

# 2117075

*by* Thomas Woods

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

### Task 1.1 – Selected Suitable Component Values

As required for this assignment various component values we generated to conduct an analysis of RL electrical circuits. It was decided to select a resistor of  $300\Omega$  and an Inductor of  $0.06H$ .

A fundamental law followed by transient circuits is the determinable time constant within the system. the definition of the time constant is the time of which a specific system can react to change. It is commonly the time taken for parameter to vary by a factor of  $1/e$ . which is approximately  $0.368$ .

The calculated time constant for this circuit is shown by.

$$\tau = \frac{L}{R} = \frac{0.06}{300} = 0.2msec$$

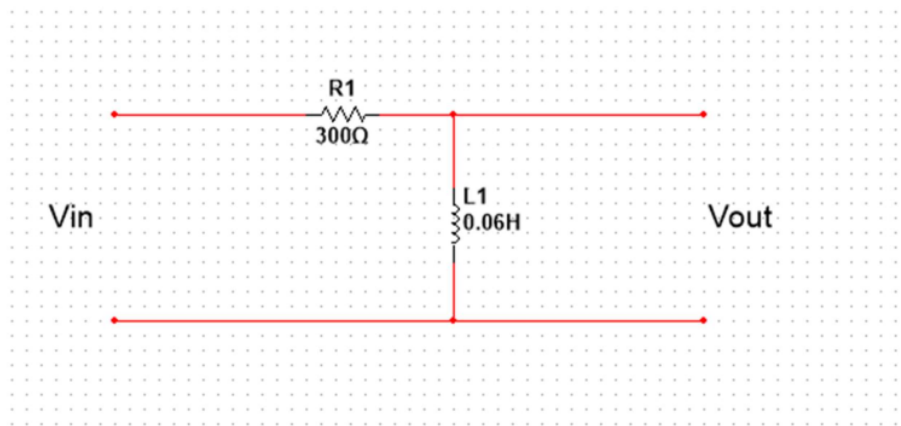


Figure 1 - Task 1 Selected Suitable Circuit Value

### Task 1.2 – Laplace Model

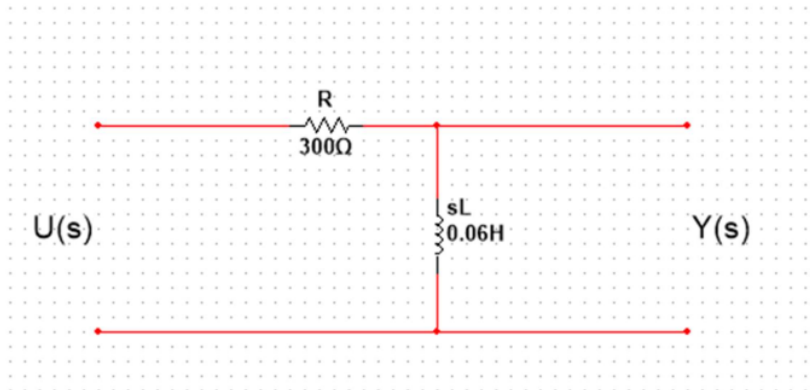


Figure 2 - Created Laplace Diagram

With the creation of the Laplace model a transfer function can be created. A transfer function is a mathematical function with relation to the output or the response of the system.

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



### Task 1.3 – Matlab Code

```
s=tf('s');  
system = (0.06)*s/((0.06)*s+300);  
step(system);  
grid on
```

Figure 3 - Task 1 Matlab Model Code

To generate a suitable simulation. Digital software was used to code the transfer function of the created circuit and the values of components were used within the code. From this code a graphical display was generated allowing for an accurate display of the output.

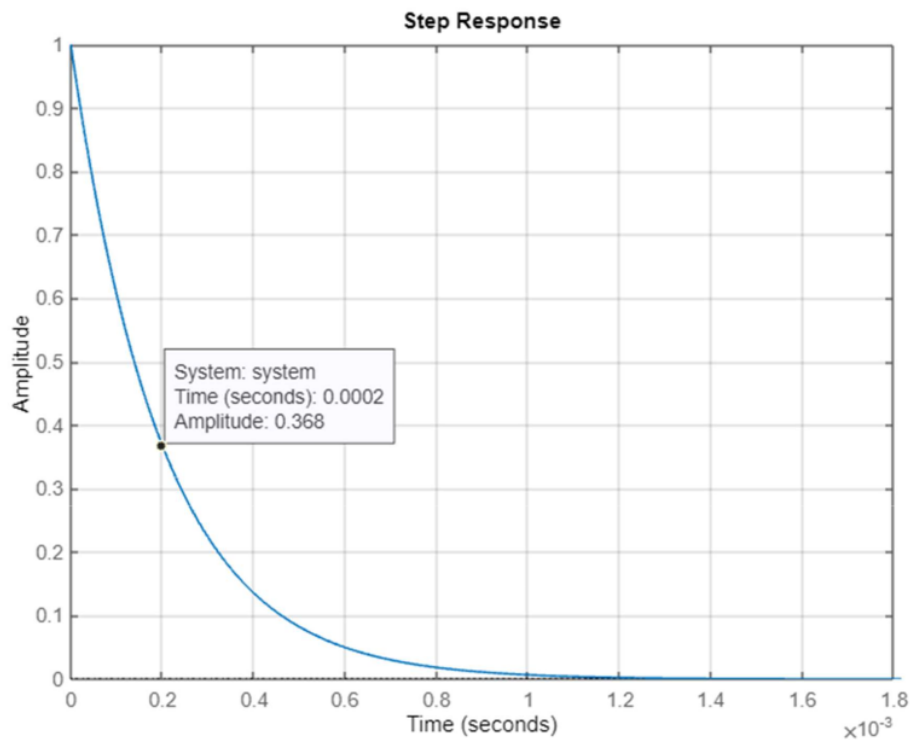


Figure 4 - Task 1 Output Graph

#### Task 1.4 – Table of Results

|        | Calculated | Simulated | Error |
|--------|------------|-----------|-------|
| $\tau$ | 0.2msec    | 0.2msec   | 0sec  |

Table 1 - Task 1 Data Comparison

#### Task 1.5 – Critical Analysis

As shown within the data collected that the calculated values for the transient system and the simulated values correspond correctly. Due to the fact of that there is no error between the calculated value and simulated value. This can be determined to the accuracy of the simulation software and the lack of rounding being carried throughout the calculations. Additionally, it can be shown that the RL system generates an exponential decay curve.



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

### Task 2.1 – Selected Suitable Values

As required for this assignment various component values we generated to conduct an analysis of RC electrical circuits. It was decided to select a resistor of  $1000\Omega$  and a capacitor of  $50\mu\text{F}$ .

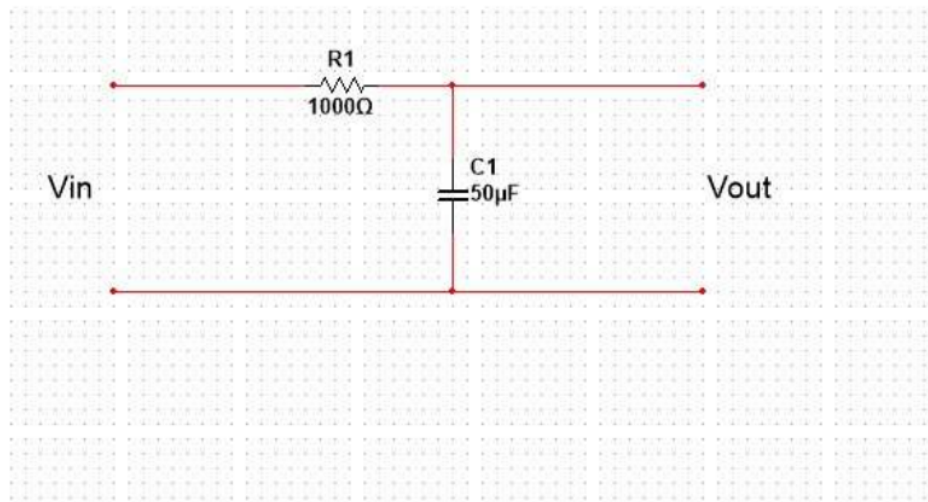


Figure 5 - Task 2 Chosen Component Values

To calculate the time constant of the circuit the equation used is. For an RC system the factor of the time factor is different compared to an RL system. this is determined by  $1-1/e$  which is approximately equal to 0.632.

$$\tau = R \times C = 1000 \times (50 \times 10^{-6}) = 0.05\text{sec}$$

## Task 2.2 – Laplace Model

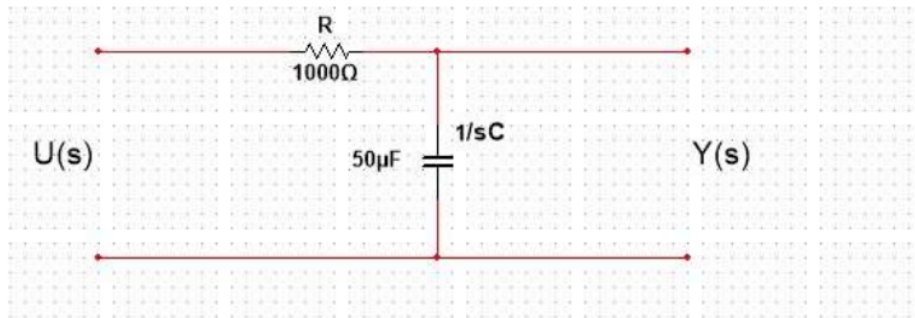


Figure 6 - Task 2 Laplace Model

With the creation of the Laplace design, it is now possible to determine the transfer function.

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

## Task 2.3 – Matlab Code

```
s=tf('s');  
system = 1/((1000)*(0.00005)*s+1);  
step(system);  
grid on
```

Figure 7 - Task 2 Matlab Model Code

As shown in the figure above it shows that code used to simulate the RC circuit. for the code used for the RC circuit the new transfer function is required. From this code a new graphical diagram is created.

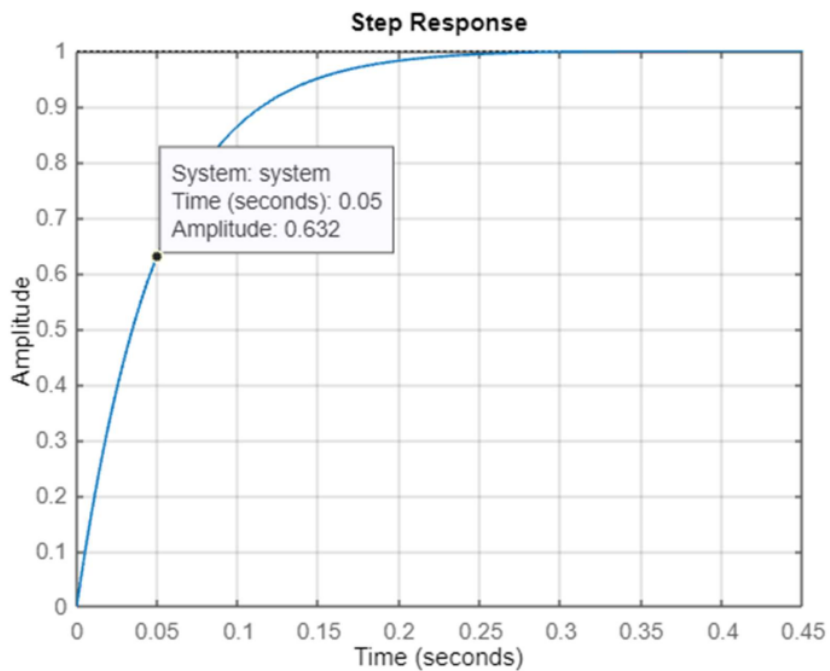


Figure 8 - Task 2 RC Graph

#### Task 2.4 – Table of Results

|        | Calculated | Simulated | Error |
|--------|------------|-----------|-------|
| $\tau$ | 0.05sec    | 0.05sec   | 0sec  |

Table 2 - Task 2 data Analysis

#### Task 2.5 – Critical Analysis

As shown within the data collected that the calculated values for the transient system and the simulated values correspond correctly. Due to the fact of that there is no error between the calculated value and simulated value. This can be determined to the accuracy of the simulation software and the lack of rounding being carried throughout the calculations. Additionally, it can be shown that the RC system generates an exponential growth curve.

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

### Task 3.1 - Calculations

Cut - off frequency.

$$\omega c = \frac{R}{L} = \frac{300}{0.06} = 5000 \text{ rads/sec}$$



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

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

Figure 9 - Task 3 Matlab Code

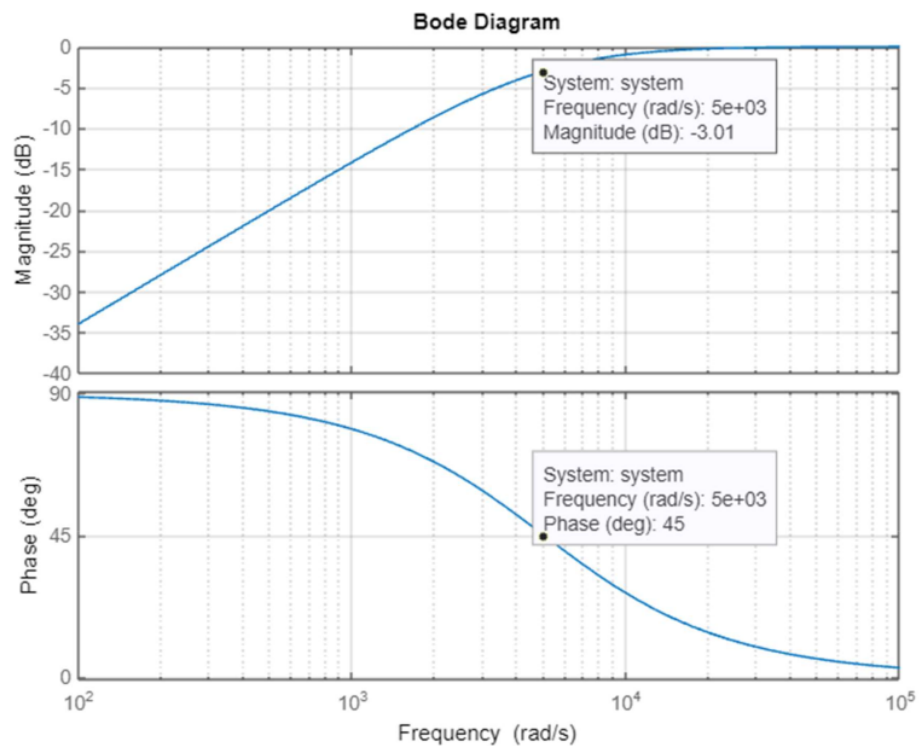


Figure 10 - Task 3 Bode Plot

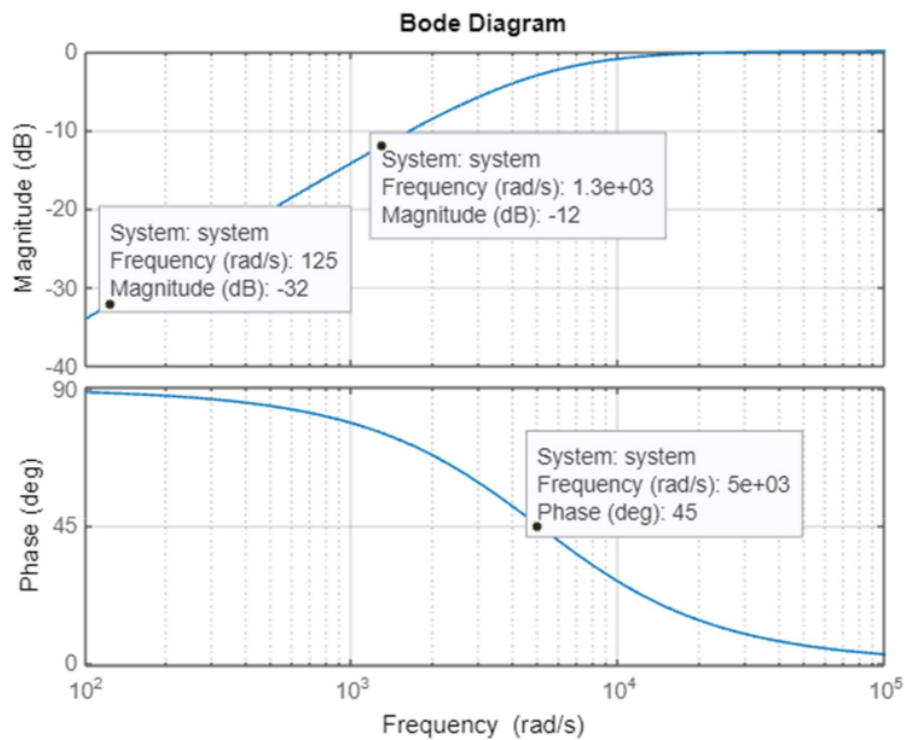


Figure 11 - Task 3 Bode Plot Roll-off.

### Task 3.3 – Table of Results

|                              | Calculated   | Measured     | Error |
|------------------------------|--------------|--------------|-------|
| Cut off Frequency $\omega_c$ | 5000rads/sec | 5000rads/sec | 0     |
| $\Phi$ Phase                 | 45°          | 45°          | 0     |
| Roll-off                     | 20 dB        | 20dB         | 0     |

Table 3 - Task 3 Data Analysis

### Task 3.4 – Critical Analysis

For this circuit, with the arrangement of components used. This generates a high pass filter. A high pass filter only allows frequencies above a certain range to pass through. The phase shift within the system at its natural frequency is 45°, this is due to it being a first order circuit with a roll-off of 20 dB/decade. Through testing it is concluded that were no errors detected, this confirms the overall analysis.

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

### Task 4.1 - Calculations

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



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

#### Task 4.2 – Matlab Code

```
s=tf('s');  
system = 20/(s+20);  
bode(system);  
grid on
```

Figure 13 - Task 4 Matlab Code

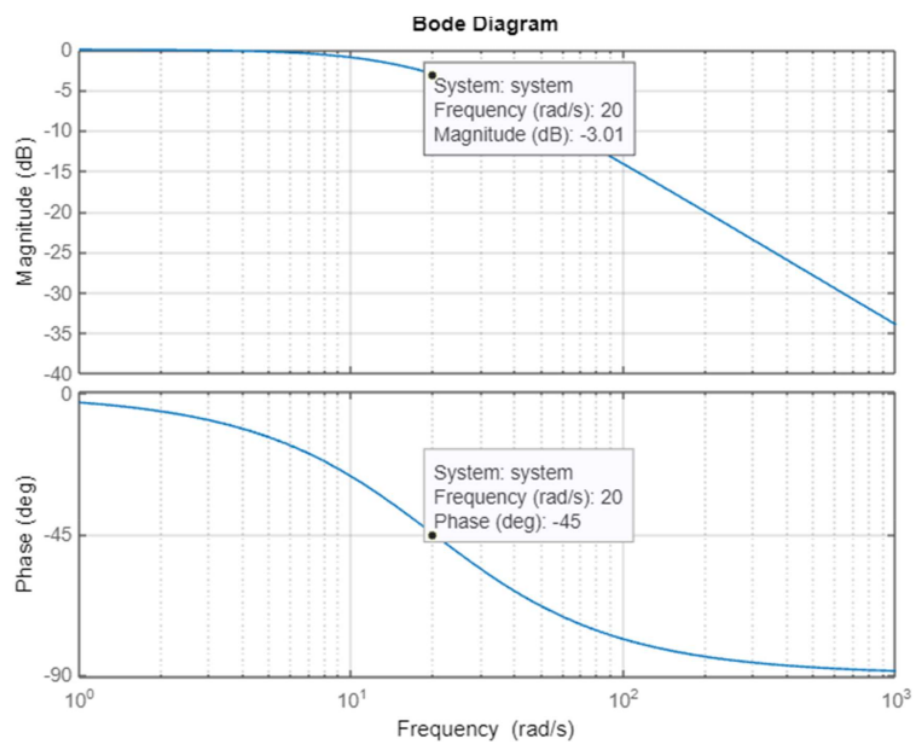


Figure 12 - Task 4 Bode Plot

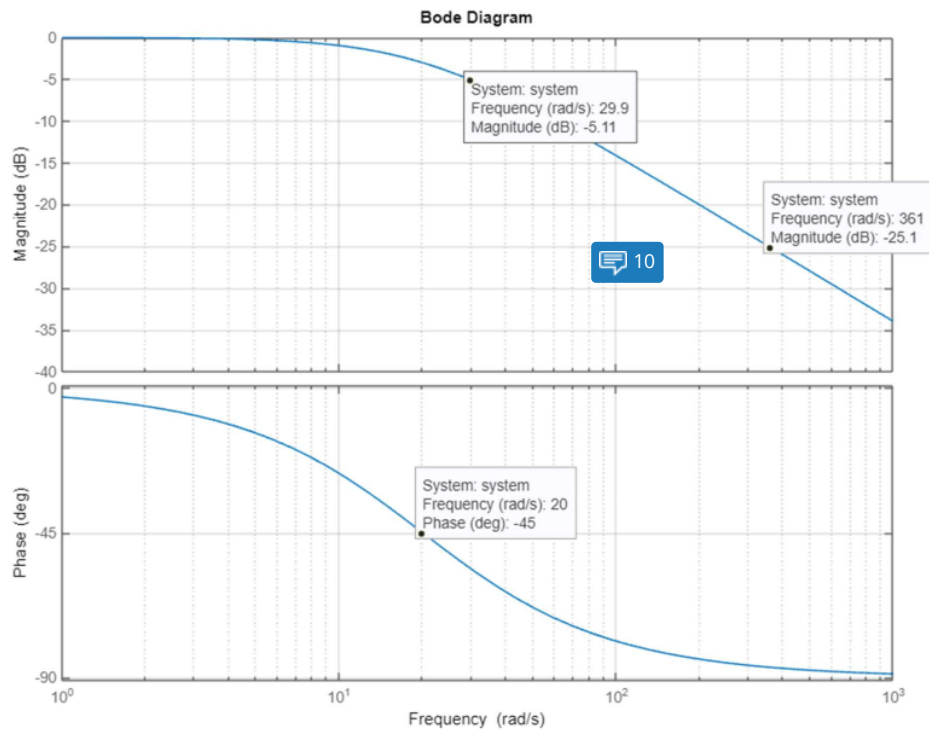


Figure 14 - Task 4 Bode Plot Roll-Off

#### Task 4.3 – Table of Results

|                              | Calculated | Measured   | Error |
|------------------------------|------------|------------|-------|
| Cut off Frequency $\omega_c$ | 20rads/sec | 20rads/sec | 0     |
| $\Phi$ Phase                 | -45°       | -45°       | 0     |
| Roll-Off                     | -20dB      | -20dB      | 0     |

Table 4 - Task 4 Data Analysis

#### Task 4.4 - Critical Analysis

With the arrangement of components used within the circuit, it generates a low pass filter. This circuit will only allow for frequencies below a certain point to pass. The phase shift within this system the phase shift was -45° at the natural frequency. And the roll-off was

As shown in table 4 there are no errors, this confirms the overall analysis.

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

### Task 5.1 – Suitable Component Values

For the task of evaluated the variations of damping on a transient system. The suitable selected component values that were chosen were. During this task, the types of damping that will be created is an under-damped, over-damped, critically damped, and no damping. This will be carried-out by altering the resistance value to change the damping factor within the system.

$$R = 4\Omega \quad L = 0.15H \quad C = 44\mu F$$

### Task 5.2 – Laplace Model

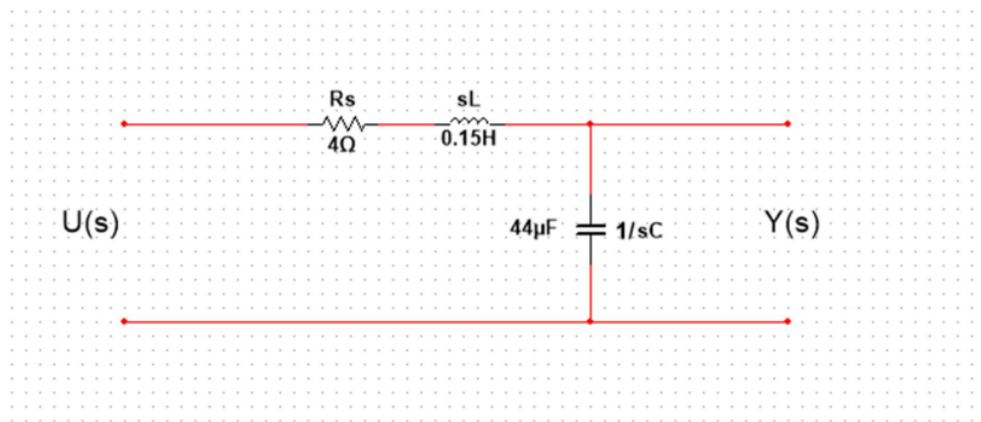


Figure 15 - Task 5 Laplace Model

From this system it is possible to create the transfer function. This is noted as.

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



### Task 5.3 – Transient Performance

Now that the transfer function has been generated for the system it now allows for the calculation of the gain( $k$ ), the damping factor( $\zeta$ ), and the Natural frequency( $\omega n$ ). The equation for calculating these values is.

$$k = 1$$

$$\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{3}{2} \sqrt{\frac{40 \times 10^{-6}}{0.15}} = 0.034$$

$$\omega_n = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.15 \times (40 \times 10^{-6})}} = 500 \text{ rad/s}$$

Due to the natural frequency not being reliant on the resistance value. This means that it will remain constant throughout the various damping circuits. However, a new damping factor will have to be evaluated. As the damping factor for this system is less than 1 it is estimated to create an underdamped curve.



#### Task 5.4 – MATLAB Model

##### Under Damping

```
1 s = tf('s');
2 system = 389.25^2/(s^2+(2*0.034*389.25)*s+389.25^2);
3 step(system);
4 grid on
5 |
```

Figure 16 - Under-Damping Matlab Code

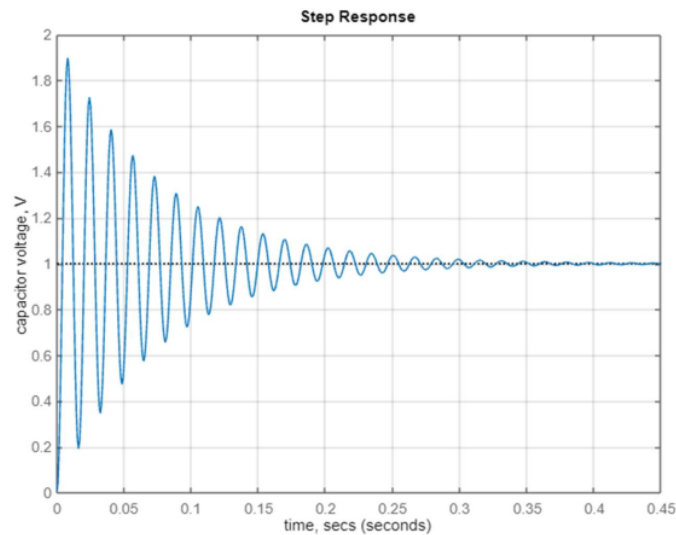


Figure 17 - Under-Damping Graphical Plot

As expected the system is underdamped. This is shown by the system slowly decreasing in amplitude.

### Over Damping

To create an over-damped system the damping must be greater than 1. To do this the resistor value has been changed to 300Ω. This should give a high enough damping to alter the system.

#### New Damping Factor

$$\frac{300}{2} \sqrt{\frac{44 \times 10^{-6}}{0.15}} = 2.57$$



```
1 s = tf('s');
2 system = 389.25^2/(s^2+(2*2.57*389.25)*s+389.25^2);
3 step (system);
4 grid on
5 |
```

Figure 18 - Over-Damped Matlab Code

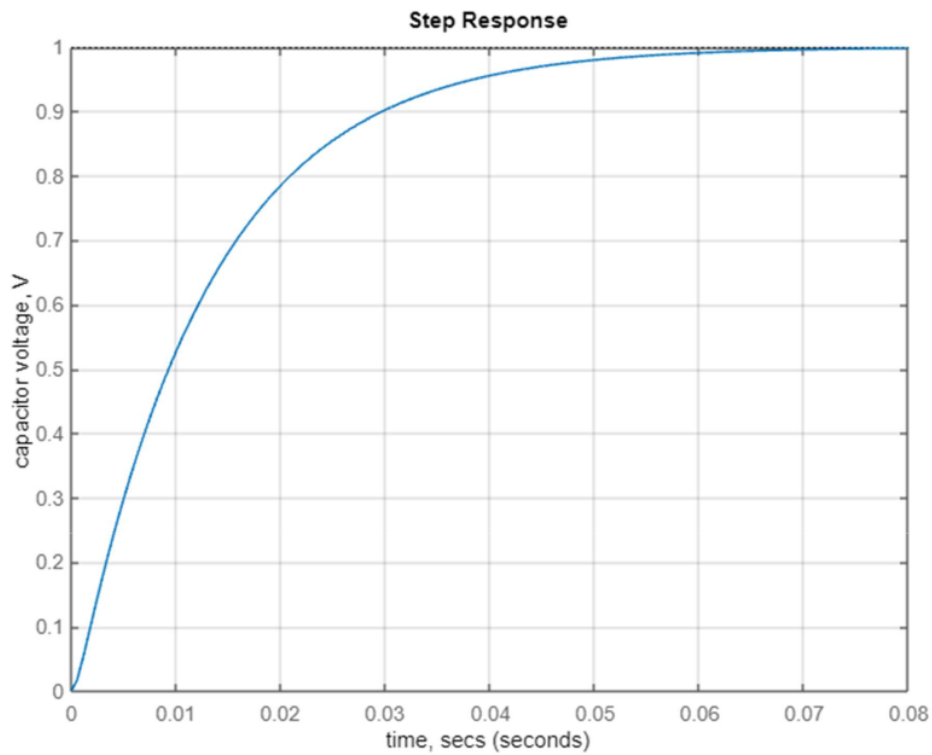


Figure 19 - Over-Damped Graphical Plot

### Critically Damping

To create a critically damped system the damping factor must be equal to 1. To do the calculations for this the damping factor equation has to be rearranged to calculate the suitable resistance value. This calculation is.

*New Damping Factor*

$$R = \frac{2 \times \zeta}{\sqrt{\frac{C}{L}}} = \frac{2}{\sqrt{\frac{44 \times 10^{-6}}{0.15}}} = 116.77\Omega$$

With the resistor set to 116.77Ω it gives a damping factor of 0.99999 which is approximately 1 this will allow 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 20 - Critically-Damped Matlab Code

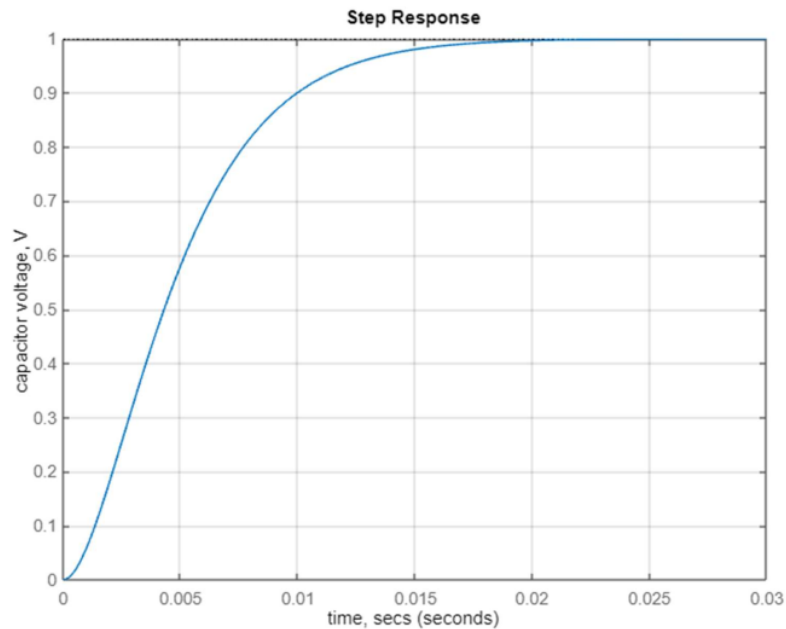


Figure 21 - Critically-Damped Graphical Plot

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

### No Damping

To create a system with no damping it requires the damping factor to be equal to 0. However, within this experiment it is impossible to get a damping factor of 0 as this would require the resistance to also be zero. Therefore, the resistance value must be set to an exceedingly small value. For this the new resistance value has been set to  $1\mu\Omega$ .

### New Damping Factor

$$\zeta = \frac{1 \times 10^{-6}}{2} \sqrt{\frac{44 \times 10^{-6}}{0.15}} = 8.56 \times 10^{-9}$$

```
1  s = tf('s');  
2  system = 389.25^2/(s^2+(2*0.000000008|*389.25)*s+389.25^2);  
3  step (system);  
4  grid on  
5
```

Figure 22 - No-Damping Matlab Code

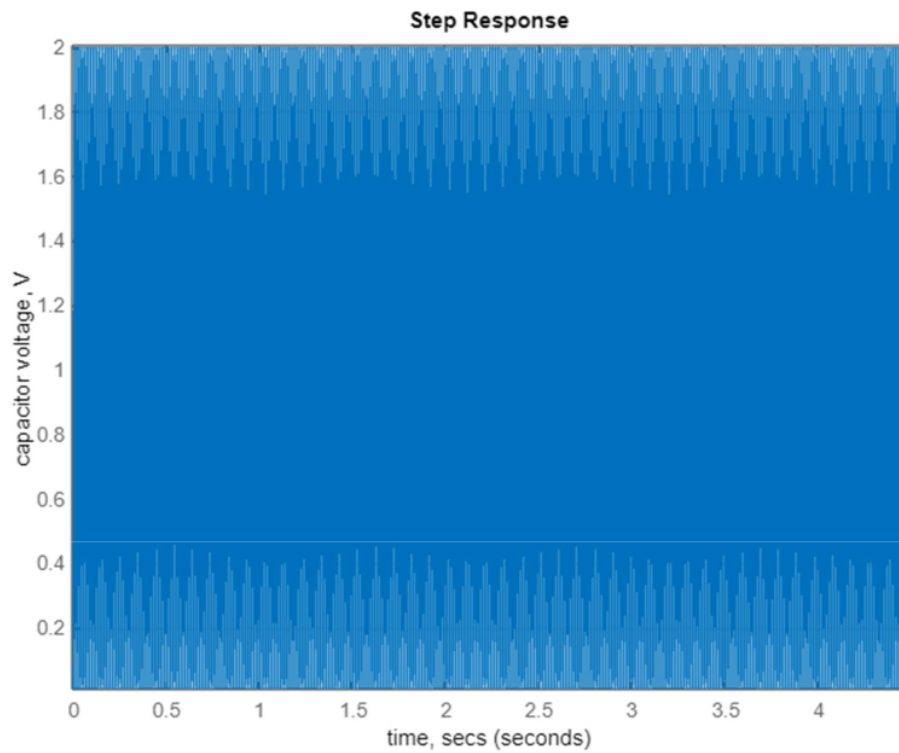


Figure 23 - No-Damping Graphical Plot

### Task 5.5 – Results Table

|          |  |  | Resistance ( $\Omega$ ) | Damping Ratio ( $\zeta$ ) | Damping Ratio | Damping Effect    |
|----------|--|--|-------------------------|---------------------------|---------------|-------------------|
| System 1 |  |  | 4 $\Omega$              | 0.034                     | $\zeta < 1$   | Under-damped      |
| System 2 |  |  | 300 $\Omega$            | 2.57                      | $\zeta > 1$   | Over-damped       |
| System 3 |  |  | 116.77 $\Omega$         | 0.9999 ~ 1                | $\zeta = 1$   | Critically-Damped |
| System 4 |  |  | 1 $\mu\Omega$           | 8.56n ~ 0                 | $\zeta = 0$   | No-Damping        |

Table 5 - Series Damping Results Table

### Task 5.7 – Critical Analysis

As shown within this task it demonstrates the distinct types of damping that can be implemented into an RLC series circuit. Each damping variation has a different effect on the systems output. For an under-damped system, the output value oscillates and overshoot the desired output and slowly reaches a steady state. An over-damped system does not overshoot the desired output. However, it is slow to reach it. A critically damped system does not oscillate and reaches the steady state output in the fastest time. Finally, a system with no damping will oscillate indefinitely with no change to the amplitude.

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

### Task 6.1 – Selected Component Values

For this task it required the evaluation of the damping on a transient parallel system. The values that have been selected for this are.

$$R = 4\Omega$$

$$L = 0.15\text{H}$$

$$C = 44\mu\text{F}$$

### Task 6.2 – Laplace Model

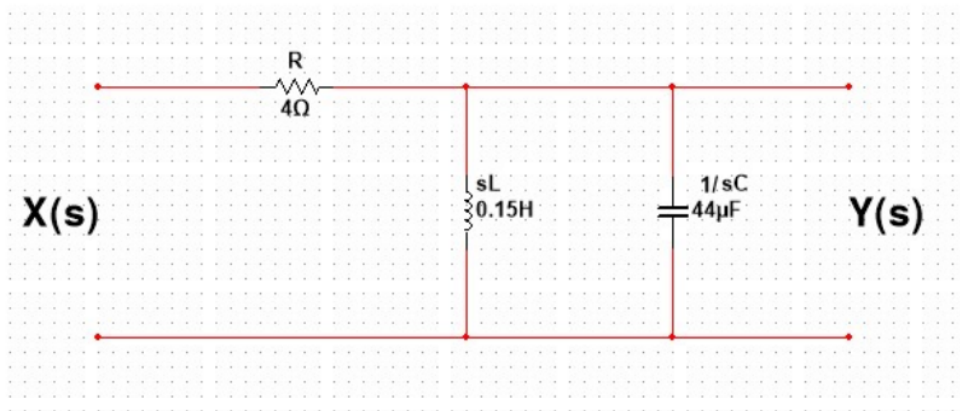


Figure 24 - Parallel RLC Laplace Model

This the figure shown above it is possible to generate a transfer function for the system.

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

### Task 6.3 – Transient Performance

Within this system there are multiple things that can be calculated these values are.

$$\zeta = \frac{1}{2R} \sqrt{\frac{L}{C}} = \frac{1}{2 \times 4} \sqrt{\frac{0.15}{44 \times 10^{-6}}} = 7.298$$

$$\frac{1}{\sqrt{0.15 \times (44 \times 10^{-6})}} = 389.25 \text{ rad/s}$$

With the damping factor for these values being 7.298 this means that the system will be over damped. Additionally, a damping factor will need to be made for each damping variation.

#### Task 6.4 – Matlab Code

Over Damped

```
s = tf('s');
system = (s*(5681.818182))/(s^2+(2*(7.298*389.25)*s)+(389.25^2));
step(system);
grid on
```

Figure 25 - Task 6 Over-damped Code

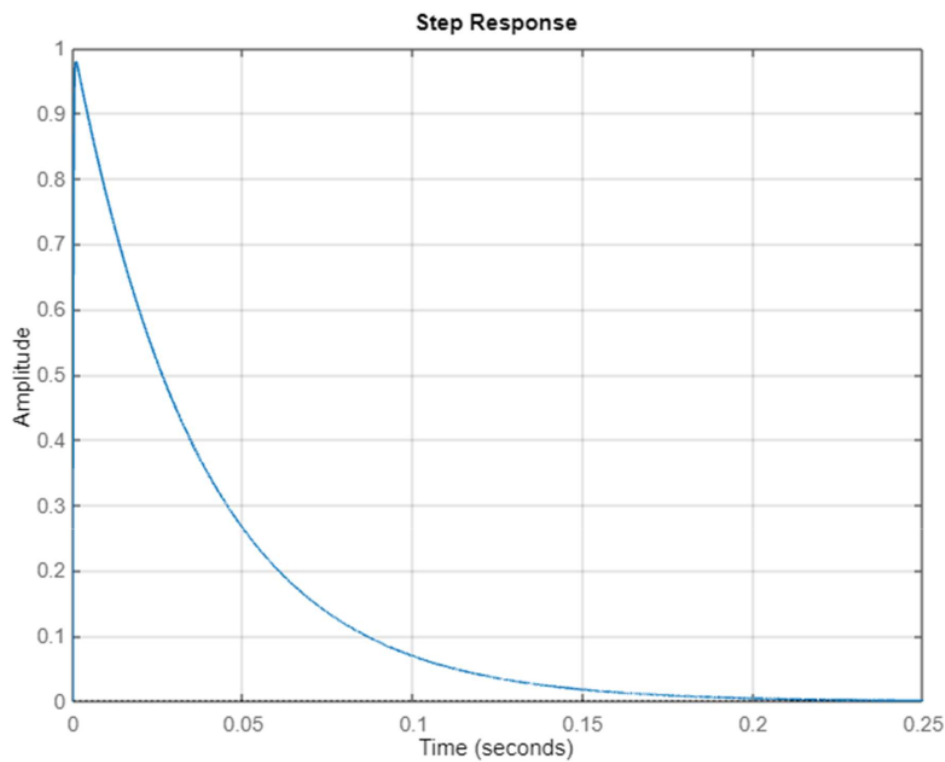


Figure 26 - Task 6 Over-damped Graph

### Under Damped

```
s= tf('s');  
system = (s*(378.7878788))/(s^2+(2*((0.4865618401)*389.25)*s)+(389.25^2));  
step (system);  
grid on
```

Figure 27 - Task 6 Under-Damped Code

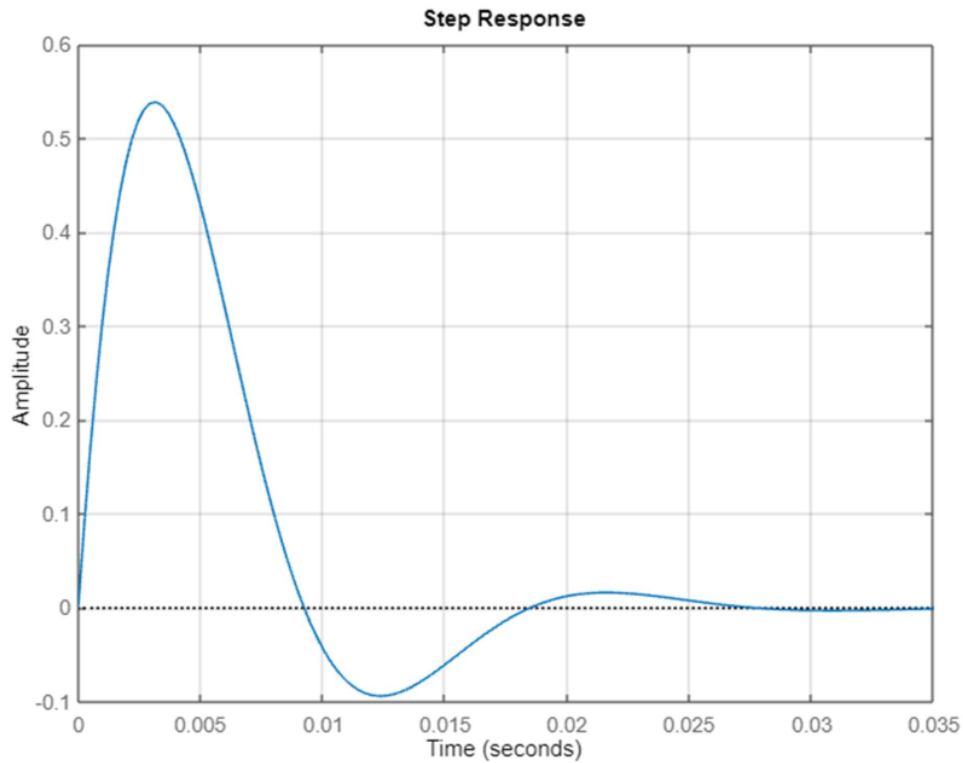


Figure 28 - Task 6 Under-damped Graph

*New Damping Factor*

$$\zeta = \frac{1}{2R} \sqrt{\frac{L}{C}} = \frac{1}{2 \times 60} \sqrt{\frac{0.15}{44 \times 10^{-6}}} = 0.487$$

### Critically Damped

```
s= tf('s');  
system = (s*(778.4989441))/(s^2+(2*(0.9999999999*389.25)*s)+(389.25^2));  
step (system);  
grid on
```

Figure 29 - Task 6 Critically Damped Code

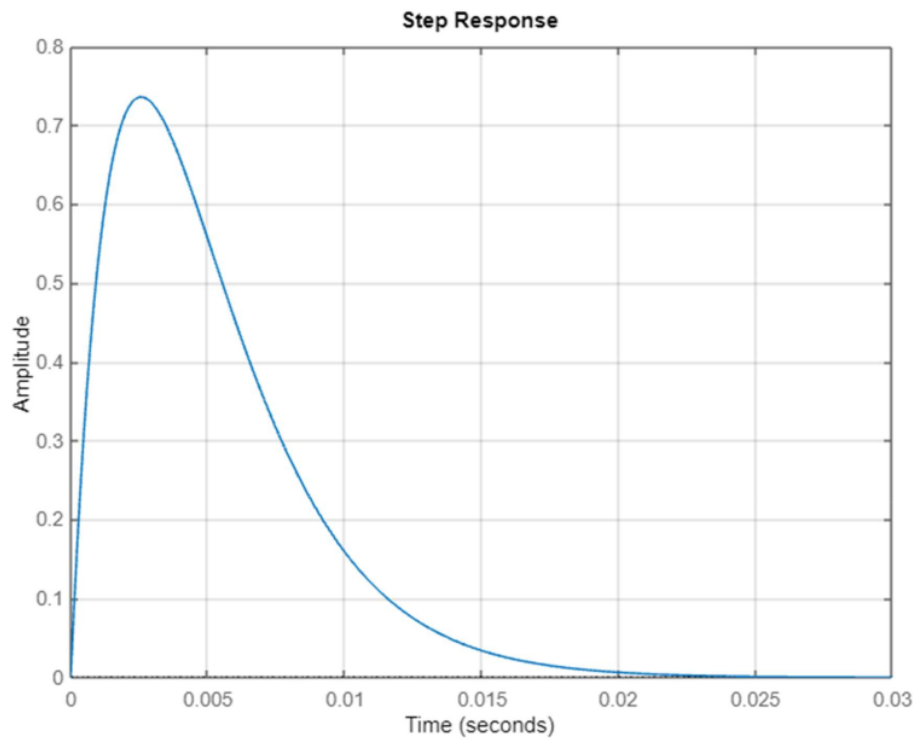


Figure 30 - Task 6 Critically Damped Graph

### New Damping Factor

$$\zeta = \frac{1}{2R} \sqrt{\frac{L}{C}} = \frac{1}{2 \times 29.19} \sqrt{\frac{0.15}{44 \times 10^{-6}}} = 0.999 \approx 1$$

### No Damping

```
s= tf('s');  
system = (s*(75.75757576))/(s^2+(2*((0.09731236802*389.25)*s))+(389.25^2));  
step (system);  
grid on
```

Figure 31 - Task 6 No Damping Code

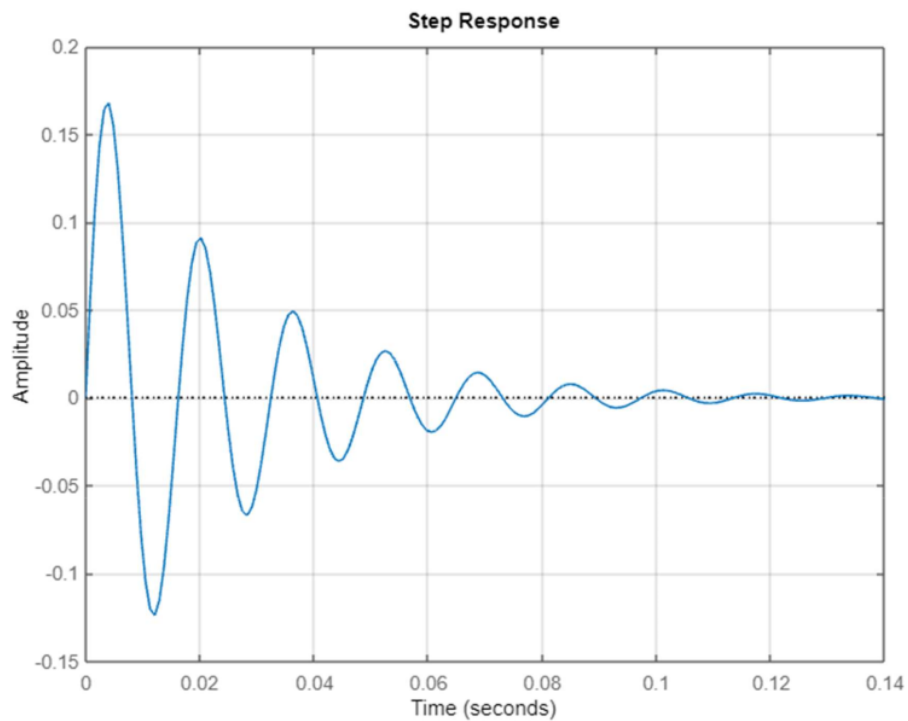


Figure 32 - Task 6 No Damping Graph

### New Damping Factor

$$\zeta = \frac{1}{2R} \sqrt{\frac{L}{C}} = \frac{1}{2 \times 300} \sqrt{\frac{0.15}{44 \times 10^{-6}}} = 0.097 \approx 0$$

### Task 6.5 – Table of Results

|          |  | Resistance ( $\Omega$ ) | Damping Factor ( $\zeta$ ) | Damping Ratio | Damping Effect    |
|----------|--|-------------------------|----------------------------|---------------|-------------------|
| System 1 |  | $\Omega$                | 0.48656184                 | $\zeta < 1$   | Under Damped      |
| System 2 |  | $\Omega$                | 7.298                      | $\zeta > 1$   | Over Damped       |
| System 3 |  | $\Omega$                | 0.99999 $\sim 1$           | $\zeta = 1$   | Critically Damped |
| System 4 |  | $\Omega$                | 0.09731236802 $\sim 0$     | $\zeta = 0$   | No Damping        |

Table 6 - Task 6 Table of Results

### Task 6.6 – Critical Analysis

The four different systems used within this task. each had a different effect on the output produced. The under-damped system quickly moved to the equilibrium but overshoot and oscillated. The over-damped system slowly decreases to the equilibrium but does not make it completely. The system with no damping had continuous oscillation and did not reach an equilibrium. For the critically damped system reached its equilibrium with no overshoot in the most efficient time. The overall analysis has been confirmed through the experimentation. The overall outputs from each of the systems is clearly shown to be affected by the damping factors.

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

### 7.1 Determine System Values

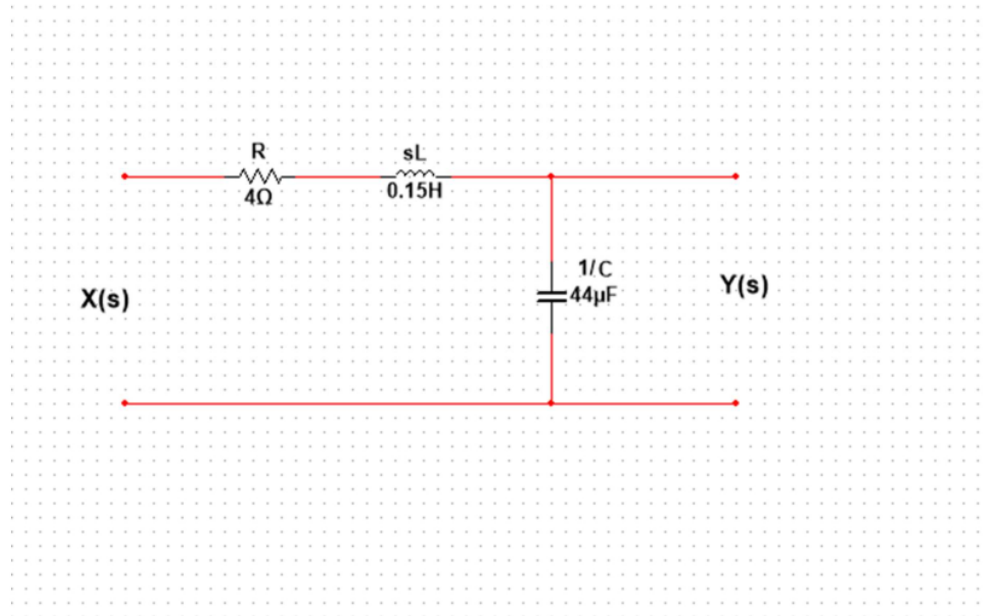


Figure 33 - Task 7 Laplace Model

The transfer function for this system is.

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

For these values different equations can be used to determine different values.

$$\omega_n = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.15 \times 44 \times 10^{-6}}} = 389.249 \text{ rad/s}$$

$$\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{4}{2} \sqrt{\frac{44 \times 10^{-6}}{0.15}} = 0.03$$

$$Q = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{4} \sqrt{\frac{0.15}{44 \times 10^{-6}}} = 14.597$$

From these values it is predicted that the values will generate a no dam  17 stem.

## 7.2 Matlab Code

### No-Damping

```
s = tf('s');  
system1 = ((1/(0.15*0.000044))/(s^2+(4/0.15)*s+(1/(0.15*0.000044))));  
bode (system1);  
grid on  
hold on
```

Figure 34 - Task 7 No Damping Matlab Code

### Under-Damped

$$\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{45}{2} \sqrt{\frac{44 \times 10^{-6}}{0.15}} = 0.385$$

$$Q = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{45} \sqrt{\frac{0.15}{44 \times 10^{-6}}} = 1.297$$

```
s = tf('s');  
system2 = ((1/(0.15*0.000044))/(s^2+(45/0.15)*s+(1/(0.15*0.000044))));  
bode (system2);
```

Figure 35 - Task 7 Under-Damped Matlab Code

### Over-Damped

$$\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{140}{2} \sqrt{\frac{44 \times 10^{-6}}{0.15}} = 1.199$$

$$Q = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{140} \sqrt{\frac{0.15}{44 \times 10^{-6}}} = 0.417$$

```
s = tf('s');  
system3 = ((1/(0.15*0.000044))/(s^2+(140/0.15)*s+(1/(0.15*0.000044))));  
bode (system3);
```

Figure 36 - Task 7 Over-Damped Matlab Code

Critically Damped

$$\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{116.77}{2} \sqrt{\frac{44 \times 10^{-6}}{0.15}} = 0.999 \approx 1$$

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

```
s = tf('s');
system4 = ((1/(0.15*0.000044))/(s^2+(116.77/0.15)*s+(1/(0.15*0.000044))));
bode (system4);
```

Figure 38 - Task 7 Critically Damped Matlab Code

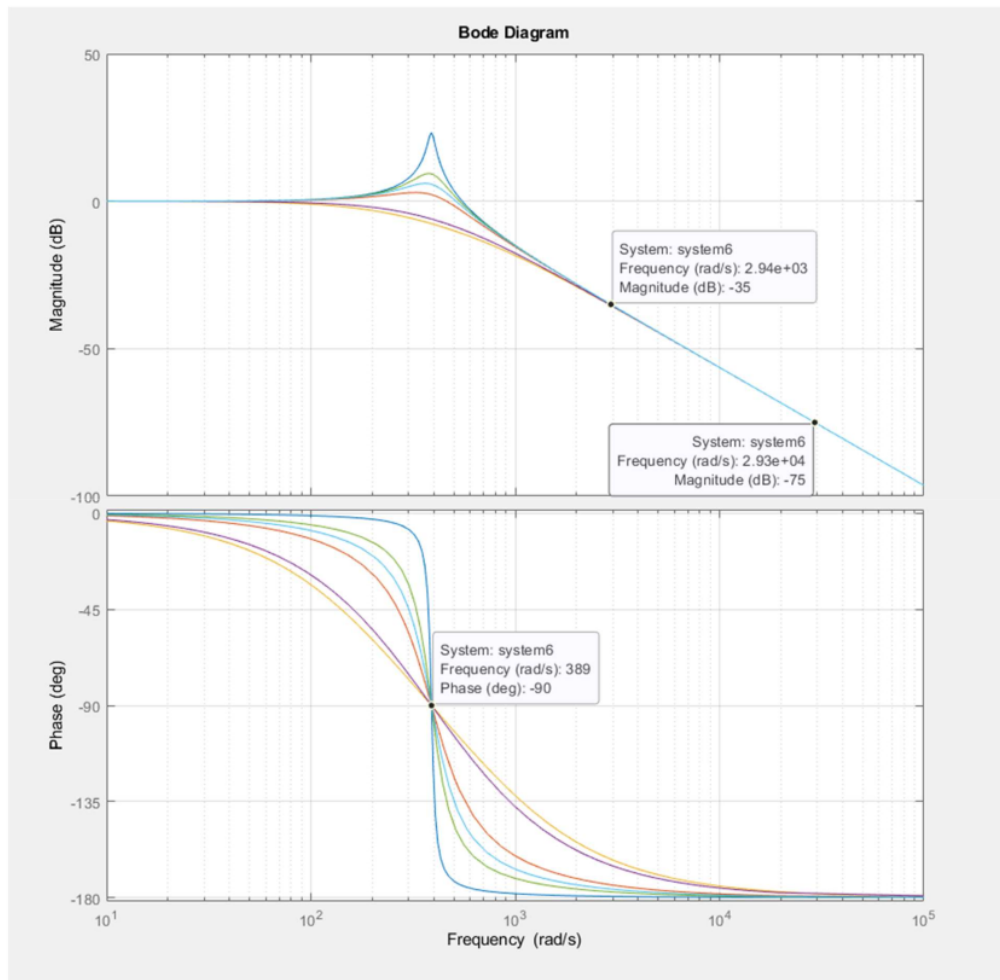


Figure 37 - Task 7 Bode Plot Graph

### 7.3 Circuit Evaluation

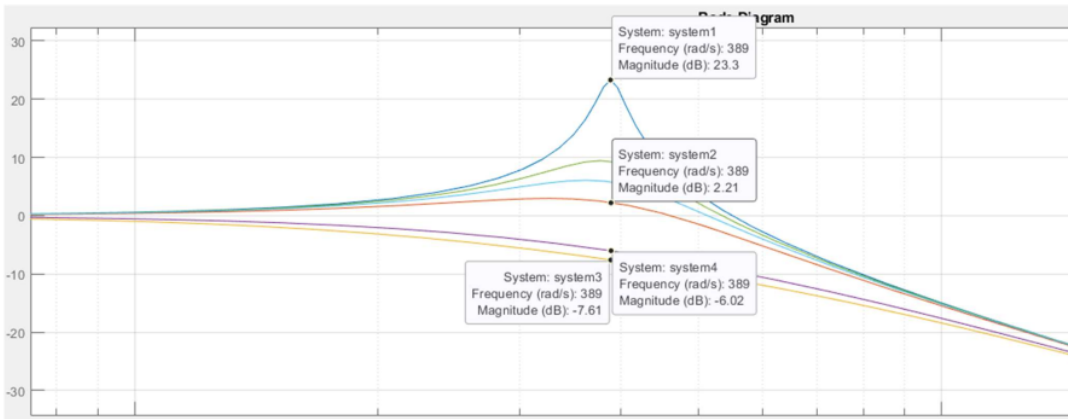


Figure 39 - Task 7 Locus Plot

No Damping

$$20\log(14.597) = 23.29$$

Under Damped

$$20\log(1.297) = 2.25$$

Over Damped

$$20\log(0.417) = -7.6$$

Critically Damped

$$20\log(0.5) = -6.02$$

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|                   | Calculated values at cut-off | Measured values at cut-off |
|-------------------|------------------------------|----------------------------|
| No-damping        | 23.29                        | 23.3                       |
| Under-damped      | 2.25                         | 2.21                       |
| Over-damped       | -7.60                        | -7.61                      |
| Critically damped | -6.02                        | -6.02                      |

### 7.4 Critical Analysis

It is clearly shown from the measured and calculated values collected, that the individual values have been confirmed. There is a visibly small variance within the data. This attributed to rounding errors conducted at the beginning of the calculations. As shown in the figure above it represents the effect that a changing resistance has on the damping factor within the system. With a decreased to the value of the resistor this will have an increased output magnitude. This generates a low pass filter, which inhibits any frequencies above the cut-off threshold.

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

### 8.1 Determine System Values

For this task, an analysis was undertaken on the performance of a second order parallel circuit. This was done with the change in the resistance values. While the other component values remained constant.

$$L = 0.15H, C = 44 \times 10^{-6}F$$



$$R = 4\Omega$$

$$\omega_0 = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.15 \times (44 \times 10^{-6})}} = 389.249$$

$$\begin{aligned}\omega_{c2} &= \frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{LC}\right)} \\ &= \frac{1}{2 \times 4 \times (44 \times 10^{-6})} \\ &\quad + \sqrt{\left(\frac{1}{2 \times 4 \times (44 \times 10^{-6})}\right)^2 + \left(\frac{1}{0.15 \times (44 \times 10^{-6})}\right)} = 5708.36\end{aligned}$$

$$\begin{aligned}\omega_{c1} &= -\frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{LC}\right)} \\ &= -\frac{1}{2 \times 4 \times (44 \times 10^{-6})} \\ &\quad + \sqrt{\left(\frac{1}{2 \times 4 \times (44 \times 10^{-6})}\right)^2 + \left(\frac{1}{0.15 \times (44 \times 10^{-6})}\right)} = 26.54\end{aligned}$$

$$\beta = \omega_{c2} - \omega_{c1} = \frac{1}{RC} = 5681.82$$

$$Q = R \sqrt{\frac{C}{L}} = 4 \times \sqrt{\frac{(44 \times 10^{-6})}{0.15}} = 0.069$$

$$R = 300$$

$$\begin{aligned}\omega_{c2} &= \frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{LC}\right)} \\ &= \frac{1}{2 \times 330 \times (44 \times 10^{-6})} \sqrt{\left(\frac{1}{2 \times 330 \times (44 \times 10^{-6})}\right)^2 + \left(\frac{1}{0.15 \times (44 \times 10^{-6})}\right)} \\ &= 428.97\end{aligned}$$

$$\begin{aligned}\omega_{c1} &= -\frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{LC}\right)} \\ &= -\frac{1}{2 \times 330 \times (44 \times 10^{-6})} \sqrt{\left(\frac{1}{2 \times 330 \times (44 \times 10^{-6})}\right)^2 + \left(\frac{1}{0.15 \times (44 \times 10^{-6})}\right)} \\ &= 353.21\end{aligned}$$

$$\beta = \frac{1}{RC} = \frac{1}{330 \times 44 \times 10^{-6}} = 75.76$$

$$Q = R \times \sqrt{\frac{C}{L}} = 330 \times \sqrt{\frac{44 \times 10^{-6}}{0.15}} = 5.14$$

$$R = 60$$

$$\begin{aligned}\omega_{c2} &= \frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{LC}\right)} \\ &= \frac{1}{2 \times 60 \times (44 \times 10^{-6})} \sqrt{\left(\frac{1}{2 \times 60 \times (44 \times 10^{-6})}\right)^2 + \left(\frac{1}{0.15 \times (44 \times 10^{-6})}\right)} \\ &= 622.27\end{aligned}$$

$$\begin{aligned}\omega_{c1} &= -\frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{LC}\right)} \\ &= -\frac{1}{2 \times 60 \times (44 \times 10^{-6})} \sqrt{\left(\frac{1}{2 \times 60 \times (44 \times 10^{-6})}\right)^2 + \left(\frac{1}{0.15 \times (44 \times 10^{-6})}\right)} \\ &= 243.49\end{aligned}$$

$$\beta = \frac{1}{RC} = \frac{1}{60 \times 44 \times 10^{-6}} = 378.79$$

$$Q = R \times \sqrt{\frac{C}{L}} = 60 \times \sqrt{\frac{44 \times 10^{-6}}{0.15}} = 1.03$$

$$R = 29.1971041$$

$$\begin{aligned}\omega_{c2} &= \frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{LC}\right)} \\ &= \frac{1}{2 \times 29.19371041 \times (44 \times 10^{-6})} \sqrt{\left(\frac{1}{2 \times 29.19371041 \times (44 \times 10^{-6})}\right)^2 + \left(\frac{1}{0.15 \times (44 \times 10^{-6})}\right)} \\ &= 939.73\end{aligned}$$

$$\begin{aligned}\omega_{c1} &= -\frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \left(\frac{1}{LC}\right)} \\ &= -\frac{1}{2 \times 29.19371041 \times (44 \times 10^{-6})} \sqrt{\left(\frac{1}{2 \times 29.19371041 \times (44 \times 10^{-6})}\right)^2 + \left(\frac{1}{0.15 \times (44 \times 10^{-6})}\right)} \\ &= 161.23\end{aligned}$$

$$\beta = \frac{1}{RC} = \frac{1}{29.19371041 \times 44 \times 10^{-6}} = 778.5$$

$$Q = R \times \sqrt{\frac{C}{L}} = 29.19371041 \times \sqrt{\frac{44 \times 10^{-6}}{0.15}} = 0.5$$

## 8.2 Matlab Code

$$R = 4$$

```
s = tf('s');
system1 = ((s*5681.82)/(s^2+(s*5681.82)+389.249^2));
bode (system1);
gridd on
hold on
```

Figure 40 - Task 8 R = 4 Matlab Code

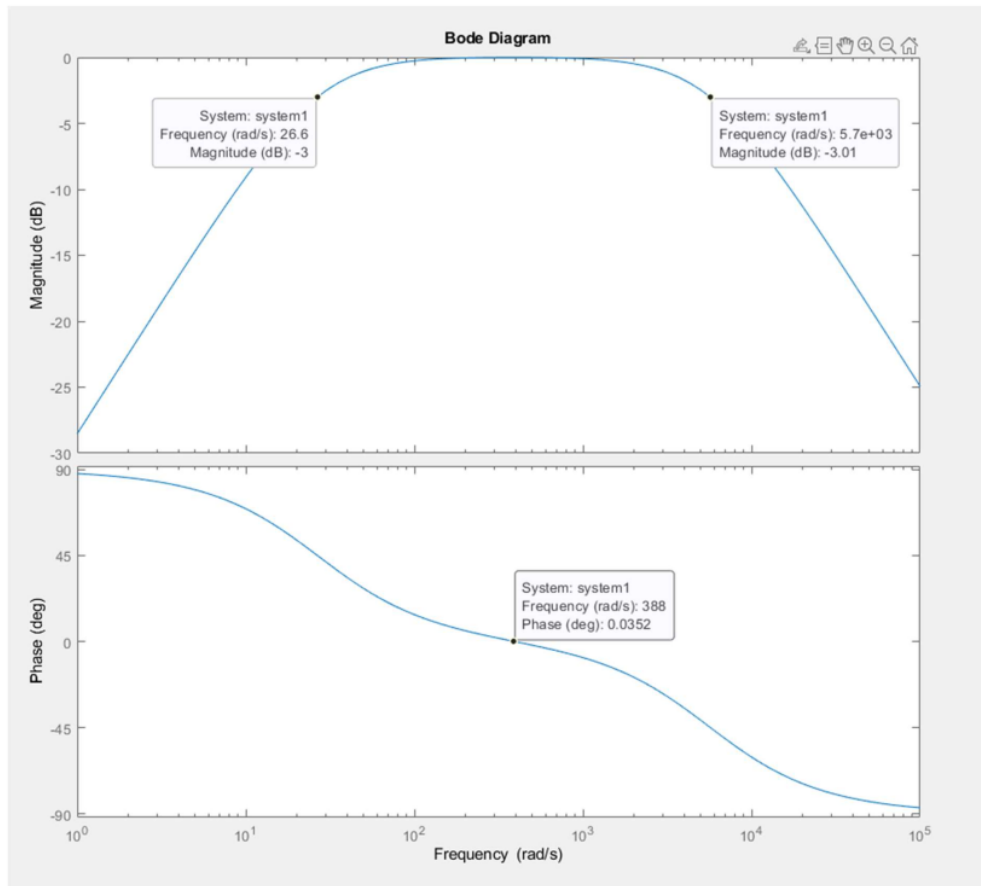


Figure 41 - Task 8 R = 4 Graph

R = 300

```
s = tf('s');
system1 = ((s*75.76)/(s^2+(s*75.76)+389.249^2));
bode(system1);
gridd on
hold on
```

Figure 42 - Task 8 R = 300 Matlab Code

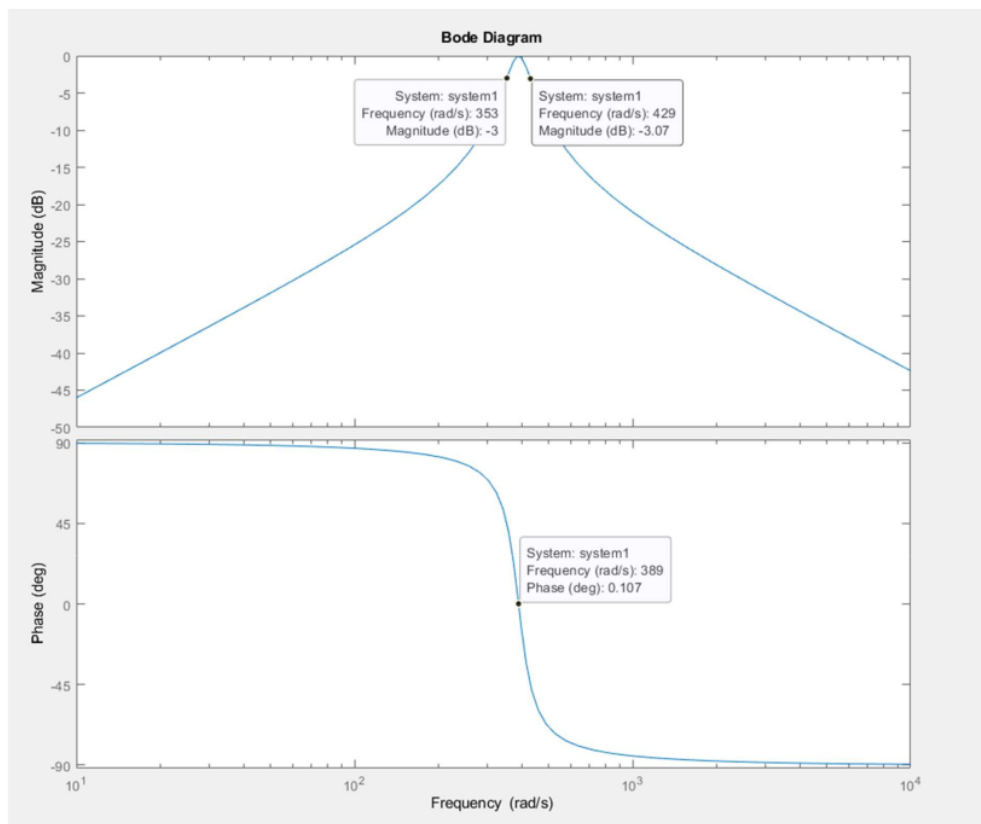


Figure 43 - Task 8 R = 300 Graph

R = 60

```
s = tf('s');
system1 = ((s*378.79)/(s^2+(s*378.79)+389.249^2));
bode (system1);
gridd on
hold on
```

Figure 44 - Task 8 R = 60 Matlab Code

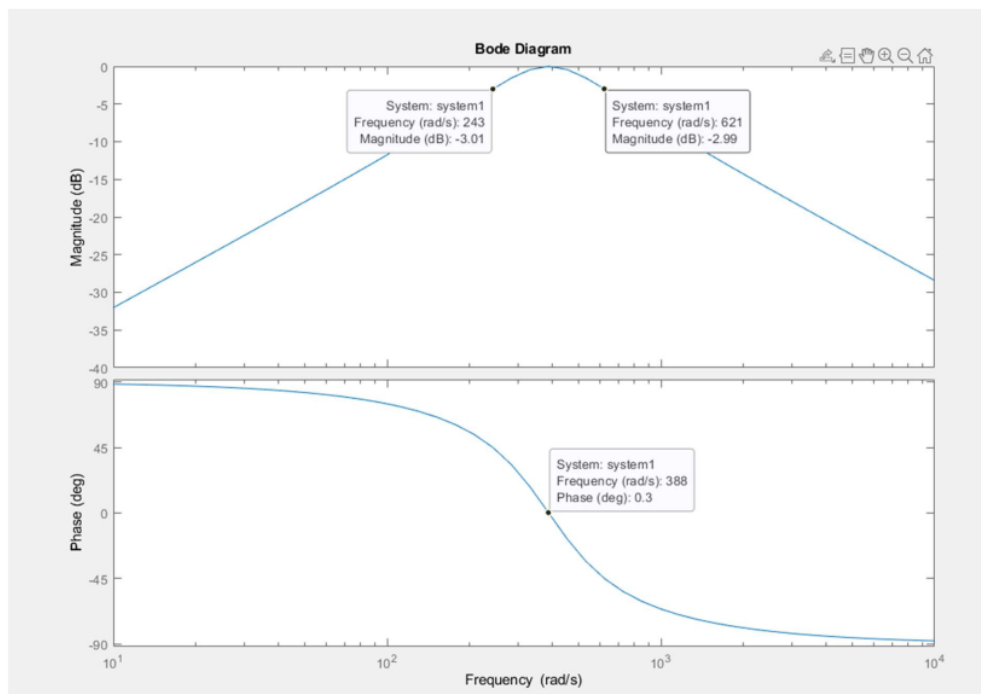


Figure 45 - Task 8 R = 60 Graph

R = 29.19371041

```
s = tf('s');
system1 = ((s*778.5)/(s^2+(s*778.5)+389.249^2));
bode (system1);
gridd on
hold on
```

Figure 46 - Task 8 R = 29.19 Matlab Code

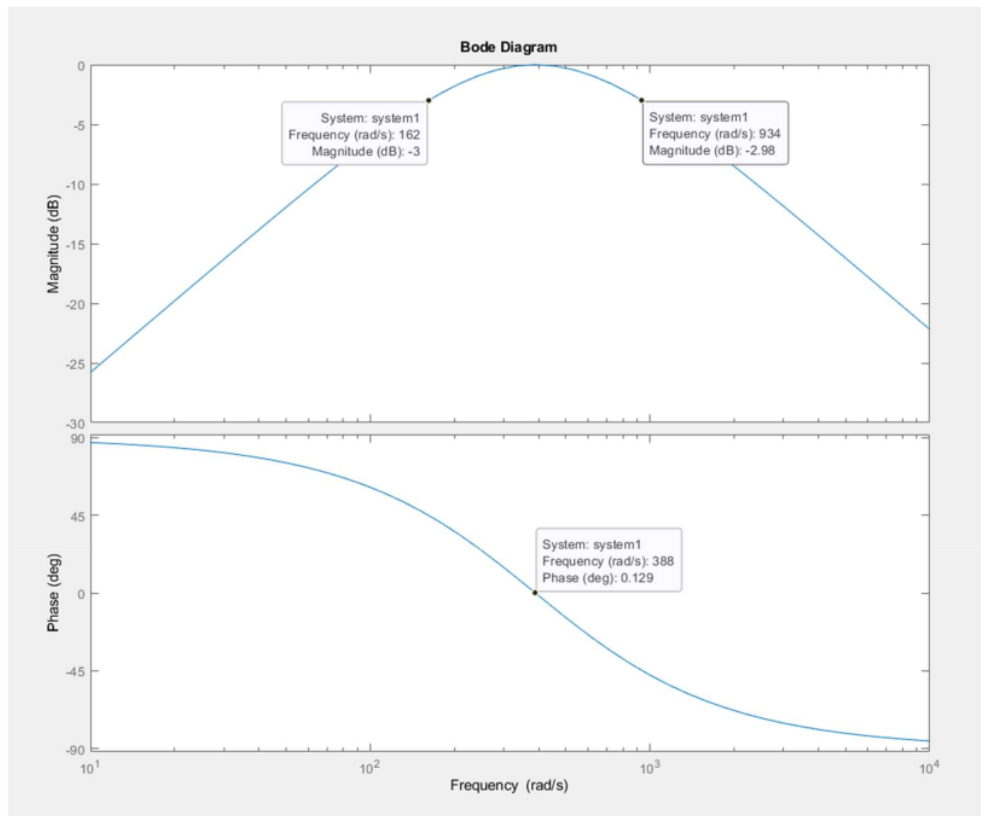


Figure 47 - Task 8 R = 29.19 Graph

### 8.3 Circuit Evaluation

#### Calculated Values

| Resistance $\Omega$ | Wo (Hz) | Lower cut-off Frequency (Hz) | Upper cut-off Frequency (Hz) | B (Hz)  |
|---------------------|---------|------------------------------|------------------------------|---------|
| 4                   | 389.249 | 26.54                        | 5708.36                      | 5681.82 |
| 300                 | 389.249 | 353.21                       | 428.97                       | 75.76   |
| 60                  | 389.249 | 243.49                       | 622.27                       | 378.79  |
| 29.19               | 389.249 | 161.23                       | 939.73                       | 778.5   |

#### Measured Values

| Resistance $\Omega$ | Wo (Hz) | Lower cut-off Frequency (Hz) | Upper cut-off Frequency (Hz) | B (Hz) |
|---------------------|---------|------------------------------|------------------------------|--------|
| 4                   | 389     | 26.6                         | 5700                         | 5673.4 |
| 300                 | 389     | 353                          | 429                          | 76     |
| 60                  | 389     | 243                          | 621                          | 378    |
| 29.19               | 389     | 162                          | 934                          | 772    |

#### Error between Calculated and Measured

| Resistance | Error in LCF | Error in HCF | Error in B |
|------------|--------------|--------------|------------|
| 4          | 0.06         | 8.36         | 8.42       |
| 300        | 0.21         | 0.03         | 0.24       |
| 60         | 0.49         | 1.27         | 0.79       |
| 29.19      | 0.77         | 5.73         | 6.5        |

### 8.4 Critical Analysis

From the results collected during this task it is visible that the resistance values have been increased. The effect this has is that it decreases the bandwidth of the system. this shows that with a greater resistance the system becomes more selective against allowing frequencies through. At the resonant frequency of 389rad/s there is a 0° phase shift. When comparing the measured and calculated they correlate correctly. However, there are some error presents this can be attributed to the rounding errors and the degree of accuracy of cursor placement on Matlab.



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

### 9.1 - Selected Component Values

for this task, a 235nF capacitor was chosen to be used within the circuit.

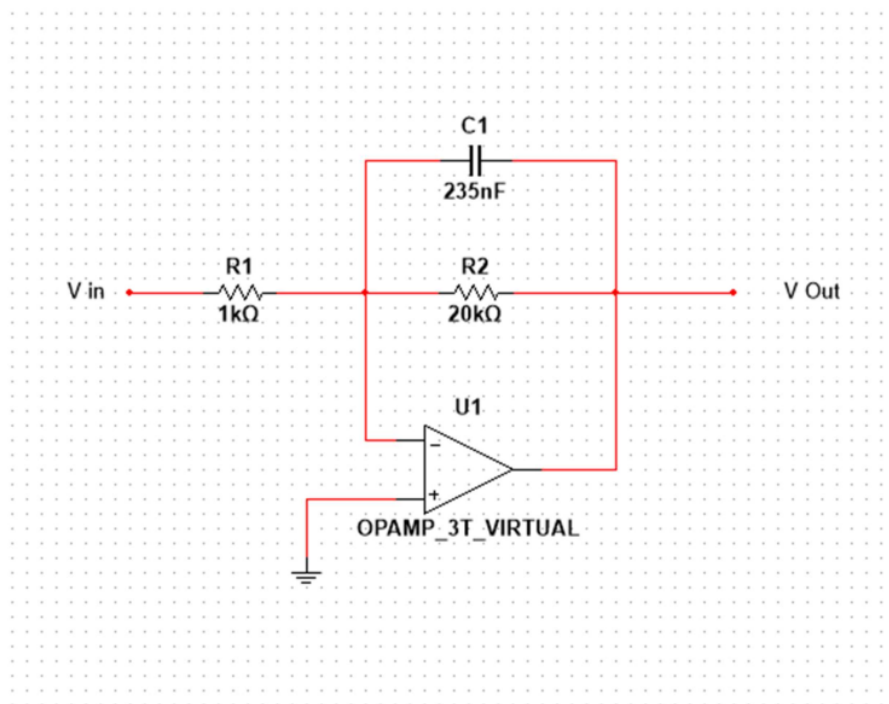


Figure 48 - Task 9 Circuit Design

### 9.2 - Suitable MATLAB Code

Calculations

$$K = \frac{R_2}{R_1} = \frac{20000}{1000} = 20$$

$$\omega_c = \frac{1}{CR_2} = \frac{1}{(235 \times 10^{-9}) \times 20000} = 212.766 \text{ rad/s}$$

$$20 \log_{10}(20) = 26.02 \text{ dB}$$

24

25

$$\text{Transfer Function} = -k \left( \frac{\omega_c}{s + \omega_c} \right) = -20 \left( \frac{212.766}{s + 212.766} \right)$$

This is the Matlab code created to generate the system.

```
s = tf('s');
system = (-20*(212.766/(s+212.766)));
bode (system);
grid on
Hold on
|
```

Figure 49 - Low Pass Filter MATLAB Code

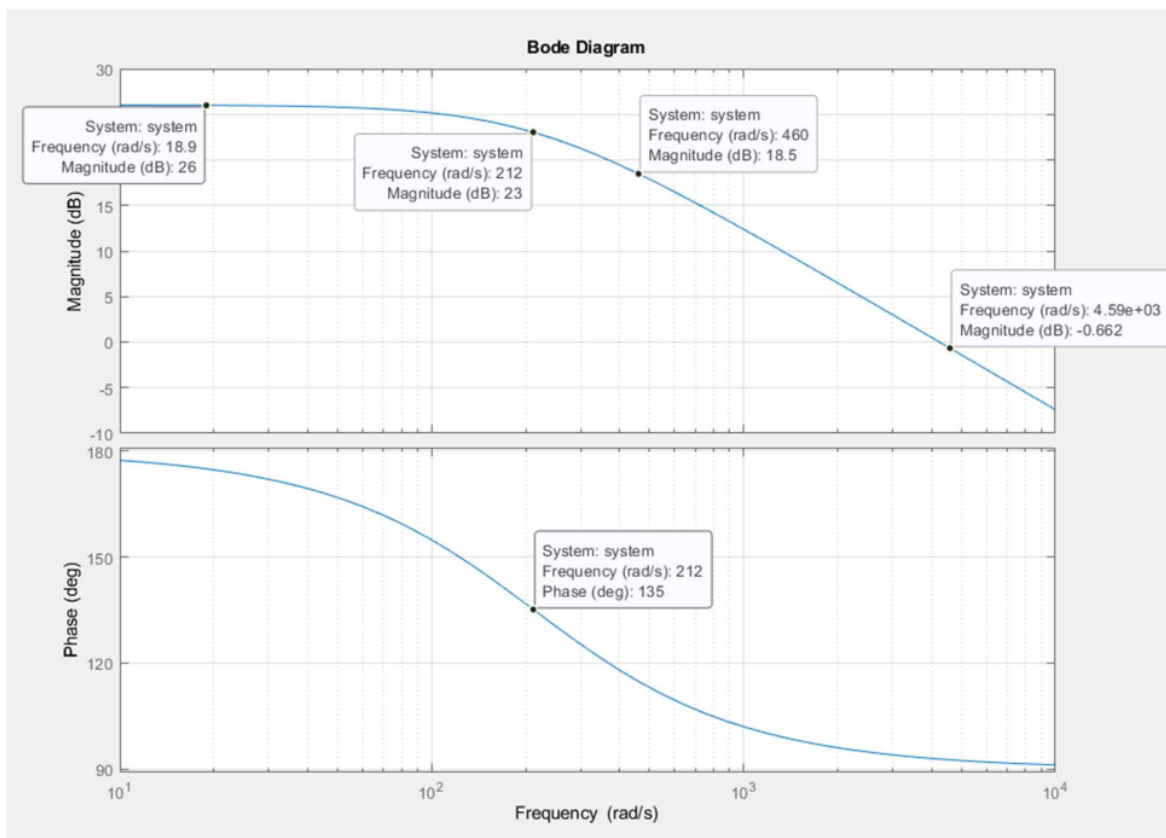


Figure 50 - Low Pass Filter Bode Plot

### 9.3 - Critical Analysis

When comparing the calculated and measured values. It can be observed that they are similar, this confirms that the system simulation was a success. As there was an inverting amplifier used this create a phase shift within the system of  $180^\circ$ . The cut-off frequency for the system can be fou

 26

$80-45 = 135^\circ$ .

 27

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

### 10.1 – Suitable Component Values

For the system, a 50nF capacitor was chosen.

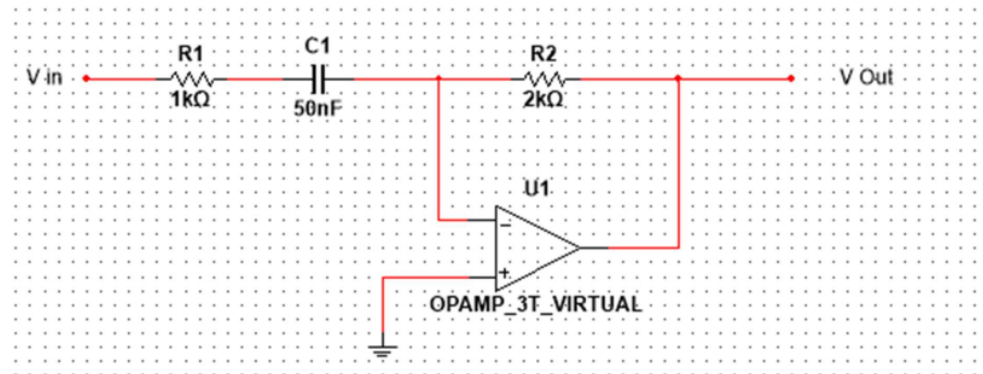


Figure 51 - High Pass Filter Circuit

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

$$k = \frac{R_2}{R_1} = \frac{2000}{1000} = 2$$

$$\omega_c = \frac{1}{(50 \times 10^{-9}) \times 1000} = 20000 \text{ rad/s}$$

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

$$\omega_c \text{ is at } -3 \text{ dB} \therefore 30.21 \text{ dB}$$

### 10.2 – Suitable MATLAB Code

```
s = tf('s');
system = (-2)*(s/(s+20000));
bode(system);
grid on
hold on
```

Figure 52 - High Pass Filter MATLAB Code

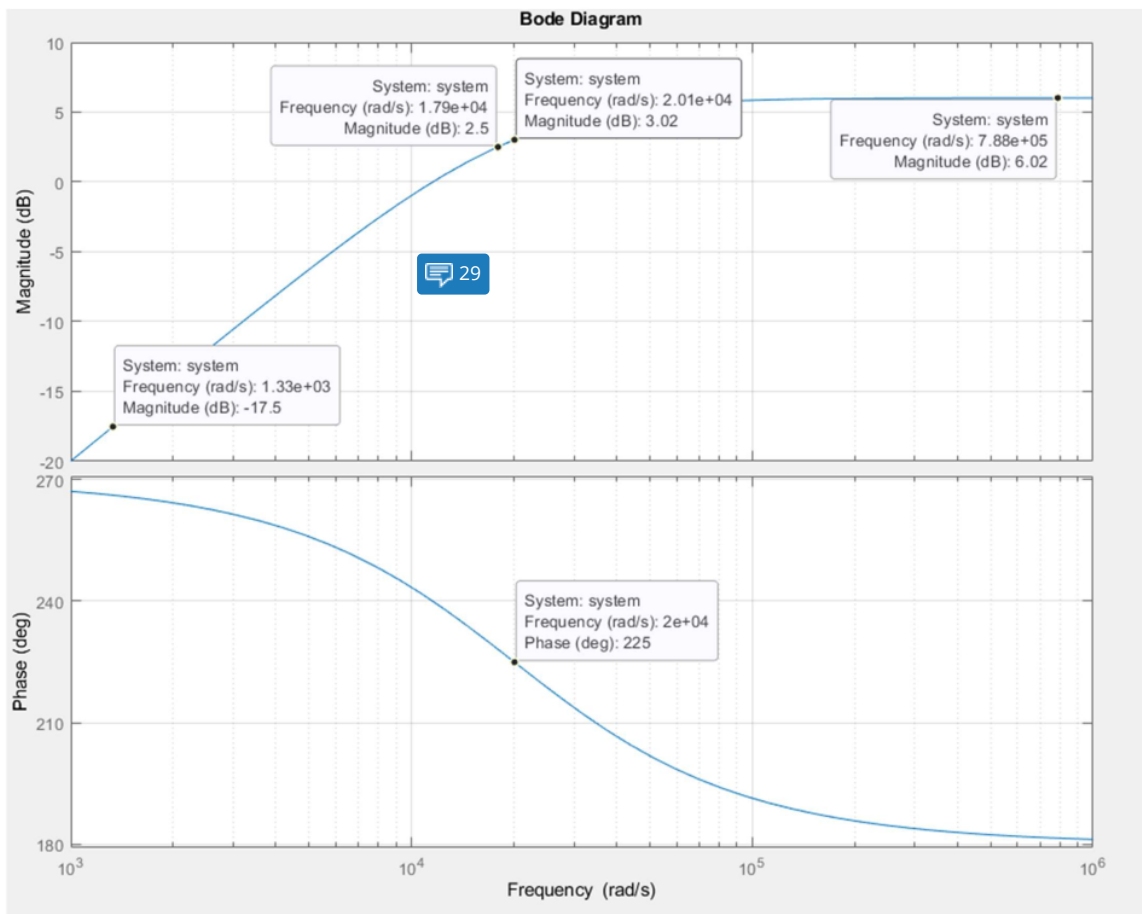


Figure 53 - High Pass Filter Bode Plot

### 10.3 – Critical Analysis

The calculated and measured match up within the system. As this system was designed to be a high pass filter. The natural frequency has a phase shift of  $45^\circ$ . As the output is inverted the phase is shifted by  $180^\circ$ . therefore the cut-off frequency can be found at  $225^\circ$ .

## Task 11 – Frequency Performance Analysis of a Sallen & Key 2<sup>nd</sup> Order Filter

### 11.1- Calculation

For this task, the resonant frequency used was set to 2000rad/s. From this information various component values can be calculated.

$$\omega_c = 2000 \text{ rad/s (Chosen value)}$$

$$R = \frac{1}{2000 \times 10^{-9}} = 5000\Omega$$

For a butter worth the value for K is equal to 1.586.

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

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

$$R_A = 586\Omega$$

To calculate the gain within the system the calculation that is used is.

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

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

From these calculations a suitable circuit can be created. Shown in figure 54 below.

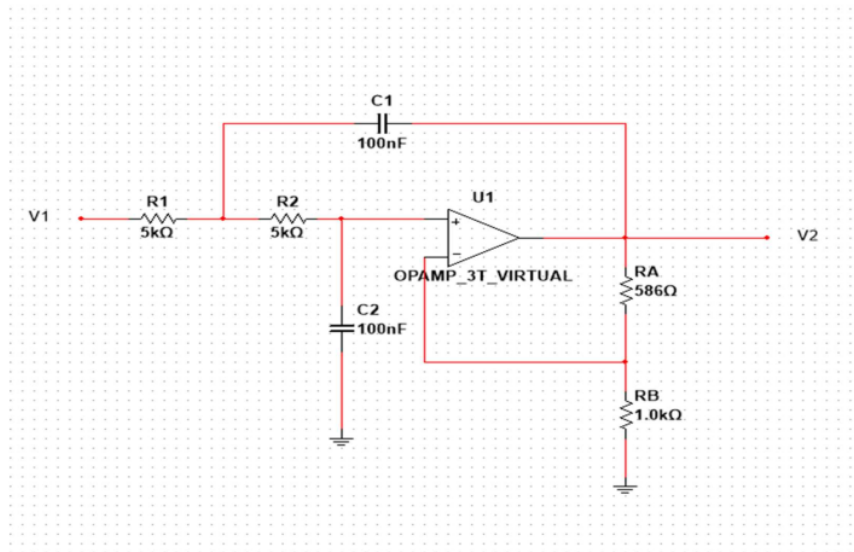


Figure 54 - Task 11 Sallen & Key Filter Circuit

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

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

11.2 - MATLAB

Simulation code was then written on MATLAB. Shown below in figure 56.

```
s = tf('s');
system = ((1.586*4000000)/(s^2+(2000/0.707)*s+4000000));
bode (system);
grid on
hold on
|
```

Figure 56 - Task 11 Suitable MATLAB Code

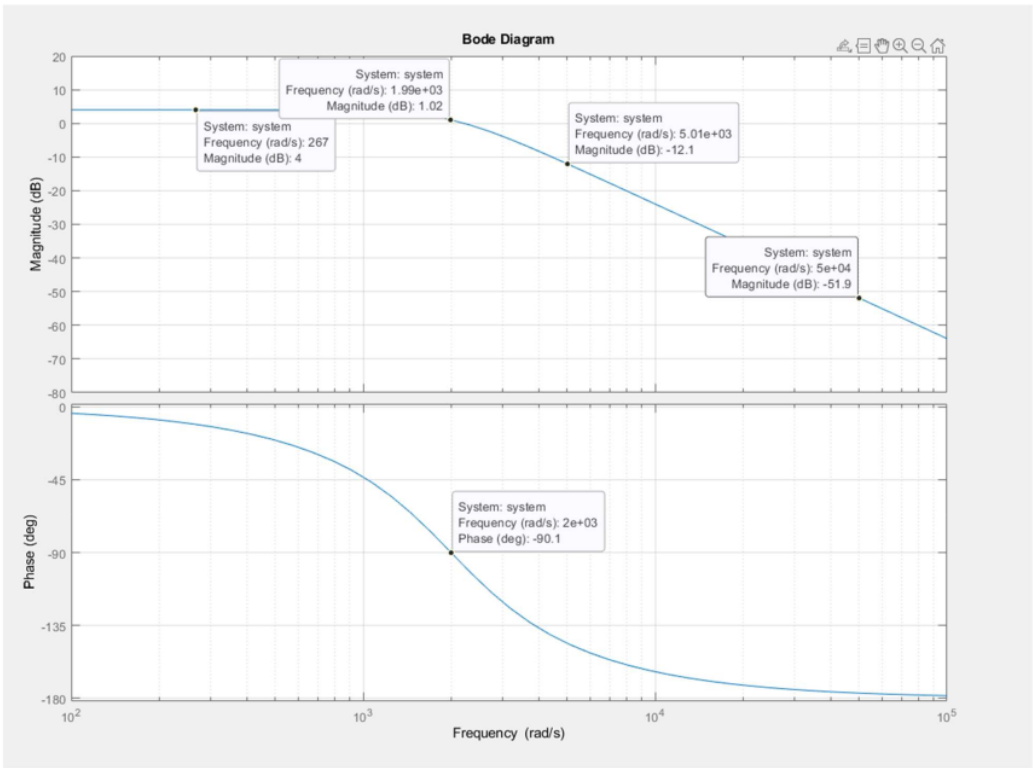


Figure 55 - Task 11 Sallen & Key Bode Plot

11.3 – Analysis

|                   | Calculated | Measured  |
|-------------------|------------|-----------|
| Cut-off Frequency | -40dB      | -39.8dB   |
| Roll-off          | 2000rad/s  | 1999rad/s |
| Gain              | 4dB        | 4dB       |

When comparing the calculated and measured results there are minor discrepancies within the data. This can be attributed to rounding errors or the degree of accuracy within the Matlab system. For this system it has a phase shift of  $-90^\circ$ . within this system it is a second order circuit. this means that the roll-off is at two decades, the roll off can be found at -40dB. This allows for the circuit to have a more selective of frequencies



## Task 12 – First Order Control System Analysis.

### 12.1 – Determined Open loop

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The open loop performance is shown as.

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

Figure 57 - Task 12 Argand Diagram Matlab code

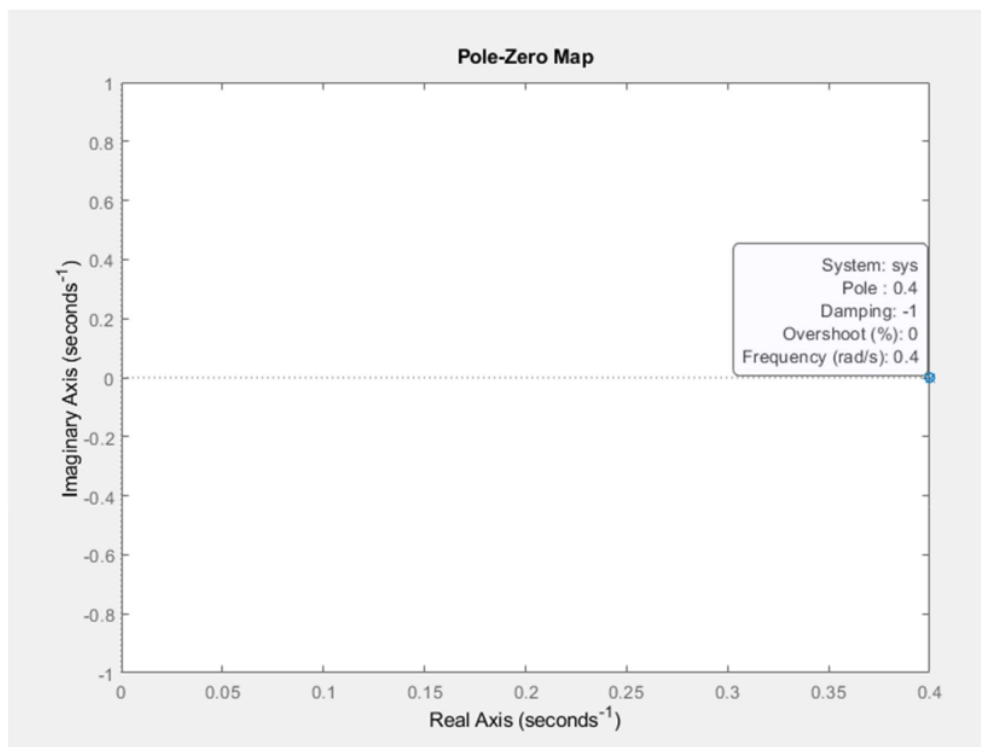


Figure 58 – Task 12 Argand Diagram

From this diagram it is shown that as the pole is in the positive region. It means that the signal is unstable.

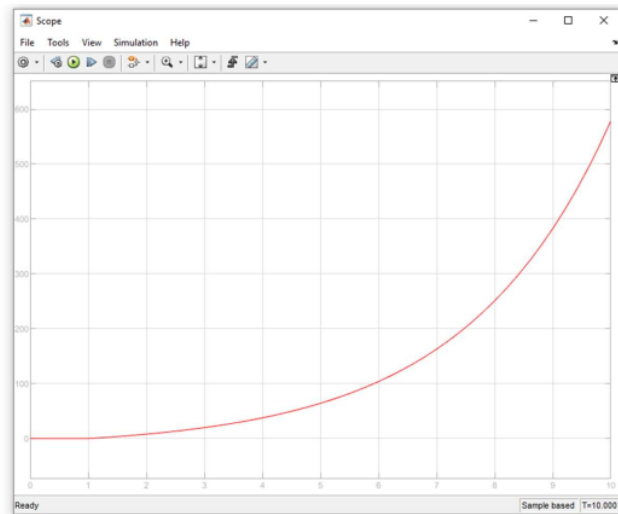
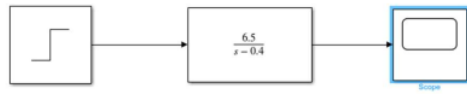


Figure 59 – Task 12 Open Loop Response

## 12.2 – produced closed loop

to generate a closed loop response in terms of k. the transfer function was altered for k = 1.

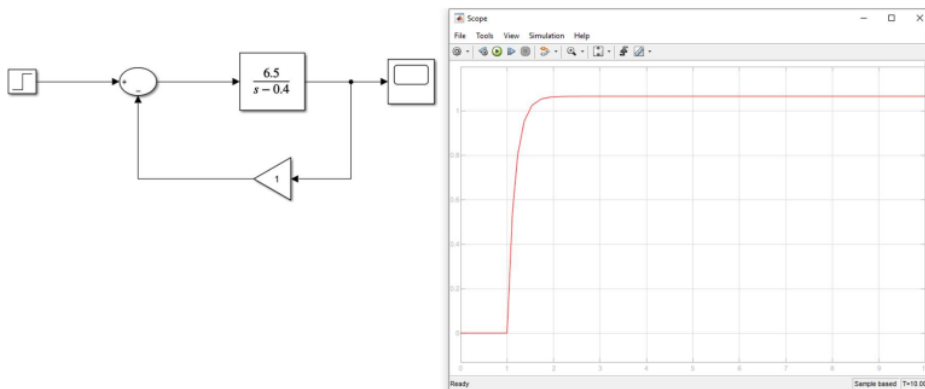


Figure 60 - Task 12 Closed Loop Response

As shown in the figure 60 above the response within the closed loop shows that the system is stable and reaches its peak and stabilises.

### 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).

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

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

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

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

$$s = -6.5k + 0.4$$

$$s = 0.4 - 6.5k$$

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

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

Figure 61 - Task 12 Locus Code

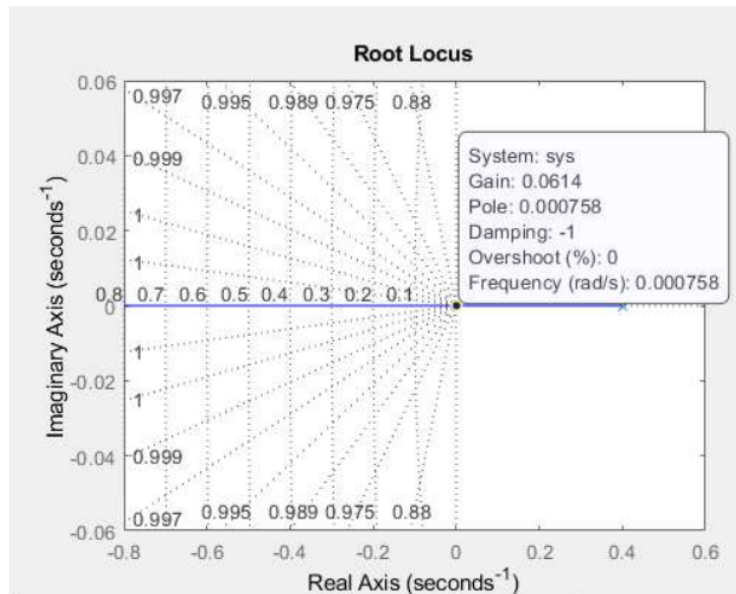


Figure 62 - Task 12 Root Locus Plot

As shown in the figure 62 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 – Built Model

$$s = 0.4 \times 6.5k$$

$$K < \min K (0.001)$$

$$s = 0.4 \times (6.5 \times 0.001) = 0.0026$$

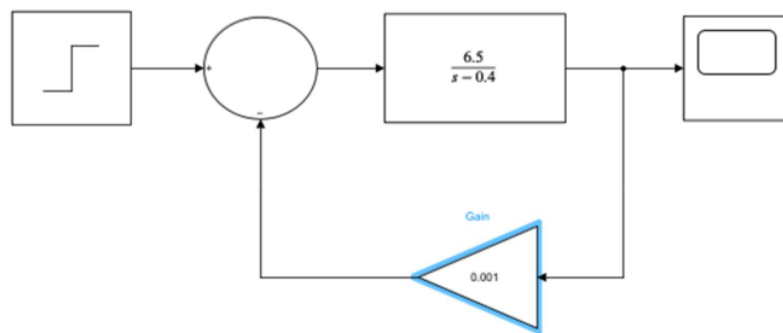


Figure 63 - Task 12 K less than Min Circuit

The Pole is at 0.026 therefor this is unstable.

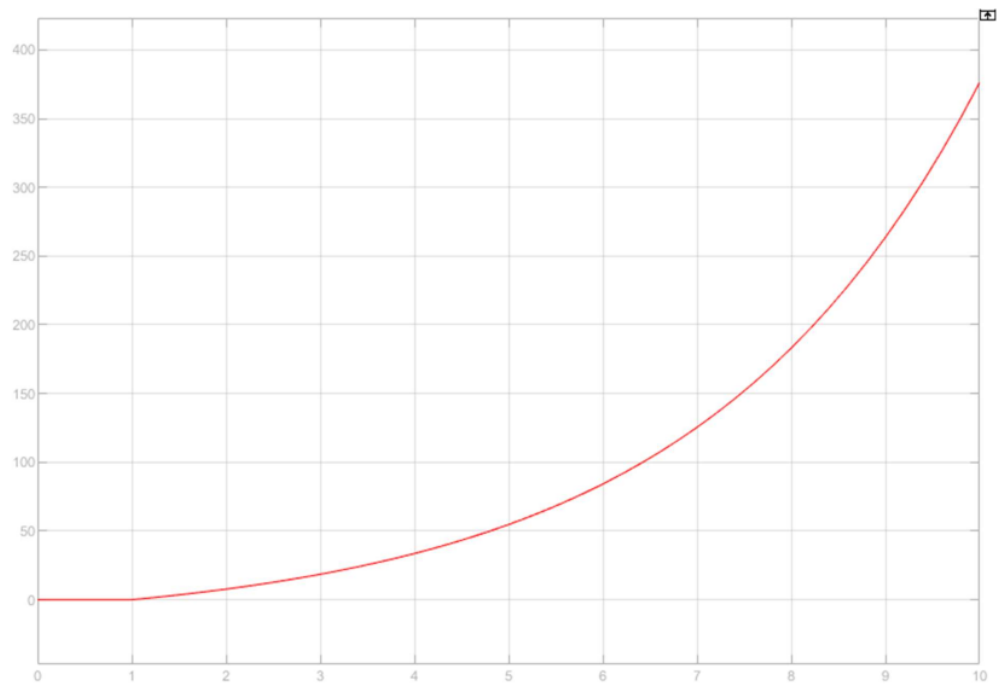


Figure 64 - Task 12 K < Mink Graph

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

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

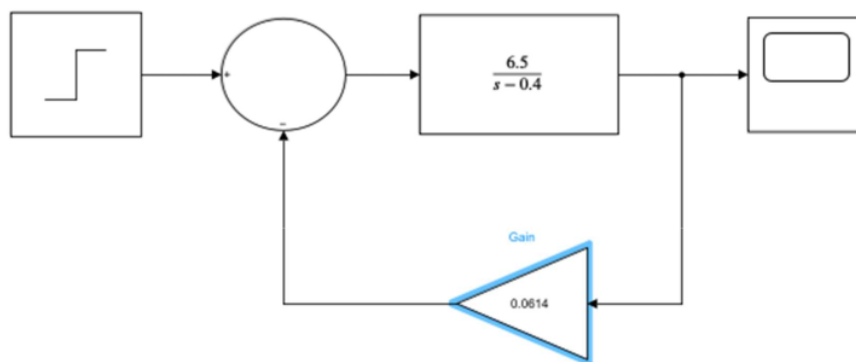


Figure 65 - Task 12 K = MinK Circuit

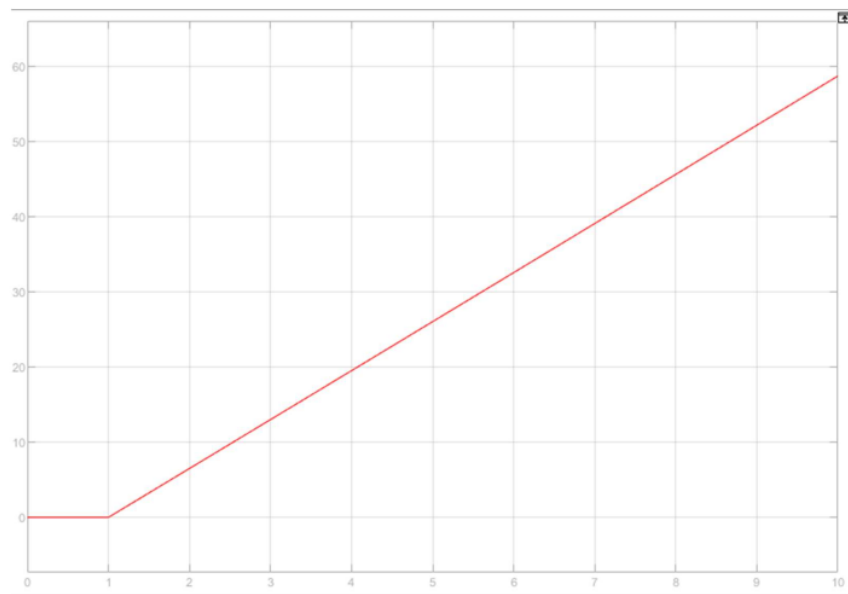


Figure 66 - Task 12  $K = \text{MinK}$  Graph

As the pole is at 0.15964 it is unstable.

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

$$s = 0.4 \times (6.5 \times 0.1) = 0.26$$

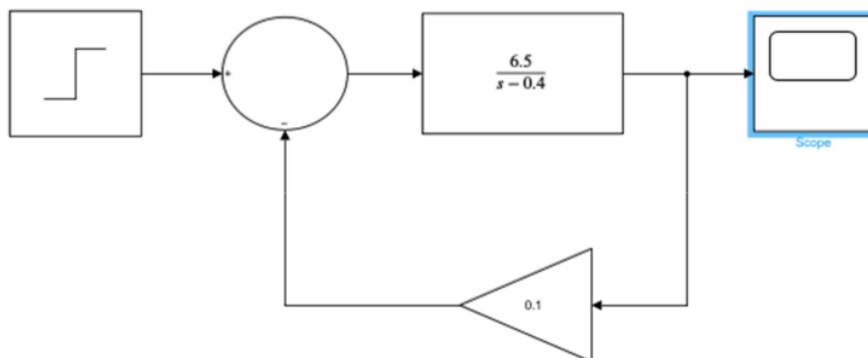


Figure 67 - Task 12  $K > \text{MinK}$  Circuit

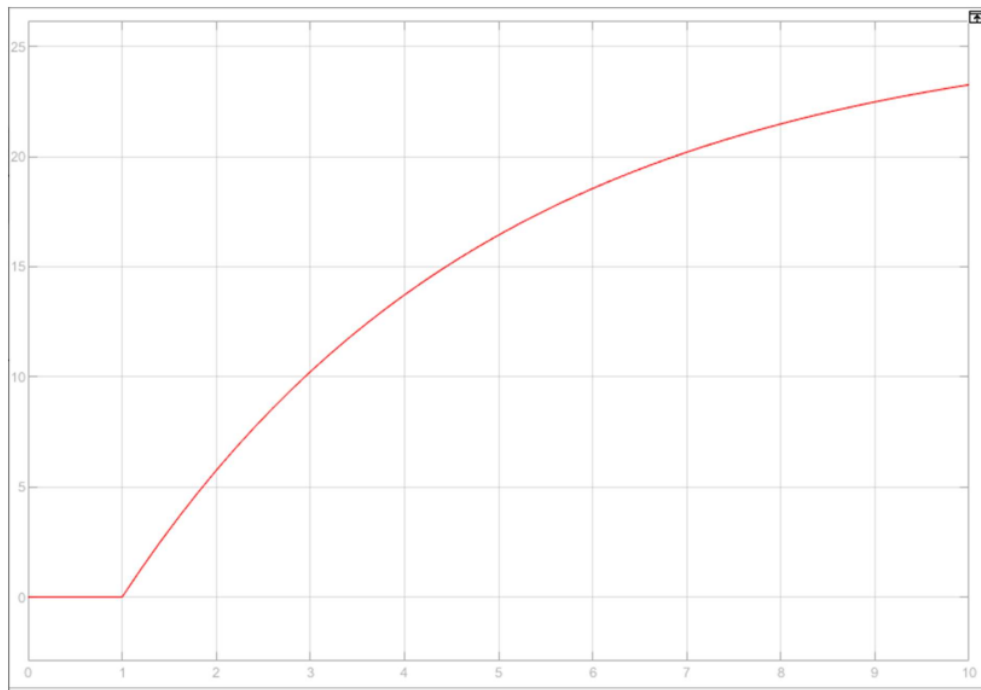


Figure 68 - Task 12  $K > \text{MinK}$  Graph

As the pole is at 2.6 this system is stable.

#### 12.5 – Table of Results

| K value | Pole    | Measured Stability | Calculated Stability |
|---------|---------|--------------------|----------------------|
| 0.001   | 0.026   | Unstable           | Unstable             |
| 0.0614  | 0.15964 | Unstable           | Unstable             |
| 0.1     | 0.26    | 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.

## Task 13 – DC Motor Model Analysis

### 13.1 – mathematical model

With the use of the two figures displayed below a model can be made to control a DC motor.

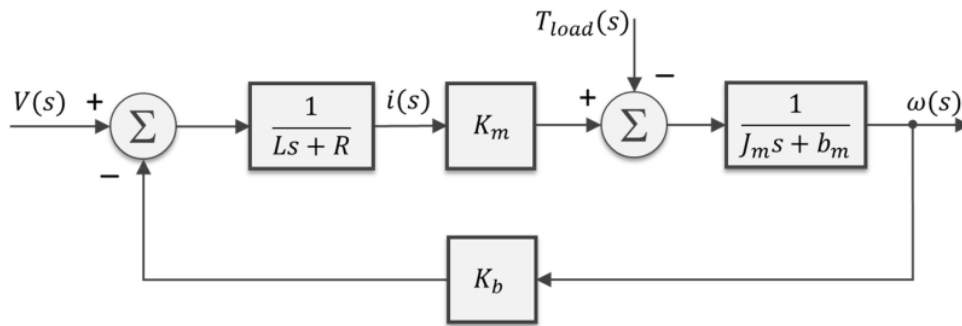


Figure 69 - Task 13 DC Motor model

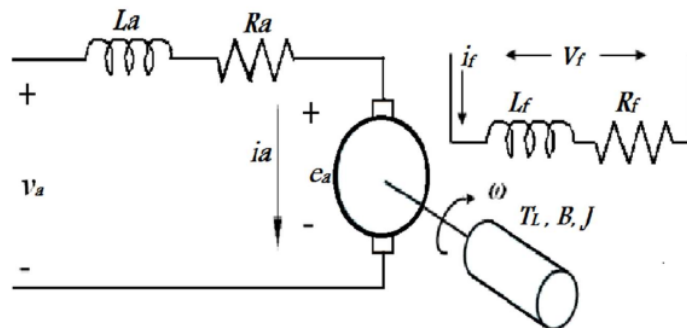


Figure 70 - Task 13 DC Motor Circuit

### 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

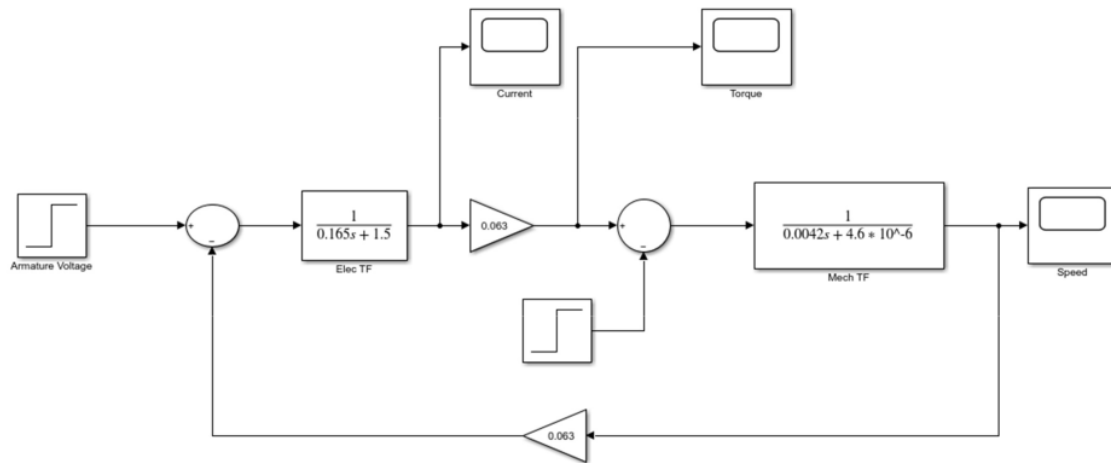


Figure 71 - DC motor Model

13.5 – analyse speed and torque response

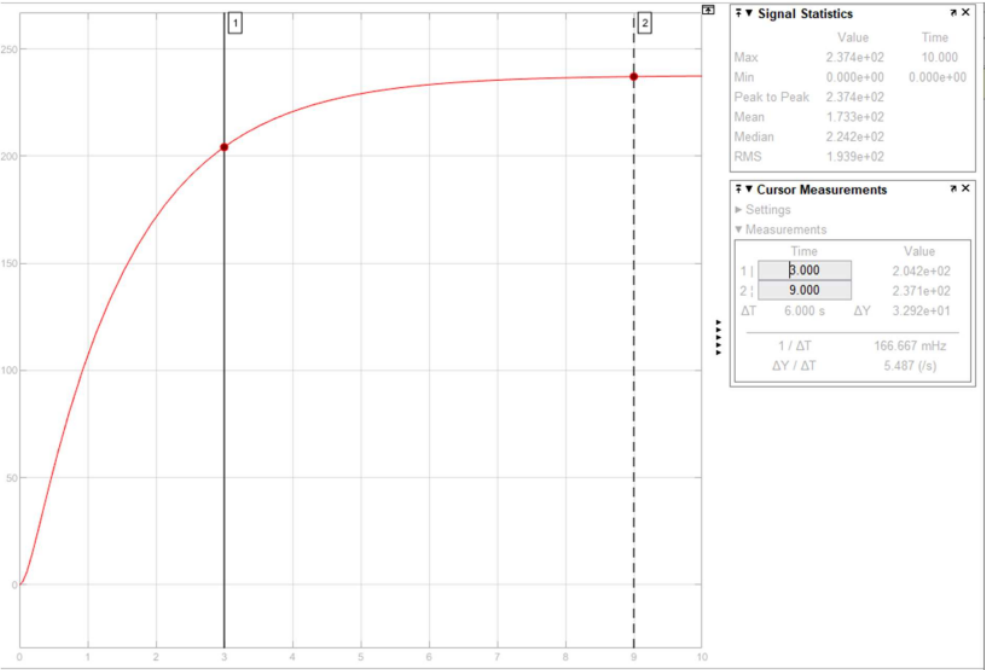


Figure 72 -Speed Growth Graph

To cause the motor to stall a stall torque is needed to be calculated. As shown in 13.2 the necessary stall torque for this system is 0.63Nm. This means that a load of at least 0.63Nm applies onto the motor will cause it to stall.

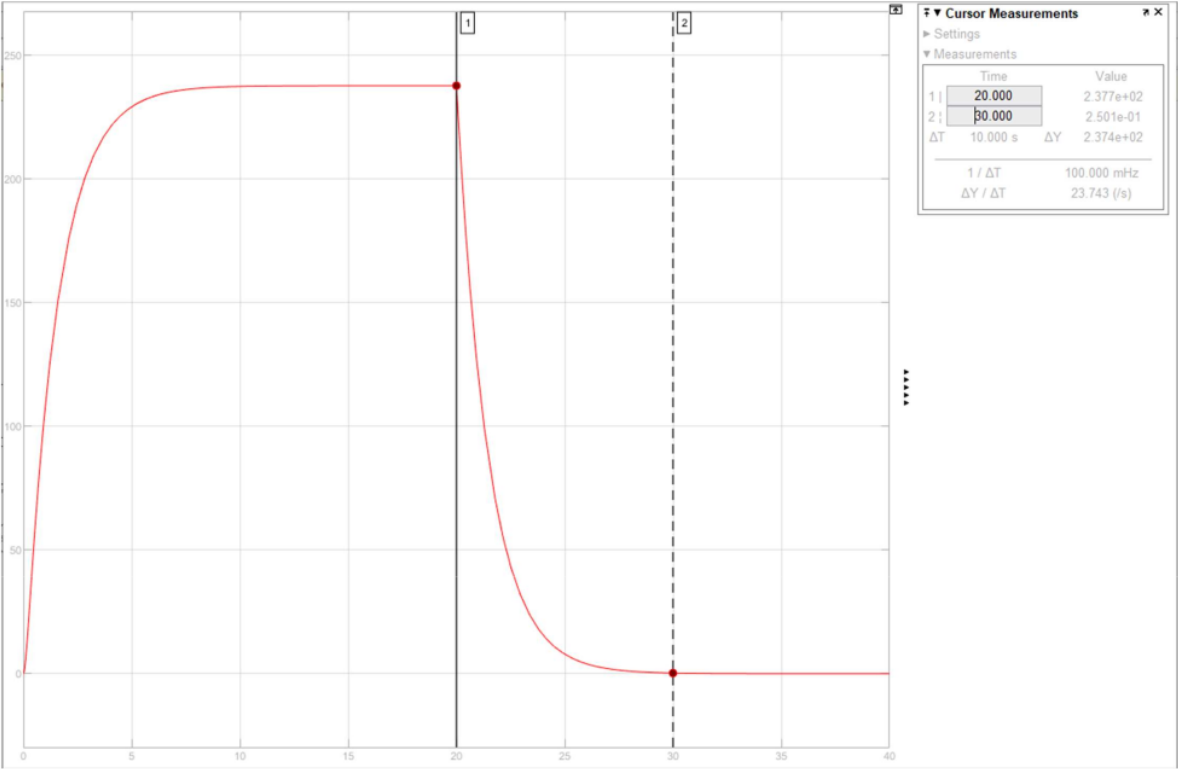


Figure 73 - Task 13 Stall Graph

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

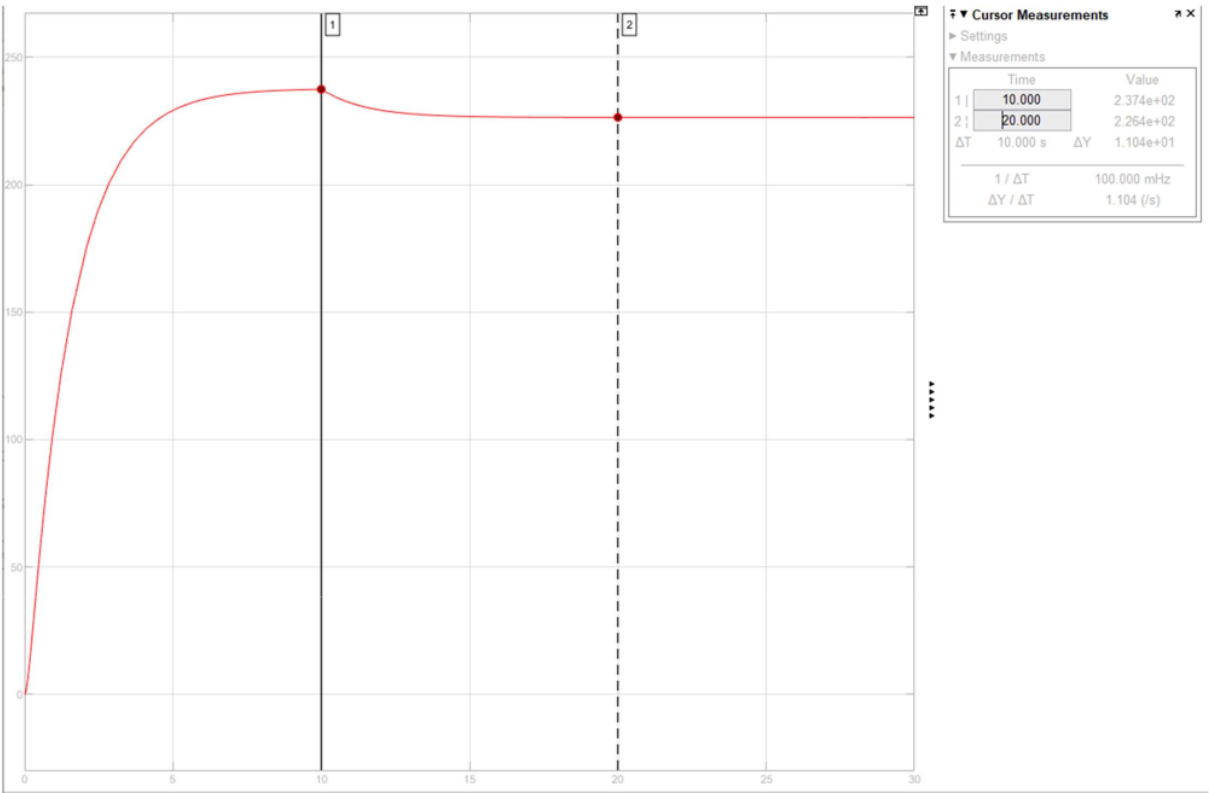


Figure 74 - Task 13 Speed Disturbance

13.7 – table

|                             | Calculated | Simulated | Error ± |
|-----------------------------|------------|-----------|---------|
| No Load Speed (No Friction) | 238.1      | 237.1     | 1       |
| Loaded Speed                | 226.36     | 226.4     | 0.004   |

Table 7 - Task 13 Results

### 13.8 – critical analysis

As can be shown in the results collected above it shows that the calculated and measured values correspond correctly. This confirms that the system was created successfully. There are minor errors that can be seen within the results. These errors can be attributed to rounding during the calculation portion or to the degree of accuracy when placing the cursors onto the graph. This task proved the ability of a designed motor to reach a set output value, and when a calculated load torque is added to the motor it causes the motor to stall. Another observation made on the system was the decrease in speed when a suitable load was applied to the motor.

## Task 14 – Proportional Speed Control System

### 14.1 – Motor Model Modifications

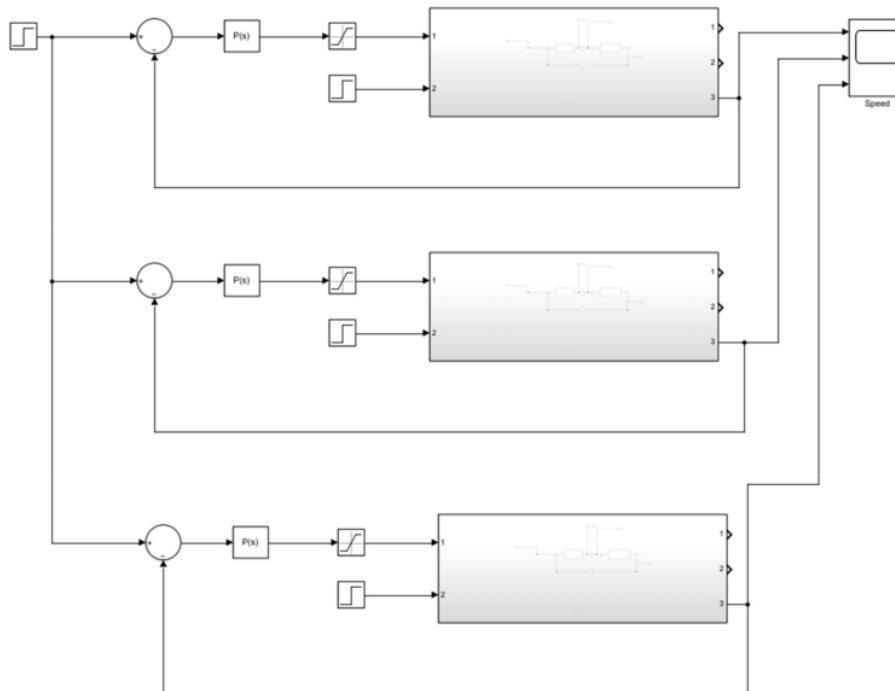


Figure 75 - Proportional System

14.2 – Adjusted Values

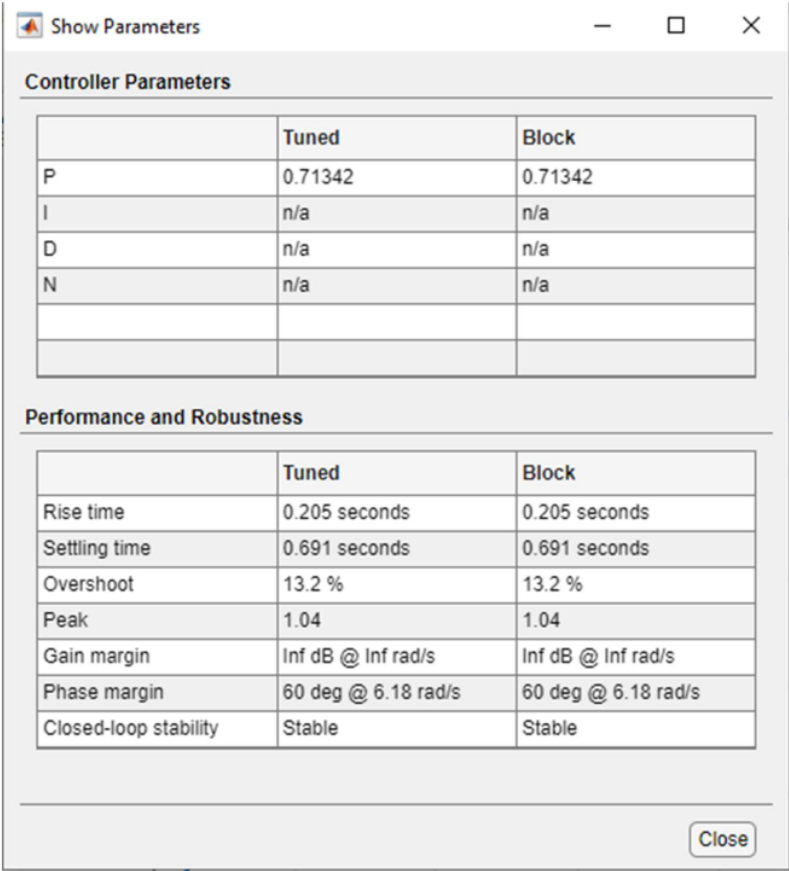


Figure 76 - Control Parameters Tuned

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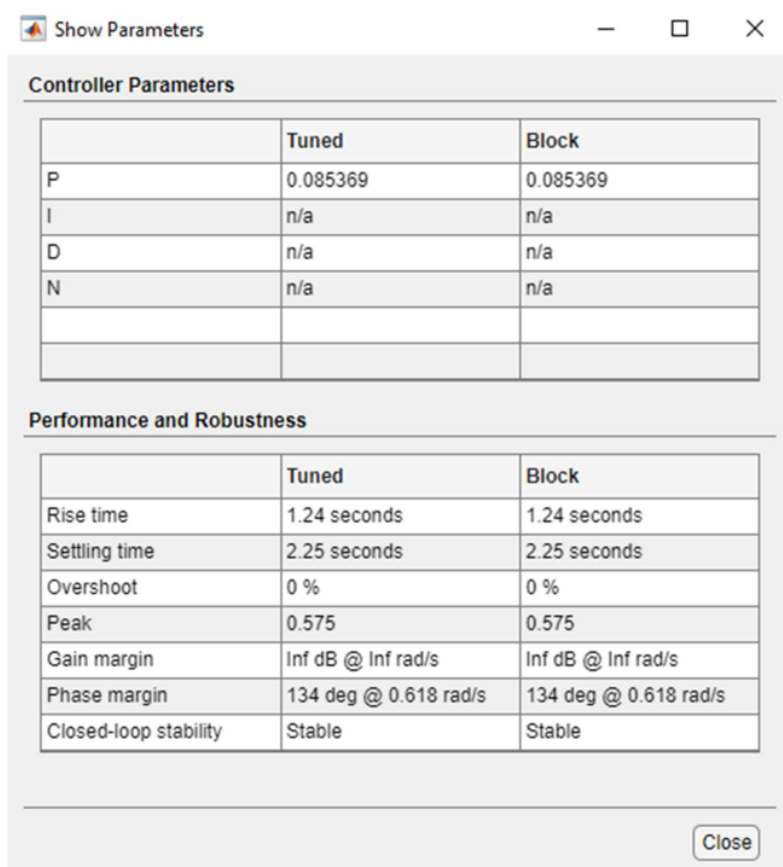


Figure 77 - Control Parameters Slower

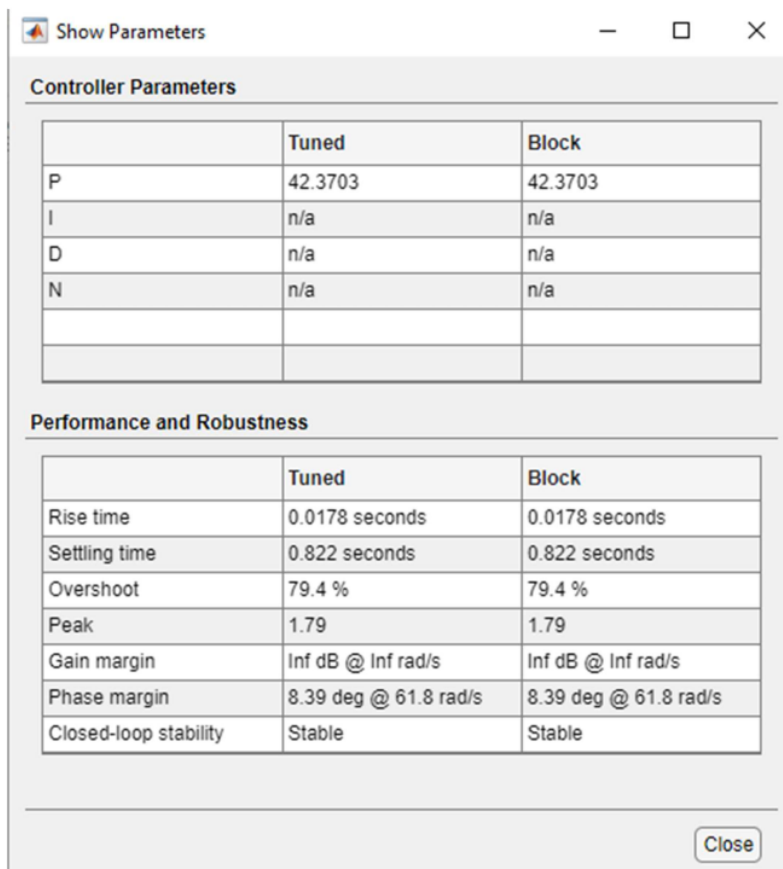


Figure 78 - Control Parameters Faster

### 14.3 – discuss effect of Kp

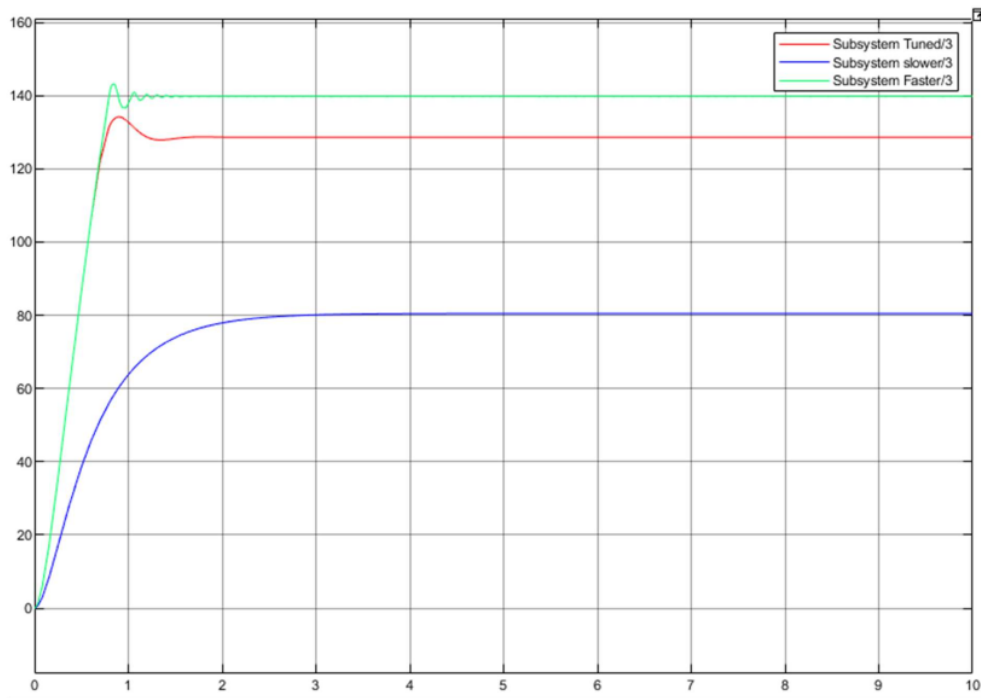


Figure 79 - Proportional effect

### 14.4 – Table

| Kp       | Steady state error | %O/S | Rise time |
|----------|--------------------|------|-----------|
| 0.71342  | 10                 | 13.2 | 0.205     |
| 0.085369 | 60                 | 0    | 1.24      |
| 42.3703  | 0                  | 79.4 | 0.0178    |

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### 14.5 – Critical Analysis

From the results collected it shows the effect that a varying proportional value has to the output of the system. This can be visualised through the various Kp values used within the system. For a singular proportional system, the most efficient Kp value used was 0.71342, this is due to having a minor steady state error, while also having a low-rise time and minimal overshoot. When compared to the other values used the effects on the output change drastically. As a Kp of 0.085369 has no overshoot within the system but it had a steady state error of 60. Likewise, with a Kp value of 42.3703 the steady state error of the system was 0. However, it had a percentage overshoot of 79.4%.

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## Task 15 – Proportional-Integral Speed Control System

### 15.1 – Model Modifications

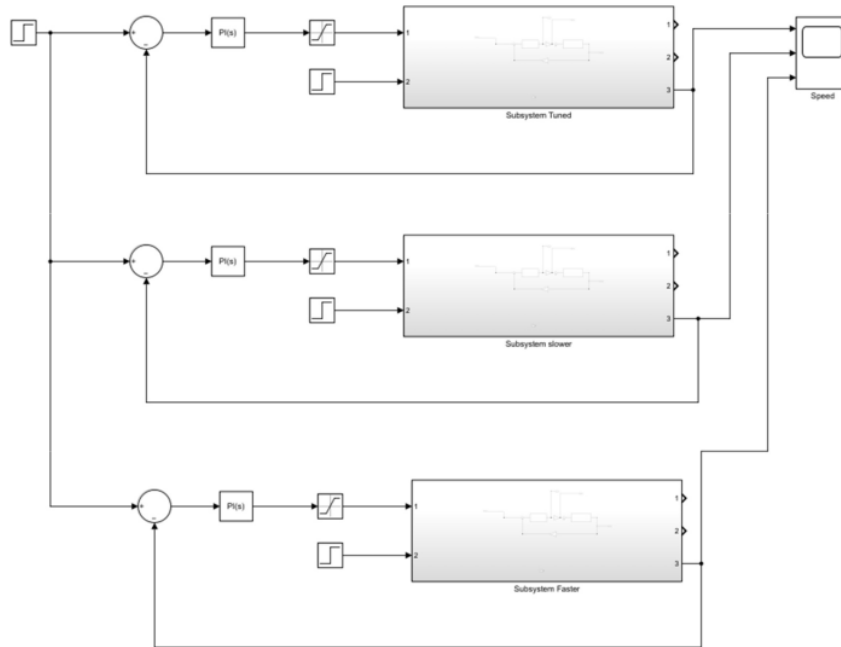


Figure 80 - Task 15 PI System

15.2 – Adjust Values

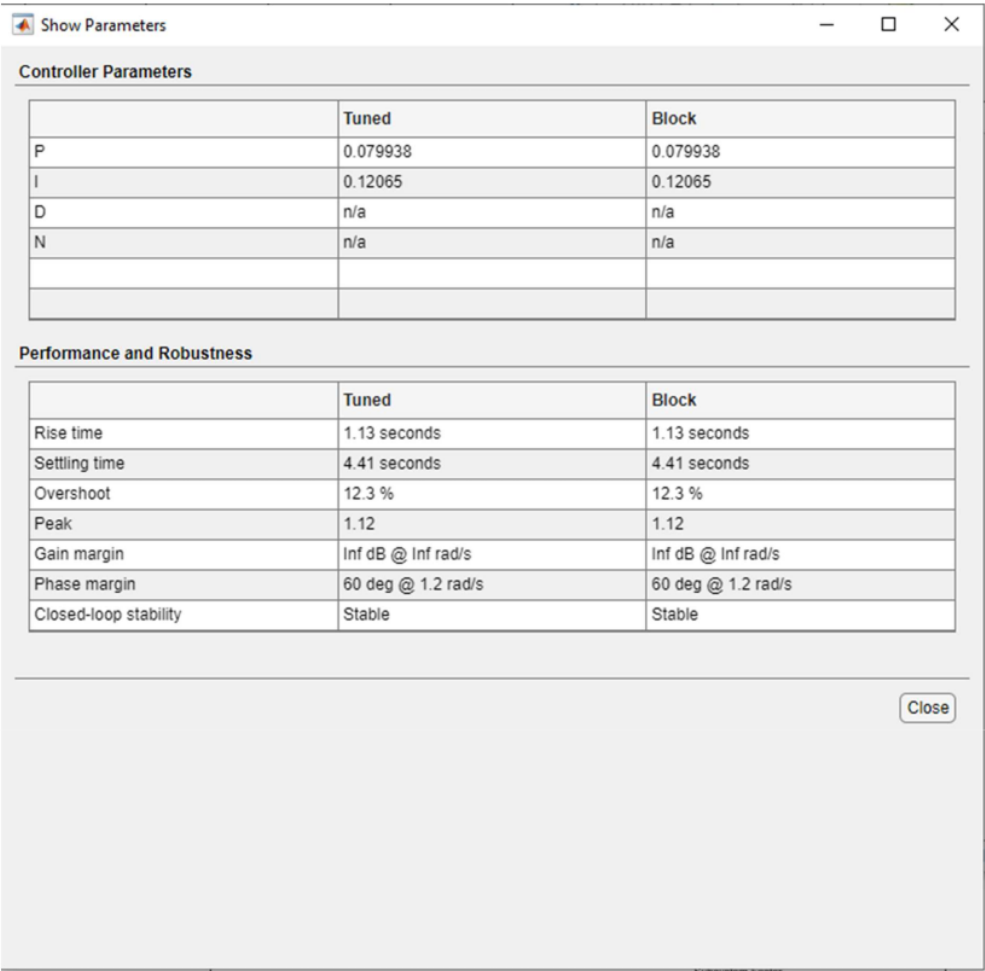


Figure 81 - Task 15 Tuned Characteristics

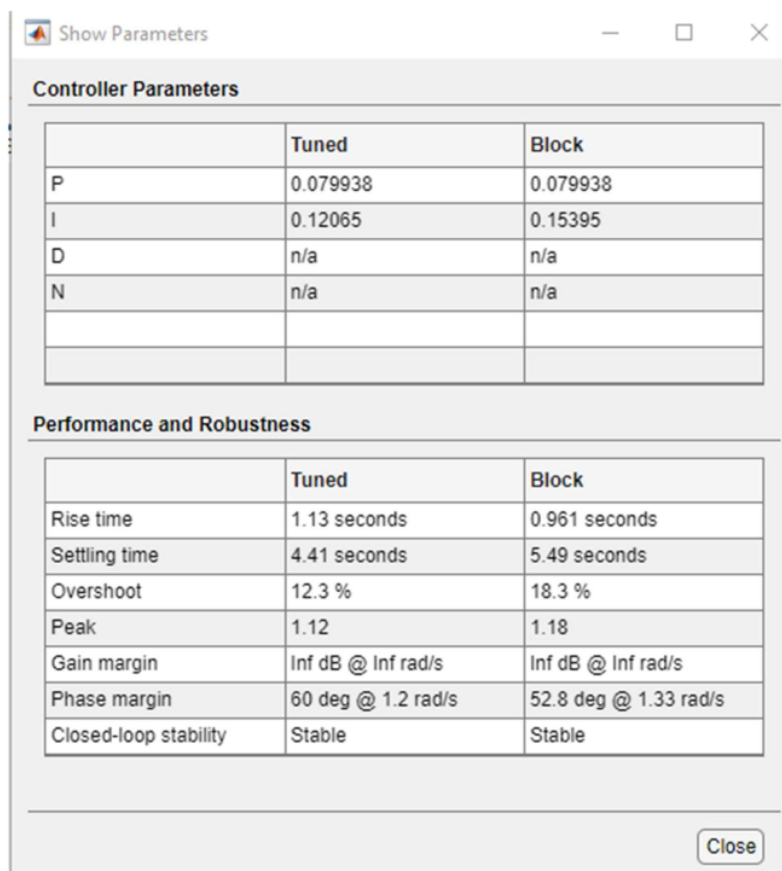


Figure 82 - Task 15 Slower Characteristics

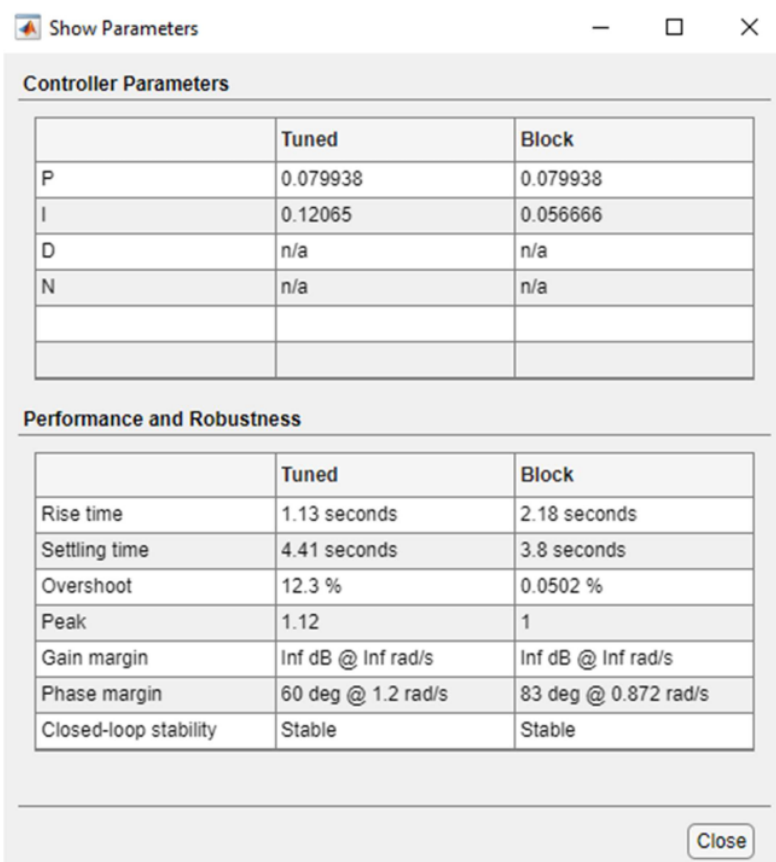


Figure 83 - Task 15 Faster Characteristics

### 15.3 – Summarise all results

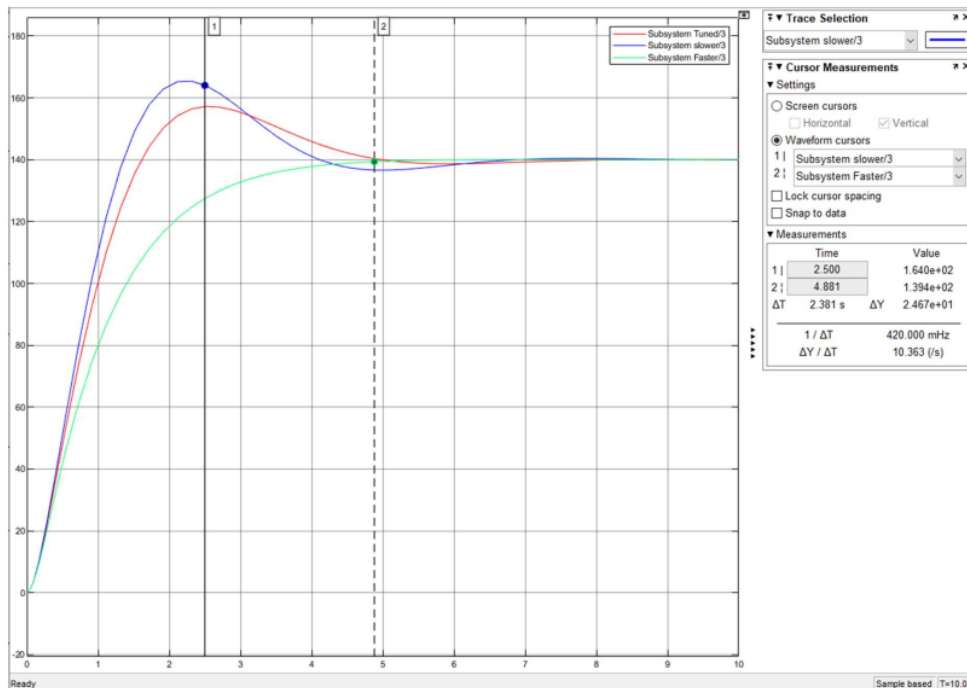


Figure 84 - Task 15 Comparison of Varying Ki

### 15.4 Table of Results

| Ki       | Steady state error | %O/S   | Rise time | Settling Time |
|----------|--------------------|--------|-----------|---------------|
| 0.12065  | 0                  | 12.3   | 1.13      | 4.41          |
| 0.15395  | 0                  | 18.3   | 0.961     | 5.49          |
| 0.056666 | 0                  | 0.0502 | 2.18      | 3.8           |

### 15.5 Critical Analysis

From the results collected during this task. It was to introduce the integral portion of a PID system, while using the tuned proportional value from the previous task. When varying the Ki value, it shows to have different effect on the output of the system. As each of the Ki values different effects percentage overshoot, rise time and settling time. The tuned value for this system is 0.12065, this is tuned for the system by having the most suitable characteristics. However, within various application of this PI system it more beneficial to use the Ki value of 0.056666 as this value generates the lowest percentage overshoot, with a sacrifice to the rise and settling times.

## Task 16 – Proportional-Integral-Derivative Speed Control System

### 16.1 – Model Modifications

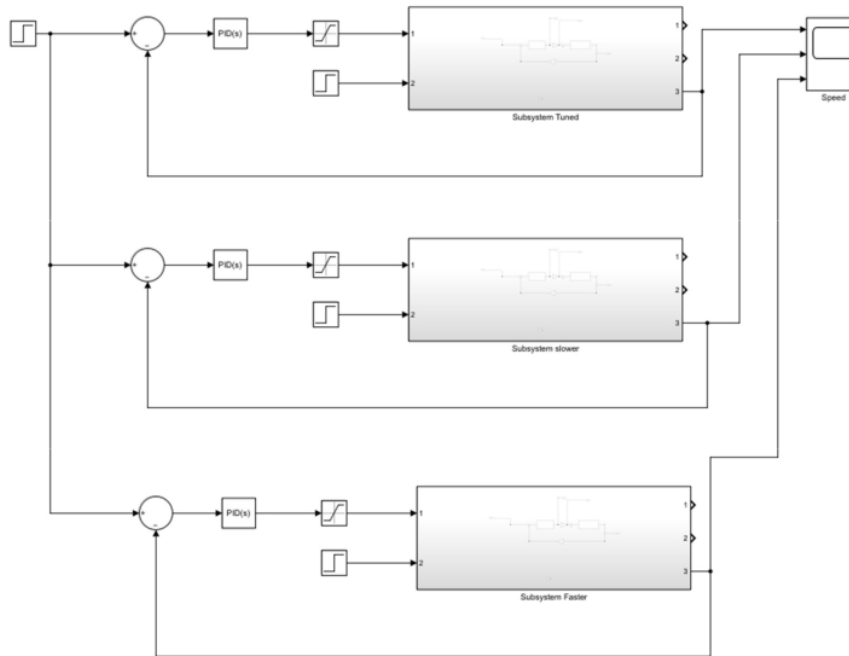


Figure 85 - Task 16 PID System

## 16.2 – Adjusted Values

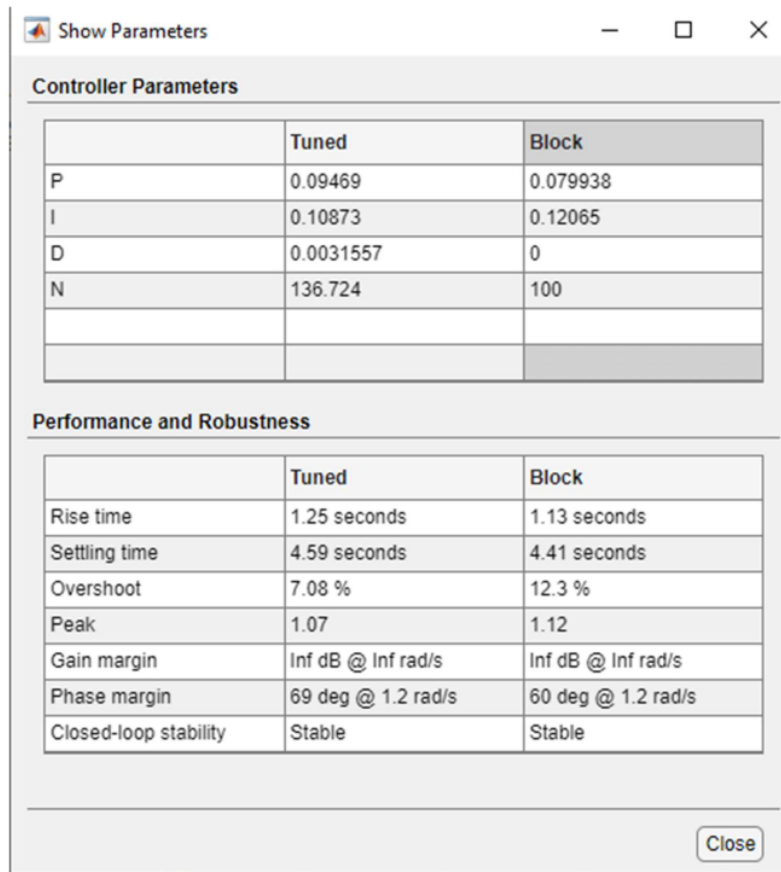


Figure 86 - Task 16 Tuned System

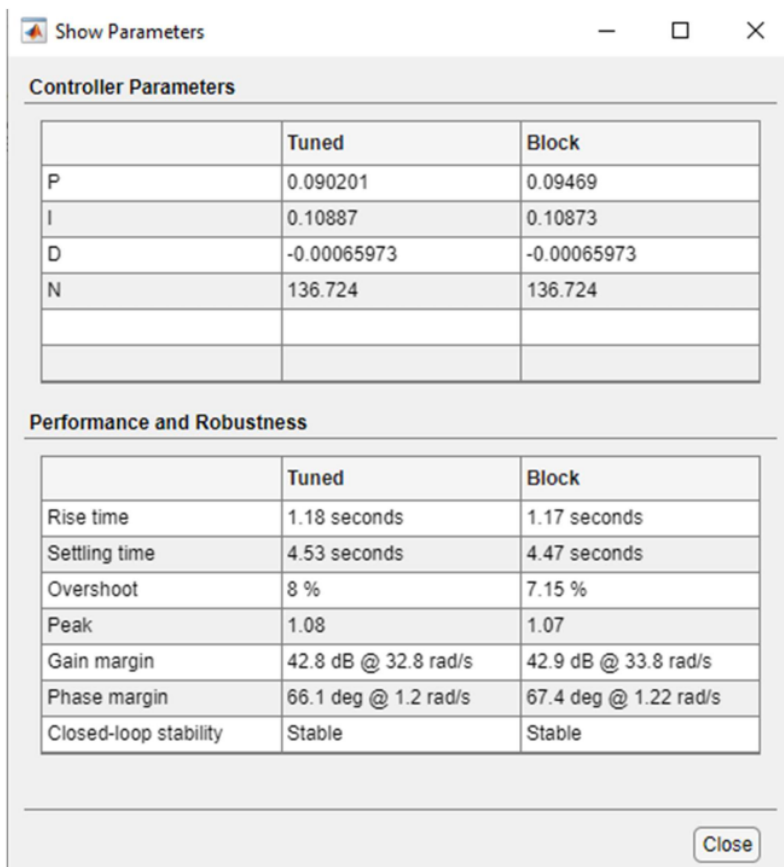


Figure 87 - Task 16 Slower System

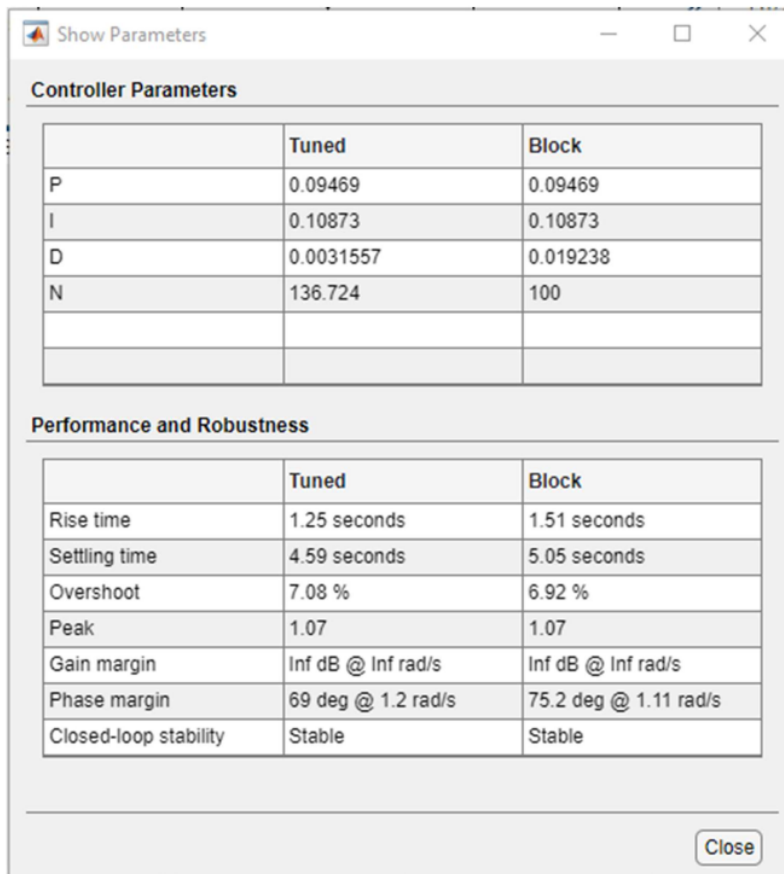


Figure 88 - Task 16 faster Characteristics



### 16.3 – Summarise all results

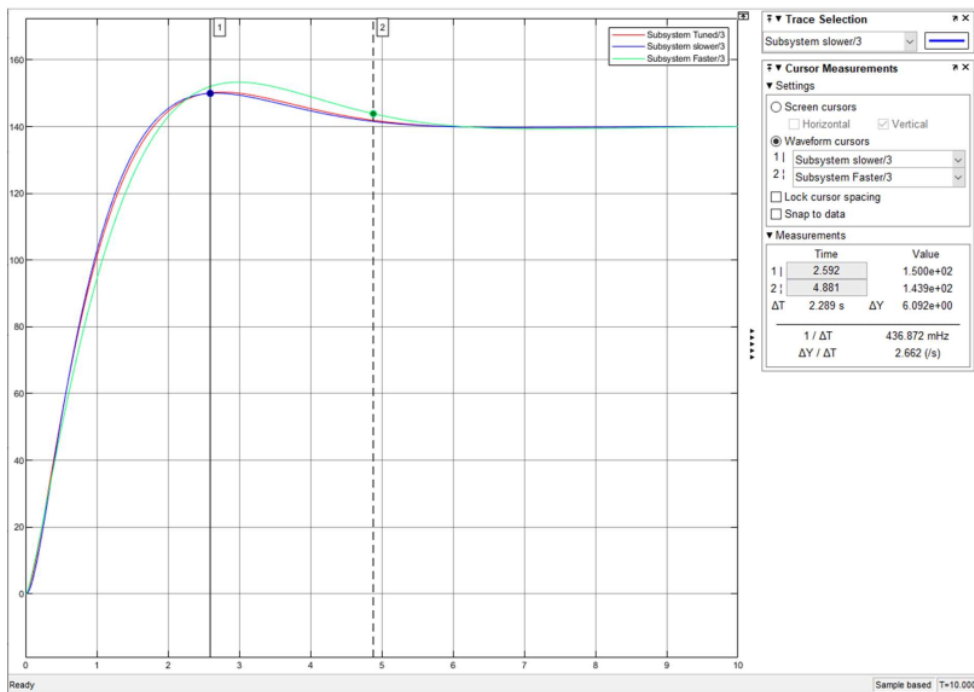


Figure 89 - Task 16 Wave Comparisons

### 16.4 Table of Results

| Kd        | Steady state error | %O/S | Rise time | Settling Time |
|-----------|--------------------|------|-----------|---------------|
| 0.003157  | 0                  | 7.08 | 1.25      | 4.59          |
| -0.000066 | 0                  | 8    | 1.18      | 4.47          |
| 0.019238  | 0                  | 6.92 | 1.51      | 5.05          |

### 16.5 Critical Analysis

For this task it involves the comparison of a varying Kd value within a PID system. With the PID block being tuned, this generates a Kd value of 0.003157, this is designed to be the most efficient Kd value with regards to the percentage overshoot, rise time and settling time. However, when varying the Kd value, with regards to a Kd value of 0.019238. This generated an output signal with the lowest overshoot percentage. However, it was also the slowest to rise and settle on the setpoint.



## Task 17 – Controller Comparisons

### 17.1 – combined Models

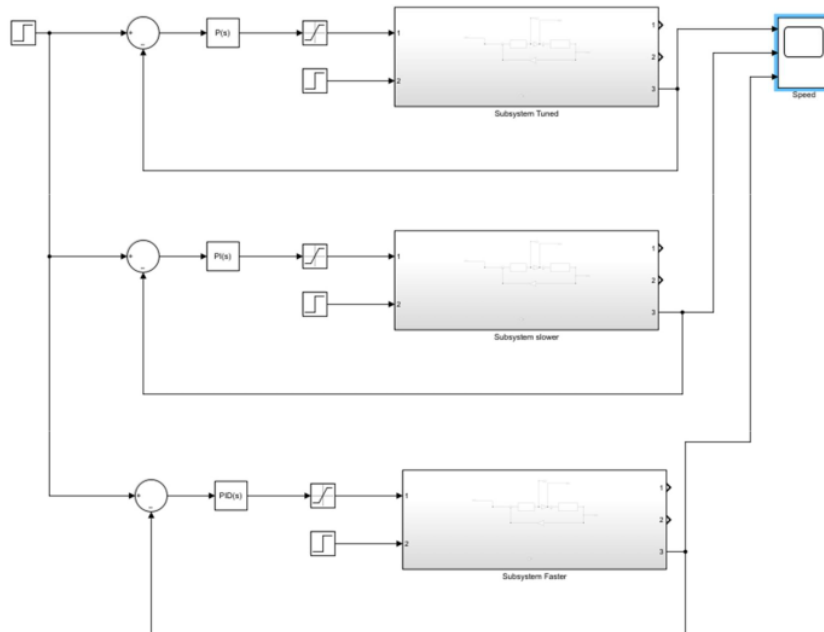


Figure 90 - Task 17 Controller System

## 17.2 – plot responses

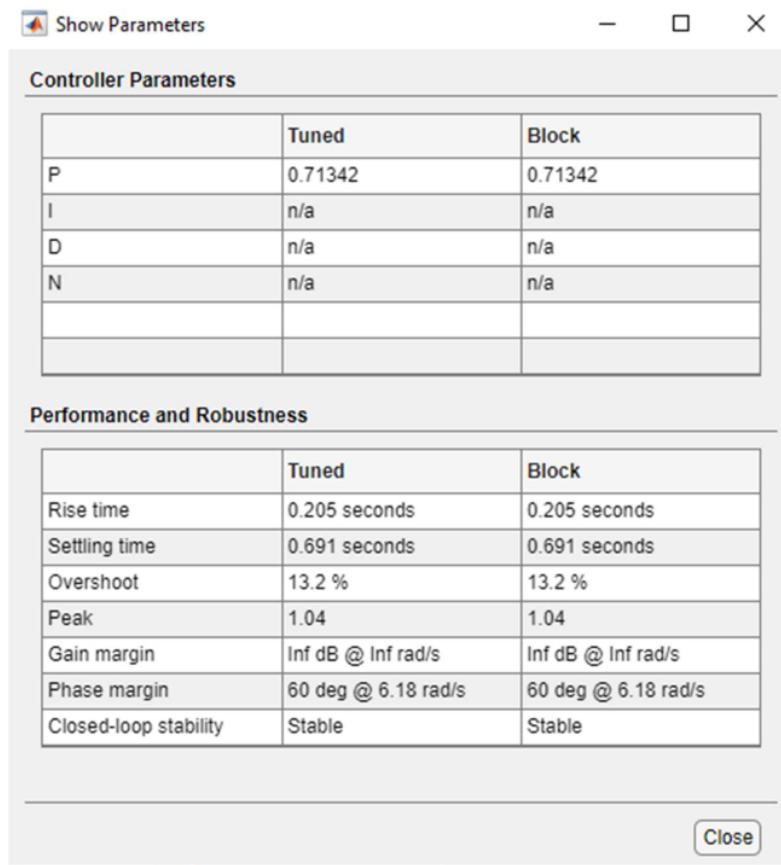


Figure 91 - Task 17 P System

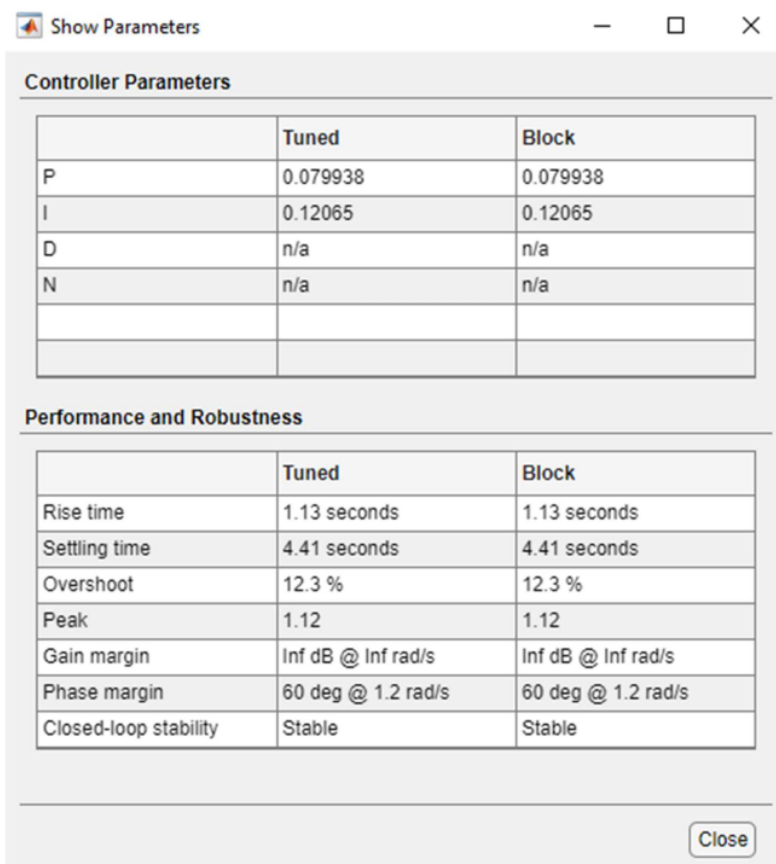


Figure 92 - Task 17 PI System

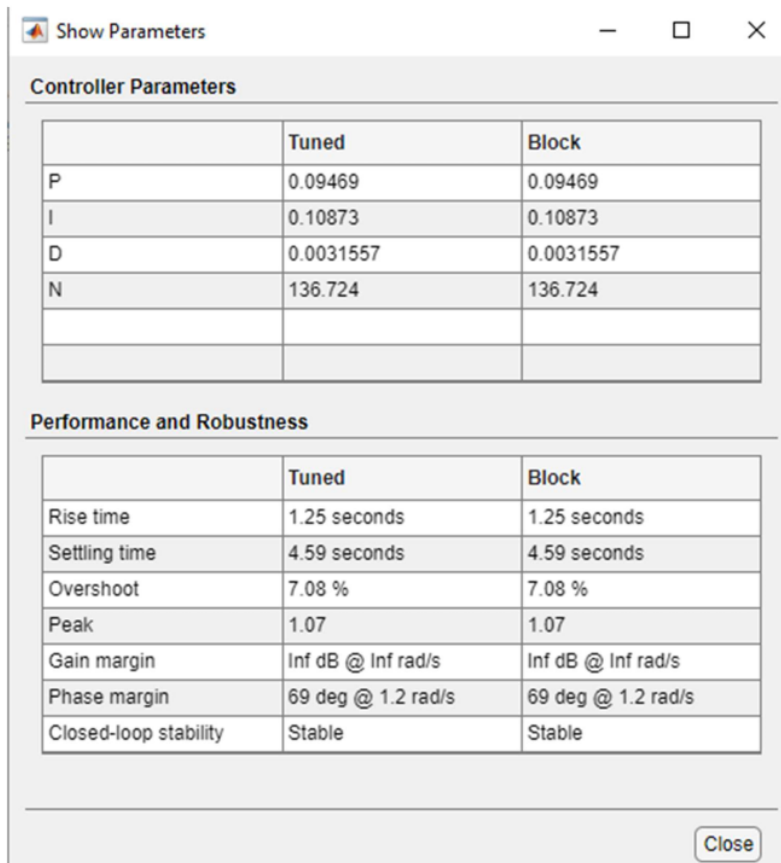


Figure 93 - Task 17 PID System

### 17.3 – Summarise all results

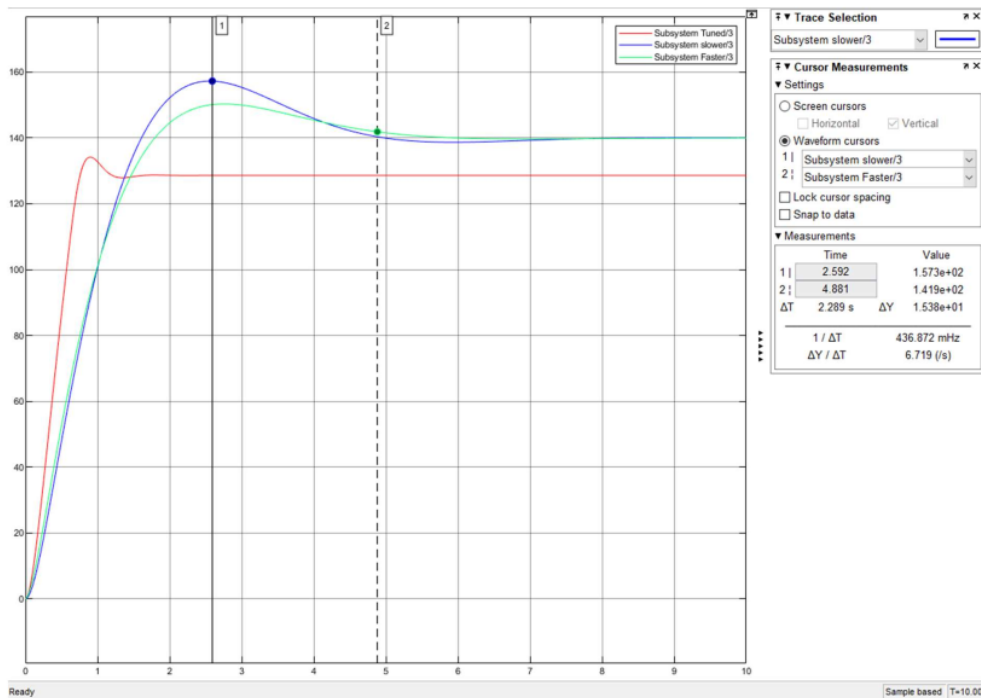


Figure 94 - Task 17 PID Controller Comparison

| Kp      | Ki      | Kd        | Steady state error | %O/S | Rise time | Settling Time |
|---------|---------|-----------|--------------------|------|-----------|---------------|
| 0.71342 | N/A     | N/A       | 10                 | 13.2 | 0.205     | 0.691         |
| 0.79938 | 0.12065 | N/A       | 0                  | 12.3 | 1.13      | 4.41          |
| 0.9469  | 0.10873 | 0.0031557 | 0                  | 7.08 | 1.25      | 4.59          |

### 17.4 Critical Analysis

As shown in the figure above it displays the difference created through distinct types of controllers. From the graph in figure 94 the red line represents the P controller, the blue line represents the PI controller, and the green line represents the PID controller. When a single P controller is used within the system the output signal cannot reach the setpoint value. With the PI controller the output signal reaches the setpoint. However, it has a large overshoot, this is not ideal for control systems. While using the PID controller it has minimal overshoot and settles with a sparse number of oscillations.

Overall, using a single P controller creates difficulties with controlling the output signal and commonly has a steady state error. When applying a PI controller this generates is more accurate than a P controller as it has a reduced overshoot and no steady state error. However, it produces a slower rise and settling time compared to a single P controller.

When using a PID controller this combines the advantages present within the two previous controllers. This allows for the creation of an optimal response. With the addition of a derivative response, creates a better output stabilisation as it can predict the disturbance within the signal by measuring the change in error. Although the PID controller is the most efficient and accurate. The selection of which controller used can vary dependent on required application and the tolerances needed, or the budget of the system.



## Task 18 – Overall Conclusions and Recommendations

Throughout the construction of this assignment there was various principles and knowledge understood and gained. Additionally, different software tools were implemented such as Matlab. This software was fundamentally used during this assignment to create a simulated system for comparison against calculated values. Another piece of knowledge gained was the use of Laplace transforms as they were applied to understand the frequency and transient response of RL and RC circuits. This allowed for a graphical representation to demonstrate the transience of a RL circuit will exponentially grow, and the transience of a RC circuit will exponentially decay. It possible to observe the transience graph changing with respect to the voltage drop across the resistor as the output reaches it steady state at  $5\tau$ .

With regards to tasks 3,4 it compares the difference between a Low pass and High Pass filter. These filters are useful a portion of an output signal needs to be removed. All first order filters have a roll off magnitude of dB. Within the low pass filter the reactance of the capacitor is large when the output frequency is low. This allows for an output frequency to pass through the system until the cut-off frequency is reached. Opposingly on the high pass filter there is no signal aloud to pass through the system until the cut-off been reached at which point it will allow frequencies greater than this value to pass.

Between Tasks 5-8. It was used to help determine the effects of a damping factor being applied within a circuit. The different damping factors that were used during these tasks were overdamped. This is created with a damping factor greater than 1, the effect this has on a system is it causes the output signal to slowly move towards the setpoint with minimal oscillation. An underdamped system is created with a damping factor less than 1. Its effects cause the output signal to move to the setpoint quicker, but it will oscillate around the setpoint for a period. A no damped system is created with a damping factor equal to 0. This causes the output signal to oscillate continuously and never reach the setpoint value. Finally, a critically damped system is created with a damping factor equal to 1. This damping system is the most efficient as it will reach the setpoint value in the quickest time possible without oscillation. These tasks demonstrated how a slight  48 ge to the value of the resistor can drastically change the effect of the output signal.

For the tasks 9,10. Objectives conducted was to observe the frequency effect on electronic systems. The bode plots collected are like those found within task 3 and 4's high and low pass filters. However, a modification made to the circuits within tasks 9 and 10 was an operational amplifier was introduced into the circuit. The effect this has on the output signal is that is provides amplification to the signal as well as gain control.

Task 11 observed the frequency performance of second order electronic circuit. The circuit designed was a Sallen & key Low pass filter with an operational amplifier present. For this system it has a phase shift of  $-90^\circ$ . within this system it is a second order circuit. this means that the roll-off is at two decades, the roll off can be found at  $-40\text{dB}$ . This allows for the circuit to have a more selective of frequencies.

For task 12 it involved an investigation into the prediction of a stability system through the calculation of its pole placement. As the pole present during task 12 was in the left-hand pane (Negative Portion). A gain value within that pane will cause the system to become stable. Whereas, if a gain value is used on the right-hand pane (positive Portion) it causes the system to become unstable.



With regards to task 13 it observes the behaviour of a motor when load is applied to it. As spotted within this task that when a load is applied across a motor the output speed slightly decreases. Additionally, the torque required to stall the motor. Upon testing it was observed that when this torque was reached the output speed of the motor began to drop to 0.

Between the tasks 14-17. These tasks compared the different effects various controllers have on an output signal. The controllers that were used during these tasks were a singular Proportional controller, a Proportional/Integral Controller, and a Proportional/Integral/Derivative Controller. With the use of a singular P controller the output signal will quickly increase rise. However, it is unable to reach the setpoint value. When a PI controller is used on a system the output signal rises slower than a single P controller although a PI controller reaches the setpoint value. However, there was a significant amount of overshoot before settling. When implementing a PID controller. This combines the benefits of both controllers as it will rise to the setpoint value in the fastest time, with minimal overshoot.

An obstacle that was discovered during this assignment was the simulation software Matlab, had numerous issues regarding file placements and cursor alignment. This caused difficulties when collecting data as the cursor placement was inaccurate. A possible recommendation that could be made to this assignment would be to conduct further investigation into higher order filter, this could include cascade filter.

FINAL GRADE

GENERAL COMMENTS

Instructor

67 /100

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PAGE 5



Comment 1

Sub headings should not be in the contents list, it is a confusing list

PAGE 6

PAGE 7

PAGE 8

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PAGE 10



Comment 2

check this TF for accuracy

PAGE 11



Comment 3

explain 0.368



### Comment 4

WW



### Comment 5

define?



### Comment 6

-20



### Comment 7

-20dB



### Comment 8

calculated value?



### Comment 9

define?



### Comment 10

check your measurement of decade



### Comment 11

-20dB/dec



## Comment 12

more theory here, e.g. the TF in terms of component values



## Comment 13

WW



## Comment 14

state root formula



## Comment 15

good analysis



## Comment 16

quantity?



## Comment 17

this needs qualifying

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### Comment 18

these values need explanation, where are they from?



### Comment 19

Quantity?



### Comment 20

rather vague, what about the roll-off, effect of the locus and Q?

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### Comment 21

where is the circuit and transfer function?

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### Comment 22

GR



### Comment 23

you have not clearly defined all quantities

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### Comment 24

TF?



### Comment 25

definitions missing

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### Comment 26

GR



### Comment 27

again, these statements need qualifying

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### Comment 28

error here

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### Comment 29

where is the explanation of these measurements? and a table comparing with theoretical results?

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### Comment 30

WW



### Comment 31

equation?



### Comment 32

needs explanation

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### Comment 33

GR



### Comment 34

Show the TF first, explain what the task is first



### Comment 35

Very good, you are correct



### Comment 36

relate to argand diagram



### Comment 37

derivation of TF?



### Comment 38

show source of these equations



### Comment 39

this needs more explanation, relate to standard form

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### Comment 40

units?

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### Comment 41

This image needs an explanation of terms

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### Comment 42

%OS does not not look correct



### Comment 43

compare with what you would expect from theory

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### Comment 44

there needs to be some context, ie. an explanation of the parameters

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### Comment 45

Too many images which seem to be showing the same thing, rather show the process once and summarize in results and analysis.

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### Comment 46

make a comparison of the effect of changing  $K_d$  with what theory predicts

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### Comment 47

Good work

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### Comment 48

Good analysis

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### Comment 49

confusing statement, poles not gain should be discussed

THOMAS WOODS

67

### 1. ENGAGEMENT WITH LITERATURE



NA

0

### 2. KNOWLEDGE AND UNDERSTANDING



Explanations are mostly correct, some are a bit vague in areas and there are some key definitions missing in some areas, Mathematical explanations are correct but lack a bit of background information as marked. 20/30

20

### 3. COGNITIVE AND INTELLECTUAL



Analysis is sound for the most part, you have summarized the results correctly. There is a lack of context in terms of relating the results to theory in a few areas as marked. Conclusion is good. 20/30

20

### 4. PRACTICAL APPLICATION



An advanced use of simulation software, results are clear and well presented. You have provided many unexplained images in task 14 - 16, you could have developed the theory more and concentrated on explaining the process with just an example image rather than displaying them all.  
21/30

21

## 5. TRANSFERABLE SKILLS



Can communicate well and in a suitable and consistent manner, there are a few minor, typos, grammar and incorrect words being used in some of the text, but overall a well presented report. 6/10

6