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by Taylor Bamford

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Task 1 Transient Analysis of a First Order RL Electrical Circuit

1.1: Select suitable component values and calculate the time constant.

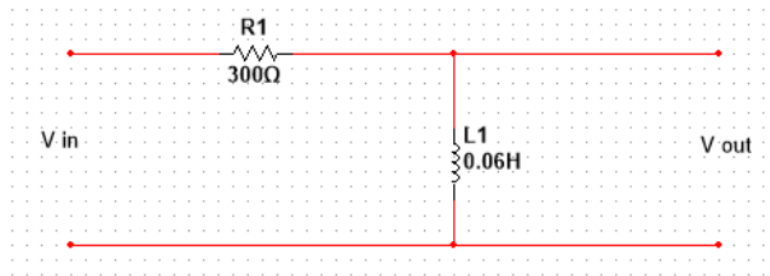


Figure 1 First Order RL Electrical Circuit Transient Analysis

Resistor = 300Ω

Inductor = $0.06H$

$$\text{Time Constant } \tau = \frac{L}{R} = \frac{0.06}{300} = 0.0002 \text{ sec}$$

1.2: Draw the Laplace model, give the transfer function in terms of the time constant.

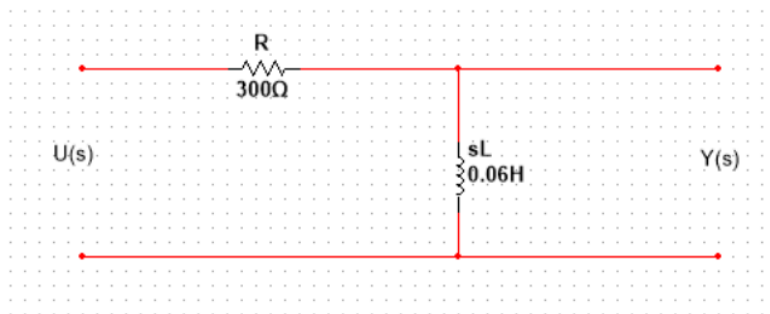


Figure 2 Laplace Model First Order RL Electrical Circuit Transient Analysis

$$H(s) = \frac{2}{R + sL} = \frac{s0.06}{300 + s0.06}$$

1.3: Write a suitable Matlab model program and perform an analysis of the transient responses to a 1V step input and measure the time constant. Provide suitably annotated graphical results.

```

1  S = tf ('s');
2  System = 0.06*s/(0.06*s + 300);
3  step (System);
4  grid on

```

Figure 3 Matlab Code for Task 1

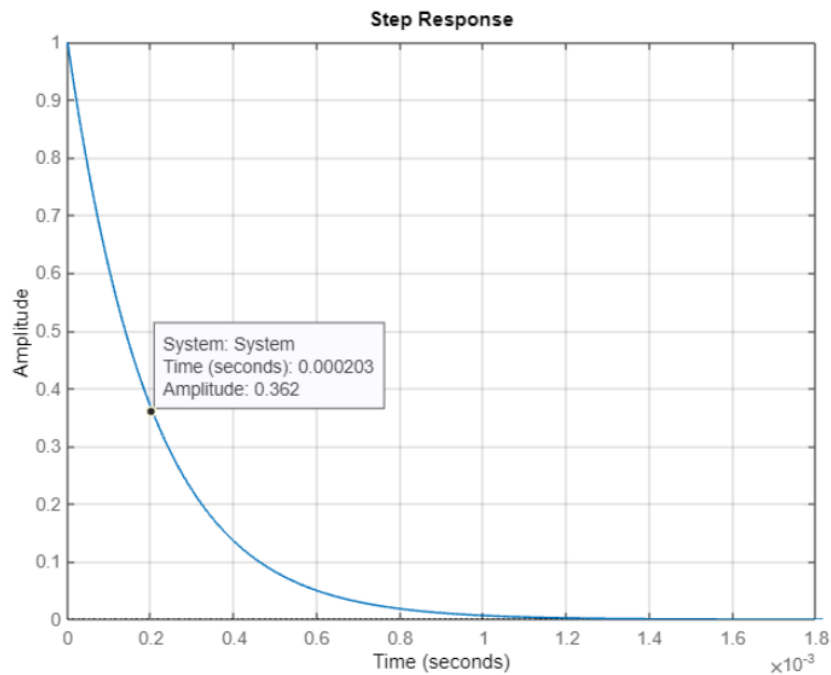


Figure 4 Time Constant Graphical for Task 1

1.4: Draw up a table with columns for theoretical and simulation results and make suitable comparisons

Calculated	Simulated	Error
0.0002	0.000203	0.000003

1.5: Critically analyse the performance of the circuit and draw up conclusions.

In this task I made a RL circuit to do transient analysis which calculates the circuit's response over time I did a calculation to work out the time constant (τ) which gave me 0.0002 I then went on to MATLAB and produced a simulated graph which I used to get the τ and I got 0.000203 this gave me an error of 0.000003 this is due to rounding in my calculation which p  3 ed this error.

Task 2 Transient Analysis of a First Order RC Electrical Circuit

2.1: Select suitable component values and calculate the time constant.

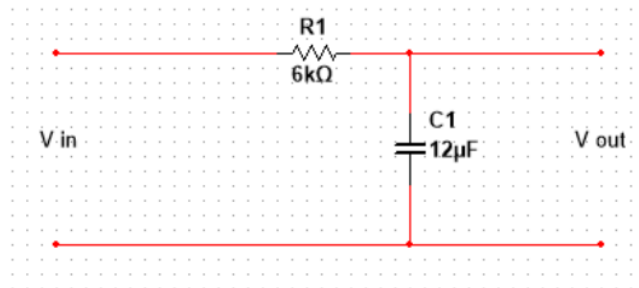


Figure 5 First Order RC Electrical Circuit for Transient Analysis

Resistor = 6000Ω

Capacitor = 0.00012 F

Time Constant $\tau = RC = 6000 * 0.00012 = 0.72 \text{ sec}$

2.2: Draw the Laplace model and give the transfer function.

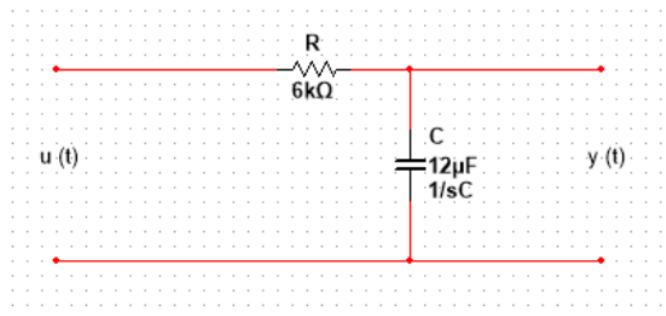


Figure 6 Laplace Model for First Order RC Electrical Circuit for Transient Analysis

$$H(s) = \frac{1}{RCs + 1} = \frac{1}{(6000) * (0.00012)s + 1} = \frac{1}{0.72s + 1}$$

2.3: Write a suitable MATLAB program and produce a suitable annotated graph.

```
1 s = tf('s');
2 system = 1/((6000*0.00012)*s) +1);
3 step (system);
4 grid on;
```

Figure 7 Matlab Code for Task 2

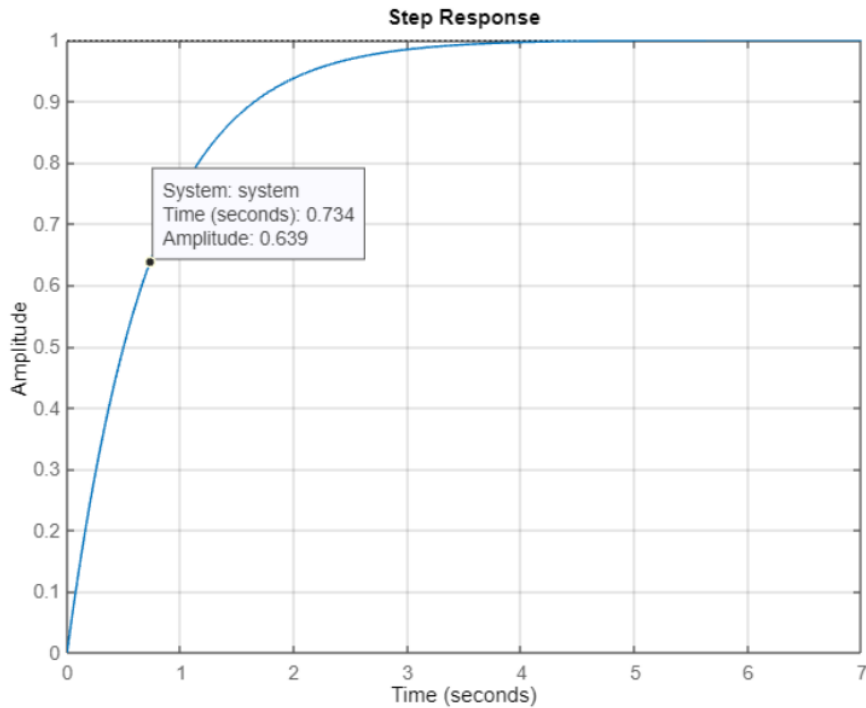


Figure 8 Time Constant Graph for Task 2

2.4: Results

Calculated	Simulated	Error
0.72	0.734	0.014

2.5: Analyse and conclusion

This task is very similar to task 1 as I'm calculating the circuit's response over time but for an RC circuit I did a calculation to work out the (τ) which gave me 0.72 seconds I then went on to MATLAB and produced a simulated graph which gave me 0.734 this gave me an error of 0.014 this is due to rounding in my calculation and the online MATLAB which isn't every accurate in its cursor which produced this error.

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

3.1: Calculate the cut-off frequency and transpose the transfer function in terms of the cut-off frequency, and determine the type of frequency response and the phase shift at the cut-off frequency.

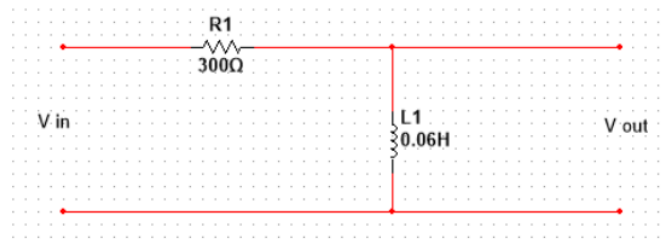


Figure 9 First Order RL Electrical Circuit for Frequency Performance

$$\omega_c = \frac{R}{L} = \frac{300}{0.06} = 5000$$

$$\frac{1}{\omega_c} \frac{s}{s+1} = \frac{s}{s+\omega_c} = \frac{s}{s+5000}$$

3.2: Write a suitable Matlab model program to perform a steady state frequency analysis and measure the cut-off frequency from the Bode plot and the phase shift. Provide suitably annotated graphical results.

```
1 s=tf('s');
2 system=s/(s+5000);
3 bode(system);
4 grid on;
```

Figure 10 Matlab Code for Task 3

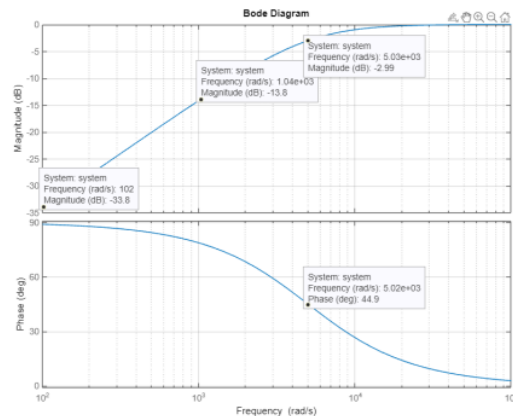


Figure 11 Frequency Performance Graph for Task 3

3.3: Draw up a table with columns for theoretical and simulation results and make suitable comparisons

	Calculated	Simulated	Error
ω_c	5000	5030	30
Φ (degrees)	45	44.9	0.1
Cut-off	-20dB	-20dB	0

3.4: Critically analyse the performance of the circuit and draw up conclusions.

Because on the layout of the circuit this will make it a highpass filter (HPF) is a electronic filter that lets high frequency signals passes thought if they are over certain cut-off frequency if they are under that frequency it will reduces the signals.

Compering my calculated and my simulated they are very close minimal errors I believe the errors that I have gathered are me rounding in my calculations and not being able to accurately place the curser on the graph. (Wikipedia, 2022)

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

4.1: Calculate the cut-off frequency and transpose the transfer function in terms of the cut-off frequency, and determine the type of frequency response and the phase shift at the cut-off frequency.

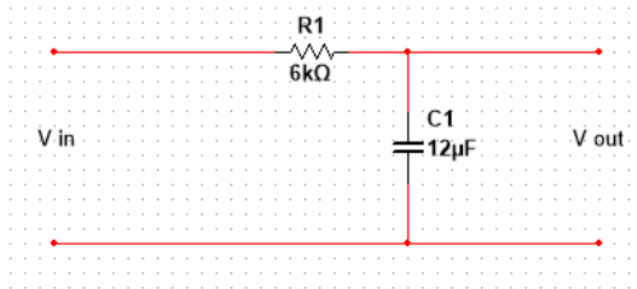


Figure 12 First Order RC Electrical Circuit for Frequency Performance

$$\omega c = \frac{1}{RC} = \frac{1}{6000 * (12 * 10^{-6})} = 13.8$$

$$H(s) = \frac{\omega c}{s + \omega c} = \frac{13.8}{s + 13.8}$$

4.2: Write a suitable Matlab model program to perform a steady state frequency analysis and measure the cut-off frequency from the Bode plot and the phase shift. Provide suitably annotated graphical results.

```

1  S = tf('s');
2  system = 13.8 / s + 13.8;
3  bode(system);
4  grid on;

```

Figure 13 Matlab Code for Task 4

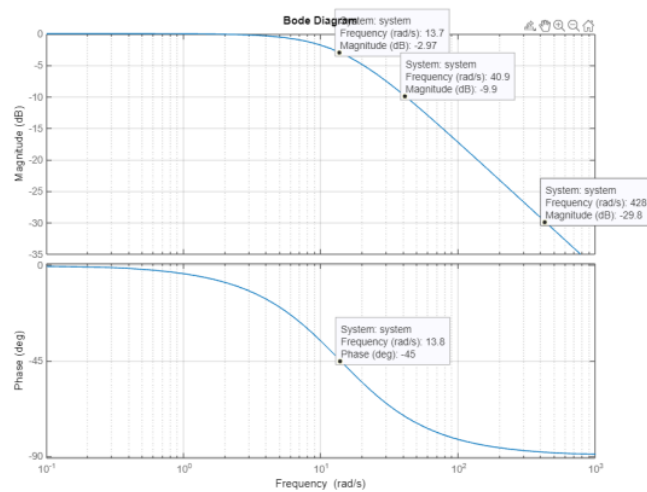


Figure 14 Frequency Performance Graph for Task 4

4.3: Draw up a table with columns for theoretical and simulation results and make suitable comparisons

	Calculated	Simulated	Error
ω_c	13.8	13.7	-0.1
Φ (degrees)	45	45	0
Cut-off	-20dB	-20dB	0

4.4: Critically analyse the performance of the circuit and draw up conclusions.

Because on the layout of the circuit this will make it a lowpass filter (LPF) is a electronic filter that lets low frequency signals pass through if they are under certain cut-off frequency if they are over that frequency it will reduce the signals.

Comparing my calculated and my simulated they are extremely close a very small error I believe the error has occurred in my rounding while doing the calculations and not being able to accurately place the cursor on the graph. (Low-Pass Filter, 2022)

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

5.1: Select suitable component values

In this task I will be making a RLC series circuit, I will be selecting the 3 different values for the components I will also be changing the resistor value 4 different times to manipulate the damping effect of the circuit.

Capacitor = $12\mu F$

Inductor = $0.06H$

Resistor will be subject to change depending on what dampening outcome I want if I want it to be under dampened (U/D), over dampened (O/D), critically dampened (C/D) or no damping (N/D) to work out the (C/D) I will need to rearrange the damping factor formula $\zeta = \frac{R}{2} \sqrt{\frac{C}{L}}$ to get it as you need the damping factor (ζ) to equal 1, the rearrange the damping factor formula is:

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

$$R = \frac{2 * 1}{\sqrt{\frac{12 * 10^{-6}}{0.06}}} = 141.421$$

Resistor Values	
Under Dampened (U/D)	5Ω
Over Dampened (O/D)	250Ω
Critically Dampened (C/D)	141.421Ω
No Damping (N/D)	$0.1\mu\Omega$

5.2: Draw the Laplace model and give the transfer function in standard format.

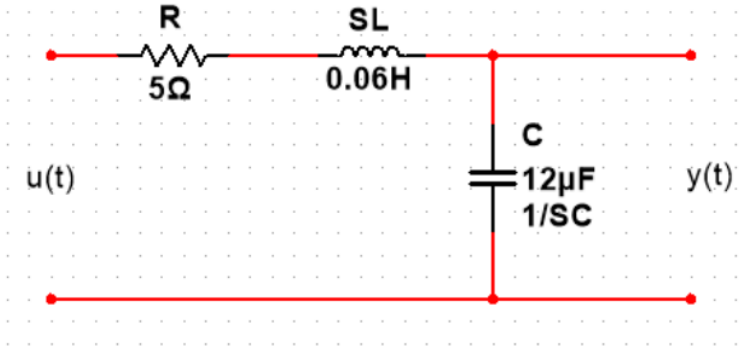


Figure 15 Laplace Model for Second Order RL Series Circuit for Transient Performance

5.3: Determine the transient performance parameters of the system for a step input from the transfer function.

In this circuit the gain (K) always equals 1, to workout the damping factor (ζ) you use this formula $\zeta =$

$\frac{R}{2} \sqrt{\frac{C}{L}}$ and to workout the natural frequency (ωn) you use this formula $\omega n = \frac{1}{\sqrt{L \times C}}$

$$\zeta = \frac{5}{2} \sqrt{\frac{12 \times 10^{-6}}{0.06}} = 0.0353$$

$$\zeta = \frac{250}{2} \sqrt{\frac{12 \times 10^{-6}}{0.06}} = 1.768$$

$$\zeta = \frac{141.421}{2} \sqrt{\frac{12 \times 10^{-6}}{0.06}} = 1$$

$$\zeta = \frac{0.1 \times 10^{-6}}{2} \sqrt{\frac{12 \times 10^{-6}}{0.06}} = 707.107 \times 10^{-12}$$

$$\omega n = \frac{1}{\sqrt{0.06 \times (12 \times 10^{-6})}} = 1178.511 \frac{rad}{s}$$



	Resistor Values			
	5Ω	250Ω	141.421Ω	0.1μΩ
Damping Factor	0.0353	1.768	1	707.107 * 10 ⁻¹²
Natural Frequency	1178.511 $\frac{rad}{s}$	1178.511 $\frac{rad}{s}$	1178.511 $\frac{rad}{s}$	1178.511 $\frac{rad}{s}$

5.4: Write a suitable MATLAB model program and perform a transient analysis. Take suitable measurements of performance. Provide suitably annotated graphical results which must be labelled and readable.

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

$$H(s) = \frac{1 * 1178.511^2}{s^2 + 2((0.0353)(1178.511)s) + 1178.511^2}$$

$$H(s) = \frac{1388888.177}{s^2 + 83.2029s + 1388888.177}$$

1	<code>s=tf('s');</code>
2	<code>system=1388888.177/(s^2+83.2029*s+1388888.177);</code>
3	<code>step(system);</code>
4	<code>grid on;</code>

Figure 16 Matlab Code for Task 5 Circuit 1

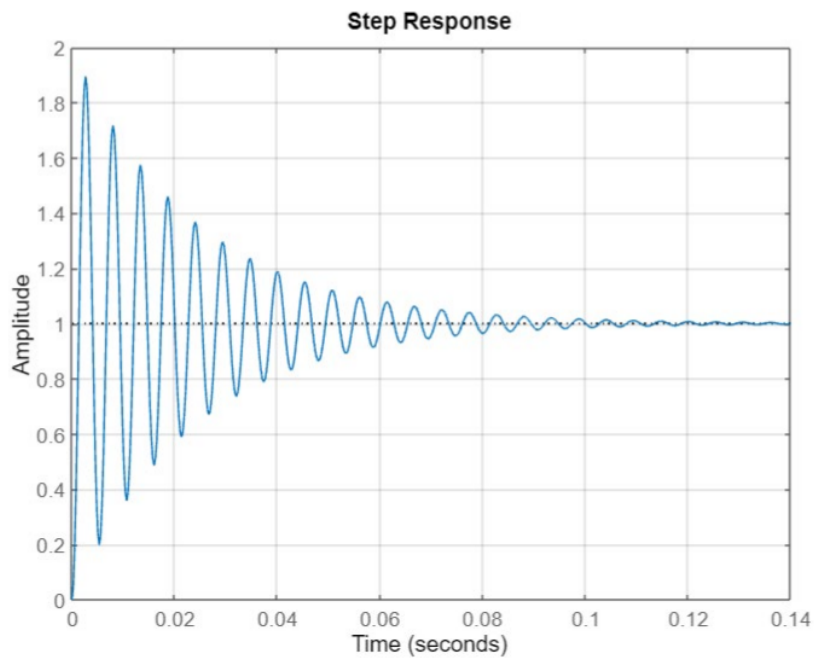


Figure 17 Transient Performance Graph for Task 5 Circuit 1

This graph is the response of an under damped RLC series circuit as you can see in the graph it oscillates up and down passed an amplitude of 1 but it will eventually even out at 1 it will just take a longer time period.

$$H(s) = \frac{1 * 1178.511^2}{s^2 + 2((1.768)(1178.511)s) + 1178.511^2}$$

$$H(s) = \frac{1388888.177}{s^2 + 4167.215s + 1388888.177}$$

```

1  s=tf('s');
2  system=1388888.177/(s^2+4167.215*s+1388888.177);
3  step(system);
4  grid on;

```

Figure 18 Matlab Code for Task 5 Circuit 2

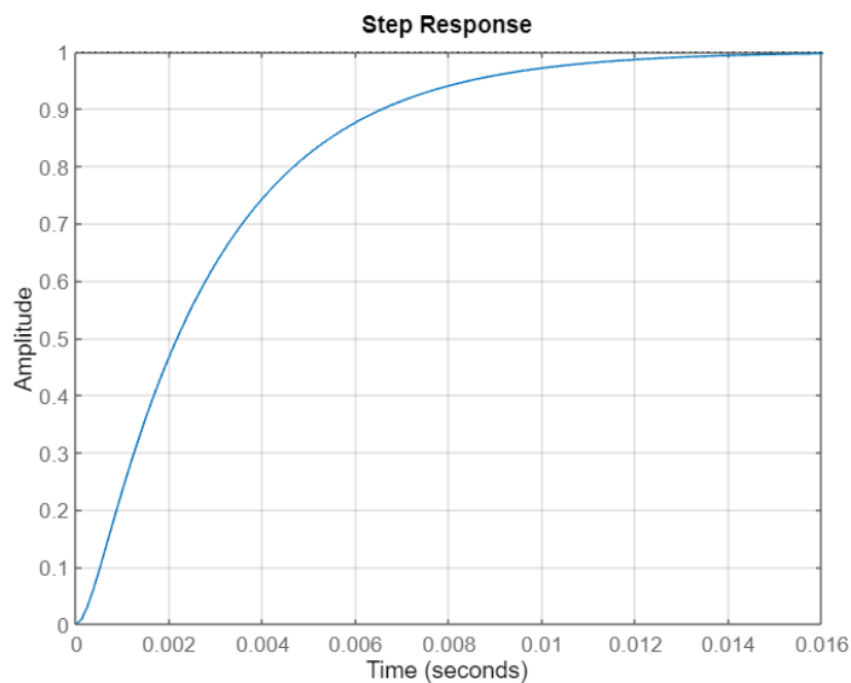


Figure 19 Transient Performance Graph for Task 5 Circuit 2

This graph is the response of an over damped RLC series circuit as you can see in the graph has a steady curve up to an amplitude of 1 and it doesn't overshoot but it takes a long time to get to an amplitude of 1.

$$H(s) = \frac{1 * 1178.511^2}{s^2 + 2((1)(1178.511)s) + 1178.511^2}$$

$$H(s) = \frac{1388888.177}{s^2 + 2357.022s + 1388888.177}$$

1	<code>s=tf('s');</code>
2	<code>system=1388888.177/(s^2+2357.022*s+1388888.177);</code>
3	<code>step(system);</code>
4	<code>grid on;</code>

Figure 20 Matlab Code for Task 5 Circuit 3

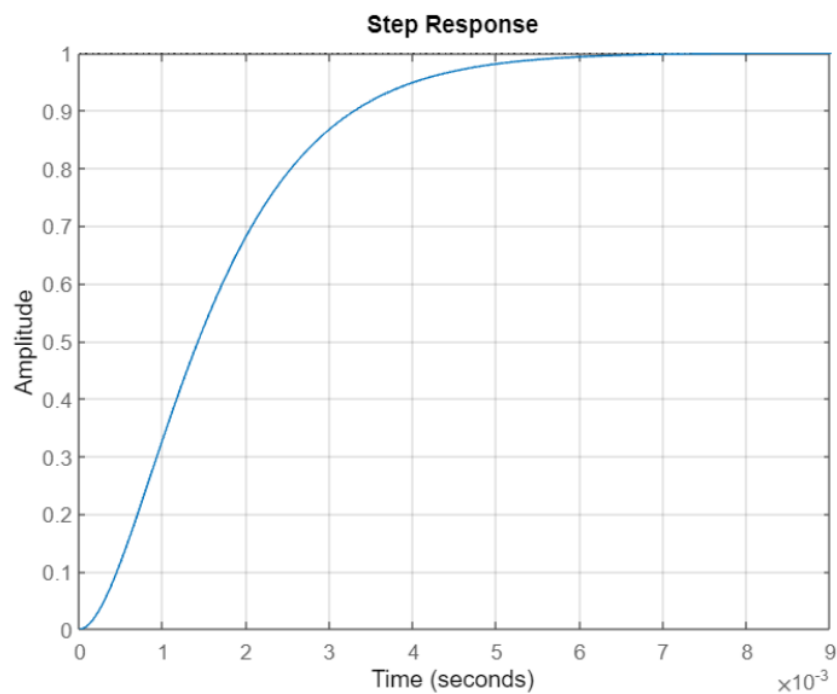


Figure 21 Transient Performance Graph for Task 5 Circuit 3

This graph is the response of critically damped RLC series circuit as you can see in the graph has a steady curve up to an amplitude of 1 and it doesn't overshoot, and it will take the shortest amount of time to get to an amplitude of 1 making it the most efficient damping profile.

$$(s) = \frac{1 * 1178.511^2}{s^2 + 2((707.107 * 10^{-12})(1178.511)s) + 1178.511^2}$$

$$H(s) = \frac{1388888.177}{s^2 + (1.667 * 10^{-6})s + 1388888.177}$$

```

1 s=tf('s');
2 system=1388888.177/(s^2+(1.667*10^-6)*s+1388888.177);
3 step(system);
4 grid on;

```

Figure 22 Matlab Code for Task 5 Circuit 4

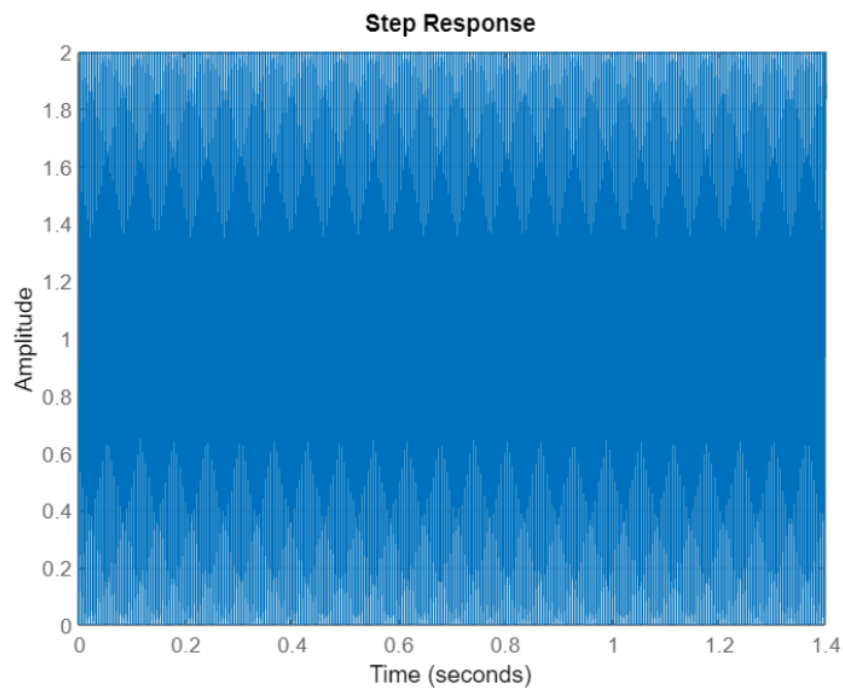


Figure 23 Transient Performance Graph for Task 5 Circuit 4

This graph is the response of no damping on a RLC series circuit as you can see in this graph it oscillates up and down passed an amplitude of 1 rapidly this will never level out at an amplitude of 1 as there is no dampening on the circuit.

5.5: Place results in a table and evaluate the performance of each circuit and make comparisons between theoretical predictions and model results.

Dampening Rate	Resistor Values	ζ
Under Dampened (U/D)	5 Ω	0.0353
Over Dampened (O/D)	250 Ω	1.768
Critically Dampened (C/D)	141.421 Ω	1
No Damping (N/D)	0.1 $\mu\Omega$	707.107 * 10 ⁻¹²

Figure 24 Table of Results Task 5

5.7: Critically analyse the performance of the circuit and draw up conclusions.

When you change the resistor value it changes the dampening factor of the circuit when the resistor value is highest this creates an overdamped response as shown in (Figure 24). When the resistor value is lowest this results in no damping circuit. To get critically damped I had to rearrange the sigma equation to find the resistor value.

When I made the resistor value lower than the critically dampened value this produced an under dampened circuit.

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

6.1: Select suitable component values.

In this task I will be making a RLC parallel circuit, I will using the same values from task 5 for my capacitor and inductor, for my resistor value this will be subject to change 4 different times to manipulate the dampening effect of the circuit.

Capacitor = $12\mu F$

Inductor = $0.06H$

Resistor will be subject to change depending on what dampening outcome I want if I want it to be under dampened (U/D), over dampened (O/D), critically dampened (C/D) or no damping (N/D) to work out the (C/D) I will need to rearrange the damping factor formula $\zeta = \frac{1}{2R} \sqrt{\frac{L}{C}}$ to get it as you need the damping factor (ζ) to equal 1, the rearrange the damping factor formula is:

$$R = \frac{1}{2\zeta} \sqrt{\frac{L}{C}}$$

$$R = \frac{1}{2} \sqrt{\frac{0.06}{12 * 10^{-6}}} = 35.35533906\Omega$$

6.2: Draw the Laplace model and give the transfer function in standard format.

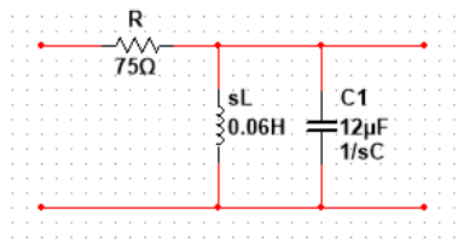


Figure 25 Laplace Model for Second Order RL Parallel Circuit for Transient Performance

6.3: Determine the transient performance parameters of the system for a step input from the transfer function.

In this circuit the gain (K) always equals 1, to workout the damping factor (ζ) you use this formula $\zeta =$

$\frac{1}{R2} \sqrt{\frac{L}{C}}$ and to workout the natural frequency (ωn) you use this formula $\omega n = \frac{1}{\sqrt{L \cdot C}}$

$$\zeta = \frac{1}{75 * 2} \sqrt{\frac{0.06}{12 * 10^{-6}}} = 0.4714$$

$$\zeta = \frac{1}{10 * 2} \sqrt{\frac{0.06}{12 * 10^{-6}}} = 3.5355$$

$$\zeta = \frac{1}{35.35533906 * 2} \sqrt{\frac{0.06}{12 * 10^{-6}}} = 1$$

$$\zeta = \frac{1}{750000 * 2} \sqrt{\frac{0.06}{12 * 10^{-6}}} = 47.14 * 10^{-6}$$

$$\omega n = \frac{1}{\sqrt{0.06 * (12 * 10^{-6})}} = 1178.511 \frac{rad}{s}$$

	Resistor Values			
	75Ω	10Ω	35.35533906Ω	750000Ω
Damping Factor	0.4714	3.5355	1	47.14 * 10 ⁻⁶
Natural Frequency	1178.511 $\frac{rad}{s}$	1178.511 $\frac{rad}{s}$	1178.511 $\frac{rad}{s}$	1178.511 $\frac{rad}{s}$

6.4: Write a suitable Matlab model program and perform a transient analysis. Take suitable measurements of performance. Provide suitably annotated graphical results which must be labelled and readable.

$$H(s) = \frac{s * \frac{1}{RC}}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

$$H(s) = \frac{s * \frac{1}{75 * (12 * 10^{-6})}}{s^2 + 2((0.4714)(1178.511)s) + 1178.511^2}$$

$$H(s) = \frac{s * 1111.1}{s^2 + 1111.1s + (1388.888 * 10^3)}$$

```
1 s=tf('s');
2 system=(s*1111.1)/((s^2)+(1111.1*s)+(1388.88*10^3));
3 step (system);
4 grid on;
```

Figure 26 Matlab Code for Task 6 Circuit 1

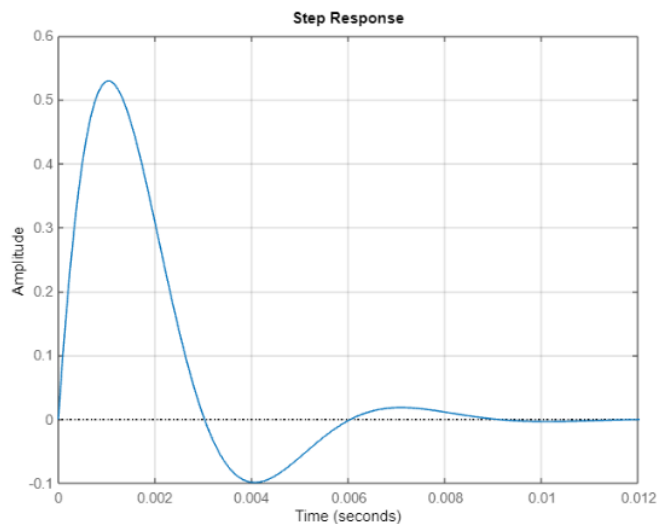


Figure 27 Transient Performance Graph for Task 6 Circuit 1

This graph is the response of an under damped RLC parallel circuit as you can see in the graph it oscillates up and down passed an amplitude of 0 but it will eventually even out at 0 it will just take a longer time period.

$$H(s) = \frac{s * \frac{1}{10 * (12 * 10^{-6})}}{s^2 + 2((3.5355)(1178.511)s) + 1178.511^2}$$

$$H(s) = \frac{s * 8333.3}{s^2 + 8333.251s + (1388.888 * 10^3)}$$

```

1 s=tf('s');
2 system=s*8333.3/((s^2)+(8333.251*s)+(1388.888*10^3));
3 step (system);
4 grid on;

```

Figure 28 Matlab Code for Task 6 Circuit 2

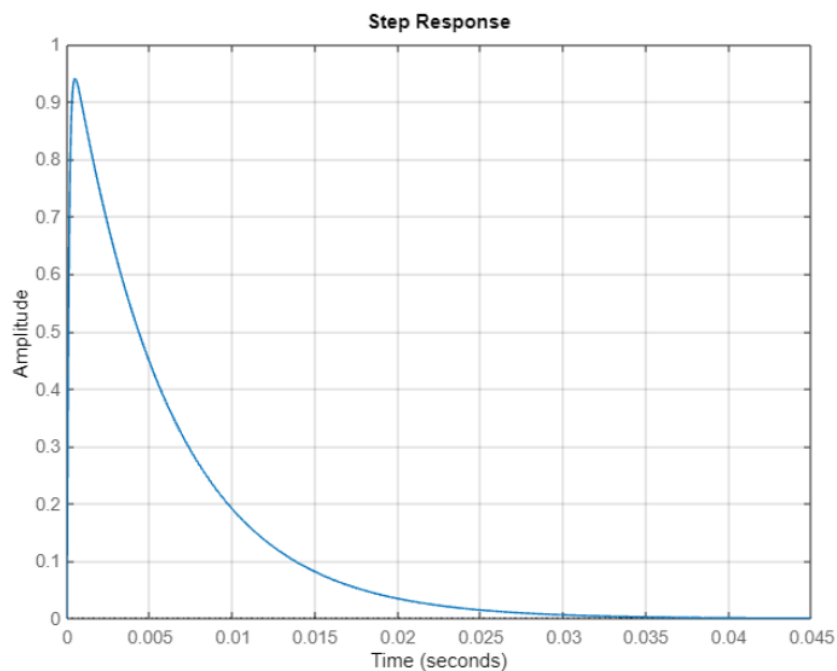


Figure 29 Transient Performance Graph for Task 6 Circuit 2

This graph is the response of an over damped RLC Parallel circuit as you can see in the graph has a steady curve down to an amplitude of 0 and it doesn't undershoot but it takes a long time to get to an amplitude of 0.

$$H(s) = \frac{s * \frac{1}{750000 * (12 * 10^{-6})}}{s^2 + 2((47.14 * 10^{-6})(1178.511)s) + 1178.511^2}$$

$$H(s) = \frac{s * 0.1}{s^2 + 0.1s + (1388.888 * 10^3)}$$

```

1 s=tf('s');
2 system=s*0.1/((s^2)+(0.1*s)+(1388.888*10^3));
3 step (system);
4 grid on;

```

Figure 30 Matlab Code for Task 6 Circuit 3

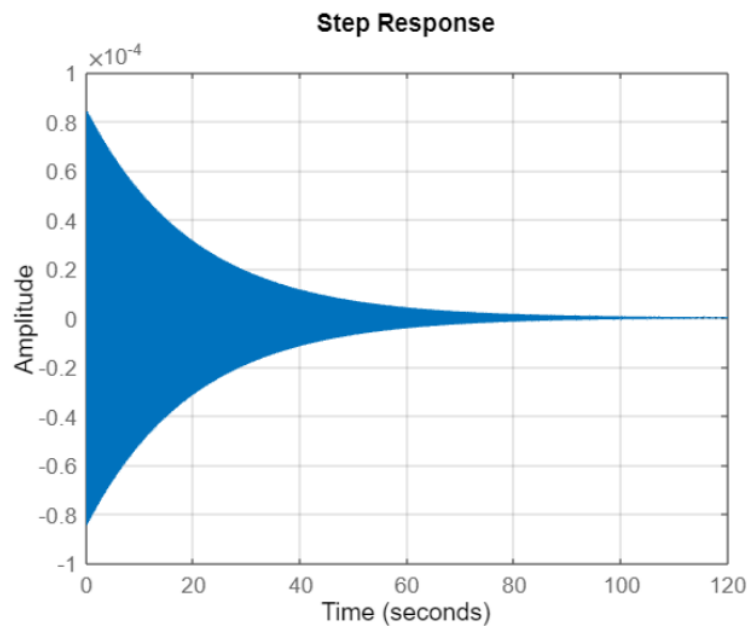


Figure 31 Transient Performance Graph for Task 6 Circuit 3

This graph is the response of no damping on a RLC parallel circuit as you can see in this graph it oscillates up and down passed an amplitude of 0 rapidly this will eventually level out at an amplitude of 0 it only goes to 0 because the capacitor is discharging but as there is no damping on the circuit this will take a very long time to do so.

$$H(s) = \frac{s * \frac{1}{35.35533906 * (12 * 10^{-6})}}{s^2 + 2((1)(1178.511)s) + 1178.511^2}$$

$$H(s) = \frac{2357.022604}{s^2 + 2357.022s + (1388.888 * 10^3)}$$

```

1 s=tf('s');
2 system=(s*2357.022604)/((s^2)+(2357.022*s)+(1388.888*10^3));
3 step(system);
4 grid on;

```

Figure 32 Matlab Code for Task 6 Circuit 4

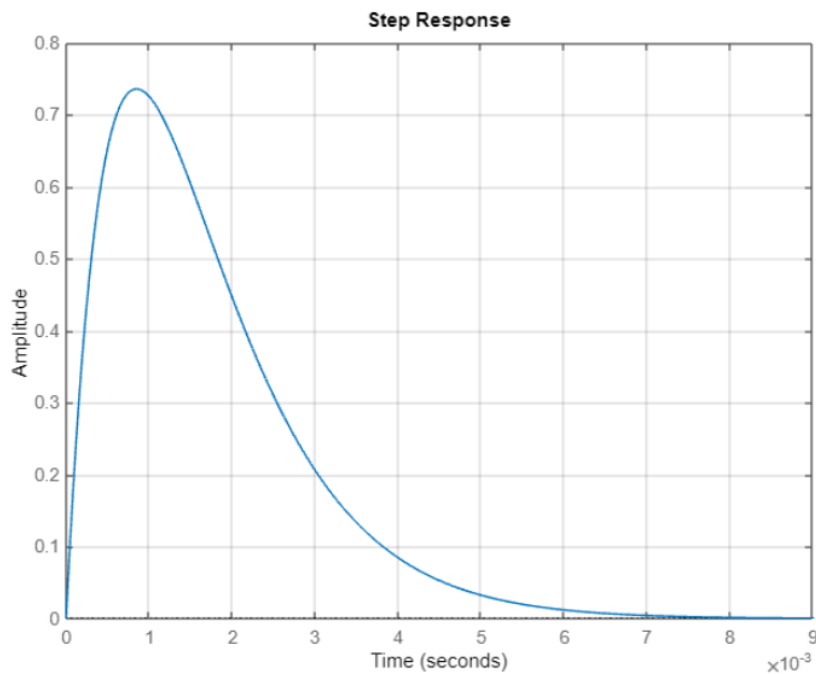


Figure 33 Transient Performance Graph for Task 6 Circuit 4

This graph is the response of critically damped RLC parallel circuit as you can see in the graph has a steady curve down to an amplitude of 0 and it doesn't undershoot, and it will take the shortest amount of time to get to an amplitude of 0 making it the most efficient damping profile.

6.5: Place results in a table and evaluate the performance of each circuit and make comparisons between theoretical predictions and model results.

Dampening Rate	Resistor Values	ζ
Under Dampened (U/D)	75 Ω	0.4714
Over Dampened (O/D)	10 Ω	3.5355
Critically Dampened (C/D)	35.35533906 Ω	1
No Damping (N/D)	750,000 Ω	$47.14 * 10^{-6}$

Figure 34 Table of Results Task 6



6.7: Critically analyse the performance of the circuit and draw up conclusions.

Unlike task 5 which when you increased the resistor value the dampening of the circuit increases as well this task is exactly the opposite when you increase the resistor value it decreases the dampening factor.

When the resistor value is highest this creates no damping response as shown in (Figure 34). When the resistor value is lowest this results in over dampened response on the circuit. To get critically damped I had to rearrange the sigma equation to find the resistor value.

When I made the resistor value higher than the critically dampened value this produced an under dampened circuit.

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

To do this task I will be using the same circuit (figure 15) and the same component values as I used in task 5.

7.1: From the transfer function, determine the frequency performance parameters such as cut-off frequencies etc from theory.

My values are:

Capacitor = $12\mu F$

Inductor = $0.06H$

Resistor = 5Ω , 250Ω , 141.421Ω , $0.1\mu\Omega$

Circuit 1

$$\frac{5}{L} = \frac{5}{0.06} = 83.3$$

$$\frac{1}{LC} = \frac{1}{0.06 * (12 * 10^{-6})} = 1388.889 * 10^3$$

$$\omega_m = \sqrt{\frac{1}{LC} - \frac{1}{2}\left(\frac{R}{L}\right)^2} = \sqrt{(1388.889 * 10^3) - \frac{1}{2}(83.3)^2} = 1177.038 \frac{rad}{s}$$

$$W_o = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.06 * 12 * 10^{-6}}} = 1178.511$$

$$Q = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{5} \sqrt{\frac{0.06}{(12 * 10^{-6})}} = 14.1421$$

$$\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{5}{2} \sqrt{\frac{12 * 10^{-6}}{0.06}} = 0.0353$$

This would make the circuit 1, underdamped as the dampening factor is below 1

Circuit 2

$$\frac{R}{L} = \frac{250}{0.06} = 4166.6$$

$$\frac{1}{LC} = \frac{1}{0.06 * (12 * 10^{-6})} = 1388.889 * 10^3$$

$$Q = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{250} \sqrt{\frac{0.06}{(12 * 10^{-6})}} = 0.2828$$

$$\zeta = \frac{R}{2} \sqrt{\frac{C}{L}} = \frac{250}{2} \sqrt{\frac{12 * 10^{-6}}{0.06}} = 1.768$$

This would make the circuit 2, overdamped as the dampening factor is above 1

Circuit 3

$$\frac{R}{L} = \frac{141.421}{0.06} = 2357.016$$

$$\frac{1}{LC} = \frac{1}{0.06 * (12 * 10^{-6})} = 1388.889 * 10^3$$

$$Q = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{141.421} \sqrt{\frac{0.06}{(12 * 10^{-6})}} = 0.5$$

$$\zeta = \frac{141.421}{2} \sqrt{\frac{12 * 10^{-6}}{0.06}} = 1$$

This would make the circuit 3, critically damped as the dampening factor is equal to 1

Circuit 4

$$\frac{R}{L} = \frac{0.1 * 10^{-6}}{0.06} = 1.6 * 10^{-6}$$

$$\frac{1}{LC} = \frac{1}{0.06 * (12 * 10^{-6})} = 1388.889 * 10^3$$

$$Q = \frac{1}{R} \sqrt{\frac{L}{C}} = \frac{1}{0.1 * 10^{-6}} \sqrt{\frac{0.06}{(12 * 10^{-6})}} = 707.107 * 10^6$$

$$\zeta = \frac{0.1 * 10^{-6}}{2} \sqrt{\frac{12 * 10^{-6}}{0.06}} = 707.107 * 10^{-12}$$

This would make the circuit 4, no damping as the dampening factor is almost a 0

7.2: Write out a suitable Matlab model program and perform a frequency analysis. Take suitable measurements of performance. Provide suitably annotated graphical results which must be labelled and readable.

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

Circuit 1

$$H(s) = \frac{\frac{1}{0.06 * (12 * 10^{-6})}}{s^2 + \frac{5}{0.06}s + \frac{1}{0.06 * (12 * 10^{-6})}}$$

$$H(s) = \frac{1388888.889}{s^2 + 83.3s + 1388888.889}$$

Circuit 2

$$H(s) = \frac{\frac{1}{0.06 * (12 * 10^{-6})}}{s^2 + \frac{250}{0.06}s + \frac{1}{0.06 * (12 * 10^{-6})}}$$

$$H(s) = \frac{1388888.889}{s^2 + 4166.6s + 1388888.889}$$

Circuit 3

$$H(s) = \frac{\frac{1}{0.06 * (12 * 10^{-6})}}{s^2 + \frac{141.421}{0.06} s + \frac{1}{0.06 * (12 * 10^{-6})}}$$

$$H(s) = \frac{1388888.889}{s^2 + 2357.016s + 1388888.889}$$

Circuit 4

$$H(s) = \frac{\frac{1}{0.06 * (12 * 10^{-6})}}{s^2 + \frac{0.1 * 10^{-6}}{0.06} s + \frac{1}{0.06 * (12 * 10^{-6})}}$$

$$H(s) = \frac{1388888.889}{s^2 + 1.6 * 10^{-6}s + 1388888.889}$$

```
1 s=tf('s');
2 system=(1/(0.06*(12*10^-6)))/((s^2)+((5/0.06)*s)+(1/(0.06*(12*10^-6))));
3 bode (system);
4
5 grid on;
6 hold on;
7
8 s=tf('s');
9 system=(1/(0.06*(12*10^-6)))/((s^2)+((25/0.06)*s)+(1/(0.06*(12*10^-6))));
10 bode (system);
11
12 s=tf('s');
13 system=(1/(0.06*(12*10^-6)))/((s^2)+((50/0.06)*s)+(1/(0.06*(12*10^-6))));
14 bode (system);
15
16 s=tf('s');
17 system=(1/(0.06*(12*10^-6)))/((s^2)+((75/0.06)*s)+(1/(0.06*(12*10^-6))));
18 bode (system);
19
20 s=tf('s');
21 system=(1/(0.06*(12*10^-6)))/((s^2)+((100/0.06)*s)+(1/(0.06*(12*10^-6))));
22 bode (system);
23
24 s=tf('s');
25 system=(1/(0.06*(12*10^-6)))/((s^2)+((125/0.06)*s)+(1/(0.06*(12*10^-6))));
26 bode (system);
27
28 s=tf('s');
29 system=(1/(0.06*(12*10^-6)))/((s^2)+((141.421/0.06)*s)+(1/(0.06*(12*10^-6))));
30 bode (system);
31
32 s=tf('s');
33 system=(1/(0.06*(12*10^-6)))/((s^2)+((250/0.06)*s)+(1/(0.06*(12*10^-6))));
34 bode (system);
35
36 s=tf('s');
37 system=(1/(0.06*(12*10^-6)))/((s^2)+(((0.1*10^-6)/0.06)*s)+(1/(0.06*(12*10^-6))));
38 bode (system);
```

Figure 35 Matlab Code for Task 7

7.3: Evaluate the performance of each circuit and make comparisons between theoretical predictions and model results.

$$20 \log(14.14) = 23.01$$
$$20 \log(0.2828) = -10.97$$
$$20 \log(0.5) = -6.02$$
$$20 \log(707.107 * 10^6) = 176.99$$

16

3.01

	Calculated (db)	Simulated (db)	error
Under Damping	23.01	23	0.01
Over Damping	-10.97	-11	0.03
Critical Damping	-6.02	-6.01	0.01
No Damping	176.99	176	0.01

Figure 36 Table of Results Task 7

7.4: Investigate by analysis and modelling, the effects of varying the value of the resistor in each circuit upon its performance. Produce graphic results from Matlab.

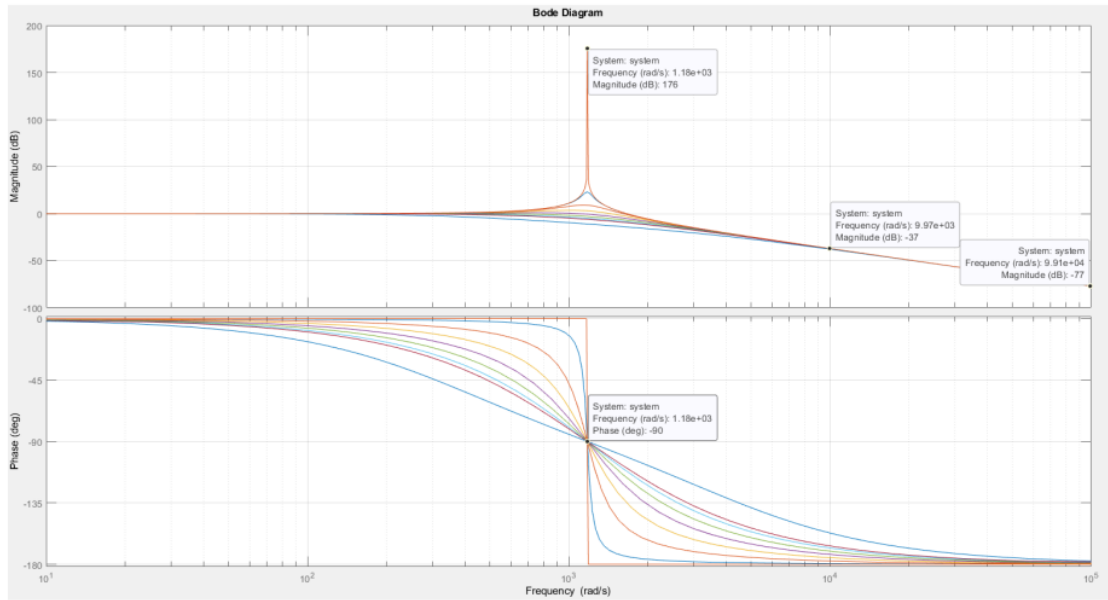


Figure 37 Frequency Performance Graph for Task 7

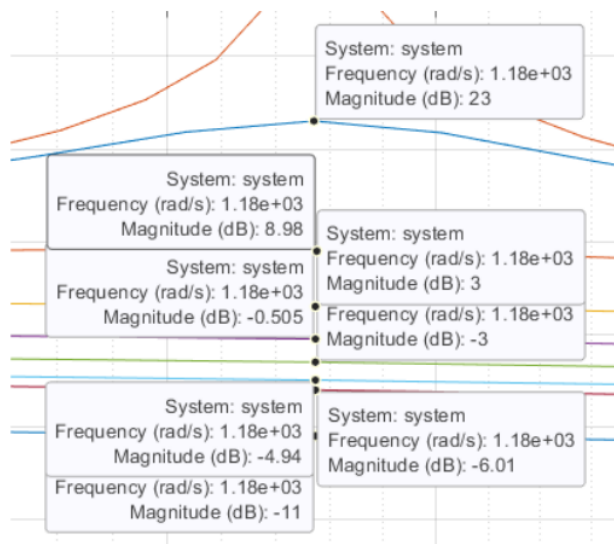


Figure 38 Frequency Performance Graph Showing Values for Task 7

7.5: Critically analyse the performance of the circuit and draw up conclusions.

It is apparent that all calculated and observed values have been verified. Rounding mistakes could result in minor differences, with the largest magnitude error being 0.03 dB shown in Figure 34, if you see figure 36 this shows how the damping factor changes as the resistance value changes, resulting in a locus diagram. The magnitude grows as the value of R decreases. Only the lower frequencies can pass through this low pass filter before the cutoff frequency.

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

To do this task I will be using the same circuit (figure 24) and the same component values as I used in task 6.

My values are:

Capacitor = $12\mu F$

Inductor = $0.06H$

Resistors = 75Ω , 10Ω , 35.35533906Ω , $750,000\Omega$

8.1: From the transfer function, determine the frequency performance parameters such as cut-off frequencies etc from theory.

Circuit 1

$$\beta = \frac{1}{RC} = \frac{1}{75 * (12 * 10^{-6})} = 1111.1$$

$$\omega_o = \frac{1}{\sqrt{LC}} = \frac{1}{\sqrt{0.06 * (12 * 10^{-6})}} = 1178.51$$

$$Q = R \sqrt{\frac{C}{L}} = 75 \sqrt{\frac{12 * 10^{-6}}{0.06}} = 1.06$$

$$\omega_{c1} = -\frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \frac{1}{LC}} = -\frac{1}{2(75)(12*10^{-6})} + \sqrt{\left(\frac{1}{2(75)(12*10^{-6})}\right)^2 + \frac{1}{(0.06)(12*10^{-6})}} = 747.34 \text{ rad/s}$$

$$\omega_{c2} = \frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \frac{1}{LC}} = \frac{1}{2(75)(12*10^{-6})} + \sqrt{\left(\frac{1}{2(75)(12*10^{-6})}\right)^2 + \frac{1}{(0.06)(12*10^{-6})}} = 1858.45 \text{ rad/s}$$

$$H(s) = \frac{s\beta}{s^2 + s\beta + \omega_o^2} = \frac{s * 1111.1}{s^2 + (s * 1111.1) + (1178.51)^2}$$

Circuit 2

$$\beta = \frac{1}{RC} = \frac{1}{10 * (12 * 10^{-6})} = 8333.3$$

$$Q = R \sqrt{\frac{C}{L}} = 10 \sqrt{\frac{12 * 10^{-6}}{0.06}} = 0.1414$$

$$\omega_{c1} = -\frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \frac{1}{LC}} = -\frac{1}{2(10)(12*10^{-6})} + \sqrt{\left(\frac{1}{2(10)(12*10^{-6})}\right)^2 + \frac{1}{(0.06)(12*10^{-6})}} = 163.46 \text{ rad/s}$$

$$\omega_{c2} = \frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \frac{1}{LC}} = \frac{1}{2(10)(12*10^{-6})} + \sqrt{\left(\frac{1}{2(10)(12*10^{-6})}\right)^2 + \frac{1}{(0.06)(12*10^{-6})}} = 8496.79 \text{ rad/s}$$

$$H(s) = \frac{s\beta}{s^2 + s\beta + \omega_0^2} = \frac{s * 8333.3}{s^2 + (s * 8333.3) + (1178.51)^2}$$

Circuit 3

$$\beta = \frac{1}{RC} = \frac{1}{35.35533906 * (12 * 10^{-6})} = 2357.022604$$

$$Q = R \sqrt{\frac{C}{L}} = 35.35533906 \sqrt{\frac{12 * 10^{-6}}{0.06}} = 0.5$$

$$\omega_{c1} = -\frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \frac{1}{LC}} = -\frac{1}{2(35.35533906)(12*10^{-6})} + \sqrt{\left(\frac{1}{2(35.35533906)(12*10^{-6})}\right)^2 + \frac{1}{(0.06)(12*10^{-6})}} = 488.16 \text{ rad/s}$$

$$\omega_{c2} = \frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \frac{1}{LC}} = \frac{1}{2(35.35533906)(12*10^{-6})} + \sqrt{\left(\frac{1}{2(35.35533906)(12*10^{-6})}\right)^2 + \frac{1}{(0.06)(12*10^{-6})}} = 2845.18 \text{ rad/s}$$

$$H(s) = \frac{s\beta}{s^2 + s\beta + \omega_0^2} = \frac{s * 2357.022604}{s^2 + (s * 2357.022604) + (1178.51)^2}$$

Circuit 4

$$\beta = \frac{1}{RC} = \frac{1}{750,000 * (12 * 10^{-6})} = 0.1$$

$$Q = R \sqrt{\frac{C}{L}} = 750,000 \sqrt{\frac{12 * 10^{-6}}{0.06}} = 10606.60172$$

$$\omega_{c1} = -\frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \frac{1}{LC}} = -\frac{1}{2(750,000)(12*10^{-6})} + \sqrt{\left(\frac{1}{2(750,000)(12*10^{-6})}\right)^2 + \frac{1}{(0.06)(12*10^{-6})}} = 1178.46 \text{ rad/s}$$

$$\omega_{c2} = \frac{1}{2RC} + \sqrt{\left(\frac{1}{2RC}\right)^2 + \frac{1}{LC}} = \frac{1}{2(750,000)(12*10^{-6})} + \sqrt{\left(\frac{1}{2(750,000)(12*10^{-6})}\right)^2 + \frac{1}{(0.06)(12*10^{-6})}} = 1178.57 \text{ rad/s}$$

$$H(s) = \frac{s\beta}{s^2 + s\beta + \omega_0^2} = \frac{s * 0.1}{s^2 + (s * 0.1) + (1178.51)^2}$$

8.2: Write out a suitable Matlab model program and perform a frequency analysis. Take suitable measurements of performance. Provide suitably annotated graphical results which must be labelled and readable.

```
1 s=tf('s');
2 system=(s*1111.1)/((s^2)+(s*1111.1)+(1178.51)^2)
3 bode (system);
4 grid on;
```

Figure 39 Matlab Code for Task 7 Circuit 1

```
1 s=tf('s');
2 system=(s*8333.3)/((s^2)+(s*8333.3)+(1178.51)^2)
3 bode (system);
4 grid on;
```

Figure 40 Matlab Code for Task 7 Circuit 2

```
1 s=tf('s');
2 system=(s*2357.022604)/((s^2)+(s*2357.022604)+(1178.51)^2)
3 bode (system);
4 grid on;
```

Figure 41 Matlab Code for Task 7 Circuit 3

```
1 s=tf('s');
2 system=(s*0.1)/((s^2)+(s*0.1)+(1178.51)^2)
3 bode (system);
4 grid on;
```

Figure 42 Matlab Code for Task 7 Circuit 4

8.3: Evaluate the performance of each circuit and make comparisons between theoretical predictions and model results.

	Calculated	Simulated	error
β	1111.1	1102	9.1
ωo	1178.51	1170	8.51
$\omega c1$	747.34	748	-0.66
$\omega c2$	1858.45	1850	8.45

	Calculated	Simulated	error
β	8333.3	8308	25.3
ωo	1178.51	1170	8.51
$\omega c1$	163.46	162	1.46
$\omega c2$	8496.79	8470	26.79

	Calculated	Simulated	error
β	2357.022604	2346	11.022604
ωo	1178.51	1170	8.51
$\omega c1$	488.16	484	4.16
$\omega c2$	2845.18	2830	15.18

	Calculated	Simulated	error
β	0.1	0	0.1
ωo	1178.51	1180	-1.49
$\omega c1$	1178.46	1180	-1.54
$\omega c2$	1178.57	1180	-1.43

8.4: Investigate by analysis and modelling, the effects of varying the value of the resistor in each circuit upon its performance. Produce graphic results from Matlab.

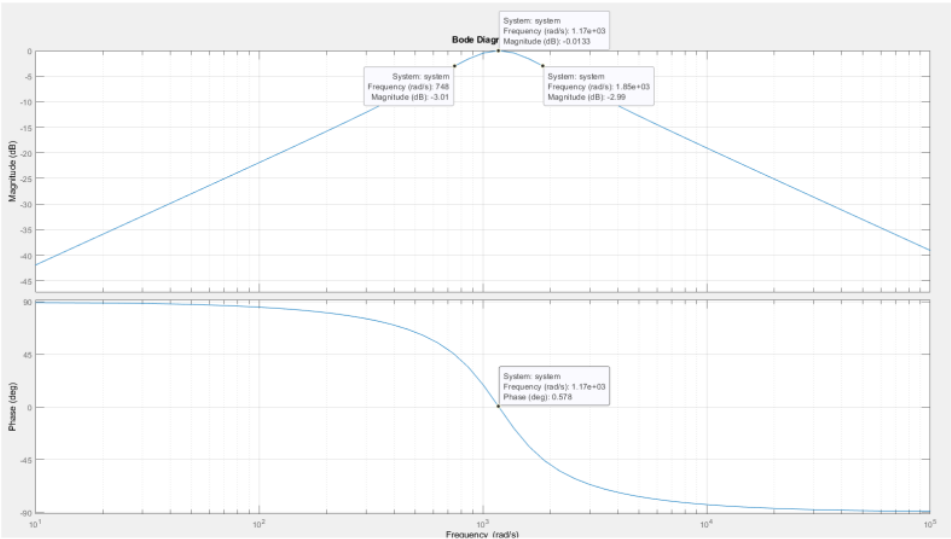


Figure 43 Frequency Performance Graph for Task 8 Circuit 1

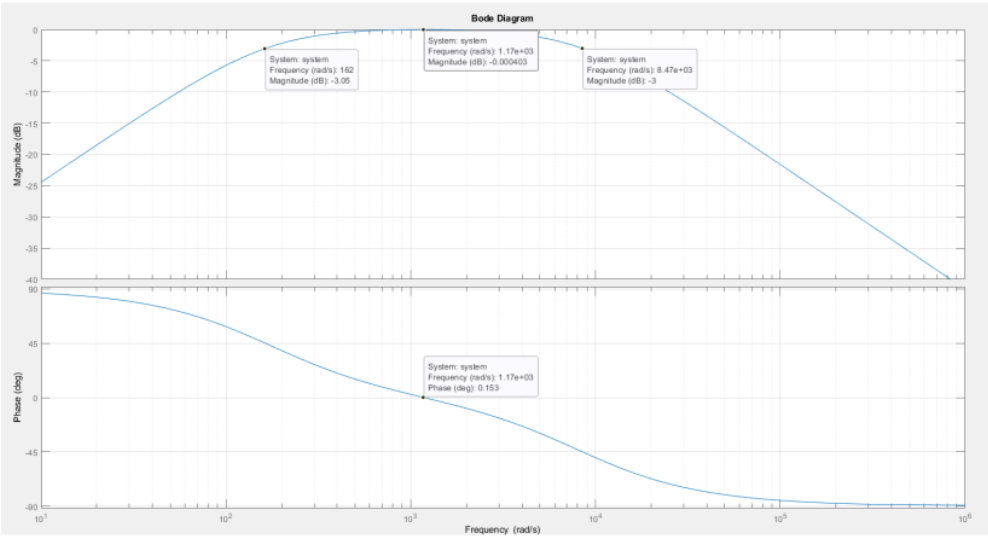


Figure 44 Frequency Performance Graph for Task 8 Circuit 2

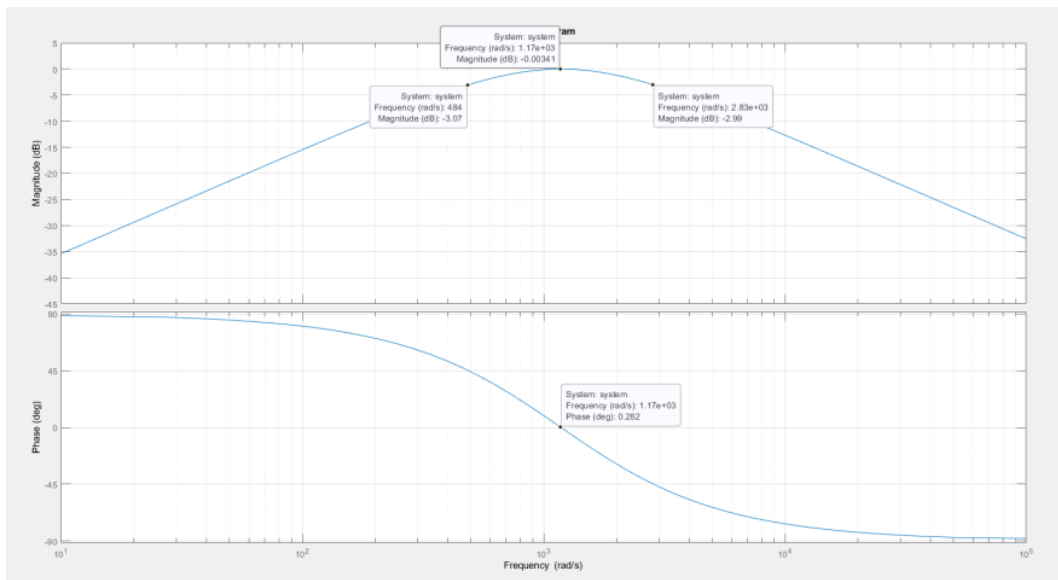


Figure 45 Frequency Performance Graph for Task 8 Circuit 3

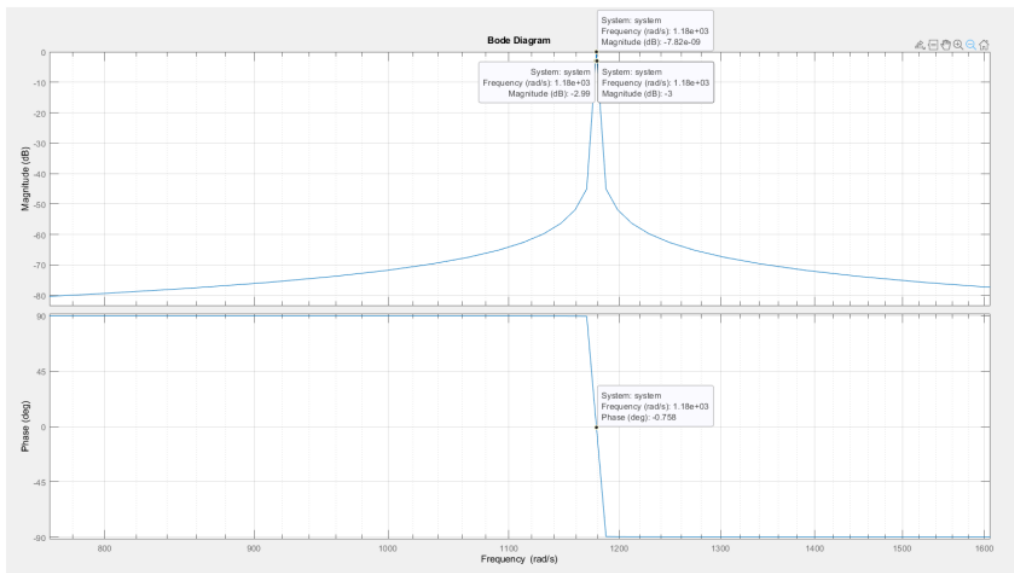


Figure 46 Frequency Performance Graph for Task 8 Circuit 4

8.5: Critically analyse the performance of the circuit and draw up conclusions.

It is evident from reading the findings that the circuit's resistance has grown. Thus, the bandwidth is reduced. This indicates that a larger resistance will make the circuit more selective.

A phase shift of 0° is observed at 1178.51 Rad/S, the resonant frequency. The majority of the calculated and simulated values line up, with the exception of certain rounding difficulties and the inability to accurately get Mat Lab to get on ± 3 -dB point.

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

9.1: Select a suitable value for C1 for the electronic system shown in figures 45 and determine the expected frequency performance.

I've chosen my capacitor to be (6nF)

Resistors 1 = 1kΩ

Resistors 2 = 20kΩ

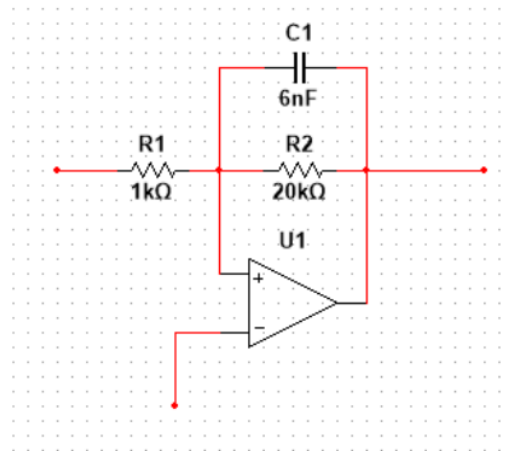


Figure 47 Frequency Performance First Order Electronic System for Task 9

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

$$\omega_c = \frac{1}{C * (R2)} = \frac{1}{(6 * 10^{-9}) * 20000} = 8333.3 \text{ rad/s}$$

$$20\log_{10}(K) = 20\log_{10}(20) = 26\text{db Gain}$$

$$26 - 3 = 23\text{dB Cut - off}$$



9.2: Write a suitable Matlab model program and produce frequency responses. Take readings of cut-off frequency, phase shift and roll-off, tabulate results and compare with theoretical values.

$$H(S) = -K \left\{ \frac{wc}{S + wc} \right\} = -20 \left\{ \frac{8333.3}{S + 8333.3} \right\}$$

```
1 s=tf('s');
2 system=(-20*(8333.3/s+8333.3))
3 bode (system);
4 grid on;
```

Figure 48 Matlab Code for Task 9

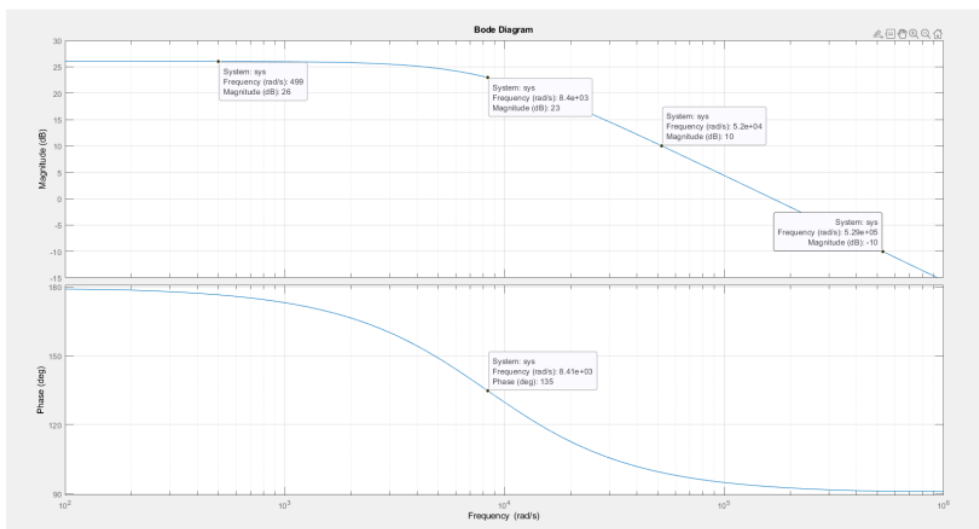


Figure 49 Frequency Performance Graph for Task 9

9.3: Critically analyse the performance of the system and draw up conclusions.

All calculated and simulated values correspond. Given that an inverting amplifier was utilised, this ends up resulting in a 180° phase shift. Phase shift at the cutoff frequency is therefore 135° (-45 + 180). The equation below demonstrates the calculated gain (26dB). Considering that the circuit is in the first order, a roll off of 20dB was performed which provide an almost perfect decade.

$$20 \log_{10}(20) = 26 \text{dB Gain}$$

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

10.1: Select a suitable value for C1 for the electronic system shown in figures 47 and determine the expected frequency performance.

I've chosen my capacitor to be (6nF)

Resistors 1 = 1k Ω

Resistors 2 = 2k Ω

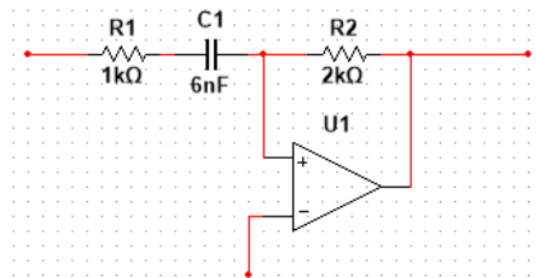


Figure 50 Frequency Performance First Order Electronic System for Task 10

$$K = \frac{R2}{R1} = \frac{2000}{1000} = 2$$

$$\omega_c = \frac{1}{C * (R1)} = \frac{1}{(6 * 10^{-9}) * 1000} = 166666.6 \text{ rad/s}$$

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

$$6.021 - 3 = 3.021\text{dB Cut - off Point}$$

10.2: Write a suitable Matlab model program and produce frequency responses. Take readings of cut-off frequency, phase shift and roll-off, tabulate results and compare with theoretical values.

$$H(S) = -K \left\{ \frac{S}{S + wc} \right\} = -2 \left\{ \frac{S}{S + 166666.6} \right\}$$

```
1 s=tf('s');
2 system (-2*(s/s+166666.6))
3 bode (system);
4 grid on;
```

Figure 51 Matlab Code for Task 10

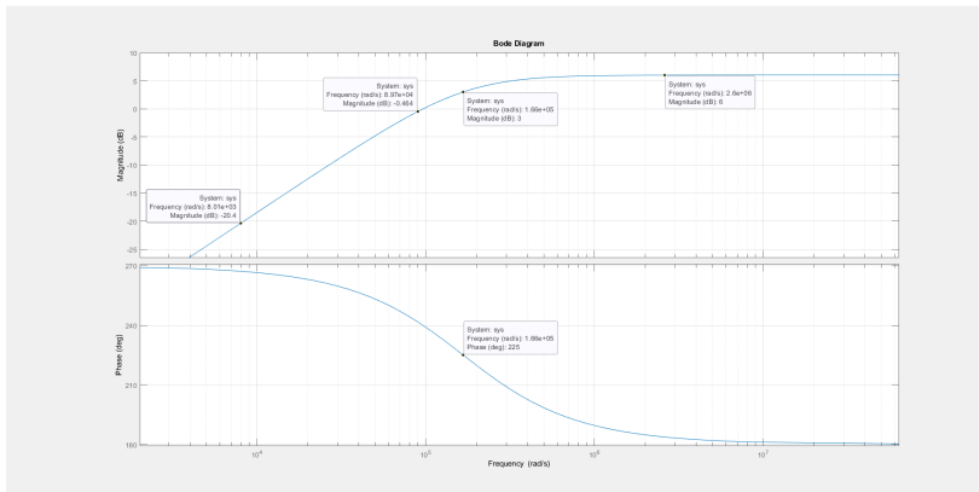


Figure 52 Frequency Performance Graph for Task 10

10.3: Critically analyse the performance of the system and draw up conclusions.

All calculated and simulated values correspond. The phase shift for a high pass filter is 45° at natural frequency. Given that it is inverted, this ends up resulting in a 180° phase shift. Phase shift at the cutoff frequency is therefore 225° (45 + 180). The equation below demonstrates the calculated gain (6.021dB). Considering that the circuit is in the first order, a roll off of 20dB was performed which provide an almost perfect decade.

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

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

11.1: Analyse the system shown in figure 50 for a Butterworth filter with $k = 1.586$. Using a Matlab model approach, produce a frequency response of the gain over a range of frequencies.

Values:

Capacitor 1 = 100nF

Capacitor 2 = 100nF

Resistors 1 = $35\text{k}\Omega$

Resistors 2 = $35\text{k}\Omega$

Resistors 3 = 586Ω

Resistors 4 = $1\text{k}\Omega$

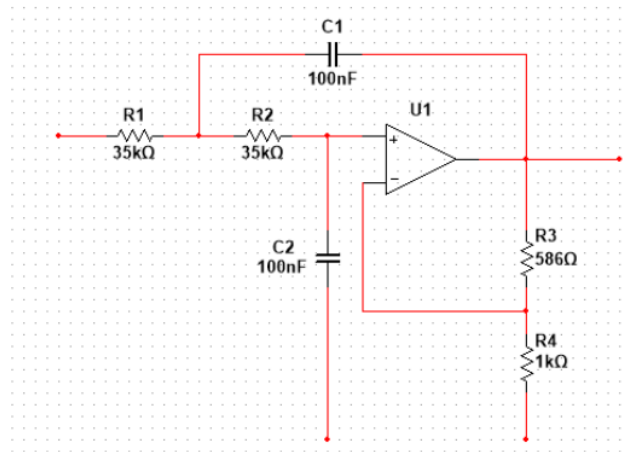


Figure 53 A Sallen & Key 2nd Order Filter

$$R3 = (K - 1) * R4 = (1.586 - 1) * 1 = 586\Omega$$

$$W_c = \frac{1}{\sqrt{R^2 * C^2}} = \frac{1}{\sqrt{(35 * 10^3)^2 * (100 * 10^{-9})^2}} = 285.71 \text{ rad/s}$$

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

$$\frac{W_c}{Q} = \frac{285.71}{0.707} = 404.12$$

11.2: Critically analyse your results and compare with theory. Evaluate the system's performance in comparison with the system in figure 5.

$$H(S) = \frac{K * W_c^2}{S^2 + \left(\frac{W_c}{Q}\right)S + W_c^2} = \frac{1.586 * 285.71^2}{S^2 + 404.12S + 285.71^2}$$

```

1 S=tf('s');
2 system =(129465.5/(S^2+404.12*S+81630.2));
3 bode(system);
4 grid on;

```

Figure 54 Matlab Code for Task 11

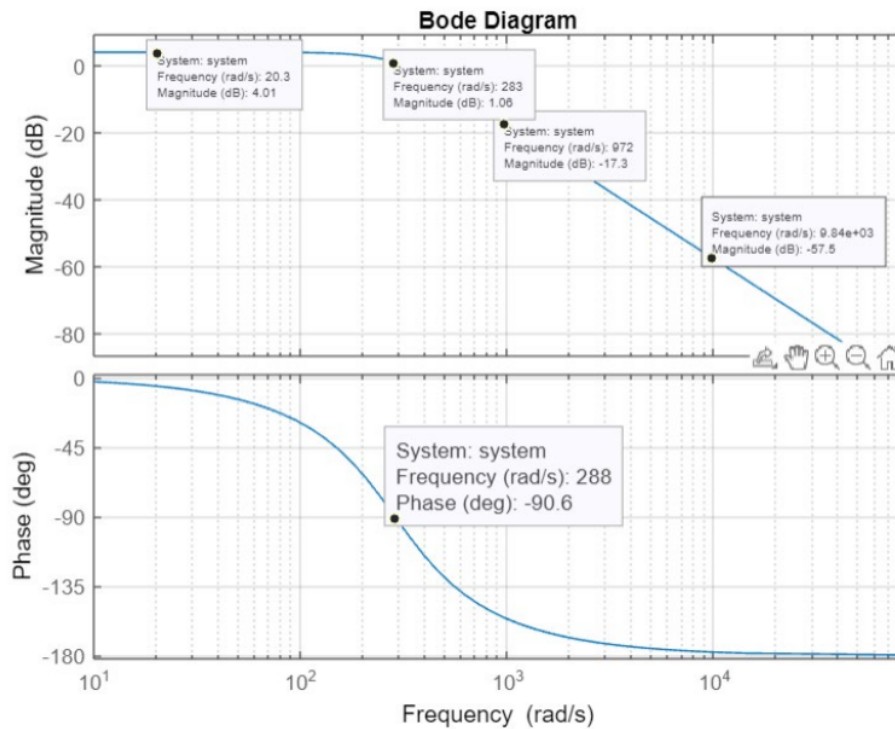


Figure 55 Frequency Performance Graph for Task 11

11.3: Critically analyse the performance of the system and draw up conclusions.

With the exception of the cut off frequency, which was wrong by 3 Rad/S, all calculated and simulated results correspond. Rounding mistakes may be to blame for this as well as the inability to accurately place the -90° point. As this is a second order circuit this changes the phase shift as well as the roll-off, which is -40dB, compared to a first order circuit with a roll off of -20dB over a decade.

As a result, a second order circuit is more specific about what frequencies it lets in. because of the steeper roll-off.



Task 12 – First Order Control System Analysis

Analyse the system model shown in figure 54.

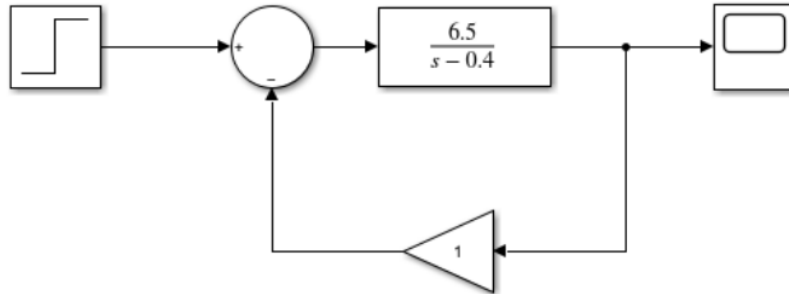


Figure 56 First Order Control System for Task 12

12.1: Determine the open loop performance, plot the argand diagram and comment on its stability.

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

Figure 57 Matlab Code for Task 12.1

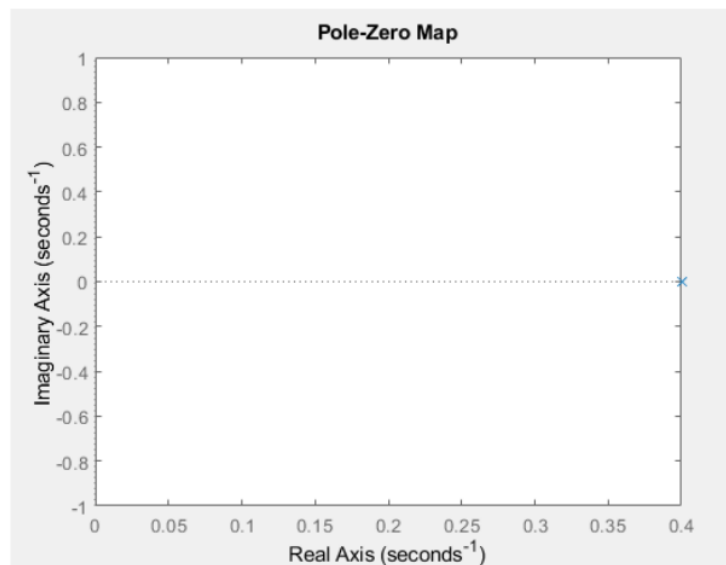


Figure 58 Pole-Zero Map for Task 12.1

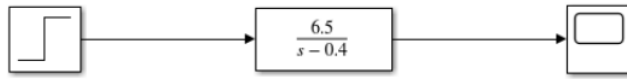


Figure 59 Open Loop Transfer Function

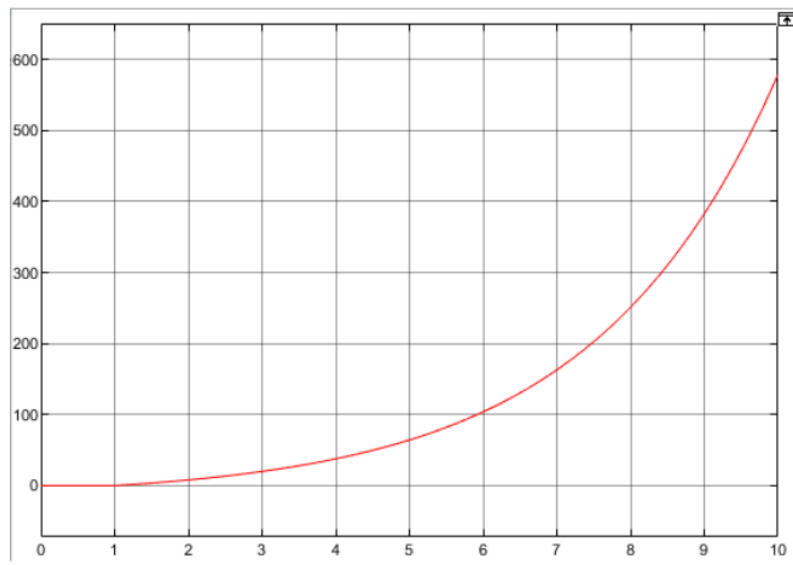


Figure 60 Open Loop Transfer Function Graph

12.2: Produce the overall closed loop transfer function in terms of K, plot the argand diagram for K 1 and comment on its stability.

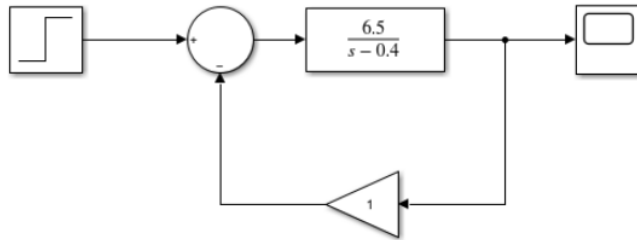


Figure 61 Closed Loop Transfer Function

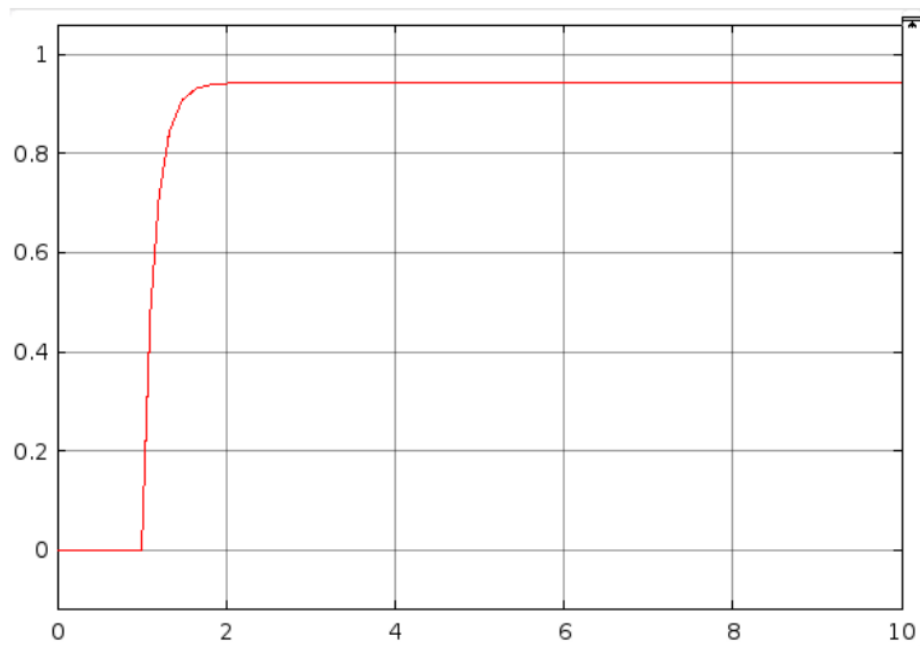


Figure 62 Closed Loop Transfer Function Graph

12.3: Determine the minimum value of K required in the feedback for stability and use a root locus plot in Matlab to confirm it.

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

Multiply by (s - 0.4)

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

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

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

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

$$s = -6.5K + 0.4$$

$$s = 0.4 - 6.5K$$

$$s = 0 = 0.4 - (6.5 * 0.0614)$$

```
1 num = [6.5];
2 den = [1 -0.4];
3 rlocus(num,den);
4 grid on
```

Figure 63 Matlab Code for Task 12.3

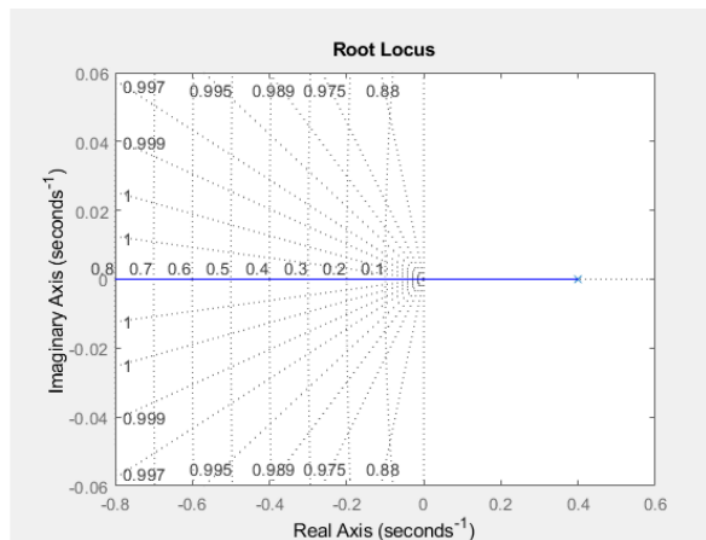


Figure 64 Root Locus Map for Task 12.3

12.4: Build the model using Simulink and measure its response to a unit step input with 3 different values of K below and above the calculated value. Present all your mathematical workings, add annotations to your graphical results.

Circuit 1

K= 5

$$S = 0.4 - 6.5K = 0.4 - 6.5(5) = -32.1$$

The pole is at -32.1, therefore stable.

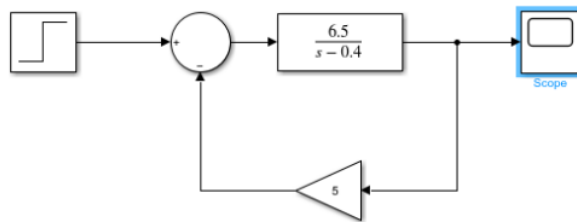


Figure 65 Closed Loop with a K=5

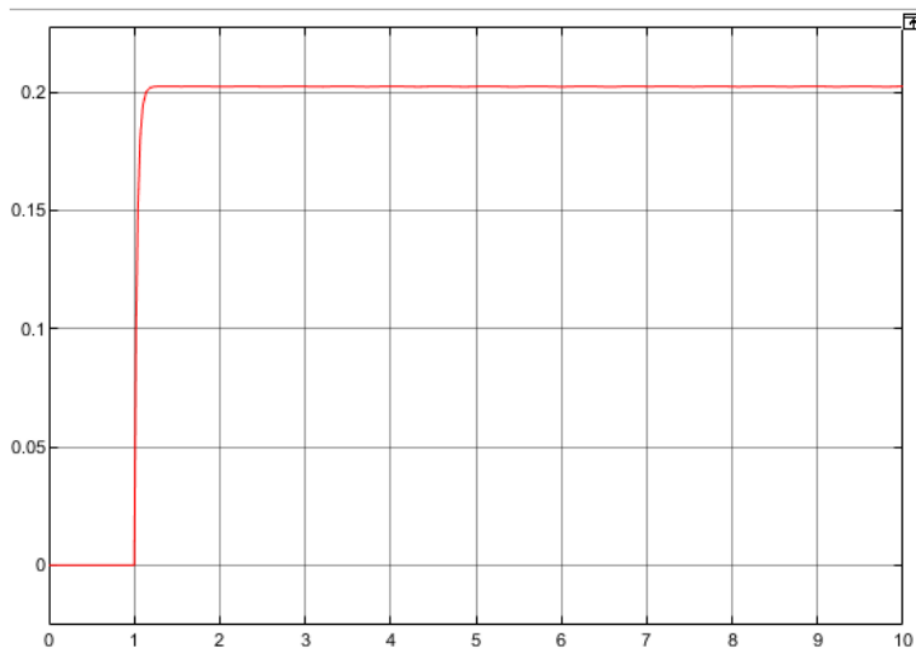


Figure 66 Task 12.4 Simulink Graph 1

Circuit 2

$K = 10$

$$s = 0.4 - 6.5K = 0.4 - 6.5(10) = -64.6$$

The pole is at -64.6, therefore stable.

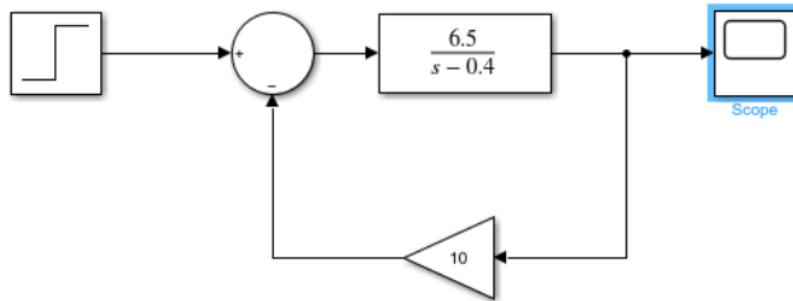


Figure 67 Closed Loop with a $K=10$

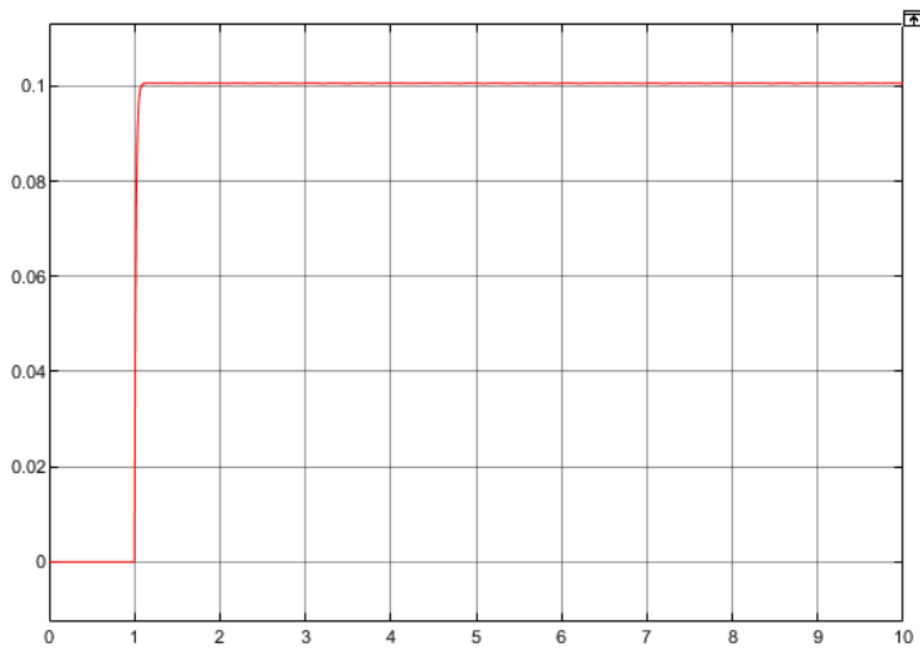


Figure 68 Task 12.4 Simulink Graph 2

Circuit 2

K= 0.005

$$S = 0.4 - 6.5K = 0.4 - 6.5(0.005) = 0.3675$$

The pole is at 0.3675, therefore unstable.

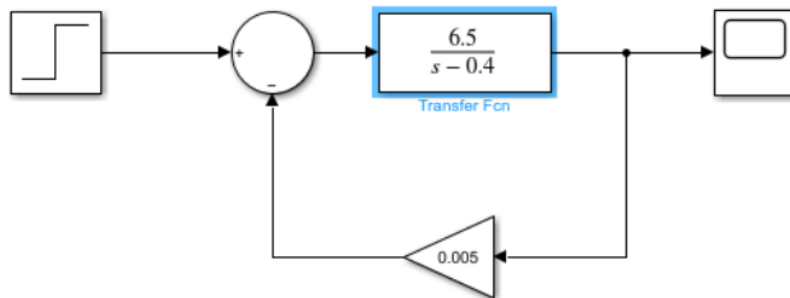


Figure 69 Closed Loop with a K=0.005

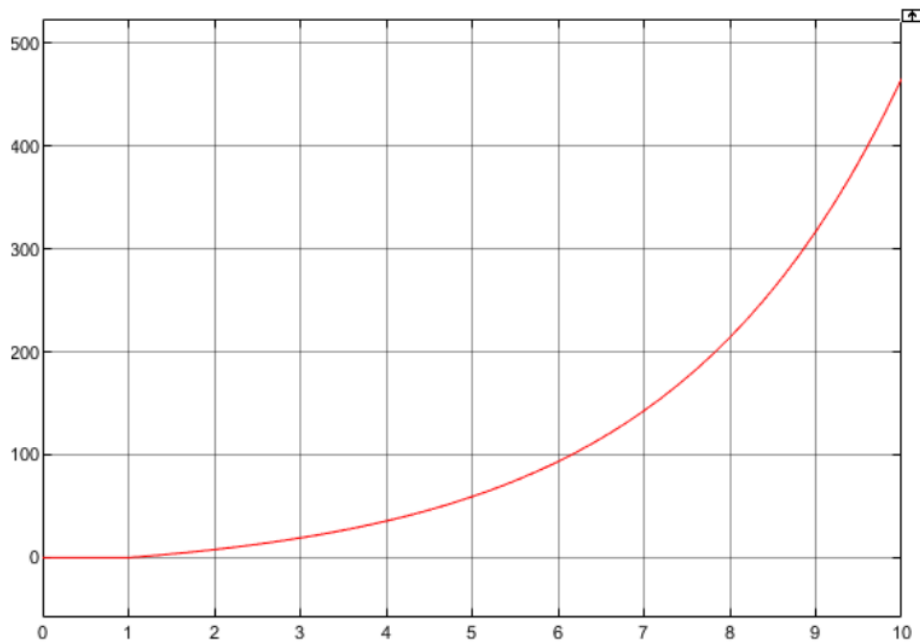


Figure 70 Task 12.4 Simulink Graph 3

12.5: Draw up a table with columns for theoretical and simulated results and make suitable comparisons.

K Value	Pole	Measured Stability	Calculated Stability
5	-32.1	Stable	Stable
10	-64.6	Stable	Stable
0.005	0.3675	Unstable	unstable

12.6: Critically analyse the performance of the circuit and draw up conclusions.

The table above makes it abundantly evident that from the Simulink model and from the formulae. Knowing what polarity of the pole will allow you to forecast the stability of the circuit. (0.0614) is the minimum feedback gain value, as determined by rearranging the equation. Any value above this will stabilise the circuit, and any value below will make it unstable. You need the negative pole in the left-hand plane for the circuit to be stable.



Task 13 – DC Motor Model Analysis

A DC permanent magnet motor has the following parameters:

- Armature resistance = 1.5 Ohms
- Armature inductance = 0.165H
- Rotor inertia = 0.0042 Kg m²
- Friction coefficient = 4.6 x 10⁻⁶ Nm/rad/s
- Motor voltage constant = 0.063 V/rad/s
- Motor torque constant = 0.063 Nm/A
- Maximum armature voltage = 24V

13.1: Develop a mathematical model of the motor and its load, produce the transfer function with the disturbance initially set to zero.

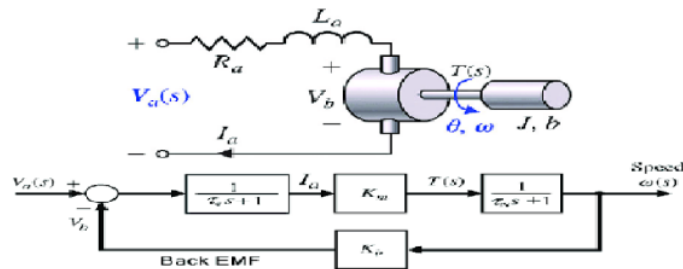


Figure 71 DC motor modal

$$G(s) = \frac{K\omega n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

13.2: Deduce the damping factor, natural frequency, stall torque and the theoretical friction-less no-load-speed.

$$\zeta = \frac{\left(\frac{b}{J} + \frac{Ra}{La}\right)}{2\omega_n} = \frac{\left(\frac{4.6 * 10^{-6}}{0.0042} + \frac{1.5}{0.165}\right)}{2 * 2.395} = 0.0115$$



$$\omega_n = \sqrt{\frac{Ra b}{La J} + \frac{K_T K_e}{La J}} = \sqrt{\frac{1.5 * (4.6 * 10^{-6})}{0.165 * 0.0042} + \frac{0.063 * 0.063}{0.165 * 0.0042}} = 2.395$$

$$T_{STALL} = \frac{K_m V_a}{R_a} = \frac{0.063 * 24}{1.5} = 1.008 Nm$$

$$\Omega_{NL} = \frac{V_a}{K_m} = \frac{24}{0.063} = 380.952 rad/s$$

13.3: Plot the poles and comment on their location in the argand diagram.

$$a = 1$$

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

24

$$c = \omega_n^2 = \left(\frac{R_a b}{L_a J} + \frac{K_T K_e}{L_a J}\right) = \left(\frac{1.5 * (4.6 * 10^{-6})}{0.165 * 0.0042} + \frac{0.063 * 0.063}{0.165 * 0.0042}\right) = 5.737$$

Pole:

$$\frac{-b \pm \sqrt{b^2 - 4ac}}{2a} = \frac{-9.092 \pm \sqrt{9.092^2 - 4 * 1 * 5.737}}{2 * 1} = -0.6822 \text{ or } -8.4098$$

13.4: Build a model of this motor system using Matlab Simulink.

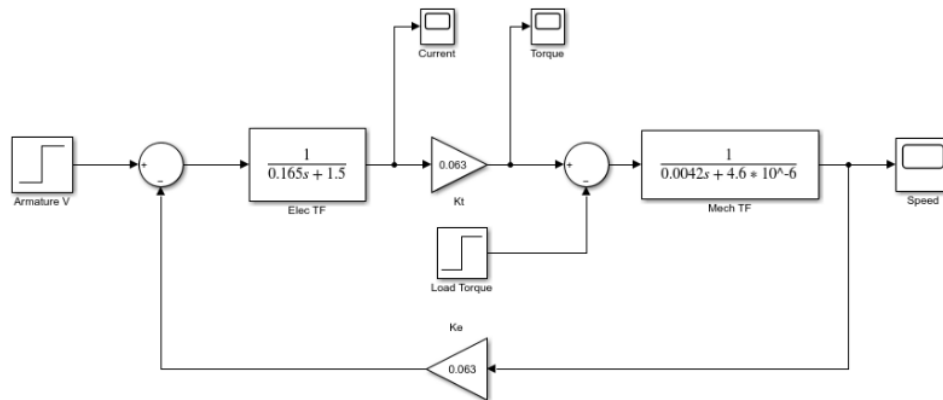
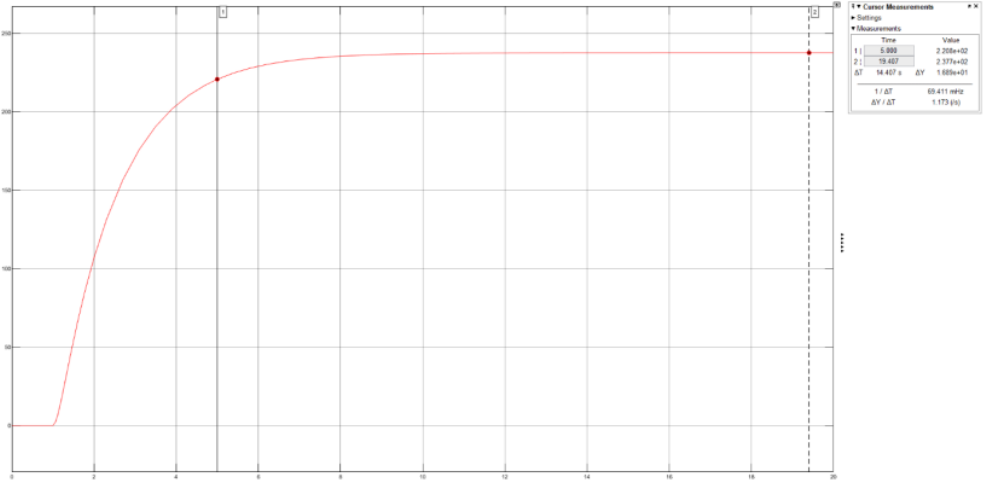


Figure 72 Simulink modal

13.5: Analyse the speed and torque responses of the motor over 20 seconds to an armature voltage step input of 15Vdc with the disturbance set to zero and thus measure the no-load-speed and torque of the motor. Measure the settling time. Apply the theoretical stall torque after 10 seconds and check the result.

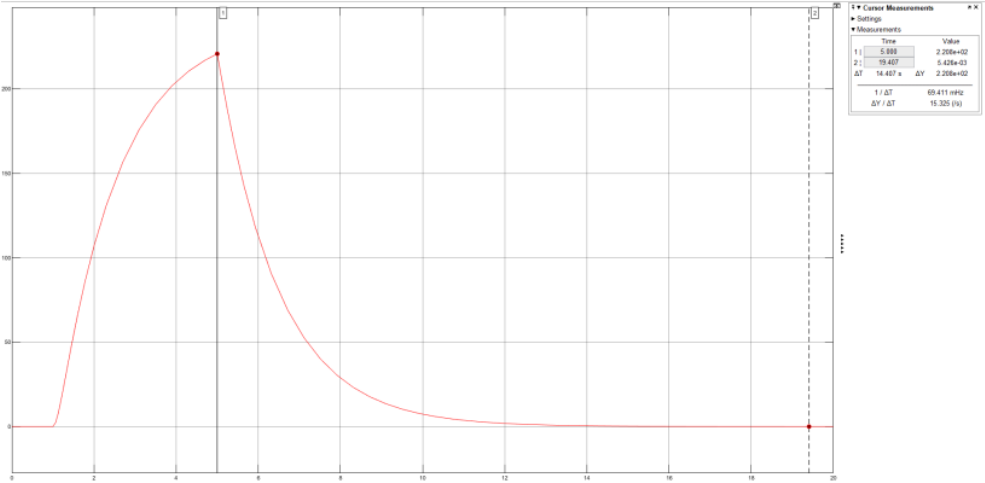
No Disturbance



13.6: Analyse the speed and torque responses of the motor over 20 seconds to an armature voltage step input of 15Vdc with the disturbance of 0.03Nm after 10 seconds and thus find the speed and current. Compare the loaded speed with the theoretical prediction.

With Disturbance

$$T_{STALL} = \frac{K_m V_a}{R_a} = \frac{0.063 * 15}{1.5} = 0.63 \, Nm$$



$$\Omega_L = \frac{V_a - \frac{R_a T_L}{K_T}}{\frac{R_a b}{K_T} + K_e} = \frac{15 - \frac{1.5 * 0.03}{0.063}}{\frac{1.5 * (4.6 * 10^{-6})}{0.063} + 0.063} = 226.3638 \, rad/s$$

13.7: Draw up a table with columns for theoretical and simulation results and make suitable comparisons

$$T_{STALL} = \frac{K_m V_a}{R_a} = \frac{0.063 * 15}{1.5} = 0.63 \, Nm$$

$$\Omega_{NL} = \frac{V_a}{K_m} = \frac{15}{0.063} = 238.095 \, rad/s$$

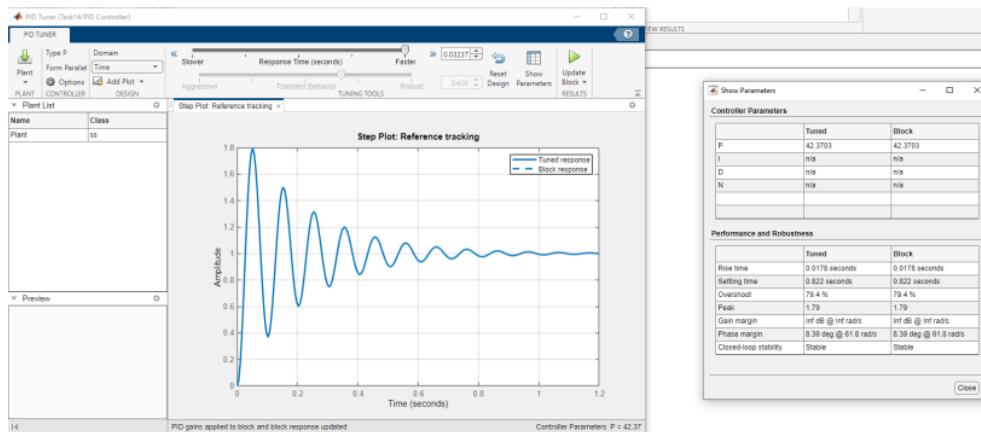
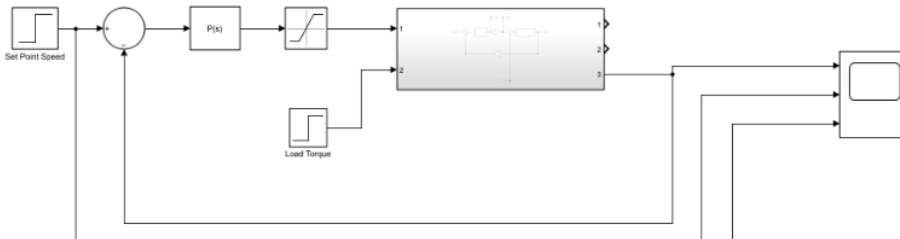
	Calculated	Simulated	Error
No Load Speed (rad/s)	238.095	237.7	0.395
Loaded Speed (rad/s)	226.3638	220.8	5.5638

13.8: Critically analyse the performance of the circuit and draw up conclusions.

I built my circuit both with and without disturbance, comparing the simulated and calculated results. My highest inaccuracy, was 5.5638 error, was with the Loaded speed. This can be attributed to human error while adding the tags or rounding issues when performing my calculations. My calculated and simulated values are in agreement with one another and demonstrate how the rad/s values for the loaded and no-load speeds are very similar. However, with the circuit without disturbance, the graph doesn't fall back to 0 like the graph for the circuit with disturbance and instead maintains a constant value of 237.7.

Task 14 – Proportional Speed Control System

14.1: Convert the motor model into a subsystem for simplicity. Add an outer loop to include a proportional controller with a step speed setpoint of 140 rad/s and speed feedback with a disturbance of 0.03Nm after 10 seconds. Use the standard PID block (set up for P only) and ensure the armature voltage is limited to maximum voltage. Run the auto tune feature and obtain the optimum value for the constant K_p .



14.2: Replicate the control system twice and feed the speed output signals into a 3-input scope. Manually adjust the values of K_p in the two new controllers above and below the auto tuned value. Run the simulation and measure the steady state error, rise time, overshoot (if any) for all three responses.

Block Parameters: PID Controller

PID 1dof (mask) (link)

This block implements continuous- and discrete-time PID control algorithms and includes advanced features such as anti-windup, external reset, and signal tracking. You can tune the PID gains automatically using the 'Tune...' button (requires Simulink Control Design).

Controller: **P** Form: **Parallel**

Time domain:
☒ Continuous-time
☐ Discrete-time

Discrete-time settings
Sample time (-1 for inherited): **-1**

▼ Compensator formula

P

Main Initialization Output Saturation Data Types State Attributes

Controller parameters
Source: **internal**
Proportional (P): **0.713417432363593**

Automated tuning
Select tuning method: **Transfer Function Based (PID Tuner App)** **Tune...**

☒ Enable zero-crossing detection

OK **Cancel** **Help** **Apply**

Show Parameters

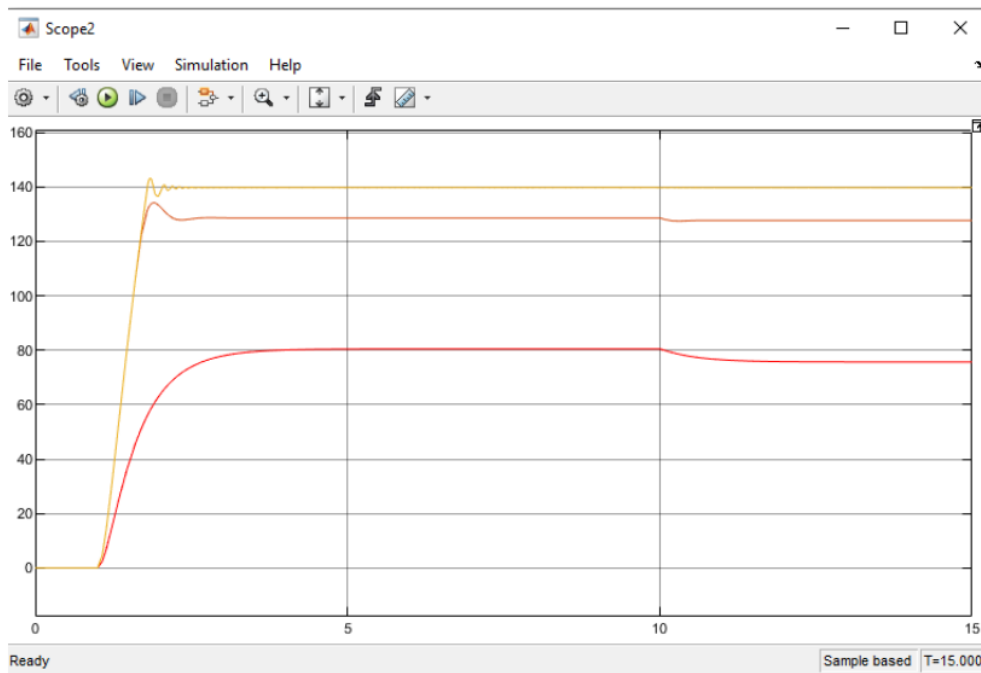
Controller Parameters

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

Performance and Robustness

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

Close



14.3: Discuss the effect of increasing or decreasing K_p .

The overshoot grows and the rising time decreases when K_p is increased, making the overshoot even quicker. When K_p is lowered steady state inaccuracy dramatically increases and the rise time might reach over one second, but then the overshoot will lower.

14.4: Draw up a table with columns for theoretical and simulation results and make suitable comparisons.

K_p Value	Steady State Error	Rise Time (S)	Overshoot
42.3703	0	0.0178	79.40 %
0.71342	12.05	0.205	13.20 %
0.085369	60	1.24	0 %

14.5: Critically analyse the performance of the circuit and draw up conclusions.

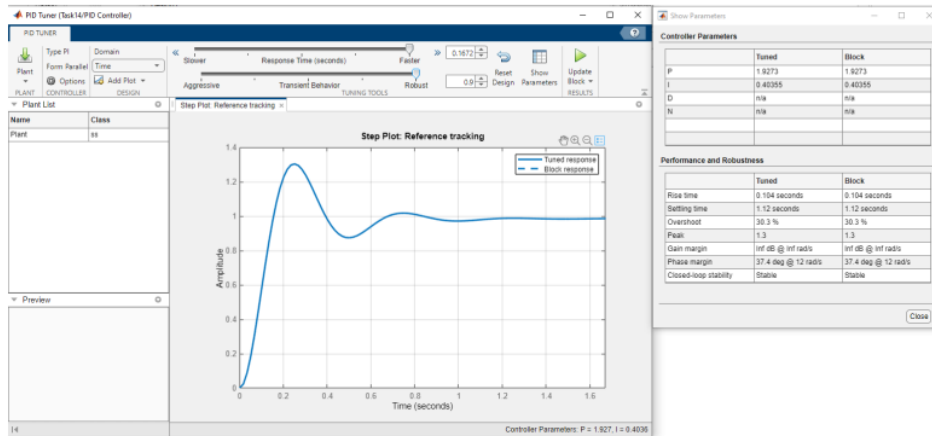
When the stable error is low, there is a strong correlation between the rise time and the overshoot. The K_p value will be high and the steady state error will be very modest if the rise time is short. These conclusions are supported by the results, which include an example of "High," "Mid," and "Low K_p values to demonstrate a clear distinction between the measured values."

To sum up, all outcomes were in line with what was predicted to happen when K_p was increased. The K_p value with the biggest overshoot was 42.3703, which also had the lowest rising time. K_p 0.085369 was the lowest value. 1.24s was its rise time, and there was no overshoot.



Task 15 – Proportional-Integral Speed Control System

15.1: Save your Matlab file under a new name and convert each controller to PI. Auto tune the first and use the same value of Kp in all three systems.



Block Parameters: PID Controller1

PID 1dof (mask) (link)

This block implements continuous- and discrete-time PID control algorithms and includes advanced features such as anti-windup, external reset, and signal tracking. You can tune the PID gains automatically using the 'Tune...' button (requires Simulink Control Design).

Controller: **PI** Form: **Parallel**

Time domain:
☒ Continuous-time
☐ Discrete-time

Discrete-time settings
Sample time (-1 for inherited): -1

Compensator formula
$$P + I \frac{1}{s}$$

Main Initialization Output Saturation Data Types State Attributes

Controller parameters
Source: **internal**
Proportional (P): 1.92731867174279
Integral (I): 0.403552338716405 ☐ Use I*Ts (optimal for codegen)

Automated tuning
Select tuning method: **Transfer Function Based (PID Tuner App)** **Tune...**

☒ Enable zero-crossing detection

OK Cancel Help Apply

15.2: Change the value of Ki in the other two controllers to demonstrate the effect of tuning. Measure the rise time, overshoot percentage, the settling time and the steady state error.

Block Parameters: PID Controller1

PID 1dof (mask) (link)

This block implements continuous- and discrete-time PID control algorithms and includes advanced features such as anti-windup, external reset, and signal tracking. You can tune the PID gains automatically using the 'Tune...' button (requires Simulink Control Design).

Controller: **PI** Form: **Parallel**

Time domain:
☒ Continuous-time
☐ Discrete-time

Discrete-time settings
Sample time (-1 for inherited): **-1**

Compensator formula
$$P + I \frac{1}{s}$$

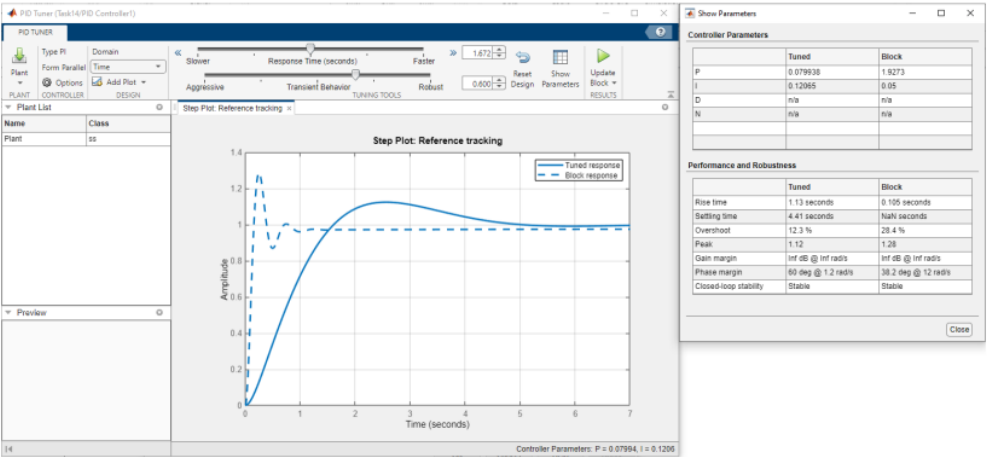
Main Initialization Output Saturation Data Types State Attributes

Controller parameters
Source: **internal**
Proportional (P): **1.92731867174279**
Integral (I): **0.05** ☐ Use I*Ts (optimal for codegen)

Automated tuning
Select tuning method: **Transfer Function Based (PID Tuner App)** **Tune...**

☒ Enable zero-crossing detection

OK Cancel Help Apply



Block Parameters: PID Controller2

PID 1dof (mask) (link)

This block implements continuous- and discrete-time PID control algorithms and includes advanced features such as anti-windup, external reset, and signal tracking. You can tune the PID gains automatically using the "Tune..." button (requires Simulink Control Design).

Controller: PI

Form: Parallel

Time domain:

☒ Continuous-time

☐ Discrete-time

Discrete-time settings

Sample time (-1 for inherited): -1

Compensator formula

$$P + I \frac{1}{s}$$

Main

Initialization

Output Saturation

Data Types

State Attributes

Controller parameters

Source: internal

Proportional (P): 1.92731867174279

Integral (I): 0.7 ☐ Use I*Ts (optimal for codegen)

Automated tuning

Select tuning method: Transfer Function Based (PID Tuner App)

Tune...

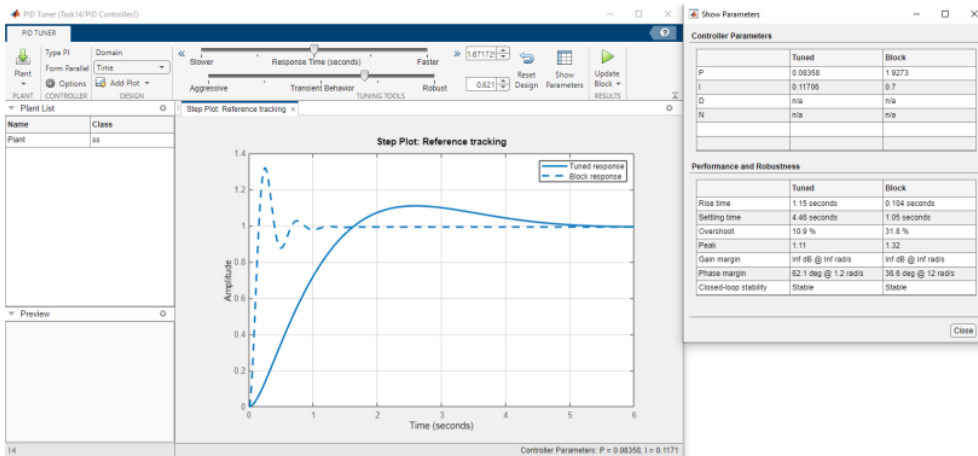
☒ Enable zero-crossing detection

OK

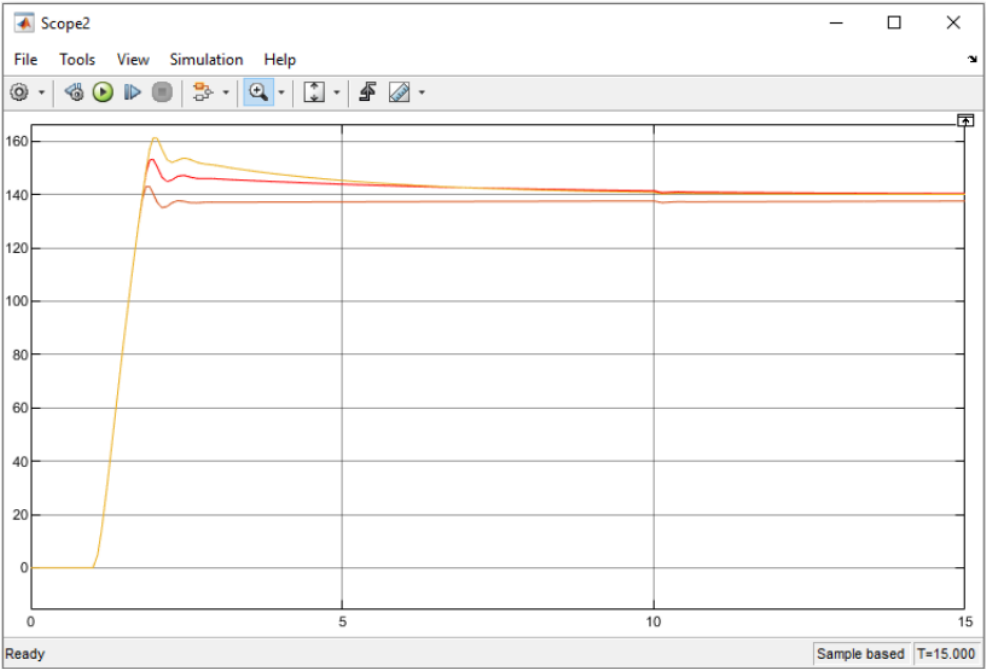
Cancel

Help

Apply



15.3: Summarise all your results in a table, critically analyse and make comparisons. What can you now say about the effect of adding integral control and its behaviour when tuned. What is the effect of changing K_i ? Draw up conclusions.



Ki Value	Steady State Error	Rise Time (S)	Overshoot	Settling Time (s)
0.40335	0	0.104	30.30 %	1.12
0.05	2	0.105	28.4%	NaN
0.7	0	0.104	31.80 %	1.05

The steady state error was twice as large when the lower K_i value was chosen, despite the fact that there is only a 0.35 difference between it and the second value. According to the results table, rise time increases as K_i value decreases. The settling time, expressed in nanoseconds, is 0.1. It's interesting that the greater K_i value settling time isn't longer than the tuned value. Each number exhibits a comparable oscillatory response; their tiny variations in rise times and overshoot % are all that separate them.

Task 16 – Proportional-Integral-Derivative Speed Control System

16.1: Save your Matlab file under a new name and convert each controller to PID. Auto tune the first and use the same value of Kp and Ki in all three systems.

Block Parameters: PID Controller

PID 1dof (mask) (link)

This block implements continuous- and discrete-time PID control algorithms and includes advanced features such as anti-windup, external reset, and signal tracking. You can tune the PID gains automatically using the 'Tune...' button (requires Simulink Control Design).

Controller: PID Form: Parallel

Time domain:
☒ Continuous-time
☐ Discrete-time

Discrete-time settings
Sample time (-1 for inherited): -1

Compensator formula

$$P + I \frac{1}{s} + D \frac{N}{1 + N \frac{1}{s}}$$

Main Initialization Output Saturation Data Types State Attributes

Controller parameters

Source: internal

Proportional (P): 1.18188193815251

Integral (I): 1.91904799500264 ☐ Use I*Ts (optimal for codegen)

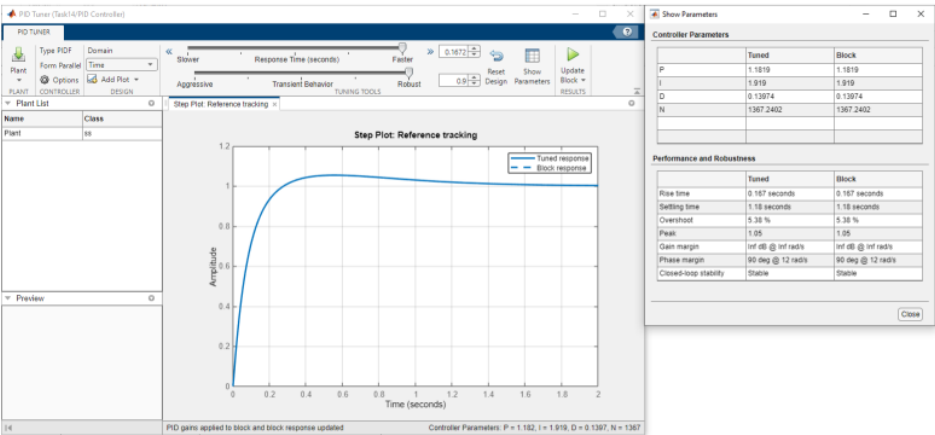
Derivative (D): 0.13974363542915

Filter coefficient (N): 1367.24019267143 ☒ Use filtered derivative

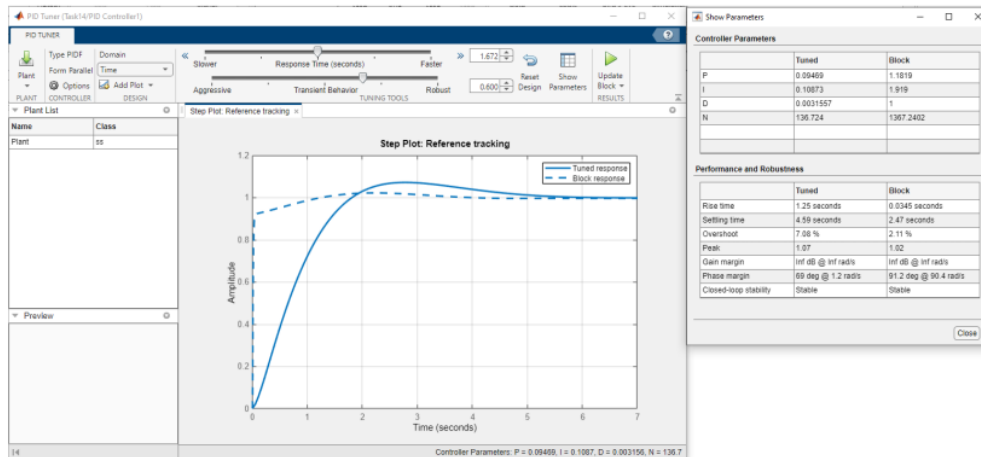
Automated tuning
Select tuning method: Transfer Function Based (PID Tuner App) Tune...

☒ Enable zero-crossing detection

OK Cancel Help Apply



16.2: Change the value of Kd in the other two to demonstrate the effect of tuning. Measure the rise time, overshoot percentage, the settling time and the steady state error.



Block Parameters: PID Controller1

PID 1dof (mask) (link)

This block implements continuous- and discrete-time PID control algorithms and includes advanced features such as anti-windup, external reset, and signal tracking. You can tune the PID gains automatically using the 'Tune...' button (requires Simulink Control Design).

Controller: **PID** Form: **Parallel**

Time domain:
☒ Continuous-time
☐ Discrete-time

Discrete-time settings
 Sample time (-1 for inherited): -1

Compensator formula

$$P + I \frac{1}{s} + D \frac{N}{1 + N \frac{1}{s}}$$

Main Initialization Output Saturation Data Types State Attributes

Controller parameters

Source: **internal**

Proportional (P): 1.18188193815251

Integral (I): 1.91904799500264 ☐ Use I*Ts (optimal for codegen)

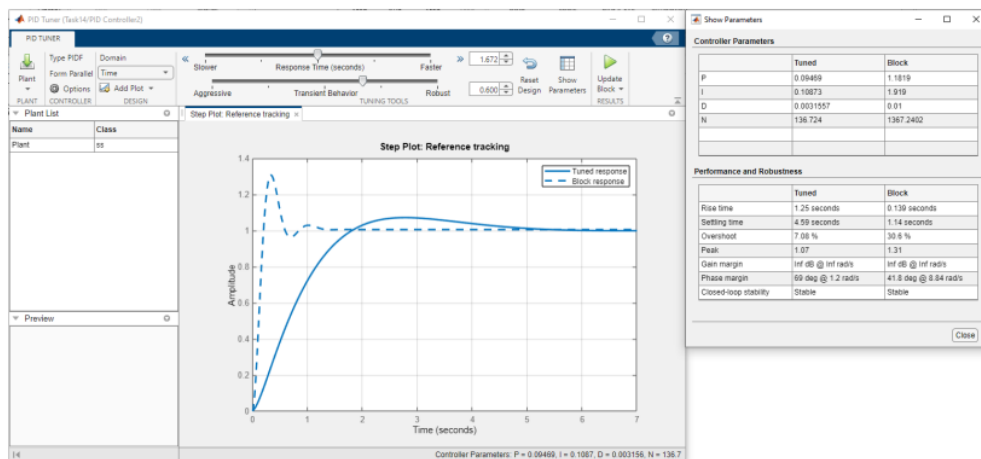
Derivative (D): 1

Filter coefficient (N): 1367.24019267143 ☒ Use filtered derivative

Automated tuning
 Select tuning method: **Transfer Function Based (PID Tuner App)** **Tune...**

☒ Enable zero-crossing detection

OK Cancel Help Apply



Block Parameters: PID Controller2

PID 1dof (mask) (link)

This block implements continuous- and discrete-time PID control algorithms and includes advanced features such as anti-windup, external reset, and signal tracking. You can tune the PID gains automatically using the 'Tune...' button (requires Simulink Control Design).

Controller: **PID** Form: **Parallel**

Time domain:
☒ Continuous-time
☐ Discrete-time

Discrete-time settings
 Sample time (-1 for inherited): **-1**

Compensator formula

$$P + I \frac{1}{s} + D \frac{N}{1 + N \frac{1}{s}}$$

Main Initialization Output Saturation Data Types State Attributes

Controller parameters

Source: **internal**

Proportional (P): **1.18188193815251**

Integral (I): **1.91904799500264** ☐ Use I*Ts (optimal for codegen)

Derivative (D): **0.01**

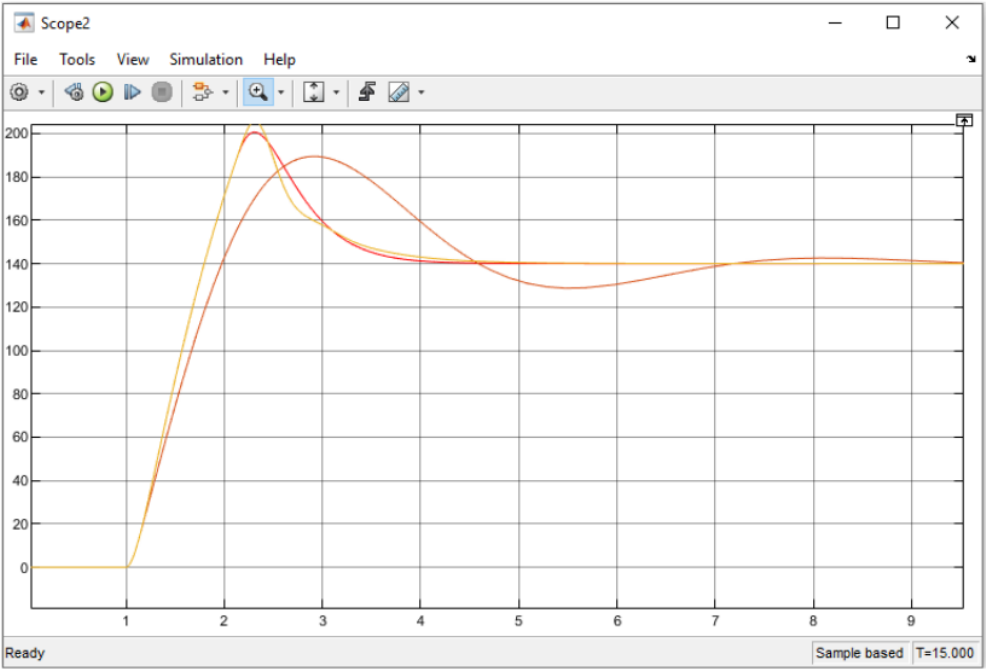
Filter coefficient (N): **1367.24019267143** ☒ Use filtered derivative

Automated tuning
 Select tuning method: **Transfer Function Based (PID Tuner App)** **Tune...**

☒ Enable zero-crossing detection

OK Cancel Help Apply

16.3: Summarise all your results in a table, critically analyse and make comparisons. What can you now say about the effect of adding derivative control and its behaviour when tuned. What is the effect of changing K_d ? Draw up conclusions.

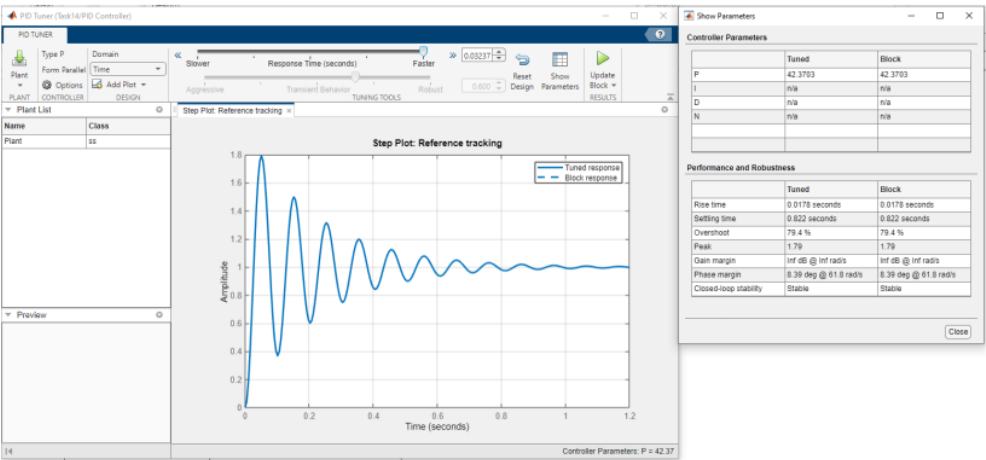
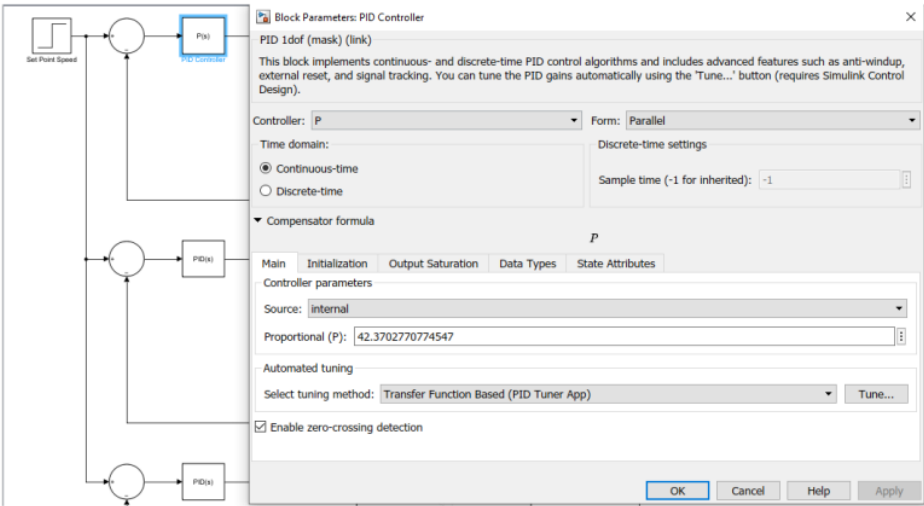


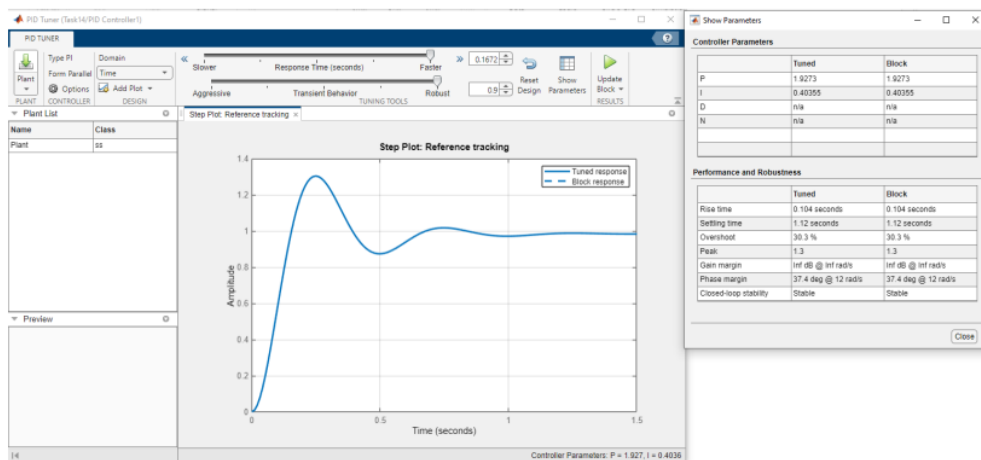
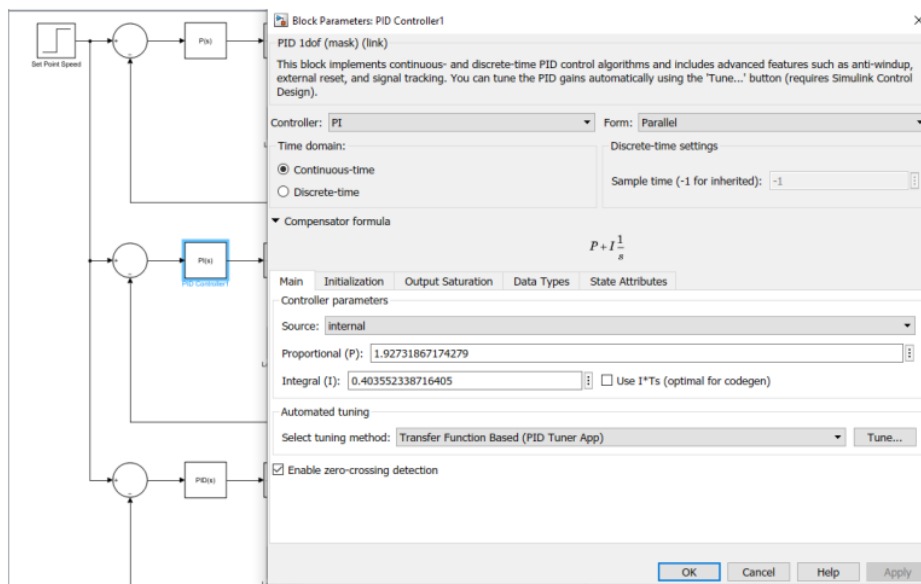
KD Value	Steady State Error	Rise Time (S)	Overshoot	Settling Time (s)
0.13974	0	0.167	5.38 %	1.18
1	0	0.0345	2.11%	2.47
0.01	0	0.139	30.60 %	1.14

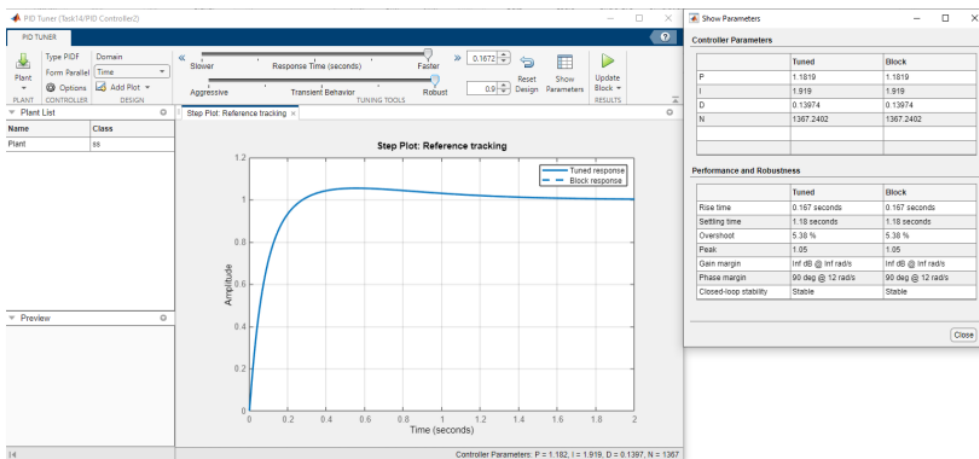
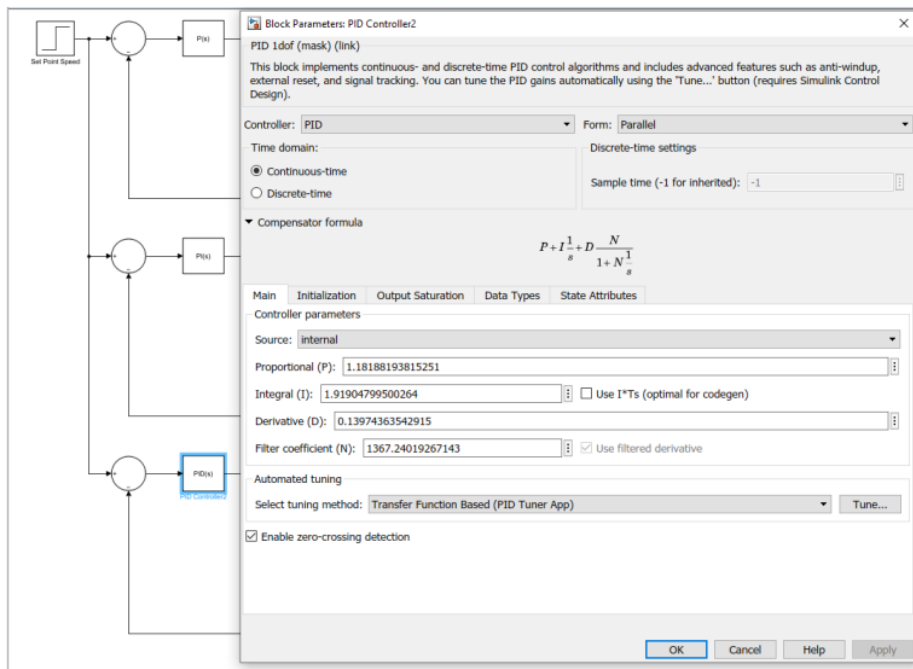
The overshoot and settling time are clearly influenced by the K_d Value, as the findings demonstrate. The two chosen values of K_d operate in an opposing manner; as the overshoot increases, the settling time decreases, and vice versa. The selected values are just marginally faster by a few milliseconds compared to the tuned K_d value, which has the slowest rising time.

Task 17 – Controller Comparisons

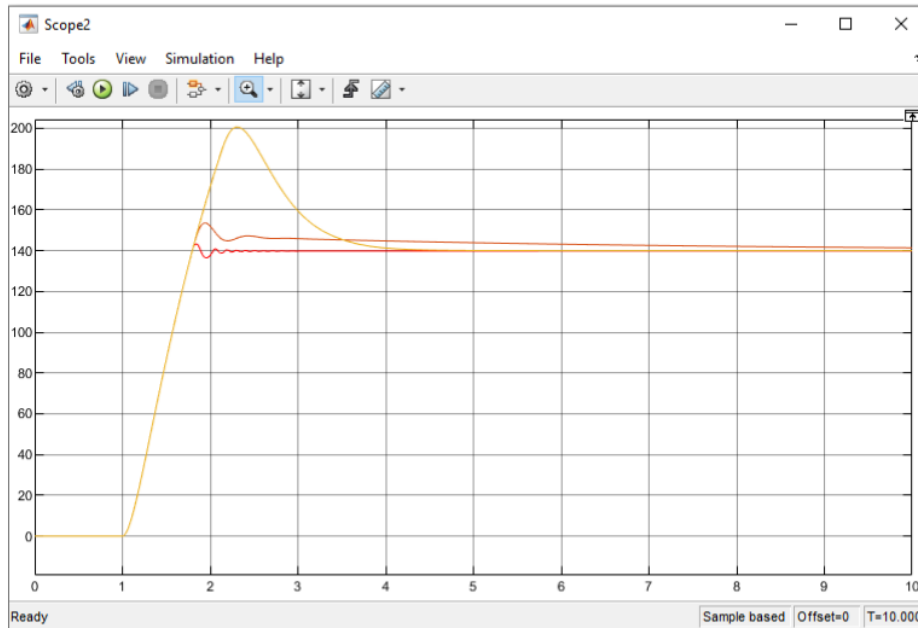
17.1: Save your Matlab file under a new name with 3 parallel controllers sharing the same input and same scope. Make one system a P controller, another a PI controller and the third can remain a PID controller.







17.2: Plot the response of the three types of controller on the same scope and demonstrate the effects of controller improvement from P to PI to PID.



17.3: Summarise all your results in a table, critically analyse and make comparisons. Draw up conclusions.

KP Value	KI Value	KD Value	Steady State Error	Rise Time (S)	Overshoot	Settling Time (s)
42.3702			0	0.0178	79.4 %	0.822
1.9273	0.4035		0	0.104	30.3%	1.12
1.8188	1.9190	0.1397	0	0.167	5.38 %	1.18

As you can see in the table and graph above as you go from the P controller to the PI controller then finally to the PID controller the overshoot decreases but the settling time increases as well as the rise time increasing as well. when it was just a P controller the overshoot was massive (79.4%) but it had the fastest time to rise time (0.0178s) and the quickest settling time (0.822s). The PI controller was the middle of the pack this had no presided major benefits to use this over PID controller. The PID controller had the lowest overshoot (5.38%) it had the slowest rise time and the slowest settling time bit it is a minuscule differences.

Task 18 – Overall Conclusions and Recommendations

For the whole assignment, summarise all your conclusions here, state what you now know, make overall conclusions and recommendations which must include your suggestions on improvement of circuits and systems.

I started by performing transient analysis on circuits, which is an assessment of a circuit reaction for a specific period of time. This was done on RC and RL circuits to figure out how much the real results differed from the simulation. The next step was to calculate the first and second order responses, which are distributed across the slope in various ways. These were accomplished using parallel electronic circuits; once more, comparing the calculated outcomes to the Matlab-completed simulations.

The second thing I done was the simulations of cascading filters allowed researchers to get insight into how filters become  32 sensitive as their order is increased. It became clear throughout the filters section of the assignment that the cursor movement can make it challenging to select the precise places on Matlab simulations. The tables were erroneously constructed as a result of this, but the logic behind it was taken into consideration. The rounding of the numbers during the calculation stage is what caused some of the findings to have inaccuracies. A sort of filter was studied in order to gain a better grasp of the intended outcome.

Open loop responses were assessed at the beginning of the control phase of the assignment in order to develop an understanding of stable and unstable systems and how to use the evaluation of a Pole-Zero Map to reach that decision. This continued with closed loops, incorporating PID control and evaluating P, I, and D separately. In this section of the assignment, you will have a complete understanding of how to operate a closed system using PID control and why each of its components is significant.

The introduction of research sections would be advised for this module to boost understanding. When attempting to perform the simulated outcomes, the software Matlab consistently caused problems. Because of the cursor selection, which got worse on the Matlab online, it was impossible to measure the outcomes. To ensure the faults were as little as possible, perhaps in the future, a better programme might be used, or the assignment could be completed without using the Matlab online.

It can be beneficial to physically implement portions of the system circuits in order to provide the students more hands-on experience. This can have a significant positive impact on certain students while having less of an impact on others. There were a few more systems that might have been explored to test the notion that the larger the order, the more filtration is obtained, rather than limiting the study to first and second order responds.

1909366

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

56/100

PAGE 1

PAGE 2



Comment 1

do not paste the question from the brief into the report

PAGE 3

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Comment 2

explain at least what this is, you should really develop it from first principles

PAGE 10

PAGE 11



Comment 3

define time constant, show equation of response, this does not explain anything



Comment 4

see comment for task 1



Comment 5

this needs an explanation



Comment 6

WW



Comment 7

wiki?



Comment 8

this is not a sufficiently deep analysis



Comment 9

WW



Comment 10

again and explanation of the source of these equations needed



Comment 11

work is descriptive only



Comment 12

there is some damping as the response decays to zero



Comment 13

your results are correct but your analysis is just purely descriptive



Comment 14

Sp



Comment 15

again, develop these equations, refer to the TF



Comment 16

this needs an explanation, what is Q?

PAGE 37



Comment 17

what about the roll-off and the locus effect of w_m moving towards w_o

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Comment 18

these quantities need a definition

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Comment 19

good

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Comment 20

correct

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Comment 21

correct

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Comment 22

correct

PAGE 60



Comment 23

you have not explained where these equations have been developed from

PAGE 61



Comment 24

to do this you must show the TF

PAGE 62

PAGE 63



Comment 25

these errors are too large and human error is not an acceptable reason



Comment 26

graph missing

PAGE 64

PAGE 65



Comment 27

this does not match graph



Comment 28

no need to repeat the results in the table



Comment 29

compare with theory



Comment 30

compare with theory



Comment 31

check this value

[Comment 32](#)

Gr

GRADING FORM: NEW CSG-RUBRIC

TAYLOR BAMFORD**56****1. ENGAGEMENT WITH LITERATURE**

NA

0**2. KNOWLEDGE AND UNDERSTANDING**

A lot of your explanations are just taken directly from the brief, you have not explained in your own words what you are doing to a sufficient level. Lots of definitions/explanations are missing, see comments. 12/30

12**3. COGNITIVE AND INTELLECTUAL**

Some critical evaluation evident, though a lot is mostly descriptive, there are good areas and you have drawn valid conclusions regarding circuit performance, see comments. 20/30

20

4. PRACTICAL APPLICATION



Good and appropriate application of techniques, images are annotated correctly, results are mostly accurate, save few errors as marked, many images remain unexplained.20/30

20

5. TRANSFERABLE SKILLS



Suitable communication used although you should not paste the question from the brief into your report. 4/10

4