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

Task 1.1 – The Selection of Suitable Component Values

To carry out the required task during this assignment, numerous component values will need to be produced for the purpose of analysis on RL electrical circuits. For the first task an inductor of 0.02H and a resistor of 140 Ω were selected.

To determine a time constant within a system, a fundamental law transient circuit law is in effect. A time constant is the time of a precise system to react to a change or difference. Usually the time taken for a parameter to differ by a factor of 1/e, which is approximately 0.368.



The following calculation was used to determine the time constant for the circuit, as displayed below.

$$\tau = \frac{L}{R} = \frac{0.02}{140} = 0.14msec$$

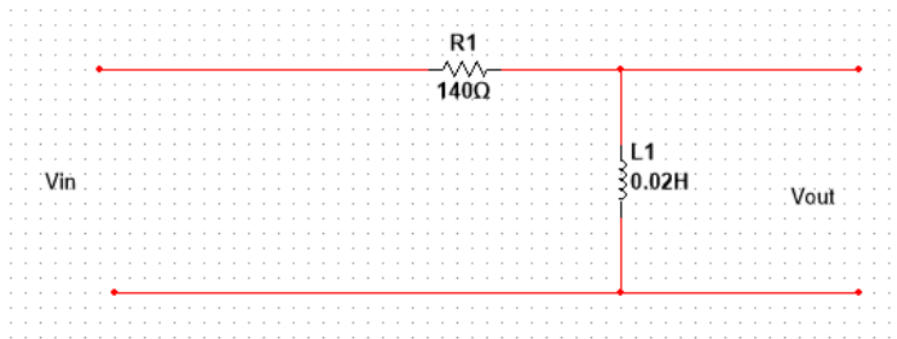


Figure 1 - Task 1 Selected Suitable Circuit Value

Task 1.2 – Laplace Model

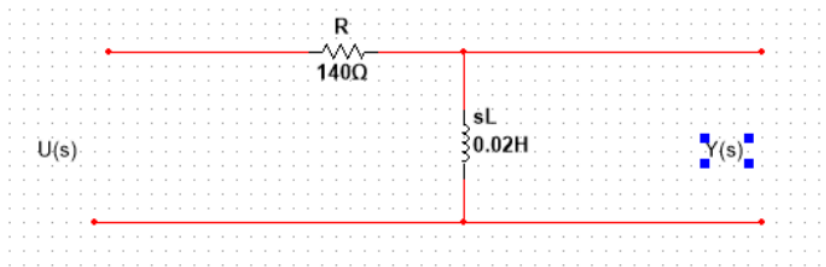


Figure 2 - Created Laplace Diagram

A transfer function can be produced through the creation of a Laplace model, as displayed above in figure2. This is a mathematical function can be used in relation to an output response in a system.

$$Hs = \frac{\tau s}{\tau s + sL}$$



Task 1.3 – MATLAB Code

```
s=tf('s');  
system=(0.02)*s/((0.02)*s+140);  
step(system);  
grid on
```

Figure 3 - Task 1 MATLAB Model Code

Using the mathematical transfer function and an application program a suitable simulation can be created. The digital software allows the transfer functions and values of electrical components to be placed in a code. This code will produce a graphical data display, providing an accurate and reliable display of the output required. This is on display in figure3 as the code used is being shown and figure4, an image of the graph created.

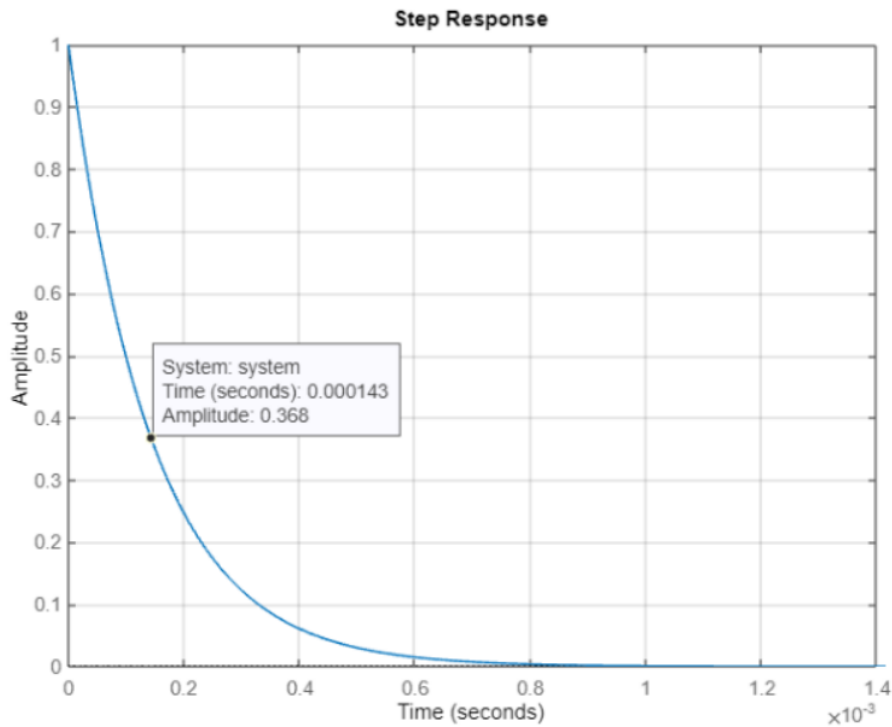


Figure 4 - Task 1 Output Graph

Task 1.4 – Table of Results

Below as displayed in Table1, is a results table showing the calculated, simulated and error values gathered during the completion of this task.

	Calculated	Simulated	Error
τ	0.14msec	0.14msec	0sec

Table 1 - Task 1 Data Comparison

Task 1.5 – Critical Analysis

As displayed through the data collected during the duration of this task, the measured and simulated values for this transient system correlated correctly. This is proven by the system having no error values. With the precise nature of the simulation software and the lack of mathematical rounding being used. This RL system creates a curve with an exponential decay, With the system being a first order, $e^{-1} = 0.368$. This value provides tau. Tau was then used to measure as a point on the graph, this proves the analysis.

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

Task 2.1 – The Selection of Suitable Values

To carry out the following task, numerous component values have been produced. These values will help provide an insight and analysis of RC electrical circuits. A capacitor value of $45\mu\text{F}$ and a resistor value of $950\ \Omega$ were selected for the completion of this task.

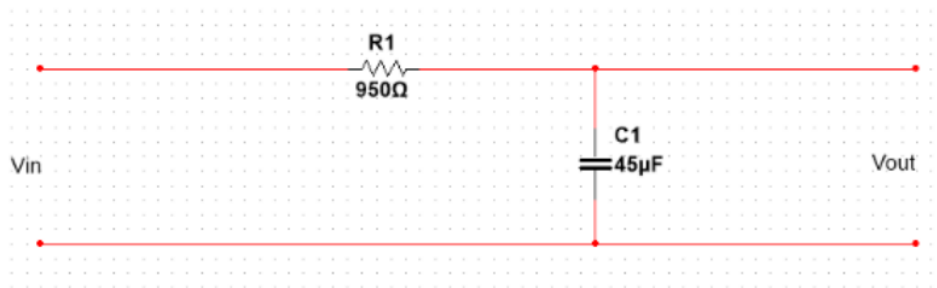


Figure 5 - Task 2 Chosen Component Values

Below is the calculation used to determine the time constant of the circuit. The time factor for an RC circuit will differ from an RL system, this is determined by $1-1/e$ which is equivalent to 0.632.

$$\tau = R \times C = 950 \times (45 \times 10^{-6}) = 42.75\mu\text{sec}$$

Task 2.2 – Laplace Model

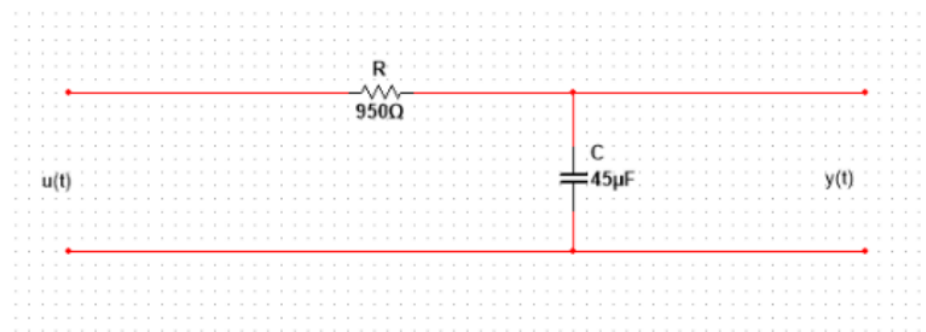


Figure 6 - Task 2 Laplace Model

Above in figure 6 is the Laplace design created, using the Laplace design a transfer function can be created and used to establish data.

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



Task 2.3 – MATLAB Code

```
s=tf('s');  
system=1/((950)*(0.000045)*s+1);  
step(system);  
grid on
```

Figure 7 - Task 2 MATLAB Model Code

Above in figure7, is a code generated through the transfer function and selected component values. This code will be used to create a simulation of the RC circuit created. This simulation will produce and provide a graphical data diagram.

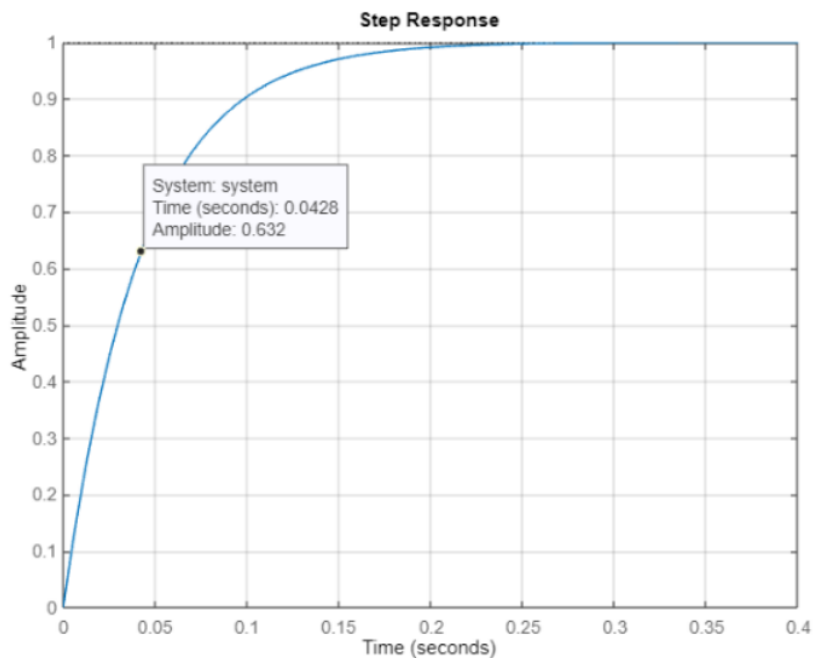


Figure 8 - Task 2 RC Graph

Task 2.4 – Table of Results

Below is table2, this table was created through the results determined and the gathered through the completion of this task.

	Calculated	Simulated	Error
τ	42.74 μ sec	42.74sec	0sec

Table 2 - Task 2 data Analysis

Task 2.5 – Critical Analysis

In the data attained through the completion of this task again there is no difference in the errors between the simulated and calculated values. This could be determined by the mathematical calculations and the accuracy of the simulation software in use. An RC system creates a curve with exponential growth. The system is first order, $1 - e^{-1} = 0.632$. This provides tau and why it is has been used to measure at this point. This proves the analysis.



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

For the completion of this task, numerous component values will need to be selected. These Values will help create an analysis on the frequency performance of a RL circuit. The values selected for the inductor are 0.02H and for the resistor 140 Ω .

Task 3.1 – Calculations

Below is the calculation used to determine the bandwidth of the system.

Cut - off frequency

$$\omega c = \frac{R}{L} = \frac{140}{0.02} = 7000 \text{ rads/sec}$$

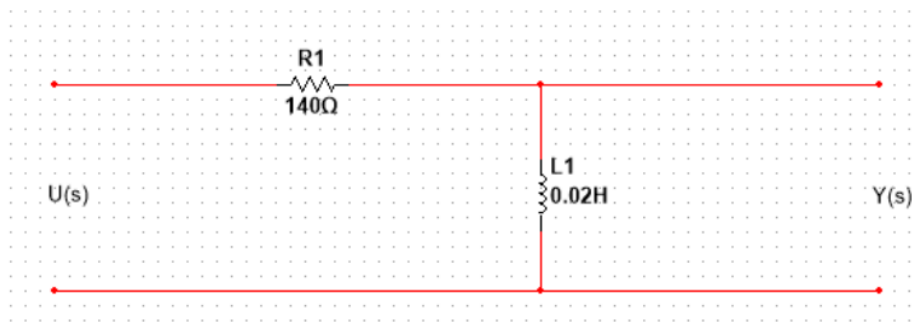


Figure 9- Laplace form of a RL circuit

Using the Laplace circuit created from the component values selected, a Laplace transform function can be generated as displayed below.

Transform Function

$$Hs = \frac{\frac{1}{\omega c} s}{\frac{1}{\omega c} s + 1} = \frac{s}{s + \omega c}$$



Task 3.2 – MATLAB Code

Below is the code generated from the Laplace transform inputted on the on the simulation software.

```
s=tf('s');  
system = s/(s+5000);  
bode(system);  
grid on
```

Figure 10 - Task 3 MATLAB Code

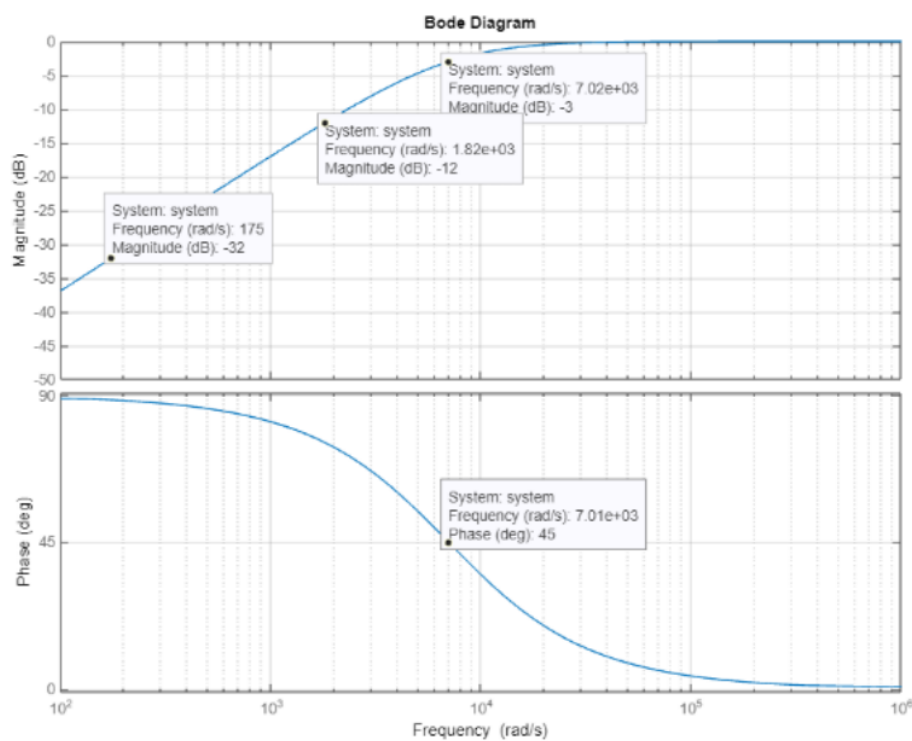


Figure 11 - Task 3 Bode Plot

Above are the output results of the simulated software with all the data points labelled to be used in the results table for comparison purposes.

Task 3.3 – Table of Results

Below are the measured and calculated values attained through the duration of this task and the error value between the both.

	Calculated	Measured	Error
Cut off Frequency ω_c	7000rads/sec	7000rads/sec	0
Φ Phase	45°	45°	0
Roll-off	20dB	20dB	0

Table 3 - Task 3 Data Analysis



Task 3.4 – Critical Analysis

Due to the current positioning of the components, this system is a high pass filter. This filter will only accept and allow higher frequencies to pass after the cut of point (3dB). As this system is regarded as a first order system, it possesses a roll off of 20dB with a phase shift at a natural frequency being 45°. As the calculated and measured values are identical, there is no error. This proves the analysis.



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

Task 4.1- The selection of suitable figures.

For the completion of this task, numerous component values will need to be selected. These Values will help create an analysis on the frequency performance of a RC circuit. The values selected for the capacitor 45μF and for the resistor 950 Ω

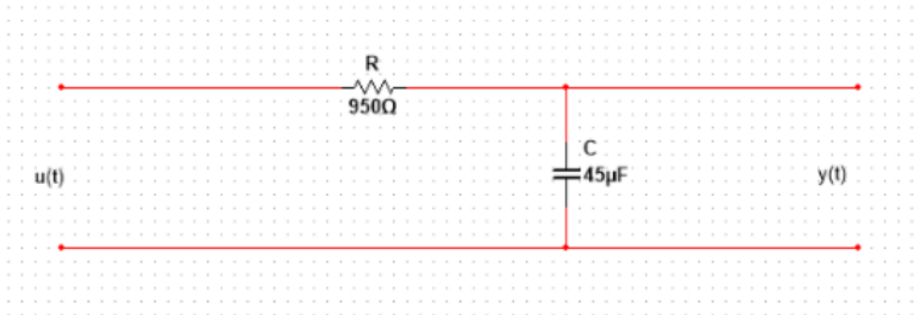


Figure 12-Laplace model

$$\omega c = \frac{1}{RC}$$

$$\omega c = \frac{1}{(950 \times 45 \times 10^{-6})}$$

$$\omega c = 23.39$$



Using the Laplace circuit created from the component values selected, a Laplace transform function can be generated as displayed below.

$$Hs = \frac{1}{\omega c s + 1} = \frac{\frac{1}{\omega c}}{\frac{\omega c}{\omega c} s + \frac{1}{\omega c}} = \frac{\omega c}{s + \omega c}$$

Task 4.2 – MATLAB Code

Below is the code generated from the Laplace transform inputted on the on the simulation software.

```
1 s=tf('s');  
2 system = 23.3/(s+23.3);  
3 bode(system);  
4 grid on
```

Figure 13 - Task 4 MATLAB Code

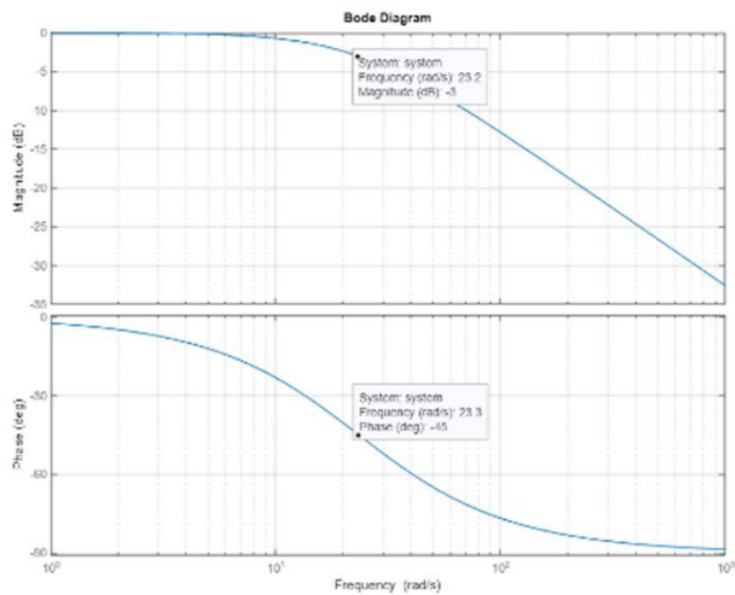


Figure 14- Bode plot diagram.

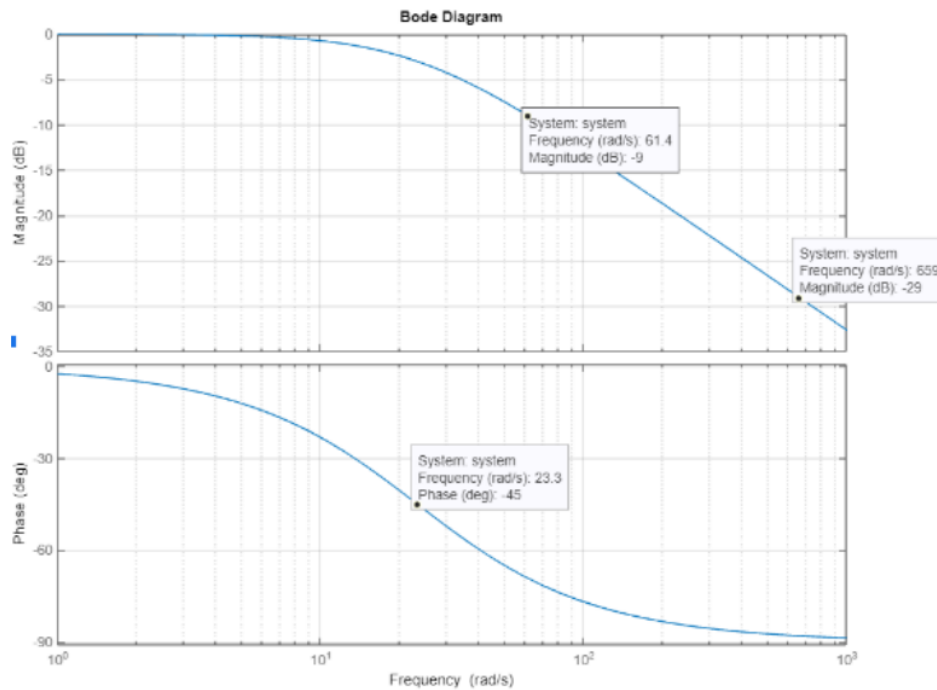


Figure 15 - Task 4 Bode Plot Roll-Off

Task 4.3 – Table of Results

Below are the measured and calculated values attained through the duration of this task and the error value between the both.

	Calculated	Measured	Error
Cut off Frequency ω_c	23.39rad/sec	23.3rad/sec	0
Φ Phase	-45°	-45°	0
Roll-Off	-20dB	-20dB	0

Table 4 - Task 4 Data Analysis

Task 4.4 - Critical Analysis

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 20dB. 

Due to the current positioning of the components, this system is a Low pass filter. This filter will only accept and allow lower frequencies to pass before the cut of point (3dB). As this system is regarded as a first order system, it possesses a roll off of 20dB with a phase shift at a natural frequency being 45°. As the calculated and measured values are identical, there is no error. This proves the analysis.

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

Task 5.1 – Suitable Component Values

During this task, numerous appropriate component values were selected to help evaluate the variations of damping on a transient system. Through the duration of this task, a variation of the types of damping will be produced such as overdamping, underdamping, no damping and critically damping. All these results will be attained through altering the damping factor within the system through changing the resistance value.

Below are the values selected.

$$R = 7\Omega \quad L = 0.3H \quad C = 50\mu F$$

Task 5.2 – Laplace Model

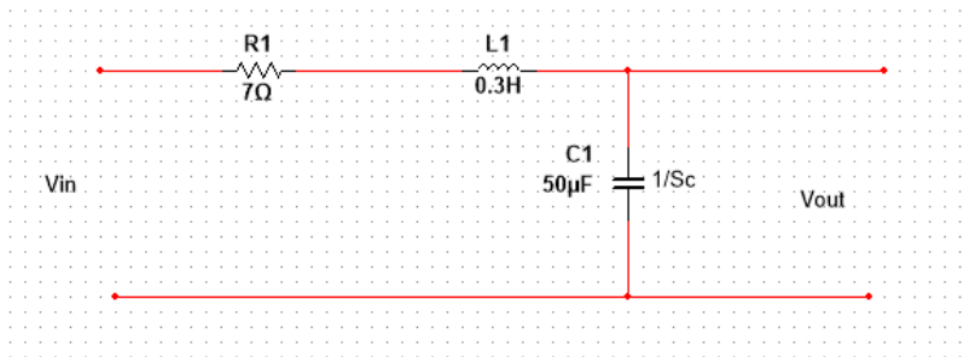


Figure 16 - Task 5 Laplace Model

Through creating a Laplace model, the following transfer function is created.

$$H(s) = \frac{k\omega n^2}{s^2 + 2\zeta\omega n + \omega n^2}$$

Task 5.3 – Transient Performance

With the transfer function being established, the ability to calculate the gain(k), the damping factor(ζ), and the Natural frequency(ωn) is achieved. The following equations allows all these values to be calculated.

$$k = 1$$

$$\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{7}{2} \sqrt{\frac{0.50 \times 10^{-6}}{0.3}} = 0.0451$$



=0.05

$$\omega_n = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.3 \times (50 \times 10^{-6})}} = 258.20 \text{ rad/s}$$

As the natural frequency isn't reliant on a resistance value, proving it will remain a constant through the various damping circuits. Although, this means a new damping factor will need to be calculated. In this system the damping factor is fewer than 1 and will be projected to create an underdamped curve.



Task 5.4 – MATLAB Model

Under Damping

```
s=tf('s');  
system=66667.24/(s^2 + 25.82*s + 66667.24);  
step(system);  
grid on
```

Figure 17 - Under-Damping MATLAB Code

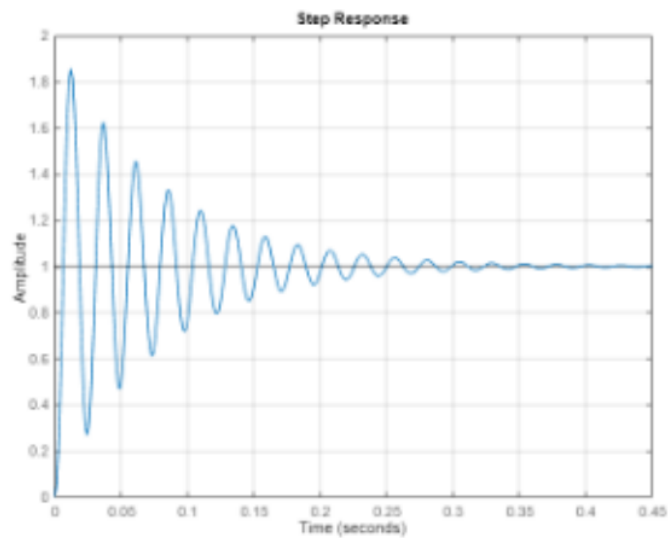


Figure 18 - Under-Damping Graphical Plot

With this system projected to be underdamped. A system slowly decreasing in amplitude will prove the analysis.

Over Damping

An over-damped system will need a damping more than 1. In order to achieve this the resistance value will need to be altered, therefore it has been altered to 290Ω. This should provide a damping high enough to change the system.

New Damping Factor

$$\frac{290}{2} \sqrt{\frac{50 \times 10^{-6}}{0.3}} = 5.9$$

```
s=tf('s');  
system = 66667.24/(s^2 + 3046.7*s + 66667.24);  
step(system);  
grid on
```

Figure 19 - Over-Damped MATLAB Code

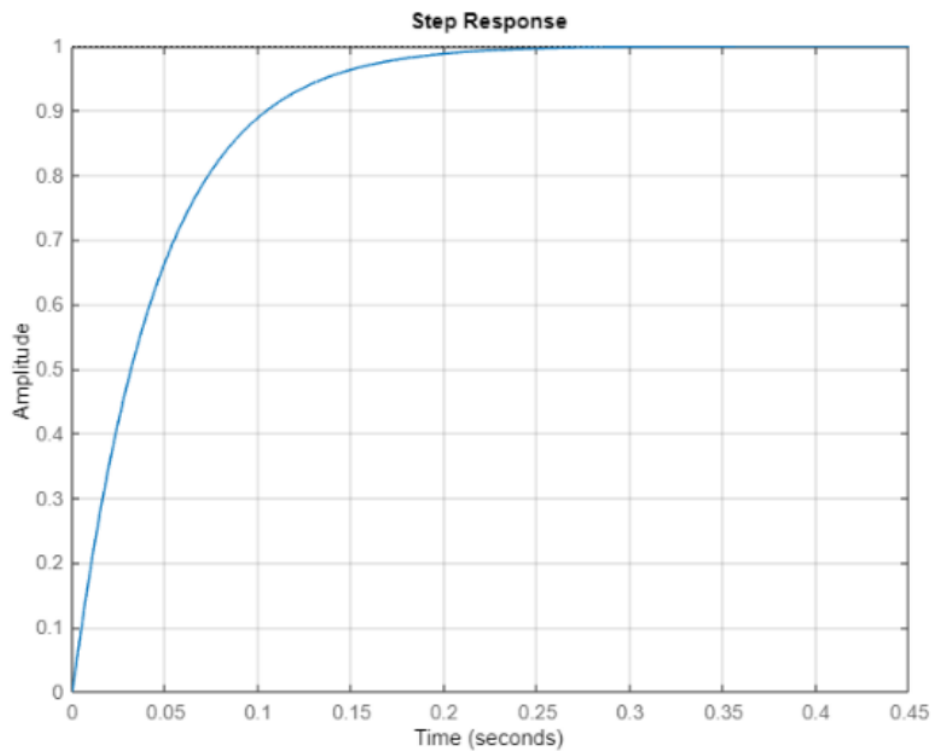


Figure 20 - Over-Damped Graphical Plot

Critically Damping

To achieve a system regarded as critical damped, the damping factor must be equal to 1. To carry out the required calculations, the damping factor equation must be rearranged to calculate to appropriate resistance value. The calculation is as follows.

New Damping Factor

$$R = \frac{2 \times \zeta}{\sqrt{\frac{C}{L}}} = \frac{2}{\sqrt{\frac{50 \times 10^{-6}}{0.3}}} = 154.92\Omega$$



With the resistor set to 154.92Ω it gives a damping factor of 0.99999 which is approximately 1 this will allow the system to be critically damped.

With the value calculated, in this instance being 154.92Ω a damping factor of 0.99999 is achieved. With the damping value achieved being approximately 1, allowing the system to be critically damped.

```

1  s = tf('s');
2  system = 389.25^2/(s^2+(2*1*389.25)*s+389.25^2);
3  step (system);
4  grid on
5

```

Figure 21 - Critically-Damped MATLAB Code

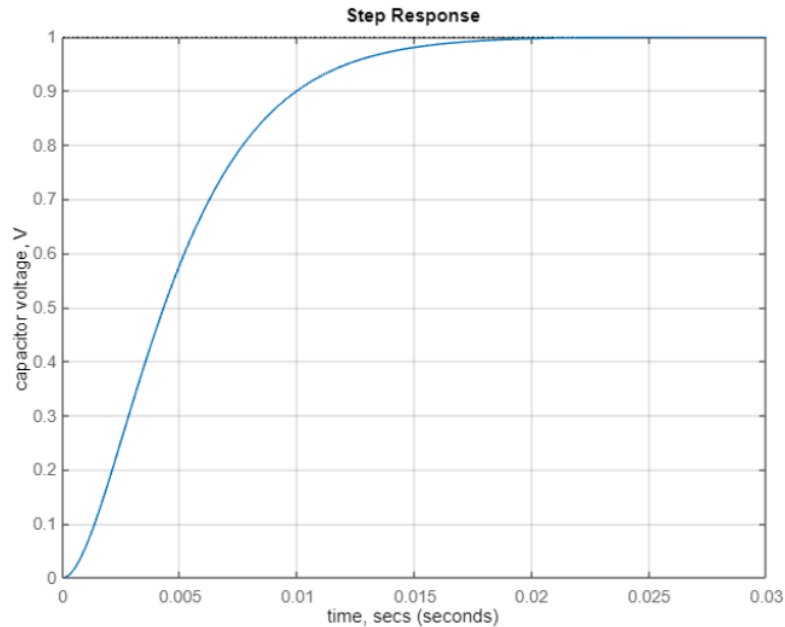


Figure 22 - Critically-Damped Graphical Plot

As shown in the figure above it demonstrates a critically damped system as it doesn't overshoot and reaches the final value in the shortest time.

As displayed in figure 22 above, a critically damped system will never overshoot and archives the desired value in the shortest time.

No Damping

A system with no damping is required to achieve a damping factor equal to 0. Although for this task a damping factor of 0 would be unachievable as the system will need a resistance that is again equal to zero. To achieve this task the resistance value has been set to a very small value. The new resistance for this circuit is $2\mu\Omega$.



New Damping Factor

$$\zeta = \frac{0.00002}{2} \sqrt{\frac{50 \times 10^{-6}}{0.3}} = 1.29 \times 10^{-6}$$

```
s=tf('s');
system=66667.24/(s^2 + 2.58*10^-6*s + 66667.24);
step(system);
grid on
```

Figure 23 - No-Damping MATLAB Code

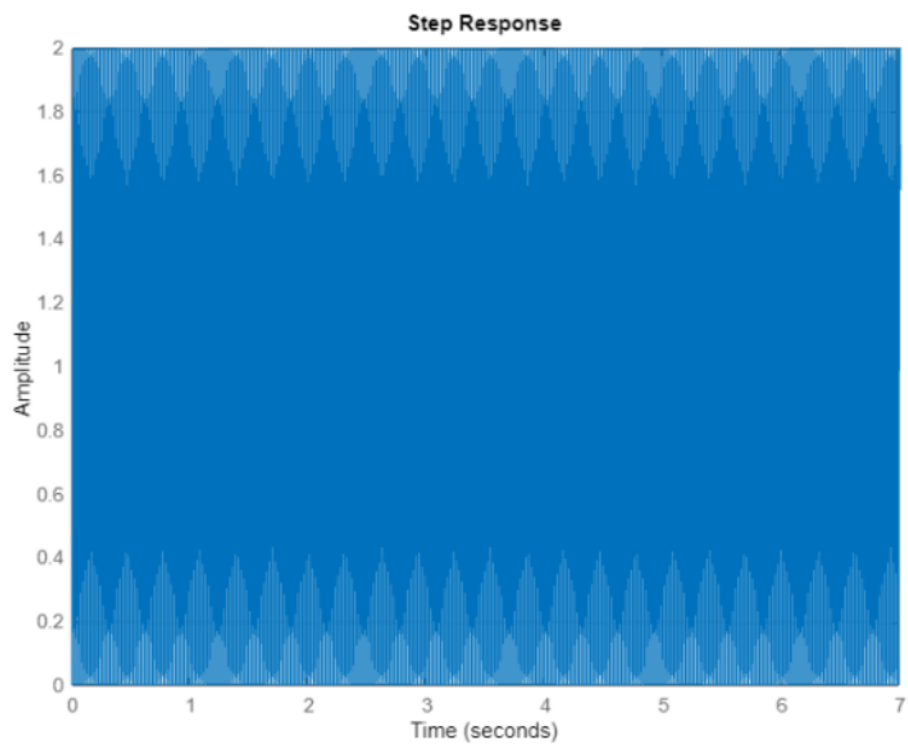


Figure 24 - No-Damping Graphical Plot

Task 5.5 – Results Table

	Resistance (Ω)	Damping Factor (ζ)	Damping Ratio	Damping Effect
System 1	7Ω	0.0451	$\zeta < 1$	Under-damped
System 2	290Ω	5.9	$\zeta > 1$	Over-damped
System 3	154.92Ω	$0.9999 \sim 1$	$\zeta = 1$	Critically-Damped
System 4	$2\mu\Omega$	$1.26\mu \sim 0$	$\zeta = 0$	No-Damping

Table 5 - Series Damping Results Table

Task 5.7 – Critical Analysis

As displayed though this task, a variety of types of damping can be integrated into RLC series circuits. All damping variations have effects with different outcomes on the systems outputs. In the case of an underdamped system, the output value fluctuates and is slow to reach the steady state whilst overshooting the intended output. An over damped system is again slow to reach its steady state however seems to not overshoot the desired output value. The system with no damping will forever fluctuate with no change in amplitude. Finally, a critically damped system will reach its steady state output in the fastest time with no oscillation.



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

Task 6.1 – Selected Component Values

To complete this task on the analysis of the evaluation of the damping on a transient parallel system. A select number of components must be selected. The component values selected are as follows.

$$R = 4\Omega$$

$$L = 0.35\text{H}$$

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

Task 6.2 – Laplace Model

For the opportunity to generate a transform function a Laplace model has been constructed as displayed below in figure 25.

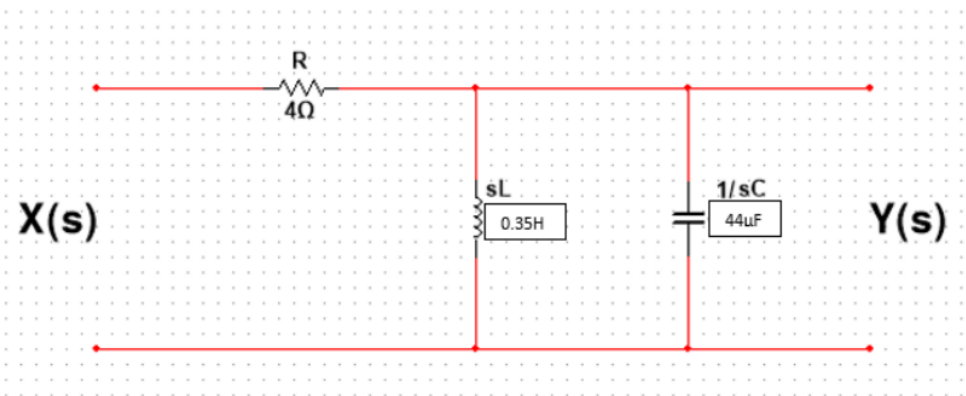


Figure 25 - Parallel RLC Laplace Model

Below is the Laplace transform function generated from the model.

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

Task 6.3 – Transient Performance

This system contains a range of values that can be calculated as displayed below.

$$\zeta = \frac{1}{2R} \sqrt{\frac{L}{C}} = \frac{1}{2 \times 4} \sqrt{\frac{0.35}{40 \times 10^{-6}}} = 11.692$$

$$\frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.35 \times (40 \times 10^{-6})}} = 267.26 \text{ rad/s}$$

After determining that 11.692 is the damping factor, this particular system will be over damped. A new dampening factor will need to be determined for each dampening variation taking place.

Task 6.4 – MATLAB Code

Over Damped

Below is the MATLAB code used to generate graphical data.

```
>> s=tf('s');
>> system = s * (1/4*40*10^-6)/(s^2 + (2 * 11.692 * 267.26*s) + 267.26^2);
>> step(system);
>> grid on
```

Figure 27 - Task 6 Over-damped Code

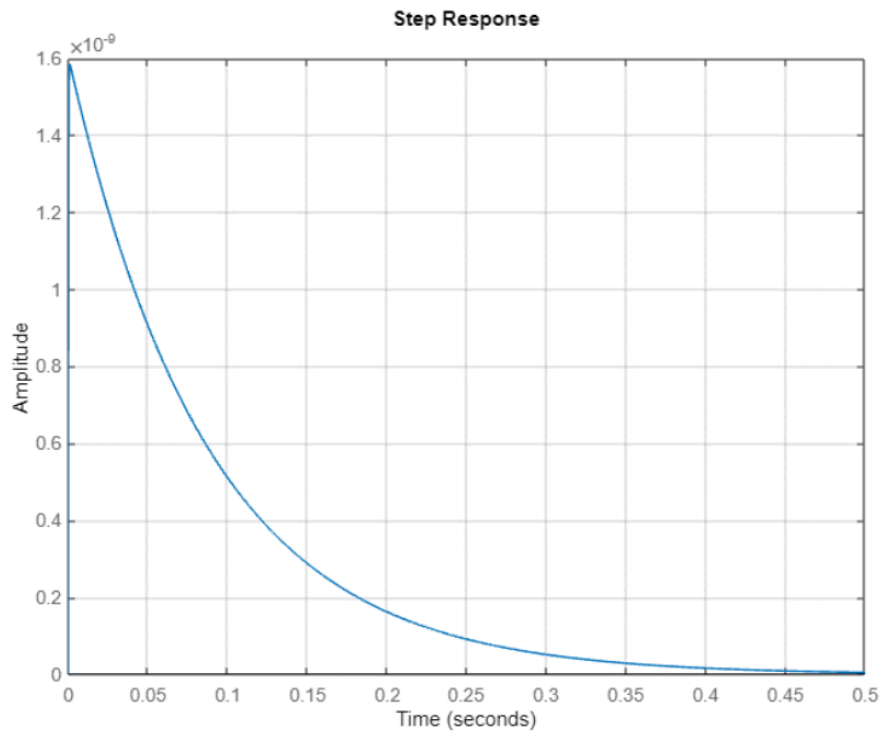


Figure 26 - Task 6 Over-damped Graph

Under Damped

Below is the new calculated damping factor.

$$R = 65\Omega \quad \zeta = \frac{1}{2 \times 65} \sqrt{\frac{0.35}{40 \times 10^{-6}}} = 0.719$$

$$H(s) = \frac{s \times \frac{1}{RC}}{s^2 + 2\zeta W_n s + W_n^2} = \frac{s \times \frac{1}{55 \times 40 \times 10^{-6}}}{s^2 + (2 \times 0.719 \times 267.26 \times s) + 267.26^2}$$

Below is the graph generated and the MATLAB code used to create the graph.

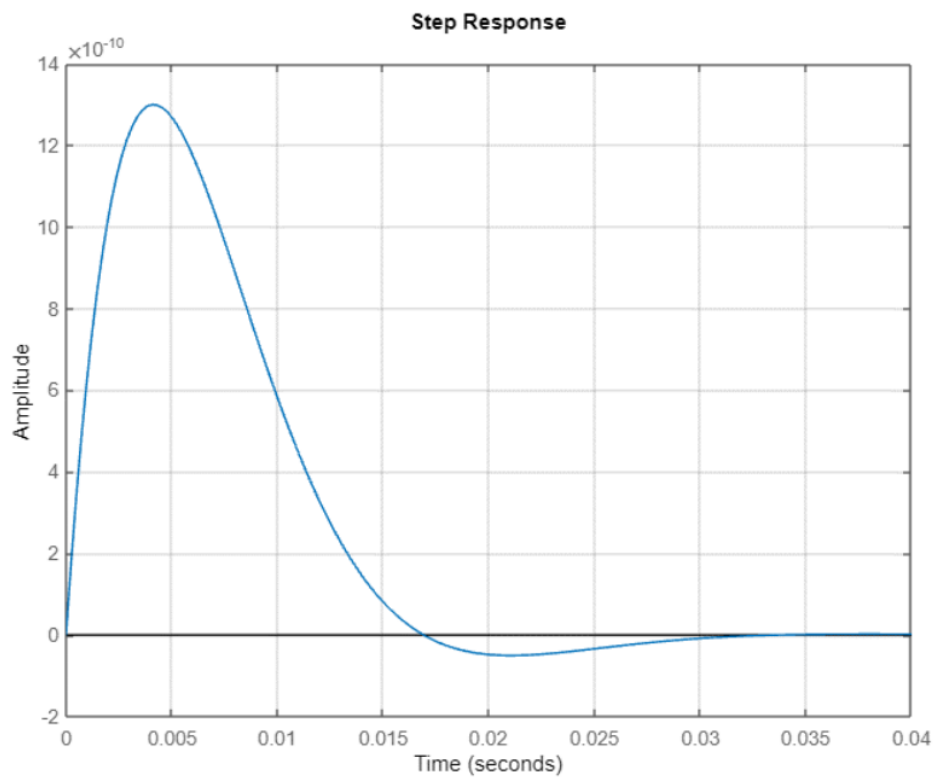


Figure 29 - Task 6 Under-damped Graph

```
>> s = tf('s');
>> system = s * (1/65*50*10^-6)/(s^2 +(2*0.719*267.26*s) + 267.26^2);
>> step (system);
>> grid on
```

Figure 28 - Task 6 Under-Damped Code

Critically Damped

Below is the rearranged equation to find the perfect resistance to create a critically damped system. After this resistance was calculated the next equation is to determine the new damping factor.

$$R = \frac{1}{2} \sqrt{\frac{L}{C}} = \frac{1}{2} \sqrt{\frac{0.35}{40 \times 10^{-6}}} = 46.77$$

$$\zeta = \frac{1}{2 \times 46.77} \sqrt{\frac{0.2}{40 \times 10^{-6}}} = 1$$

$$H(s) = \frac{s \times \frac{1}{RC}}{s^2 + 2\zeta W_n s + W_n^2} = \frac{s \times \frac{1}{46.77 \times 40 \times 10^{-6}}}{s^2 + (2 \times 1 \times 267.26 \times s) + 267.26^2}$$

Below is the MATLAB code used to generate a digital graphical data.

```
>> s = tf('s');  
>> system = s * (1/46.77*40*10^-6)/(s^2 + (2*1*267.26*s)+267.26^2);  
>> step(system);  
>> grid on;
```

Figure 30 - Task 6 Critically-Damped Code

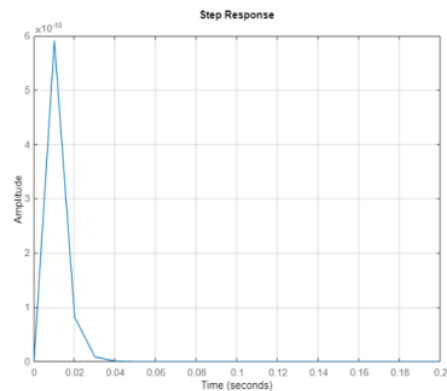


Figure 31 - Task 6 Critically-Damped Graph

No Damping

Below is the new resistance to determine the next damping factor.

$$R = 275\Omega \quad \zeta = \frac{1}{2 \times 275} \sqrt{\frac{0.35}{40 \times 10^{-6}}} = 0.170$$

$$H(s) = \frac{s \times \frac{1}{RC}}{s^2 + 2\zeta W_n s + W_n^2} = \frac{s \times \frac{1}{275 \times 40 \times 10^{-6}}}{s^2 + (2 \times 0.170 \times 267.26 \times s) + 267.26^2}$$

Below is the code inputted onto MATLAB to create the next digital data graph.

```
s=tf('s');  
system = s * (1/275*40*10^-6)/(s^2+(2*0.170*267.26*s)+267.26^2);  
step(system);  
grid on
```

Figure 33 - Task 6 No Damping Code

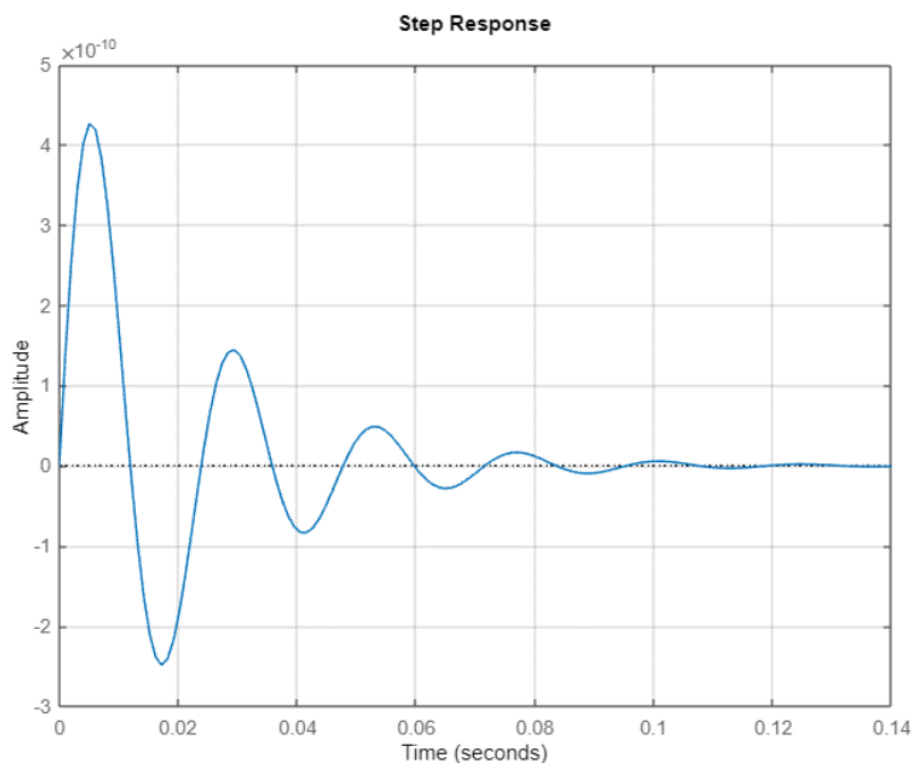


Figure 32 - Task 6 No Damping Graph

Task 6.5 – Table of Results

Below is a table showing the results obtained through the completion of the task.

	Resistance (Ω)	Damping Factor (ζ)	Damping Ratio	Damping Effect
System 1	Ω	0.719	$\zeta < 1$	Under Damped
System 2	Ω	11.692	$\zeta > 1$	Over Damped
System 3	Ω	0.99999 ~ 1	$\zeta = 1$	Critically Damped
System 4	Ω	0.170	$\zeta = 0$	No Damping

Table 6 - Task 6 Table of Results

16

Task 6.6 – Critical Analysis

As show in the graphical simulation all damping factors have effects on the properties of the circuits proving that all analysis obtains and calculated has been proven by the graphical simulation. There was no overshoot in the critically damped system. The no damping system reaches its desired equilibrium however oscillates on to get there. The over damped circuit never reaches the equilibrium no matter how slowly it raises to get there. The underdamped system accelerated quickly however overshoot and then oscillated for a period of time. This circuit is regarded as a first order circuit and will always be decaying.

Task 7 – Frequency Performance Analysis of a Second Order Series Electrical Circuit.

7.1 The Determine System Values

For the task on analysis of the frequency performance of a second order series electrical circuit a value was need to be selected for the resistance. This value would again be varied to create different effects on the dampening of the system as previously displayed in other tasks.

17

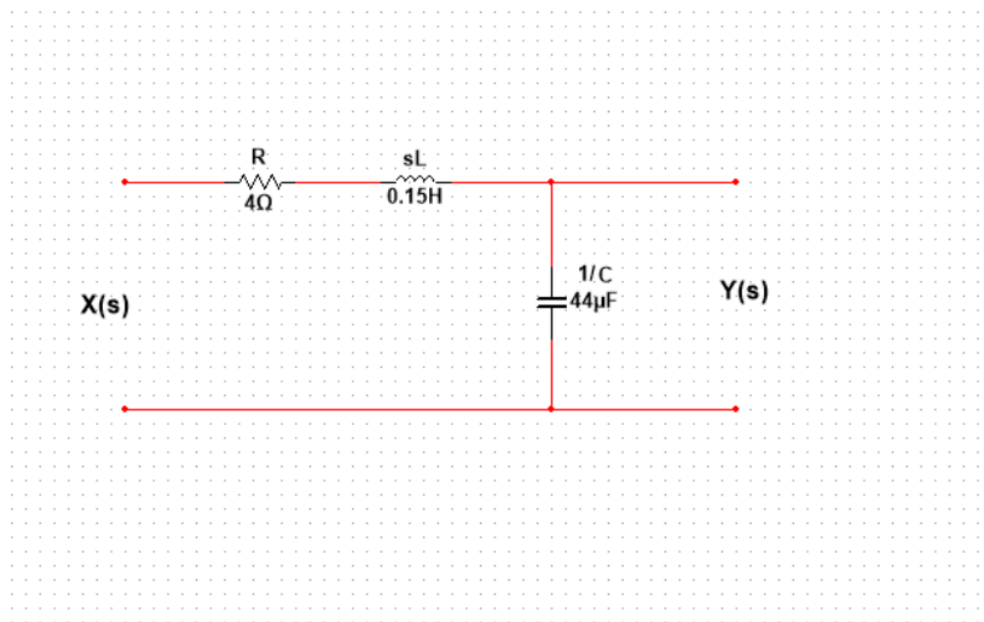


Figure 34 - Task 7 Laplace Model

Above in the Laplace model constructed to provide opportunity to create a transfer function.

No-Damping

As show below is the transfer function for the system.

18

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

For the following values a variety of equations can be established to determine different values.

$$\omega_n = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.35 \times 40 \times 10^{-6}}} = 267.26 \text{ rad/s}$$

$$\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{4}{2} \sqrt{\frac{40 \times 10^{-6}}{0.35}} = 0.03$$

$$Q = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{4} \sqrt{\frac{0.35}{40 \times 10^{-6}}} = 23.385$$



Using the calculated values, a no damping system will be produced.

7.2 MATLAB Code

Under-Damped

$$\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{50}{2} \sqrt{\frac{40 \times 10^{-6}}{0.35}} = 0.267$$

$$Q = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{50} \sqrt{\frac{0.35}{40 \times 10^{-6}}} = 1.871$$

$$H(s) = \frac{s \times \frac{1}{LC}}{s^2 + \frac{R}{L}s + \frac{1}{LC}} = \frac{s \times \frac{1}{0.35 \times 40 \times 10^{-6}}}{s^2 + \frac{50}{0.35}s + \frac{1}{0.35 \times 40 \times 10^{-6}}}$$

Using the calculated values an under-damped system will be produced.

Over-Damped

$$\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{220}{2} \sqrt{\frac{40 \times 10^{-6}}{0.35}} = 1.176$$

$$Q = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{220} \sqrt{\frac{0.35}{40 \times 10^{-6}}} = 0.425$$

$$H(s) = \frac{s \times \frac{1}{LC}}{s^2 + \frac{R}{L}s + \frac{1}{LC}} = \frac{s \times \frac{1}{0.35 \times 40 \times 10^{-6}}}{s^2 + \frac{220}{0.35}s + \frac{1}{0.35 \times 40 \times 10^{-6}}}$$

Using the calculated values an over-damped system will be produced.

Critically Damped

$$R = 2 \sqrt{\frac{L}{C}} = 2 \sqrt{\frac{0.35}{40 \times 10^{-6}}} = 187.08 \Omega$$

$$\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{187.08}{2} \sqrt{\frac{40 \times 10^{-6}}{0.35}} = 0.999 \approx 1$$

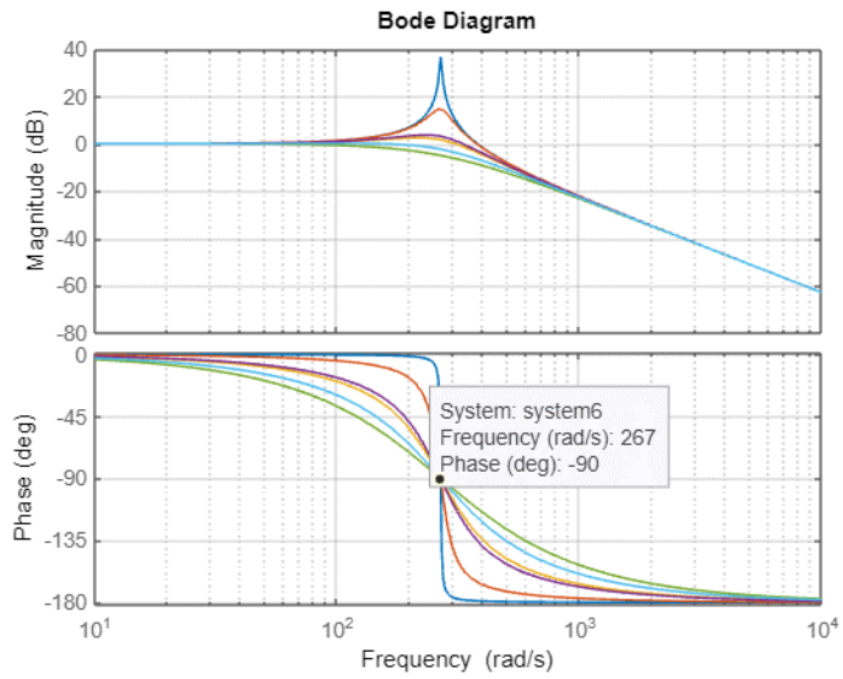
$$Q = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{116.77} \sqrt{\frac{0.15}{44 \times 10^{-6}}} = 0.5$$

$$H(s) = \frac{s \times \frac{1}{LC}}{s^2 + \frac{R}{L}s + \frac{1}{LC}} = \frac{s \times \frac{1}{0.35 \times 40 \times 10^{-6}}}{s^2 + \frac{187.08}{0.35}s + \frac{1}{0.35 \times 40 \times 10^{-6}}}$$

Using the calculated values, a critically damped system will be produced.

Below is the MATLAB code used to generate a graphical data to prove if the calculations were correct through simulations.

```
>> s=tf('s');
system1= 71428.571428/(s^2+4*s+71428.571428);
bode(system1);
>> grid on
>> hold on
>>
>> s=tf('s');
system2= 71428.571428/(s^2+50*s+71428.571428);
bode(system2);
>> s=tf('s');
system3= 71428.571428/(s^2+220*s+71428.571428);
bode(system3);
>> s=tf('s');
system4= 71428.571428/(s^2+187.08*s+71428.571428);
bode(system4);
>> s=tf('s');
system5= 71428.571428/(s^2+475*s+71428.571428);
bode(system5);
>> s=tf('s');
system6= 71428.571428/(s^2+350*s+71428.571428);
bode(system6);
>>
```



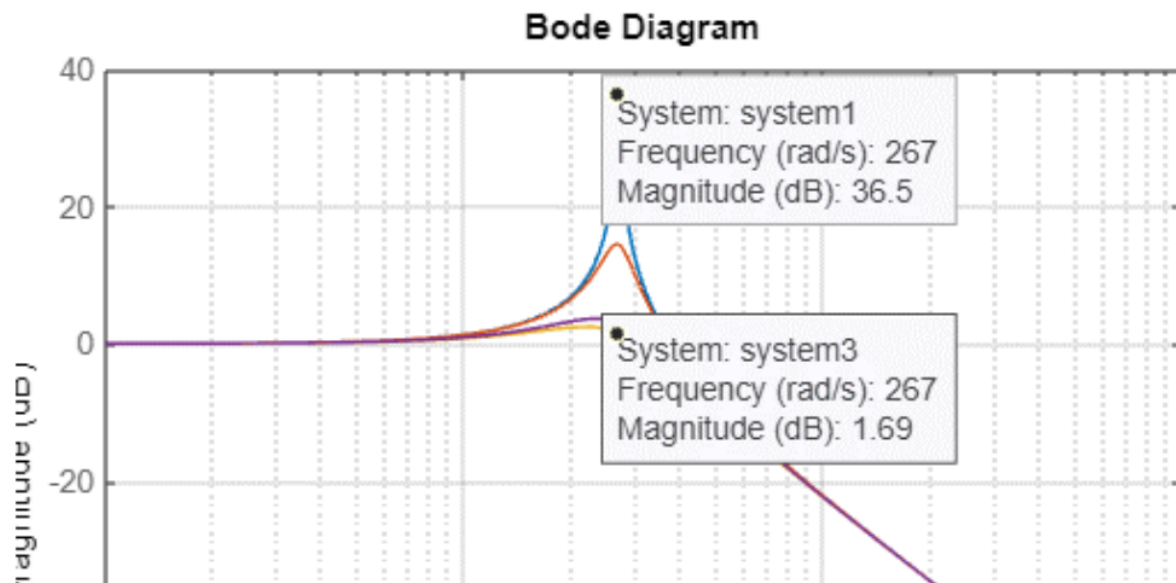
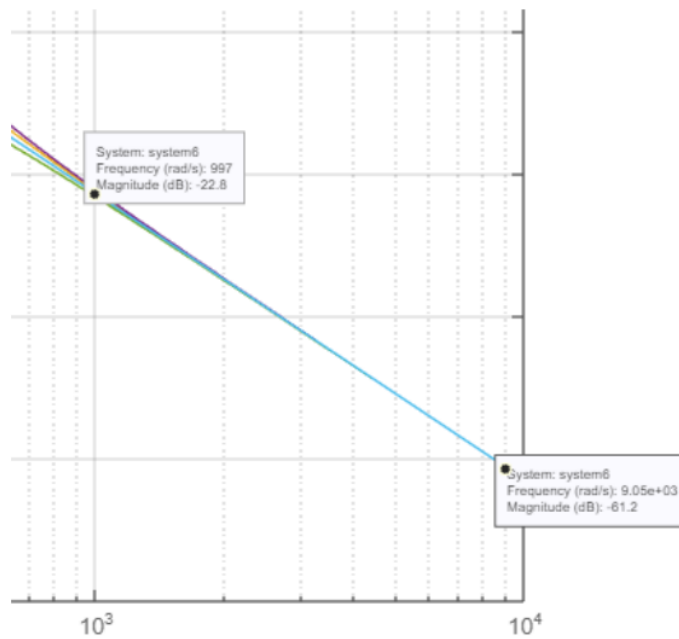


Figure 35 - Task 7 Locust Representation



7.3 Circuit Evaluation

Below are more calculations to determine the magnitude of the circuit. These values are then compared against the measured values previously taken from the graphical data produce from the digital software.

Underdamped

$$20\text{Log}(1.871) = 5.44\text{dB}$$

Overdamped

$$20\text{Log}(0.4025) = -7.43\text{dB}$$

Critically damped

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

No damping

$$20\text{Log}(23.385) = 27.38\text{dB}$$

	Measured values at the cut off frequency (magnitude Db)	Calculated values at the cut off frequency (magnitude Db)
Underdamped	5.38	5.44
Overdamped	-7.43	-7.43
Critically damped	-6.02	-6.02
No damping	36	36.5

7.4 Critical Analysis

All the data collected through the completion of this task, both measured and calculated can confirm that the systems are correct. Again, there are slight differences due to the mathematical rounding with the largest being a magnitude error of 0.5 db. Through changing the damping factor by varying the resistance a locus diagram has been created. This has been achieved by decreasing the value of the resistance incrementally, thus changing the magnitude. The system is considered a low pass filter, as only the smaller frequencies can be passed before the cut off frequency.

Task 8 - Frequency Performance Analysis of a Second Order Parallel Electrical Circuit

8.1 Determining the System Values.

In this task for analysis to take place, the resistance would need to again differ with the other component values remaining the constant. With the resistance of the circuit varying an analysis on the second order parallel circuit could take place.

Below are the calculations used.

$$L = 0.35H, \quad C = 40 \times 10^{-6}F$$

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

$$W_o = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.35 \times 40 \times 10^{-6}}} = 267.26 \text{ Rad/S}$$

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

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

$$R = 65 \Omega$$

$$\frac{1}{RC} = \frac{1}{65 \times 40 \times 10^{-6}} = 384.6 \text{ Hz}$$

$$Q = R\sqrt{\frac{C}{L}} = 65 \sqrt{\frac{40 \times 10^{-6}}{0.35}} = 0.69$$

$$\begin{aligned} W_{c1} &= -\frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{LC}\right)} \\ &= -\frac{1}{2 \times 65 \times 40 \times 10^{-6}} + \sqrt{\left(\frac{1}{2 \times 65 \times 40 \times 10^{-6}}\right)^2 + \left(\frac{1}{0.35 \times 40 \times 10^{-6}}\right)} = 136.95 \text{ Hz} \end{aligned}$$

$$\begin{aligned} W_{c2} &= \frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{LC}\right)} = \frac{1}{2 \times 65 \times 40 \times 10^{-6}} + \sqrt{\left(\frac{1}{2 \times 65 \times 40 \times 10^{-6}}\right)^2 + \left(\frac{1}{0.35 \times 40 \times 10^{-6}}\right)} \\ &= 521.57 \text{ Hz} \end{aligned}$$

$$R = 6 \Omega$$

$$\beta = \frac{1}{RC} = \frac{1}{6 \times 40 \times 10^{-6}} = 4166.6 \text{ Hz}$$

$$Q = R \sqrt{\frac{C}{L}} = 6 \sqrt{\frac{40 \times 10^{-6}}{0.35}} = 0.06$$

$$\begin{aligned} W_{c1} &= -\frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{LC}\right)} \\ &= -\frac{1}{2 \times 6 \times 40 \times 10^{-6}} + \sqrt{\left(\frac{1}{2 \times 6 \times 40 \times 10^{-6}}\right)^2 + \left(\frac{1}{0.35 \times 40 \times 10^{-6}}\right)} = 17.1 \text{ Hz} \end{aligned}$$

$$\begin{aligned} W_{c2} &= \frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{LC}\right)} = \frac{1}{2 \times 6 \times 40 \times 10^{-6}} + \sqrt{\left(\frac{1}{2 \times 6 \times 40 \times 10^{-6}}\right)^2 + \left(\frac{1}{0.35 \times 40 \times 10^{-6}}\right)} \\ &= 4183.74 \text{ Hz} \end{aligned}$$

$$R = 34.72 \, \Omega$$

$$\beta = \frac{1}{RC} = \frac{1}{34.72 \times 40 \times 10^{-6}} = 720.05 \text{ Hz}$$

$$Q = R \sqrt{\frac{C}{L}} = 34.72 \sqrt{\frac{40 \times 10^{-6}}{0.35}} = 0.4$$

$$\begin{aligned} W_{c1} &= -\frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{LC}\right)} \\ &= -\frac{1}{2 \times 34.72 \times 40 \times 10^{-6}} + \sqrt{\left(\frac{1}{2 \times 34.72 \times 40 \times 10^{-6}}\right)^2 + \left(\frac{1}{0.35 \times 40 \times 10^{-6}}\right)} \\ &= 88.38 \text{ Hz} \end{aligned}$$

$$\begin{aligned} W_{c2} &= \frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{LC}\right)} \\ &= \frac{1}{2 \times 34.72 \times 40 \times 10^{-6}} + \sqrt{\left(\frac{1}{2 \times 34.72 \times 40 \times 10^{-6}}\right)^2 + \left(\frac{1}{0.35 \times 40 \times 10^{-6}}\right)} = 808.40 \text{ Hz} \end{aligned}$$

$$R = 300 \, \Omega$$

$$\beta = \frac{1}{RC} = \frac{1}{300 \times 40 \times 10^{-6}} = 83.3 \text{ Hz}$$

$$Q = R \sqrt{\frac{C}{L}} = 300 \sqrt{\frac{40 \times 10^{-6}}{0.35}} = 3.21$$

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

$$= -\frac{1}{2 \times 300 \times 40 \times 10^{-6}} + \sqrt{\left(\frac{1}{2 \times 300 \times 40 \times 10^{-6}}\right)^2 + \left(\frac{1}{0.35 \times 40 \times 10^{-6}}\right)} = 228.82 \text{ Hz}$$

$$W_{c2} = \frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{LC}\right)} = \frac{1}{2 \times 250 \times 50 \times 10^{-6}} + \sqrt{\left(\frac{1}{2 \times 250 \times 50 \times 10^{-6}}\right)^2 + \left(\frac{1}{0.2 \times 50 \times 10^{-6}}\right)}$$

$$= 312.16 \text{ Hz}$$

8.2 MATLAB Code

Below are the MATLAB codes used to generate to compare the calculated data against the simulated graphical data.

R = 65 Ω

```
>> s=tf('s');
>> system = s *384.6/(s^2+384.6*s+267.26^2);
>> bode (system);
>> grid on
>> hold on
```

Figure 36-Matlab code

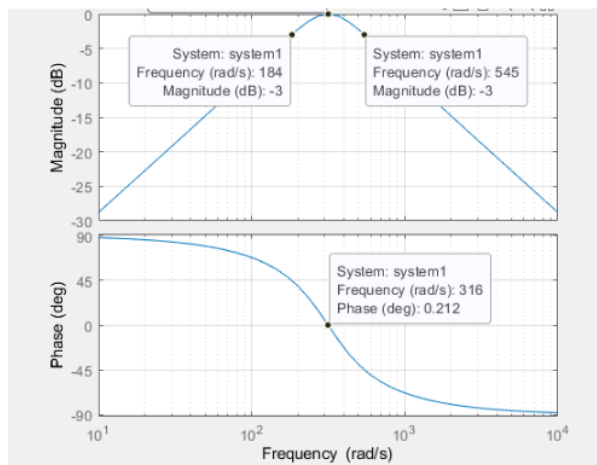


Figure 37 65 ohms

R = 6 Ω

```

s=tf('s');
system = s*4166.6/(s^2+4166.6*s+267.26^2);
bode(system);
grid on
hold on

```

Figure 38-MATLAB Code

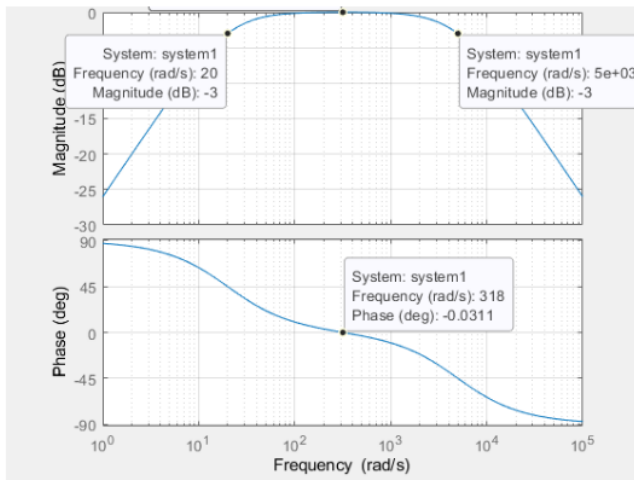


Figure 39 6 Ohms

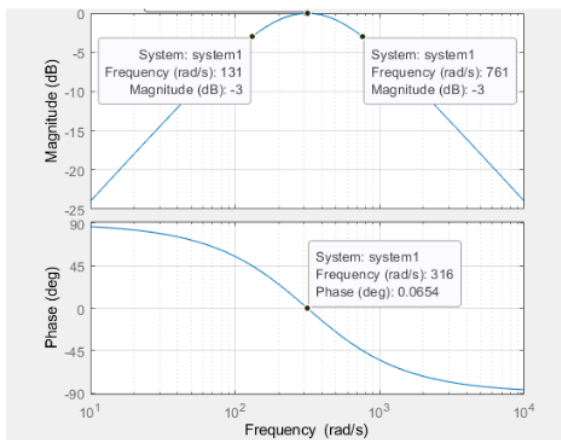
$R = 31.62 \, \Omega$

```

>> s=tf('s');
>> system=s*720.05/(s^2 + 720.05*s+267.26^2);
>> bode(system);
>> grid on
>> hold on

```

Figure 40- Matlab code



$R = 300 \, \Omega$

```
>> s=tf('s');
>> sysytem= s*83.3/(s^2+83.3*s+267.26^2);
>> bode(sysytem);
>> grid on
>> hold on
```

Figure 41- MATLAB code

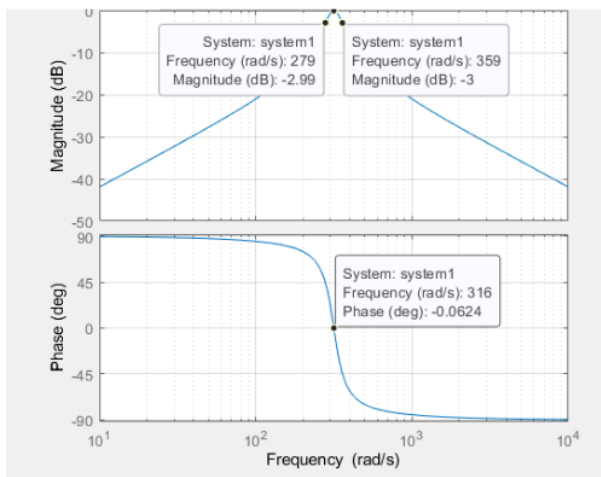


Figure 42 250 Ohms

8.3 Investigate against different values

Calculated values

Below are two tables to compare the calculated bandwidth, upper and lower frequencies.

Resistance Ω	Wo (Hz)	Lower cut off frequency (Hz)	Upper cut off frequency (Hz)	β (Hz)
65 Ω	267.26	136.95	521.57	384.6
6 Ω	267.26	17.1	4183.74	4166.74
34.72 Ω	267.26	88.38	808.48	720.05
300 Ω	267.26	228.82	312.16	83.3

Measured values

Resistance Ω	Wo (Hz)	Lower cut off frequency (Hz)	Upper cut off frequency (Hz)	β (Hz)
65 Ω	267.26	136.95	521.57	384.6
6 Ω	267.26	17.1	4183.74	4166.74
34.72 Ω	267.26	88.38	808.48	720.05
300 Ω	267.26	228.82	312.16	83.3

8.4 Critical Analysis

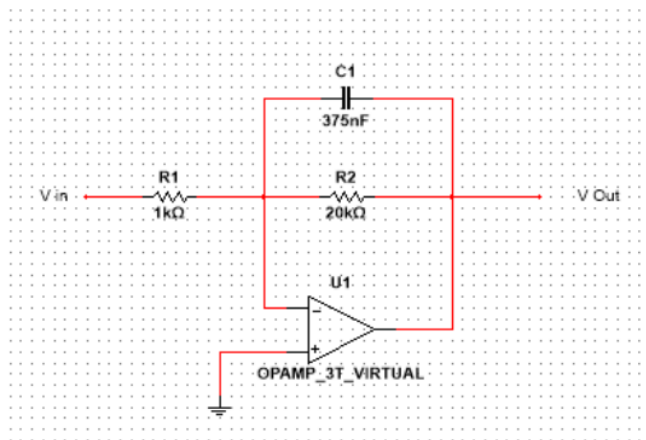
From the results obtained, it is noticeable that the bandwidth has decreased to the increase in resistance through the system. This makes the circuit more selective as the resistance gets higher. At the resonant frequency of 267.26 Rad/S, the displayed phase shift is 0°. The majority of the calculated values couple up with the simulated values provided through the use of MATLAB. Some results may not match up but surprisingly the bandwidth is always perfect.



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

9.1 - The Component Values selected.

For the task, to analyse the frequency of a first order electronic system, a component value for the capacitor must be established. The capacitor selected was 375nF.



Calculations

Below are the calculations used to determine the frequency and gain for this system.

$$k = \frac{R_2}{R_1}$$

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

$$\omega_c = \frac{1}{375 \times 10^{-9} \times 20000} = 133.3 \text{ Rad/s}$$

Below is the Transfer function established from the Laplace model and component values.

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

9.2 - Suitable MATLAB Code

The following code was established from the Laplace transfer function, and placed in a digital software to produce graphical data of the system.

```
>> s = tf('s');
>> system = (-20*(133.3 / (s + 133.3)));
>> bode (system);
>> grid on
>> hold on
```

Figure 44 - Low Pass Filter MATLAB Code

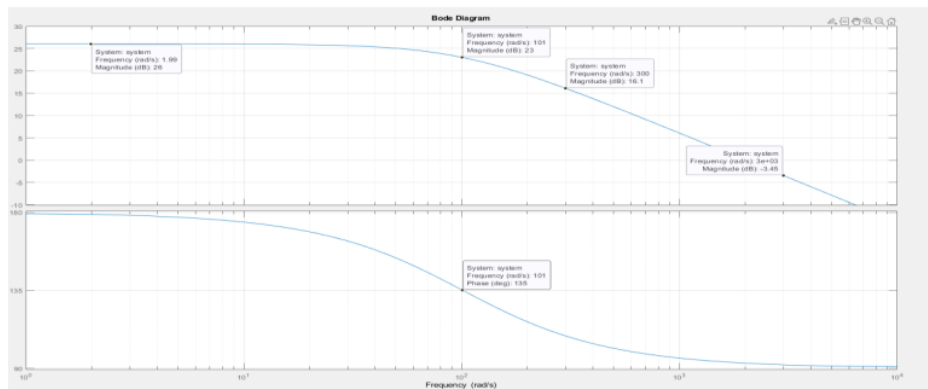


Figure 43 - Low Pass Filter Bode Plot

9.3 - Critical Analysis

The values calculated couple up with the measured values. As the amplifier used is an inverting amplifier, a phase shift of 180° is achieved. Thus, at the cut off frequency the phase shift = $-45 + 180 = 135^\circ$. The following equation proves that calculated values are correct. As this circuit is a first order system it has a roll off of 20dB.

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



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

10.1 – Suitable Component Values

For the task, to analyse the frequency of a first order electronic system, a component value for the capacitor must be established. The capacitor selected was 65nF.

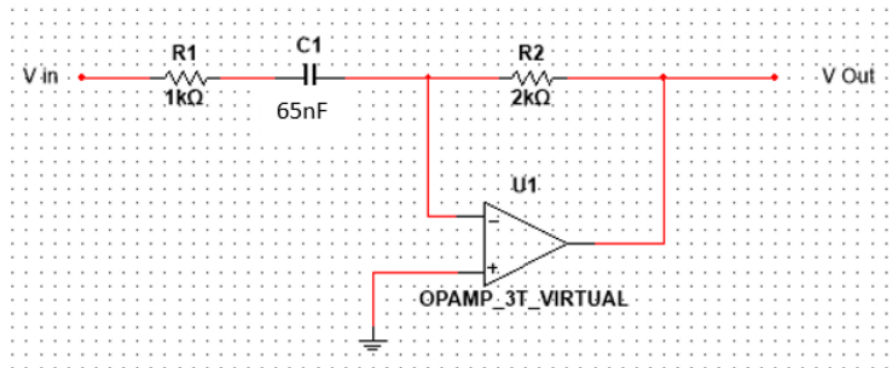


Figure 45 - High Pass Filter Circuit

Calculations

Below are the calculations used to determine the frequency and gain for this system.

$$k = \frac{R_2}{R_1}$$

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

$$\omega_c = \frac{1}{(65 \times 10^{-9}) \times 1000} = 15384.62 \text{ rad/s}$$

$$20 \log_{10}(2) = 6.021 \text{ dB}$$

$$\omega_c \text{ is at } -3 \text{ dB} \therefore 3.021 \text{ dB}$$

Below is the Transfer function established from the Laplace model and component values.

$$H(s) = -\frac{R_2}{R_1} \left[\frac{s}{s + \frac{1}{CR_1}} \right] \rightarrow -k \left[\frac{s}{s + \omega_c} \right]$$

10.2 – Suitable MATLAB Code

The following code was established from the Laplace transfer function, and placed in a digital software to produce graphical data of the system.

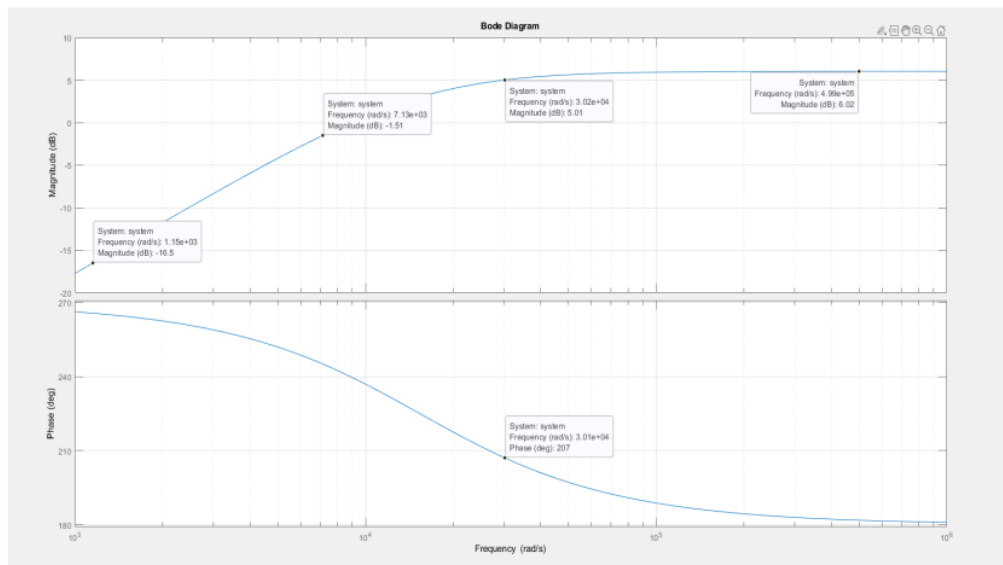


Figure 47 - High Pass Filter Bode Plot

10.3 – Critical Analysis

The values calculated couple up with the measured values. As this system is a high pass filter the natural frequency is 45° . As the amplifier used is an inverting amplifier, a phase shift of 180° is achieved. Thus, at the  27 frequency the phase shift = $45 + 180 = 225^\circ$. The following equation proves that calculated values are correct. As this circuit is a first order system it has a roll off of 20dB.

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

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

11.1- Calculation

For this task, the resident frequency used was set to 1700rad/s. This information allowed for numerous component values to be calculated.

$$R = \frac{1}{1700 \times 100 \times 10^{-9}} = 5882.35\Omega$$

A Butterworth filter has a value for K is equal to 1.586.

$$R_A = (k - 1) \times R_B$$

$$R_A = (1.586 - 1) \times 1000\Omega$$

$$R_A = 586\Omega$$



The calculation for gain through the system, is the calculation shown below.

$$\text{Gain(dB)} = 20 \log_{10}(1.586) = 4(\text{dB})$$

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

These calculations allow for a suitable circuit to be constructed. As displayed below in figure 48.

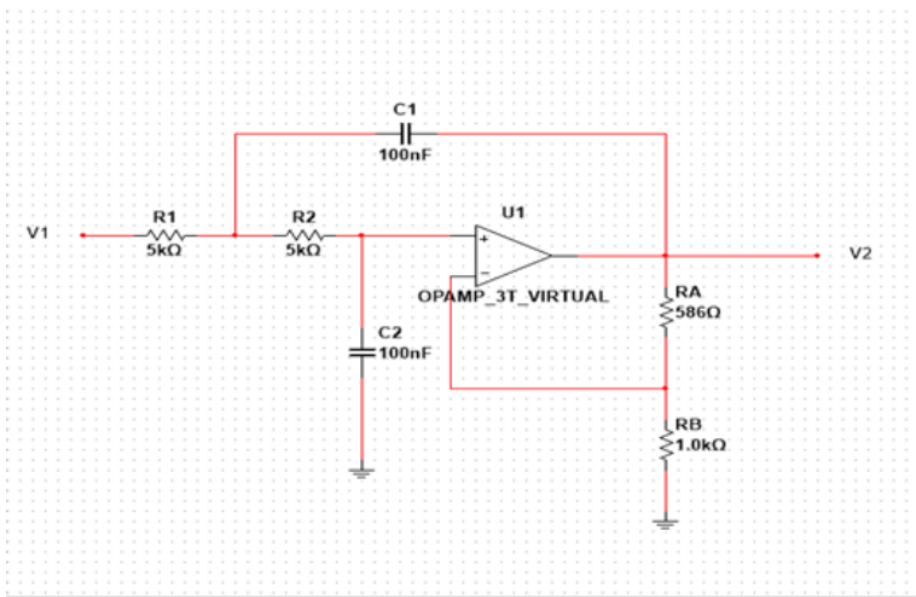


Figure 48- Task 11 Sallen & Key filter circuit.

From this circuit a suitable transfer function can be created. As the system is a low pass filter the transfer function is noted as.

This circuit provides an opportunity appropriate transfer function to be created. The system will be considered a low pass filter as noted in the transfer function below.

$$LPF H(s) = \frac{k\omega^2}{s^2 + \frac{\omega_c}{Q}s + \omega_c^2}$$

11.2 - MATLAB

```
>> system = (1.586*(1700)^2)/((s)^2 + ((1700/0.707)*s) + 1700^2);
>> bode (system);
>> grid on
>> hold on
```

Figure 49 - Task 11 Suitable MATLAB Code

The Simulation code was then written on digital software. Displayed above in figure 49.

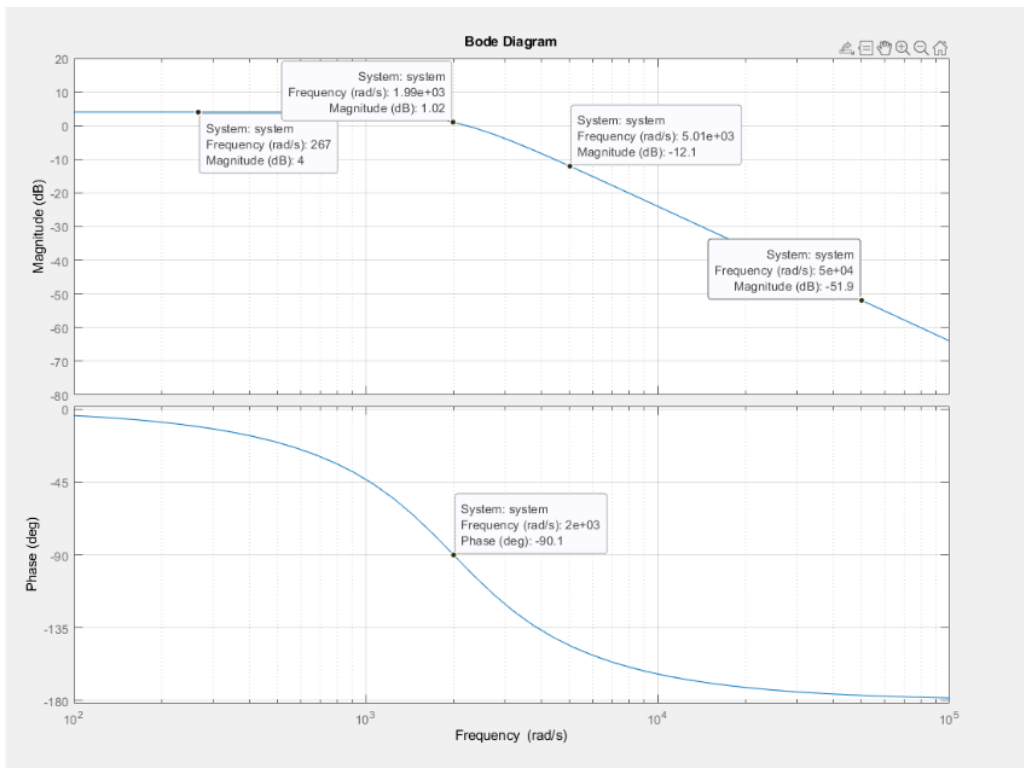


Figure 50 - Task 11 Sallen & Key Bode Plot

11.3 – Analysis

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

The values attained through the calculated and simulated results all couple up barring the cut off frequency, this will probability be down to a mathematical rounding error. As this circuit is consider a second order circuit it has a roll off of -40dB unlike the first order circuit previously display in task 9 & 10 with a roll off of -20 over a decade. This suggests that a second order circuit has more selective frequencies range that allow frequencies to pass through the system. This is proven by the steeper roll off.

Task 12 – First Order Control System Analysis.

12.1 – Determined Open loop

The open loop performance is demonstrated as shown below in figure 51.

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

Figure 51 - Task 12 Argand Diagram MATLAB code

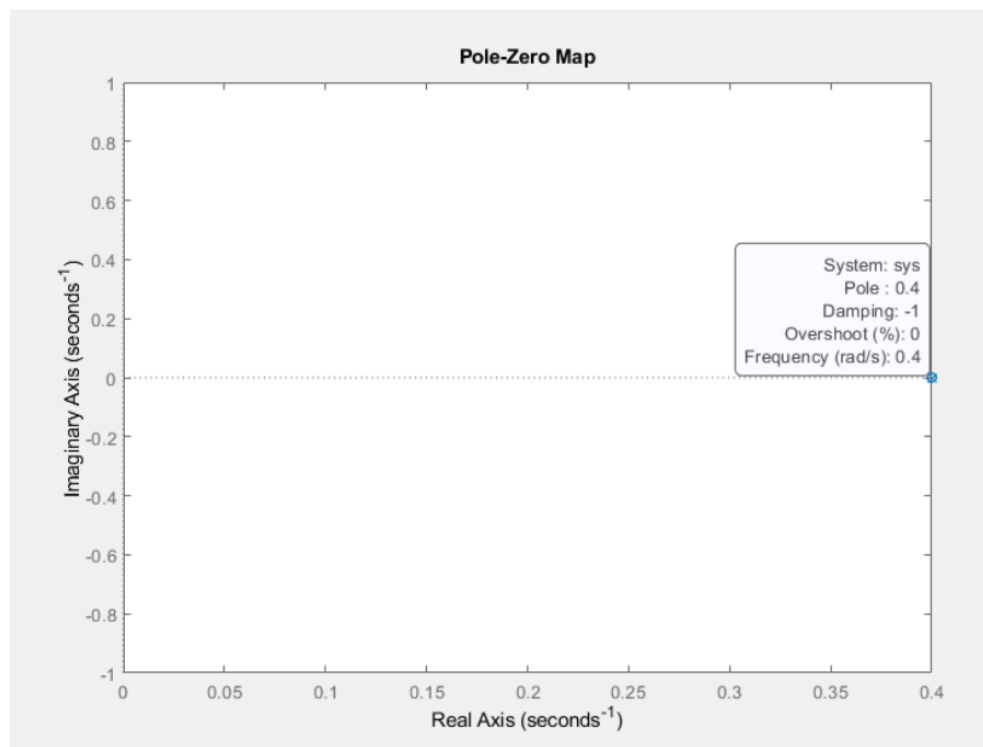


Figure 52 – Task 12 Argand Diagram

In the diagram above the pole is displayed in a positive region, this would prove that the signal is unstable.

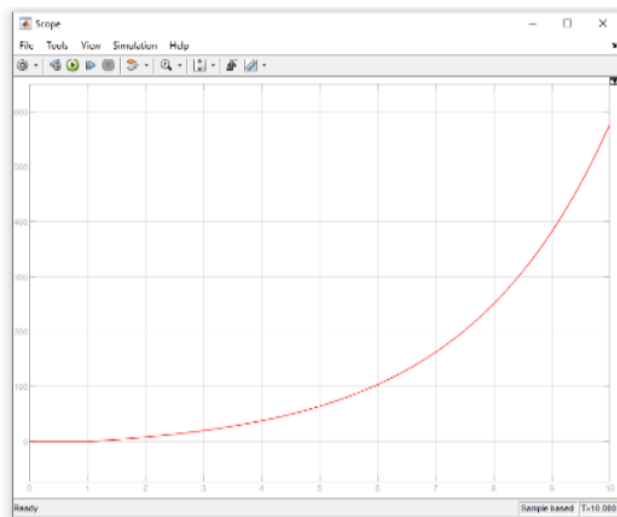
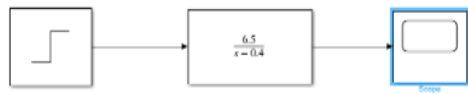


Figure 53 – Task 12 Open Loop Response

12.2 – Produced closed loop

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

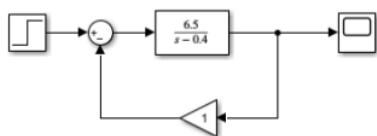


Figure 54 Closed loop transfer function

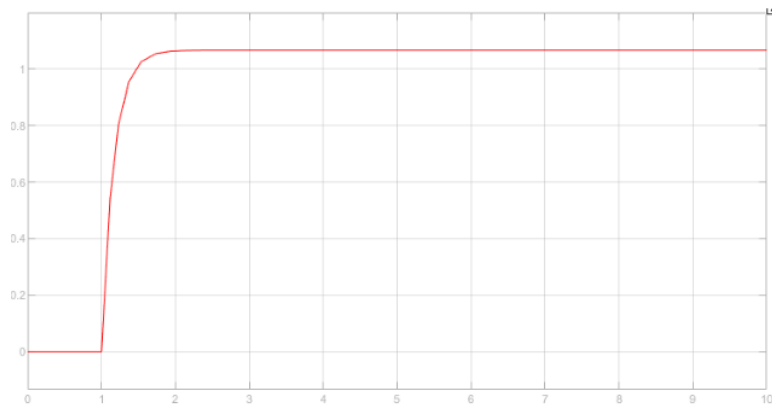


Figure 55 Closed loop transfer function

This response would suggest that the response achieves a peak whilst stabilising proving that this system is stable.

12.3 - Calculations

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

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

Then multiply the equation by $(s - 0.4)$.

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

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

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

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

$$s = -6.5k + 0.4$$

$$s = 0.4 - 6.5k$$

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



```
>> simulink
>> clear all
>> num = [6.5];
>> den = [1, -0.4];
>> rlocus(num,den);
grid
>>
```

Figure 56 - Task 12 Locus Code

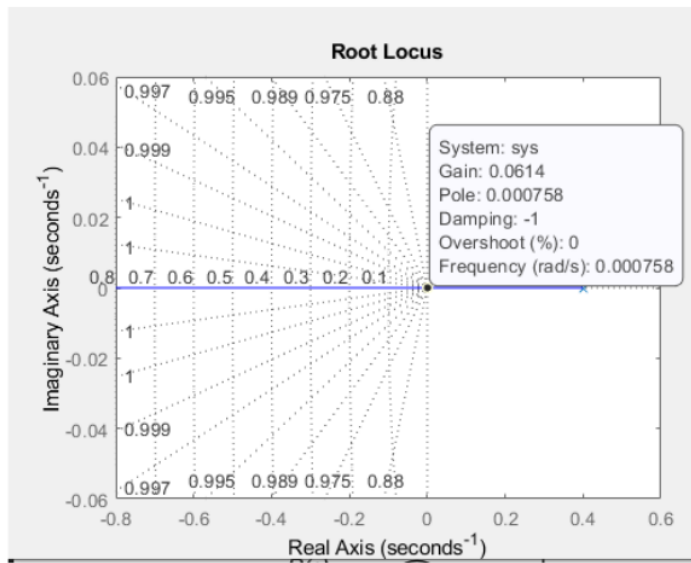


Figure 57-root locus.

As shown in the figure 57 above it can be observed that the minimum value for gain within the root locus is 0.0614. This is used to create a pole of 0. This confirms the calculation made previously

12.4

$$s = 0.4 \times 6.5k$$

$$K < \text{mink}(0.001)$$

$$s = 0.4 \times (6.5 \times 0.02) = 0.052$$

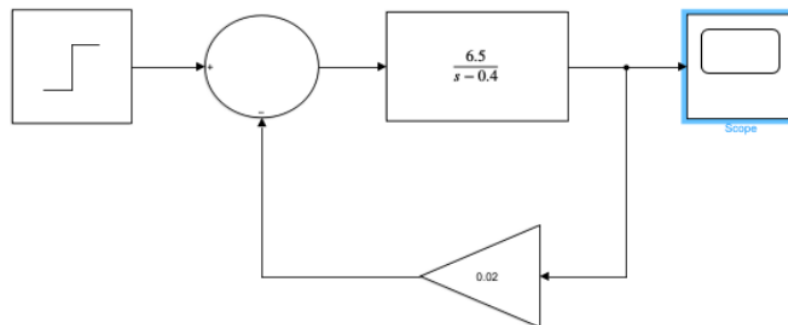


Figure 58 - Task 12 K less than Min Circuit

The Pole is at 0.052 therefor this is considered unstable.

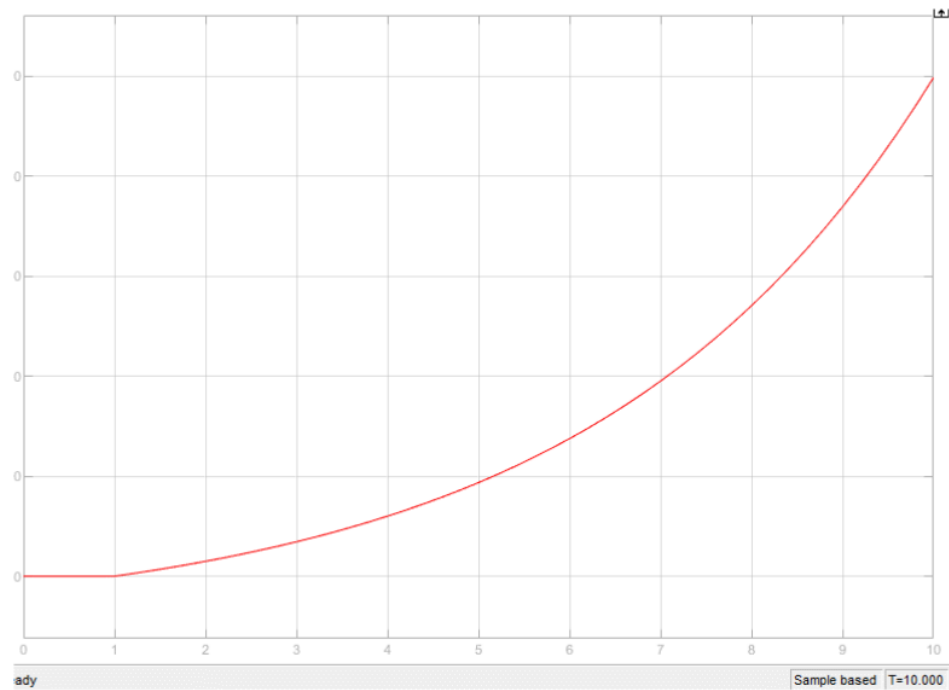


Figure 59 - Task 12 K < Mink Graph

$$K = \text{Mink}(0.0614)$$

$$s = 0.4 \times (6.5 \times 0.0614) = 0.15964$$

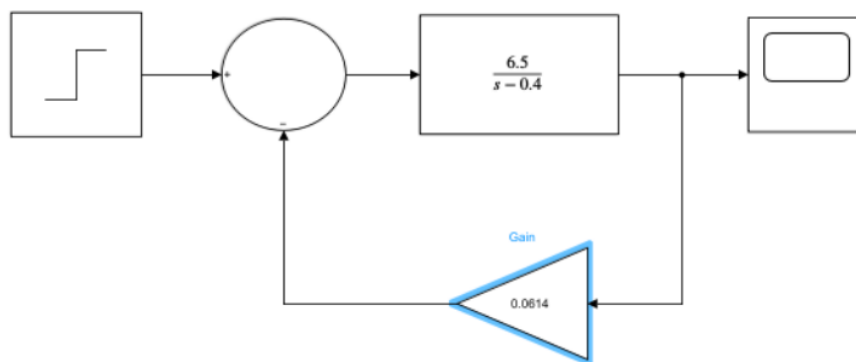


Figure 60 - Task 12 K = Mink Circuit

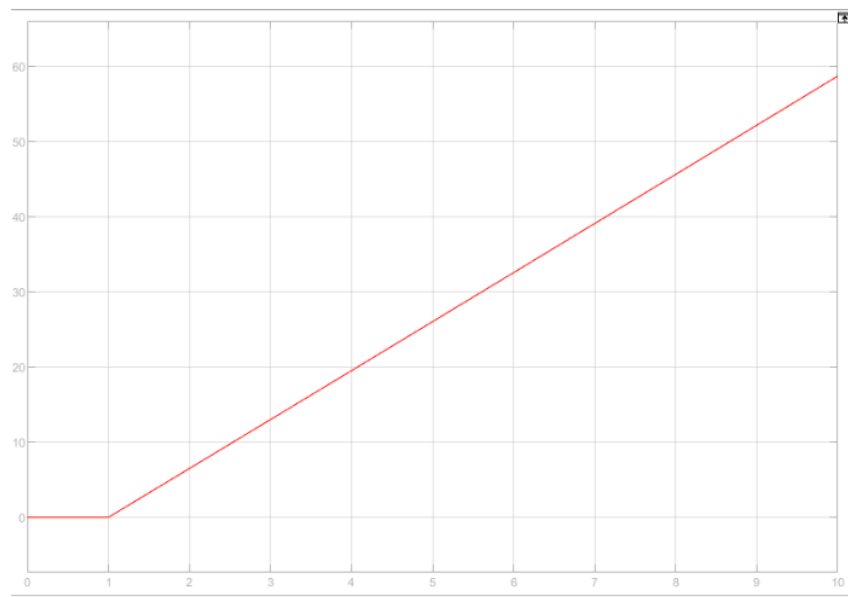


Figure 61 - Task 12 $K = \text{Mink}$ Graph

As the pole is at 0.15964 it is considered unstable.

$K > \text{Mink}(0.1)$

$$s = 0.4 \times (6.5 \times 0.2) = 0.52$$

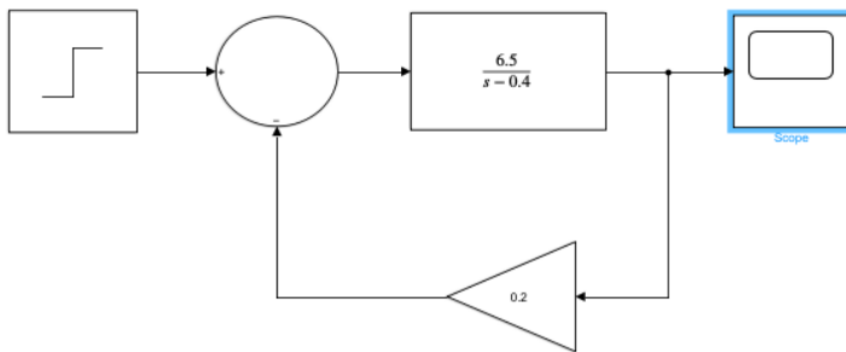


Figure 62 - Task 12 $K > \text{Mink}$ Circuit

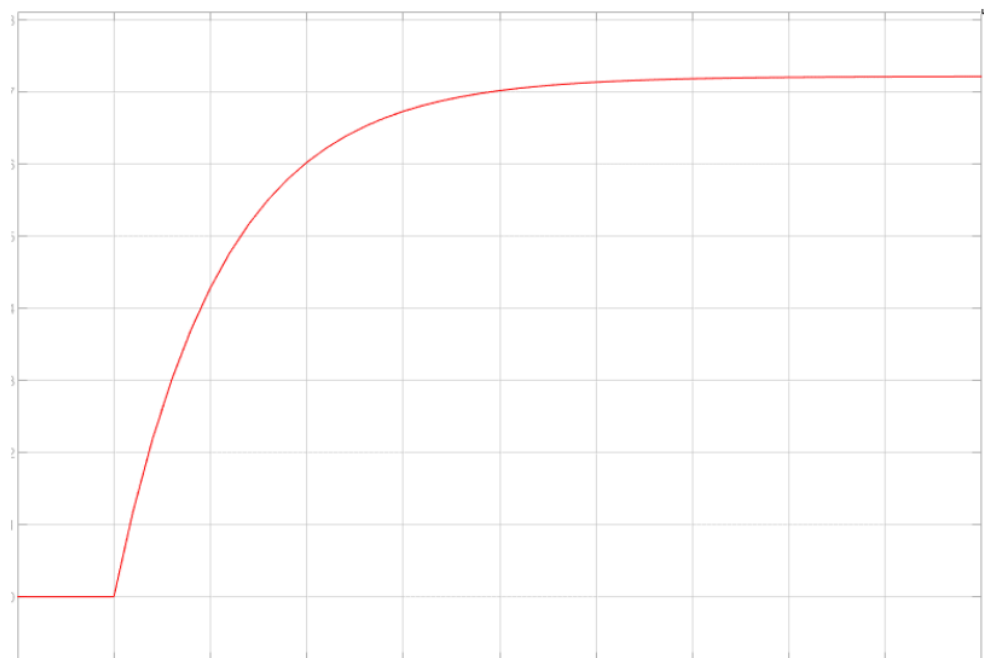


Figure 63 - Task 12 K > Mink Graph

As the pole is at 0.52 this is considered a stable system.

12.5 – Table of Results

Below is a table of figures attained through the completion of this task.

K value	Pole	Measured Stability	Calculated Stability
0.02	0.052	Unstable	Unstable
0.0614	0.15964	Unstable	Unstable
0.2	0.52	Stable	Stable

12.6 - Critical Analysis

As shown in the table presented above, it suitable to ascertain a prediction of stability of a circuit through the polarity of its poles. With the use of the rearranged equations above its possible to determine the minimum value for k. exceeding this value causes the output signal to stable. While having a value for k lower than the minimum keeps the signal unstable.

As displayed in the table above, an appropriate estimation of stability of a circuit through the polarity of the poles. Using rearrange equations the opportunity to calculate the minimum value for. By having a value that exceeds gain product  ble output, by having a gain value lower than the minimum keeps the signal unstable.

Task 13 – DC Motor Model Analysis

13.1 – Mathematical model

Below are two figures used to display a model made DC motor Control.

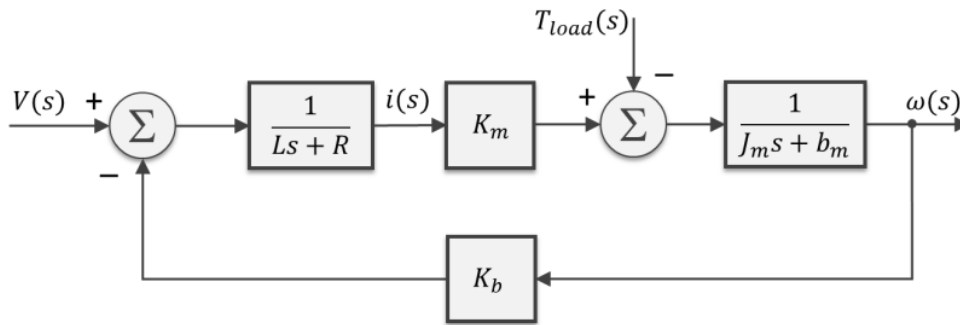


Figure 64 - Task 13 DC Motor model

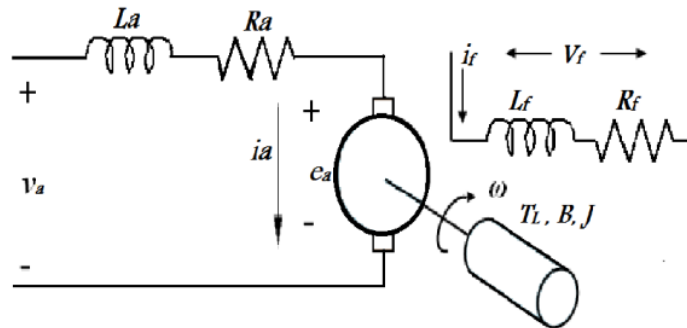


Figure 65 - Task 13 DC Motor Circuit

13.2 – Deduce damping factor

$$\text{No Load Speed (No Friction)} \Omega_{NL} = \frac{V_a}{K_e} = \frac{15}{0.063} = 238.1 \text{ rad/s}$$

$$\begin{aligned} \text{No load Speed (with Friction)} \Omega &= \frac{K_T V_a}{b R_a + K_T K_e} \\ &= \frac{0.063 \times 15}{(4.6 \times 10^{-6} \times 1.5) + (0.063 \times 0.063)} = 237.68 \text{ rad/s} \end{aligned}$$

$$\text{Stall Torque } T_m = \frac{(K_T \times V_a)}{R_a} = \frac{(0.063 \times 15)}{1.5} = 0.63 \text{ Nm}$$

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

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

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

13.3 – Plot poles

$$G(s) = \frac{\left(\frac{K_T}{L_a J}\right)}{s^2 + s \left(\frac{b}{J} + \frac{R_a}{L_a}\right) + \frac{R_a b}{L_a J} + \frac{K_T K_e}{L_a J}}$$

Poles

$$a = 1$$

$$b = (2 \times \zeta \times \omega_n) = \left(\frac{b}{J} + \frac{R_a}{L_a}\right) = \left(\frac{4.6 \times 10^{-6}}{0.0042} + \frac{1.5}{0.165}\right) = 9.092$$

$$c = \omega_n^2 = \left(\frac{R_a b}{L_a J} + \frac{K_T K_e}{L_a J}\right) = \left(\frac{1.5 \times (4.6 \times 10^{-6})}{0.165 \times 0.0042} + \frac{0.063 \times 0.063}{0.165 \times 0.0042}\right) = 5.74$$

$$x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-9.092 \pm \sqrt{9.092^2 - 4(1)(5.74)}}{2(1)}$$

Poles at -0.683 and -8.409



13.4 – Build model

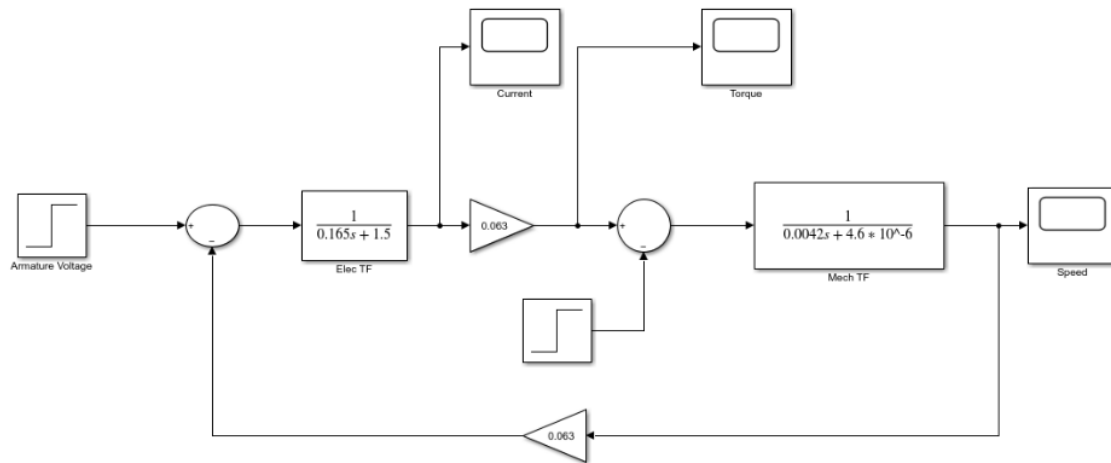


Figure 66 - DC motor Model

13.5 – Analyse speed and torque response

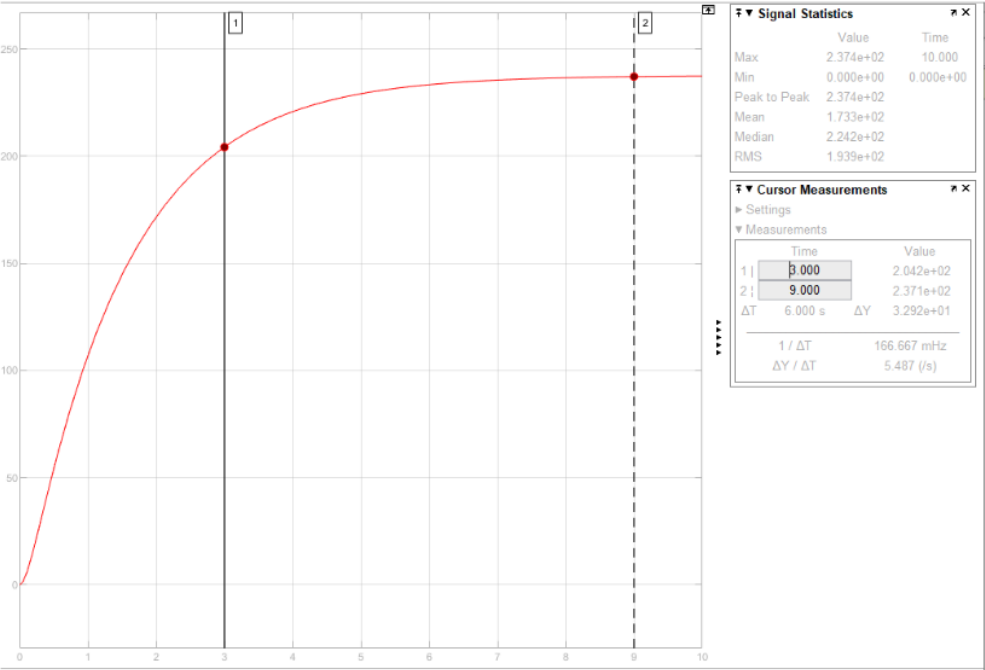


Figure 67 -Speed Growth Graph

A value is needed to be calculated to display the necessary stall torque to stall the motor. The essential stall torque of 0.63Nm has been displayed in task 13.2 This suggests that the motor will stall when a load of at least 0.63Nm is applied to the system.

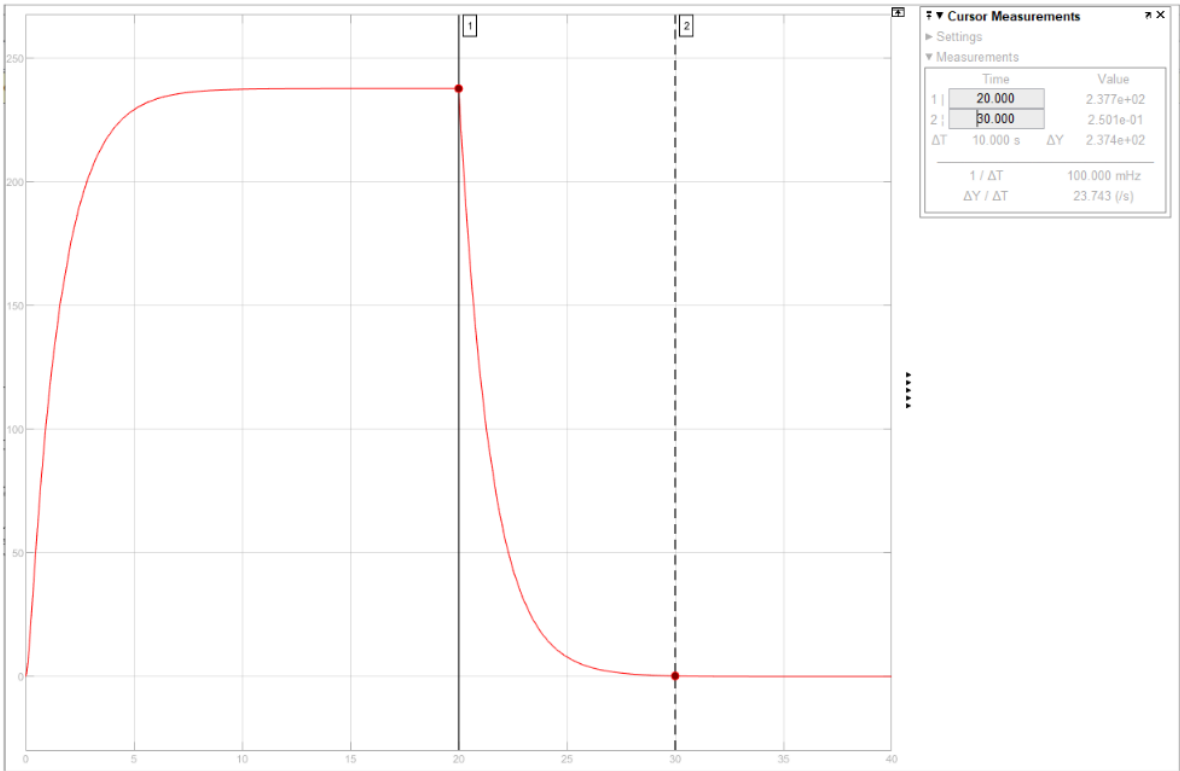


Figure 68 - Task 13 Stall Graph

13.6 – Another analysis

As shown in the figure below it shows the effect that a load has on the motor. As the motor reaches its steady speed at 20 seconds a load is applied causing the speed of the motor to reduce to 226.36 rad/s



Demonstrated below in figure 68, The consequence of the load has on the motor. At 20 seconds the motor will achieve its steady state at 20 seconds. When the load is applied the frequency speed of the motor will decrease to 226.36 rad/s.

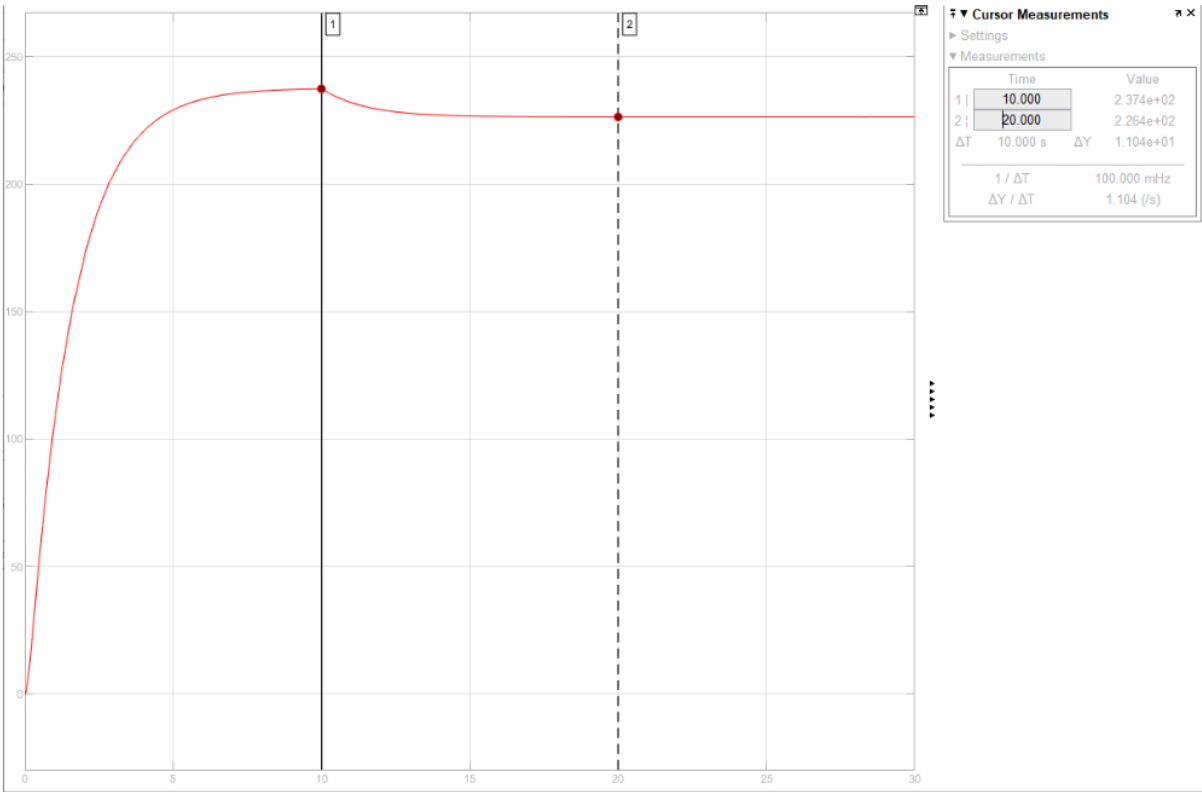


Figure 69 - Task 13 Speed Disturbance

13.7 – Table

Below is a table demonstrating the calculated and simulated values. This provides us with an error value of the difference between both values.

	Calculated	Simulated	Error ±
--	------------	-----------	---------

No Load Speed (No Friction)	238.1	237.1	1
Loaded Speed	226.36	226.4	36 .004

Table 7 - Task 13 Results

13.8 – Critical Analysis

As shown by the results obtained through the completion of the task display that the measured and calculated values correspond appropriately. This proves the ability of a motor to achieve a customary output value through design, this calculated load torque is added to the motor triggering the motor to stall. This information proves that the system constructed is a success. The only issue in this task is the slight inconsistencies between the simulated and calculated values, this is down to mathematical rounding or the position inaccuracy of the cursor on the graph.

Task 14 – Proportional Speed Control System

14.1 – Motor Model Modifications

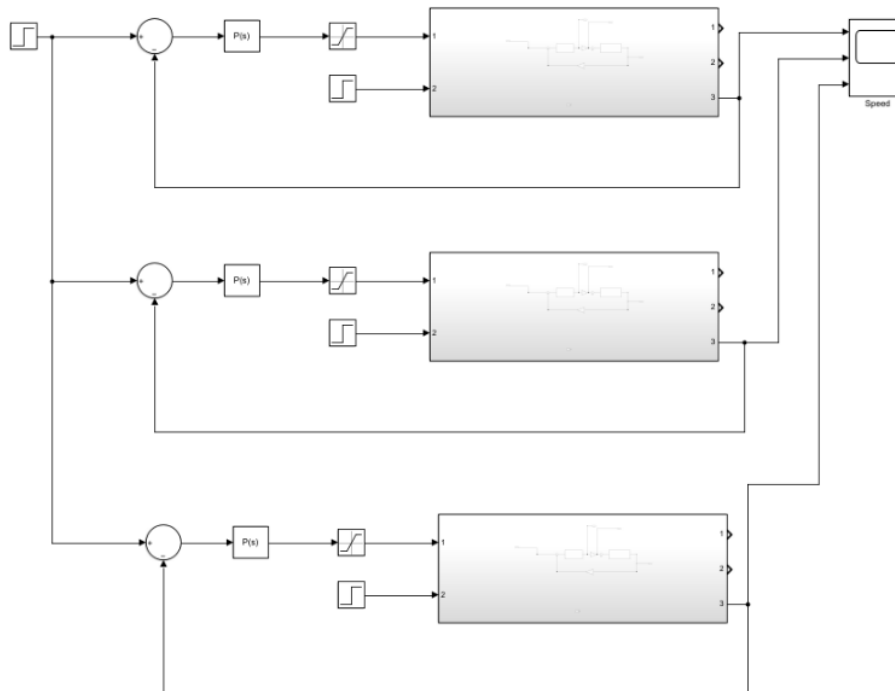


Figure 70 - Proportional System

14.2 – Adjusted Values

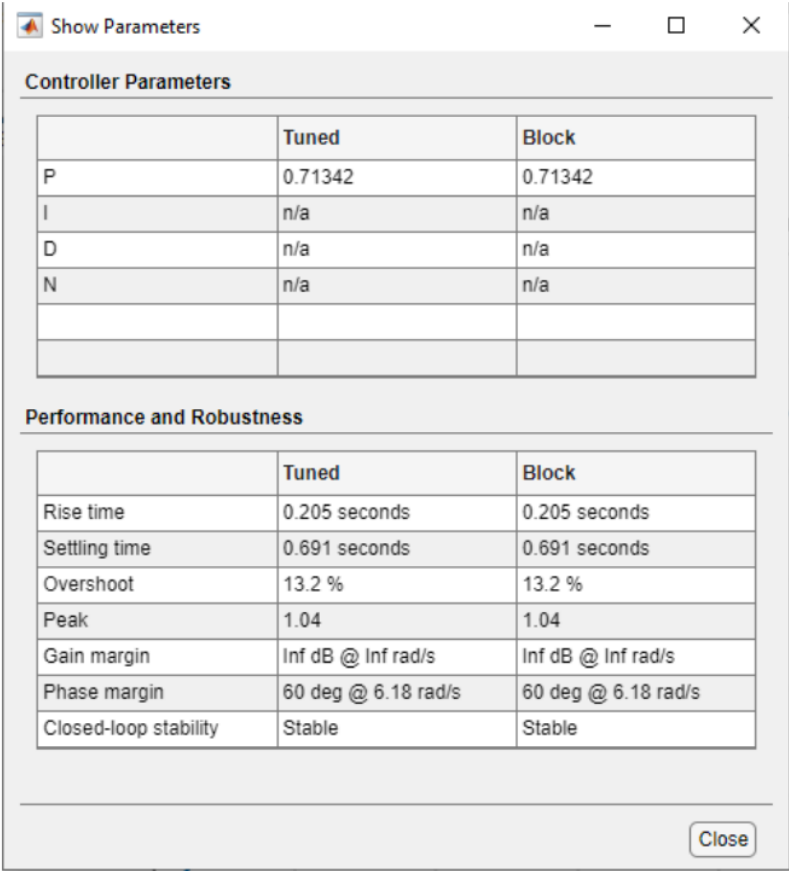


Figure 71 - Control Parameters Tuned

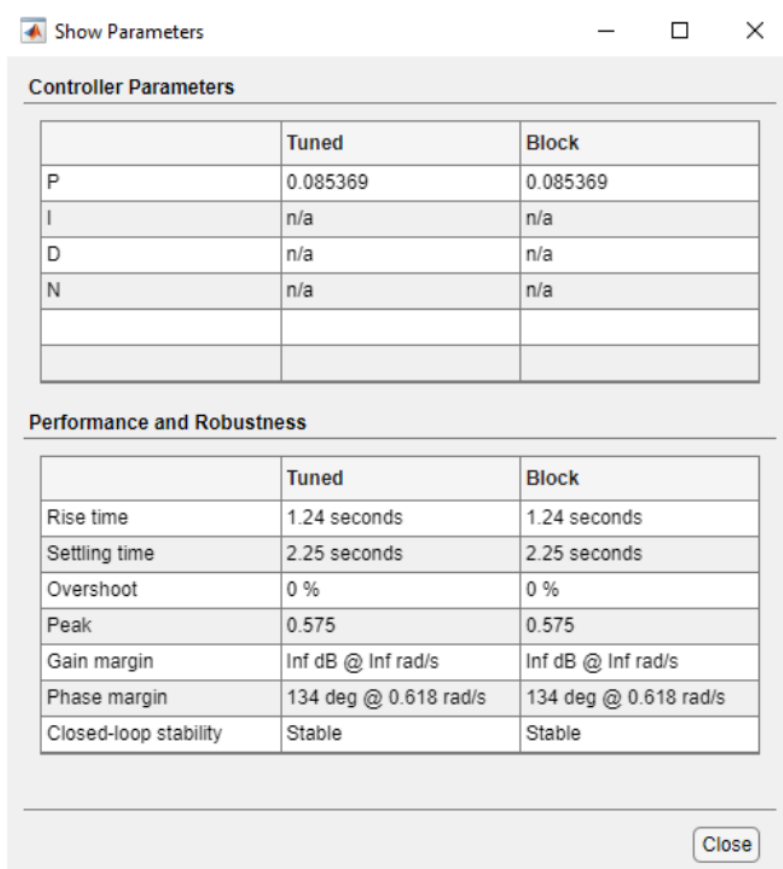


Figure 72 - Control Parameters Slower

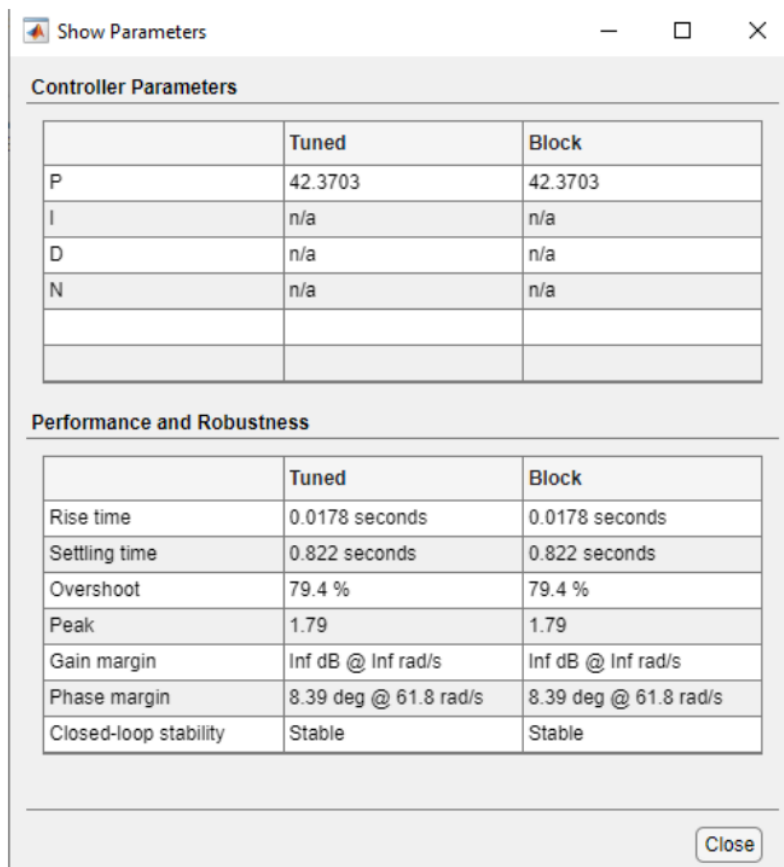


Figure 73 - Control Parameters Faster

14.3 – discuss effect of Kp

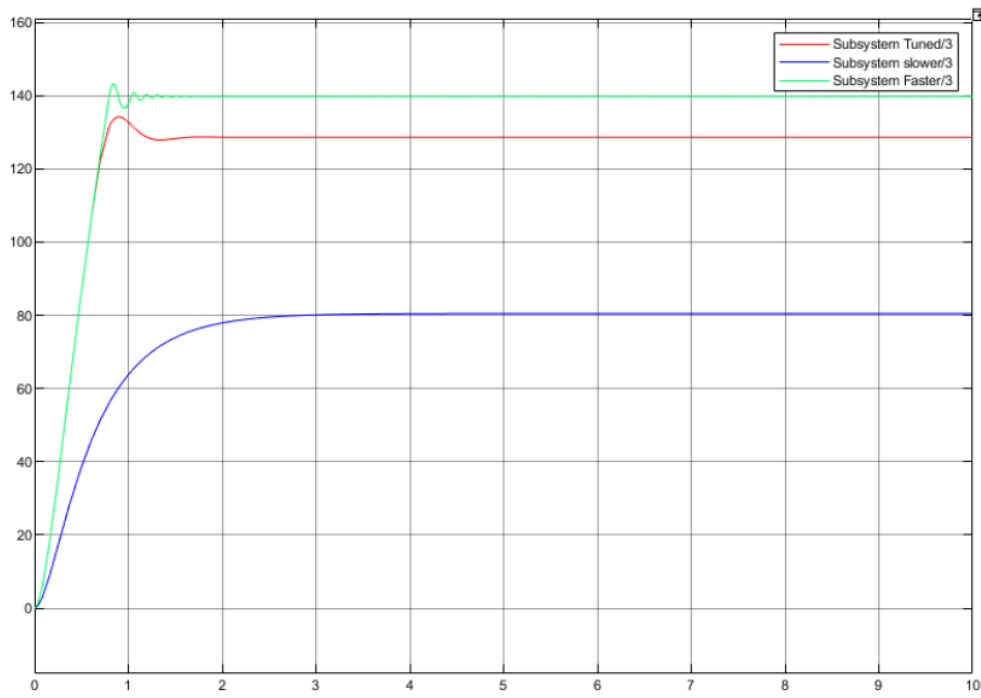


Figure 74 - Proportional effect

14.4 – Table

Kp	Steady state error	%O/S	Rise time
0.71546	10	13.2	0.205
0.085451	60	0	1.24
42.3701	0	79.4	0.0178

38

14.5 – Critical Analysis

The effect of a varying proportional value is displayed on the results achieved on the output of the system. This is displayed through the use of various Kp values used inside the system. In the case of the singular proportional system, the most competent kp value used was 0.71546, this was due to having a slight steady state error with a minimal overshoot and low raising time. Whilst comparing this value with the other values collected the effects are considerably drastic. With the Kp being 42.3701 had a steady state error being 0 with an

overshoot percentage of 79.4%. A Kp designate at 0.085451 has no overshoot within the system with a steady state error of 60.

Task 15 – Proportional-Integral Speed Control System

15.1 – Model Modifications

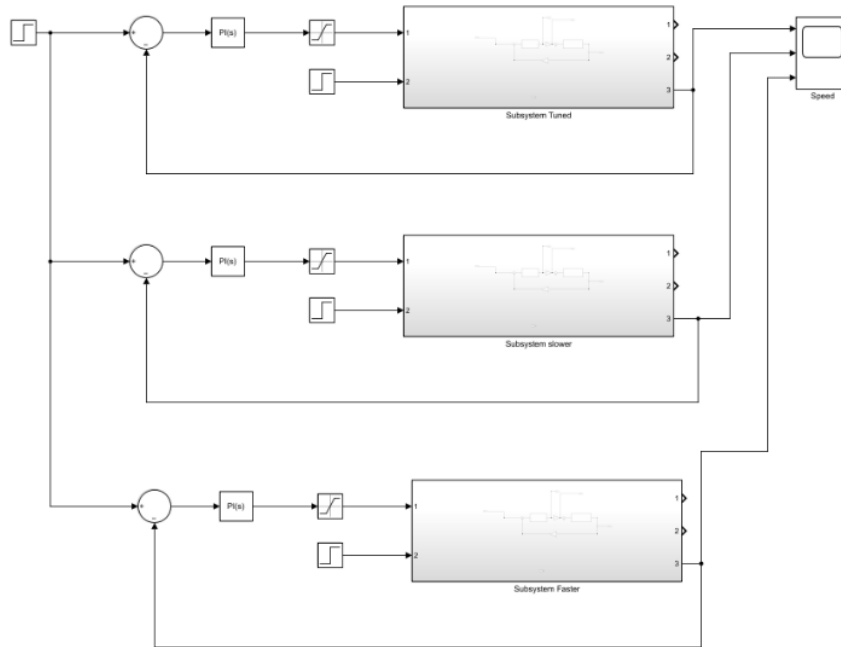


Figure 75 - Task 15 PI System

15.2 – Adjust Values

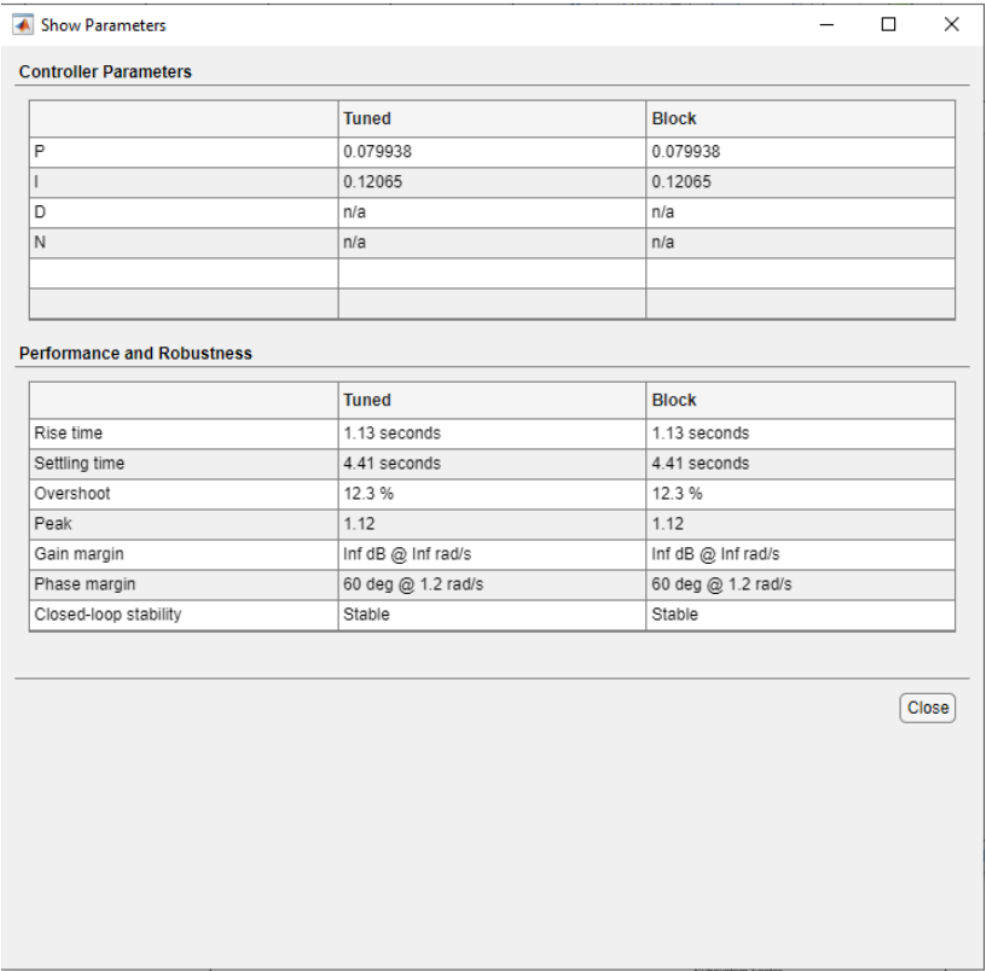


Figure 76 - Task 15 Tuned Characteristics

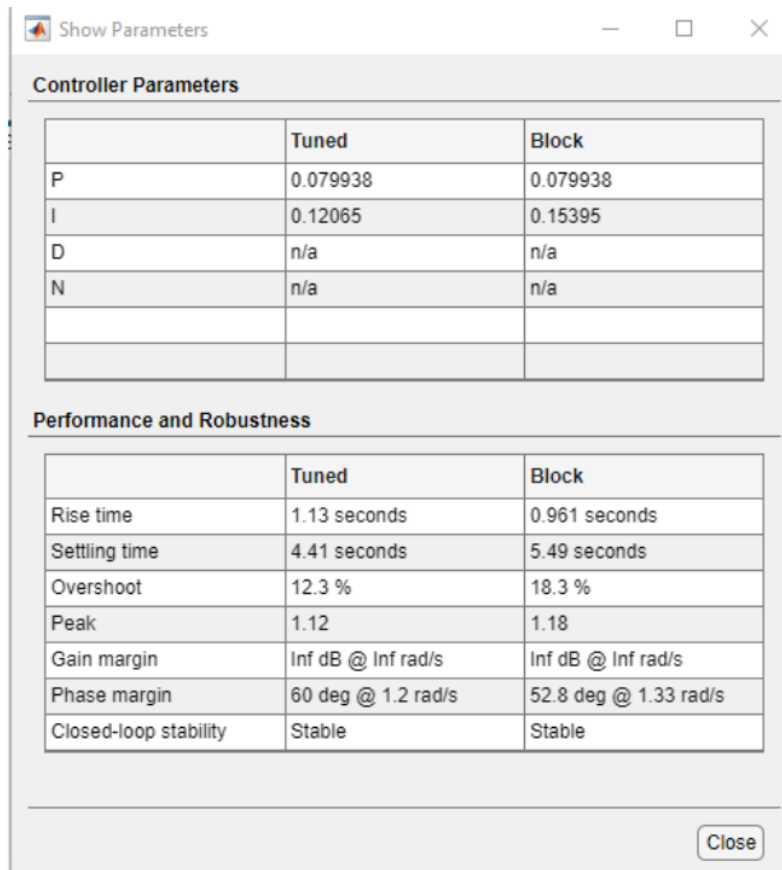


Figure 77 - Task 15 Slower Characteristics

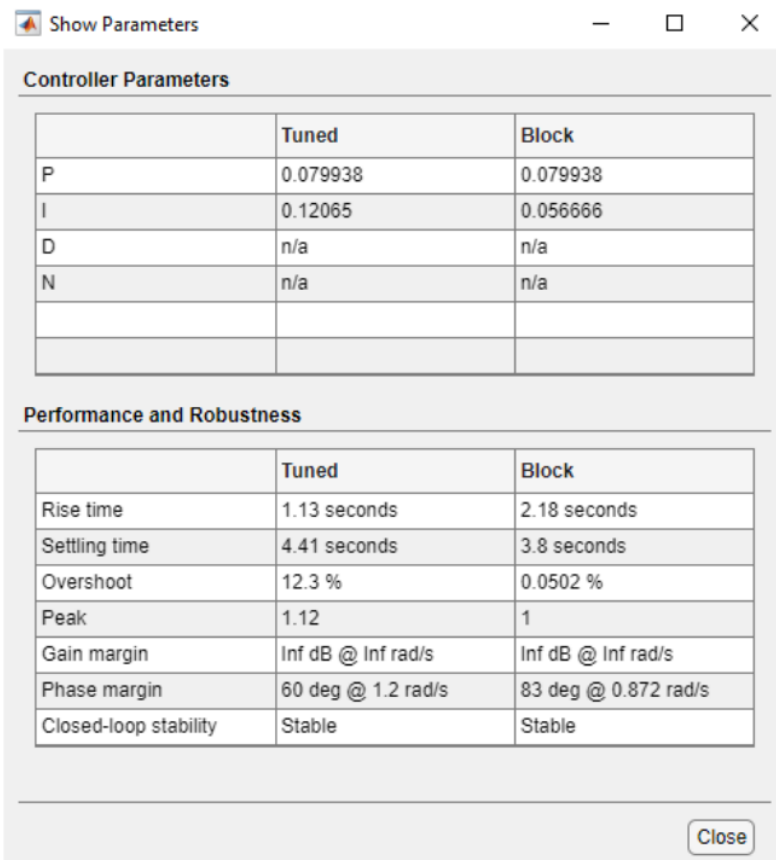


Figure 78 - Task 15 Faster Characteristics

15.3 – Summarise all results

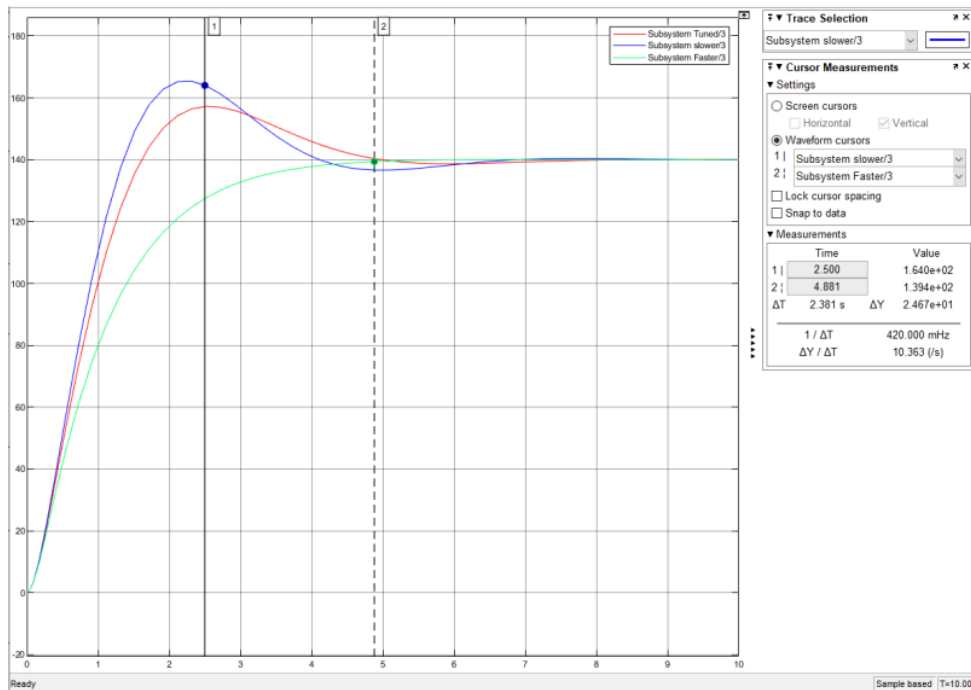


Figure 79 - Task 15 Comparison of Varying Ki

15.4 Table of Results

Ki	Steady state error	%O/S	Rise time	Settling Time
0.12074	0	12.3	1.13	4.41
0.15389	0	18.3	0.961	5.49
0.056765	0	0.0502	2.18	3.8

15.5 Critical Analysis

The results obtained through the completion of this task, is an introduction to the integral portion of a PID system whilst using the previously tuned proportional value from task 14. Through verifying the Ki value, a difference in the effects on the output of the system is displayed. As the different Ki values effect the overshoot percentage, settling time and raise time. The value of a tuned system is 0.12074, This has been nominated by having the most appropriate values and characteristics. Although, numerous applications of this PI system

have a beneficial to the use of the K_i value 0.056765 as this value produces a system that sacrifices the settling and raise times for the lowest overshoot percentage.



Task 16 – Proportional-Integral-Derivative Speed Control System

16.1 – Model Modifications

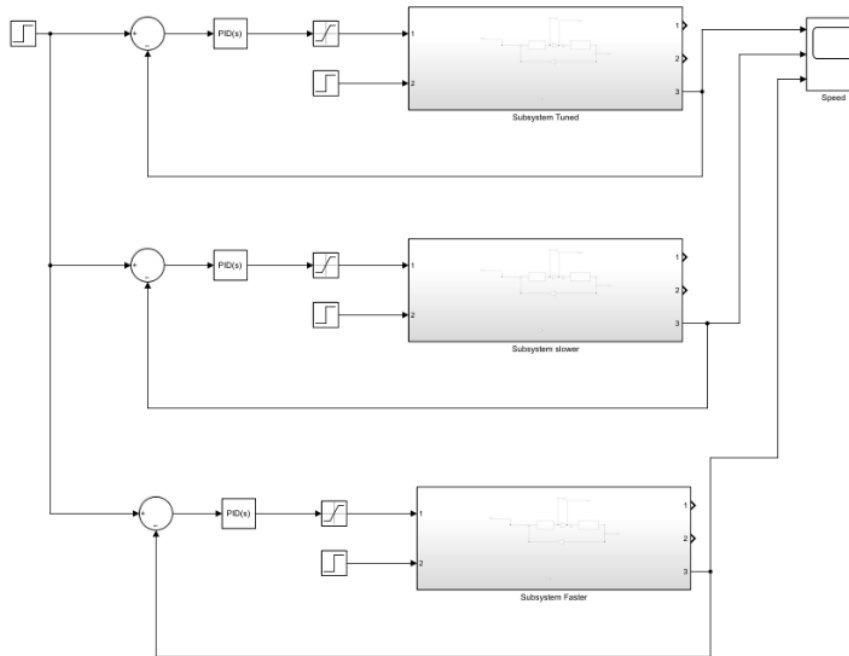


Figure 80 - Task 16 PID System

16.2 – Adjusted Values

 Show Parameters
 — □ ×

Controller Parameters		
	Tuned	Block
P	0.09469	0.079938
I	0.10873	0.12065
D	0.0031557	0
N	136.724	100

Performance and Robustness		
	Tuned	Block
Rise time	1.25 seconds	1.13 seconds
Settling time	4.59 seconds	4.41 seconds
Overshoot	7.08 %	12.3 %
Peak	1.07	1.12
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	69 deg @ 1.2 rad/s	60 deg @ 1.2 rad/s
Closed-loop stability	Stable	Stable

Close

Figure 81 - Task 16 Tuned System

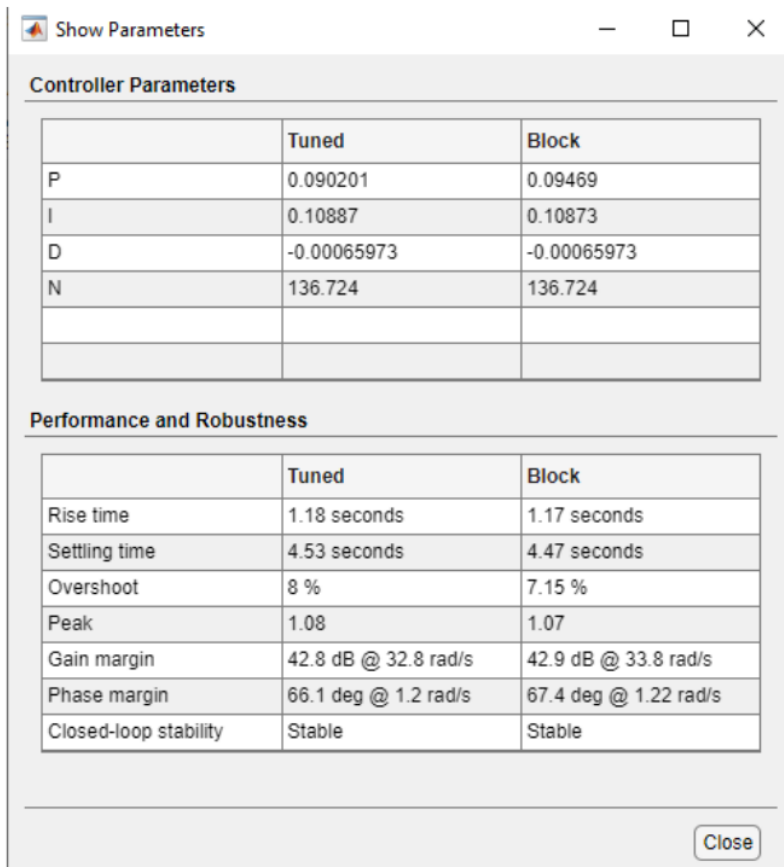


Figure 82 - Task 16 Slower System

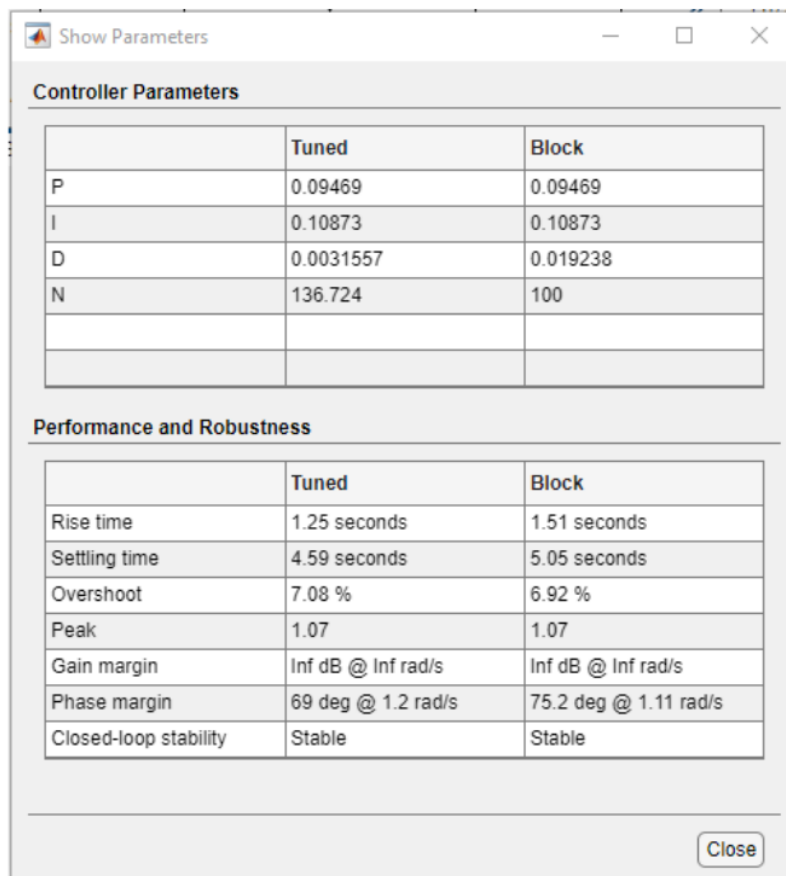


Figure 83 - Task 16 faster Characteristics

16.3 – Summarise all results

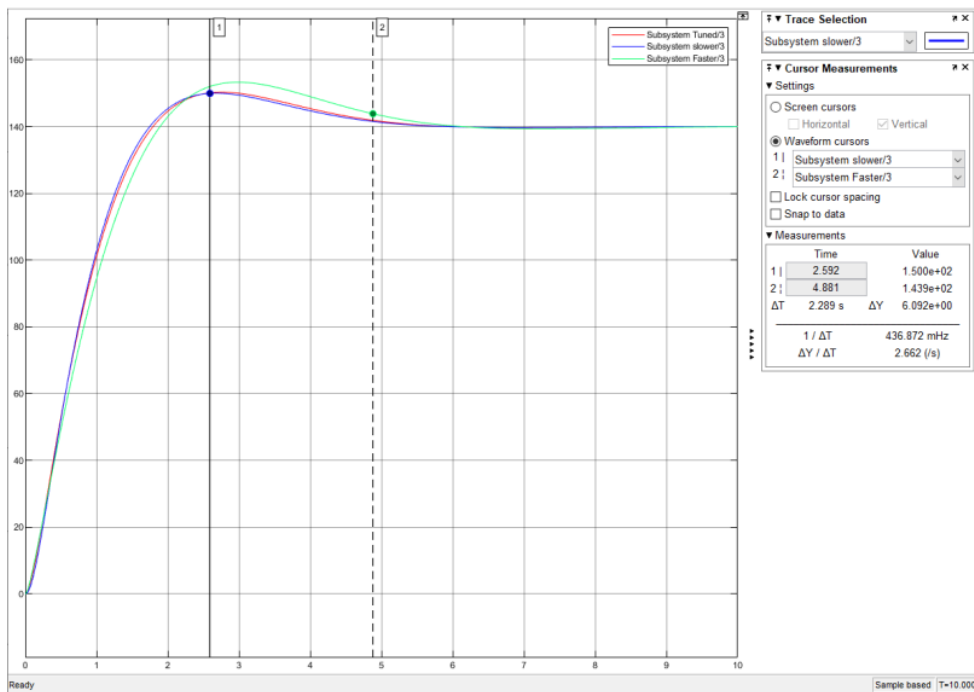


Figure 84 - Task 16 Wave Comparisons

16.4 Table of Results

Kd	Steady state error	%O/S	Rise time	Settling Time
0.003165	0	7.08	1.25	4.59
-0.000069	0	8	1.18	4.47
0.019241	0	6.92	1.51	5.05

16.5 Critical Analysis

During the completion of this task, involves a contrast of a changing Kd value within a PID system. The PID block that has been tuned, creates a Kd value of 0.003156, This Kd value is the most effective value in terms of settling and raise time and overshoot. Although, by changing the Kd value to 0.019238. This creates a signal output with the slowest settle and raise setpoints with the smallest overshoot percentage.

Task 17 – Controller Comparisons

17.1 – Combined Models

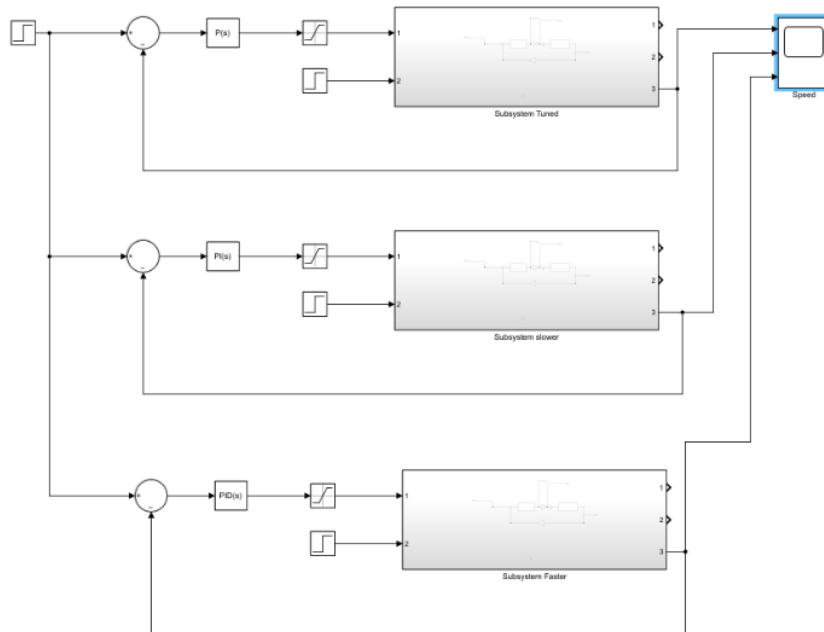


Figure 85 - Task 17 Controller System

17.2 – Plot responses

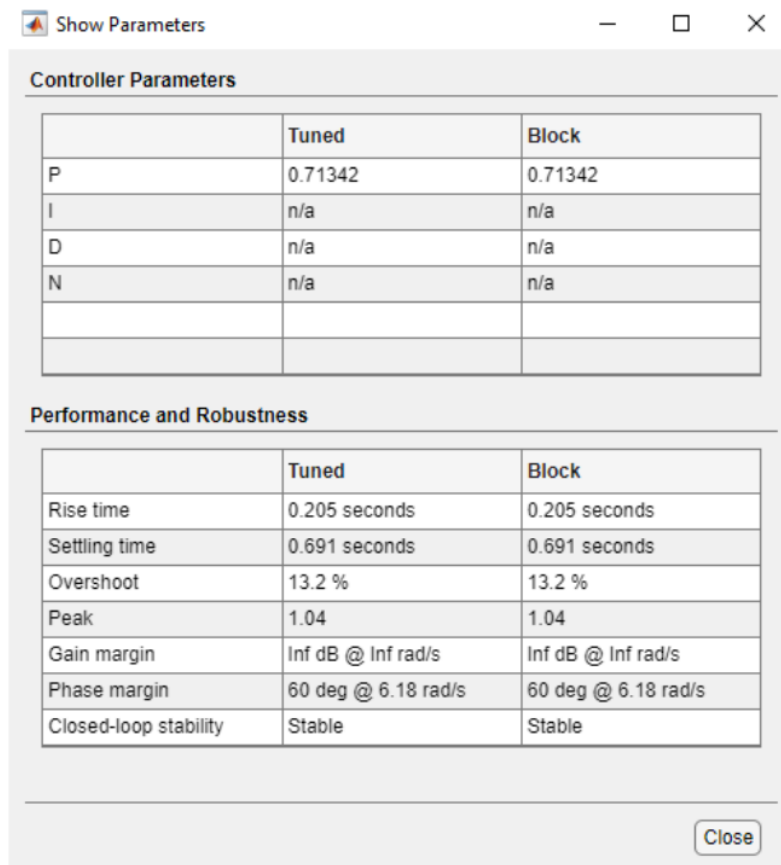


Figure 86 - Task 17 P System

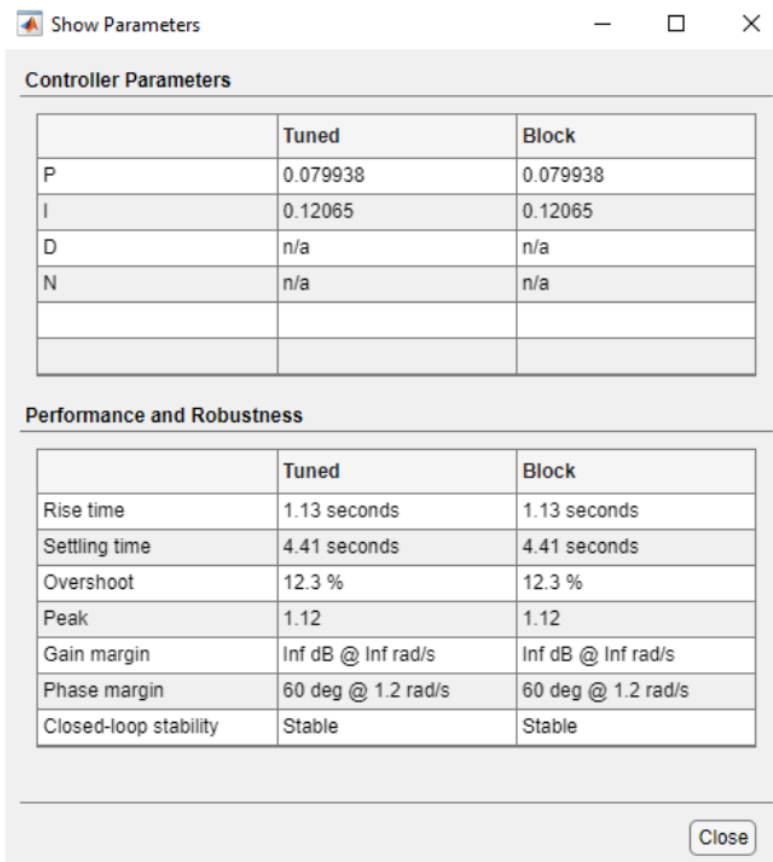


Figure 87 - Task 17 PI System

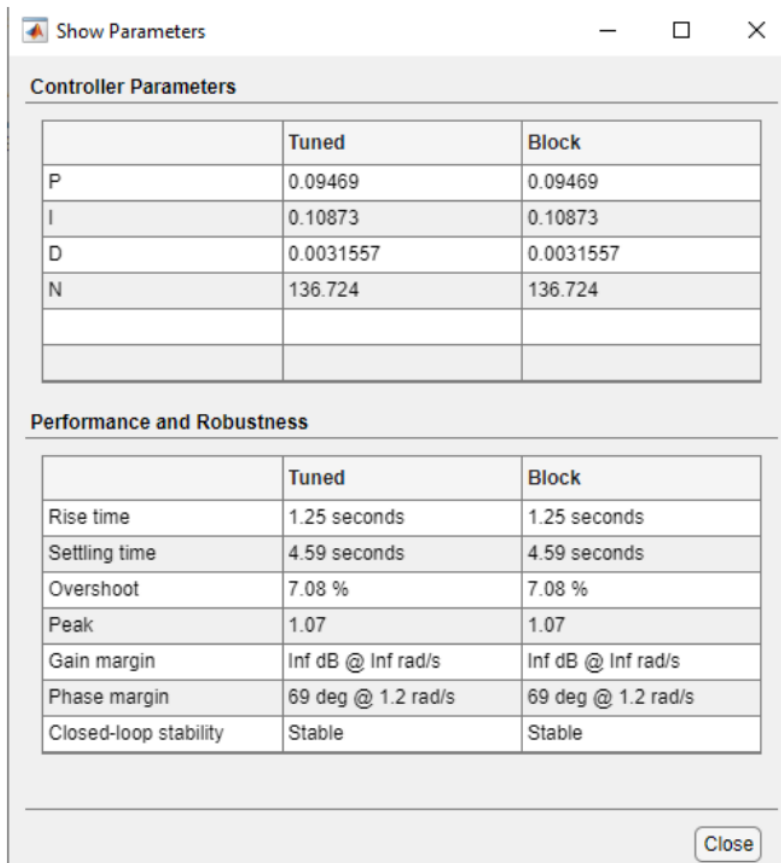


Figure 88 - Task 17 PID System

17.3 – Summarise all results

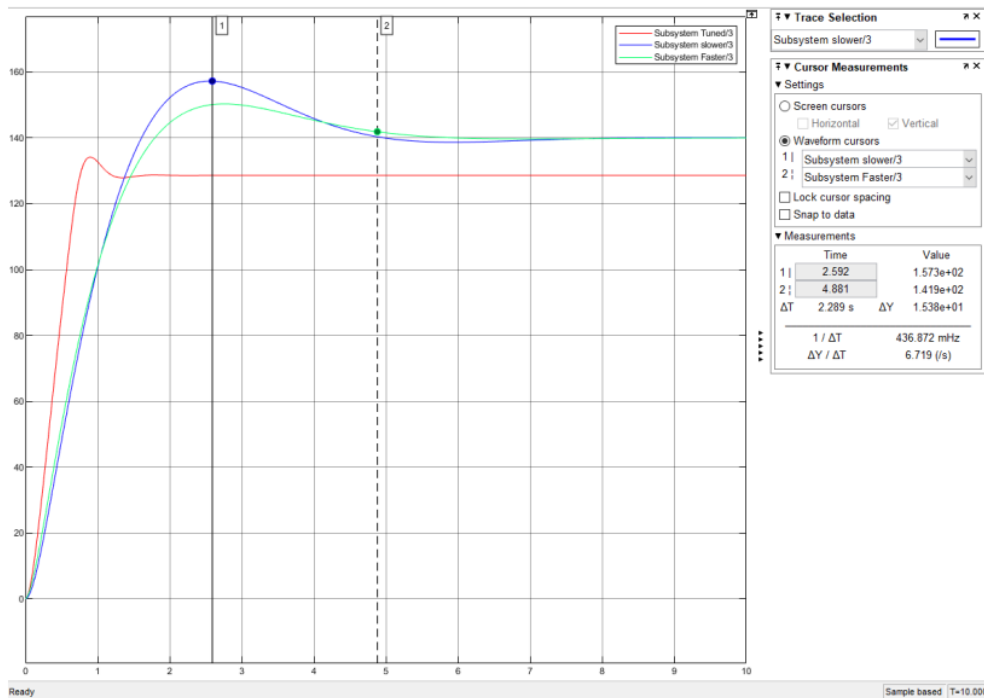


Figure 89 - Task 17 PID Controller Comparison

Kp	Ki	Kd	Steady state error	%O/S	Rise time	Settling Time
0.71344	N/A	N/A	10	13.2	0.205	0.691
0.79932	0.12059	N/A	0	12.3	1.13	4.41
0.94691	0.10877	0.0031551	0	7.08	1.25	4.59

17.4 Critical Analysis

As displayed above in the table, there is a variance in distinct versions of controllers. The graph on display in figure 88 display the different versions of controllers. The green line represents the PID controller, the red line displays the P controller and the blue line represents PI controller. In the singular P controller, is a system that the output cannot reach the desired output setpoint value. Although this is different with the PI controller as it reaches the set point value but has a major overshoot which isn't perfect for a control system. Through using a PID controller a light number of oscillations with a limited amount of overshoot.

Generally, Through the application of a P controller provides difficulties with a steady state error and the overall control of the output signal. A higher precision circuit is produced whilst using a PI controller over a P type controller as it contains minimal overshoot with no steady state error. Although, this system does create a lower raise and settling time compare to the singular P type controller. Whilst using the PID controller to syndicates all the previous stated advantages of both controllers, allowing for a system with the perfect response. It produces better stabilisation and derivative response allowing the system to predict future disturbance in the signal by measuring the change in the error. This controller may be the most optic, effective and precise system but is extremely reliant on the tolerances, application and price of the system.

Task 18 – Overall Conclusions and Recommendations

Through the completion of this assignment, a variety of knowledge and understanding around the subjects has been attained with different and unique software tools implemented throughout the tasks. The software previously stated was used to help acquire a simulated comparison to help compare the previously calculated values. The calculated values previously stated used Laplace transforms for RC and RL circuits, this produced graphical representation of the frequency and transient response by demonstrating exponential growth in an RL circuit and exponential decay in an RC circuit. With the transient graph the opportunity arose to observe the voltage across the resistor as the steady state reaches 5τ .

In regards to task 3 and 4 a comparison on the differences of between both low pass and high pass filters. These filters remove a percentage of output signals that are removed. A low pass filter includes a large capacitor that lowers output frequency. This provides a system that will only allow certain frequencies to pass through the system's circuit until the cut off frequency has been achieved. The opposite of a low pass filter is the high pass filter, this allows no output signal to pass through until the cut off frequency has been achieved allowing only the frequencies larger than the value to pass.

Between tasks 5-8 were used to govern the effects of a damping factor applied on the circuit. These were determined by the damping factors these factors have drastic effects on the output signal through critically damped, overdamped, underdamped and no damped system.

In tasks 9,10 & 11 the objective was to analyse and witness the effects on frequencies on electronic systems. These Bode plots are almost similar to those previously stated in task 3 & 4 low and high pass filters. In task 9 and 10 an inverting operational amplifier was added to the system's circuit, providing amplification and further control to the output signal within the system.

The remaining tasks were carried out using digital software Simulink to help construct Motor models and integrated motor models to see the effects of torque on the motor's variables. These tests help distinguish what effect torque has on the motor and the best system to control a system. Through this investigation a knowledge was gained into different methods of control and how each impacted the circuit. This provided great understanding into which system is needed for which task and how the system can be utilized to attain the best [possible output signal with as little oscillation as possible].

Through the completion of this assignment many areas in need of improvement and recommendations were brought to the fore front. These include mathematical and curve placement errors effecting results gathered. In the future a practical assessment could be carried out to compare both the calculated and measured values with the new physically carried out data.

FINAL GRADE

GENERAL COMMENTS

Instructor

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Comment 1

good work in introducing task

PAGE 10



Comment 2

not quite correct TF

PAGE 11



Comment 3

very good analysis



Comment 4

you are correct



Comment 5

good



Comment 6

develop from potential divider rule



Comment 7

-20dB/dec



Comment 8

-3dB



Comment 9

unit? definition?



Comment 10

repetition, see comment for task 3



Comment 11

show how these are developed, also show the TF in terms of component values

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Comment 12

good

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Comment 13

correct

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Comment 14

good work

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PAGE 27



Comment 15

good, what about wc?

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Comment 16

damping is present as the response is seen to decay to zero

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Comment 17

WW



Comment 18

WW

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need definitions for these quantities

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Comment 20

the root equation is missing



Comment 21

vague, what values exactly?



Comment 22

explain the locus effect



Comment 23

what order?

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Comment 24

these quantities need at least a name, you should explain/define them

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Comment 25

can you explain why you think this is surprising?



Comment 26

include base equation



Comment 27

phase



Comment 28

good work



Comment 29

good work



Comment 30

show TF



Comment 31

explain what a pole is



Comment 32

show the minimum k value calculated



Comment 33

avoid repetition



Comment 34

good work



Comment 35

a load of how much?



Comment 36

you could have included your calculation with friction



Comment 37

stall torque

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Comment 38

check this figure

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Comment 39

good work

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Comment 40

good work

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Comment 41

WW



Comment 42

WW

GRADING FORM: NEW CSG-RUBRIC

HARRI CRIDDLE

71

1. ENGAGEMENT WITH LITERATURE



NA

0

2. KNOWLEDGE AND UNDERSTANDING



Knowledge is reasonably extensive, you have added some context and introduced each task. There are some key definitions which not apparent but in general a good display of theory and knowledge. 20/30

20

3. COGNITIVE AND INTELLECTUAL

 Sound critical analysis in most areas, you have interpreted results and offered some reasoning. See comments. 21/30 **21**

4. PRACTICAL APPLICATION

 Advanced application of methods seen in the code and response graphs which are clearly annotated. **23**

5. TRANSFERABLE SKILLS

 Can communicate well, consistently and confidently, there are a few wrong words and grammatical errors as marked.7/10 **7**