

2117261

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Task 1

1.1

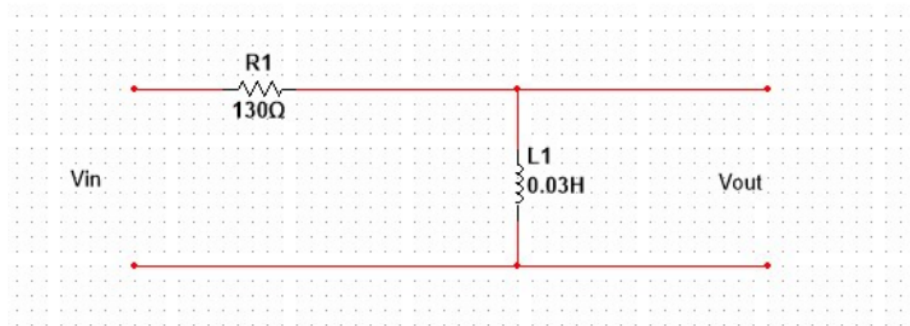


Figure 1 RL circuit

This is a transient analysis of a first order RL electrical circuit.

These are the values used for this task

$$R = 130\Omega \quad L = 0.03 \text{ H}$$

$$\tau = \frac{L}{R} = \frac{0.03}{130} = 231 \mu\text{s}$$

1.2

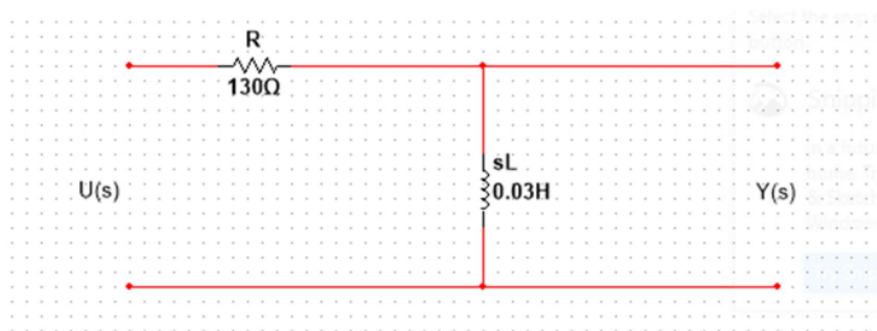


Figure 2 Laplace form

$$\text{Laplace formula} = H(s) = \frac{sL}{sL + R} = \frac{0.03s}{0.03s + 130}$$

1.3

```
task1.m x +
1 s = tf ('s');
2 system = 0.03*s/(0.03*s +130);
3 step (system);
4 grid on
5 |
```

Figure 3 Mat Lab code

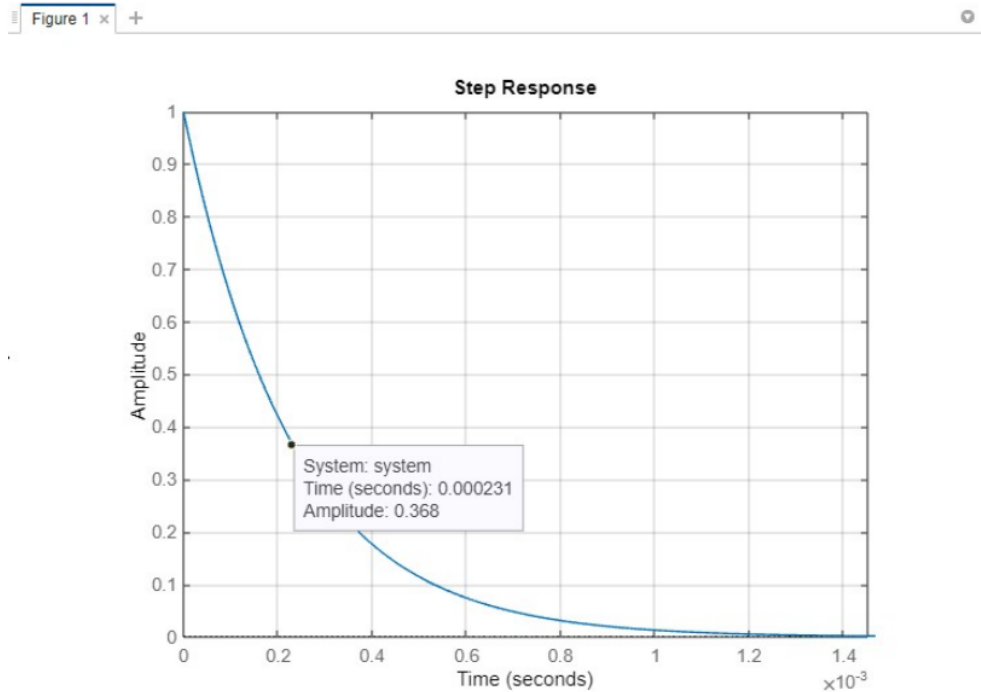


Figure 4 Mat Lab graph

1.4

	Calculated	simulated	Error
Tau	231uS	231uS	0 S

1.5

It is clear to see from the results that there are no errors. The response is an exponential decay, as the circuit is first order, $e^{-1} = 0.368$. That is why tau has been measured at this point on the graph. This proves the analysis.



Task 2

This is a transient analysis of a first order RC electrical circuit.

2.1

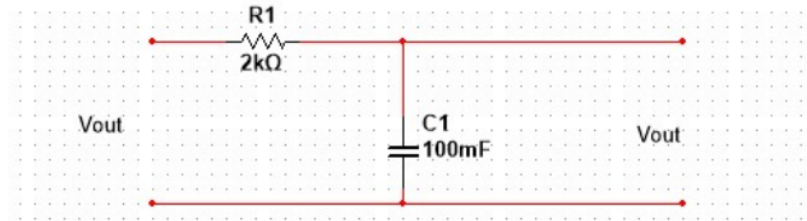


Figure 5 RC circuit

These are the values chosen for this task.

$$R = 2000\Omega \quad C = 100\text{mF}$$

$$\tau = RC = 2000 \times 100 \times 10^{-3} = 200\text{s}$$

2.2

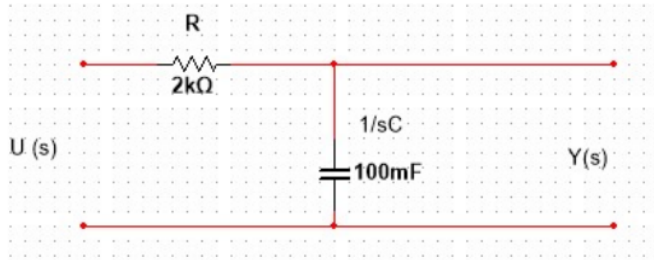


Figure 6 Laplace form

$$\text{Laplace formula} = H(s) = \frac{1}{RCs+1} = \frac{1}{2000 \times 100 \times 10^{-3} s + 1}$$

2.3

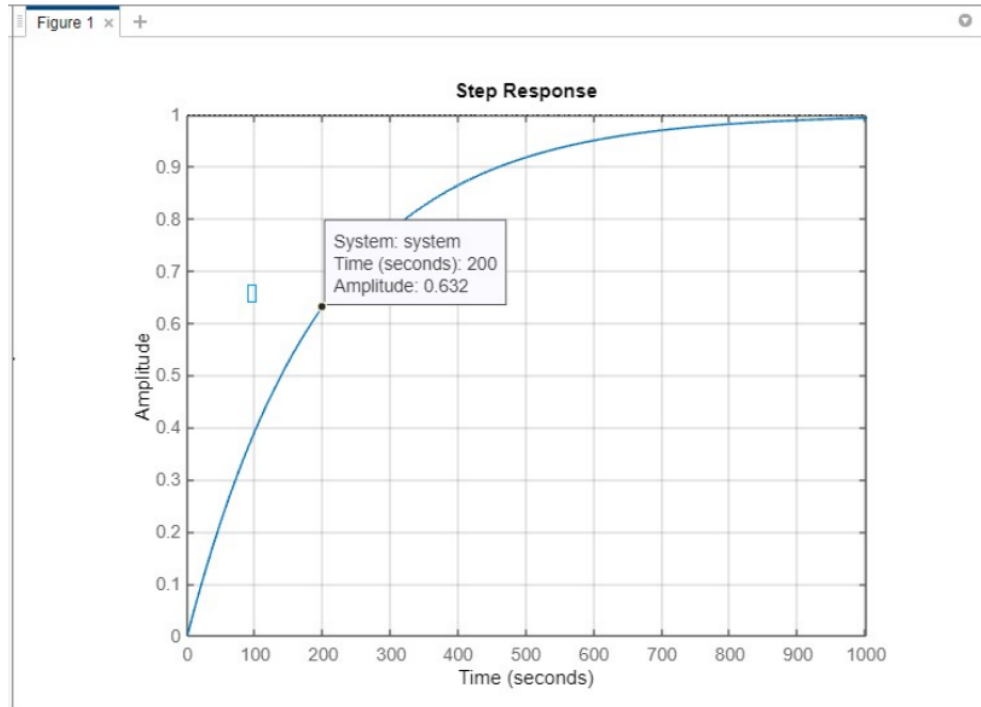


Figure 8 Mat Lab graph

```

task2.m x +
1      s = tf('s');
2      system = 1/((2000) * (0.1)*s +1);
3      step (system);
4      grid on
  
```

Figure 7 Mat Lab code

2.4

	Calculated	simulated	Error
Tau	200s	200s	0 S

2.5

It is clear to see from the results that there are no errors. The response is an exponential decay, as the circuit is first order, $1 - e^{-1} = 0.632$. that is why tau has been measured at this point. This proves the anal

Task 3

3.1

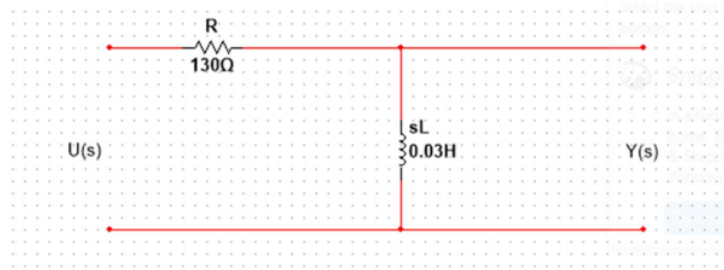


Figure 9 Laplace form of an RL circuit

This is a frequency performance analysis of a first order RL electrical circuit.

The values chosen are, $R = 130\Omega$ $L = 0.03\text{ H}$

$$\text{Cut-off frequency} = \omega_c = \frac{R}{L} = \frac{130}{0.03} = 4333.3 \text{ Rad/S}$$

$$\text{Laplace formula} = H(s) = \frac{\frac{1}{\omega_c}}{\frac{1}{\omega_c} + 1} = \frac{s}{s + \omega_c} = \frac{1}{s + 4333.3}$$

3.2

```
task3.m x +
1 s = tf('s');
2 system = s / (s + 4333.3);
3 bode(system);
4 grid on;
5 |
```

Figure 11 Mat Lab code

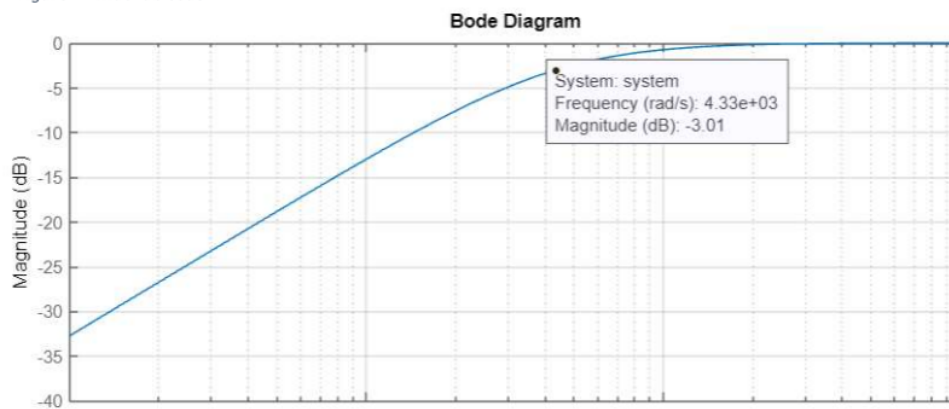


Figure 10 Mat lab graph, magnitude at natural frequency

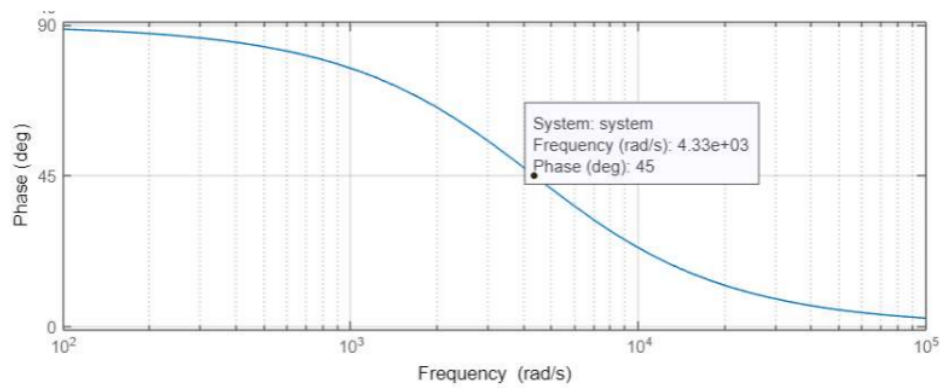


Figure 12 Phase shift at natural frequency

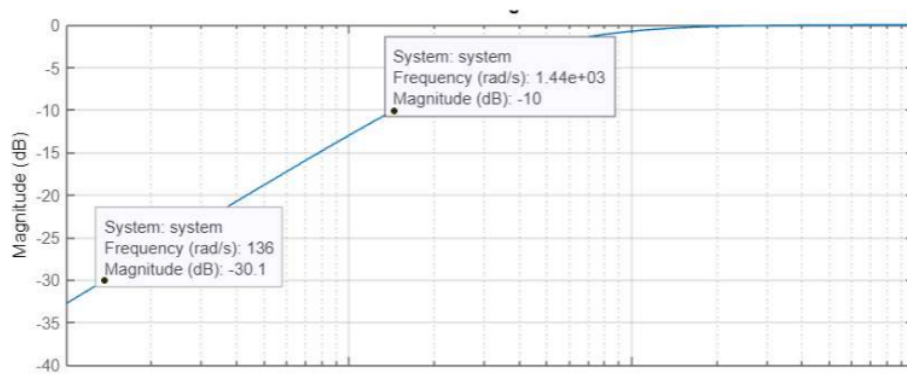


Figure 13 roll off

3.3

	Calculated	Measured
ω_c	4333.3 Rad/S	4333
Phase	45 °	45 °
Roll off	20 dB	20 dB

3.4

Due to the lay out of the components, this is a high pass filter. This only allows high frequencies to pass, after the 3dB point. There aren't any errors. Therefore, confirming the analysis. The phase shift at natural frequency is 45°. Because it is a first order circuit the roll of is 20dB.



Task 4

4.1

This is a frequency performance analysis of a first order RC electrical circuit.

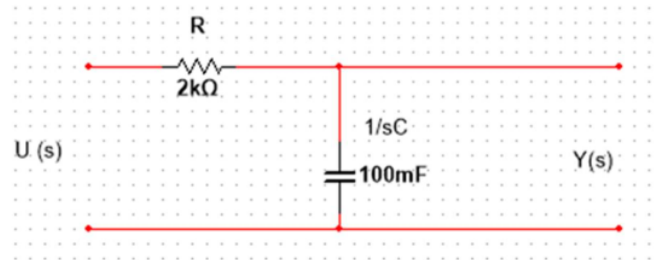


Figure 14 Laplace form RC circuit

$$R = 2000\Omega \quad C = 100\text{mf}$$

$$\text{Cut-off frequency} = \omega_c = \frac{1}{RC} = \frac{1}{2000 \times 100 \times 10^{-3}} = 5 \text{ mRad/S}$$

$$\text{Laplace formula} = H(s) = \frac{1}{\omega_c + 1} = \frac{\frac{1}{\omega_c}}{\frac{1}{\omega_c} + \omega_c} = \frac{\omega_c}{s + \omega_c} = \frac{5 \times 10^{-3}}{s + 5 \times 10^{-3}}$$

4.2

```
task3.m x task4.m x +
1      s = tf('s');
2      system = 5*10^-3 / ((s) + 5*10^-3);
3      bode (system);
4      grid on;
```

Figure 15 Mat Lab code

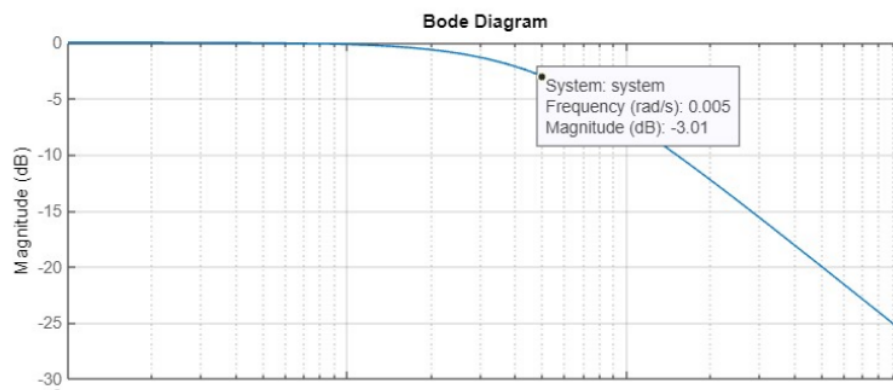


Figure 16 magnitude at natural frequency

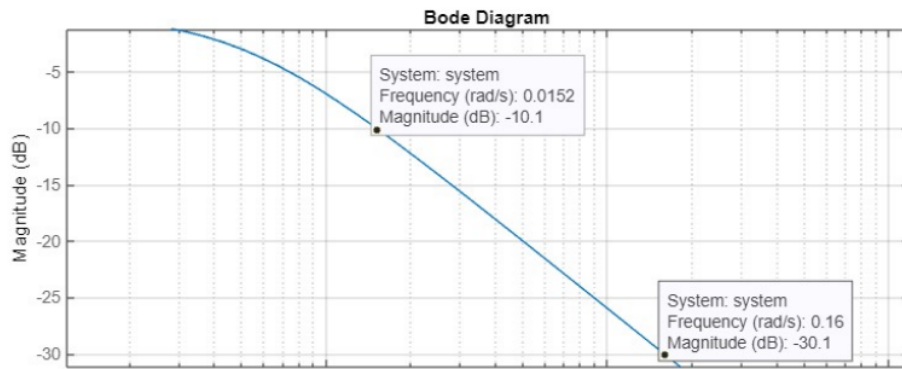


Figure 17 Roll off

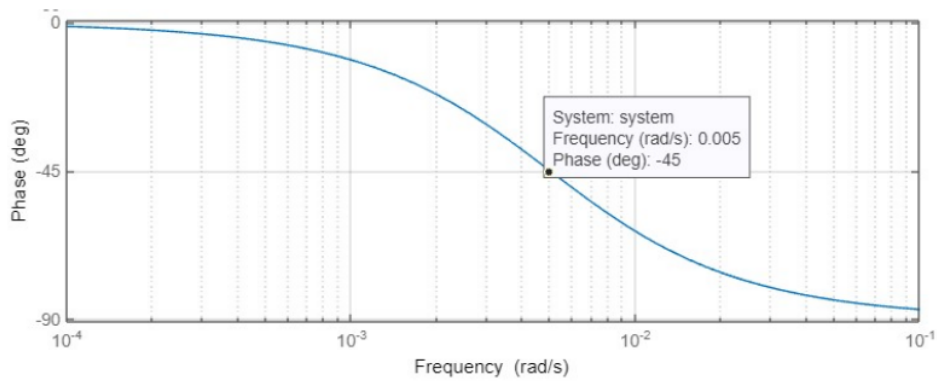


Figure 18 Phase shift at natural frequency

4.3

	Calculated	Measured
ω_c	5 mRad/S	5 mRad/S
Phase	7 degrees	45 degrees
Roll off	20 dB	20 dB

4.4

Due to the lay out of the components, this is a low pass filter. This only allows low frequencies to pass, before the 3dB point. There aren't any errors. Therefore, confirming the analysis. The phase shift at natural frequency is 45°. Because it is a first order circuit the roll of is 8

Task 5

Transient performance analysis of a second order series electrical circuit.

5.1

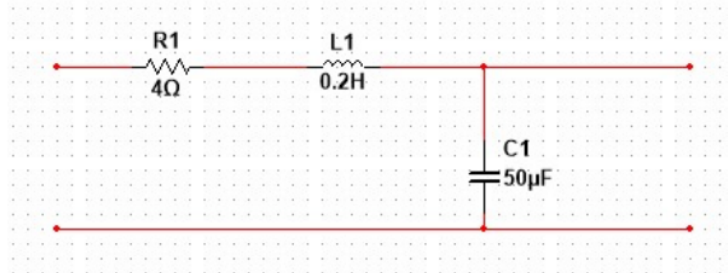


Figure 19 RLC circuit

These are the components values that have been chosen.

$$R = 4\Omega \quad L = 0.2 \quad C = 50\mu\text{F} \quad K = 1$$

5.2

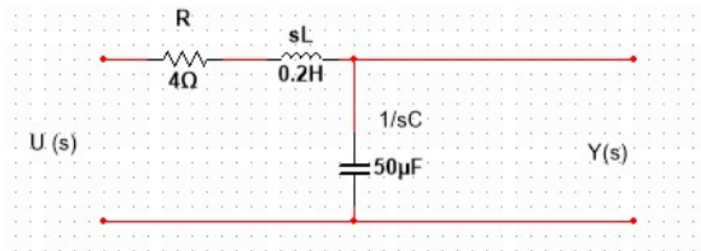


Figure 20 Laplace for RLC circuit

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



5.3

To calculate natural frequency and the damping factor these equations are used;

$$\text{Natural frequency} = W_n = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.2 \times 50 \times 10^{-6}}} = 316.23 \text{ Rad/S}$$

Each circuit will have the same natural frequency.

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

Underdamped

$$\text{Damping factor} = \zeta = \frac{R}{C} \sqrt{\frac{C}{L}} = \frac{4}{2} \sqrt{\frac{50 \times 10^{-6}}{0.2}} = 0.03$$

$$H(s) = \frac{K W n^2}{s^2 + 2 \zeta W n s + W n^2} = \frac{1 \times 316.23^2}{s^2 + ((2 \times 0.03 \times 316.23) \times s) + 316.23^2}$$

Overdamped

$$\text{Damping factor} = \zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{280}{2} \sqrt{\frac{50 \times 10^{-6}}{0.2}} = 2.21$$

$$H(s) = \frac{K W n^2}{s^2 + 2 \zeta W n s + W n^2} = \frac{1 \times 316.23^2}{s^2 + ((2 \times 2.22 \times 316.23) \times s) + 316.23^2}$$

Critically damped

To attain a critically damped circuit. The damping factor must equal one. By rearranging the damping factor equation for resistance and using zeta as one. This can be made possible.

$$R = \frac{2 \times \zeta}{(\sqrt{\frac{C}{L}})} = \frac{2 \times 1}{(\sqrt{\frac{50 \times 10^{-6}}{0.2}})} = 126.49$$

$$\text{Damping factor} = \zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{126.49}{2} \sqrt{\frac{50 \times 10^{-6}}{0.2}} = 1$$

$$H(s) = \frac{K W n^2}{s^2 + 2 \zeta W n s + W n^2} = \frac{1 \times 316.23^2}{s^2 + ((2 \times 1 \times 316.23) \times s) + 316.23^2}$$

No damping

The number 0.000001 Ω was used to attain a damping factor of close to zero.

$$\text{Damping factor} = \zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{0.000001}{2} \sqrt{\frac{50 \times 10^{-6}}{0.2}} = 79.05 \times 10^{-9}$$

$$H(s) = \frac{K W n^2}{s^2 + 2 \zeta W n s + W n^2} = \frac{1 \times 316.23^2}{s^2 + ((2 \times 79.05 \times 10^{-9} \times 316.23) \times s) + 316.23^2}$$

5.4

Underdamped

```
1 s = tf('s');
2 system=316.23^2/(s^2 + 18.97*s + 316.23^2);
3 step (system);
4 grid on;
```

Figure 21 Mat Lab code

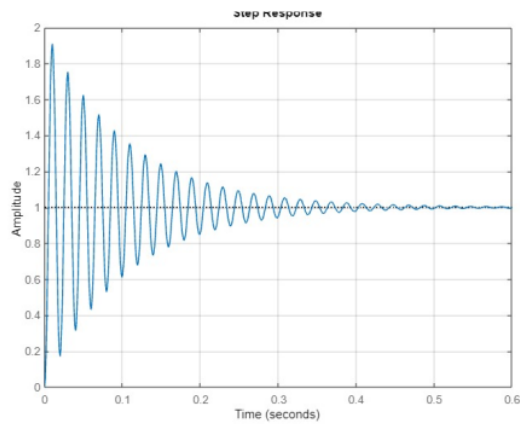


Figure 22 Underdamped

Overdamped

```
1 s = tf('s');
2 system=316.23^2/ (s^2 + 1397.74*s + 316.23^2);
3 step (system);
4 grid on;
```

Figure 23 Mat Lab code

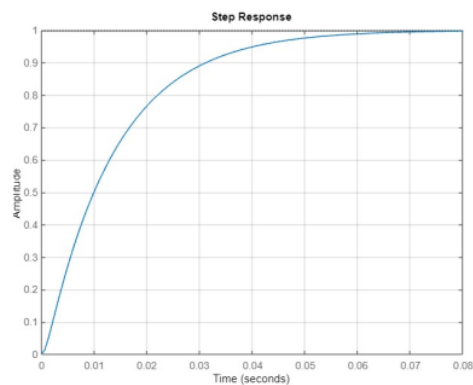


Figure 24 Over damped

Critically damped

```

1  s = tf('s');
2  system=316.23^2/ (s^2 + 632.4*s + 316.23^2);
3  step (system);
4  grid on;

```

Figure 25 Mat Lab code

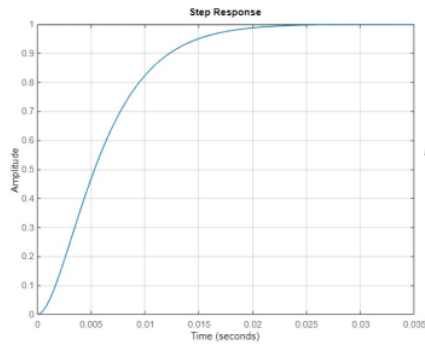


Figure 26 Critically damped

No damping

```

1  s = tf('s');
2  system=316.23^2/ (s^2 + 5.00003522*10^-6 *s + (316.23^2));
3  step (system);
4  grid on;

```

Figure 27 Mat Lab

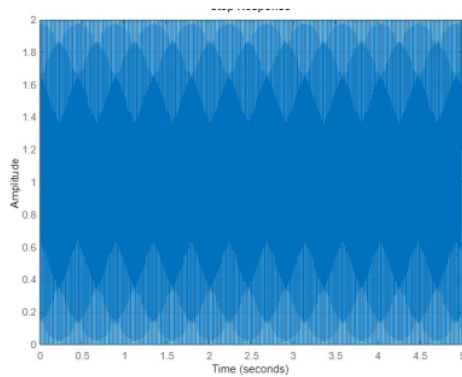


Figure 28 No damping

5.6

Resistor values(Ω)	Damping factor(ζ)	Effect
4	0.03 ($\zeta < 1$)	Underdamping
280	2.22 ($\zeta > 1$)	Overdamping
126.49	1397.74 ($\zeta = 1$)	Critically damped
0.00001	79.05×10^{-9} ($\zeta = 0$)	No damping

5.7

All analysis has been confirmed by the production of the graphs. The damping factors clearly effect the circuits and their properties. As this was a second order circuit, it was growing. The critically damped had no overshooting. The no damping had oscillations and v  10 each equilibrium. The over damped circuit slowly grows to equilibrium, but not quite. Underdamping moved quickly to equilibrium but overshoot and  11 ed for time.

Task 6

6.1

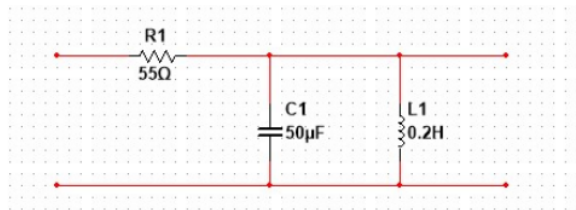


Figure 29 RLC circuit

These are the components values that have been chosen.

$$R = 55\Omega \quad L = 0.2 \quad C = 50\mu F \quad K = 1$$

6.2

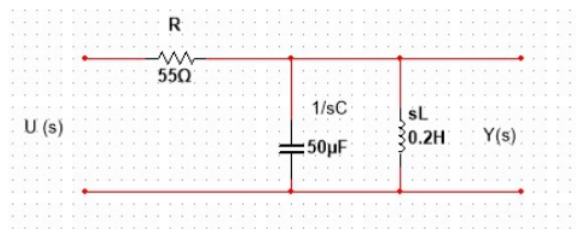


Figure 30 Laplace form RLC circuit

As $H(s) = \frac{s \times \frac{1}{RC}}{s^2 + (\frac{1}{RC} \times s) + \frac{1}{LC}}$ and $H(s) = \frac{K W_n^2}{s^2 + 2 \zeta W_n s + W_n^2}$ are equal, the dom  12 can be swapped to form this equation .

$$\text{Transfer function} = H(s) = \frac{s \times \frac{1}{RC}}{s^2 + 2 \zeta W_n s + W_n^2} \quad \text{13}$$

6.3

To calculate natural frequency and the damping factor these equations are used;

$$\text{Natural frequency} = W_n = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.2 \times 50 \times 10^{-6}}} = 316.23 \text{ Rad/S}$$

Each circuit will have the same natural frequency.

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

Underdamped

$$R = 55\Omega \quad \zeta = \frac{1}{2 \times 55} \sqrt{\frac{0.2}{50 \times 10^{-6}}} = 0.575$$

$$H(s) = \frac{s \times \frac{1}{RC}}{s^2 + 2\zeta W_n s + W_n^2} = \frac{s \times \frac{1}{55 \times 50 \times 10^{-6}}}{s^2 + (2 \times 0.575 \times 316.23 \times s) + 316.23^2}$$

Overdamped

$$R = 4\Omega \quad \zeta = \frac{1}{2 \times 4} \sqrt{\frac{0.2}{50 \times 10^{-6}}} = 7.90$$

$$H(s) = \frac{s \times \frac{1}{RC}}{s^2 + 2\zeta W_n s + W_n^2} = \frac{s \times \frac{1}{4 \times 50 \times 10^{-6}}}{s^2 + (2 \times 7.9 \times 316.23 \times s) + 316.23^2}$$

Critically damped

To attain a critically damped circuit. The damping factor must equal one. By rearranging the damping factor equation for resistance and using zeta as one. This can be made possible.

$$R = \frac{1}{2} \sqrt{\frac{L}{C}} = \frac{1}{2} \sqrt{\frac{0.2}{50 \times 10^{-6}}} = 31.62\Omega$$

$$\zeta = \frac{1}{2 \times 31.62} \sqrt{\frac{0.2}{50 \times 10^{-6}}} = 1$$

$$H(s) = \frac{s \times \frac{1}{RC}}{s^2 + 2\zeta W_n s + W_n^2} = \frac{s \times \frac{1}{31.62 \times 50 \times 10^{-6}}}{s^2 + (2 \times 1 \times 316.23 \times s) + 316.23^2}$$

No damping

$$R = 250\Omega \quad \zeta = \frac{1}{2 \times 250} \sqrt{\frac{0.2}{50 \times 10^{-6}}} = 0.126$$

$$H(s) = \frac{s \times \frac{1}{RC}}{s^2 + 2\zeta W_n s + W_n^2} = \frac{s \times \frac{1}{250 \times 50 \times 10^{-6}}}{s^2 + (2 \times 0.126 \times 316.23 \times s) + 316.23^2}$$

6.4

Underdamped

```
1 s = tf('s');
2 system = s * (1/(55*50*10^-6)) / (s^2+(2*0.575*316.23*s)+316.23^2);
3 step(system);
4 grid on;
```

Figure 31 Mat Lab code

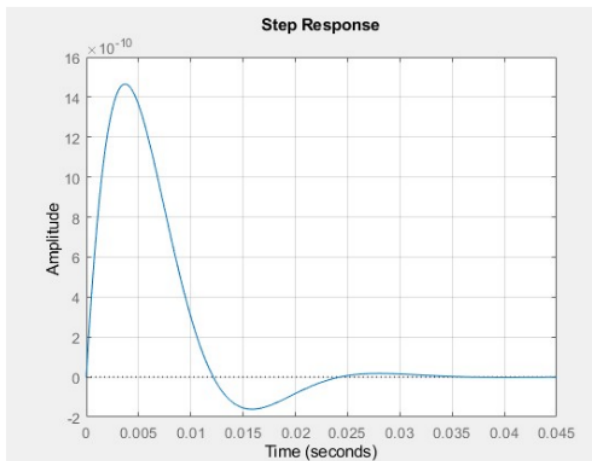


Figure 32 Underdamped

Overdamped

```
1 s = tf('s');
2 system = s * (1/4*50*10^-6) / (s^2+(2*7.9*316.23*s)+316.23^2);
3 step(system);
4 grid on;
```

Figure 33 Mat Lab Over damped

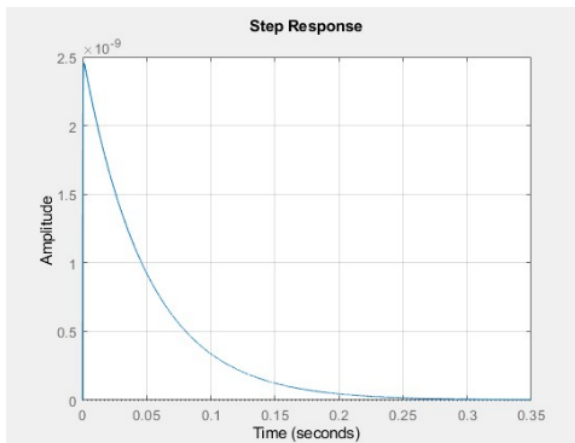


Figure 34 Overdamped

Critically damped

```
1 s = tf('s');
2 system = s * (1/31.62*50*10^-6) / (s^2+(2*1*316.23*s)+316.23^2);
3 step(system);
4 grid on;
```

Figure 35 Mat Lab code

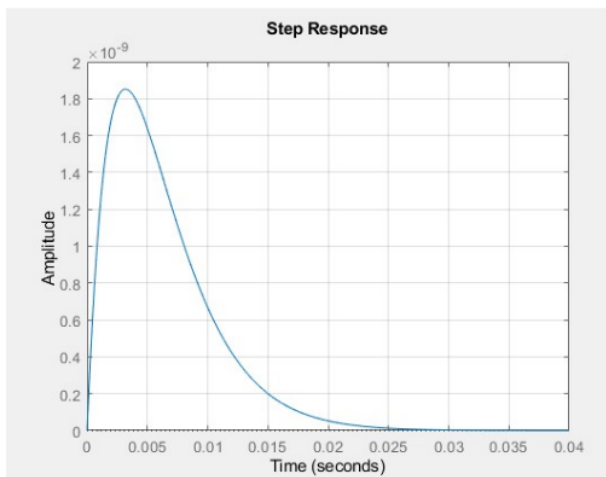


Figure 36 Critically damped

No damping

```
1 s = tf('s');
2 system = s * (1/250*50*10^-6) / (s^2+(2*0.126*316.23*s)+316.23^2);
3 step(system);
4 grid on;
```

Figure 37 Mat Lab code

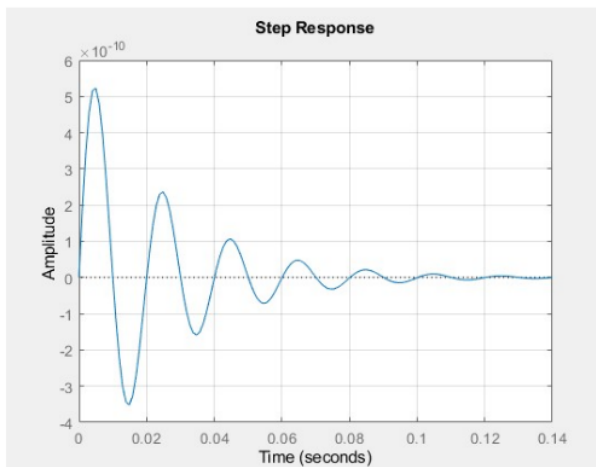


Figure 38 No damping

6.5

Resistor values(Ω)	Damping factor(ζ)	Effect (check)
55	0.03 ($\zeta < 1$)	Underdamping
4	2.22 ($\zeta > 1$)	Overdamping
32.62	1397.74 ($\zeta = 1$)	Critically damped
250	79.05×10^{-9} ($\zeta = 0$)	No damping

6.6

The critically damped had no overshooting. The no damping had oscillations and will not reach equilibrium. The over damped circuit slowly grows to equilibrium, but not quite. Underdamping moved quickly to equilibrium but overshoot and oscillated for time. As this was a first order circuit, it was decaying. All analysis has been confirmed by the production of the graphs. The damping factors clearly effect the circuit and their properties.



Task 7

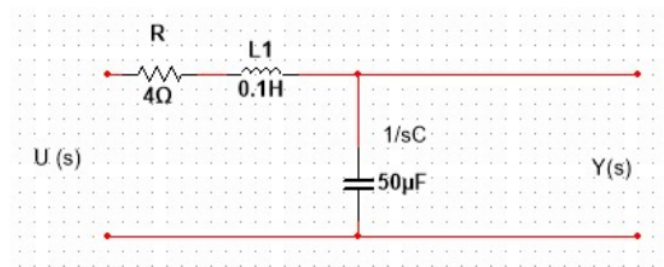


Figure 39 Laplace form

7.1

This is the transfer function used;

$$\text{Transfer function} = H(s) = \frac{s \times \frac{1}{LC}}{s^2 + \frac{R}{L}s + \frac{1}{LC}} = \frac{s \times \frac{1}{0.1 \times 50 \times 10^{-6}}}{s^2 + \frac{R}{0.1}s + \frac{1}{0.1 \times 50 \times 10^{-6}}}$$



$$\text{This is the cut-off frequency} = \omega_c = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.1 \times 50 \times 10^{-6}}} = 447.21 \text{ Rad/S}$$

This is the max frequency for no damping

$$\sqrt{\frac{1}{LC} - \frac{1}{2} \left(\frac{R}{L} \right)^2} = \sqrt{\frac{1}{0.1 \times 50 \times 10^{-6}} - \frac{1}{2} \left(\frac{4}{0.1} \right)^2} = 446.32 \text{ Rad/S}$$

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

Underdamped

$$R = 40\Omega \quad \text{Gain} = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{40} \sqrt{\frac{0.1}{50 \times 10^{-6}}} = 1.12$$

$$H(s) = \frac{s \times \frac{1}{LC}}{s^2 + \frac{R}{L}s + \frac{1}{LC}} = \frac{s \times \frac{1}{0.1 \times 50 \times 10^{-6}}}{s^2 + \frac{40}{0.1}s + \frac{1}{0.1 \times 50 \times 10^{-6}}}$$

$$\text{Damping factor} = \zeta = \frac{40}{2} \sqrt{\frac{50 \times 10^{-6}}{0.1}} = 0.44$$

Overdamped

$$R = 150\Omega \quad \text{Gain} = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{150} \sqrt{\frac{0.1}{50 \times 10^{-6}}} = 0.30$$

$$H(s) = \frac{s \times \frac{1}{LC}}{s^2 + \frac{R}{L}s + \frac{1}{LC}} = \frac{s \times \frac{1}{0.1 \times 50 \times 10^{-6}}}{s^2 + \frac{150}{0.1}s + \frac{1}{0.1 \times 50 \times 10^{-6}}}$$

$$\text{Damping factor} = \zeta = \frac{150}{2} \sqrt{\frac{50 \times 10^{-6}}{0.1}} = 1.68$$

Critically damped

$$R = 2 \sqrt{\frac{L}{C}} = 2 \sqrt{\frac{0.1}{50 \times 10^{-6}}} = 89.44\Omega \quad \text{Gain} = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{89.44} \sqrt{\frac{0.1}{50 \times 10^{-6}}} = 0.50$$

$$H(s) = \frac{s \times \frac{1}{LC}}{s^2 + \frac{R}{L}s + \frac{1}{LC}} = \frac{s \times \frac{1}{0.1 \times 50 \times 10^{-6}}}{s^2 + \frac{89.44}{0.1}s + \frac{1}{0.1 \times 50 \times 10^{-6}}}$$

$$\text{Damping factor} = \zeta = \frac{89.44}{2} \sqrt{\frac{50 \times 10^{-6}}{0.1}} = 1.00$$

No damping

$$R = 4\Omega \quad \text{Gain} = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{4} \sqrt{\frac{0.1}{50 \times 10^{-6}}} = 11.1$$

$$H(s) = \frac{s \times \frac{1}{LC}}{s^2 + \frac{R}{L}s + \frac{1}{LC}} = \frac{s \times \frac{1}{0.1 \times 50 \times 10^{-6}}}{s^2 + \frac{4}{0.1}s + \frac{1}{0.1 \times 50 \times 10^{-6}}}$$

$$\text{Damping factor} = \zeta = \frac{4}{2} \sqrt{\frac{50 \times 10^{-6}}{0.1}} = 0.04$$

7.2

This is the MATLAB code;

```

1  s = tf('s');
2  system1 = 200000/ (s^2 + 40*s + 200000);
3  bode (system1);
4  grid on
5  hold on
6
7  s = tf('s');
8  system2 = 200000/ (s^2 + 1500*s + 200000);
9  bode (system2);
10 s = tf('s');
11 system3 = 200000/ (s^2 + 400*s + 200000);
12 bode (system3);|
13 s = tf('s');
14 system4 = 200000/ (s^2 + 894.4*s + 200000);
15 bode (system4);
16 s = tf('s');
17 system5 = 200000/ (s^2 + 300*s + 200000);
18 bode (system5);
19 s = tf('s');
20 system6 = 200000/ (s^2 + 550*s + 200000);
21 bode (system6);
22
23 grid on

```

Figure 40 Mat Lab code

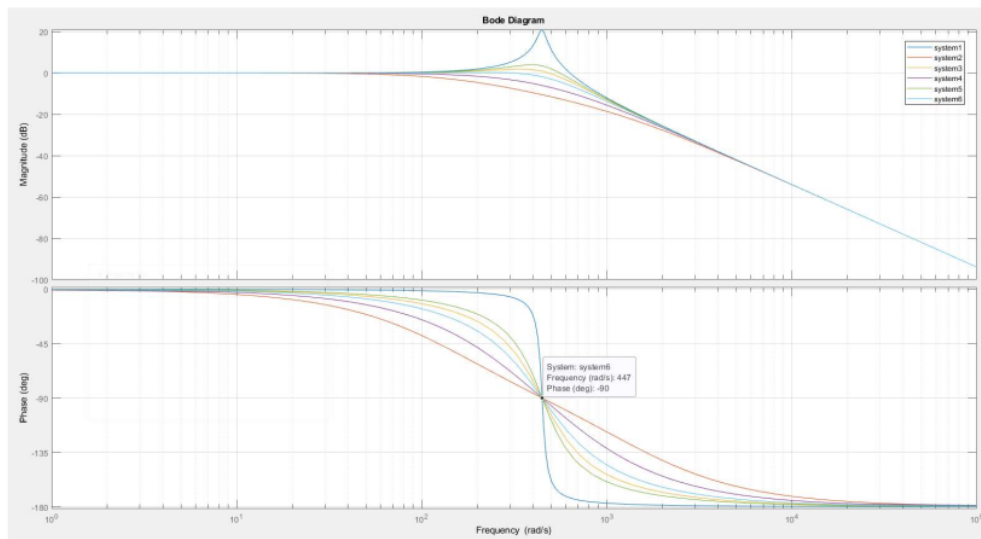


Figure 41 Locus and phase shift

This is the phase shift at the cut off frequency of 447 Rad/S

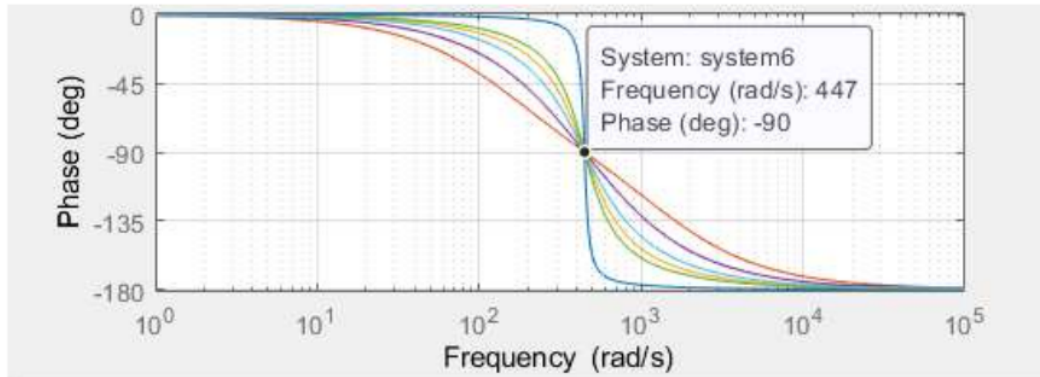


Figure 42 Phase shift

This is the roll off, when measuring a decade. The roll off should be -40 dB in a second order circuit.

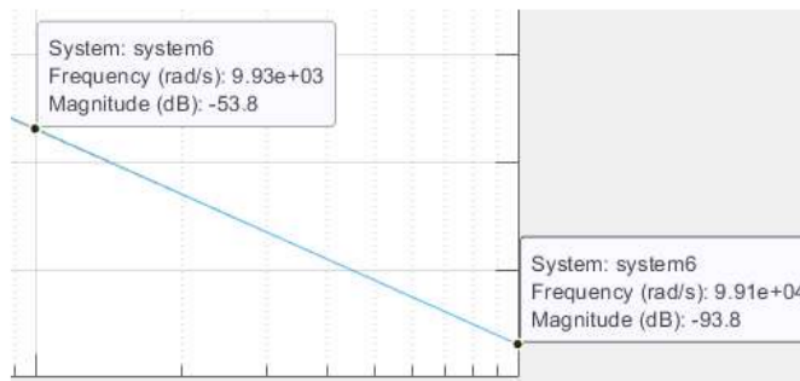


Figure 43 Roll off

7.3

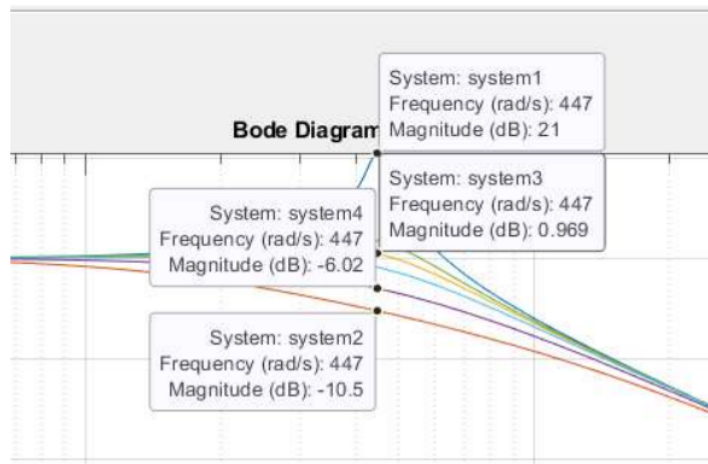


Figure 44 Gain

$$\text{Log}_{20}(Q) = \text{Magnitude dB}$$

Underdamped

$$20\text{Log}(1.12) = 0.98 \text{ dB}$$

Overdamped

$$20\text{Log}(0.30) = -10.46 \text{ dB}$$

Critically damped

$$20\text{Log}(0.5) = -6.02 \text{ dB}$$

No damping

$$20\text{Log}(11.1) = 20.9 \text{ dB}$$

	Measured values at the cut off frequency (magnitude Db)	Calculated values at the cut off frequency (magnitude Db)
Underdamped	0.97	0.98
Overdamped	-10.5	-10.46
Critically damped	-6.02	-6.02
No damping	21	20.9

7.4

It is clear to see that all measured and calculated value have been confirmed. There may be small difference due to rounding errors, with the biggest magnitude error of 0.1dB. In figure 44, by changing the value of the resistance, the damping factor varies, thus creating a low pass filter. By decreasing the value of R, the magnitude increases. This is a low pass filter, therefore only the smaller frequencies can be passed, before the cut off frequency.

Task 8

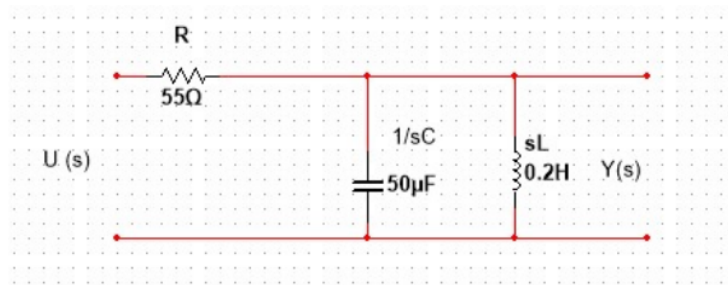


Figure 45 Laplace form

8.1

These are the frequency performance parameters for the circuit;

$$Q = R \sqrt{\frac{C}{L}} \quad W_{c1} = -\frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{LC}\right)} \quad W_{c2} = \frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{LC}\right)}$$

$$W_o = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.2 \times 50 \times 10^{-6}}} = 316.23 \text{ Rad/S}$$

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

$$H(s) = \frac{s\beta}{s^2 + s\beta + W_o^2}$$

$$R = 55 \, \Omega$$

$$\beta = \frac{1}{RC} = \frac{1}{55 \times 50 \times 10^{-6}} = 363.6 \text{ Hz}$$

$$Q = R \sqrt{\frac{C}{L}} = 55 \sqrt{\frac{50 \times 10^{-6}}{0.2}} = 0.87$$

$$\begin{aligned} W_{c1} &= -\frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{LC}\right)} \\ &= -\frac{1}{2 \times 55 \times 50 \times 10^{-6}} + \sqrt{\left(\frac{1}{2 \times 55 \times 50 \times 10^{-6}}\right)^2 + \left(\frac{1}{0.2 \times 50 \times 10^{-6}}\right)} \\ &= 134.70 \text{ Hz} \end{aligned}$$

$$\begin{aligned} W_{c2} &= \frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{LC}\right)} \\ &= \frac{1}{2 \times 55 \times 50 \times 10^{-6}} + \sqrt{\left(\frac{1}{2 \times 55 \times 50 \times 10^{-6}}\right)^2 + \left(\frac{1}{0.2 \times 50 \times 10^{-6}}\right)} = 498.33 \text{ Hz} \end{aligned}$$

$$R = 4 \, \Omega$$

$$\beta = \frac{1}{RC} = \frac{1}{4 \times 50 \times 10^{-6}} = 5000 \text{ Hz}$$

$$Q = R \sqrt{\frac{C}{L}} = 4 \sqrt{\frac{50 \times 10^{-6}}{0.2}} = 0.06$$

$$\begin{aligned} W_{c1} &= -\frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{LC}\right)} \\ &= -\frac{1}{2 \times 4 \times 50 \times 10^{-6}} + \sqrt{\left(\frac{1}{2 \times 4 \times 50 \times 10^{-6}}\right)^2 + \left(\frac{1}{0.2 \times 50 \times 10^{-6}}\right)} = 19.9 \text{ Hz} \end{aligned}$$

$$\begin{aligned} W_{c2} &= \frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{LC}\right)} \\ &= \frac{1}{2 \times 4 \times 50 \times 10^{-6}} + \sqrt{\left(\frac{1}{2 \times 4 \times 50 \times 10^{-6}}\right)^2 + \left(\frac{1}{0.2 \times 50 \times 10^{-6}}\right)} = 5019.92 \text{ Hz} \end{aligned}$$

$$R = 31.62 \, \Omega$$

$$\beta = \frac{1}{RC} = \frac{1}{31.62 \times 50 \times 10^{-6}} = 632.51 \text{ Hz}$$

$$Q = R \sqrt{\frac{C}{L}} = 31.62 \sqrt{\frac{50 \times 10^{-6}}{0.2}} = 0.5$$

$$\begin{aligned} W_{c1} &= -\frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{LC}\right)} \\ &= -\frac{1}{2 \times 31.62 \times 50 \times 10^{-6}} + \sqrt{\left(\frac{1}{2 \times 31.62 \times 50 \times 10^{-6}}\right)^2 + \left(\frac{1}{0.2 \times 50 \times 10^{-6}}\right)} \\ &= 130.97 \text{ Hz} \end{aligned}$$

$$\begin{aligned} W_{c2} &= \frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{LC}\right)} \\ &= \frac{1}{2 \times 31.62 \times 50 \times 10^{-6}} + \sqrt{\left(\frac{1}{2 \times 31.62 \times 50 \times 10^{-6}}\right)^2 + \left(\frac{1}{0.2 \times 50 \times 10^{-6}}\right)} \\ &= 763.48 \text{ Hz} \end{aligned}$$

$R = 250 \, \Omega$

$$\beta = \frac{1}{RC} = \frac{1}{31.62 \times 50 \times 10^{-6}} = 80 \, \text{Hz}$$

$$Q = R \sqrt{\frac{C}{L}} = 250 \sqrt{\frac{50 \times 10^{-6}}{0.2}} = 3.95$$

$$\begin{aligned} \omega_{c1} &= -\frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{LC}\right)} \\ &= -\frac{1}{2 \times 250 \times 50 \times 10^{-6}} + \sqrt{\left(\frac{1}{2 \times 250 \times 50 \times 10^{-6}}\right)^2 + \left(\frac{1}{0.2 \times 50 \times 10^{-6}}\right)} \\ &= 278.75 \, \text{Hz} \end{aligned}$$

$$\begin{aligned} \omega_{c2} &= \frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{LC}\right)} \\ &= \frac{1}{2 \times 250 \times 50 \times 10^{-6}} + \sqrt{\left(\frac{1}{2 \times 250 \times 50 \times 10^{-6}}\right)^2 + \left(\frac{1}{0.2 \times 50 \times 10^{-6}}\right)} \\ &= 358.74 \, \text{Hz} \end{aligned}$$

8.2

$R = 55 \, \Omega$

```
1 s = tf('s');
2 system1 = s * 363.6 / (s^2 + 363.6*s + 316.23^2);
3 bode(system1);
4 grid on
5 hold on
```

Figure 46 Mat Lab code

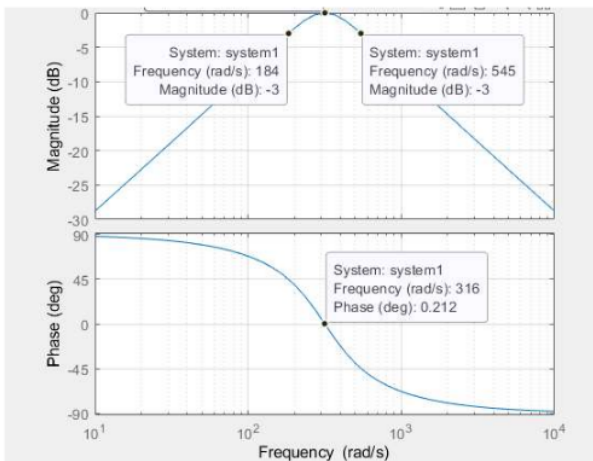


Figure 47 250 ohms

$R = 4 \Omega$

```

1  s = tf('s');
2  system1 = s * 5000 / (s^2 + 5000*s + 316.23^2);
3  bode (system1);
4  grid on
5  hold on

```

Figure 48 Mat Lab code

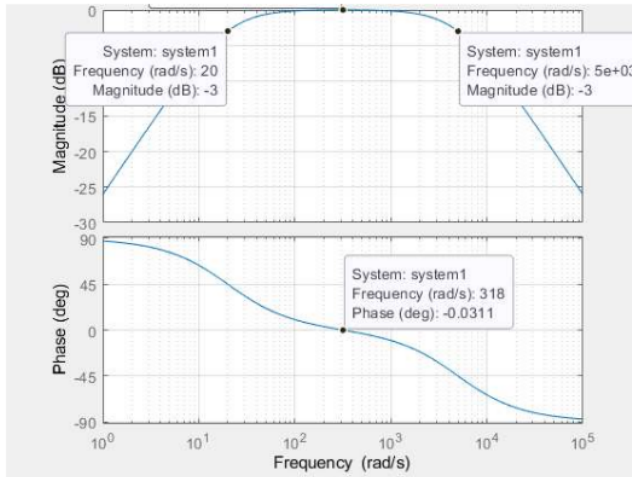


Figure 49 4 Ohms

$R = 31.62 \Omega$

```

1  s = tf('s');
2  system1 = s * 632.51 / (s^2 + 632.51*s + 316.23^2);
3  bode (system1);
4  grid on
5  hold on

```

Figure 51 Mat Lab code

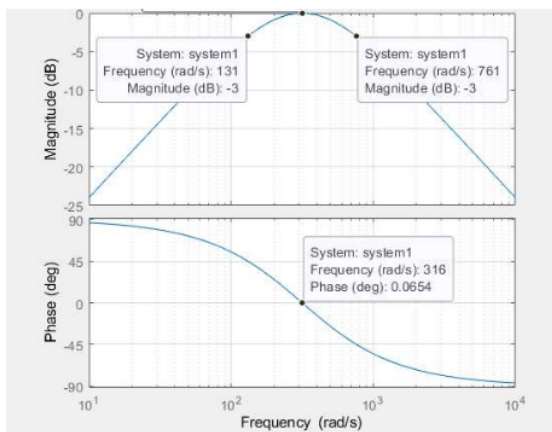


Figure 50 31.63 Ohms

$R = 250 \, \Omega$

```

1  s = tf('s');
2  system1 = s * 80 / (s^2 + 80*s + 316.23^2);
3  bode (system1);
4  grid on
5  hold on

```

Figure 52 Mat Lab code

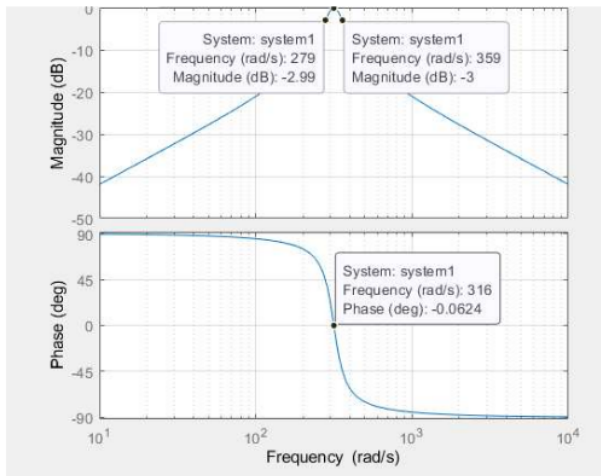


Figure 53 250 Ohms

8.3

Calculated values

Resistance Ω	ω_0 (Hz)	Lower cut off frequency (Hz)	Upper cut off frequency (Hz)	β (Hz)
4	316.62	19.9	5019.9	5000
31.62	316.62	130.97	763.48	632.51
55	316.62	134.70	498.33	363.60
250	316.62	278.75	358.74	80

Measured values

Resistance Ω	ω_0 (Hz)	Lower cut off frequency (Hz)	Upper cut off frequency (Hz)	β (Hz)
4	316.62	20	5003	4983
31.62	316.62	131	761	630
55	316.62	184	545	363
250	316.62	279	359	80

The measured bandwidth has been calculated by deducting the two -3Db points on the Mat Lab graphs.

19

8.4

Conclusion

From reading the results taken, it is clear that as the resistance of the circuit has been increased. This decreases the bandwidth. This means that the circuit is more selective with a higher resistance. At resonant frequency of 316 Rad/S, a phase shift of 0° is seen. Most calculated and measured values match up other than some errors due to rounding and not being able to get on the -3-dB point on Mat Lab. At a resistance of 55 Ohms, the cut off frequencies don't match up, but the bandwidth surprisingly almost perfect. This may be an anomaly.

20

Task 9

9.1

21

A value of 400nF has been chosen.

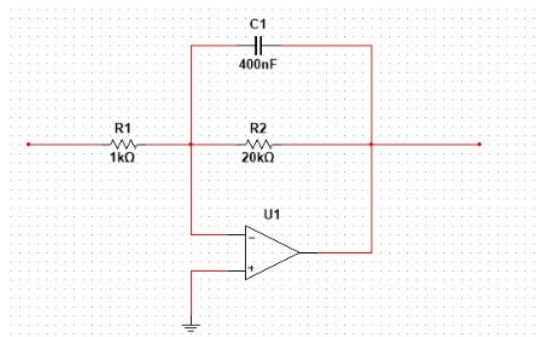


Figure 54 capacitor value chosen

9.2

These are the cut off parameters.

Calculations

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

$$W_c = \frac{1}{400 \times 10^{-9} \times 20000} = 125 \text{ Rad/s}$$

$$\text{Transfer function} = -k \left[\frac{W_c}{s + W_c} \right] = -20 \left(\frac{125}{s + 125} \right)$$

This is the mat lab code

```
1 s = tf('s');
2 system1 = (-20 * (125 / (s + 125)));
3 bode (system1);
4 grid on
5 hold on
```

Figure 55 mat lab code

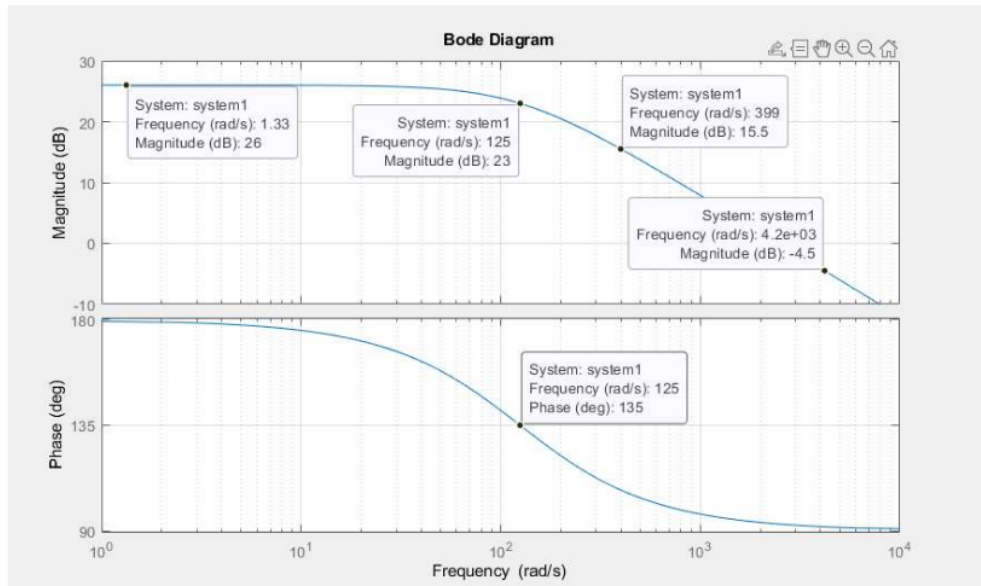


Figure 56 Mat lab annotations

Conclusion

All measured and calculated values marry up. As an inverting amplifier was used, this gives a phase shift of 180° . Therefore, at cut off frequency phase shift $= -45 + 180 = 135^\circ$. The equation below proves the calculated gain and measured values are correct. A roll off of 20dB was measured as the circuit is in the first order.



$$20 \log(20) = 26.02$$



Task 10

10.1

A value of 30nF was chosen.

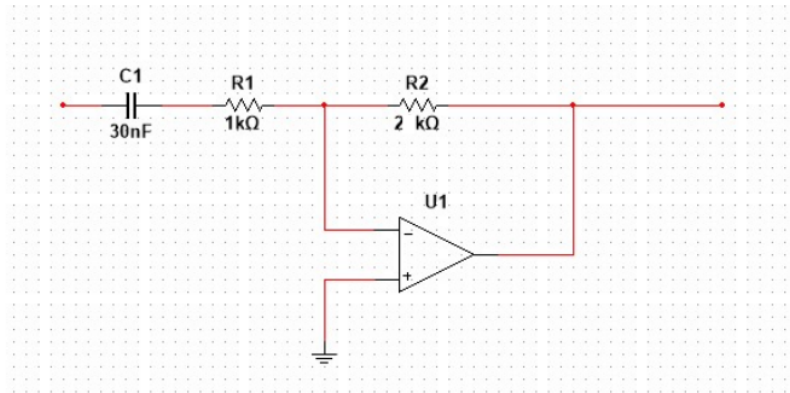


Figure 57 capacitor value chosen

10.2

These are the cut off parameters.

Calculations

$$k = \frac{2000}{1000} = 2$$

$$W_c = \frac{1}{30 \times 10^{-9} \times 1000} = 33333.3 \text{ Rad/s}$$

$$\text{Transfer function } H(s) = -k \left[\frac{s}{s + W_c} \right] = -2 \left(\frac{s}{s + 33333.3} \right)$$

```
1 s = tf('s');
2 system1 = (-2 * (s / (s + 33333.3)));
3 bode (system1);
4 grid on
5 hold on
```

Figure 58 mat lab code

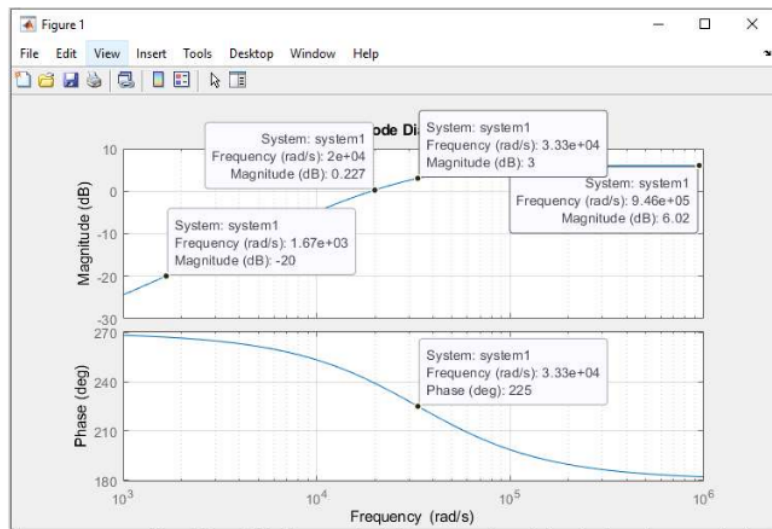


Figure 59 mat lab annotations

Conclusion

All measured and calculated values marry up. For a high pass filter, at natural frequency, the phase shift is 45° . As it is inverted, the phase has shifted 180° . Therefore, at cut off frequency phase shift $= 45 + 180 = 225^\circ$. The equation below proves the calculated gain and measured values are correct. A roll off of 20Db was measured as the circuit is in the first order.

$$20 \log(2) = 6.02$$



Task 11

11.1

This is the system analysis for Butterworth filter with a gain of 1.586.

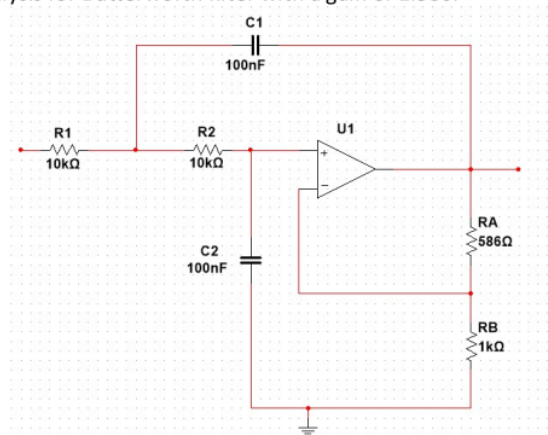


Figure 60 Butterworth low pass filter

Calculations

$$W_c = \frac{w}{RC} = 1000 \text{ Rads (chosen)}$$

$$R1 \text{ and } R2 = \frac{1}{1000 \times 100 \times 10^{-9}} = 10k\Omega$$

$$RB = 1000\Omega \quad RA = (K - 1)RB = (1.586 - 1) \times 1000 = 586\Omega$$

$$Q = \frac{1}{3 - k} = \frac{1}{3 - 1.586} = 0.707$$

$$G(\text{dB}) = 20 \log(k) = 20 \log(1.586) = 4 \text{ dB}$$

$$H(s) = \frac{k \times W_c^2}{s^2 + \frac{W_c}{Q} s + W_c^2} = \frac{1.586 \times 1000^2}{s^2 + \frac{1000}{0.707} s + 1000^2}$$

Mat Lab

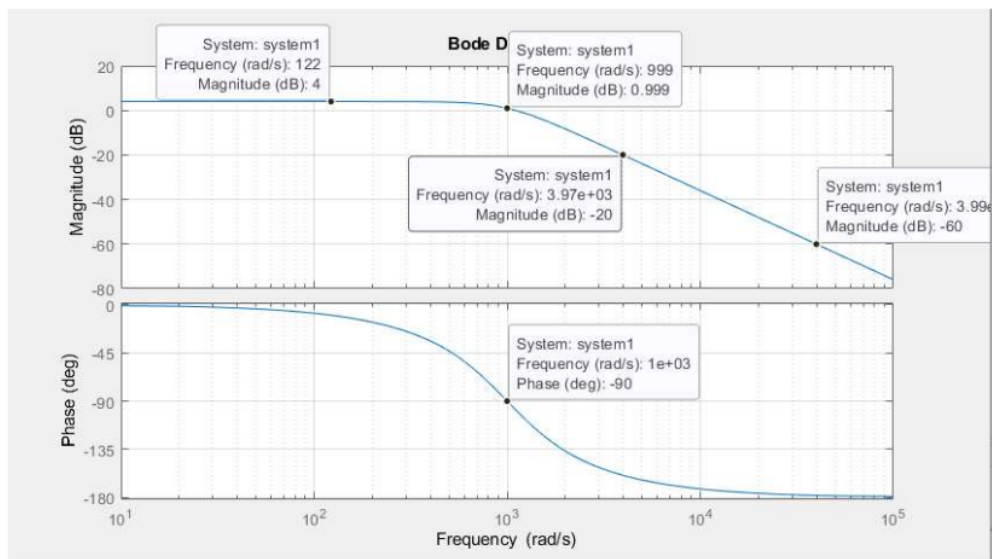


Figure 61 Butterworth mat lab results

```

Task11.m
1  s = tf('s');
2  system1 = (1.586 * (1000)^2) / ((s)^2 + ((1000/0.707)*s) + 1000^2);
3  bode (system1);
4  grid on
5  hold on

```

Figure 62 Task 11 mat lab code

11.2 Analysis and comparison

	Calculated	Simulated
Roll off	-40dB	-40dB
Cut off frequency	1000 Rad/s	999 Rad/s
Gain	4dB	4dB

All calculated and simulated results match, other than the cut off frequency that was out by 1 Rad/s, this could be because of rounding errors. Differently to the circuit in task nine. The phase shift measured was -90° . The circuit in task nine was a first order circuit the roll off over a decade was -20dB, in comparison to the second order circuit in task eleven, that has a roll off of -40dB. Therefore, the second order circuit is more selective in what frequency it allows to pass through the circuit. As the roll, off is steeper.

25

Task 12

26

12.1

These are the open loop performances.

```

T12.m
1  num = [6.5];
2  den = [1, -0.4];
3  [z,p,k] = tf2zp(num,den)
4  pzmap (num,den)

```

Figure 63 Task 12 argand diagram Mat Lab

From the argand diagram it is clear to see that the pole is positive (0.4). This means that the signal will be unstable. Pole exists at $s-0.4=0$ i.e. $s=+0.4$

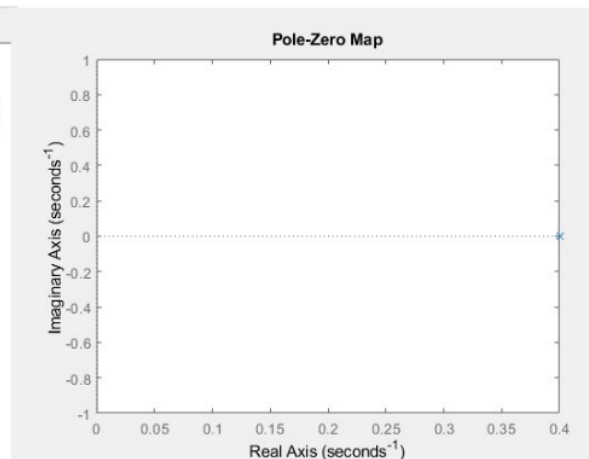


Figure 64 Task 12 argand diagram

This is the open loop response using Simulink, with these transfer functions.

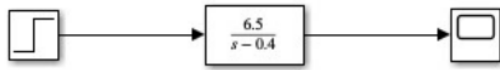


Figure 65 Open loop transfer function

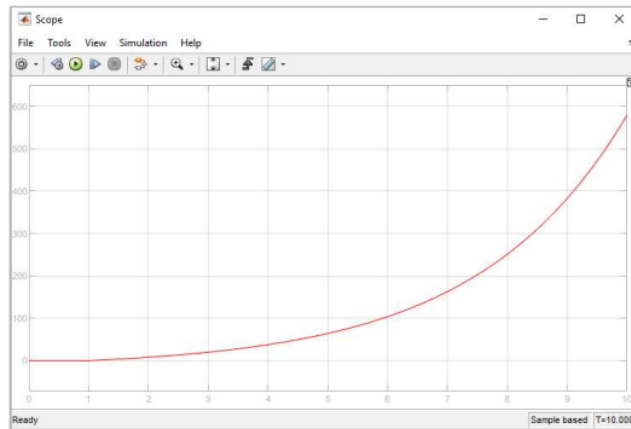


Figure 66 Open loop response

12.2

This is the overall closed loop transfer function in terms of K, with response for K = 1.

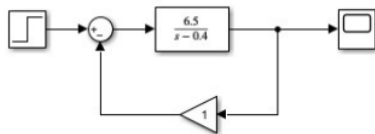


Figure 67 Closed loop transfer function

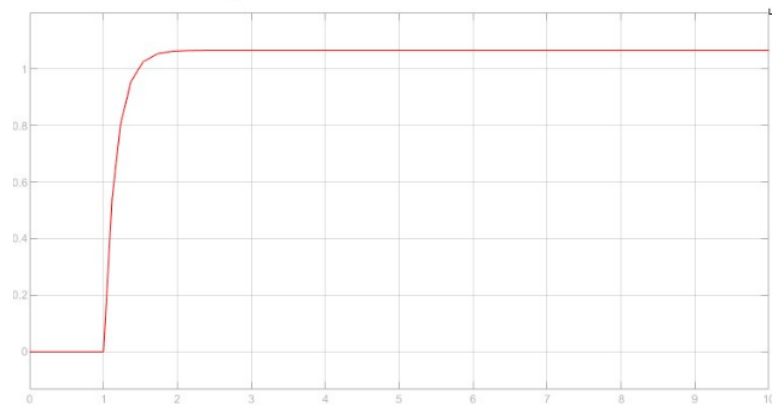


Figure 68 Closed loop transfer function

From this response it is clear that the response is stable as it reaches a peak and stabilises.

12.3

This is the minimum value for K to get the feedback stable. The transfer function must be rearranged to find the minimum value for K to get a 0 at the denominator.

$$\frac{6.5}{s - 0.4}$$

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

Multiply by $(s - 0.4)$

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

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

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

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

$$s = -6.5K + 0.4$$

$$s = 0.4 - 6.5K$$

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



This can be confirmed by using a root locus in mat lab. This is the code.

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

Figure 69 Task 12 locus code

It is clear to make a comparison of the findings as the root locus clearly indicates that the minimum number for gain is 0.0614. to make a pole of zero. This confirms the calculations.

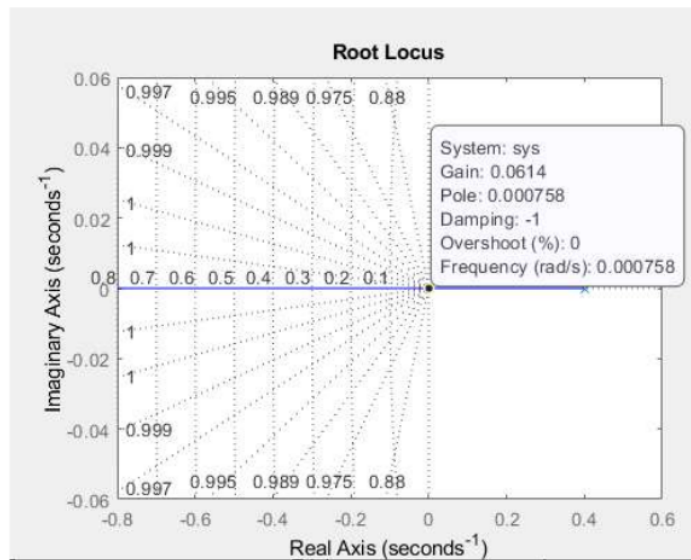


Figure 70 Task 12 root locus

12.4

The gain was then varied to show the difference in stability.

$$K = 2$$

This is the response when the gain is 2.

$$s = 0.4 - 6.5 K = 0.4 - 6.5 (2) = -12.6$$

The pole is at -12.6, therefore stable.

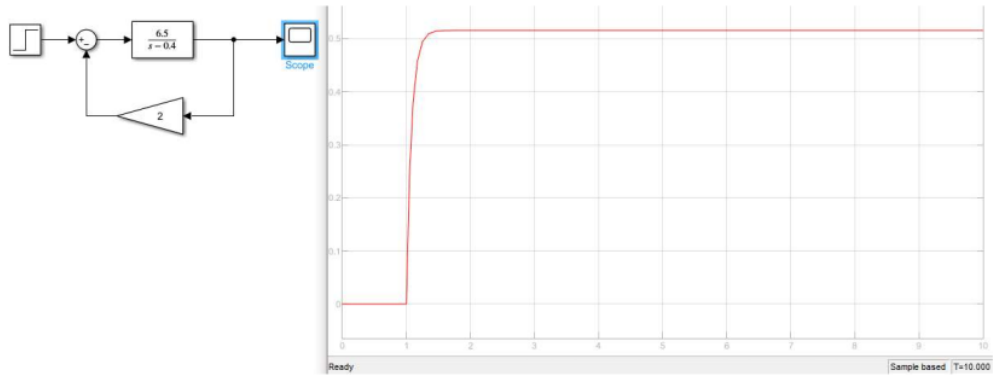


Figure 71 Response with $k=2$

$$K = 0.0614$$

This is the response when the gain is 4.

$$s = 0.4 - 6.5 K = 0.4 - 6.5 (0.0614) = 0.009$$

The pole is at 0, therefore unstable.

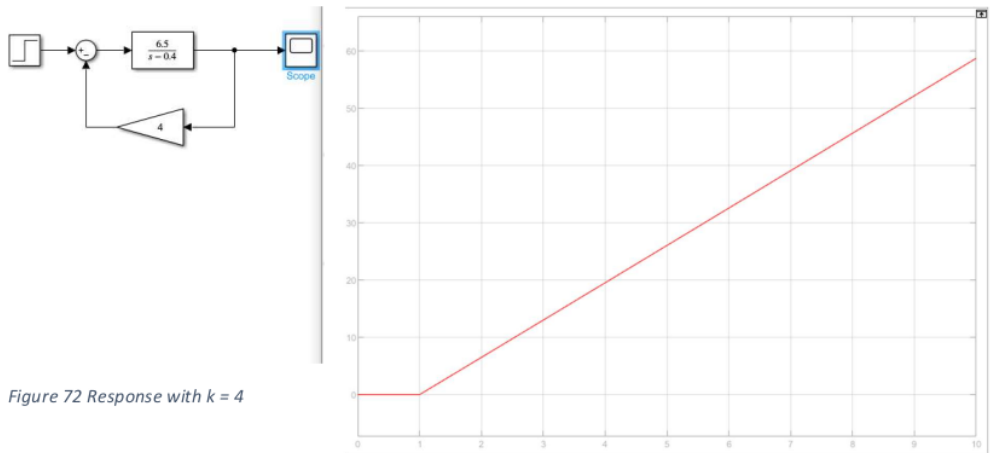


Figure 72 Response with $k = 4$

$K = 0.009$

This is the response when the gain is 0.009.

$$s = 0.4 - 6.5 K = 0.4 - 6.5 (0.009) = 0.3415$$

The pole is at 0.3415, therefore unstable.

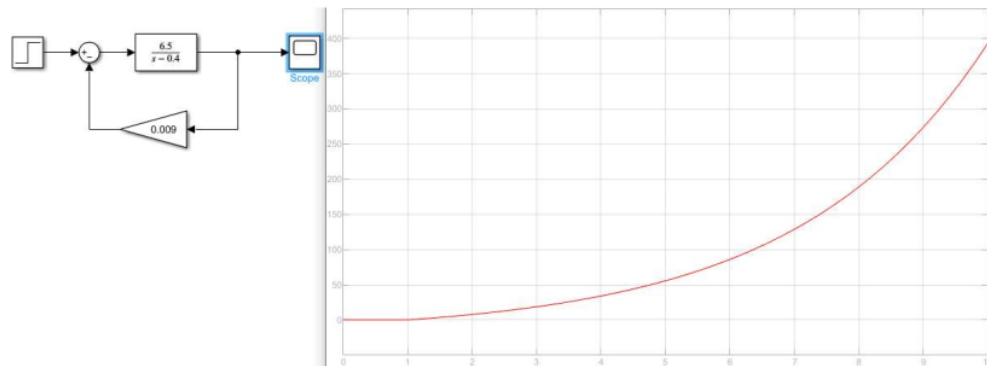


Figure 73 Response with a k of 0.009

12.5

K value	Pole	Measured stability	Calculated stability
2	-12.6	stable	stable
4	-25.6	stable	stable
0.09	0.3415	unstable	unstable

12.6

Conclusion

It is clear to see from the table shown above that from the Simulink model and from the equations. The stability of the circuit can be predicted by knowing what polarity the pole is. From rearranging the equation, the minimum feedback gain value for the circuit is 0.0614. Any value higher than this will make the circuit stable and anything lower, unstable. This is because the negative pole will be present in the left-hand plane. If in the left-hand plane. The circuit is stable.

Task 13

13.1

By using the circuits in figures below. A closed loop response can be created to control a DC motor.

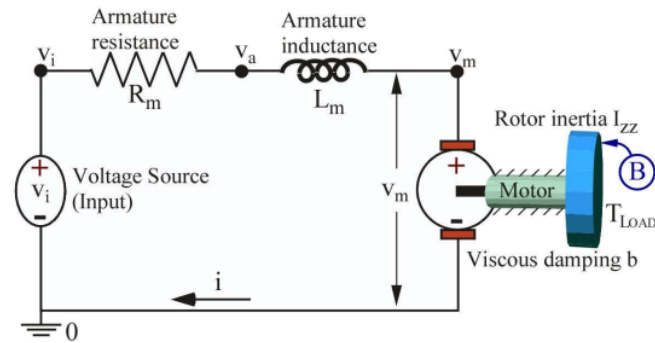


Figure 74 Dc motor circuit

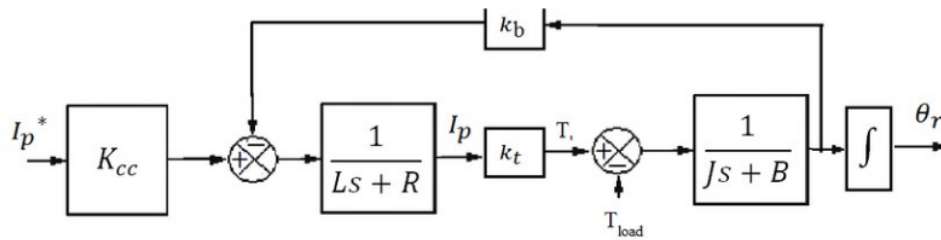


Figure 75 DC motor model

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

29

13.2

The natural frequency was calculated using the equation below.

$$\omega_n = \sqrt{\frac{Ra b}{La J} + \frac{Kt Ke}{La J}}$$

$$\omega_n = \sqrt{\frac{1.5 \times 4.6 \times 10^{-6}}{0.165 \times 0.0042} + \frac{0.063 \times 0.063}{0.165 \times 0.0042}}$$

$$\omega_n = 2.395 \text{ Rad/S}$$

The damping factor was calculated by using the formula below.

$$\zeta = \frac{\frac{b}{J} + \frac{Ra}{La}}{2\omega n}$$

$$\zeta = \frac{\left(\frac{4.6 \times 10^{-6}}{0.0042} + \frac{1.5}{0.165}\right)}{2 \times 2.395}$$

$$\zeta = 1.898$$



These are the steady state characterises.

$$\text{Stall torque } (T_{\text{stall}}) = \frac{Kt Va}{Ra} = \frac{0.063 \times 15}{1.5} = 0.63 \text{ N/m}$$

$$\text{No load speed (without friction)} \Omega_{nl} = \frac{Va}{Ke} = \frac{15}{0.063} = 238.01 \text{ Rad/S}$$

$$\text{No load speed (with friction)} \Omega = \frac{Kt Va}{b Ra + Kt Ke} = \frac{0.063 \times 15}{(4.6 \times 10^{-6}) 1.5 + 0.063 \times 0.063} = 237.68 \text{ Rad/S}$$

13.3

The calculations below determine the poles of the circuit.

$$A = 1$$

$$B = \left(\frac{b}{J} + \frac{Ra}{La}\right) = \left(\frac{4.6 \times 10^{-6}}{0.0042} + \frac{1.5}{0.165}\right) = 9.09$$

$$C = \frac{Ra b}{La J} + \frac{Kt Ke}{La J} = \frac{1.5 \times 4.6 \times 10^{-6}}{0.165 \times 0.0042} + \frac{0.063 \times 0.063}{0.165 \times 0.0042} = 5.74$$

Now the above are substituted into the following.

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

$$\text{Answer} = -0.683 / -8.409$$

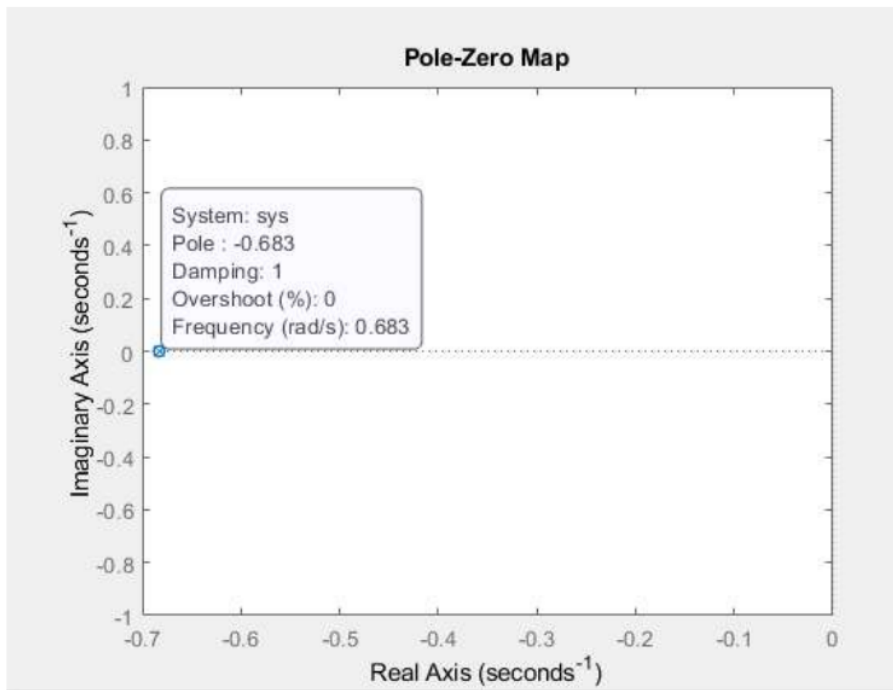


Figure 76 Argand diagram -0.683

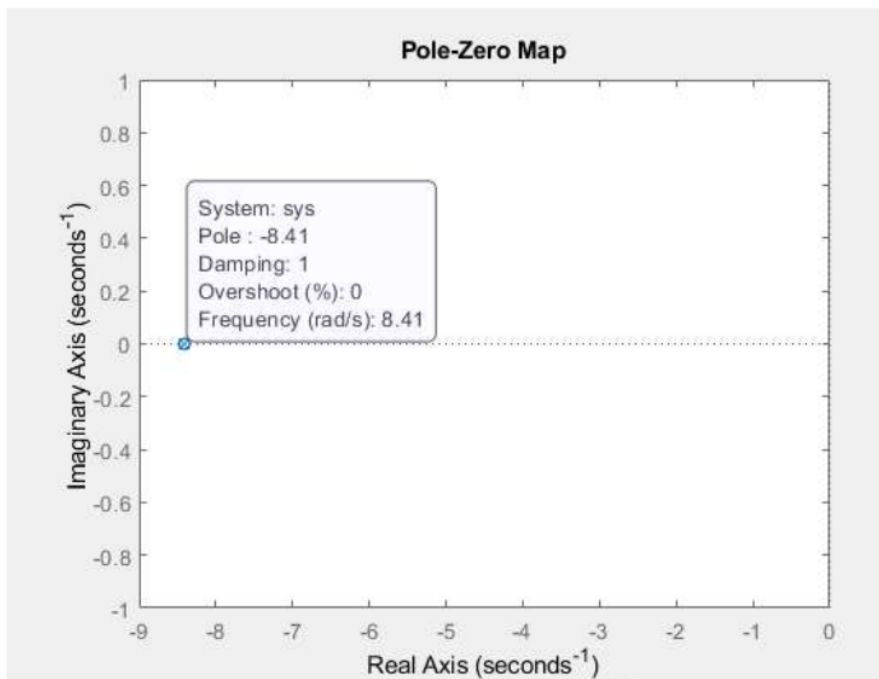


Figure 77 Argand diagram -8.409

13.4

This is the circuit used for the open loop response.

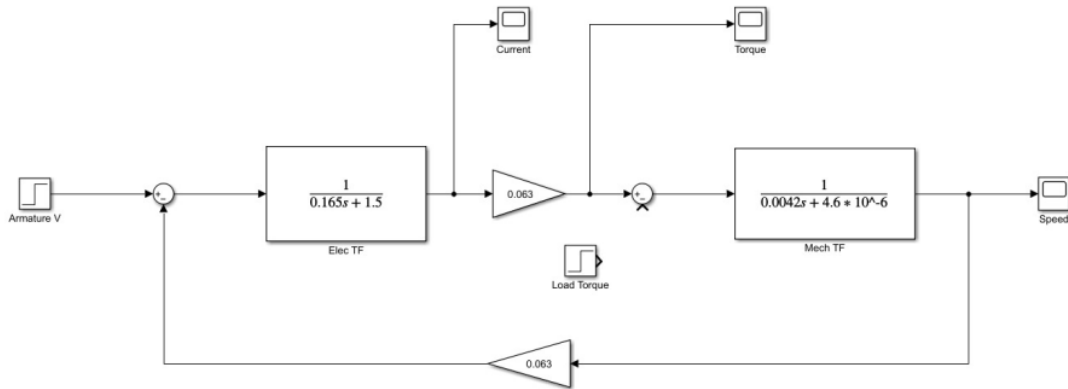


Figure 78 Simulink task 13

13.5

This is analysis of a speed and torque responses of a motor over 30 seconds to an armature voltage step input of 15Vdc with the disturbance set to zero and thus measure the no-load-speed and torque of the motor.

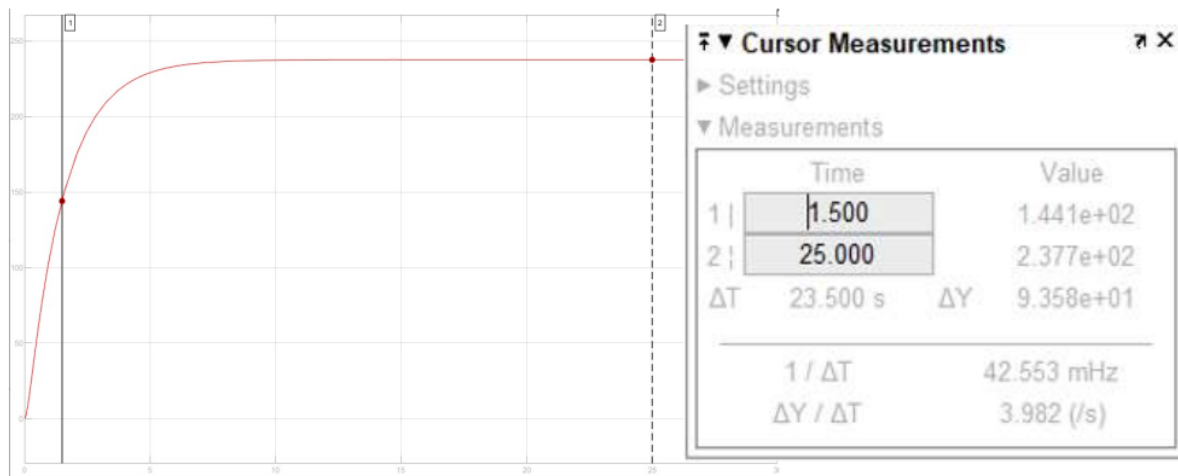


Figure 79 Open loop response with no disturbances

This is the theoretical stall torque after 15 seconds and check the result.

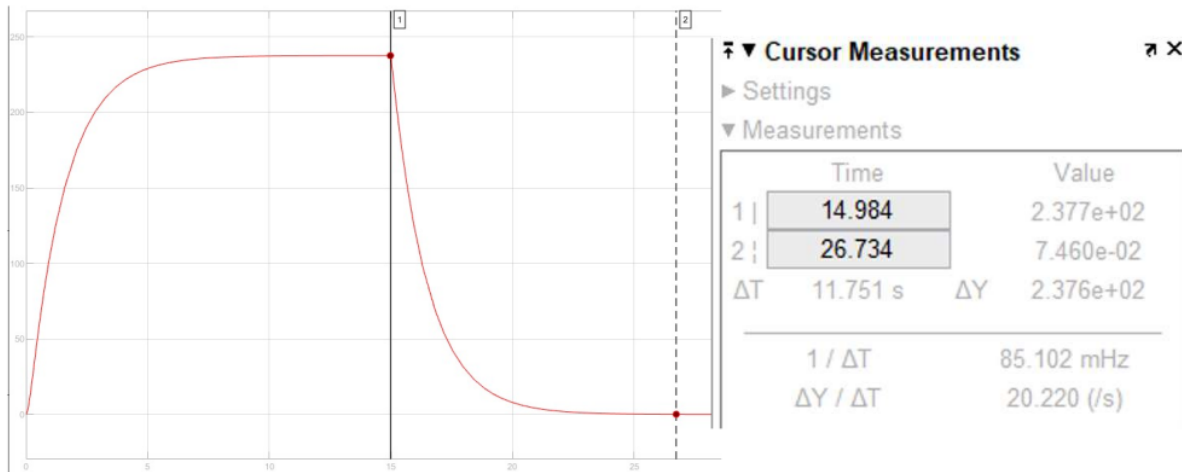


Figure 80 Open loop response with stall torque

13.6

This is analysis of the speed and torque responses of the motor over 20 seconds to an armature voltage step input of 15Vdc with the disturbance of 0.03Nm after 10 seconds and thus finding the speed and current.

$$\text{Loaded speed } \Omega_L = \frac{V_a - \frac{K_e T_l}{K_t}}{\frac{R_a b}{K_t} + K_e} = \frac{15 - \left(\frac{0.063 \times 0.03}{0.063} \right)}{\left(\frac{1.5 \times 4.6 \times 10^{-6}}{0.063} \right) + 0.063} = 226.36 \text{ Rad/s}$$

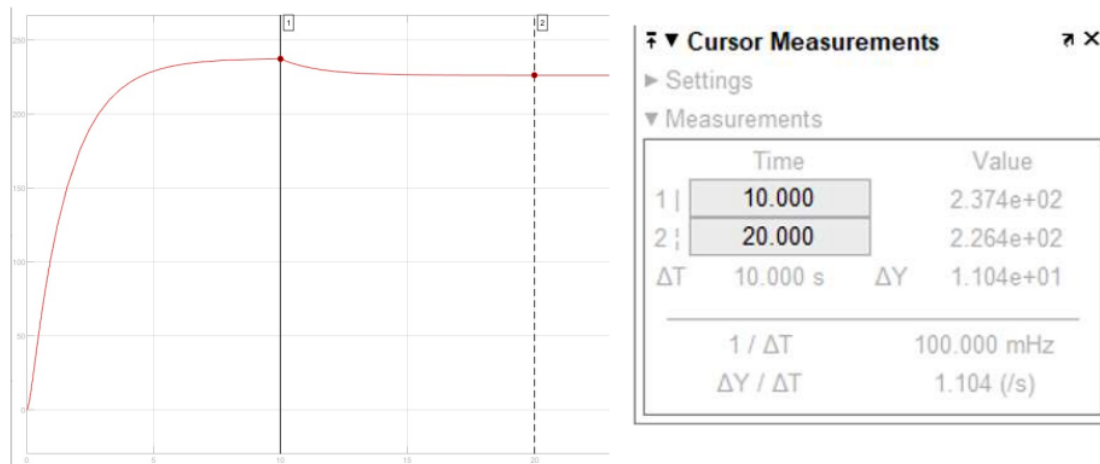


Figure 81 Open loop response with disturbance

13.7

	Calculated	Simulated	Error
No load speed(rad/S)	238.01	237.7	0.31
Loaded speed (Rad/S)	226.36	226.4	0.04

13.8

The circuit performed as expected. Included is the stall load, disturbance and no load. As the circuit is open loop, there is no defence against disturbances. Hence why when the TStall was calculated and simulated it stalled. Confirming theoretical and practical evaluations. The steady state characteristics have also been confirmed. There is minimal error, as seen in the table above.

Task 14

14.1

The motor model has been converted into a subsystem for simplicity. An outer loop has been added to include a proportional controller with a step speed setpoint of 140 rad/s and speed feedback with a disturbance of 0.03Nm after 10 seconds. The PID block (set up for P only) has been used to ensure the armature voltage is limited to maximum voltage. The auto tune feature has been run and the optimum value for the constant K_p upper, lower, and mid-range has been found.

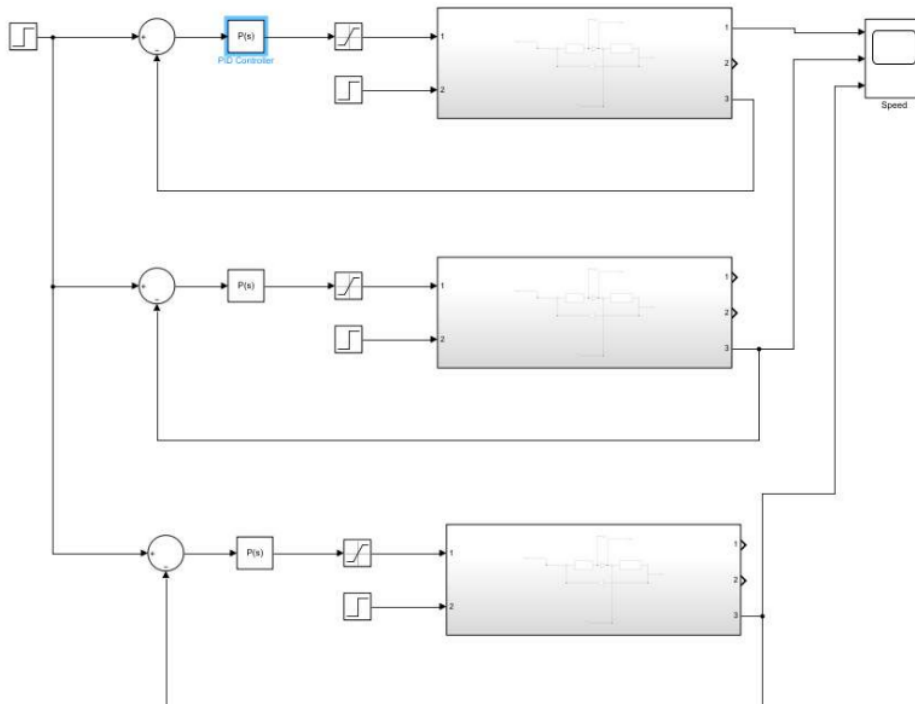


Figure 82 Kp loop

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

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

Figure 84
Optimal value
for a mid-range
Kp

14.2

The same was done for the lower and upper range of Kp.

Controller Parameters		
	Tuned	Block
P	0.085369	0.085369
I	n/a	n/a
D	n/a	n/a
N	n/a	n/a

Performance and Robustness		
	Tuned	Block
Rise time	1.24 seconds	1.24 seconds
Settling time	2.25 seconds	2.25 seconds
Overshoot	0 %	0 %
Peak	0.575	0.575
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	134 deg @ 0.618 rad/s	134 deg @ 0.618 rad/s
Closed-loop stability	Stable	Stable

Figure 85 Kp bottom range

Figure 86 Optimal value for a low range P

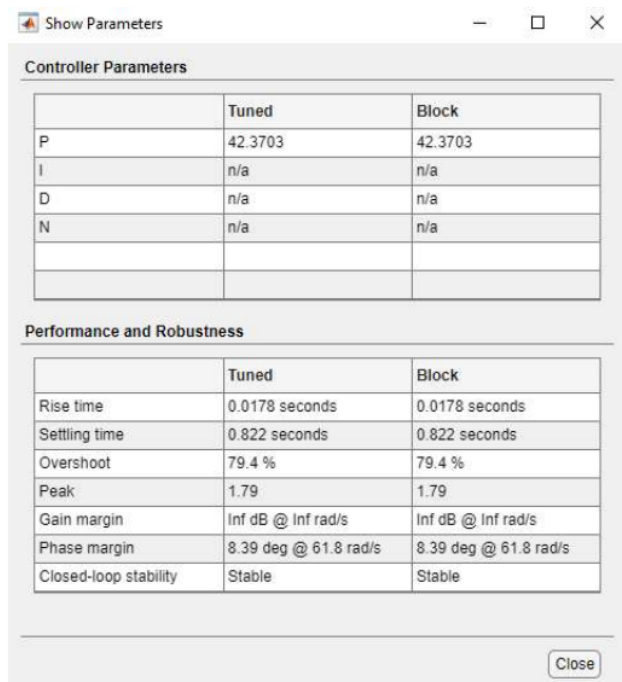


Figure 87 Optimal value for a high range P

14.3

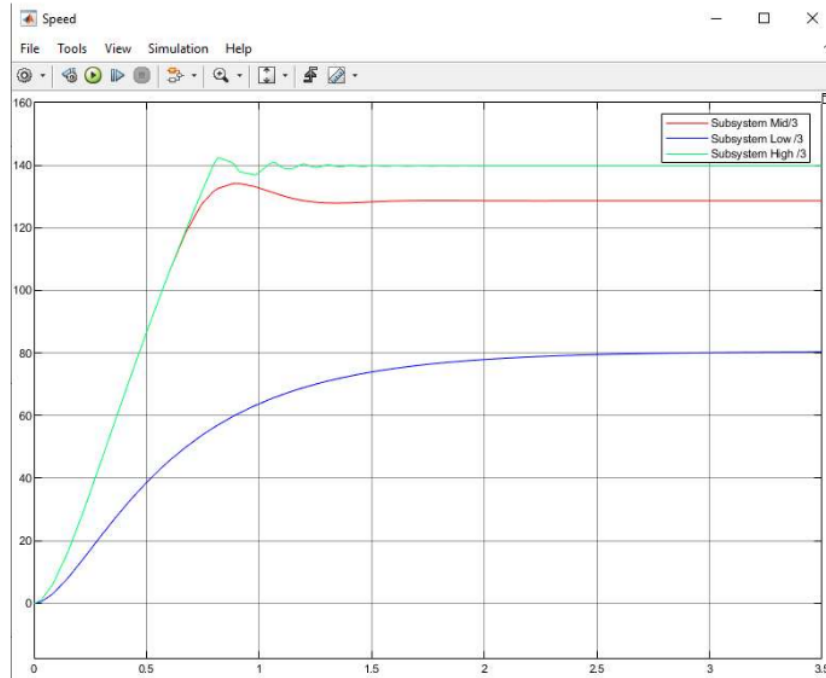


Figure 88 Kp graph

By increasing K_p , the circuit's aggression to the set point increases and the overshoot increases.

14.4

K_p	Steady state error	%O/S	Rise time (s)
42.37 (High)	0	79.4	0.0187
0.713 (Mid)	10	13.2	0.204
0.085 (Low)	60	0	1.24

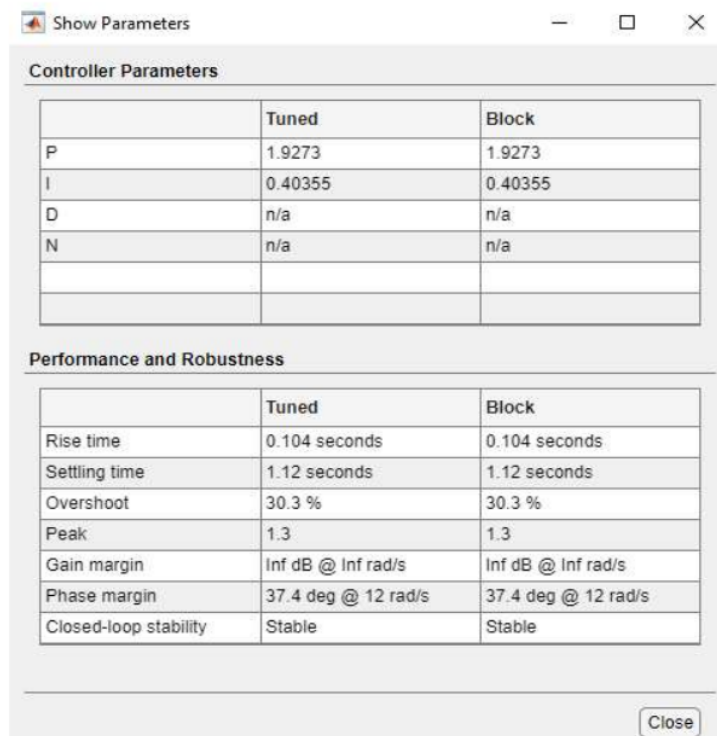
14.5

To conclude all results met all expectations for the effects of increasing K_p in a proportional loop. The highest K_p was 42.37, this had the lowest rise time and highest overshoot as expected. The lowest K_p was 0.085. this had the lowest rise time of 1.24s and no overshoot. This didn't have enough gain to reach the set point and reached a steady error of 40 Rad/S.

Task 15

15.1

This is a proportional-integral speed control system. K_p has been automatically tuned and has been kept the same for the three PI loops. Which is 1.9273, this can be seen in the block part of the parameter's controller below. Each controller has been converted into a PI controller. As seen in figure 82.



Controller Parameters		
	Tuned	Block
P	1.9273	1.9273
I	0.40355	0.40355
D	n/a	n/a
N	n/a	n/a

Performance and Robustness		
	Tuned	Block
Rise time	0.104 seconds	0.104 seconds
Settling time	1.12 seconds	1.12 seconds
Overshoot	30.3 %	30.3 %
Peak	1.3	1.3
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	37.4 deg @ 12 rad/s	37.4 deg @ 12 rad/s
Closed-loop stability	Stable	Stable

Figure 89 Middle Ki

15.2

Show Parameters

Controller Parameters		
	Tuned	Block
P	0.079938	1.9273
I	0.12065	0.056666
D	n/a	n/a
N	n/a	n/a

Performance and Robustness		
	Tuned	Block
Rise time	1.13 seconds	0.105 seconds
Settling time	4.41 seconds	NaN seconds
Overshoot	12.3 %	28.4 %
Peak	1.12	1.28
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	60 deg @ 1.2 rad/s	38.2 deg @ 12 rad/s
Closed-loop stability	Stable	Stable

Close

Figure 90 Low K_i

Show Parameters

Controller Parameters		
	Tuned	Block
P	0.079938	1.9273
I	0.12065	0.5
D	n/a	n/a
N	n/a	n/a

Performance and Robustness		
	Tuned	Block
Rise time	1.13 seconds	0.104 seconds
Settling time	4.41 seconds	1.1 seconds
Overshoot	12.3 %	30.8 %
Peak	1.12	1.31
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	60 deg @ 1.2 rad/s	37.1 deg @ 12 rad/s
Closed-loop stability	Stable	Stable

Figure 91 High K_i

15.3

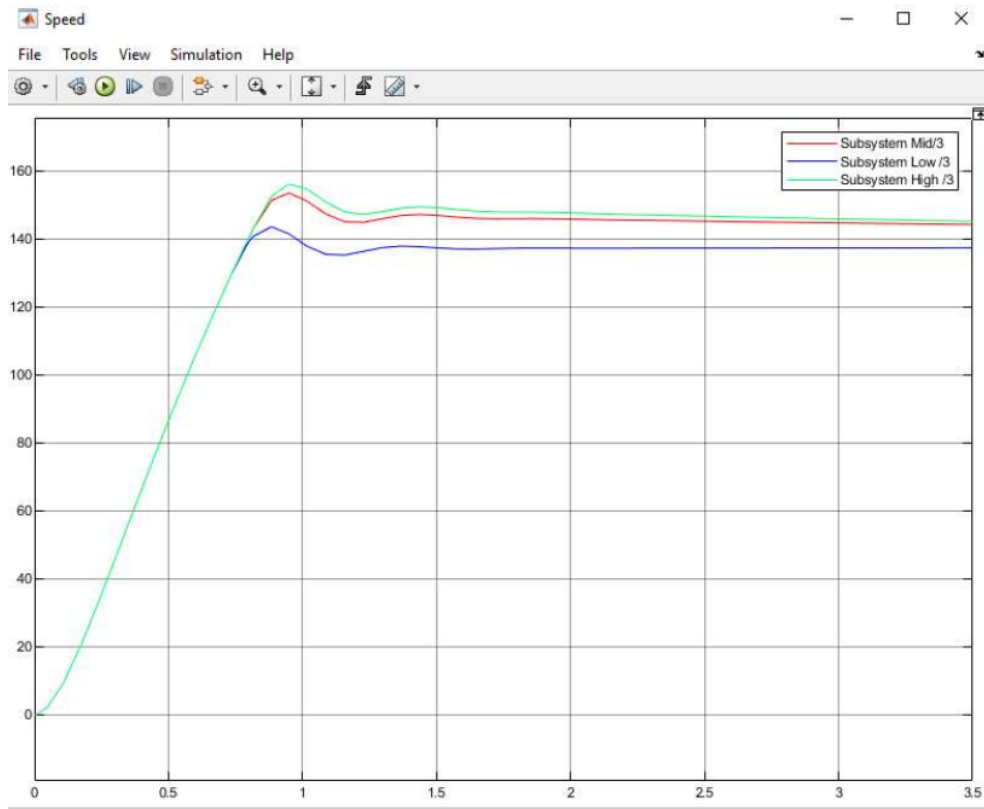


Figure 92 Ki graph

Every loop includes the same Kp of 1.9273.

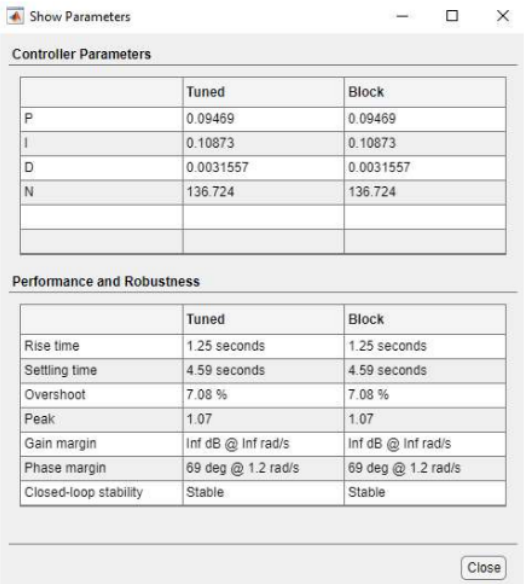
Ki	Steady state error	%O/S	Rise time (s)	Settling time (s)
0.5 (High)	5	30.8	0.104	1.1
0.05666 (Low)	2	28.4	0.105	Na
0.40355 (Mid)	4	30.3	0.104	1.12

It is clear to see from the table that from decreasing the value of Ki, the circuit becomes tamer. This is confirmed by looking at the percentage overshoot in the table. The rise time was consistent across all three examples. The Ki of 0.05666 isn't large enough to settle the circuit, this is why that it hasn't got a settle time and doesn't even reach the set point. This has been highlighted in the table.

Task 16

16.1

This is a proportional-integral-derivative speed control system. Each controller has been converted into a PID controller. As seen in figure 82. K_p and K_i has been automatically tuned and has been kept the same for the three PID loops. Which K_p is 0.09469 and a K_i of 0.10873, this can be seen in the block part of the parameter's controller below.

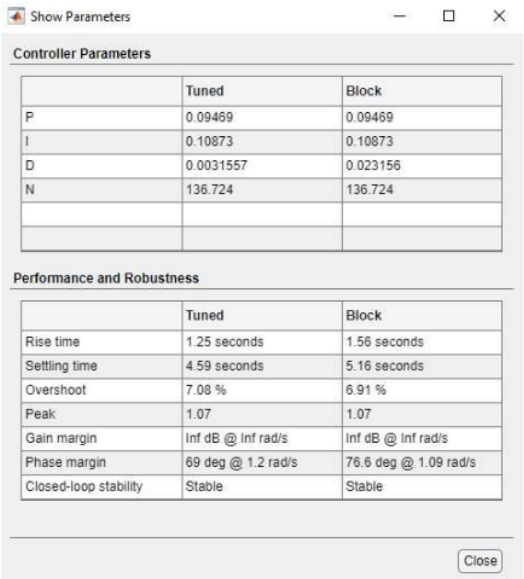


Controller Parameters		
	Tuned	Block
P	0.09469	0.09469
I	0.10873	0.10873
D	0.0031557	0.0031557
N	136.724	136.724

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

16.2

Figure 93 Middle K_d



Controller Parameters		
	Tuned	Block
P	0.09469	0.09469
I	0.10873	0.10873
D	0.0031557	0.023156
N	136.724	136.724

Performance and Robustness		
	Tuned	Block
Rise time	1.25 seconds	1.56 seconds
Settling time	4.59 seconds	5.16 seconds
Overshoot	7.08 %	6.91 %
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	76.6 deg @ 1.09 rad/s
Closed-loop stability	Stable	Stable

Figure 94 High K_d

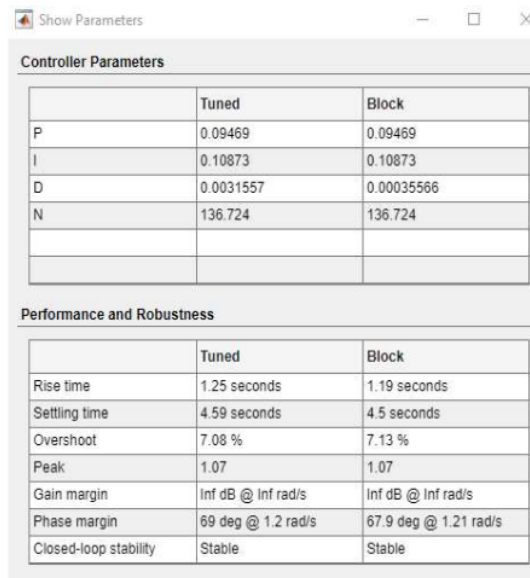


Figure 95 Low Kd

16.3

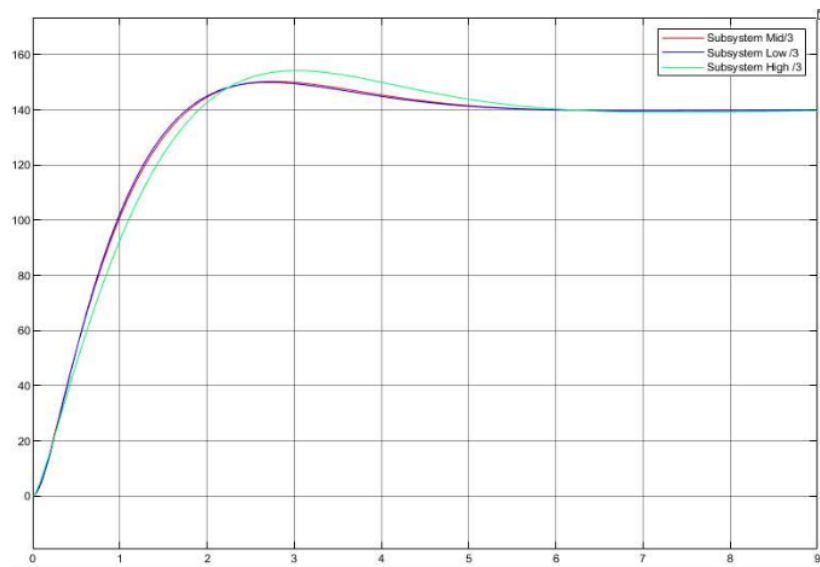


Figure 96 Kd graph

Every loop includes the same K_p of 0.0946896335942199.

Every loop includes the same K_i of 0.108726898325678.

Kd	Steady state error	%O/S	Rise time (s)	Settling time (s)
0.0031556 (Mid)	0	7.08	1.25	4.59
0.0003556 (Low)	0	7.13	1.19	4.5
0.0231556 (high)	0	6.91	1.56	5.16

It is clear to see from the table that from increasing the value of K_d , the circuit becomes tamer. This is confirmed by looking at the percentage overshoot in the table. There is also no steady state error with a PID loop. The rise time was marginally different across the board, by increasing K_d the rise time was slower, this is because it working against the rise as the rate of change is changing. With a higher K_d , the overshoot decreases.

Task 17

17.1

Three parallel controllers sharing the same input and same scope have been made as seen in figure 82. One system is a P controller, another a PI controller and the third can remain a PID controller. All have been tuned automatically with different K_p , K_i and K_d .

17.2

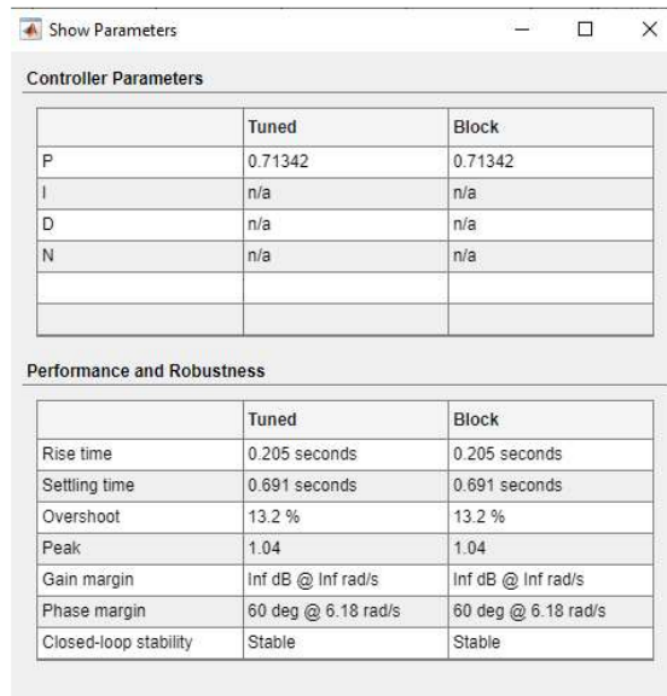


Figure 97 K_p

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

Figure 98 Kp Ki

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

Figure 99 Kp Ki Kd

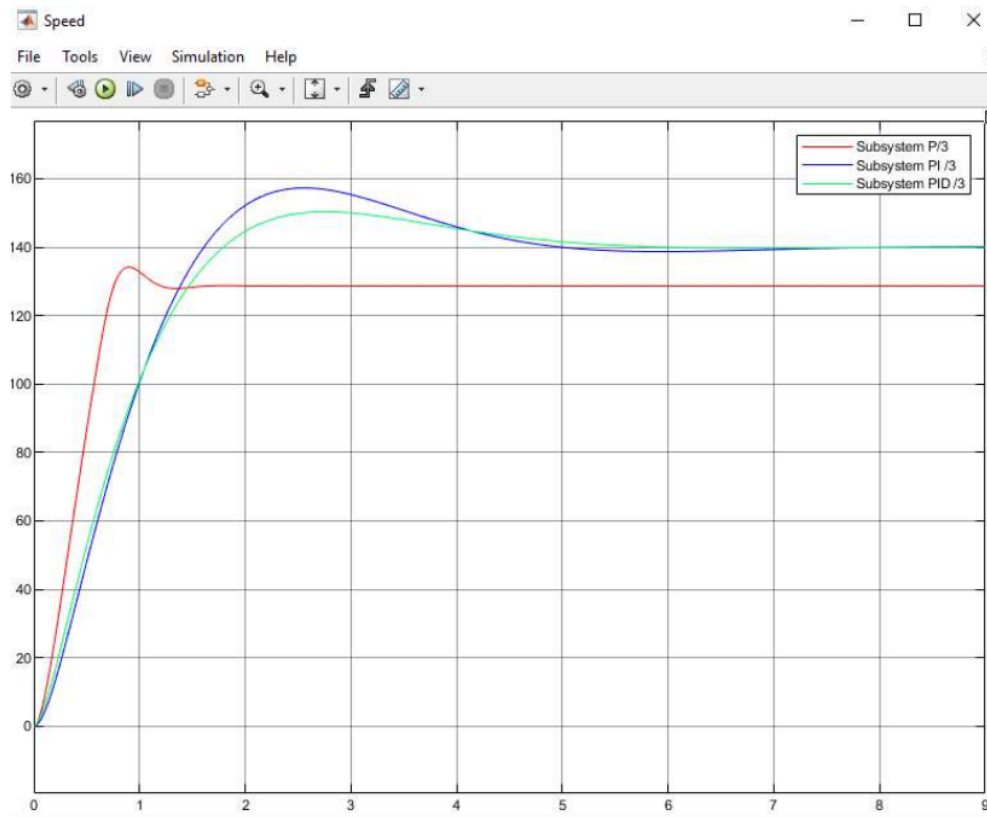


Figure 100 Comparison graph

Kp	Ki	Kd	Steady state error	%O/S	Rise time (s)	Settling time (s)
0.71342			10	13.2	0.205	0.691
0.079938	0.12065		0	12.3	1.13	4.41
0.0031557	0.10873	0.0469	0	7.08	1.25	4.59

The legend in the top right of the graph states what loop is what. The effects of this P loop confirm the theory evaluation. As it overshoots and reaches a steady state error of 10 Ras/S. The P isn't aggressive enough to reach the set point on its own. The PI loop has enough gain to reach the set point but overshoot considerably more then the PID loop, which reaches the set point (rise time) marginally slower but has a lower overshoot. The PID also has a slower settling time. This can all be seen in the table above.

Using just P would be hard to control and use. The best solution is to use a PID loop. Which is less aggressive but settles slower.

Task 18

This assignment has been beneficial to my understanding of three topics. These are; transient behaviour, filters and DC motor PID closed loop systems. They have all been simulated by using MATLAB. By using the software, theoretical and measured values can be compared and verified. Transfer function of La Place transforms were used to do this.

Transient analysis

The transient and frequency of RC, RL and RLC circuit have been analysed. The circuits were first and second order circuits. The response from a discharge of a RC circuit was confirmed. It was measured at Tau and up to five Tau. It was verified that it would stop charging at five Tau. The response is an exponential decay, as the circuit is first order, $e^{-1} = 0.368$. That is why tau has been measured at this point on the graph. This proves the analysis. The charge of the RL circuit was measured, the response is an exponential decay, as the circuit is first order, $1 - e^{-1} = 0.632$

Frequency Performance Analysis

The first filter evaluated was a first order high pass filter. This only passes high frequencies through the circuit, after the 3dB point. This is advantageous if you want lower frequencies not to be passed. The phase shift at the natural frequency of a high pass filter is 45° . For a first order filter, it will have a roll off of 20dB, this determines the steepness of the roll off over a decade. The second first order filter evaluated was a low pass filter. This has the same characteristics as the high first order high pass, but only allows low frequencies to pass.

The damping factor was investigated. The critically damped systems had no overshooting. The no damping systems had oscillations and will not reach equilibrium. The over damped systems circuit slowly grows to equilibrium. Underdamping systems moved quickly to equilibrium but overshoot and oscillated for time.

In task seven changing the value of the resistance, the damping factor varies, thus creating a locus diagram. By decreasing the value of R, the magnitude increases. The low pass filter only passes the smaller frequencies, before the cut off frequency.

In task eight from varying the resistance of the circuit, and increasing. This decreases the bandwidth. This means that the circuit is more selective with a higher resistance.

Task nine and ten an op amp was added to task three and four to create a first order high and low pass electronic circuits. The purpose of the circuit was to shift the phase 180° and this was confirmed by MATLAB. Task eleven is a second order low pass filter using an op amp. This has a roll off of 40dB over a decade.

DC Motor Model Analysis

Task twelve uses an open loop system. It confirms the theory of having a negative pole present in the left-hand plane. If in the left-hand plane. The circuit is stable. This was verified by showing negative and positive pole behaviour by using sumlink.

Task thirteen is the beginning of the DC motor analysis. At task thirteen it is only a open loop response. The first response investigated was a no disturbances and it reached its set point with no problems. Then a disturbance was applied and the set point wasn't reached and had a steady state error. Then a stall torque was applied by calculating. This stalled the motor. This confirms the theory.

Task fourteen was three examples of P loops by varying K_p . This showed that by having a low K_p the circuit isn't aggressive enough to reach the set point of 140 Rad/S. But then if the circuit had an overly aggressive K_p the circuit would overshoot and oscillate.

35

Task fifteen was three examples of PI loops keeping K_p constant and varying K_i . If you increase K_i the circuit would overshoot more. But if the K_i is too small it doesn't have enough aggression to settle. As seen with the value of 0.05666.

Task sixteen was three examples of PID loops with K_p and K_i staying constant and varying K_d . There is also no steady state error with a PID loop. By increasing K_d , the overshoot percentage lessens and rise time increases.

Task seventeen compares a P, PI and PID loop. It is clear which one is more efficient, which is PID. This is because it is aggressive at the start when the rate of change is more so K_d works hard but then closer to the set point it works against the P and I making it overshoot less, but has a slower settle time.

Recommendations

A recommendation to be made is to use the MATLAB and not MATLAB online as some features are unavailable on the online version and the cursors are hard to place.

Another recommendation to be made could be to investigate a 3rd and 4th order cascading filter and not a 2nd order Sallen and key filter.

FINAL GRADE

GENERAL COMMENTS

Instructor

62/100

PAGE 1

PAGE 2

 **Comment 1**
meaningless

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

 **Comment 2**
Introduce the task with a statement

PAGE 10

 **Comment 3**
explain why by using an equation



Comment 4

do not put units in the TF



Comment 5

brief



Comment 6

-20dB



Comment 7

-45 deg



Comment 8

-20dB



Comment 9

lacks explanation



Comment 10

what was?



Comment 11

descriptive, no deeper explanations offered



Comment 12

WW



Comment 13

far too brief of an attempt to explain what the background theory is here

PAGE 22

PAGE 23

PAGE 24

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Comment 14

more of an in depth analysis is needed, base your analysis on theory and the equations, simply describing the graphs is too vague



Comment 15

R is known

PAGE 26

PAGE 27

PAGE 28

PAGE 29



Comment 16

explain this



Comment 17

explain this locus

PAGE 30



Comment 18

these quantities need explaining

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PAGE 32

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Comment 19

explanation is far too vague



Comment 20

Gr



Comment 21

Again, there should be some explanation of the task, circuit, expected operation etc.

PAGE 36



Comment 22

explain this with reference to the TF



Comment 23

??

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Comment 24

same comment as for task 9 applies

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PAGE 40



Comment 25

this is a better analysis attempt



Comment 26

Again, explain the task up front, set the context

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Comment 27

so what did you calculate as the minimum k ?

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Comment 28

explain what a pole is, explain what you mean by left hand plane

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Comment 29

explain this equation

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Comment 30

missing derivations

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Comment 31

why this error?

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WW

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Comment 33

method ok, relate to expected theoretical results

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Comment 34

good work here

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Comment 35

good work

GRADING FORM: NEW CSG-RUBRIC

ELIAS THOMAS

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1. ENGAGEMENT WITH LITERATURE



NA

0

2. KNOWLEDGE AND UNDERSTANDING



Explanations of electrical/electronic circuits are limited, some missing definitions and little relation to TF. Accurate knowledge of control circuits displayed, See comments. 16/30

16

3. COGNITIVE AND INTELLECTUAL



Analysis is descriptive in parts, particularly for the electrical and electronic circuits, conclusion is comprehensive.16/30

16

4. PRACTICAL APPLICATION



An advanced application of methods, data and results are clear and accurate, methods used are exact and well presented. 24/30

24

5. TRANSFERABLE SKILLS



Communication is effective and points are put across well, there needs to be more context given to the task and an upfront task objective/introduction. 6/10

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