m  x  +
1      s = tf('s');
2      system1 = s * 544.4 / (s^2 + 544.4*s + 272.12^2);
3      bode (system1);
4      grid on
5      hold on
6
```

Figure 49 $R = 40.82$ code

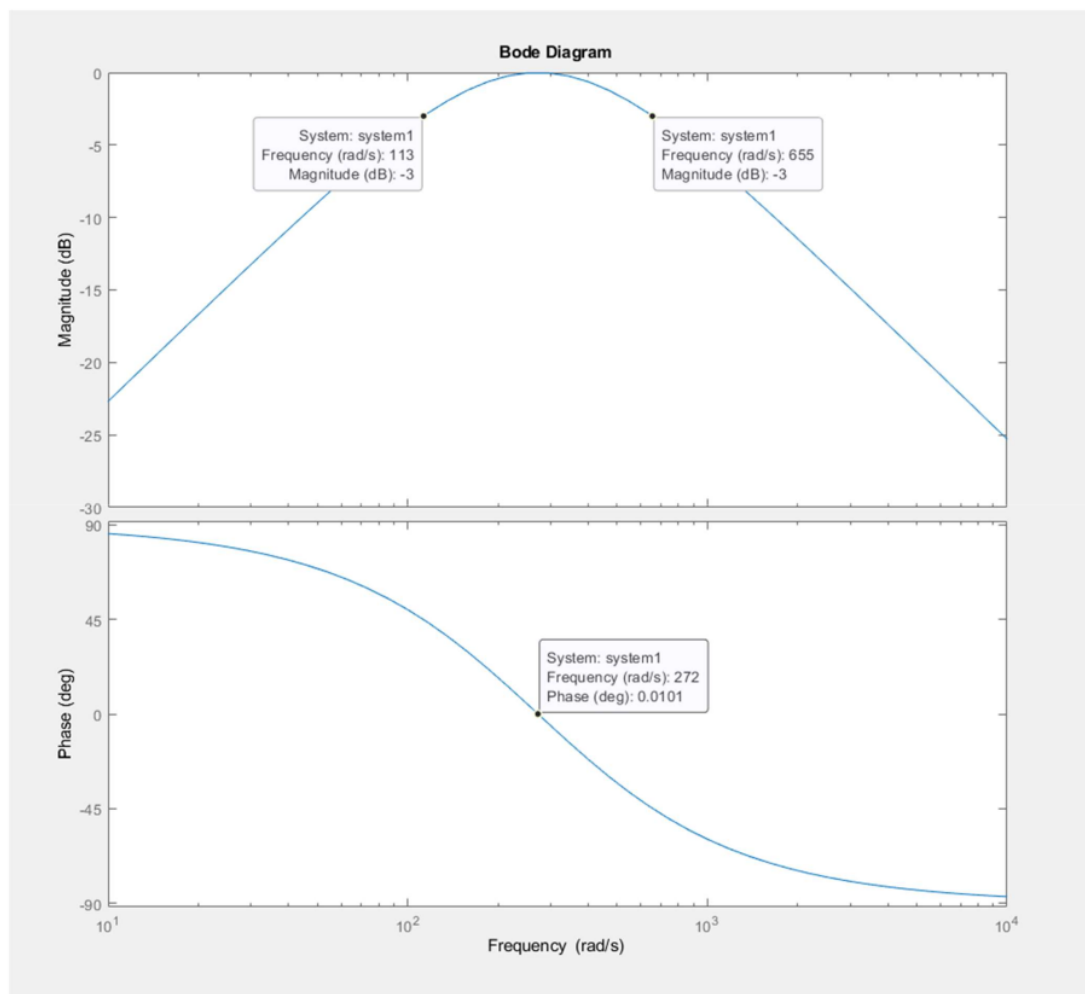


Figure 50 $R = 40.82$ results

$R=320\ \Omega$

```
task8320.m  x  +
1  s = tf('s');
2  system1 = s * 69.4 / (s^2 + 69.4*s + 272.12^2);
3  bode (system1);
4  grid on
5  hold on
6
```

Figure 51 $R = 320$ code

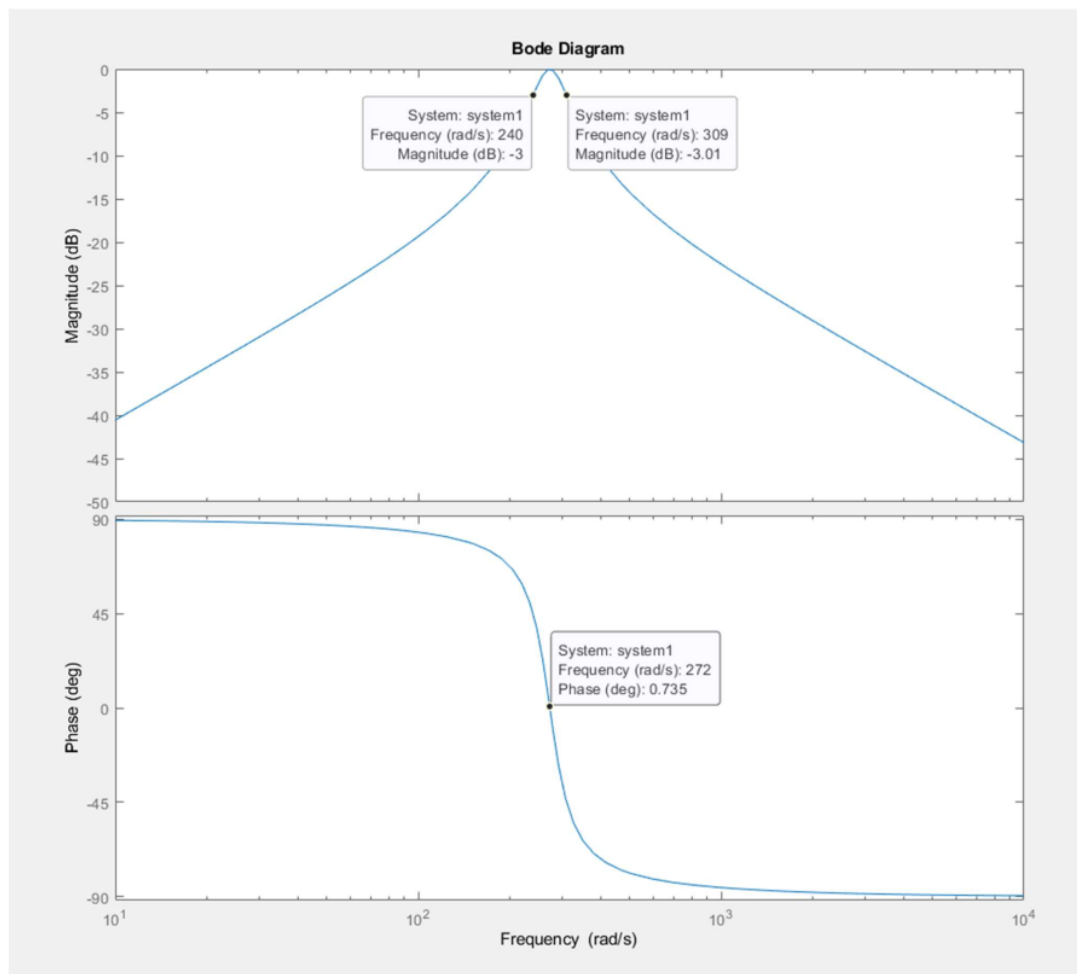


Figure 52 $R = 320$ results

8.3

Calculated

Resistance Ω	Wo (Hz)	Lower cut off frequency (Hz)	Upper cut off frequency (Hz)	β (Hz)
50	272.17	129.14	575.59	444.4
5	272.17	16.60	4461.05	4444.4
40.82	272.17	112.73	657.12	544.4
320	272.17	239.65	309.09	69.4

Measured

Resistance Ω	Wo (Hz)	Lower cut off frequency (Hz)	Upper cut off frequency (Hz)	β (Hz)
50	272.17	130	572	442
5	272.17	16.7	4444	4427
40.82	272.17	113	655	542
320	272.17	240	309	69

8.4

As can be seen in the results collected and calculated above, as the resistance decreases the bandwidth will increase. This demonstrates a more selective circuit using higher resistances. As can be seen from the tables of results above, both the calculated and measured results are very similar. The slight differences may be due to rounding error or placement of the probe  on the measured graphs.

Task 9 – Frequency Performance Analysis of a First Order Electronic System

9.1



Below is the value that has been selected

C = 450nF

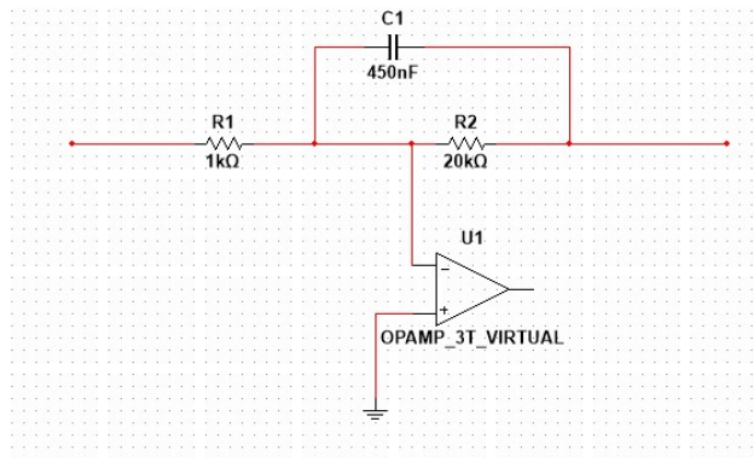


Figure 53 First order electronic system circuit

9.2

$$k = \frac{20000}{1000} = 20$$

$$W_c = \frac{1}{450 \times 10^{-9} \times 20000} = 111.1 \text{ Rad/s}$$

$$\text{Transfer function} = -20 \left(\frac{111.11}{s + 111.11} \right)$$

Using the calculations above the following MATLAB code was produced

```
task9.m
1  s = tf('s');
2  system = (-20*(111.11/(s+111.11)));
3  bode (system);
4  grid on;
```

Figure 54 First order electronic system code

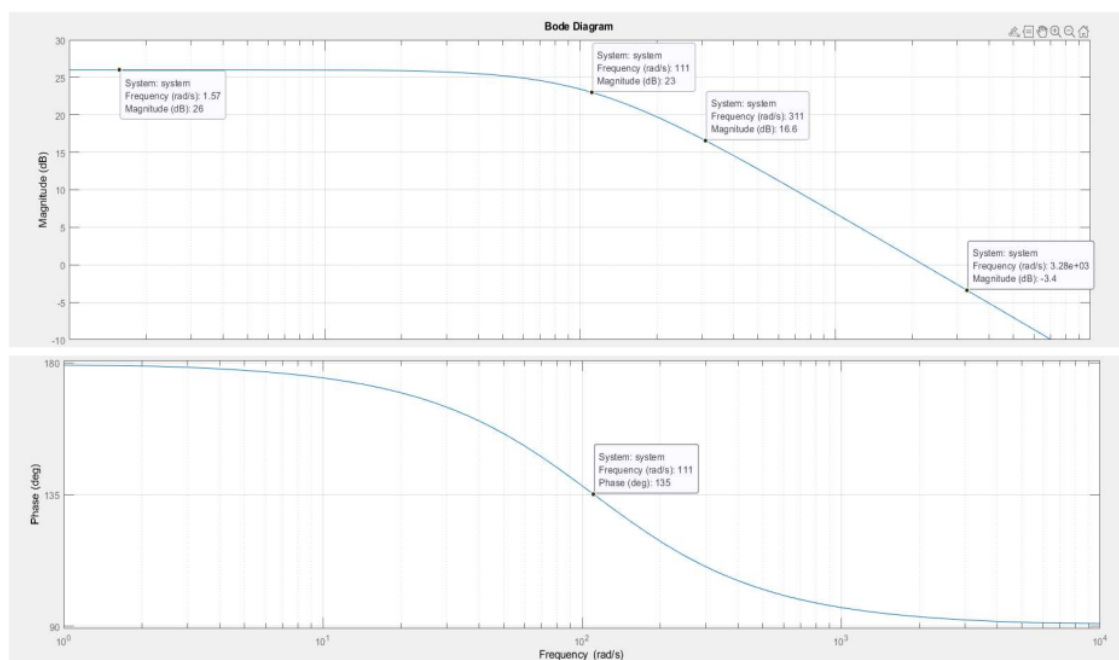


Figure 55 First order electronic system results

9.3

As can be seen by the MATLAB results both these and the calculated match up with tolerances. Thus meaning $-45 + 180 = 135$ degrees and the cut off frequency phase shift. A 20Db roll off was measured as can be seen I from the results, this is as the circuit is a first order. $20\log(26.02)$ proves the fact of the calculated gain and measured results are true.

Task 10 – Frequency Performance Analysis of a First Order Electronic System

10.1

As can be seen below the selected value was C=40nF

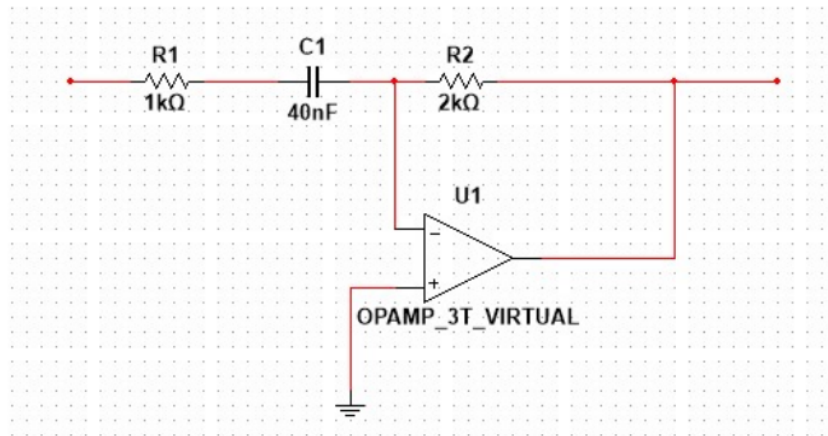


Figure 56 First order electronic system circuit

10.2

Below the cut-off parameters can be seen.

$$\text{Transfer function } H(s) = -k \left(\frac{s}{s+W_c} \right) = -2 \left(\frac{s}{s+25,000} \right)$$

$$K = 2000 \div 1000 = 2$$

$$W_c = \frac{1}{CR1} = \frac{1}{40 \cdot 10^{-9} \cdot 1000} = 25,000$$

```

task10.m
1  s = tf('s');
2  system1 = (-2 * (s/(s + 25000)));
3  bode(system1);
4  grid on
5  hold on
6

```

Figure 57 First order electronic system code

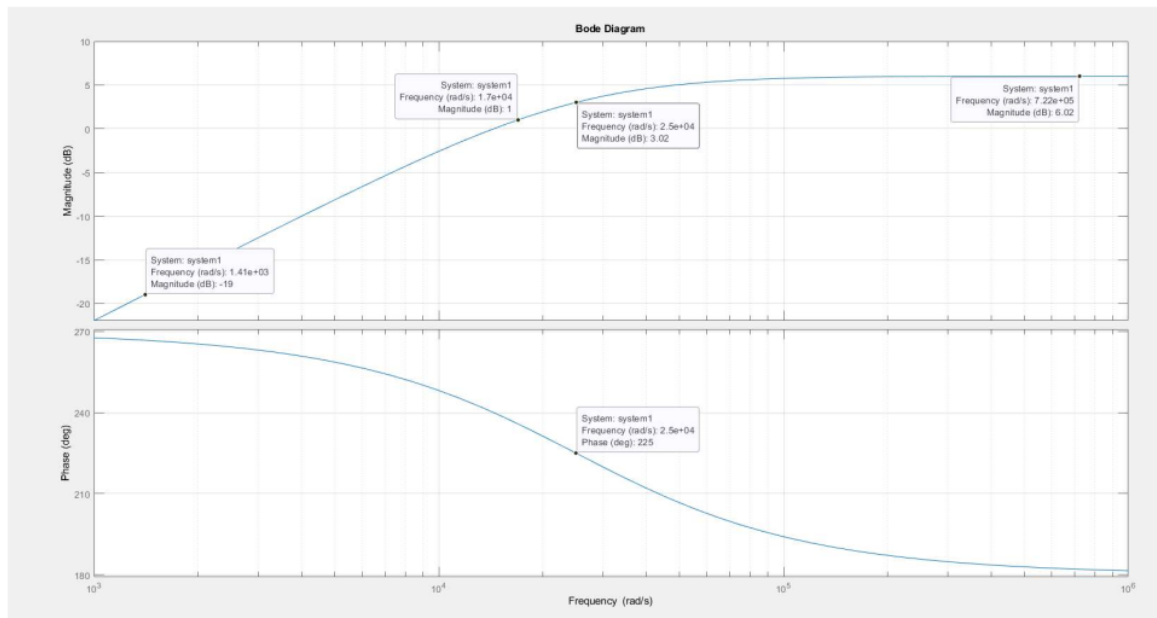


Figure 58 First order electronic system results

10.3

Once again as seen above both the calculated and measured results match up. The phase shift can be seen at 45 degrees at natural frequency due to it being a high pass filter. Thus, further meaning the phase has shift to 180 degrees. To obtain the new cut off frequency phase shift the following calculation is carried out, $180 - 45 = 225$. This is backed up by the measured evidence above, also this shows a roll-off of 20db measured as it is a first order circuit. Below is the equation proving all values correct.

$$20 \log \left(\frac{2}{25000} \right) = 6.02$$

Task 11 – Frequency Performance Analysis of a Sallen & Key 2 nd Order Filter

11.1

Below is the design of a Butterworth filter

$$W_c = 2,000 \text{ rad/s}$$

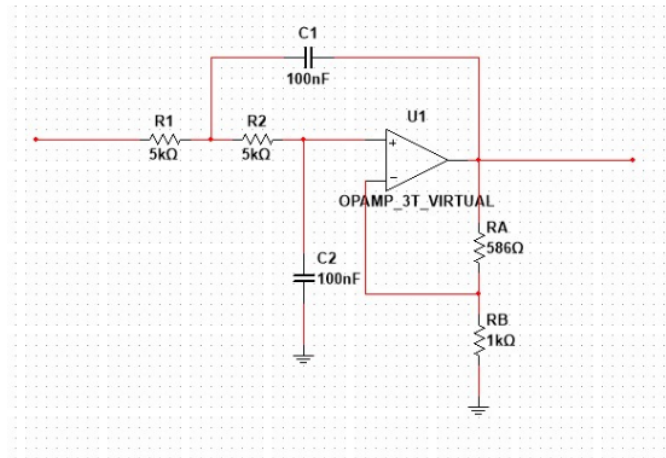


Figure 59 Butterworth filter circuit

$$W_c = 2,000 \text{ rad/s}$$

$$C = 100 \text{ nF}$$

$$R = \frac{1}{W_c C} = \frac{1}{2,000 \times 100 \times 10^{-9}} = 5 \text{ k}$$

$$k = 1.586 \quad 20 \log k = 4 \text{ dB}$$

$$R_A = (k - 1) \quad R_B = 586 \Omega$$

$$Q = \frac{1}{3 - k} = 0.707$$

$$H(s) = \frac{(1.586 \times 2,000)^2}{s^2 + \left(\frac{2,000}{0.707}\right)s + 2,000^2}$$

11.2

```

Task11.m
1  s = tf('s');
2  system = ((1.586*2000)^2/(s^2+(2000/0.707)*s+4000000));
3  bode (system);
4  grid on
5  hold on
6

```

Figure 60 Butterworth code

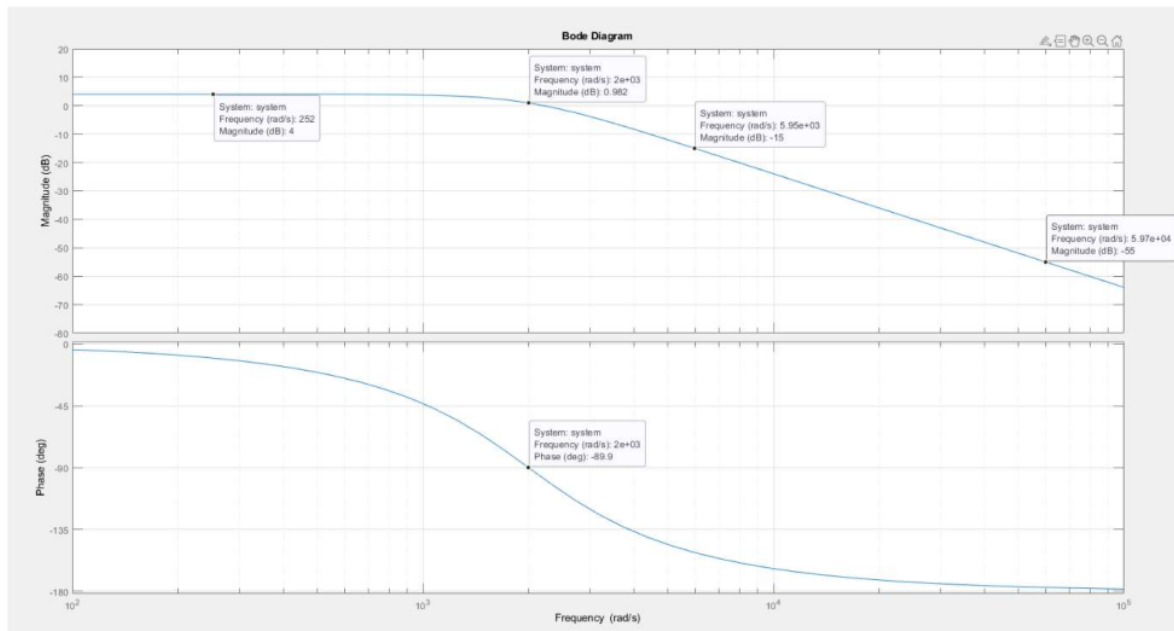


Figure 61 Butterworth results

	Calculated	Simulated
Roll off	-40dB	-40dB
Cut off frequency	2,000 rad/s	2,000 rad/s
Gain	4dB	4dB

As can be seen in the results both the simulated and calculated matched up perfectly with 0 error.

11.3

The phase shift here was measure -90 degrees as seen in the measures results above the result was 89.9 degrees this due to human and software tolerances. Differently to tasks previous, the roll-off here was measured to -40dB. This meaning this second order circuit is more selective  23 frequencies are allowed to pass through, due to the steeper roll-off.

Task 12 – First Order Control System Analysis

12.1

24

```
1 num = [6.5];  
2 den = [1, -0.4];  
3 [z, p, k] = tf2zp(num,den)  
4 pzmap (num,den)
```

Figure 63 Pole zero code

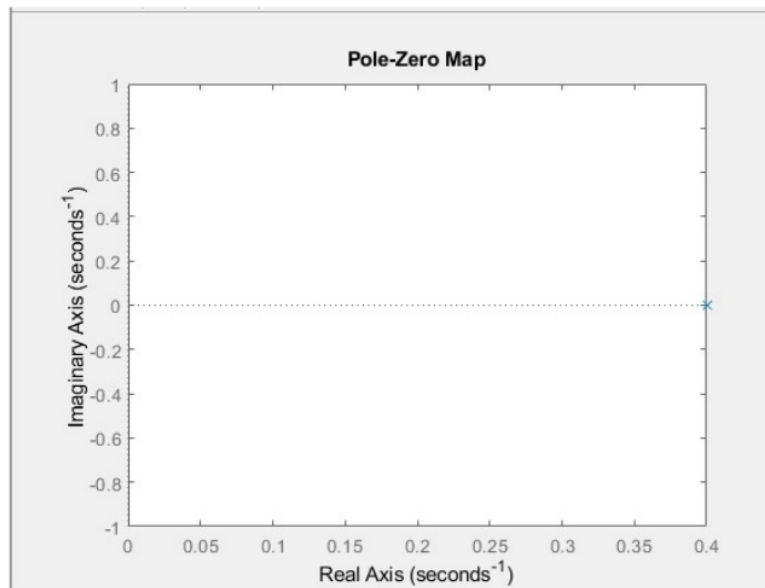


Figure 62 Pole zero results

It can be seen from the argand diagram that the pole is positive meaning that is unstable as it's 0.4.

25

The open loop transfer function response can be seen below

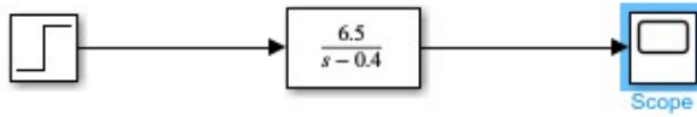


Figure 64 Open loop circuit

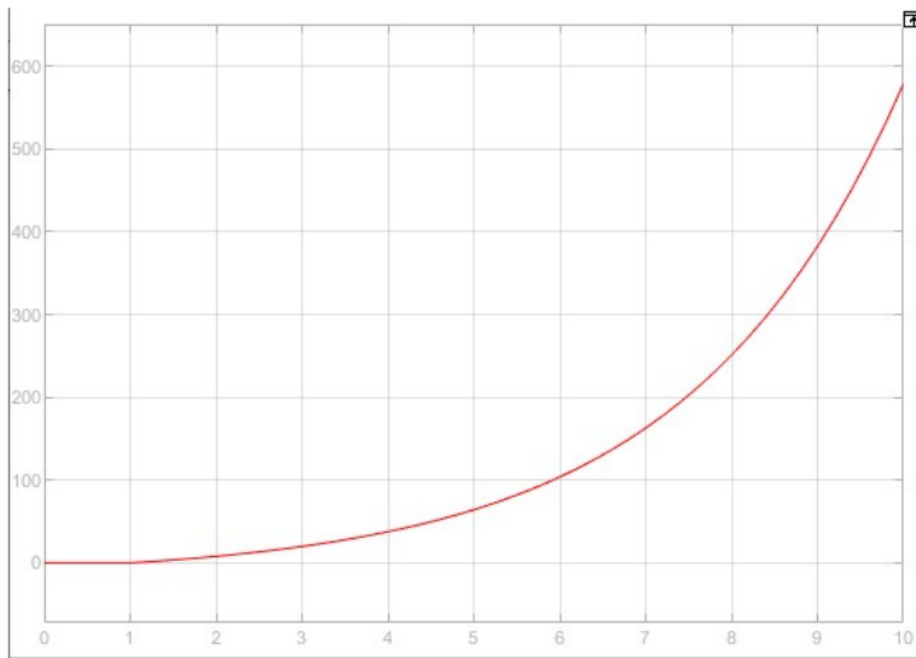


Figure 65 Open loop results

12.2

Taking k as equal to 1 below is the closed loop transfer function response.

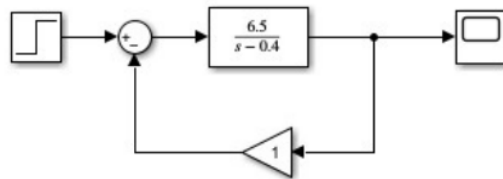


Figure 66 $k=1$ model

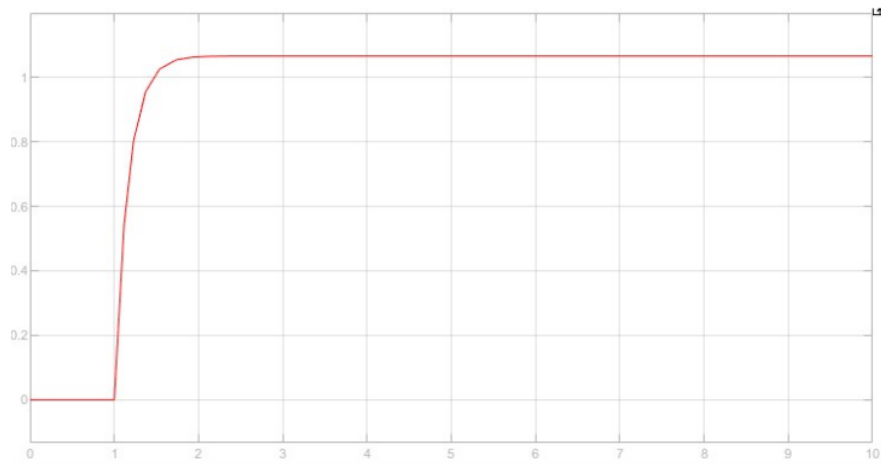


Figure 67 $k=1$ results

Using Simulink to produce the above results it can be seen the response is one that climbs to its peak then stabilises. Therefore, producing an overall stable response.

12.3

Below is the rearranged transfer function for for the minimum value of k. this will allow the feedback to be stable.

$$\frac{6.5}{s - 0.4}$$
$$\frac{Y(s)}{R(s)} = \frac{G(s)}{1 + G(s)H(s)} = \frac{\frac{6.5}{s - 0.4}}{1 + \left(\frac{6.5}{s - 0.4} \times K\right)}$$

$$\frac{6.5}{s - 0.4 + (6.5 \times K)}$$

$$s - 0.4 + 6.5K = 0$$

$$s + (6.5K - 0.4) = 0$$

$$s = -(6.5K - 0.4)$$

$$s = -6.5K + 0.4$$

$$s = 0.4 - 6.5K$$

$$s = 0 = 0.4 - (6.5 \times 0.0614)$$



Using MATLAB and a root locus this can now be confirmed.

```
1  simulink
2  clear all
3  num = [6.5];
4  den = [1 -0.4];
5  rlocus(num,den);
6  grid
```

Figure 68 Root locus code

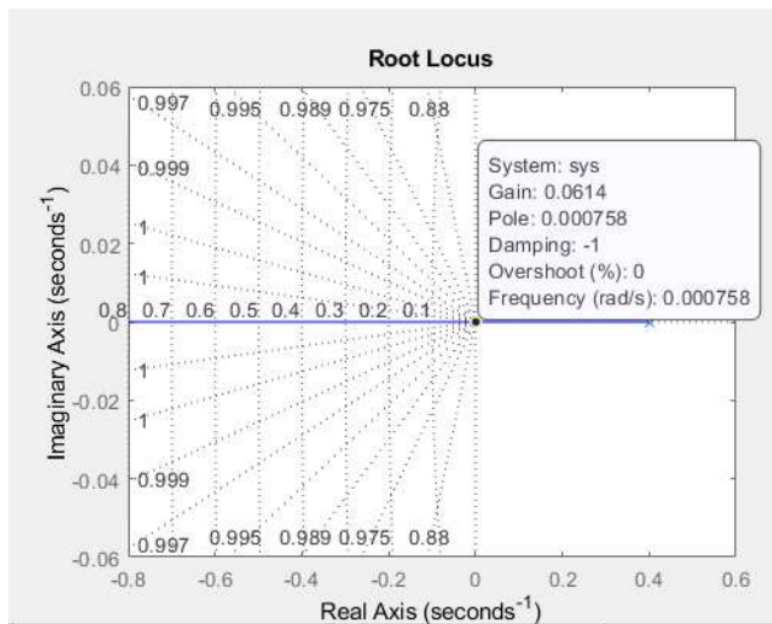


Figure 69 Root locus results

The results of the above root locus back up those of the theory and calculations.

12.4

Below three values of k were chosen to display the differences in stability.

$$k = 3$$

$$s = 0.4 - 6.5(3) = -19.1$$

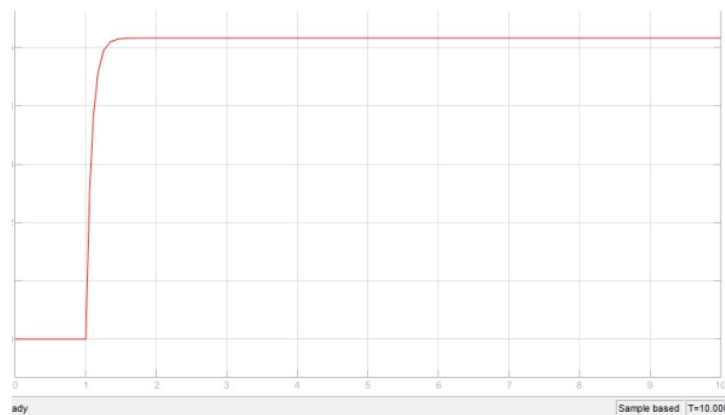


Figure 70 $k=3$ results

$$k = 0.0614$$

$$s = 0.4 - 6.5 (0.0614) = 0.0009$$

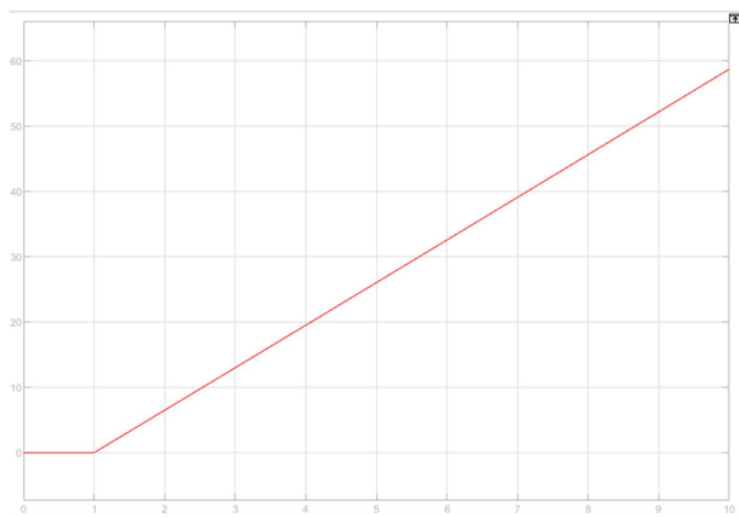


Figure 71 $k = \text{minimum } (0.0614)$ results

$$k = 0.007$$

$$s = 0.4 - 6.5 (0.007) = 0.3545$$

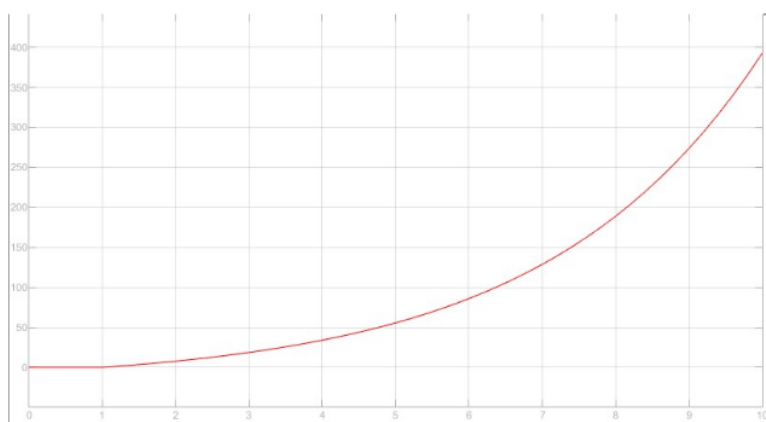


Figure 72 $k=0.007$ results

12.5

K value	Pole	Measured stability	Calculated stability
3	-19.1	stable	stable
0.0614	0.0009	unstable	unstable
0.007	0.3545	unstable	unstable

12.6

By looking at the polarity of the pole the stability of the circuit can be predicted. Anything below the rearranged value for k of 0.0614 will make the system unstable and any value over being stable, as seen in the graphical and table results above. This is due to 0.0614 being the minimum feedback gain required for the circuit. The higher values are stable because the pole is a negative value therefore positioned in the left-hand side, once again as seen in all results above. 0.0614 has a linear graph never stabilising, therefore this minimum is also unstable.

Task 13 – DC Motor Model Analysis

13.1

Below are the DC motor model and circuits used throughout the task

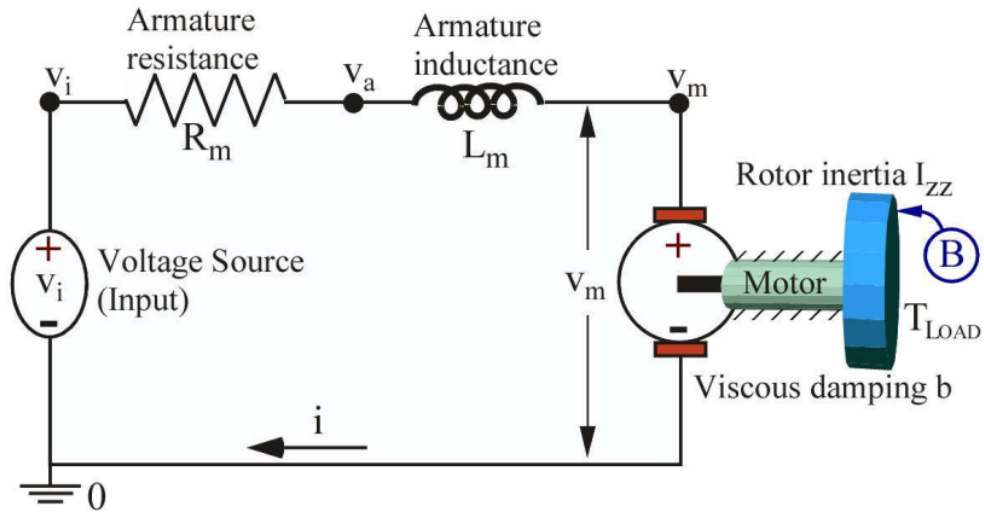


Figure 73 DC motor model

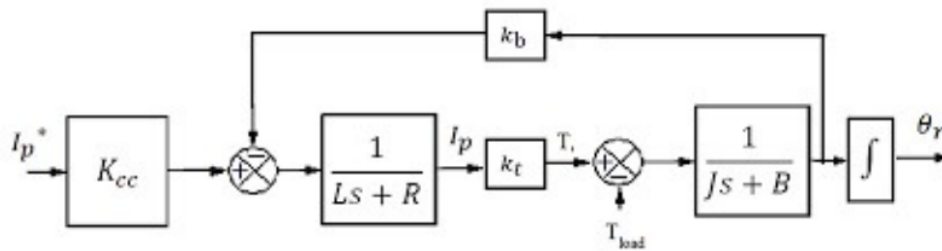


Figure 74 DC motor circuit

The transfer function, with the disturbance initially set to 0, is as follows.

$$G(s) = \frac{Kwn^2}{s^2 + S \zeta wn s + wn^2}$$

28

13.2

The equations below are those used to work out various characteristics and results of a DC motor.

$$\text{No load speed (no friction)} \Omega_{NL} = \frac{V_a}{K_a} = \frac{15}{0.063} = 238.1 \text{ rad/s}$$

$$\begin{aligned} \text{No load speed (with friction)} \Omega &= \frac{K_T V_a}{b R_a + K_T K_e} \\ &= \frac{0.063 \times 15}{(4.6 \times 10^{-6} \times 15) + (0.063 \times 0.063)} = 237.68 \text{ rad/s} \end{aligned}$$

$$\text{Small Torque } T_M = \frac{(K_T \times V_a)}{R_a} = \frac{(0.063 \times 15)}{15} = 0.63 \text{ Nm}$$

$$\begin{aligned} \text{Natural frequency } \omega_n &= \sqrt{\left(\frac{R_a b}{L_a j}\right) + \left(\frac{K_T K_e}{L_a j}\right)} \\ &= \sqrt{\left(\frac{(1.5 \times (4.6 \times 10^{-6}))}{((0.165 \times 0.0042))}\right) + \left(\frac{(0.063 \times 0.063)}{((0.165 \times 0.0042))}\right)} = 2.395 \text{ rad/s} \end{aligned}$$

$$\text{Damping factor } \zeta = \frac{\left(\frac{b}{j} + \frac{R_a}{L_a}\right)}{2 \times \omega_n} = \frac{\left(\left(\frac{4.6 \times 10^{-6}}{0.0042}\right) + \left(\frac{1.5}{0.165}\right)\right)}{2 \times 2.395} = 1.898$$

13.3

Below are the equations required to calculate the poles.

$$A = 1$$

$$B = \left(\frac{b}{j} + \frac{R_a}{L_a}\right) = \left(\frac{4.6 \times 10^{-6}}{0.0042} + \frac{1.5}{0.165}\right) = 9.09$$

$$C = \frac{R_a b}{L_a j} + \frac{K_T K_e}{L_a j} = \frac{1.5 \times 4.6 \times 10^{-6}}{0.165 \times 0.0042} + \frac{0.063 \times 0.063}{0.165 \times 0.0042} = 5.74$$

Taking these answers and substituting into a quadratic formula will provide the answers needed to plot on the argand diagrams.

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-9.09 \pm \sqrt{9.09^2 - 4(1)(5.74)}}{2 \times 1} = -0.683$$

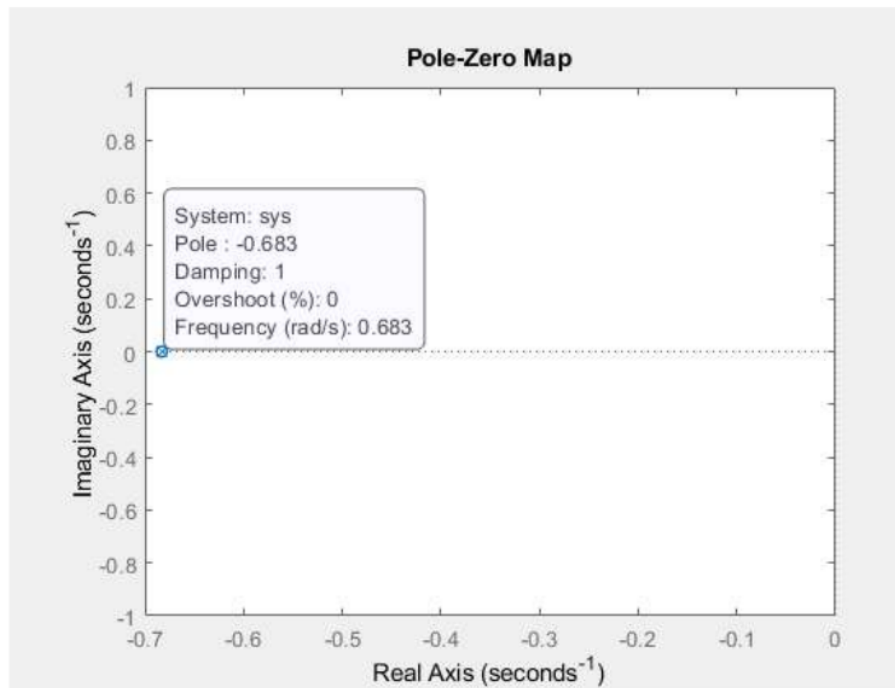


Figure 75 Pole-zero map results

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-9.09 \pm \sqrt{9.09^2 - 4(1)(5.74)}}{2 \times 1} = -8.409$$

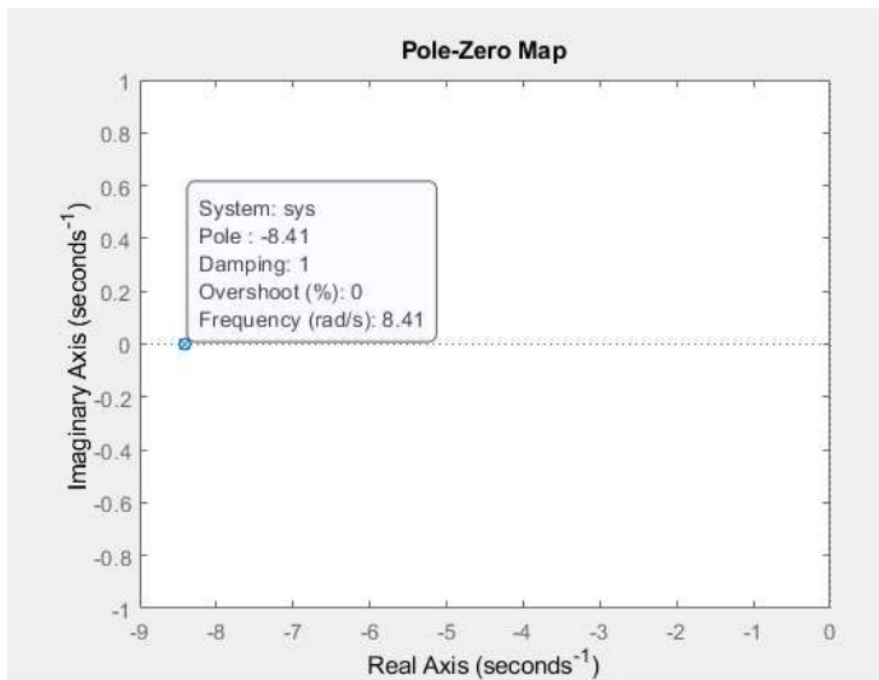


Figure 76 Pole-zero map results

These plots being negative therefore in the left-hand pane, means the system should be a stable one.

13.4

This is a model of the motor produced on MATLAB

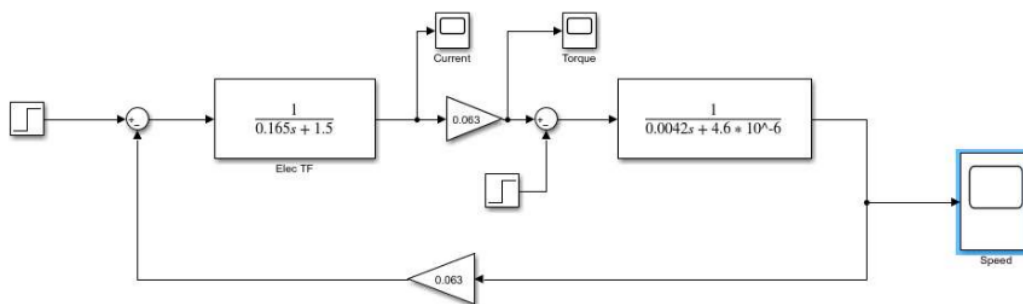


Figure 77 Motor model

13.5

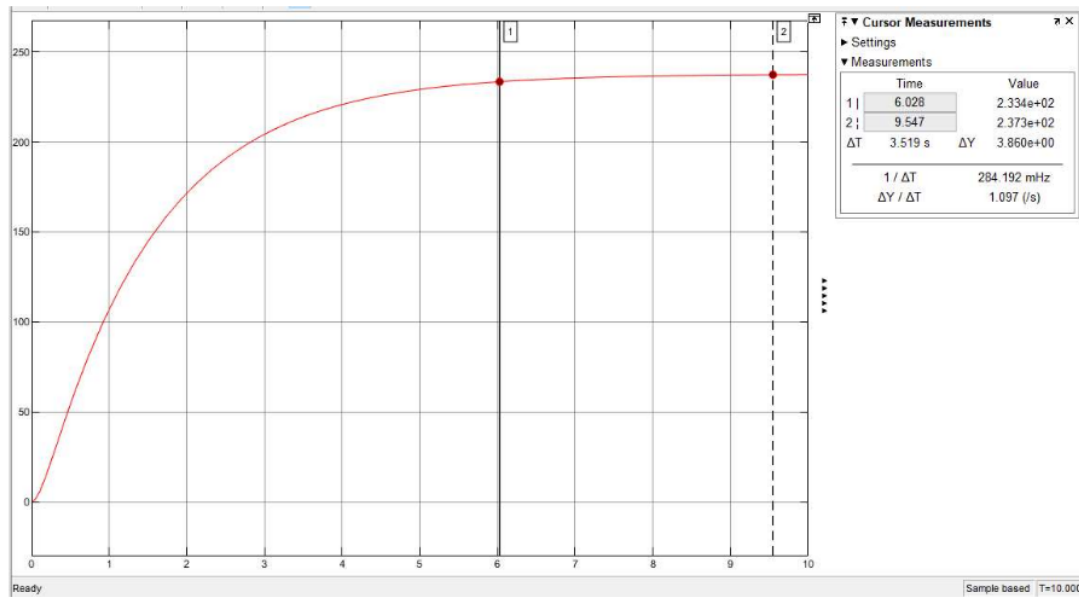


Figure 78 DC motor results

These results show the speed and torque response over a 30 second time frame when the armature voltage is 15V and no disturbance. Here the no load speed and torque of the motor can be seen.

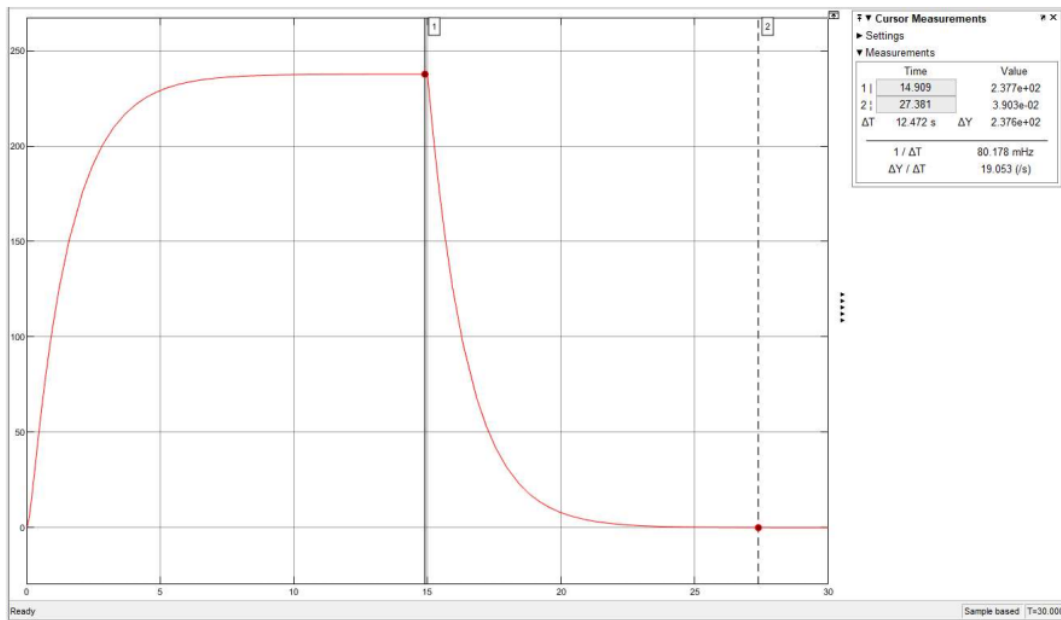


Figure 79 Stall results

A theoretical stall torque was placed upon the motor at the halfway point of 15 seconds, the results are as seen above.

13.6

$$\text{Loaded speed } \Omega_L = \left(\frac{15 - \left(\frac{1.5 \times 0.003}{0.063} \right)}{\left(\frac{1.5 \times (4.6 \times 10^{-6})}{0.063} \right)} \right) = 226.36 \text{ rad/s}$$

A theoretical load has been added to the motor, the results are analysed again with and input of 15Vdc but a disturbance of 0.03NM added after 10 seconds of the overall 20 running time. The speed and current can be seen in the results below.

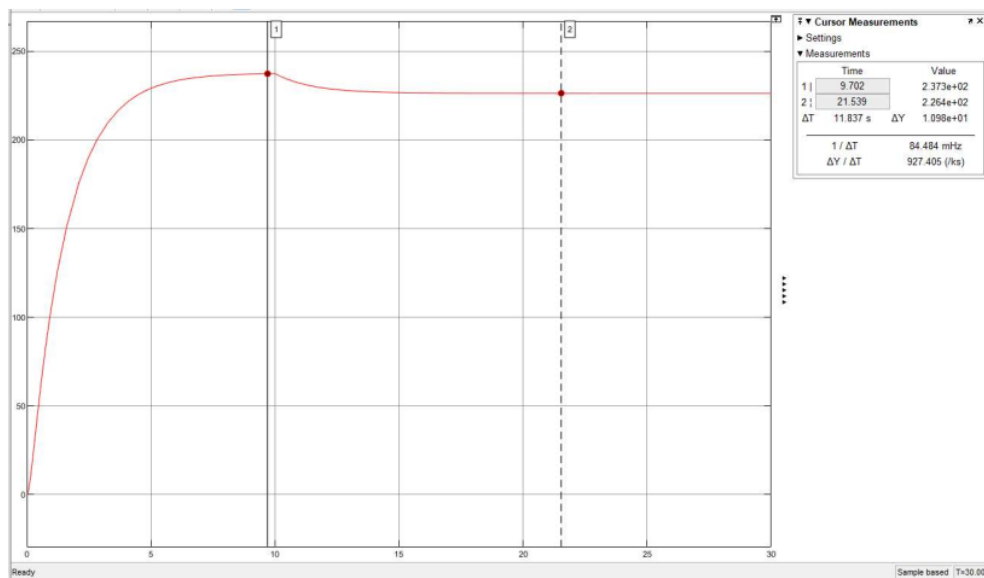


Figure 80 Load results

13.7

	Calculated	Simulated	Error
No load speed (rad/S)	238.1	237.3	0.8
Loaded speed (Rad/S)	226.36	226.4	0.04

13.8

As can be seen in the table of results there is very little error when comparing the calculated and simulated results, the little error could be due to rounding or human error when placing the markers on the graph. These results conclude that when a load is applied to the motor the speed will be slower. This then causing the current to increase and the torque likewise to try overcome the disturbance and maintain the motor's speed. The stall torque seen above is the amount required to slow then stop the motor. Friction placed upon the motor would ideally not affect the speed but it does as prove for the results.

Task 14 – Proportional Speed Control System

14.1

Below the motor model has been placed into sub-system with a proportional (P). The parameters have been set up according to the brief. A PID block set to only P has been added to make sure the armature voltage is limited.

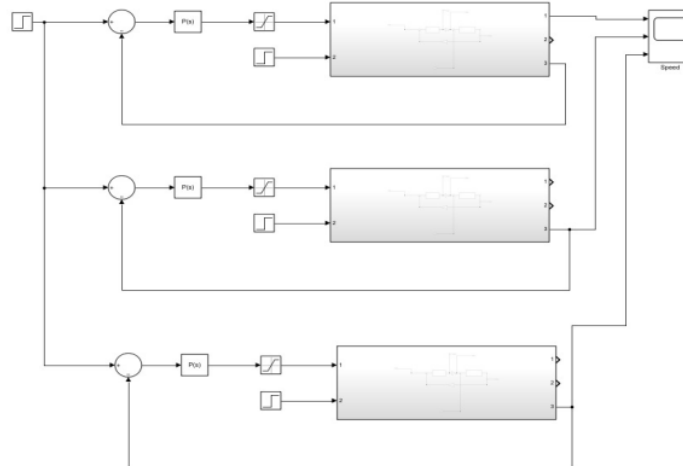


Figure 81 Proportional model

14.2

The system was simulated as seen below with the value of k_p changed 3 times.

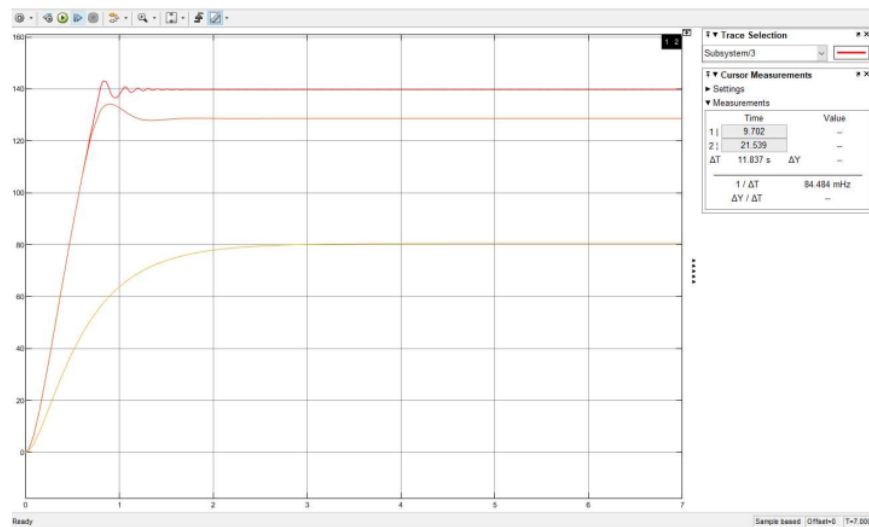
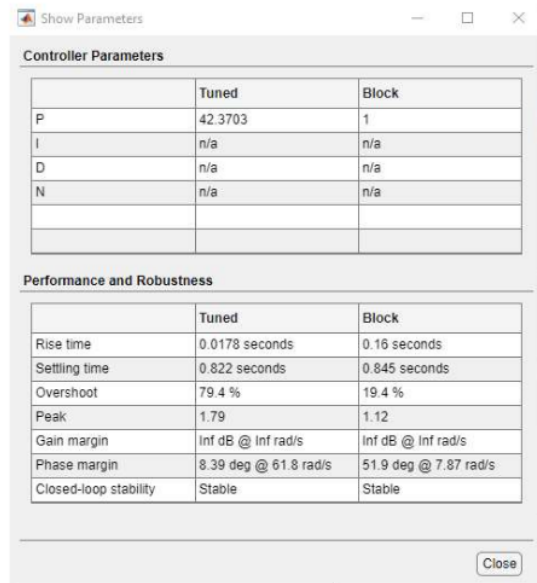


Figure 82 P results

14.3

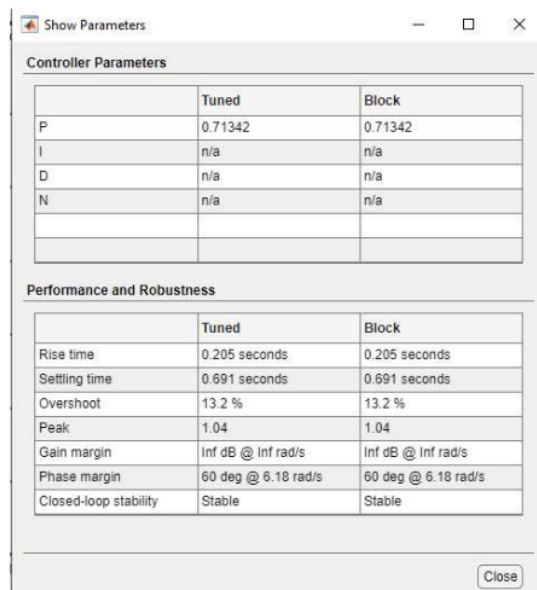
Each of the subsystem was tuned in order to get the best response, this was done using the PID tuner as seen below.



Controller Parameters		
	Tuned	Block
P	42.3703	1
I	n/a	n/a
D	n/a	n/a
N	n/a	n/a

Performance and Robustness		
	Tuned	Block
Rise time	0.0178 seconds	0.16 seconds
Settling time	0.822 seconds	0.845 seconds
Overshoot	79.4 %	19.4 %
Peak	1.79	1.12
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	8.39 deg @ 61.8 rad/s	51.9 deg @ 7.87 rad/s
Closed-loop stability	Stable	Stable

Figure 83 P value 1



Controller Parameters		
	Tuned	Block
P	0.71342	0.71342
I	n/a	n/a
D	n/a	n/a
N	n/a	n/a

Performance and Robustness		
	Tuned	Block
Rise time	0.205 seconds	0.205 seconds
Settling time	0.691 seconds	0.691 seconds
Overshoot	13.2 %	13.2 %
Peak	1.04	1.04
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	60 deg @ 6.18 rad/s	60 deg @ 6.18 rad/s
Closed-loop stability	Stable	Stable

Figure 84 P value 2

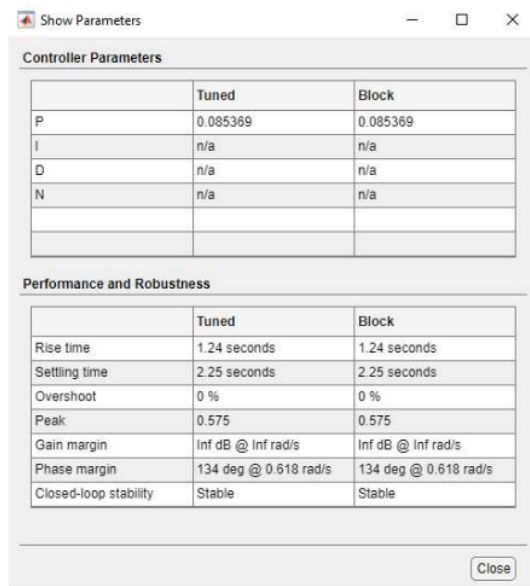


Figure 85 P value 3

14.4

Results from all three kp values are as follows.

Kp	SSE	% O/S	Rise Time
42.3702	0	79.4%	0.0178
0.7134	10	13.2%	0.205
0.0853	60	0%	1.24

14.5

To conclude, all results were as expected considering the characteristics as the Kp value decreased. As seen in the table above when the Kp value was tuned to the highest the SSE was the lowest, the overshoot was the highest and the rise time the lowest. The SSE value decreased as the Kp decreased, the overshoot also decreased as the Kp did, but the rise time increased. The table shows the optimal value being 0.7134 as it has been tuned.

Task 15 – Proportional-Integral Speed Control System

15.1

The same subsystem as used in the previous task was used but altered so that the proportional controller used P and I to see the effects would have on the system. The results after using the different values I and taking P as the tuned value for all are as follows.

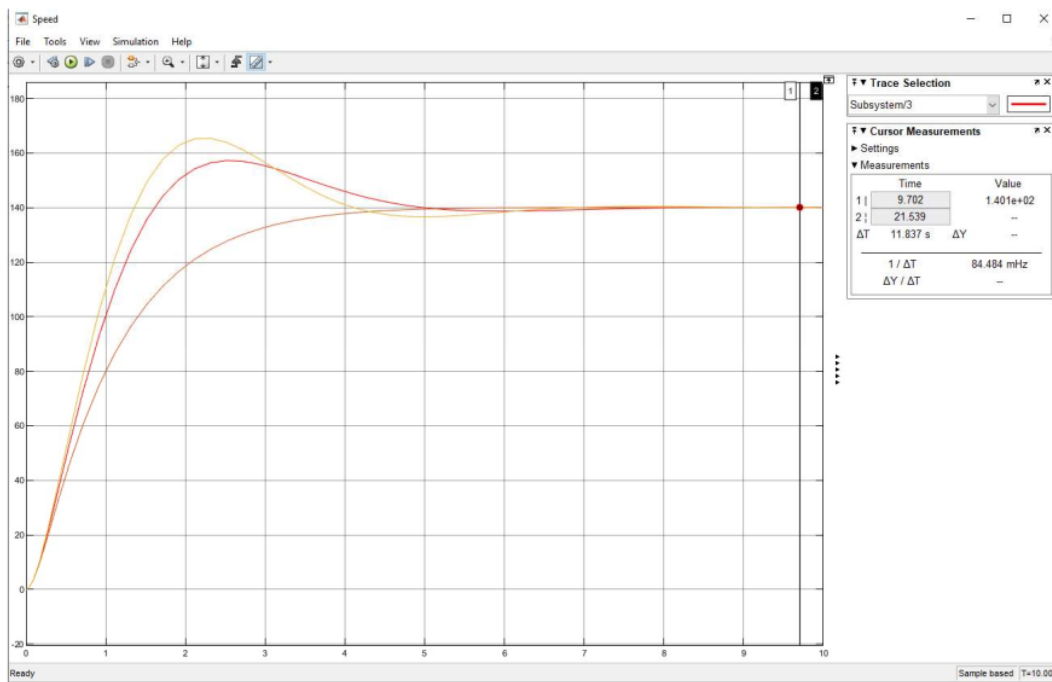


Figure 86 PI results

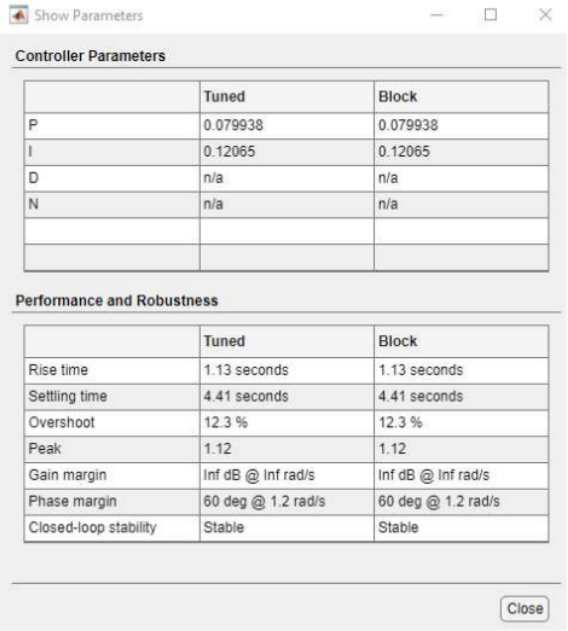


Figure 87 PI value 1

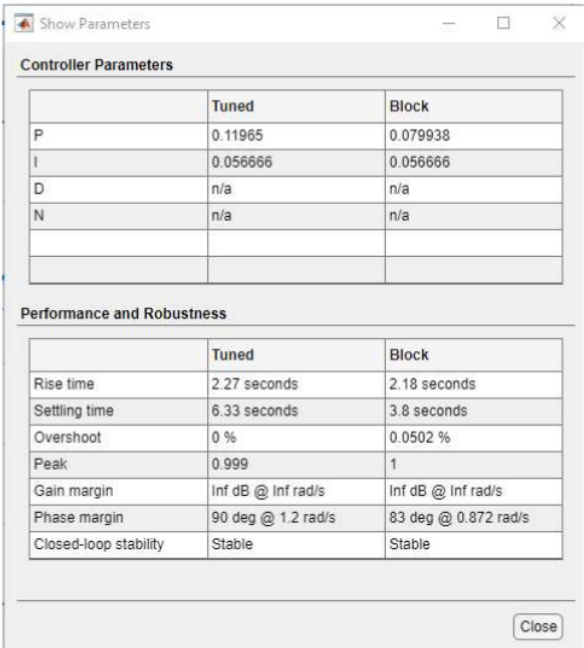


Figure 88 PI value 2

15.3

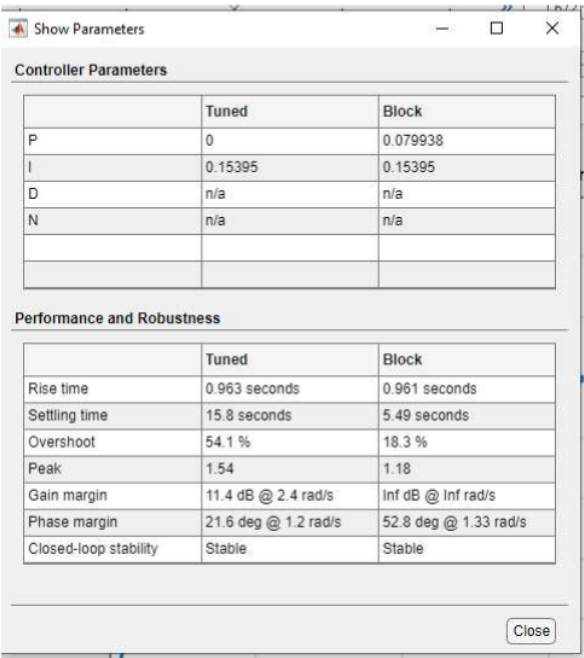


Figure 89 PI value 3

The results have once again been collected and placed in a table for comparison.

Ki	SSE	% O/S	Rise Time	Settling Time
0.1206	0	12.3%	1.13	4.41
0.0566	0	0.502%	2.18	3.8
0.1539	0	18.3%	0.961	5.49

The table of results shows that the higher the ki value the more it will overshoot. The value of ki being higher also means the setting time will be higher but the rise time will decrease as ki increases. Adding ki allowed the response to be a lot smoother with less overshoot throughout and far less SSE. The table shows the optimal value being 0.1206 as it has been tuned.

Task 16 – Proportional-Integral-Derivative Speed Control System

16.1

Again, the same values and subsystem was used, but a PID controller as used and 3 different values used for K_d . The responses of these changes have been captured below.

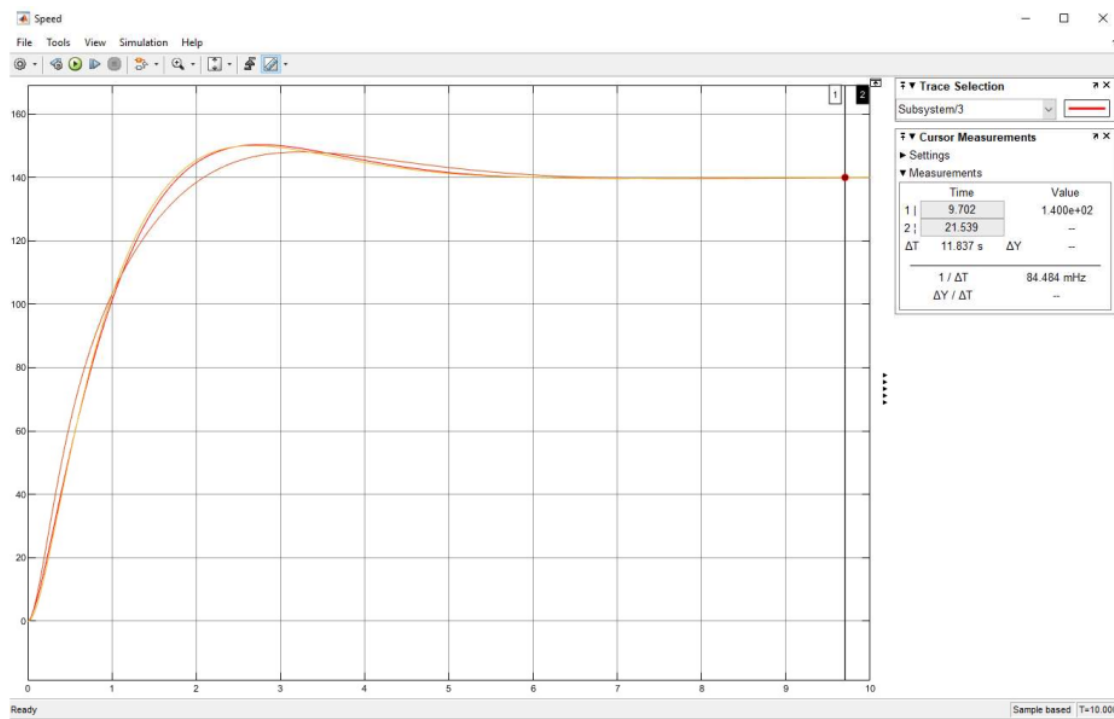
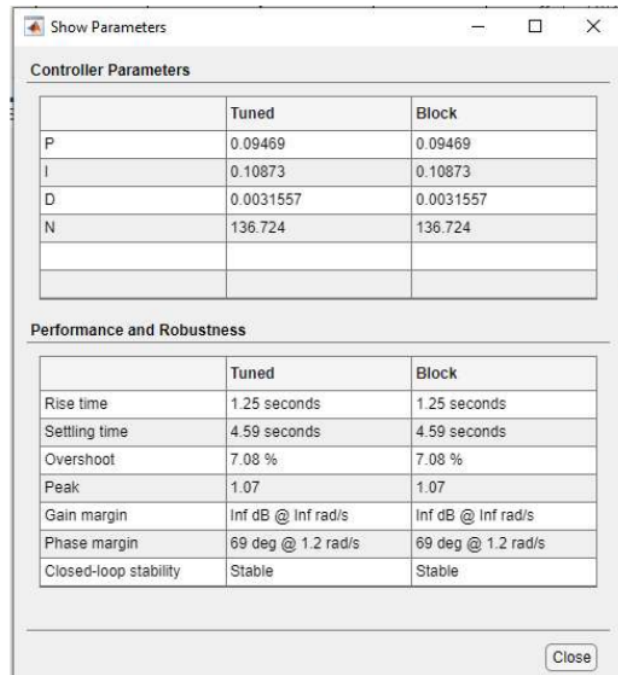


Figure 90 PID results

16.2



Show Parameters

Controller Parameters

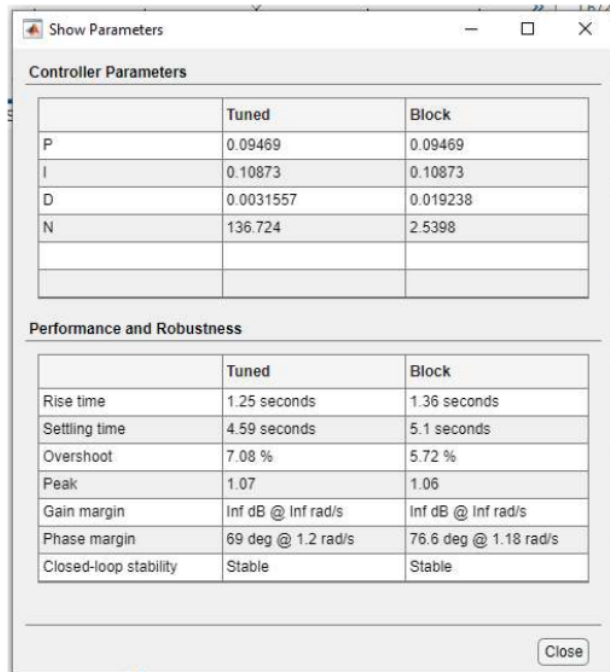
	Tuned	Block
P	0.09469	0.09469
I	0.10873	0.10873
D	0.0031557	0.0031557
N	136.724	136.724

Performance and Robustness

	Tuned	Block
Rise time	1.25 seconds	1.25 seconds
Settling time	4.59 seconds	4.59 seconds
Overshoot	7.08 %	7.08 %
Peak	1.07	1.07
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	69 deg @ 1.2 rad/s	69 deg @ 1.2 rad/s
Closed-loop stability	Stable	Stable

Close

Figure 91 PID value 1



Show Parameters

Controller Parameters

	Tuned	Block
P	0.09469	0.09469
I	0.10873	0.10873
D	0.0031557	0.019238
N	136.724	2.5398

Performance and Robustness

	Tuned	Block
Rise time	1.25 seconds	1.36 seconds
Settling time	4.59 seconds	5.1 seconds
Overshoot	7.08 %	5.72 %
Peak	1.07	1.06
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	69 deg @ 1.2 rad/s	76.6 deg @ 1.18 rad/s
Closed-loop stability	Stable	Stable

Close

Figure 92 PID value 2

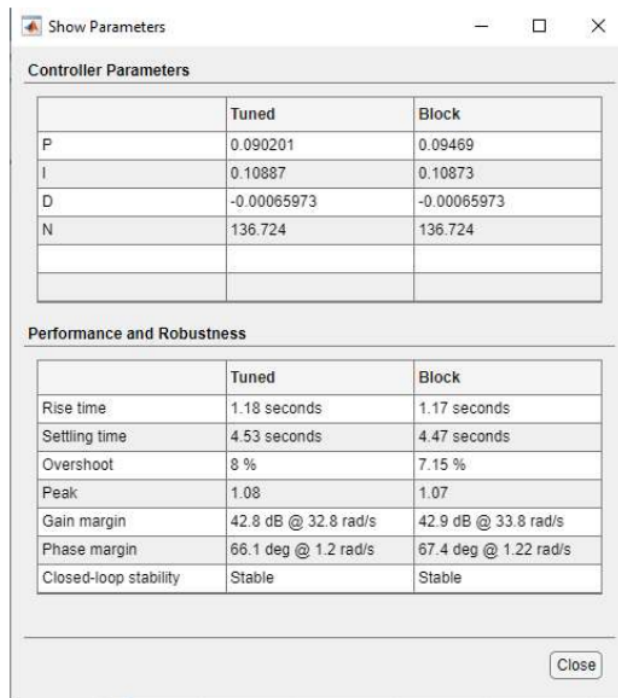


Figure 93 PID value 3

16.3

Kd	SSE	% O/S	Rise Time	Settling Time
0.00316	0	7.08%	1.25	4.59
0.1923	0	5.72%	1.36	5.1
-0.0006	0	7.15%	1.17	4.47

From the results above, now kd has been added, the response is even smoother with a relatively even amount of o/s, rise time and settling time across the 3 selected values. The graphical results show that having a PID controller allows the system to be controlled to its optimum as all the results are close when rising, overshooting and to where and when they settle, as well as to the values they settle at. The table shows the optimal value being 0.00316 as it has been tuned.

Task 17 – Controller Comparisons

17.1

The system here was changed so that one controlled P, one PI and the other PID. All three controllers were in parallel sharing the same input and scope. The purpose of this is to compare the effects of the controllers' improvements. All results are as seen below.

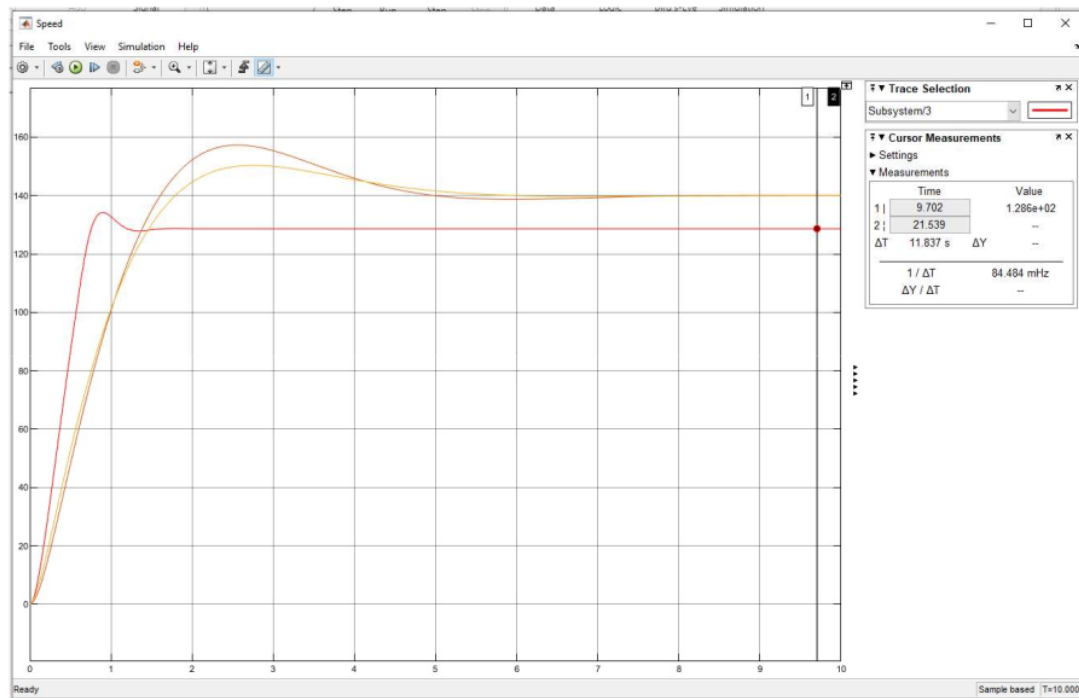


Figure 94 P, I and D results

17.2

Show Parameters

Controller Parameters		
	Tuned	Block
P	0.71342	0.71342
I	n/a	n/a
D	n/a	n/a
N	n/a	n/a

Performance and Robustness		
	Tuned	Block
Rise time	0.205 seconds	0.205 seconds
Settling time	0.691 seconds	0.691 seconds
Overshoot	13.2 %	13.2 %
Peak	1.04	1.04
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	60 deg @ 6.18 rad/s	60 deg @ 6.18 rad/s
Closed-loop stability	Stable	Stable

Close

Figure 95 Just P

Show Parameters

Controller Parameters		
	Tuned	Block
P	0.079938	0.079938
I	0.12065	0.12065
D	n/a	n/a
N	n/a	n/a

Performance and Robustness		
	Tuned	Block
Rise time	1.13 seconds	1.13 seconds
Settling time	4.41 seconds	4.41 seconds
Overshoot	12.3 %	12.3 %
Peak	1.12	1.12
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	60 deg @ 1.2 rad/s	60 deg @ 1.2 rad/s
Closed-loop stability	Stable	Stable

Close

Figure 96 P and I

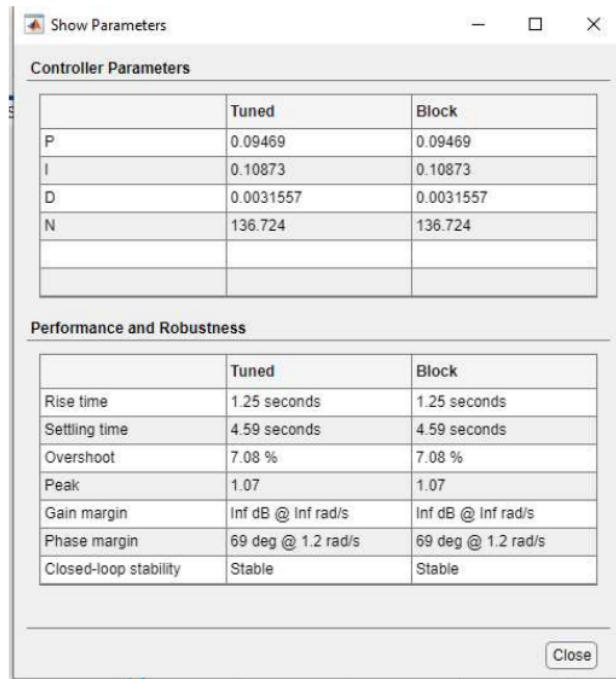


Figure 97 P, I and D

17.3

The results from the 3 are as seen in the table below.

Kp	Ki	Kd	SSE	% O/S	Rise Time	Settling Time
0.71342	x	X	10	13.2%	0.205	0.691
0.07993	0.1206	X	2	12.3%	1.13	4.41
0.00315	0.1087	0.0031	0	7.08%	1.25	4.59

The differences can be clearly seen between the 3 controllers and are displayed both in the table and the graph above. Using only P to control, the results never reach the setpoint required therefore having a high SSE. When Ki was added, the system got far closer to the setpoint required but still had a large amount of overshooting which needs to be controlled further. Lastly Kd was combined with Kp and Ki allowing the system to reach the setpoint without any SSE, as well as having less overshoot. It sacrifices the rise and settling time to do so but not majorly compared to that of PI. To conclude using P only means the system is too hard to control and the correct response will never occur. The results also showing that P is unsuitable to a system where a disturbance is applied. PI provides an overall better control due to it being able to stop closer to the setpoint and does so whilst

overshooting less. However, it does so by taking longer than that of just P. PID allows takes the benefits of both previous combined with K_d to allow it to reach the setpoint with little overshoot, be an optimised result. The addition of d allows the disturbances to be cons³⁴ using error. Although PID is by far most accurate a decision of what is required would rely upon the accuracy require from the system.

Task 18 – Overall Conclusions and Recommendations

During the assignment further knowledge of various aspects of electrical principles was gained. To complete the tasks software such as multisim, MATLAB and Simulink were used to compare measured results against calculated. RL, RC and RLC circuits were analysed during the beginning tasks using Laplace transforms and the transfer function.

From the tasks including high and low pass filters it was learnt that each differently are useful at only letting certain frequencies through. Each circuit respectively measure the roll-off at the relevant dB as demonstrated throughout. The design of a high pass filter only allows high frequencies to pass through after the 3db point, with a low pass being the opposite response.

The major effects a damping factor have on circuits can be seen between tasks 5-8. Over and under damped having opposite effects in the way of over moving slowly towards the equilibrium and under moving much faster towards it but will oscillate at the setpoint. It was found a system that has no damping will never make the equilibrium and when it reaches a steady point it will oscillate at that value. Critically damped was seen to be the most effective (figure 23) as it efficiently reaches the equilibrium and does not oscillate at it. By varying the resistor value the effects this had were reordered and compared.

Through task 9 and 10 frequency performances in electronic systems were analysed. The graphical results seen here were similar to those of 3 and 4 due to both acting like a high/low pass filter. The circuits of 9 and 10 were improved by adding an Op amp allowing further control and amplification.

Task 11 focused on frequency performance analysis of a sallen & sey 2nd order filter. This second order circuit was measure at -40dB and was more selective with frequencies were allowed to move through due to its steeper roll-off.

From task 12 it was learnt that the stability of the system depended upon the poles positioning. Poles in the left-hand pane therefore a negative value and higher than minimum value were stable when measure. Those at or lower than the minimum was proved unstable and positive.

The results conclude, in task 13, that when a load is applied to the motor the speed will be slower. This then causing the current to increase and the torque likewise to try overcome the disturbance and maintain the motors speed. The stall torque seen above is the amount required to slow then stop the motor. Friction placed upon the motor would ideally not affect the speed but it does as proven when tested.

Tasks 14 to finish were all about PID setting and control. It was found throughout that the tuned values across P, I and D were most effective across the measured results in terms of control. The system got better and more controlled as I was added to P and further when all 3 were combined. This was proven in the results tables collected as the tasks progressed. To conclude these the type of controller best

fitting would be that of the PID, but when selecting would depend on the level of accuracy required. This is due to expense of a PID.

A recommendation would be is to use the installed version of MATLAB only due to the complications encountered using the online version. On MATLAB instead of placing cursors typing the selected value of where they should go would improve accuracy of the results is a further improvement that could be made. Further investigations into filters could be carried out by looking into a 3rd or 4th cascades instead or as well as the 2nd order.

FINAL GRADE

GENERAL COMMENTS

Instructor

62/100

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PAGE 3

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PAGE 9

 **Comment 1**
give the equation

PAGE 10

PAGE 11

 **Comment 2**
good work

PAGE 12



Comment 3

good work



Comment 4

missing an s



Comment 5

missing some - signs



Comment 6

needs more explanation



Comment 7

s missing



Comment 8

comment as for task 3



Comment 9

explain this

 **Comment 10**
WW

 **Comment 11**
WW

 **Comment 12**
needs more explanation

 **Comment 13**
check this and explain it

 **Comment 14**

criteria? this needs far more context and explanation



Comment 15

WW

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Comment 16

definition of quantities missing

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Comment 17

good work

PAGE 48



Comment 18

What circuit is this, what are your objectives



Comment 19

define terms

PAGE 49



Comment 20

explain /show equation

PAGE 50



Comment 21

see comment as per task 9

PAGE 51



Comment 22

this needs far more explanation

PAGE 52

PAGE 53

PAGE 54



Comment 23

good work

PAGE 55



Comment 24

you should not start a task with some code and an image! set the context first



Comment 25

explain this, why?

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Comment 26

calculated min k?

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Comment 27

be precise, what is a pole, left hand plane of what?

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Comment 28

explain

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Comment 29

there is an error here due to friction



Comment 30

correct but how?

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Comment 31

incorrect

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Comment 32

none?

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Comment 33

tuned to what specification?

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Comment 34

mostly correct, some vagueness and confusion

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GRADING FORM: NEW CSG-RUBRIC

KYRAN PRITCHARD

62

1. ENGAGEMENT WITH LITERATURE



NA

0

2. KNOWLEDGE AND UNDERSTANDING



Explanations of electrical/electronic circuits are limited and descriptive, there are missing definitions and equations not fully explained.

16

Control circuits are given more in the way of context and explanation.16/30

3. COGNITIVE AND INTELLECTUAL



Analysis is mostly descriptive, data is presented and accurate but deeper relation to theory needed. 15/30

15

4. PRACTICAL APPLICATION



Advanced application of methods, all work is accurate and clearly presented, there are some comments as marked. 24/30

24

5. TRANSFERABLE SKILLS



Written communication is effective, report flows well, some tasks need an introduction. 7/10

7