

2320271

by Lewis Bell

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Introduction

Gaining a thorough understanding of advanced electrical and electronic engineering concepts, with an emphasis on control systems, is the aim of this project. In order to forecast the performance of these systems, the assignment will employ theoretical approaches to analyse, model, and simulate essential ideas. The goal is to critically evaluate the behaviour of electrical circuits and control systems under a range of scenarios by using methodical methodologies. This will help with the design and optimisation of these systems by utilising both analytical and simulation tools.

Task 1

1.1

This is a first order RL electrical circuit's transient analysis.

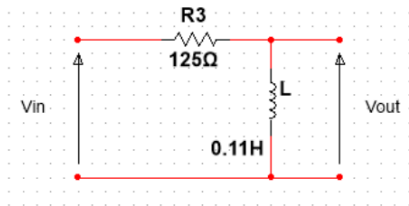


Figure 1

Here are the specific values used within this task.

$$R = 125\Omega \quad L = 0.11H$$

To calculate Tau the equation below was used.

$$\tau = \frac{L}{R} = \frac{0.11}{125} = 8.8 \times 10^{-4} s \text{ (0.00088s)}$$

1.2

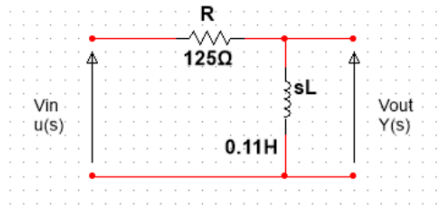


Figure 2

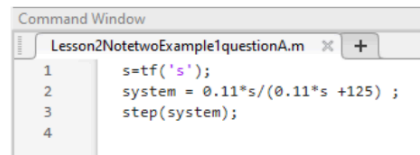
$$\text{Laplace Formula} = H(s) = \frac{sL}{sL + R} = \frac{0.11s}{0.11s + 125}$$

Transfer Function

$$\begin{aligned} G(s) &= \frac{Y(s)}{U(s)} = \frac{sL}{sL + R} \\ &= \frac{s \frac{L}{R}}{1 + s \frac{L}{R}} \\ &= \frac{\tau s}{\tau s + 1} \\ &= \frac{8.8 \times 10^{-4} s}{8.8 \times 10^{-4} s + 1} \text{ or } \frac{0.11s}{0.11s + 125} \end{aligned}$$

1.3

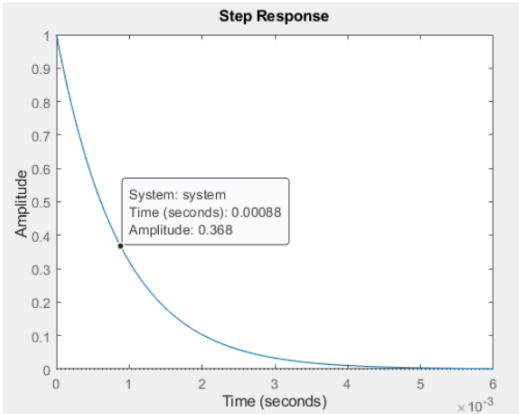
A suitable model program may then be created using MATLAB and the Transfer Function. This software would be used to measure the time constant and examine the transient response to a 1V step input.



```

Command Window
Lesson2NotetwoExample1questionA.m  X +
1      s=tf('s');
2      system = 0.11*s/(0.11*s +125) ;
3      step(system);
4
  
```

Figure 3



6

Figure 4

The graph, which was supplied by Matlab, created an exponential decay as seen in Figure 4 above. This is because the circuit is first order.

1.4

The computed and simulated values for the time constant are displayed in the table below (Table 1).

	Simulated	Calculated	Error
Tau	0.00088s	0.00088s	0s

Table 1

1.5

The results make it very evident that there are no mistakes. Given that the circuit is first order $e^{-1} = 0.368$.

e^{-1} as shown above comes from the fact that;

$$y(t) = U'(\text{Step Input}) \left(e^{-\frac{t}{\tau}} \right) \text{ when } t \text{ is equal to } \tau.$$

$$y(t) = U(e^{-1})$$

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The response is an exponential decay. Tau has been measured at this location on the graph for that reason in which validates the analysis.

Task 2

2.1

The component values, which were selected at random in accordance with the brief, are shown below, just as in task 1, but It's an RC circuit this time.

This is a first order RC electrical circuit's transient analysis.

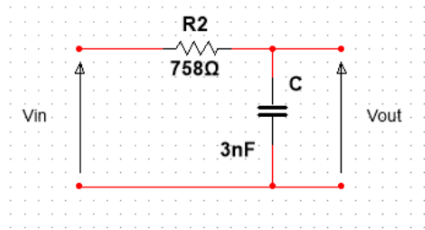


Figure 5

Here are the specific values used within this task.

$$R = 758\Omega \quad C = 3\text{nF}$$

$$\tau = RC = 758 \times 3 \times 10^{-9} = 2.274 \times 10^{-6} \text{ s } (0.000002274 \text{ s})$$



2.2

In order to guarantee that the transfer function was developed in terms of the time constant, a suitable Laplace model was constructed below.

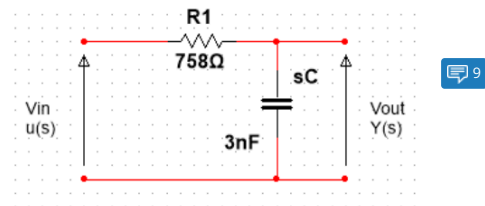


Figure 6

$$\text{Laplace Formula} = H(s) = \frac{1}{RCs + 1}$$

Transfer Function

$$\tau = RC$$

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

$$H(s) = \frac{1}{758 \times 3 \times 10^{-9} + 1}$$

10

2.3

```
1 s = tf('s');
2 system = 1/((758) * (3*10^-9)*s +1);
3 step (system);
```

Figure 7

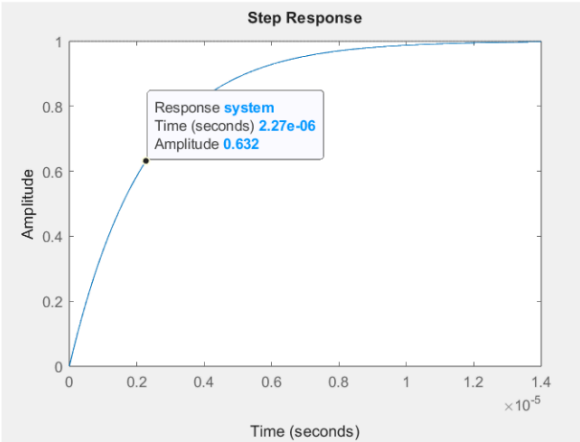


Figure 8

As shown above in Figure 8 is a graph provided by Matlab, the graph produced an exponential growth this is due to the circuit being a second order.

11

2.4

	Simulated	Calculated	Error
Tau	0.00000227	0.000002274s	0.000000004s

Table 2

2.5

The results make it evident that there are no errors. As the circuit is first order, the response is exponential growth and $1 - e^{-1} = 0.632$.

$$y(t) = 'U'(\text{Step Input}) \left(e^{-\frac{t}{\tau}} \right) \text{ when } t \text{ is equal to } \tau. \quad \text{12}$$

$$y(t) = U(1 - e^{-1})$$

To prove the analysis tau has been measured at this point, and the extremely small error is due to the fact the simulation equipment doesn't provide a result with enough decimal places.

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Task 3

3.1

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

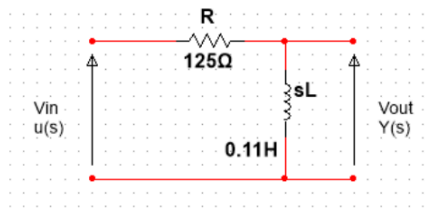


Figure 9

Here are the specific values used within this task, the same used from Task 1.

$$R = 125\Omega \quad L = 0.11H$$

$$\text{Cut off frequency} = \omega c = \frac{R}{L} = \frac{125}{0.11} = 1136.36 \text{ Rad/S}$$

$$\text{Laplace Formula} = H(s) = \frac{\frac{1}{\omega c}}{\frac{1}{\omega c} + 1} = \frac{s}{s + \omega c} = \frac{1}{s + 1136.36}$$

3.2

```
MattlabTask.m
1 s = tf('s');
2 system = s/(s+1136.36);
3 bode(system) |;
4 grid on
```

Figure 10

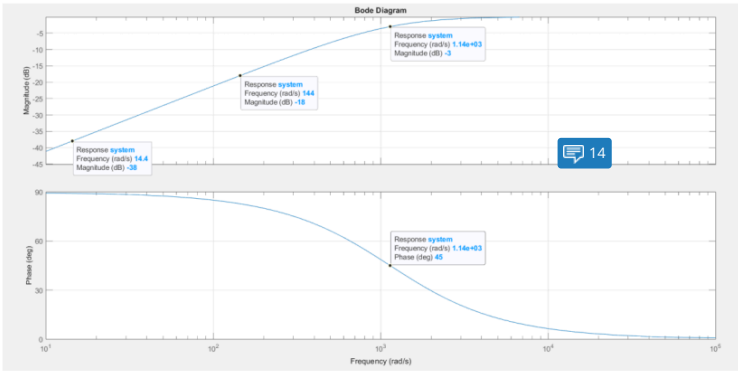


Figure 11

3.3

	Calculated	Measured
ω_c	1136.36 Rad/s	1.14×10^3 /1140 Rad/s
Phase	45 degrees	45 degrees
Roll off	20dB	20dB

Table 3

3.4

This is a high pass filter because of the component layout. Only high frequencies exceeding the -3dB threshold are permitted to pass through, due to the fact at the -3dB point the cut off frequency is provided. There is a very minimal error within the ω_c value. In which still consequently, verifies the analysis. At natural frequency, there is a 45 degrees phase shift. The roll-off is 20dB since it is a first order circuit.

Task 4

4.1

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

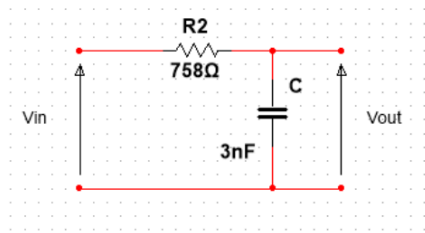


Figure 12

The values chosen for this task are the same as Task 2, $R = 758$ $C = 3\text{nF}$

Calculated cut off frequency $= \omega_c = \frac{1}{RC} = \frac{1}{758 \times 3 \times 10^9} = 4.39 \times 10^{-13} \text{ rad/s}$

Laplace Formula $= H(s) = \frac{1}{\omega_c s + 1} = \frac{1}{\frac{1}{\omega_c} + s} = \frac{\omega_c}{s + \omega_c} = \frac{4.39 \times 10^{-13}}{s + 4.39 \times 10^{-13}}$

4.2

```

1  s = tf('s');
2  system = 4.39*10^-13/ ((s) + 4.39*10^-13);
3  bode |<system);
4  grid on

```

Figure 13

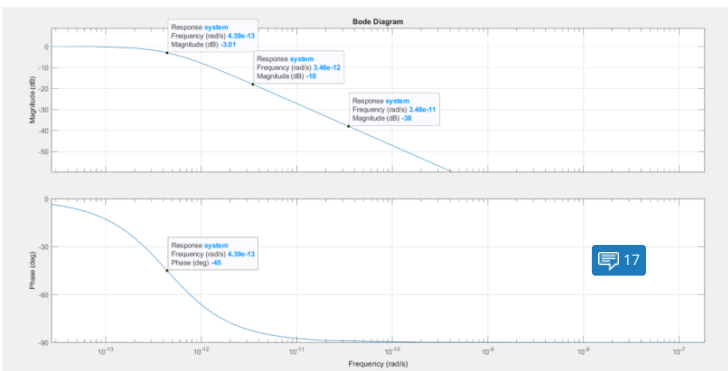


Figure 14

4.3

	Calculated	Measured
ωc	4.39×10^{-13}	4.39×10^{-13}
Phase	45 Degrees	45 Degrees
Roll off	20 dB	20dB

Table 4

4.4

This is a low pass filter because of the way the components are arranged. Only low frequencies before the -3dB threshold are permitted to pass through, because of the fact at -3dB the cut off frequency value is provided. In which still consequently, verifies the analysis. At natural frequency, there is a 45 degrees phase shift. The roll-off is 20dB since it is a first-order circuit.



Task 5

5.1

As seen from the circuit below we can see that we have all component values including Resistance, inductance and capacitance. For this task the inductance and capacitance stay the same throughout, but the resistance value will change to see the damping effect, the different damping will include underdamped, overdamped, critically damped and no damping.

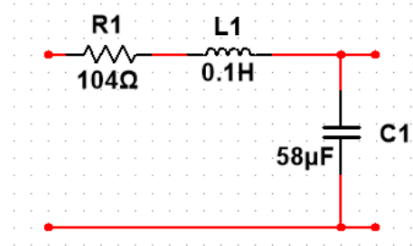


Figure 15

The component values chosen are;

$R = 104\Omega$ Overdamped, 21Ω Underdamped, 83.04547985Ω Critically Damped and 0.0000001Ω for no damping.

$L = 0.1\text{H}$



$C = 58\mu\text{F}$

$K = 1$

5.2

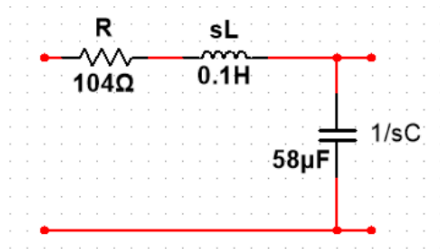


Figure 16

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



5.3

The natural frequency and the damping factors were calculated via these equations.

$$\text{Natural frequency} = W n = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.1 \times 58 \times 10^{-6}}} = 415.22 \text{ Rad/S}$$

The natural frequency will be the same for each circuit.

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

Overdamped

$$\text{Damping factor} = \zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{104}{2} \sqrt{\frac{58 \times 10^{-6}}{0.1}} = 1.25$$

$$H(s) = \frac{K W n^2}{s^2 + 2 \zeta W n s + W n^2} = \frac{1 \times 415.22^2}{s^2 + ((2 \times 1.25 \times 415.22) \times s) + 415.22^2}$$

Underdamped

To attain an underdamped value the resistance value was changed to 21Ω.

$$\text{Damping factor} = \zeta = \frac{R}{C} \sqrt{\frac{C}{L}} = \frac{21}{2} \sqrt{\frac{58 \times 10^{-6}}{0.1}} = 0.252$$

$$H(s) = \frac{K W n^2}{s^2 + 2 \zeta W n s + W n^2} = \frac{1 \times 415.22^2}{s^2 + ((2 \times 0.686 \times 415.22) \times s) + 415.22^2}$$

Critically damped

To achieve a circuit that is critically damped. One must be the damping factor. by employing zeta as one and rewriting the damping factor equation  23 instance. This can be made possible.

$$R = \frac{2 \times \zeta}{\left(\sqrt{\frac{C}{L}}\right)} = \frac{2 \times 1}{\left(\sqrt{\frac{58 \times 10^{-6}}{0.1}}\right)} = 83.04547985 \Omega \text{ (ANS)}$$

$$\text{Damping factor} = \zeta = \frac{R}{C} \sqrt{\frac{C}{L}} = \frac{(ANS)}{2} \sqrt{\frac{58 \times 10^{-6}}{0.1}} = 1$$

$$H(s) = \frac{K W n^2}{s^2 + 2 \zeta W n s + W n^2} = \frac{1 \times 415.22^2}{s^2 + ((2 \times 1 \times 415.22) \times s) + 415.22^2}$$

No damping

To get a damping factor near zero, 0.0000001 Ω was resistance figure used.

$$\text{Damping factor} = \zeta = \frac{R}{C} \sqrt{\frac{C}{L}} = \frac{0.0000001}{2} \sqrt{\frac{58 \times 10^{-6}}{0.1}} = 1.204 \times 10^{-9}$$

$$H(s) = \frac{K W n^2}{s^2 + 2 \zeta W n s + W n^2} = \frac{1 \times 415.22^2}{s^2 + ((2 \times 1.204 \times 10^{-9} \times 415.22) \times s) + 415.22^2}$$

5.4

All Matlab code and graph is from the Laplace transform within 5.3 for every damping state.

Overdamped

```
1 s = tf('s');
2 system = 415.22^2/(s^2 + 2*1.25*415.22*s + 415.22^2);
3 step(system);
4 grid on
```

Figure 17

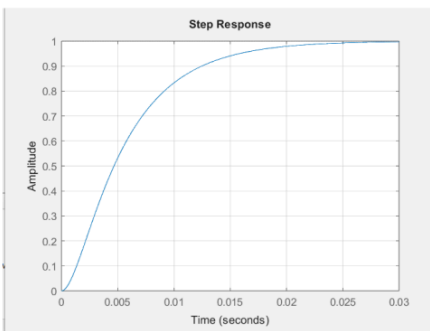


Figure 18

Underdamped

```
1 s = tf('s');
2 system = 415.22^2/(s^2 + 2*0.252*415.22*s + 415.22^2);
3 step(system);
4 grid on
```

Figure 19

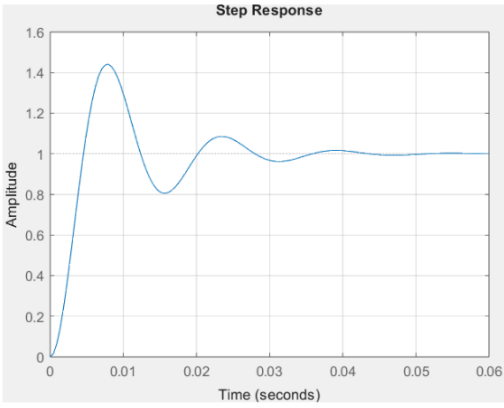


Figure 20

Critically damped

```
1 s = tf('s');  
2 system = 415.22^2/(s^2 + 2*1415.22*s + 415.22^2);  
3 step (system);  
4 grid on
```

Figure 21

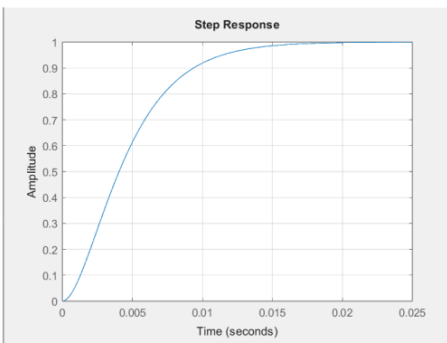


Figure 22

No damping

```
1 s = tf('s');
2 system = 415.22^2/(s^2 + 2*1.204*10^-9*415.22*s + 415.22^2);
3 step (system);
4 grid on
```

Figure 23

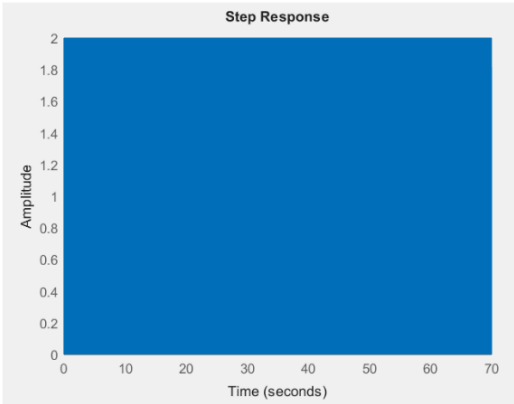


Figure 24

5.5

Resistor Value(Ω)	Damping factor(ς)	Effect
104	1.25	Underdamping
57	0.686	Overdamping
83.04547985	1	Critically damped
0.0000001	1.204×10^{-9}	No damping

Table 5

5.7

The creation of the graphs has validated every analysis. It is evident that the damping variables have an impact on the circuits and their characteristics. As it is a

second order circuit, it was growing. The overshooting was absent in the critically damped. No damping, there were oscillations and the system would not stabilise. Though not exactly, the over-damped circuit gradually approaches a state of stability. After rapidly reaching equilibrium, underdamping overshoot and oscillated for a while.



Task 6

6.1

Within this task there are 6 different resistance values used to create a bode plot, the 6 values for R1 used are 104Ω, 83.04547985 Ω, 21 Ω, 17 Ω, 7.5 Ω & 1.3 Ω. These values are used within the calculations below to find ζ , along with the component values of 0.1H and 58μF. The same circuit is used throughout as shown in figure 25, the only difference will be depending on what damper is being produced the R1 value will change to one of the specifics listed prior.

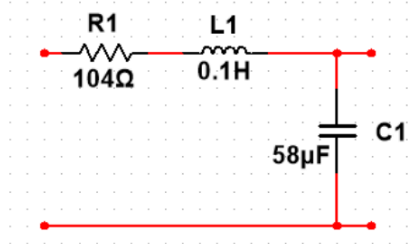


Figure 25

Below is the transfer function for this specific circuit configuration.

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



Natural frequency at oscillation

$$\omega_n = \frac{1}{\sqrt{LC}}$$

Damping Factor

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

Frequency for max amplitude

$$\omega_m = \sqrt{\frac{1}{LC} - \frac{1}{2} \left(\frac{R}{L}\right)^2}$$

Quality Factor

$$Q = \frac{1}{R} \sqrt{\frac{C}{L}}$$

Resonant frequency

$$\omega_o = \frac{1}{\sqrt{L \times C}}$$

Overdamped

Using the same values as within the previous task(5), the resistance value for the overdamped is 104Ω . All answers shown below, the equations for which are shown within 6.1.

$$\zeta = \frac{104}{2} \sqrt{\frac{58 \times 10^{-6}}{0.1}} = 1.25$$

$$\omega_m = \sqrt{\frac{1}{0.1 \times 58 \times 10^{-6}} - \frac{1}{2} \left(\frac{104}{0.1}\right)^2} = 606.9482737$$

$$Q = \frac{1}{104} \sqrt{\frac{0.1}{58 \times 10^{-6}}} = 0.3992571147$$

In terms of transfer function.

$$H(s) = \frac{\frac{1}{LC}}{s^2 + \left(\left(\frac{R}{L}\right)xs\right) + \frac{1}{LC}} = H(s) = \frac{172413.7931}{s^2 + \left(\left(\frac{104}{0.1}\right)xs\right) + 172413.7931}$$

Critically damped

Using the same values as within the previous task(5), the resistance value for the critically damped is 83.04547985Ω. All answers shown below, the equations for which are shown within 6.1.

$$\zeta = \frac{83.04547985}{2} \sqrt{\frac{58 \times 10^{-6}}{0.1}} = 1$$

$$Wm = \sqrt{\frac{1}{0.1 \times 58 \times 10^{-6}} - \frac{1}{2} \left(\frac{83.04547985}{0.1} \right)^2} = 415.2273993$$

$$Q = \frac{1}{83.04547985} \sqrt{\frac{0.1}{58 \times 10^{-6}}} = 0.5$$

In terms of transfer function.

$$H(s) = \frac{\frac{1}{LC}}{s^2 + \left(\left(\frac{R}{L}\right)xs\right) + \frac{1}{LC}} = H(s) = \frac{172413.7931}{s^2 + \left(\left(\frac{83.04547985}{0.1}\right)xs\right) + 172413.7931}$$

Underdamped(1)

Using the same values as within the previous task(5), the resistance value for the underdamped is 21Ω. All answers shown below, the equations for which are shown within 6.1.

$$\zeta = \frac{21}{2} \sqrt{\frac{58 \times 10^{-6}}{0.1}} = 0.252$$

$$Wm = \sqrt{\frac{1}{0.1 \times 58 \times 10^{-6}} - \frac{1}{2} \left(\frac{21}{0.1} \right)^2} = 387.767$$

$$Q = \frac{1}{21} \sqrt{\frac{0.1}{58 \times 10^{-6}}} = 1.97727333$$

In terms of transfer function.

$$H(s) = \frac{\frac{1}{LC}}{s^2 + \left(\left(\frac{R}{L} \right) x s \right) + \frac{1}{LC}} = H(s) = \frac{172413.7931}{s^2 + \left(\left(\frac{21}{0.1} \right) x s \right) + 172413.7931}$$

Underdamped(2)

Using the same values as within the previous task(5), the resistance value for the underdamped is 17Ω. All answers shown below, the equations for which are shown within 6.1.

$$\zeta = \frac{17}{2} \sqrt{\frac{58 \times 10^{-6}}{0.1}} = 0.204$$

$$Wm = \sqrt{\frac{1}{0.1 \times 58 \times 10^{-6}} - \frac{1}{2} \left(\frac{17}{0.1} \right)^2} = 397.446$$

$$Q = \frac{1}{17} \sqrt{\frac{0.1}{58 \times 10^{-6}}} = 2.442514113$$

In terms of transfer function.

$$H(s) = \frac{\frac{1}{LC}}{s^2 + \left(\left(\frac{R}{L} \right) x s \right) + \frac{1}{LC}} = H(s) = \frac{172413.7931}{s^2 + \left(\left(\frac{17}{0.1} \right) x s \right) + 172413.7931}$$

Underdamped(3)

Using the same values as within the previous task(5), the resistance value for the underdamped is 7.5Ω. All answers shown below, the equations for which are shown within 6.1.

$$\zeta = \frac{7.5}{2} \sqrt{\frac{58 \times 10^{-6}}{0.1}} = 0.0903$$

$$Wm = \sqrt{\frac{1}{0.1 \times 58 \times 10^{-6}} - \frac{1}{2} \left(\frac{7.5}{0.1} \right)^2} = 411.826$$

$$Q = \frac{1}{7.5} \sqrt{\frac{0.1}{58 \times 10^{-6}}} = 5.536365324$$

In terms of transfer function.

$$H(s) = \frac{\frac{1}{LC}}{s^2 + \left(\frac{R}{L} \right) s + \frac{1}{LC}} = H(s) = \frac{172413.7931}{s^2 + \left(\frac{7.5}{0.1} \right) s + 172413.7931}$$

Underdamped(4)

Using the same values as within the previous task(5), the resistance value for the underdamped is 1.3Ω. All answers shown below, the equations for which are shown within 6.1.

$$\zeta = \frac{1.3}{2} \sqrt{\frac{58 \times 10^{-6}}{0.1}} = 0.0156$$

$$W_m = \sqrt{\frac{1}{0.1 \times 58 \times 10^{-6}} - \frac{1}{2} \left(\frac{1.3}{0.1} \right)^2} = 415.125$$

$$Q = \frac{1}{1.3} \sqrt{\frac{0.1}{58 \times 10^{-6}}} = 31.94056917$$

In terms of transfer function.

$$H(s) = \frac{\frac{1}{LC}}{s^2 + \left(\frac{R}{L} \right) s + \frac{1}{LC}} = H(s) = \frac{172413.7931}{s^2 + \left(\frac{1.3}{0.1} \right) s + 172413.7931}$$

R value(Ω)	Frequency for max amplitude (Wm)	Quality factor(Q)	Damping factor(ζ)
104	606.9482737	0.3992571147	1.25
83.04547985	415.2273993	0.5	1
21	387.767	1.97727333	0.252
17	397.446	2.442514113	0.204
7.5	411.826	5.536365324	0.0903
1.3	415.125	31.94056917	0.0156

Table 6

6.2

I must precisely enter the transfer functions into the Matlab code in order to receive accurate graphs and results from the answers. The Matlab code will then provide me graphs of phase angle against frequency and magnitude against frequency. The code I entered into Matlab is shown below in figure 26.

```

1  s = tf('s');
2  system1 = 172413.7931/(s^2+1040*s+172413.7931) ;
3  bode(system1) ;
4  grid on
5  hold on
6
7  s = tf('s');
8  system2 = 172413.7931/(s^2 + 830.4547985 *s+172413.7931) ;
9  bode(system2);
10 s = tf('s');
11 system3 = 172413.7931/(s^2 + 210 *s+172413.7931) ;
12 bode(system3);
13 s = tf('s');
14 system4 = 172413.7931/(s^2 + 170 *s+172413.7931) ;
15 bode(system4);
16 s = tf('s');
17 system5 = 172413.7931/(s^2 + 75 *s+172413.7931) ;
18 bode(system5);
19 s = tf('s');
20 system6 = 172413.7931/(s^2 + 10 *s+172413.7931) ;
21 bode(system6);
22

```

Figure 26

Below within figure 27 shows the bode diagram plot, along with a label of each individual plots resistance.

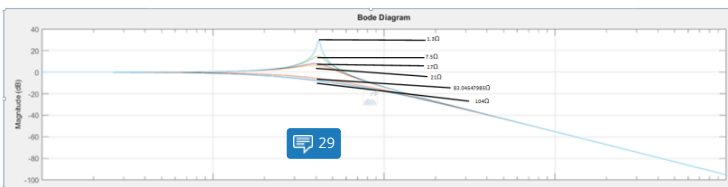


Figure 27

Within figure 28, is the bode plot provided with all data labels equipped along with the frequency and magnitude value.

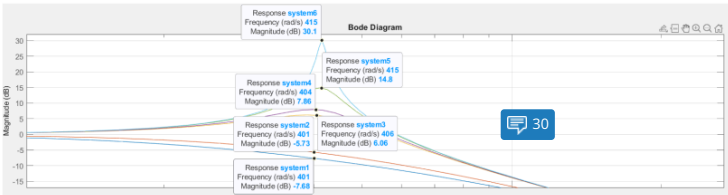


Figure 28

Here shows a 40db gap as this is a second order circuit the decade gap increases to 40db instead of 20db in a regular first order circuit.

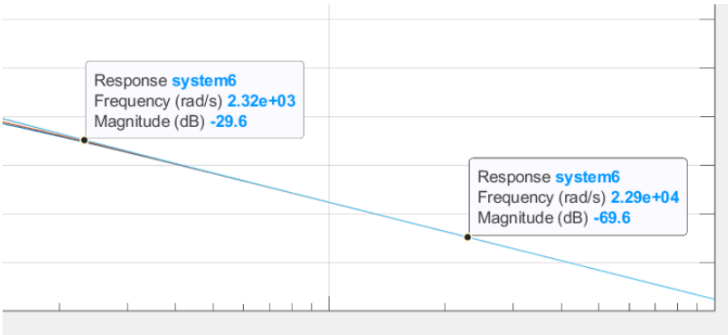


Figure 29

As shown within figure 30 is the resonant frequency, which is the same value throughout whatever the damping factor is.

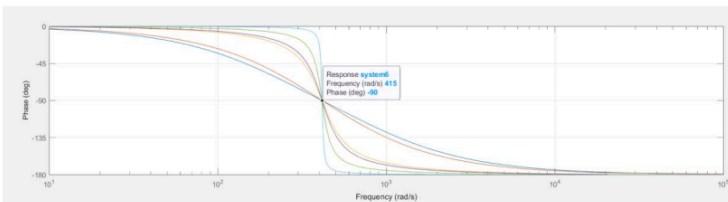


Figure 30

Here is the resonant frequency calculation, proving the plot is correct at -90 degrees, with very a very minimal difference between calculation and plot.

$$W_o = \frac{1}{\sqrt{LC}}$$
$$W_o = \frac{1}{\sqrt{0.1 \times 58 \times 10^{-6}}} = 415.22 \text{ rad/s}$$

Calculated	Mattlab
415.22	415

Table 7

6.3,6.4,6.5

The results from Matlab further aided in identifying trends within how the quality factor and the frequency for maximum amplitude behave when presented with a varying resistance. It can be seen within table 6 that the lower the damping factor and quality factor are, the higher the frequency at maximum amplitude. This applies for all variations of the damping factor apart from the critically damped stage. The reasoning behind this is at the critically damped state, no oscillations occur, meaning the quality factor is irrelevant here. The frequency reading is visible in the results, ultimately trying to reach resonant frequency and helped when the resistance is lowered. After the resonant frequency was identified in the calculation stage, the Matlab results back up the calculations via the 'spike' in the readings. The quality factor is essentially a ratio of how efficient and effective a circuit is performing the higher the better. The damping factor is essentially a measure of how quickly the oscillations decay, the lower the better. The phase shift section is also valid as there is a phase shift of -90 degrees at resonant frequency, and the theory is as expected.



Task 7

7.1

The suitable value of capacitance chosen for this task was 300nF, this value was used to determine the frequency performance of a low pass frequency circuit, also the resistance values R1 & R2 are 1kΩ & 20kΩ.

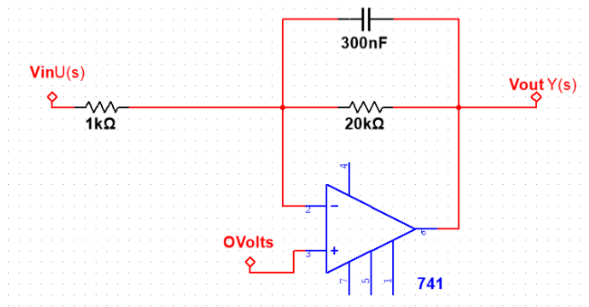


Figure 31

The transfer function used for this task can be seen below;

$$H(s) = -k \frac{Wc}{s + Wc} \quad H(s) = -20 \frac{166.6}{s + 166.6}$$

To determine the values of k and Wc the following equations were used.

$$K = \frac{R2}{R1} = \frac{20000}{1000} = 20$$

$$Wc = \frac{1}{CR2} = \frac{1}{300 \times 10^{-9} \times 20000} = 166.6 \text{ rad/s}$$

7.2

Here shows the transfer function in Matlab code with the specific values chosen for this task.

```
s = tf('s');
system1 = -20*(166.6/(s + 166.6)) ;
bode(system1) ;
grid on
```

Figure 32

Shown below in figure 33 is the bode plot provided by Matlab. The plots on the graph show the magnitude at 23 as this equates to the calculated 166.6. The reasoning for the plot being at 23 is because the maximum dB value the graph reaches is 26, and we require the value 3 less.

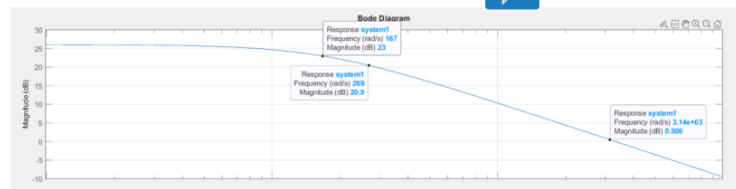


Figure 33

Here shows the phase shift of this circuit, as seen the phase degree is at 135 within figure 34 below. This is due to the fact we are using an inverted amplifier which has a phase degree of 180 degrees, but due to the fact in this case the capacitor is in parallel, meaning that it is lagging by 45 degrees as this is where the 135 phase degree comes from.

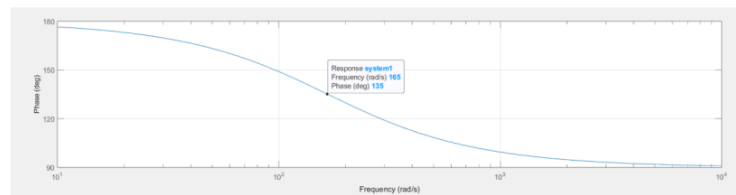


Figure 34

	Calculated	-3db	135 phase degree
Frequency (rad/s)	166.6	167	165

Table 8

7.3

Considering the characteristics of a conventional low pass filter, the estimations were accurate, as shown by the Matlab screenshots shown in figures 32, 33, and 34 above. The graph's maximum gain is represented by a straight horizontal line, which is followed by a steadily decreasing slope. According to the labels plotted on the graph, the cutoff frequency is extremely near to the calculated value, and the slope shows a 20dB difference over a decade. The correctness of the Matlab's data label placement is the cause of this issue. At the cutoff frequency, a low pass filter circuit exhibits a phase shift of 135 degrees. This is because, unlike with a high pass filter, the output voltage is lagging instead of leading.

35

Task 8

8.1

The value of capacitance chosen to be used within this task was 30nF. The specific value chosen was to determine the frequency performance of a high pass frequency circuit. The resistor values within this task were $R_1 = 1\text{K}\Omega$, $R_2 = 2\text{K}\Omega$.

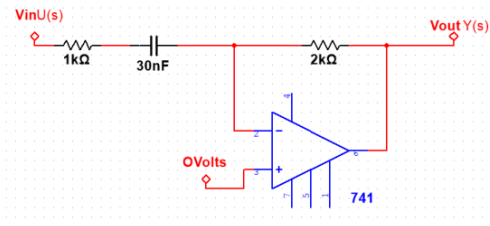


Figure 35

The transfer function used for this task can be seen below;

$$H(s) = -k \frac{S}{S + W_c} \quad H(s) = -2 \frac{S}{S + 33333.3}$$

To determine the values of k and W_c the following equations were used.

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

$$W_c = \frac{1}{CR1} = \frac{1}{30 \times 10^{-9} \times 1000} = 33333.3 \text{ rad/s}$$

8.2

Here shows the transfer function in Matlab code with the specific values chosen for this task.

```
s = tf('s');
system1 = -2*(s/(s + 33333.3)) ;
bode(system1) ;
grid on
```

Figure 36

The bode plot that Matlab provided is displayed in figure 37 below. The graph's plots display the magnitude at 3, which corresponds to the calculated 33333.3 rad/s. The plot's position at 3 is justified by the fact that the graph's maximum dB value is 6, and the necessary value is 3 less than the maximum magnitude.

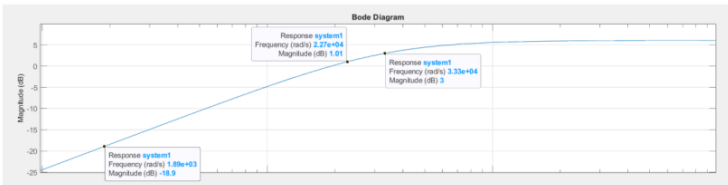


Figure 37

Figure 38 below illustrates the circuit's phase shift, with the phase degree at 225. This is because we are utilising an inverted amplifier, which has a 180-degree phase degree. However, because the capacitor is in series in this instance, it is leading by 45 degrees, which is where the 225 phase degree originates.

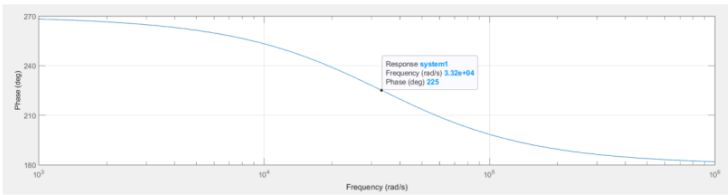


Figure 38

	Calculated	-3db	225 phase degree
Frequency (rad/s)	33333.3	3.33×10^4	3.32×10^4

Table 9



8.3

The characteristics of a conventional high pass filter in the Matlab screenshots above, in figures 36, 37, and 38, provide convincing proof that the calculations were accurate. As the filter achieves its maximum gain, the graph's rising slope turns into a flat straight line. The graph's labels indicate that the cut off frequency is around the calculated value and that the slope is a 20dB variation over a decade. The placement precision of the Matlabs data labels is the route cause of the slight error. At the cutoff frequency, a high pass filter circuit displays a 225 degree phase shift. This is because, unlike with a low pass filter, the output voltage is leading instead of lagging.

Task 9

9.1

Shown below within figures 39 & 40 is the open loop response using Simulink, the transfer function used can be seen within figure 39.

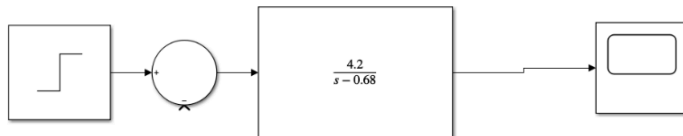


Figure 39

The output of this system increases exponentially over time due to its instability, as the graph below illustrates.

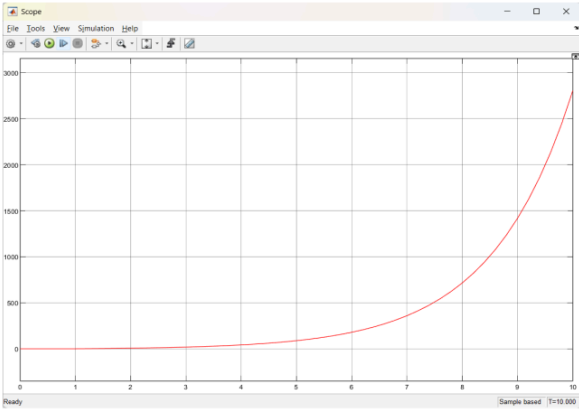


Figure 40

The code that was entered into Matlab to produce the argand diagram in figure 42 is displayed below, along with the open loop circuit performances.

```
1 sys = tf([4.2],[1 -0.68]);
2 rlocus(sys)
3 grid on
```

Figure 41

It is evident from the argand diagram below that the pole is positive and situated at 0.68 on the graph, as indicated by the data label. The signal will be unstable at this value of 0.68 since it is more than 0. (Fig. 42)

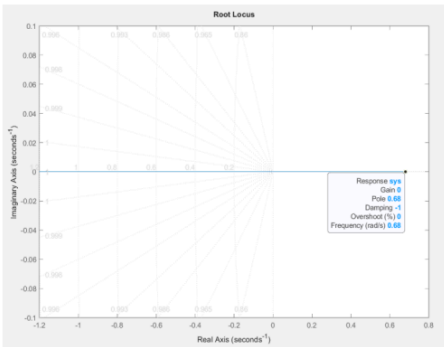


Figure 42

9.2

The closed loop control system model, which was made using Simulink and includes a step input, summing junction, transfer function, gain, and scope, is displayed below.

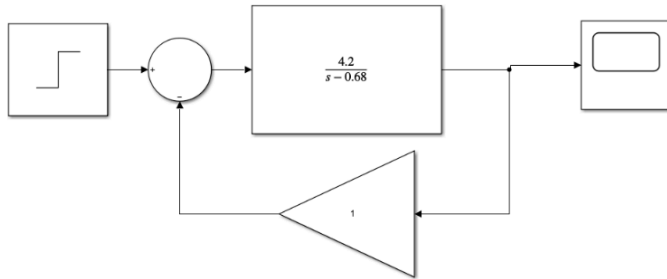


Figure 43

The closed loop transfer function is displayed below.

$$\frac{\frac{4.2}{s - 0.68}}{1 + \frac{4.2k}{(s - 0.68)}}$$

39

Then, by multiplying top and bottom by $(s - 0.68)$, this can be made simpler.

$$\frac{4.2}{s - 0.68 + 4.2K}$$

40

Another way to simplify the transfer function is as follows:

$$\frac{4.2}{s + 3.52K}$$

From this plot within figure 44 it is clear that the response is stable due to it reaching a peak value and stabilising.

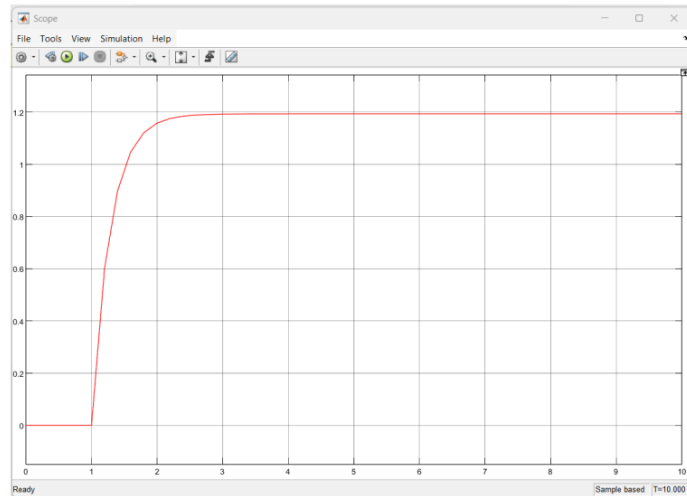


Figure 44

Here shows the Matlab code used to provide the argand diagram for this closed loop circuit.(Figure 45)

```
1 sys = tf([4.2],[1 -0.68 + 4.2 * 1]);
2 rlocus(sys)
3 grid on
```

Figure 45

Below Is the argand diagram(Figure 46) provided from Matlab, this diagram shows us the response of the overall closed loop transfer function in terms of K. The plot below can be seen for K = 1. The graphs stability is clear with the pole value of -3.52 meaning the signal is stable, due to it being on the negative side of 0 or in other words the Left hand side of the plane.

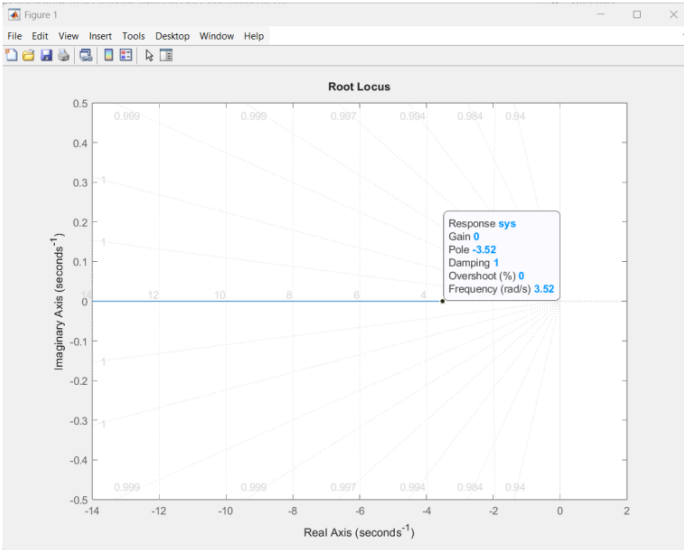


Figure 46

9.3

After determining the lowest value of K required in the feedback for system stability, a root locus plot can be created in Matlab to verify this.

Below shows the rearrangement to get the minimum value of K. This is required in the feedback for stability.

1. $s - 0.68 + 4.2k = 0$
2. $s = 0.68 - 4.2k$
3. $0 = 0.68 + 4.2k$
4. $-0.68 = -4.2k$
5. $k = \frac{-0.68}{-4.2} = 0.162$



Below shows the code inputted to Matlab, this was used to provide a root locus plot.

```

s = tf('s');
system = tf(4.2/(s - 0.68));
rlocus(system);
grid on

```

Figure 47

The Root Locus Plot, which is displayed in Figure 48 below, demonstrates that, according to the calculations above, the minimal value of K for a stable circuit is 0.16. Another data point at the pole, +0.68, indicates that the gain is equal to zero, while another data point, with a pole of -0.675, indicates that the gain is 0.32. These data points demonstrate that a system's stability increases with its gain.

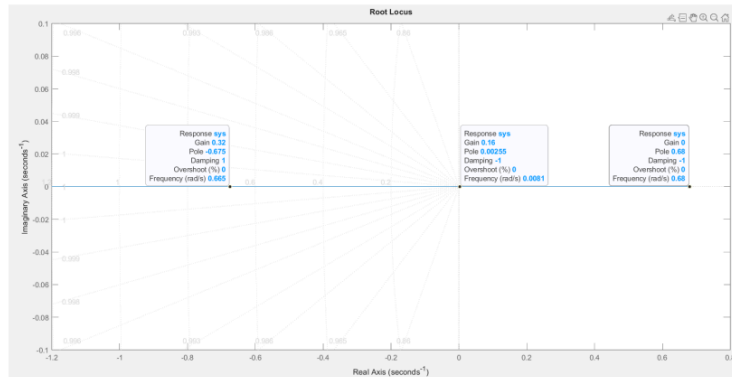


Figure 48

After calculating a minimum value of 0.162, a value more than the minimum value of 0.301, and a value less than the minimum value necessary for system stability (0), the value of k will be provided.

Stable System Value (0.162)

The closed loop control system model, which was made on Simulink and includes a step input, summing junction, transfer function, gain with a value of 0.162, and a scope, is displayed below (Figure 49).

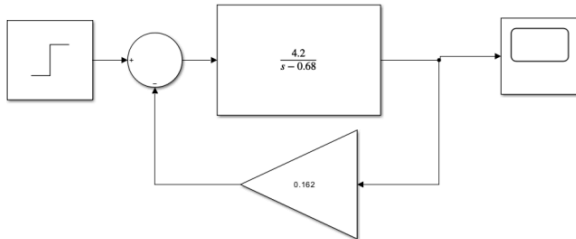


Figure 49

The graph that follows demonstrates how the system's output stabilises with time. At a magnitude of 1, the system reaches a balance. (Figure 50)

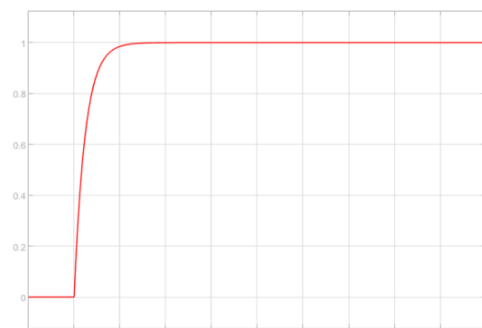


Figure 50

Value greater then the minimum value of K (0.32)

Below is a Simulink model of a closed loop control system that includes a step input, a summing junction, a transfer function, a 0.32 gain, and a scope.

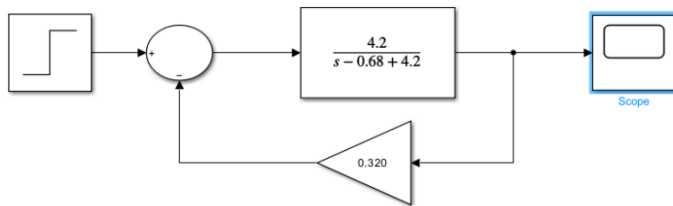


Figure 51

The output of this system levels out over time as it becomes stable, as the graph below illustrates. The magnitude of the system reaches its peak at about 0.850.

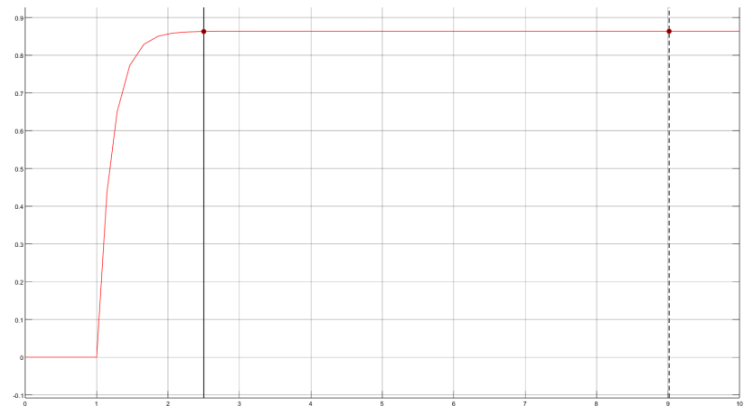


Figure 52

Value less then the minimum value of K(0.1)

The Simulink model of the closed loop control system, which includes a step input, a summing junction, a transfer function, a gain with a value of 0, and a scope, is displayed below.

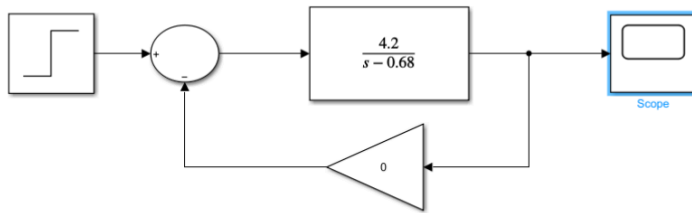


Figure 53

The graph below illustrates how this system's output increases exponentially over time due to its instability.

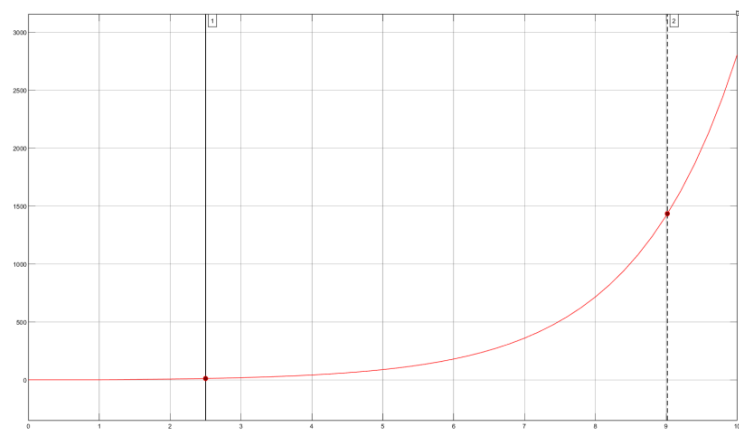


Figure 54

With the Simulink simulation, a comparison can be made by the various different responses by changing the value of K.

Value of K	Pole	Stability Response
1	-3.52	Stable
0.32	-0.675	Stable
0.162	0.00255	Marginally Stable
0	0.68	Stable

Table 10

43

9.6

This task has delivered a thorough examination of the behaviours seen in both open and closed-loop systems, emphasizing how each responds under varying conditions. It also underscores the crucial role of gain in closed-loop systems, particularly how its adjustment influences system performance and stability. Feedback is used to counter external disruptions, supporting the goal of maintaining steady operation.

From the comparison data, it becomes evident that there is a direct link between gain and system response, when one shifts, the other typically follows. Achieving system stability remains a central focus in design, and the observed trends confirm that gain adjustment is a key factor in moving the system towards or away from desired stability.

Additionally, the data incorporates damping values, reinforcing previously discussed concepts. When system poles lie in the stable region, damping reflects this with consistent values, while shifts toward instability align with theoretical ⁴⁴ations, showing contrasting damping behaviour.

44

Task 10

Introduction

The design process of a DC motor will be demonstrated in this task using a Simulink block diagram model system. To examine how the motor model acts in relation to time, pertinent research will be stimulated using an electrical and mechanical transfer function.

Parameters

The selected parameters below are used for this model.

Armature Resistance

$$R_a = 1.5 \text{ Ohms}$$

Armature Inductance

$$L_a = 0.2 \text{ H}$$

Rotar Inertia

$$J = 0.00035 \text{ Kg } m^2$$

Friction coefficient

$$B = 3.68 \times 10^{-6} \text{ Nm/rad/s}$$

Motor Voltage Constant

$$K_e = 0.025 \text{ V/Rad/s}$$

Motor Torque constant

$$K_t = 0.0025 \text{ Nm/A}$$

Maximum Armature Voltage

$$V_A(\text{Max}) = 24 \text{ V}$$



10.1

This task involves two transfer functions, one related to the motor's electrical side and the other to its mechanical side. Both functions are crucial as they help predict the motor's behaviour if implemented in real-world applications. The electrical

transfer function focuses on the relationship between current and voltage, while the mechanical transfer function examines the rotor speed in relation to the torque applied. By combining these functions, we can gain insights into various motor behaviours. In addition to the transfer functions, there are two gains that share the same value. One corresponds to the torque, while the other represents the voltage. These gains are essential for accounting for real-world factors that affect motor systems.

To gather data on various parameters during testing, scopes will be utilized. They will be especially helpful in measuring torque, current, and speed, providing graphical outputs that can support conclusions and reveal trends during the analysis phase. A unit step will be introduced to simulate a disturbance, allowing for comparisons between the motor's behaviour when a load is applied and when it is not. The system leverages negative feedback to stabilize the motor's speed and improve control. This feedback helps limit excessive current and torque, minimizing overshoot and enhancing result accuracy.

This system incorporates three types of motor torque: load torque, which represents the force the motor works against to move a mechanical system; friction torque, which resists parts from rubbing together, like bearings; and the startup torque, which is higher than the running torque due to the motor being stationary at the start. The total mechanical torque is the sum of these individual torques.

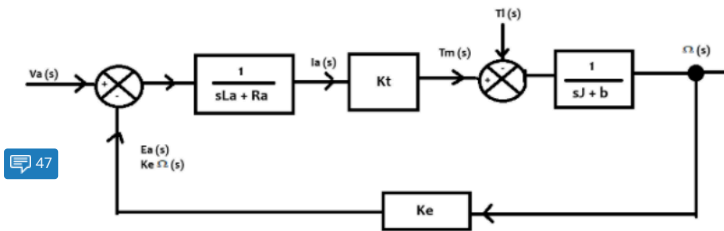


Figure 55

The transfer function shown below is for the motor model with zero disturbance:

$$G(s) = \frac{\frac{K_t}{La \times J}}{s^2 + s\left(\frac{b}{J} + \frac{Ra}{La}\right) + \left(\frac{Ra \times b}{La \times J} + \frac{K_t \times K_e}{La \times J}\right)}$$

10.2

The following formula was used to get the natural frequency.

Natural Frequency

$$\omega_n = \sqrt{\frac{Ra b}{La J} + \frac{Kt Ke}{La J}}$$
$$\omega_n = \sqrt{\frac{1.5 \times 3.68 \times 10^{-6}}{0.2 \times 0.00035} + \frac{0.025 \times 0.025}{0.025 \times 0.00035}} = \mathbf{3.01 \text{ Rad/s}}$$

The following formula was used to get the damping factor.

Damping Factor

$$\zeta = \frac{\frac{b}{J} + \frac{Ra}{La}}{2\omega_n}$$
$$\zeta = \frac{\left(\frac{3.68 \times 10^{-6}}{0.00035} + \frac{1.5}{0.2}\right)}{2 \times 3.01} = \mathbf{1.252}$$

The characteristics of the steady state are as follows.

Stall Torque

$$\text{Stall Torque} = \frac{Kt}{Ra} \times Va$$
$$\text{Stall Torque} = \frac{0.025}{1.5} \times 14 = \mathbf{0.233 \text{ N/m}}$$

Friction-Less no-load-speed

$$\text{No load speed (without friction)} \Omega_{nl} = \frac{Va}{Ke}$$
$$\text{No load speed (without friction)} \Omega_{nl} = \frac{14}{0.025} = \mathbf{560 \text{ Rad/s}}$$

No Load Speed With Friction

$$\frac{Kt Va}{bRa + Kt Ke}$$

$$\left(\frac{0.025 \times 24}{3.68 \times 10^{-6} \times 1.5 + 0.025 \times 0.025} \right) = 555.09 \text{ Rad/S}$$

Loaded Speed

$$\frac{V_a - \frac{R_a T_l}{K_t}}{\frac{R_a b}{K_t} + K_e}$$

$$\frac{14 - \frac{1.5 \times 0.05}{0.025}}{\frac{1.5 \times 3.68 \times 10^{-6}}{0.025} + 0.025} = 436.14 \text{ Rad/S}$$

In this context, stall torque refers to the maximum torque a motor can generate while remaining stationary. If the applied load torque surpasses the stall torque, the motor will be unable to operate correctly.

The calculations above demonstrate the maximum torque the motor can produce when at rest, as well as the corresponding motor speeds while factoring in friction when necessary.

Graphs can now be generated and analysed under two conditions, with and without an applied load. These graphs should effectively illustrate the impact of a load on a motor's speed when introduced into the system

10.4

Shown below is the Motor system within Simulink, this system contains 3X Scope, 2X Gain, 2X Transfer Function, 2X Summing Junction and a step input.

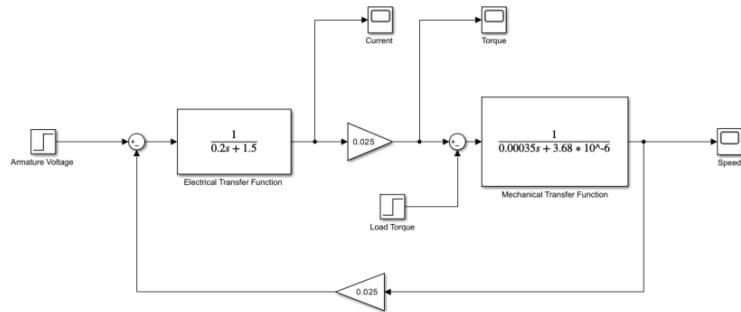


Figure 56

10.5

The figure 57 below provides a graphical representation of the motor model operating without a load. As expected, the speed increases and stabilizes at the no-load speed, accounting for friction. Additionally, the scope readings for torque and current can be analysed. In the absence of a load, a significant initial spike is expected, representing the torque required to start the motor, with the current exhibiting a similar pattern. This behaviour is evident in figures 58 & 59 below.

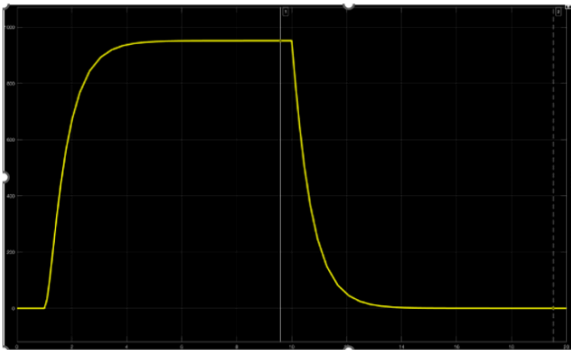


Figure 57

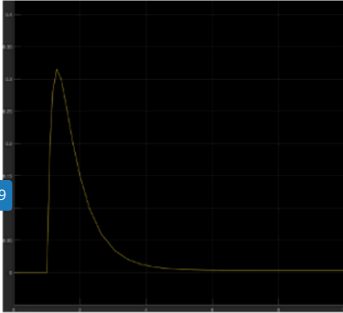


Figure 58

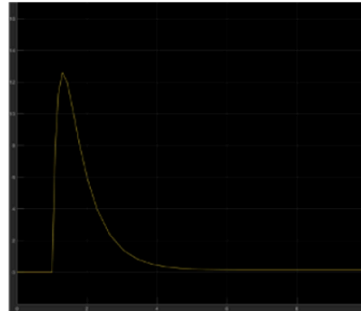


Figure 59

10.6

The figure 60 below illustrates the motor model under identical conditions, with a load introduced at the 10-second mark. As anticipated, the speed decreases to the previously calculated loaded speed, confirming the accuracy of the calculations. The scope readings below display a transient-like response following the load application at 10 seconds. This occurs because the motor cannot instantly adjust to the new steady-state speed and must first overcome the inertia of the stationary system, resulting in a gradual increase before stabilizing at the expected value.

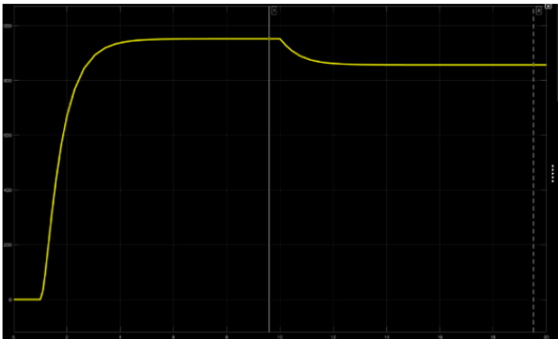


Figure 60

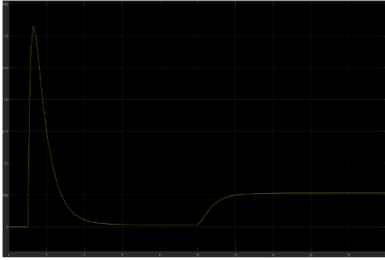


Figure 61

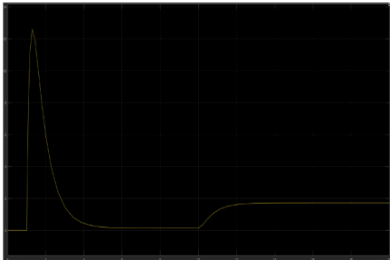


Figure 62

10.7

	Calculated (Rad/S)	Simulated (Rad/S)	Error (Rad/S)
No Load Speed With Friction	555.09	555.11	+0.02
Under Load Speed	436.14	436.18	+0.04

Table 11

10.8



Through extensive testing and calculations, well-supported conclusions can be drawn with clear evidence to validate any claims. The data from graphs and recorded responses demonstrate that introducing a load to a motor system negatively impacts its performance for several reasons. When a load is applied, the motor's speed decreases, primarily due to the increased torque demand. As the load intensifies, so does the motor's workload. Torque and speed in a motor are closely linked, often influencing each other when one variable changes. Additionally, the current demand rises when a load is introduced, with this claim being reinforced by the scope screenshots.

All scope screenshots reveal a significant inrush spike whenever the motor starts, regardless of whether a load is present. This occurs because the motor begins from a stationary position with no back EMF, allowing a substantial amount of current to be drawn. Furthermore, the motor must overcome its own inertia at startup, with the drawn current playing a crucial role in generating enough torque for initial movement. The rapid buildup of the magnetic field further contributes to this surge, collectively resulting in the noticeable spike in current.

The calculated and simulated values exhibited minimal error, indicating accurate and reliable computations.

Task 11

Introduction

In this task, the motor model is converted into a subsystem for simplicity, incorporating a proportional controller with a step speed setpoint of 140 rad/s and a disturbance of 0.03 Nm after 10 seconds. The auto-tune feature is used to determine the optimal K_p value. The system is then replicated twice, adjusting K_p to analyze its impact on steady-state error, rise time, and overshoot. Finally, the effects of varying K_p are discussed.

11.1/11.2

Seen below is the combined sub circuits which lead into a 3 input scope. The sub circuits contain a step(X3), summing junction(X3), PID controller(X3) & Sub circuit(X3). This combined circuit is what provides the graph in which shows the effect of changing the K_p value. The Selected values of 1.6, 0.8 & 0.4 are inputted into the PID Controller, the setpoint value of 140 rad/s, disturbance of 0.03Nm and limitation of $\pm 24V$ also inputted to which then dictates the information provided.

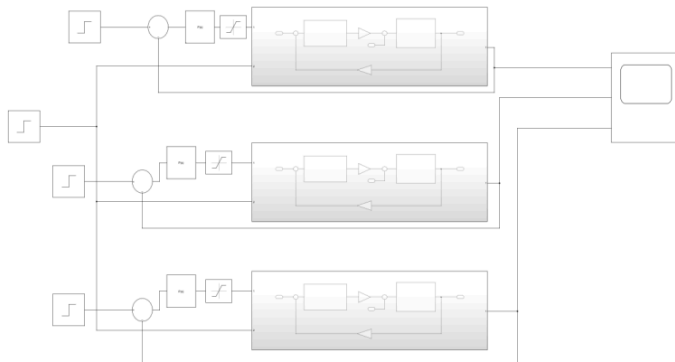


Figure 63



Figure 64

Below is the graph previously mentioned, this graph contains three different sub circuits, showing the effect of varying the value of K_p individually.

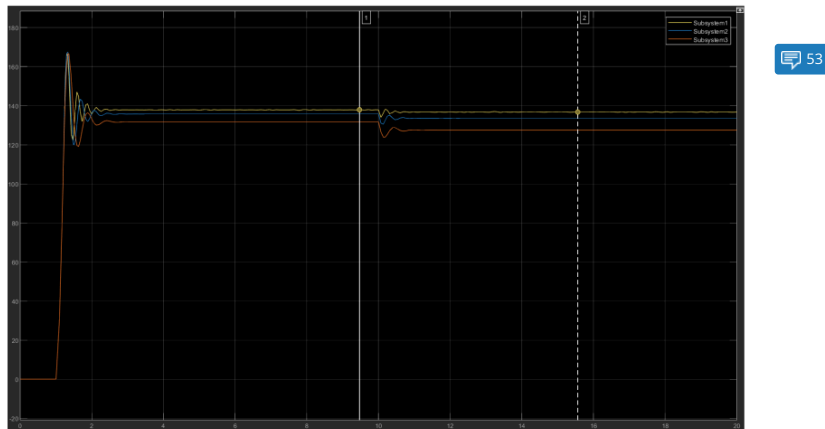


Figure 65

11.3

It is evident to see from the figure 65 above that the 3 sub circuits have different effects from varying the value of K_p . When increasing the value of K it is subsequently increasing the Oscillations, increasing the Overshoot and reducing the steady state error. As seen the yellow sub circuit has the smallest value of K_p at 0.4 as it has the smallest oscillations, overshoot and the closest to the setpoint. Where as the orange sub circuit has larger oscillations, over shoot and a steady state close to

the setpoint. Evidently increasing the value of Kp increases the Oscillations and Overshoot but decreases the steady state error. Decreasing the Kp value does also have an effect but the opposite of what increasing it does.

11.4

Following on from the Simulink results, the categories of the table below have been filled. The value of Overshoot, Rise time and settle time are provided by the auto tune function within Simulink, as shown within figures 66, 67 & 68.

	Kp	Overshoot(%)	Rise Time(s)	Settle Time(s)	Steady State Error(rad/s)
Sub System 1	1.6	60.8	0.049	0.962	2
Sub System 2	0.8	49.4	0.0716	0.989	8
Sub System 3	0.4	36.6	0.108	0.91	15

Table 12

Kp value of 1.6

	Tuned	Block
Rise time	0.208 seconds	0.049 seconds
Settling time	1.06 seconds	0.962 seconds
Overshoot	17.5 %	60.8 %
Peak	0.999	1.58
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	60 deg @ 5.87 rad/s	18 deg @ 23.5 rad/s
Closed-loop stability	Stable	Stable

Figure 66

Kp value of 0.8

	Tuned	Block
Rise time	0.208 seconds	0.0716 seconds
Settling time	1.06 seconds	0.989 seconds
Overshoot	17.5 %	49.4 %
Peak	0.999	1.45
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	60 deg @ 5.87 rad/s	25.4 deg @ 16.3 rad/s
Closed-loop stability	Stable	Stable

Figure 67

Kp value of 0.4

	Tuned	Block
Rise time	0.208 seconds	0.108 seconds
Settling time	1.06 seconds	0.91 seconds
Overshoot	17.5 %	36.6 %
Peak	0.999	1.28
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	60 deg @ 5.87 rad/s	35.9 deg @ 11.2 rad/s
Closed-loop stability	Stable	Stable

Figure 68

11.5

As anticipated, increasing the constant produced the expected results. The data indicates that as the constant increases, there is a notable rise in the percentage overshoot. Additionally, a reduction in rise time and steady-state error is observed. However, a key issue is that the settling time behaves differently than expected. Instead of decreasing, it increased. This could be attributed to the excessive increase in the constant, which may lead to oscillations and, consequently, instability, thereby causing the settling time to rise.



Task 12

Introduction

This task explores the impact of PI control tuning by modifying the integral gain(KI), while keeping the proportional gain(Kp) the same. A matlab model is used and adjusted by converting all PI controllers to show the effect of varying the KI value, whilst being displayed on a graph.

12.1

Seen within figure 69 below is the same circuit used as within task 11, the only change within is the function blocks. Each function block from each sub circuit is not a PI not a P as for this task a PI block is required.

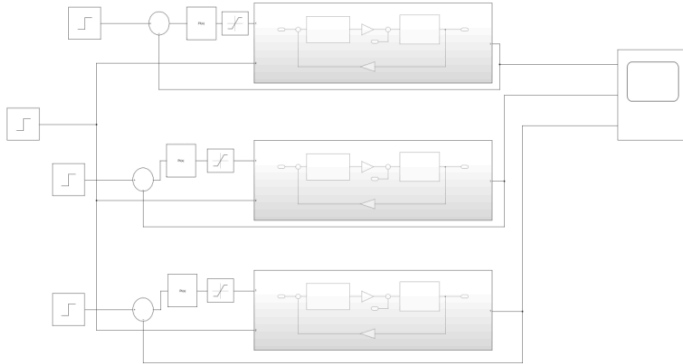


Figure 69

Below shows the PI function block as previously mentioned.

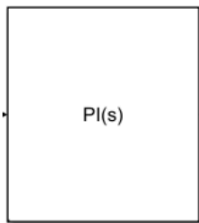


Figure 70

12.2

The parameters shown below are provided from the auto tune function within Matlab, within this function it provides us with performance values such as Rise time, settling time and overshoot. But for this task we used the auto tune parameters to find the key value of KI and as seen below it is 0.65567. This key value was found by using the sliders shown in figure 72 , The sliders allow adjustment to the Kp value to allow it to reach the 1.6 chosen within the previous task by adjusting the response time and transient behaviour, this then also provided the value for KI, this value was then used throughout the task within sub circuit 1.



Figure 71

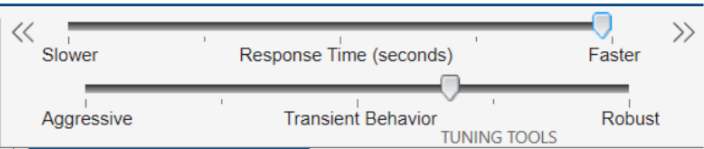


Figure 72

The graph below provided from Matlab, shows the effect of each sub circuit with different values of KI and the constant value of 1.6 for Kp. The values chosen for KI

are the key value of 0.65567 for sub circuit one, sub circuit twos value of KI is 3.2 and sub circuit 3s value of 0.8.

As seen within the graph the difference in response is obvious, the key value within sub circuit one has the least amount of oscillations and overshoot, but also reaches steady state the quickest. Very similar to sub circuit three, because the values are so close (0.65567 and 0.8) with sub circuit three having slightly larger oscillations and overshoot but reaching the steady state at a very similar rate. Sub circuit 2 on the other hand has much larger oscillations and over shoot as can be seen, the time it takes to reach the steady state value of 140 is also longer, meaning that when the value of KI is increased the oscillations and overshoot also increase and it takes longer to reach the steady state value.

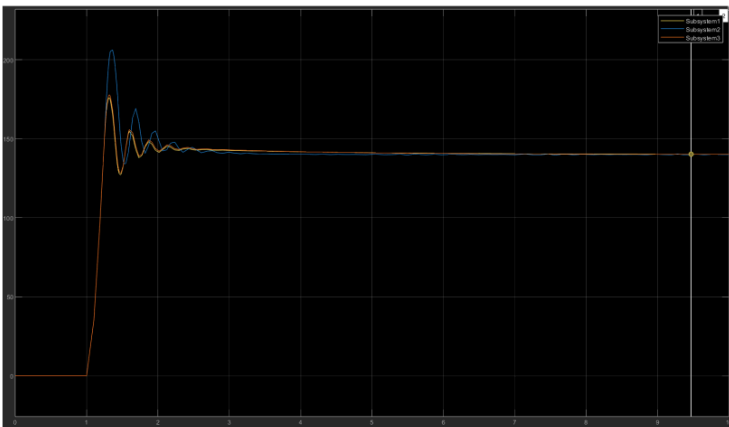


Figure 73

	Kp	Ki	Overshoot(%)	Rise Time(s)	Settle Time(s)
Sub System 1	1.6	0.65567	60.7	0.0492	1.1
Sub System 2	1.6	3.2	70	0.0477	1.35
Sub System 3	1.6	0.8	61.3	0.0491	1.1

Table 13

Kp of 1.6 & KI of 0.65567

Performance and Robustness		
	Tuned	Block
Rise time	0.509 seconds	0.0492 seconds
Settling time	1.85 seconds	1.1 seconds
Overshoot	9.8 %	60.7 %
Peak	1.1	1.61
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	60 deg @ 2.57 rad/s	17 deg @ 23.5 rad/s
Closed-loop stability	Stable	Stable

Figure 74

Kp of 1.6 & KI of 0.8

Performance and Robustness		
	Tuned	Block
Rise time	0.509 seconds	0.0491 seconds
Settling time	1.85 seconds	1.1 seconds
Overshoot	9.8 %	61.3 %
Peak	1.1	1.61
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	60 deg @ 2.57 rad/s	16.8 deg @ 23.5 rad/s
Closed-loop stability	Stable	Stable

Figure 76

The MATLAB graph demonstrates the impact of varying KI on system response with a constant Kp of 1.6. Sub-circuit 1 with a KI value of 0.65567 exhibits the most stable response, with minimal oscillations, overshoot, and the fastest settling time. Sub-circuit 3 (KI = 0.8) behaves similarly but with slightly increased oscillations and overshoot. In contrast, Sub-circuit 2 (KI = 3.2) shows significant oscillations and the highest overshoot, leading to a longer settling time. This confirms that increasing KI amplifies oscillations and overshoot, reducing system stability. The optimal KI value balances response speed and stability, with Sub-circuit 1 demonstrating the most efficient performance.



57

Kp of 1.6 & KI of 3.2

Performance and Robustness		
	Tuned	Block
Rise time	0.509 seconds	0.0477 seconds
Settling time	1.85 seconds	1.35 seconds
Overshoot	9.8 %	70 %
Peak	1.1	1.7
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	60 deg @ 2.57 rad/s	13.1 deg @ 23.5 rad/s
Closed-loop stability	Stable	Stable

Figure 75

Task 13

Introduction

The impact of PID control tuning is demonstrated in this task by varying the derivative gain (K_d) while maintaining constant proportional (K_p) and integral (K_i) gains. The effect of changing K_d will be observed through the construction of a Matlab model.

13.1

The updated circuit for this task is illustrated in figure 77, where each controller has been upgraded from a PI Controller to a PID Controller. The optimal values obtained from previous tasks have been applied to each controller, and the auto-tune function was utilized once again to determine the appropriate K_d value.

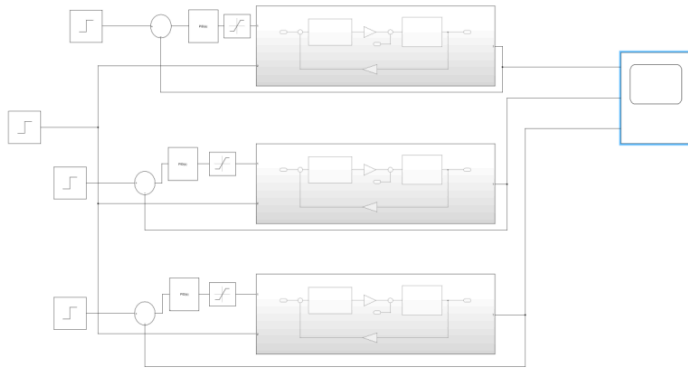


Figure 77

Below shows the PID function block.

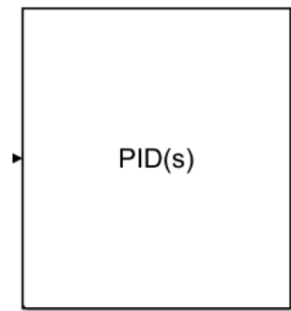


Figure 78

13.2

The graph presented in figure 79 displays three distinct responses. One represents the tuned circuit, while the other two were selected arbitrarily to provide a basis for comparison within the circuit.

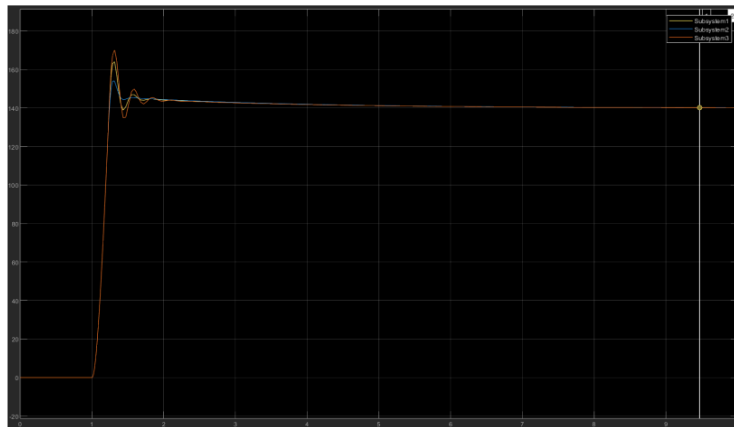


Figure 79

13.3

	Kp	Ki	Kd	Overshoot(%)	Rise Time(s)	Settle Time(s)
Sub System 1	1.6	0.65567	0.0115	38.8	0.046	0.547
Sub System 2	1.6	0.65567	0.0230	25.9	0.0415	0.307
Sub System 3	1.6	0.65567	0.0460	48.1	0.0475	0.582

Table 14

Kp of 1.6, Ki of 0.65567 & Kd of 0.0115 Kp of 1.6, Ki of 0.65567 & Kd of 0.0230

	Tuned	Block
Rise time	0.579 seconds	0.046 seconds
Settling time	2.12 seconds	0.547 seconds
Overshoot	6.87 %	38.8 %
Peak	1.07	1.39
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	69 deg @ 2.57 rad/s	33.5 deg @ 25.1 rad/s
Closed-loop stability	Stable	Stable

Figure 80

	Tuned	Block
Rise time	0.579 seconds	0.0415 seconds
Settling time	2.12 seconds	0.307 seconds
Overshoot	6.87 %	25.9 %
Peak	1.07	1.26
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	69 deg @ 2.57 rad/s	46.4 deg @ 28.1 rad/s
Closed-loop stability	Stable	Stable

Figure 81

Kp of 1.6, Ki of 0.65567 & Kd of 0.0460

	Tuned	Block
Rise time	0.579 seconds	0.0475 seconds
Settling time	2.12 seconds	0.582 seconds
Overshoot	6.87 %	48.1 %
Peak	1.07	1.48
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	69 deg @ 2.57 rad/s	25.6 deg @ 24.1 rad/s
Closed-loop stability	Stable	Stable

Figure 82

As seen from the graph provided in figure 79 the response of PID control is evident. Sub – circuit 2 shows the maximum affect of the use of PID control, using the 3 specific values of Kp of 1.6, Ki of 0.65567 & Kd of 0.0230. These specific values for the best output were found from the auto tune function within Matlab. The 3 sub circuits clearly show the effect of changing the values of Kd, as when the values are more and less then the specific value of 0.0230, the oscillations, rise time and settle time values increase as seen from table 14.

Task 14

Introduction

In this task, P, PI, and PID controllers are implemented in parallel within a MATLAB simulation in order to compare them. Plotting and analysis will be done on their reactions to the same simulations. To assess control improvements from P to PID, key performance parameters like rising time, overshoot, and settling time will be compared.

14.1

The final modifications to the circuit are shown in figure 83. In this task, one controller is configured as P, another as PI, and the last as PID. Each controller has been assigned the appropriate optimally tuned values.



Figure 83

14.2

The graph in figure 84 displays the responses generated by the three different controllers. Subsystem 1 represents the P Controller, Subsystem 2 corresponds to the PI Controller, and Subsystem 3 signifies the PID Controller.

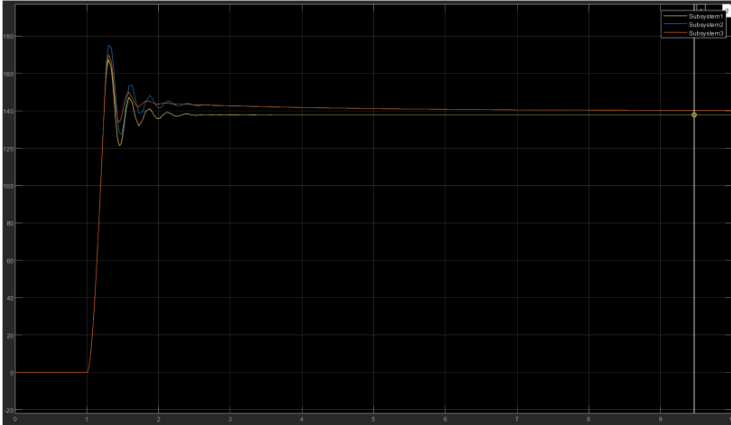


Figure 84

14.3

	Kp	Ki	Kd	Overshoot (%)	Rise Time (s)	Settle Time (s)
Sub System 1	1.6	N/A	N/A	60.8	0.049	0.962
Sub System 2	1.6	0.65567	N/A	60.7	0.0492	1.1
Sub System 3	1.6	0.65567	0.0230	38.8	0.046	0.547

Table 15

P

	Tuned	Block
Rise time	0.208 seconds	0.049 seconds
Settling time	1.06 seconds	0.962 seconds
Overshoot	17.5 %	60.8 %
Peak	0.999	1.58
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	60 deg @ 5.87 rad/s	18 deg @ 23.5 rad/s
Closed-loop stability	Stable	Stable

Figure 85

PI

	Tuned	Block
Rise time	0.509 seconds	0.0492 seconds
Settling time	1.85 seconds	1.1 seconds
Overshoot	9.8 %	60.7 %
Peak	1.1	1.61
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	60 deg @ 2.57 rad/s	17 deg @ 23.5 rad/s
Closed-loop stability	Stable	Stable

Figure 86

PID

	Tuned	Block
Rise time	0.579 seconds	0.046 seconds
Settling time	2.12 seconds	0.547 seconds
Overshoot	6.67 %	38.8 %
Peak	1.07	1.39
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	69 deg @ 2.57 rad/s	33.5 deg @ 25.1 rad/s
Closed-loop stability	Stable	Stable

Figure 87

By examining both the results table and the response graph, it is evident that all controllers enhance the response as expected. The P Controller responds quickly but exhibits the highest percentage of overshoot and a significantly larger steady-state error compared to the other controllers. The PI Controller reduces the steady-state error but slightly compromises the settling time. However, the PID Controller demonstrates the best overall performance by minimizing overshoot, improving rise time, and reducing settling time. In summary, when compared to the P and PI controllers, the PID Controller proves to be the most effective and should always be considered when available.



Task 15

Electrical Conclusion

This assignment has provided a comprehensive analysis of electrical circuit performance, particularly in transient and frequency responses of RL and RC circuits. Through theoretical calculations and MATLAB simulations, time constant, cutoff frequencies, and phase shifts were evaluated. The results demonstrated that RL circuits exhibit slower transient responses compared to RC circuits due to inductive energy storage. Additionally, second-order circuits introduced oscillation behaviour influenced by damping. The comparison between theoretical and simulated results confirmed the reliability of mathematical models in predicting the circuits behaviour. The impact of varying resistance in transient and frequency performance was evident, highlighting the critical role of component selection in circuit design.

Electronic Conclusion

The analysis of first and second order electronic systems provided insight into the frequency response characteristics of capacitive circuits. The investigation of frequency performance through Bode plots allowed for accurate determination of cutoff frequencies, phase shifts, and system stability. Electronic circuits demonstrated behaviours with theoretical expectations, where capacitance influences both the transient response and frequency domain performance. The results highlighted the importance of precise component selection to achieve desired filtering and amplification characteristics. The use of MATLAB simulations provided a valuable tool for predicting real-world circuit behaviour, displayed with graphs.

One potential improvement would be the integration of advanced filtering techniques or active control systems to enhance frequency response performance in practical applications such as signal processing and communications.

Control Conclusion

The control system analysis, particularly of proportional, integral, and derivative controllers, demonstrated the effectiveness of tuning parameters in optimizing system response. The proportional controller provided a basic response but come with steady state error, more overshoot and later rise and settle times. Introducing integral action improved steady state accuracy but at the cost of increased overshoot and settling time. The addition of derivative control helped mitigate overshoot while maintaining stability. The simulations confirmed that a well tuned PID controller offers the best balance between response speed, stability, and accuracy. This also highlighted the impact of improper tuning, where excessive integral or derivative gains led to instability.

Future recommendations include exploring adaptive PID tuning algorithms or model predictive control techniques for improved performance.

62

/100

PAGE 1

PAGE 2

**Comment 1**

Meaningless titles, use titles that help the reader navigate the report.

PAGE 3

**Comment 2**

See previous comment

PAGE 4

PAGE 5

PAGE 6

**Comment 3**

Too general in nature, your language needs to be more specific.

PAGE 7

**Comment 4**

Tau is the name of the symbol, not quantity.

PAGE 8

**Comment 5**

TF is correct

PAGE 9

**Comment 6**

Correct annotation.

**Comment 7**

Ymax not U

PAGE 10



Comment 8

See previous comment regarding terminology.



Comment 9

1/sC

PAGE 11



Comment 10

missing variable



Comment 11

It is not second order.

PAGE 12



Comment 12

There are small mistakes throughout



Comment 13

Lacks depth.

PAGE 13



Comment 14

Correct annotation



Comment 15

-20dB/dec



Comment 16

Lacks depth.

PAGE 14



Comment 17

correct annotation

PAGE 15



Comment 18

Minor errors and lacks depth.



Comment 19

WW



Comment 20

This needs further clarification.

PAGE 16



Comment 21

This needs an explanation in terms of damping factor.



Comment 22

All equations need some form of explanation or at the minimum a statement of source.

PAGE 17



Comment 23

Gr

PAGE 18

PAGE 19

PAGE 20

PAGE 21



Comment 24

Again lacks depth and is purely descriptive in nature. Refer to the frequency form of the standard TF and explain the variables and the comparison with derivation of TF from circuit analysis.



Comment 25

Sp/WW



Comment 26

For a higher grade an analysis of the circuit from basic principles should be used to derive this. Or as a minimum some summary of the source of this TF.

PAGE 22

PAGE 23

PAGE 24

PAGE 25

PAGE 26



Comment 27

A sensible set of results.



Comment 28

Avoid all redundant sentences.

PAGE 27



Comment 29

Good annotation.

PAGE 28



Comment 30

A well annotated response graph.



Comment 31

WW

PAGE 29



Comment 32

WW



Comment 33

A fair analysis.

PAGE 30

PAGE 31



Comment 34

You are correct in your statement and graphical annotation.

PAGE 32



Comment 35

Compare with the passive type for greater marks.

PAGE 33

PAGE 34



Comment 36

Correct results and well annotated graphs.



Comment 37

Again, your analysis is descriptive and lacks depth.

PAGE 35



Comment 38

Correct graph and prediction.

PAGE 36



Comment 39

It is important to state where this comes from, i.e. the negative feedback equation.



Comment 40

Have you set $K=1$?

PAGE 37

PAGE 38



Comment 41

Correct analysis.



Comment 42

Correct annotations and predictions.



Comment 43

Mistake here?



Comment 44

Difficult to follow and too general, be specific about the actual system in question.



Comment 45

A circuit diagram would aid the readers comprehension of these parameters.



Comment 46

What do they depend on?



Comment 47

Correct model.



Comment 48

Missing cursors for comparison with calculated values.



Comment 49

Missing titles.



Comment 50

Results are sensible, a shame you missed the cursors out.



Comment 51

Your explanation of the reason for this is missing.



Comment 52

Explain this block.



Comment 53

Use of a meaningful legend, would aid in the simplicity and results interpretation.



Comment 54

Sensible results.



Comment 55

A fair analysis based on sensible results.



Comment 56

Inserting variable values and results into text is to be avoided, simply use a table and look at the trends.



Comment 57

What about SSE?



Comment 58

See comments as for task 11.



Comment 59

A fair analysis based on sensible results and a well structured approach.



Comment 60

This sentence is not correct.



Comment 61

You are mistaken here.

LEWIS BELL

62

1. ENGAGEMENT WITH LITERATURE

NA

0

2. KNOWLEDGE AND UNDERSTANDING

Reasonably detailed and mostly accurate knowledge displayed. There are some mistakes and omissions as commented but generally good.
18/30

18

3. COGNITIVE AND INTELLECTUAL

Some critical analysis exists, though mostly descriptive in nature, this does improve in the final control section where the results have been analysed correctly. 19/30

19

4. PRACTICAL APPLICATION

A good and appropriate application of techniques, mostly the approach has been methodical with few areas for improvement as commented. 19/30

19

5. TRANSFERABLE SKILLS

Can communicate well and the report structure is good, there are a few areas for development as commented and a few errors exist in the written communication. 6/10

6