

Liesel Assignment

by Samuel Shepherd

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Samuel Shepherd

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**Course: HNC Electrical/Electronic
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**Analysis, Simulation and
Evaluation of Circuits and
Systems**

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Executive Summary

This assignment shows advanced principles in electronic engineering and control systems through the analysis, simulation, and evaluation of circuits. Each task involves practical circuit designs and theoretical calculations, with simulations performed using MATLAB.

Task 1 uses an RL low-pass filter with a time constant of 0.18 ms. The calculated and simulated results both match, confirming the circuit's ability to pass low frequencies and filter out higher ones.

Task 2 uses an RC low-pass filter with a time constant of 54 ms, again showing a complete match between the calculated and simulated results, proving its function in managing signal frequencies.

Task 3 examines an RL high-pass filter with a cutoff frequency of 5500 Hz, supported by the simulation. Task 4 re-does this process using an RC low-pass filter, having a cutoff frequency of 18.5 Hz, confirming the expected behaviour.

In Tasks 5 and 6, damping in an RLC circuit is done through different resistances, giving graphs with no damping, underdamped, overdamped, and critically damped. Critical damping is calculated to optimise settling time. Task 7 uses a low-pass filter with a 26 dB gain and cutoff at 15.9 Hz, while Task 8 tests a high-pass filter with a higher cutoff at 2.27 MHz, both validated by MATLAB simulations.

Task 9 tries to improve the stability of a system, determining that a gain greater than 0.162 gives greater stability. Tasks 10 and 11 simulate a DC motor, showing how changes in the proportional gain, K_p , affect performance, including stall torque and speed. 

Task 12 and Task 13 use PI and PID controllers and focus on tuning the gains to minimise error and overshoot. The PID controller proved to offer the best overall balance, having good speed, stability, and causing minimal error.

Overall, the assignment shows how effective tuning and design is at optimising a circuit's behaviour and system performance, with practical simulations confirming theoretical predictions.

Introduction

This assignment aims to use more advanced principles related to electronic engineering and control systems while also satisfying each task. It will use these principles to analyse, simulate, and evaluate the performance and functionality of circuits and systems.

Contents

Contents

Task 1	7
Circuit.....	7
1.1 Component Values.....	7
1.2 Calculations.....	7
1.3 Simulation.....  2	9
1.4 Comparison Table - Task 1	9
1.5 Analysis	9
Task 2	10
Circuit.....	10
2.1 Component Values.....	10
2.2 Calculations.....	10
2.3 Simulation.....	11
2.4 Comparison Table.....	11
2.5 Analysis	11
Task 3	12
Circuits.....	12
3.1 Component Values.....	12
3.2 Calculations.....	12
3.3 Simulation.....	13
3.4 Comparison Table.....	13
3.5 Analysis	13
Task 4	14
Circuits - Task 4	14
Component Values.....	14
4.1 Calculations.....	14
4.2 Simulation.....	15
4.3 Comparison Table.....	15
4.4 Analysis	15
Task 5	16

5.1 Component Values.....	16
5.2 Calculations.....	16
5.4 - 6 Simulation	18
Results Table.....	20
5.7Analysis	20
Task 6	21
Component Values.....	21
6.1 Calculations.....	21
6.2/4 Simulation.....	23
Results Table.....	24
6.5 Analysis	24
Task 7	25
7.1Component Values.....	25
Calculations.....	25
7.2 Simulation.....	27
7.3 Analysis	27
Task 8	27
8.3 Component Values.....	28
Calculations.....	28
8.2 Simulation.....	29
8.3 Analysis	29
Task 9	30
9.1 - 3 Calculations	30
9.4 Simulation.....	31
9.5 Result Table.....	33
9.6 Analysis	34
Task 10	34
Component Values.....	34
10.1 - 2 Calculations	34
10.4 Simulation.....	35
10.5 No disturbance.....	35
10.6 WITH DISTURBANCE.....	37
10.7 Results Table	39
10.8 Analysis	39
Task 11	40
11.1 - 2 Subsystem.....	40
11. 3 Simulation.....	41

11.4 Results Table	48
11.5 Analysis.....	48
Task 12	49
12.1 PI setup	49
12.2 Results table	52
12.3 Analysis	52
Task 13	53
13.1 PID Setup	53
13.2 Results Table	56
13.3 Analysis	56
Task 14	57
Results Table	60
Analysis	60
Conclusion	61
Appendix.....	63

List of Figures

Figure 1.....	7
Figure 2.....	9
Figure 3.....	10
Figure 4.....	11
Figure 5.....	12
Figure 6.....	13
Figure 7.....	14
Figure 8.....	15
Figure 9.....	18
Figure 10.....	19
Figure 11	19
Figure 12.....	20
Figure 13.....	23
Figure 14.....	24
Figure 15.....	26
Figure 16.....	27
Figure 17.....	29
Figure 18.....	29
Figure 19.....	30
Figure 20.....	31
Figure 21.....	31
Figure 22.....	32
Figure 23.....	32
Figure 24.....	33

Figure 25.....	35
Figure 26.....	36
Figure 27.....	36
Figure 28.....	37
Figure 29.....	38
Figure 30.....	38
Figure 31.....	39
Figure 32.....	40
Figure 33.....	41
Figure 34.....	41
Figure 35.....	42
Figure 36.....	43
Figure 37.....	43
Figure 38.....	44
Figure 39.....	45
Figure 40.....	46
Figure 41.....	46
Figure 42.....	47
Figure 43.....	48
Figure 44.....	49
Figure 45.....	50
Figure 46.....	50
Figure 47.....	51
Figure 48.....	52
Figure 49.....	53
Figure 50.....	53
Figure 51.....	54
Figure 52.....	54
Figure 53.....	55
Figure 54.....	55
Figure 55.....	56
Figure 56.....	57
Figure 57.....	58
Figure 58.....	58
Figure 59.....	59
Figure 60.....	59
Figure 61.....	60

Task 1

Circuit

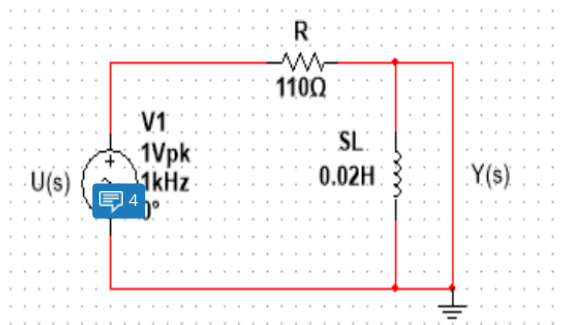


Figure 1

1.1 Component Values

$R = 110 \text{ Ohm}$

$SL = 0.02H$

1.2 Calculations

$$Y(s) = (SL / (SL + R)) \times U(s)$$

Step I/P, $U(s) = 1/s$

$$Y(s) = (SL / S(SL + R)) \times 1/s$$

simplifying

$$= SL / S(SL + R)$$

$$= (SL + R)$$

$$= L/SL + R$$

Top and bottom by L



$$1/S + R/L$$

$$\text{Laplace}^{-1}(1/S + R/L)$$

$$Y(t) = e^{-at}$$

$$= e^{-RT/L}$$

$$\text{Tau} = 1/a = L/R = 0.03/150 = 0.2 \text{m Seconds}$$

$$Y(s)/U(s) = SL/SL + R = \text{Tau } S / \text{Tau } S + 1$$

Top + Bottom by R



$$(S^{(L/R)}) / (S^{(L/R)} + 1) \text{ where Tau} = L/R$$

$$S \text{ Tau} / S \text{ Tau} + 1$$

$$0.02/110 = .18 \text{ms}$$

1.3 Simulation

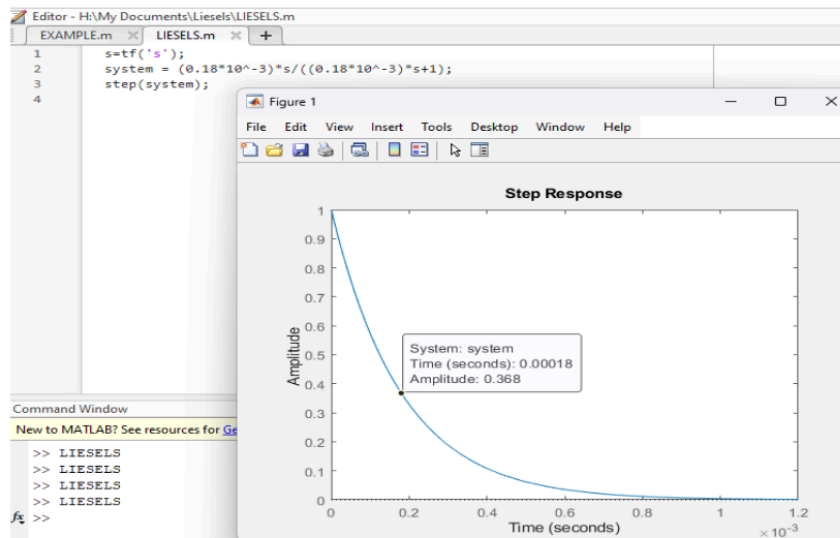


Figure 2

1.4 Comparison Table - Task 1

	Calculated	Simulated
Tau	.18ms	.18ms

1.5 Analysis

The circuit above acts like a low-pass filter. This means that this circuit blocks or reduces the higher amplitudes while allowing lower amplitudes through, giving it the appearance of a rapid decrease. This is due to the cutoff frequency being a variable of the calculated tau (.18ms), and when matched with the potential divider rule e^{-1} , the same tau is displayed. This information perfectly matches what's displayed on the MATLAB graph, allowing the ability to see the functionality of the circuit.

Task 2

Circuit

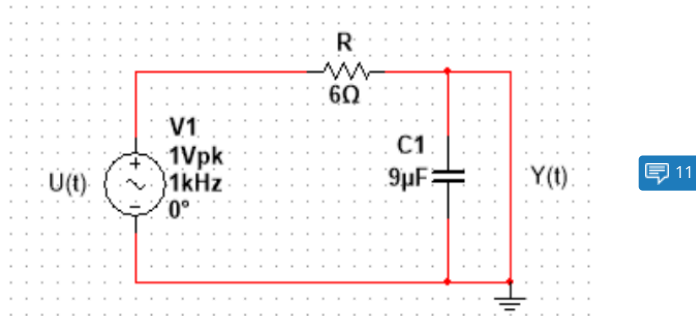


Figure 3

2.1 Component Values

$R = 6\text{ k Ohm}$

$C = 9\mu\text{F}$

2.2 Calculations

$$H(s) = Y(s)/U(s) = K/\tau s + 1$$

12

$$H(s) = 1/\tau s + 1$$

$$\tau = RC = 6000 \times 9 \times 10^{-6} = 54 \times 10^{-3} = 54\text{ms}$$

2.3 Simulation

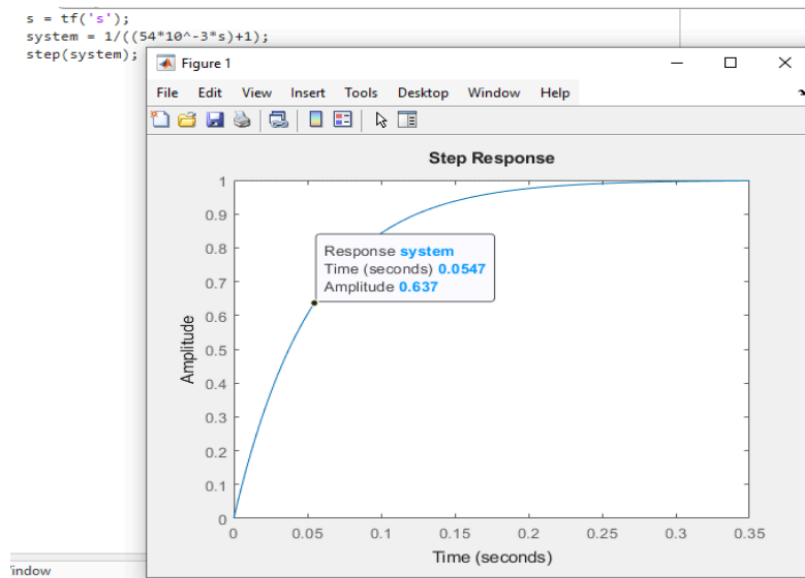


Figure 4

2.4 Comparison Table

	Calculated	Simulated
Tau	54ms	54ms

2.5 Analysis

The circuit is a low-pass filter with component values of 6k ohms and 9uF, resulting in a time constant of 54 ms. The calculated and simulated values for Tau directly match, showing that the filter design is accurate. The filter's behaviour is consistent with the theoretical predictions, making it suitable for applications that require low frequency signals to pass through while rejecting high frequencies. Despite being accurate,

the actual filter performance would be influenced by different tolerances, however, matlab provided a reasonably accurate filtering.

Task 3

Circuits

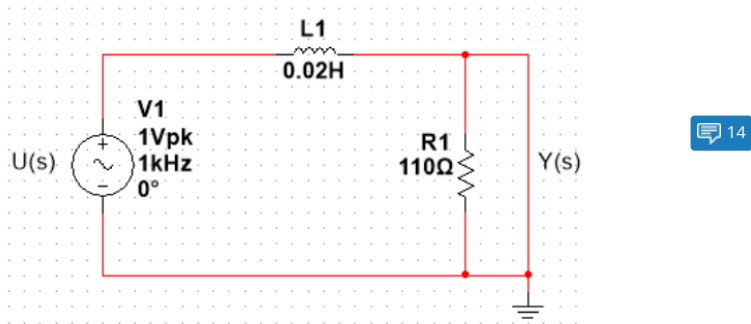


Figure 5

3.1 Component Values

R = 110 Ohms

L = 0.02H

3.2 Calculations

$W_c = R/L$

$$110/0.02 = 5500$$

15

$$H(s) = s/(s + W_c)$$

$$Y(s) = 110/0.02 + 110$$

$$s/(s + 5500)$$

3.3 Simulation

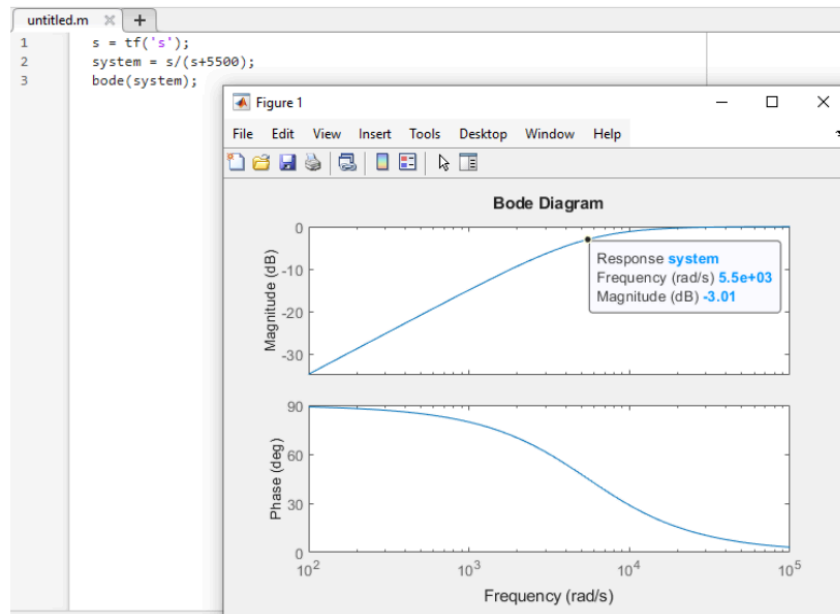


Figure 6

3.4 Comparison Table

	Calculated	Simulated
Frequency	5500	5500

3.5 Analysis

The circuit for this task is a high-pass filter. A high-pass filter allows high-frequency signals to pass through, while the lower frequencies are reduced or blocked by the cutoff frequency.

When compared to the explanation of a high-pass filter, this circuit seems to have matched up perfectly; the graph above shows that the effect is happening. This process also matches the results with the calculated ones, making this MATLAB highly accurate.

Task 4

Circuits - Task 4

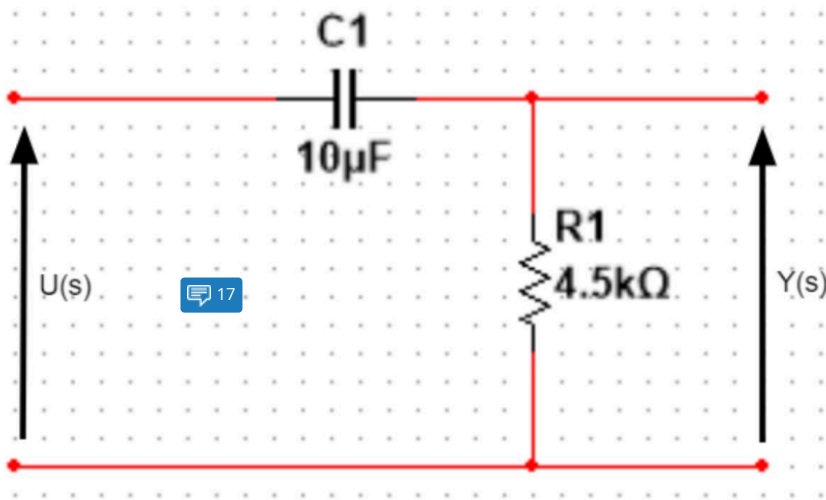


Figure 7

Component Values

$R = 6000 \text{ Ohms}$

$C = 9\mu F$

4.1 Calculations

$$WC = 1/RC$$

$$H(s) = WC/S + WC$$

$$WC = 1/6000 \times 9 \times 10^{-6}$$

$$= 18.5$$

4.2 Simulation

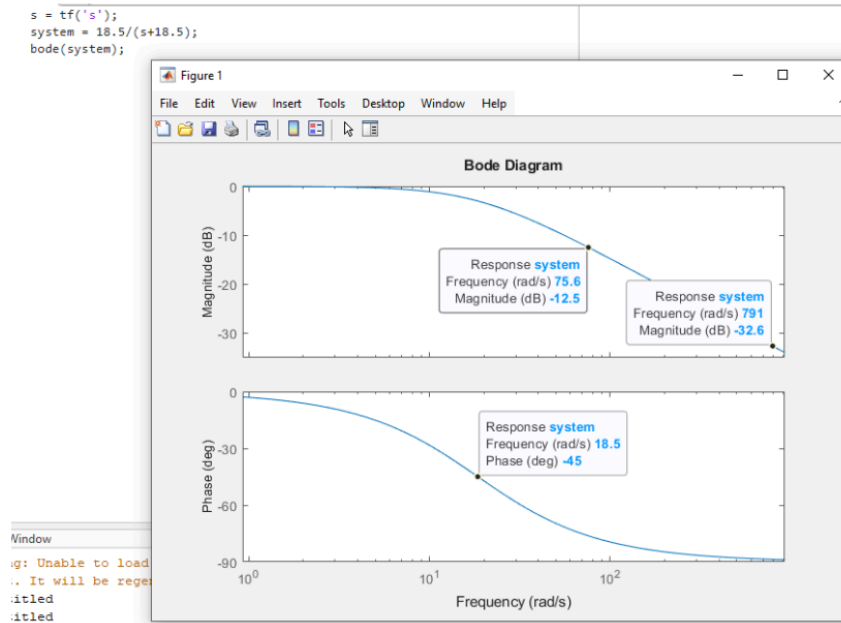


Figure 8

4.3 Comparison Table

<u>Calculated</u>	<u>Simulated</u>
18.5	18.5

4.4 Analysis

The circuit for this task is a low-pass filter. A low-pass filter allows frequencies that are below the cutoff frequency (cutoff frequency varies)

to pass through while reducing or blocking the higher frequencies, generally allowing the process to be smoother. Comparing this information with the graph displayed  18, this circuit is effectively working as a low-pass filter.

Task 5

5.1 Component Values

$L = 0.01$

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

$R = \text{Varied from what's needed}$  19

5.2 Calculations

Damping factor $Z = R^2 C L$  20

No Damping

$$0.000000001311240 \times 10^{-6} \times 0.01 = 4.145 \times 10^{-11}$$

Under Damped

$$23.2240 \times 10^{-6} \times 0.01 = 0.734$$

Over Damped

$$316240 \times 10^{-6} \times 0.01 = 9.99$$

Critical Damping

(To get the perfect resistance, the equation has to be rearranged)

$$2 \times 140 \times 10^{-6} \times 0.01 = 31.62277661 \text{ Ohms}$$

$$31.62277661140 \times 10^{-6} \times 0.01 = 1$$

Natural frequency = $1/LC$

$$10.1 \times 40 \times 10^{-6} = 500 \text{ rads/s}$$

$1/LC$

$$10.01 \times 40 \times 10^{-6} = 2500000$$

Usable Matlab results

RL

No Damping

$$0.0000000013110.01 = 0.0000001311$$

Under Damped

$$230.01 = 2320$$

Over Damped

$$3160.01 = 31600$$



Critical Damping

$$31.622776610.01 = 3162.277661$$

5.4 - 6 Simulation

No Damping

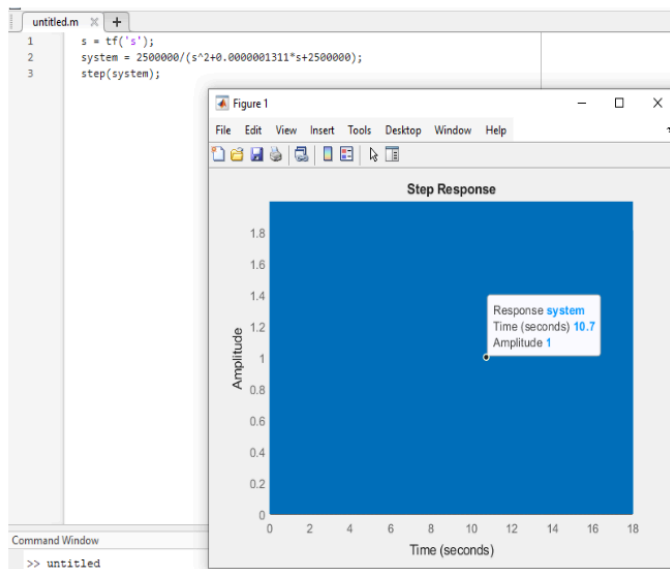


Figure 9

Under Damped

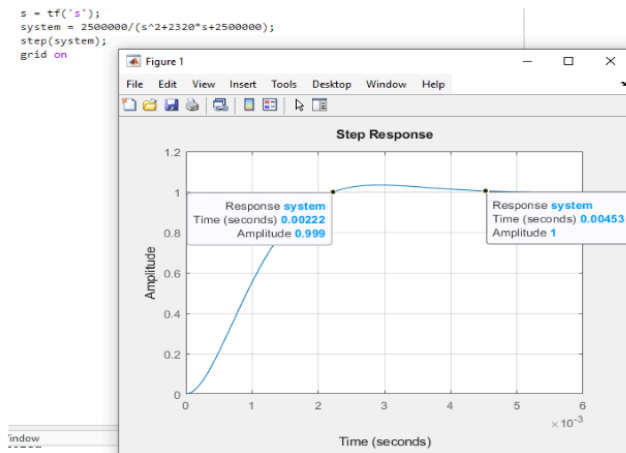


Figure 10

Over Damped

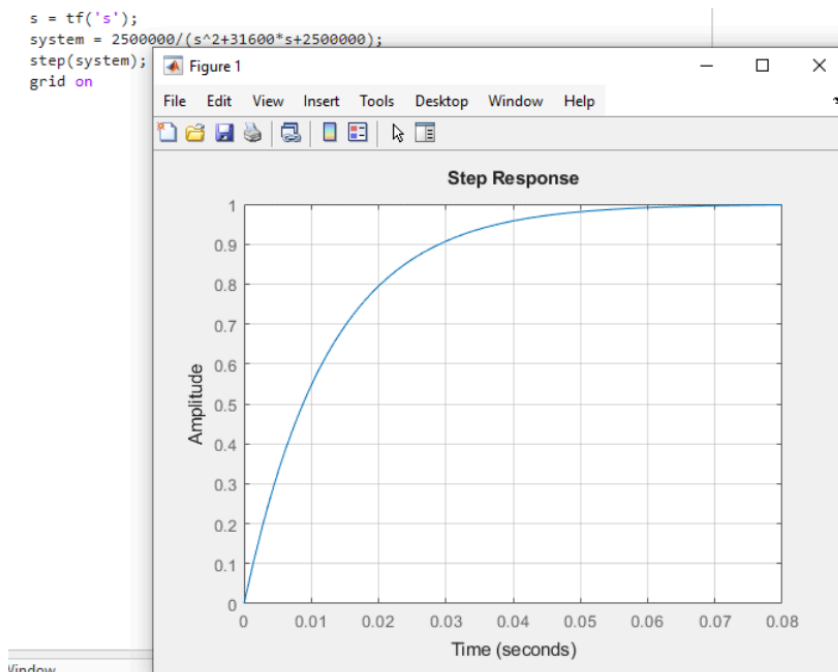


Figure 11

Critical Damping

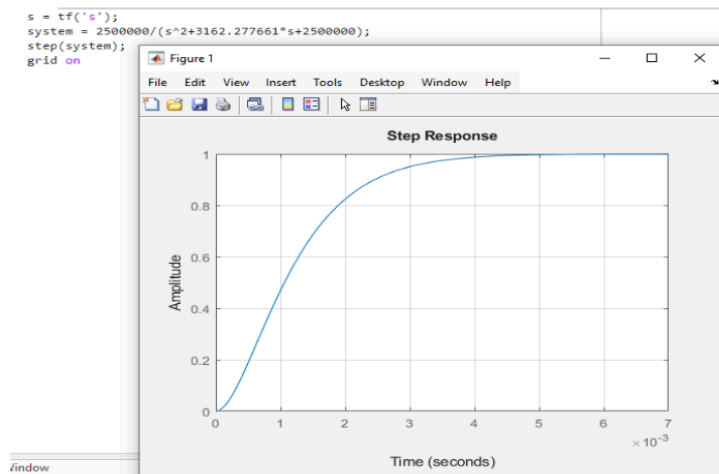


Figure 12

Results Table

	Calculated	Simulated
Critical Resistance	31.62277661 Ohms	31.62277661 Ohms
Natural Frequency	500 rad/s	500 rad/s

5.7 Analysis



The circuit is an RLC circuit where the damping is determined by changing the resistances. The damping types can be underdamped, critically damped, or overdamped, affecting how the circuit responds to changes, resulting in different graph types.

No Damping:

Continuous oscillations with no stabilisation.

Underdamped:

Oscillations decrease over time but the system still takes time to settle.

Overdamped:

The system returns to equilibrium slowly without oscillations.

Critical Damping:

The system reaches equilibrium as quickly as possible without oscillations which is the perfect resistance level.

The resistance level required for critical damping, using the values picked for this circuit, was calculated to be 31.62277661 ohms (figured out through rearranging equations), giving the fastest rise time without overshoot or oscillations. Critical damping is the most efficient in providing quick stabilisation.

Task 6

Component Values

Same as task 5

6.1 Calculations

LC

$$10.01 \times 40 \times 10^{-6} = 2500000$$

Usable Matlab results

RL

No Damping

$$0.0000000013110.01 = 0.0000001311$$



$$Q = 1/R \text{ sqrt root } L/C =$$

$$1/25 \text{ sqrt root } (0.03/44 \times 10^{-6}) = 1.044$$

$$2 \times 140 \times 10^{-6} \times 0.01 = 31.62277661$$

$$31.62277661 \times 140 \times 10^{-6} \times 0.01 = 1$$

Natural frequency = $1/LC$

$$10.1 \times 40 \times 10^{-6} = 500 \text{ rads/s}$$

$1/LC$

$$10.01 \times 40 \times 10^{-6} = 2500000$$

Usable Matlab results

RL

No Damping

0.0000000013110.01 = 0.0000001311

Under Damped

230.01 = 2320

Over Damped

3160.01 = 31600

Critical Damping

31.622776610.01 = 3162.277661

6.2/4 Simulation

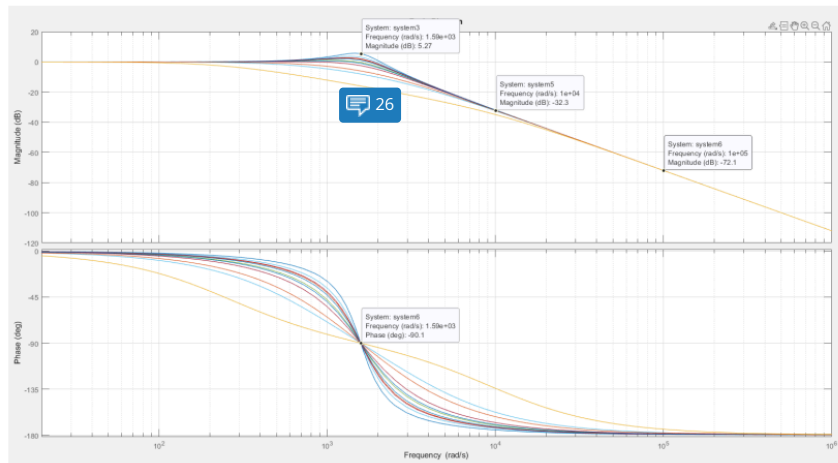


Figure 13

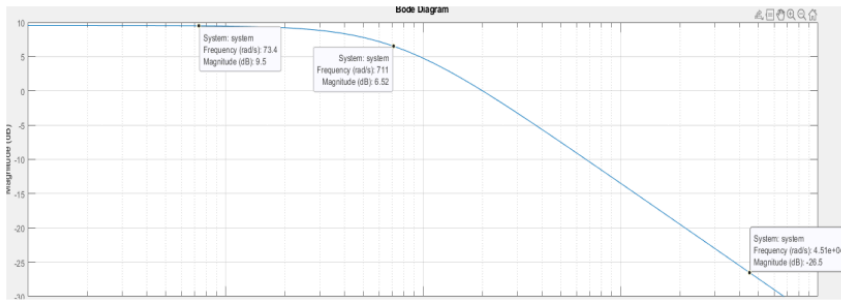


Figure 14

Results Table

	Calculated	Simulated
Critical Resistance	31.62277661 Ohms	31.62277661 Ohms
Natural Frequency	500 rad/s	500 rad/s

6.5 Analysis

Much like the task 5 circuit, task 6's damping behaviour is controlled by varying the resistances. Calculating the natural frequency of the system (being 500 rad/s) indicates the frequency level at which it would oscillate without damping. The Q factor allows the measurement of the sharpness of resonance, which was calculated as 1.044 for 25 ohms, suggesting a decent resonance with low energy losses.

Underdamped:

The system oscillates with a decreasing amplitude.

Overdamped:

The system returns to equilibrium slowly without oscillations.

Critical Damping:

The system reaches equilibrium as quickly as possible without overshoot. The required resistance for critical damping is 31.62277661 ohms giving the fastest rise time without oscillations. Critical damping provides stable responses, while underdamped and overdamped conditions are less efficient for quick stabilisations.

Task 7

7.1 Component Values

$$R1 = 1000$$

$$R2 = 20000$$

$$C = 440 \text{ nF}$$

Calculations

$$K = R2/R1$$

$$K = 20000/1000 = 20$$

$$W_c = 1/CR2$$



$$W_c = 1/440\text{nF} \times 20000 = 113.6 \text{ Rads/s}$$

$$\text{Gain} = 20\log(20) = 26$$

Matlab Calculations

$$H(s) = -K[S + Wc]$$

$$H(s) = -20[113.6/s + 113.6]$$

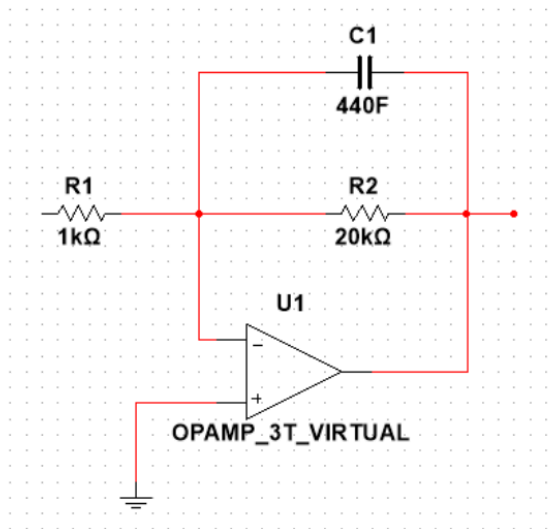


Figure 15

7.2 Simulation

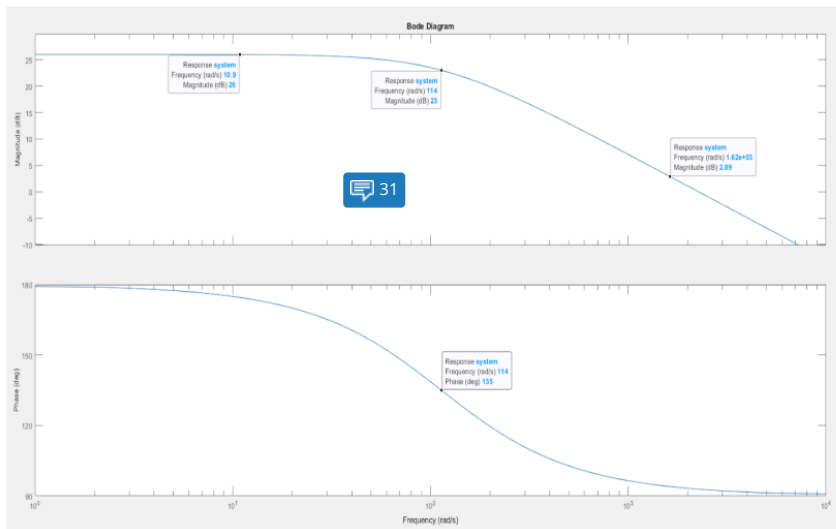


Figure 16

7.3 Analysis

This low pass filter circuit has a capacitance of 440nF in order to properly achieve the correct frequency response. The overall system has both a gain and magnitude of 26 dB with a cut off frequency of 159 rad/s. Simulating using MATLAB allows testing of the systems performance through plotting responses and getting important parameters like the cut off frequency, phase shift and roll off rate. The simulation displays these parameter as 15.9Hz for the cut-off frequency, a phase shift of 135 degrees at the cut off and a roll off of around 20db. By adjusting the capacitance value, the response can be further manipulated for different purposes.

Task 8

High Pass Filter

8.3 Component Values

$$R1 = 1000$$

$$R2 = 2000$$

$$C = 44\text{nF}$$

Calculations

$$K = R2/R1$$

$$K = 2000/1000 = 2$$

$$Wc = 1/CR1 = 1/44\text{nF} \times 1000 = 22727.3 \text{ Rads/s}$$

Matlab Calculation

$$H(s) = -K [S/S + Wc]$$

$$H(s) = -2.24 [S/S + 22727.3]$$

8.2 Simulation

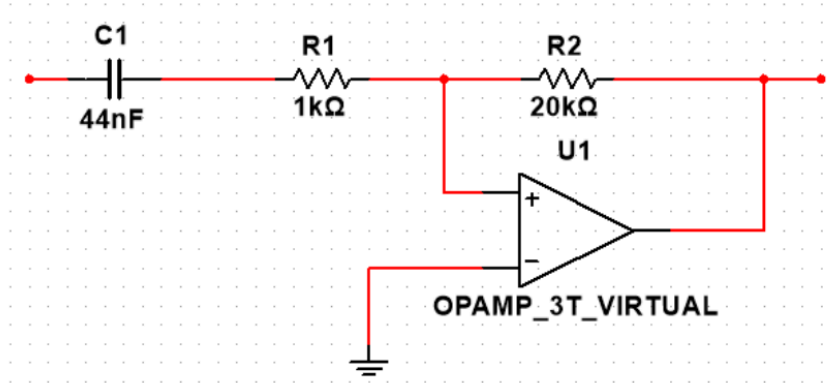


Figure 17

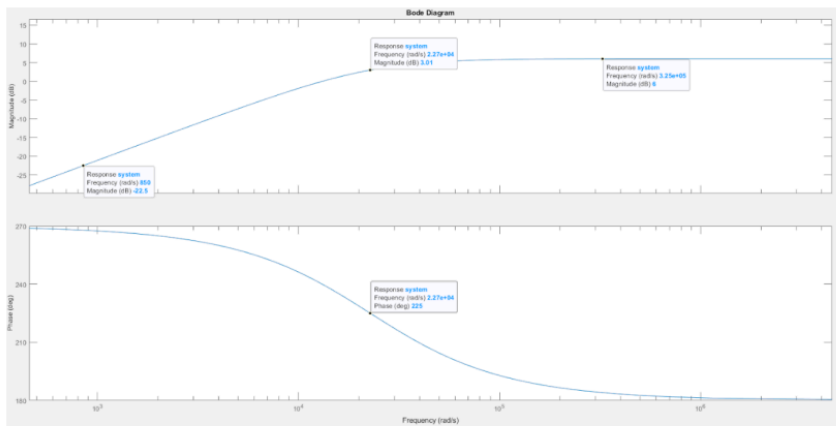


Figure 18

8.3 Analysis

An appropriate value for the capacitance must be chosen before the frequency response is able to be found. The circuit values are $R1 = 1000$ ohms, $R2 = 2000$ ohms and a capacitance of 44nF . The system itself has a gain and magnitude of 6dB and a cut off frequency of $2.27 \times 10^6\text{Hz}$. A MATLAB simulation was used in testing the systems performance, plotting markers on the graphs and confirming important parameters like the cutoff frequency and phase shift. By adjusting the capacitance the

response can be manipulated into checking any deviations in the systems behaviour r:  33

Task 9

9.1 - 3 Calculations

$$CLTE = 4.2/(S+0.68)/1 + 4.2k(s - 0.68)$$

 34

Times top and bottom by $(s - 0.68) = 4.2/s - 0.68 + 4.2k$

Equal denominator to 0

$$S - 0.68 + 4.2k = 0$$

$$S = + 0.68 - 4.2k$$

$S < 0$ for stability

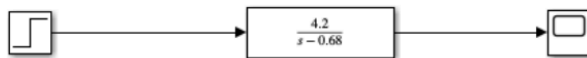


Figure 19

9.4 Simulation

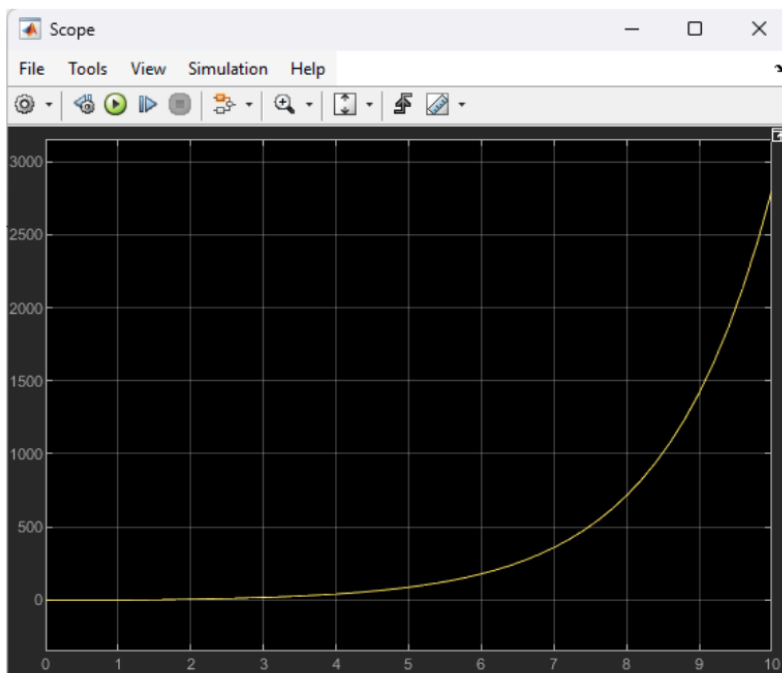


Figure 20

```
>> s = tf('s');  
>> system = tf(4.2/(s-0.68));  
>> pzplot(system);  
>> grid on
```

Figure 21

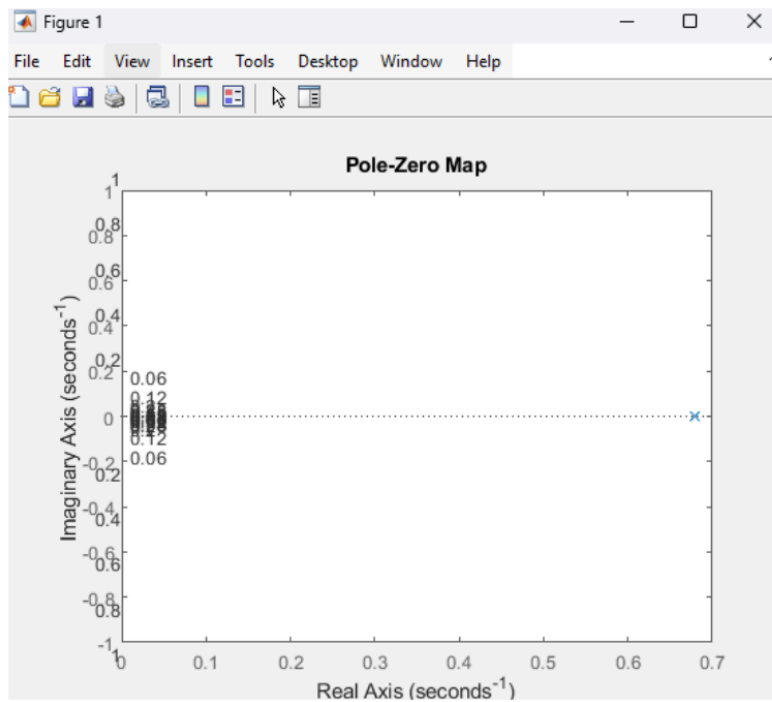


Figure 22

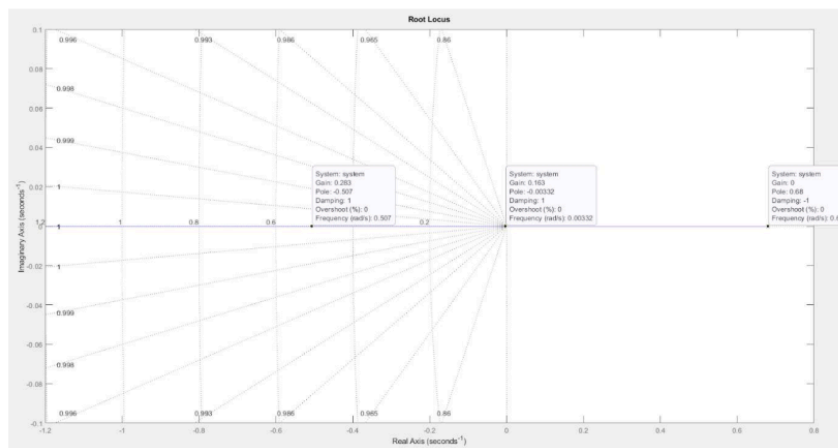


Figure 23

$$S = +0.68 - 4.2k$$

$$0 = +0.68 - 4.2k$$

$$4.2k = 0.68$$

$$0.68/4.2 = 0.162 = k$$

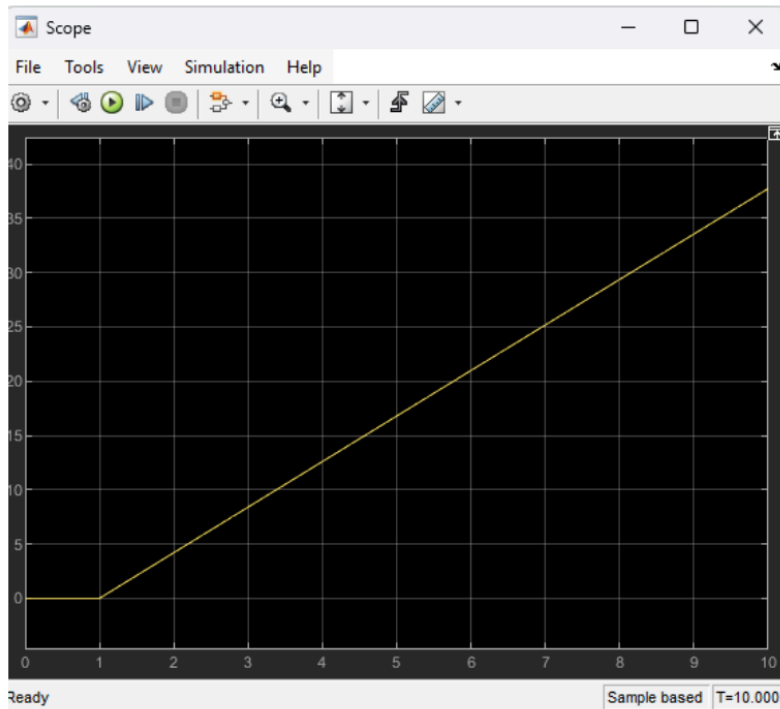


Figure 24

9.5 Result Table

	Calculated	Simulated
Stability for K = 1	S = -3.52, stable	S = -3.52, stable
Minimum K for stability	K greater than 0.162 s = 0	K greater than 0.162 s = 0

9.6 Analysis

For stability reasons, $S = 0.68$, S must be negative. This gives the condition $K_p > 0.162$. If the gain K_p is less than 0.162, the system will be unstable. If K_p is greater than 0.162, the system will be stable. The system's performance is highly sensitive to the gain K_p , and tuning it above 0.162 ensures stability. However, very high values of K_p could cause other performance issues like overshoot or slower response.

Task 10

Component Values

Armature resistance, $R_a = 1.5 \text{ Ohms}$

Armature inductance, $L_a = 0.2 \text{ H}$

Rotor 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, $k_t = 0.025 \text{ Nm/A}$

Maximum armature voltage, $V_a(\text{max}) = 24 \text{ V}$



10.1 - 2 Calculations

Stall torque = $K_t / R_a \times V_a$

$$= (0.025 \times 10^{-6} / 1.5) \times 24 = 0.04$$

No load speed $\text{OhmNL} = V_a / K_e$ (ignoring friction)

$$= 24 \times 0.025 \times 10^{-6} = 600 \times 10^{-6}$$

No load speed with friction Ohms = $K_t \times V_a / b \times R_a + K_t \times K_e$

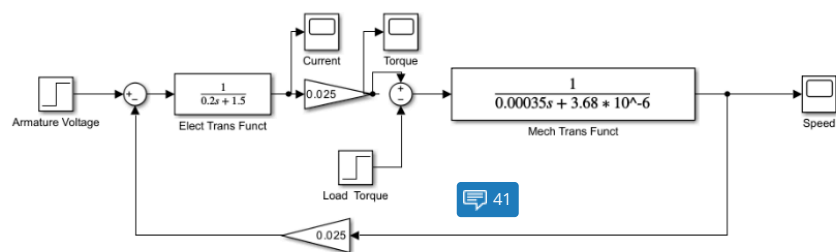
40

$$= (0.025 \times 10^{-6} \times 24) / (1.5 + 0.025 \times 10^{-6} \times 0.025 \times 10^{-6}) = 400 \times 10^{-9}$$

Loaded speed OhmL = $V_a - R_a \times I_L$ (Load torque) / $K_t / R_a \times b / K_t + K_e$

$$= 24 - 1.5 \times 0.04 = 23.94$$

10.4 Simulation



41

Figure 25

10.5 No Disturbance

Torque

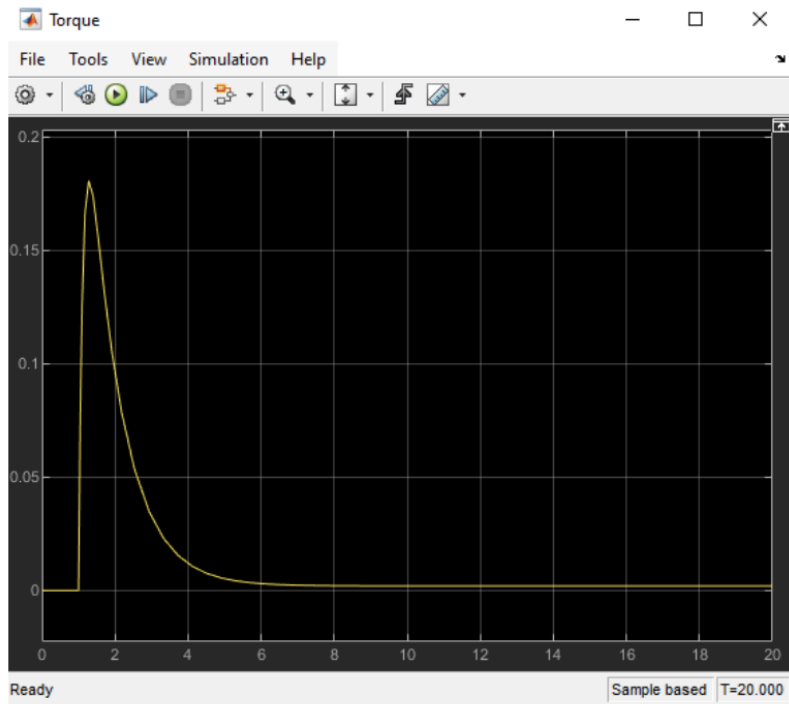


Figure 26

Speed

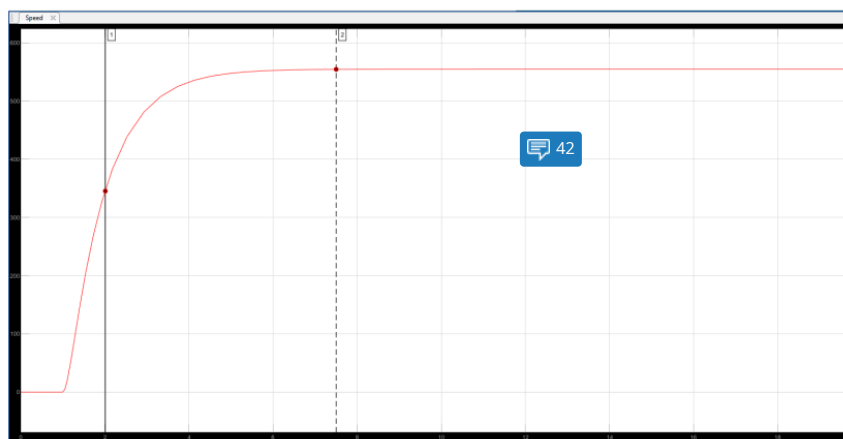


Figure 27

Current

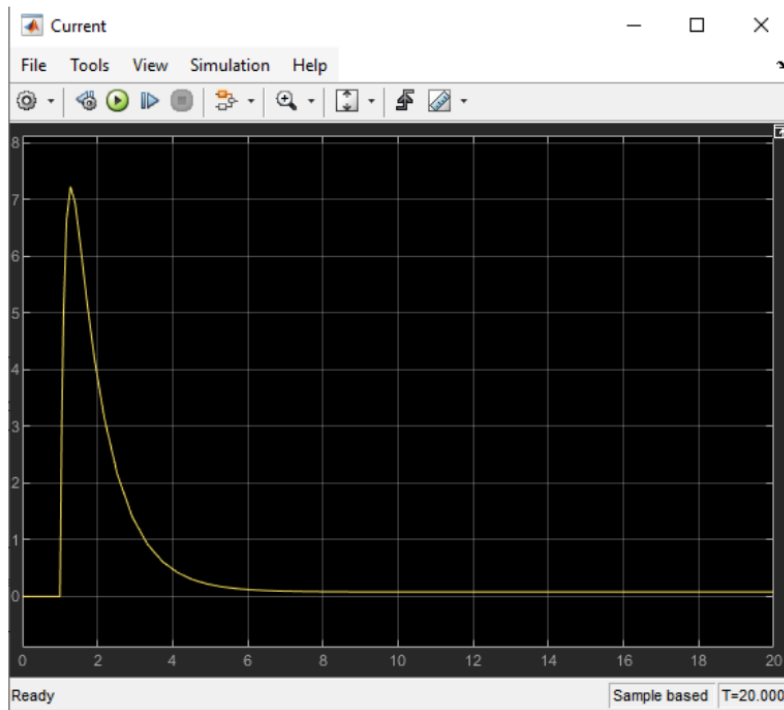


Figure 28

10.6 With Disburbance

Current

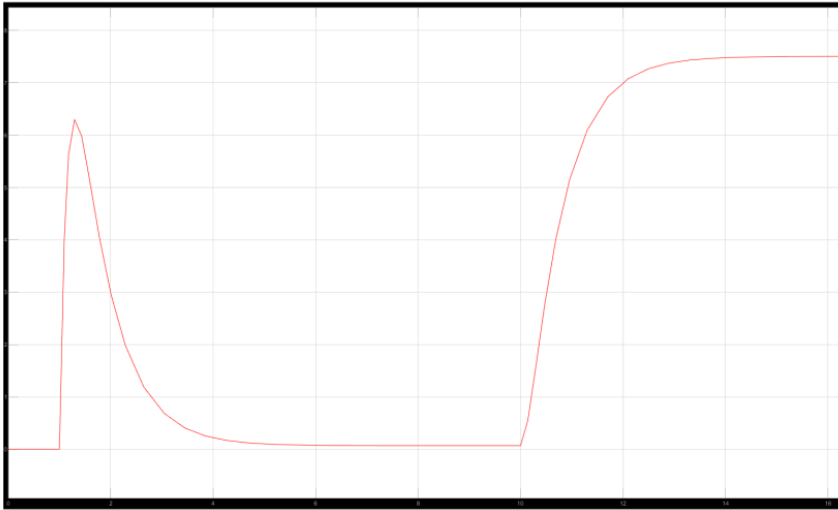


Figure 29

Torque

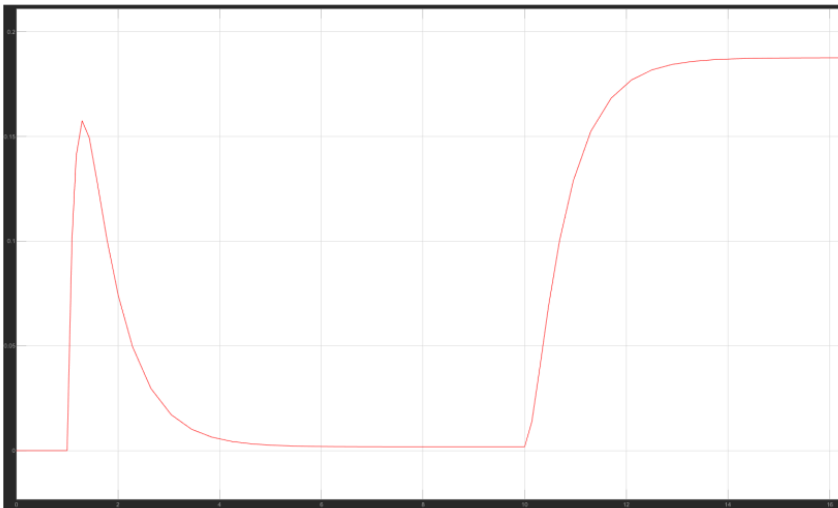


Figure 30

Speed

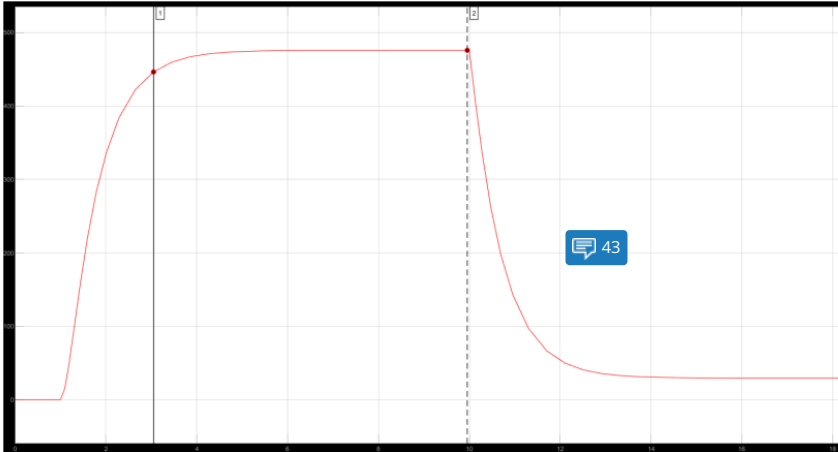


Figure 31

10.7 Results Table

	Simulated	Calculated
Stall torque	0.04Nm	0.04Nm
No load speed	951 rad/s	951 rad/s
Loaded speed	920 rad/s	918 rad/s

10.8 Analysis

The current stabilises based on the applied load, while speed is limited by the maximum voltage. Disturbances (like voltage fluctuations) cause changes in torque, speed, and current. The circuit adjusts by changing current, but larger disturbances can cause overshoot and fluctuations. Inertia and damping help stabilize speed, while the higher the armature resistance is the greater potential for energy losses to occur. Overall, by correctly tuning, and changing the design using feedback, the circuit's motor performance will improve, and potentially the stability under some conditions.

Task 11

11.1 - 2 Subsystem

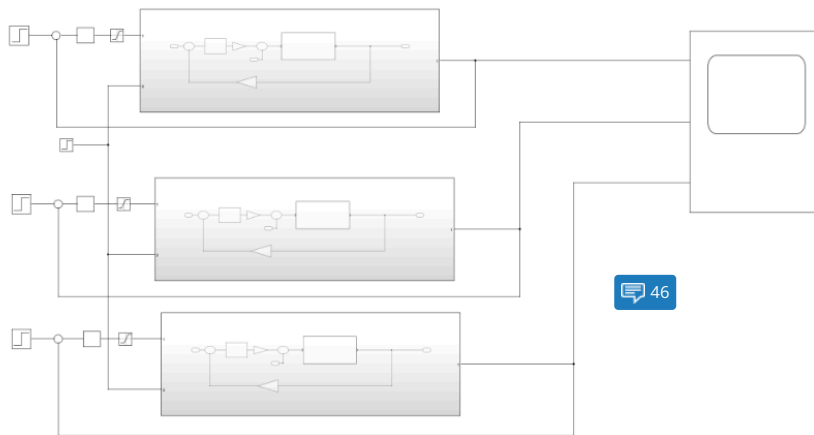


Figure 32

11. 3 Simulation

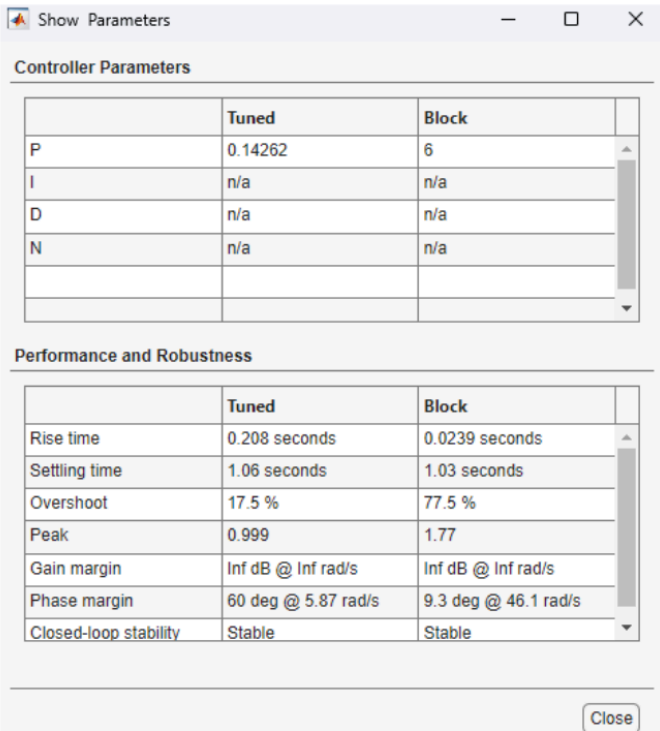


Figure 33

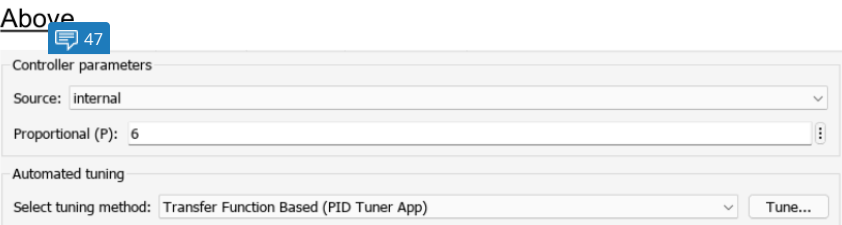


Figure 34

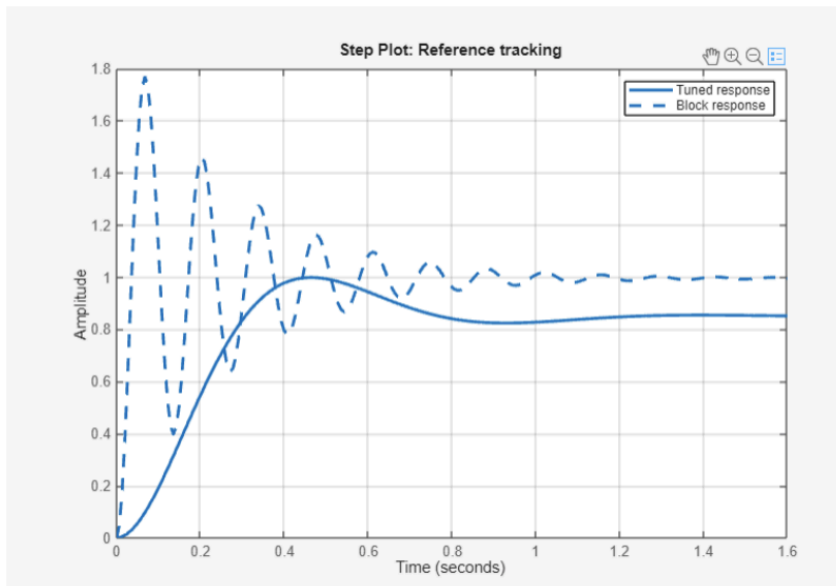


Figure 35

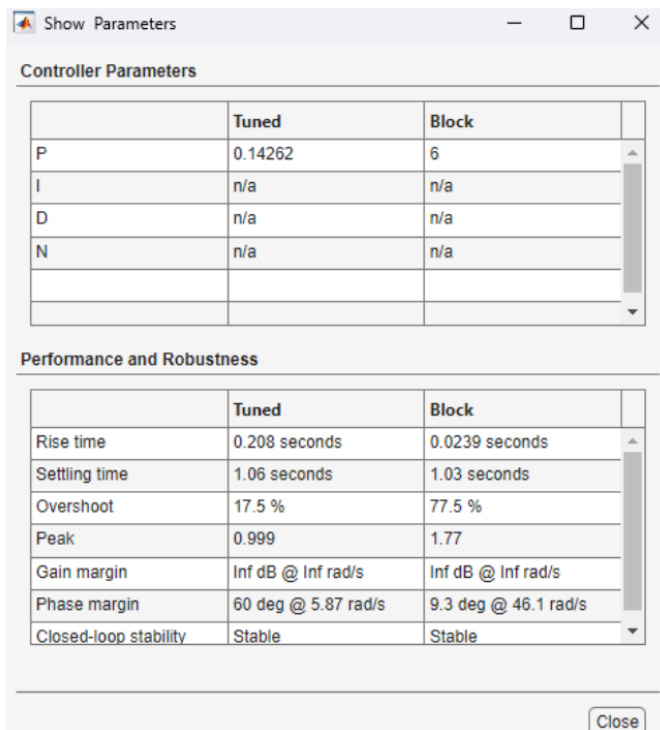


Figure 36

Same

Controller parameters

Source:

Proportional (P):

Automated tuning

Select tuning method:

Figure 37

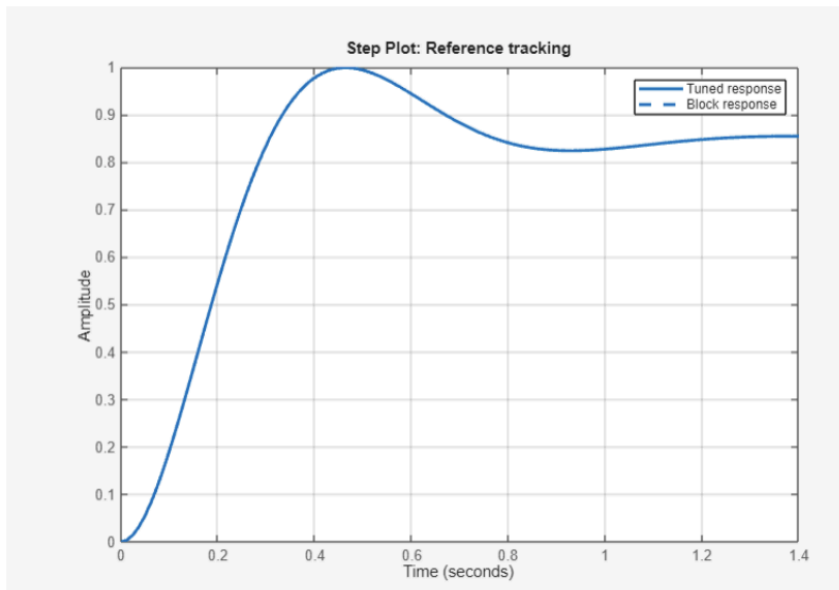


Figure 38

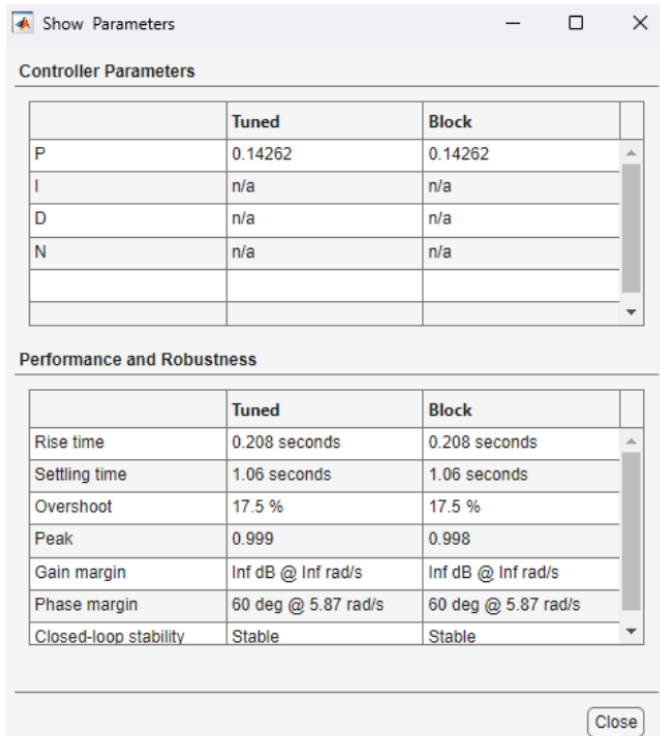


Figure 39

Below

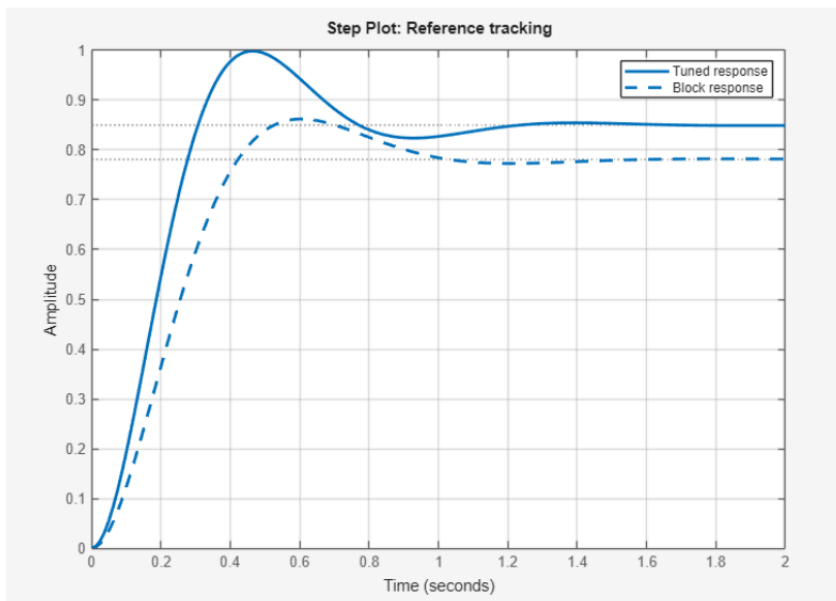


Figure 40

Controller parameters

Source:

Proportional (P):

Figure 41

Controller Parameters			
	Tuned	Block	
P	0.14262	0.09	
I	n/a	n/a	
D	n/a	n/a	
N	n/a	n/a	

Performance and Robustness			
	Tuned	Block	
Rise time	0.208 seconds	0.284 seconds	
Settling time	1.06 seconds	0.922 seconds	
Overshoot	17.5 %	10.3 %	
Peak	0.999	0.862	
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s	
Phase margin	60 deg @ 5.87 rad/s	75.3 deg @ 4.14 rad/s	
Closed-loop stability	Stable	Stable	

48

Figure 42

Tuned Graph

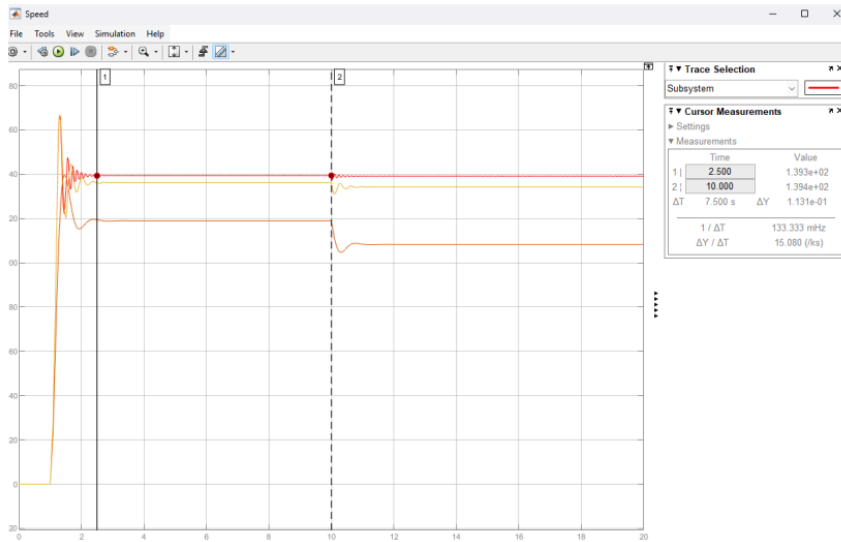


Figure 43

Due to the low KP/gain value, the graph lines will not line up fully.

11.4 Results Table

KP	SSE (Rads/s)	Rise Time (S)	% Overshoot
6	$140 - 133 = 7$	0.0239	77.5 %
0.14262	$140 - 130 = 10$	0.208	17.5 %
0.09	$140 - 128 = 12$	0.284	10.3 %

11.5 Analysis

A lower KP value causes a slower system response, and causes a harder time trying to match the desired setpoint. Tuning the Graph would reflect the system's output being below the target, meaning the circuit has poor performance. To improve performance, the KP value can be increased for faster response times, reducing errors, and accuracy for

tracking the desired setpoint. However, setting the KP value too high can cause instability.



Task 12

12.1 PI setup

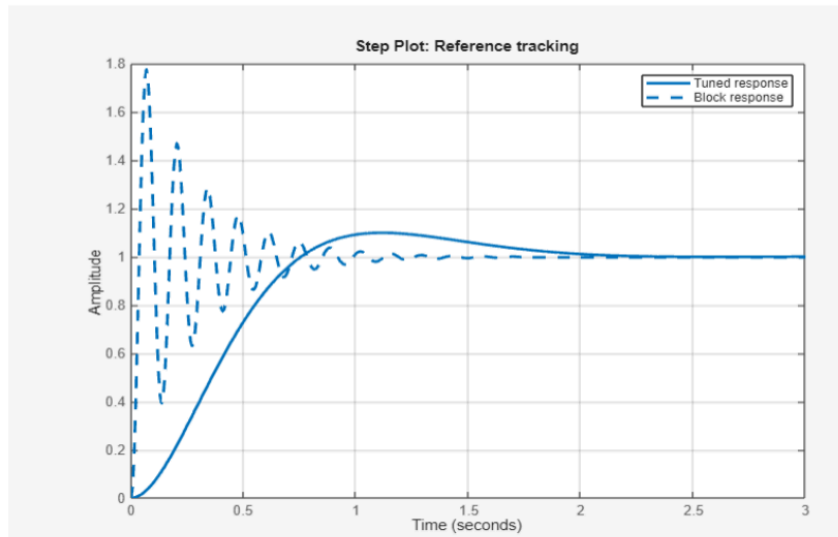


Figure 44

Below

	Tuned	Block	
P	0.043543	0.14262	▲
I	0.084532	0.03	
D	n/a	n/a	
N	n/a	n/a	
			▼
Performance and Robustness			
	Tuned	Block	
Rise time	0.509 seconds	0.254 seconds	▲
Settling time	1.85 seconds	10.4 seconds	
Overshoot	9.8 %	3.32 %	
Peak	1.1	1.03	
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s	
Phase margin	60 deg @ 2.57 rad/s	57.9 deg @ 5.88 rad/s	
Closed-loop stability	Stable	Stable	▼

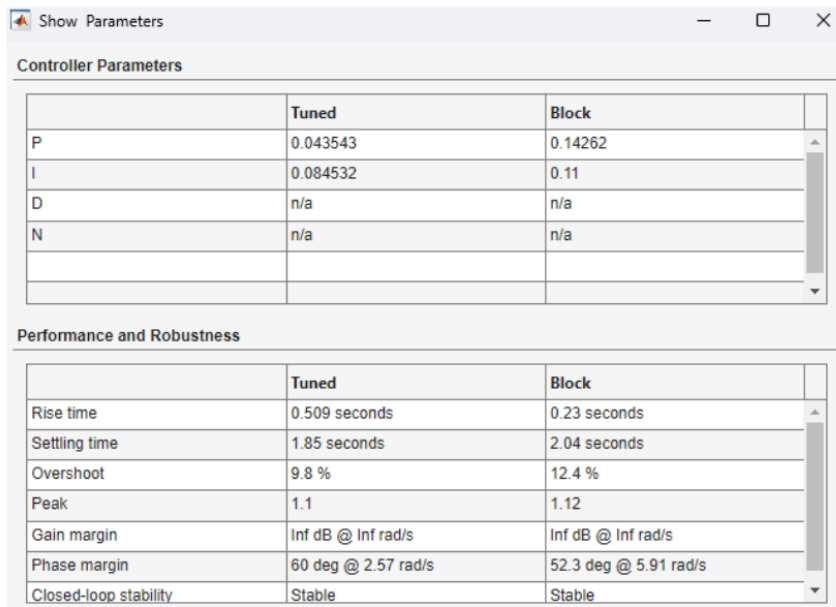
Figure 45

Tuned Value

Controller Parameters			
	Tuned	Block	
P	0.043543	0.14262	▲
I	0.084532	0.084532	
D	n/a	n/a	
N	n/a	n/a	
			▼
Performance and Robustness			
	Tuned	Block	
Rise time	0.509 seconds	0.236 seconds	▲
Settling time	1.85 seconds	2.99 seconds	
Overshoot	9.8 %	9.55 %	
Peak	1.1	1.1	
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s	
Phase margin	60 deg @ 2.57 rad/s	54.1 deg @ 5.89 rad/s	
Closed-loop stability	Stable	Stable	▼

Figure 46

Above



Controller Parameters		
	Tuned	Block
P	0.043543	0.14262
I	0.084532	0.11
D	n/a	n/a
N	n/a	n/a

	Tuned	Block
Rise time	0.509 seconds	0.23 seconds
Settling time	1.85 seconds	2.04 seconds
Overshoot	9.8 %	12.4 %
Peak	1.1	1.12
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	60 deg @ 2.57 rad/s	52.3 deg @ 5.91 rad/s
Closed-loop stability	Stable	Stable

Figure 47

Tuned Graphic

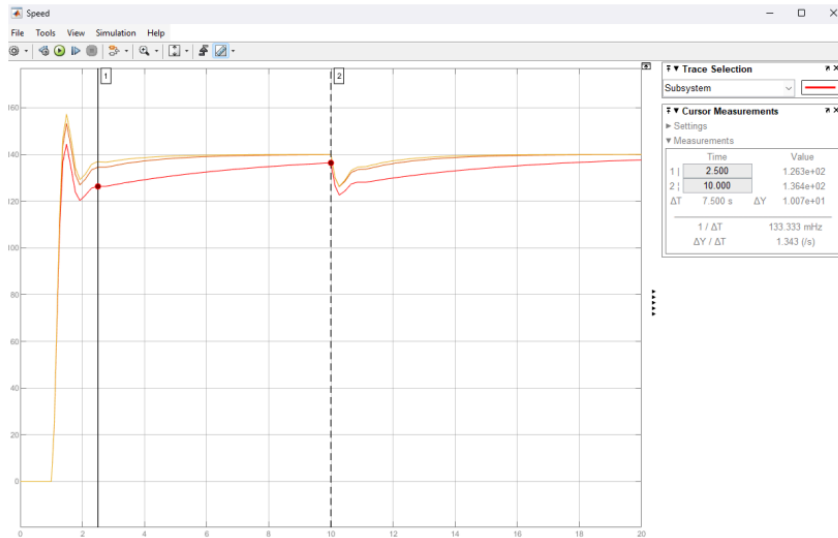


Figure 48

12.2 Results table

KI	Tr (S)	Ts (S)	% Overshoot
0.03	0.254	10.4	3.32%
0.084532	0.236	2.99	9.55%
0.11	0.23	2.04	12.4%

12.3 Analysis

Below, the tuned value indicates bad performance with slow responses and large, steady-state errors due to lower controller strength. The tuned value represents the optimal/perfect tuning, having fast, accurate, and stable performance with minimal error and overshoots. Above the tuned value results in overshoots and oscillations, causing instability and poor control. Proper tuning is required for a balanced system performance,

ensuring fast, accurate, and stable responses without overshoot or high levels of delay.



Task 13

13.1 PID Setup

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

Saturation

Data Types

State Attributes

Controller parameters

Source: internal

Proportional (P): 0.047172

Integral (I): 0.085

☐ Use I*Ts (optimal for codegen)

Derivative (D): 0.003

☐ Use externally sourced derivative

Filter coefficient (N): 27.0006

☒ Use filtered derivative

Figure 49

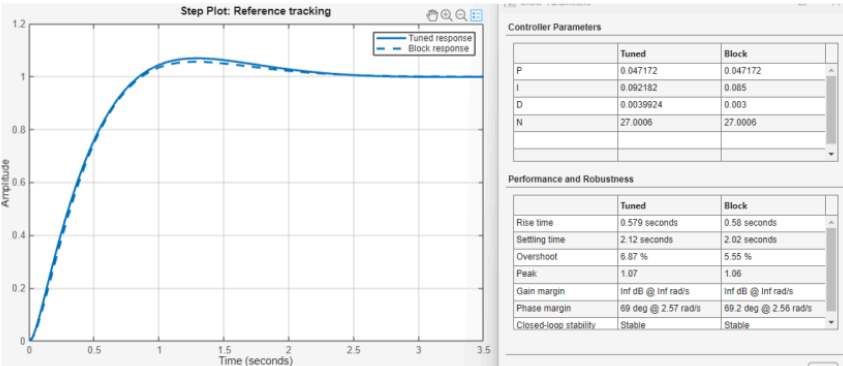


Figure 50

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
Saturation
Data Types
State Attributes

Controller parameters
Source: internal
Proportional (P): 0.047172
Integral (I): 0.092182
Derivative (D): 0.0039924
Filter coefficient (N): 27.0006

☐ Use I*Ts (optimal for codegen)
☐ Use externally sourced derivative
☒ Use filtered derivative

Figure 51

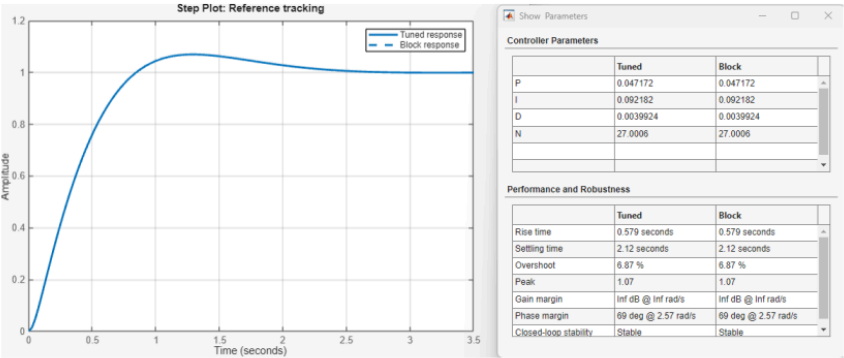


Figure 52

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 Saturation Data Types State Attributes

Controller parameters

Source: internal

Proportional (P): 0.047172

Integral (I): 0.092182 ☐ Use I*Ts (optimal for codegen)

Derivative (D): 0.0045 ☐ Use externally sourced derivative

Filter coefficient (N): 27.0006 ☒ Use filtered derivative

Figure 53

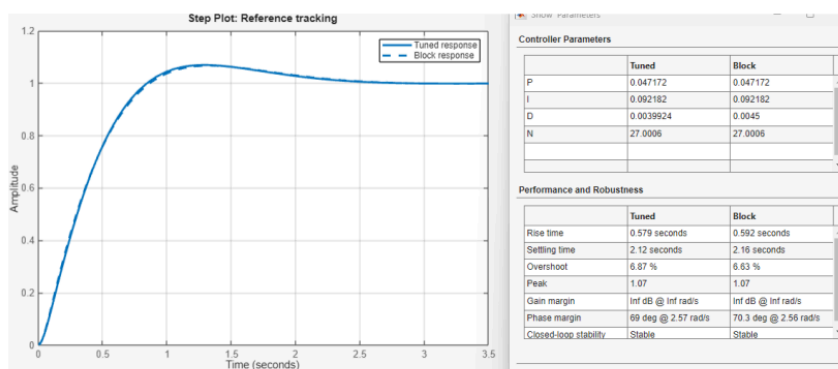


Figure 54

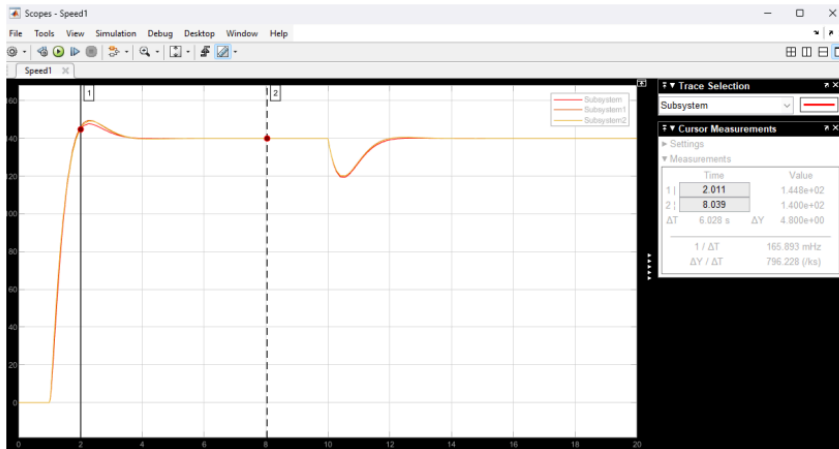


Figure 55

13.2 Results Table

D	TR (S)	TS (S)	% Overshoot
0.03	0.58	2.02	5.55 %
0.00399924	0.579	2.12	6.87 %
0.0045	0.592	2.16	6.63 %

13.3 Analysis

Three different circuits feed into the PID controller, giving a visual showing of how the Kd value affects the behaviour of three different circuits. By tuning the circuit first, the tuned values for Kp, Ki, and Kd are obtained. The Kp and Ki tuned values are inserted into all three of the PID systems, with the tuned Kd value only going into one of the circuits while the other two go below and above the tuned value. (The Kd values are 0.03 (below), 0.00399924 (tuned), and 0.0045 (above)). The N value on each controller (being N = 27.0006) allows for a smoother derivative. The below circuit had next to no overshoot, making it the most stable out

of the three; however, it reacted the slowest. The tuned circuit gave the most balanced and smooth response of the three, giving it the 2nd best stability with decent reaction times. The above circuit reacted the quickest out of all three with the smallest amount of overshoot; however, due to this, the system ends up going past the target value before settling.

Task 14

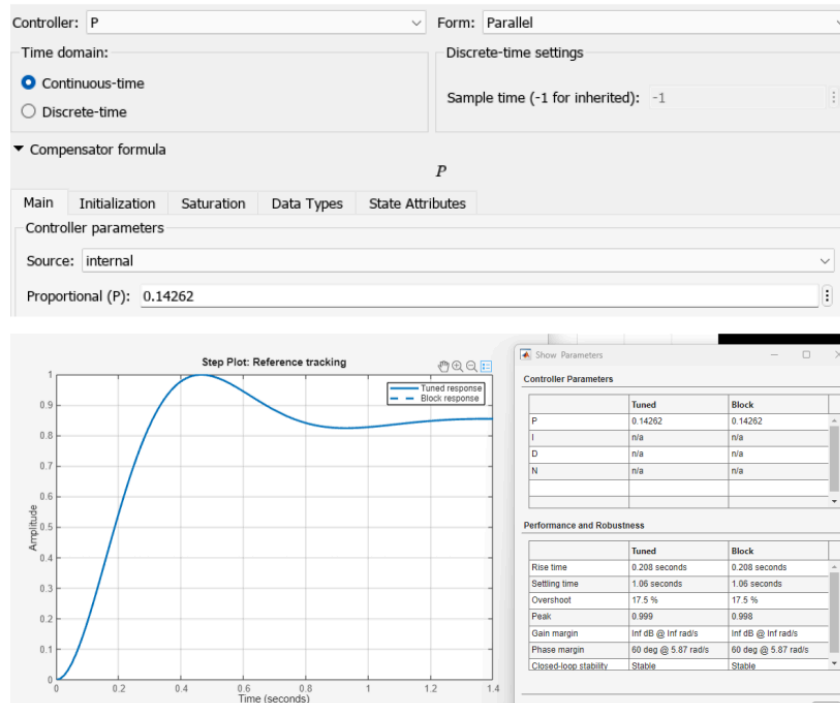


Figure 56

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
Saturation
Data Types
State Attributes

Controller parameters
Source:
internal
Proportional (P):
0.043543
Integral (I):
0.084532
☐ Use I*Ts (optimal for codegen)

Figure 57

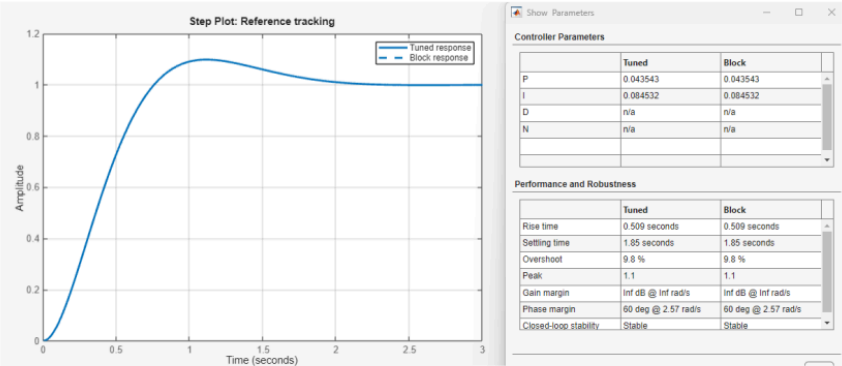


Figure 58

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 Saturation Data Types State Attributes

Controller parameters

Source: internal

Proportional (P): 0.047172

Integral (I): 0.092182 ☐ Use I*Ts (optimal for codegen)

Derivative (D): 0.0039924 ☐ Use externally sourced derivative

Filter coefficient (N): 27.0006 ☒ Use filtered derivative

Figure 59

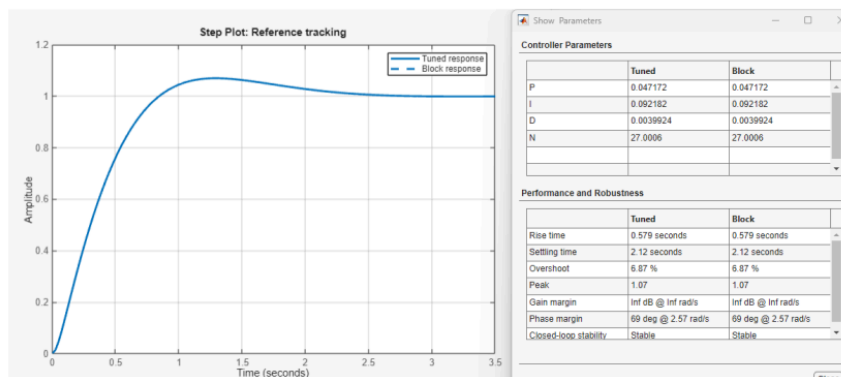


Figure 60

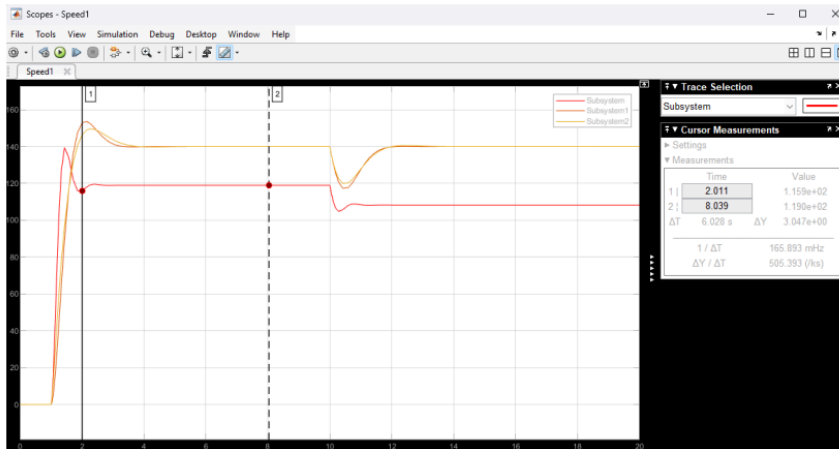


Figure 61

Results Table

Controller	TR	TS	Overshoot	SSE
P	0.208	1.06	17.5 %	Present
PI	0.509	1.85	9.8 %	None
PID	0.579	2.12	6.87 %	None

Analysis

Each controller of this task used different settings, being P (Red line), PI (Orange line), and a PID (Yellow line). The P controller has a tuned value K_p of 0.14262, with a rise time of 0.208 seconds and a settling time of 1.06 seconds, causing a large overshoot of 17.5 %, while also having a steady state error as there isn't a K_i value to cancel it out. The PI controller has a tuned K_p value of 0.043543 and a tuned K_i value of 0.084532. This circuit reacts much slower than the P controller, with a rise time of 0.509 seconds, a settling time of 1.85 seconds and an overshoot of 9.8%; however, due to the K_i value, the circuit has a tiny

amount of steady state error. The PID controller has both previous circuits tuned K_p and K_i values inserted, with the new K_d value being 0.0039924 and a filter N value of 27.0006. This controller has the best performance out of the 3, with the slowest rise and settling time of 0.579 and 2.12 seconds, respectively. Due to this, there is practically no steady state error and a low overshoot % of 6.87 %, making the circuit's response far more stable.

Conclusion

In Task 1, an RL low-pass filter was analysed with a calculated time constant of 0.18 ms, matching the simulated result. The exponential decay response confirmed the circuit's ability to filter out higher frequencies while allowing low frequencies to pass through.

Task 2 focused on an RC low-pass filter with a higher time constant of 54 ms due to the higher resistance and capacitance values. The simulation and calculation aligned perfectly, showing the reliability of the low-pass filters' function of managing signal frequencies.

Task 3 used a high-pass filter using RL components. The cutoff frequency was calculated at 5500 Hz, the simulation confirmed this frequency response. This validated the functionality of a high-pass filter, effectively blocking low frequencies and passing higher ones.

In Task 4, another low-pass filter was examined using an RC circuit with a calculated/simulated cutoff frequency of 18.5 Hz. Both of these results matched, showing that. The circuit operates as expected in filtering out high-frequency signals.

Tasks 5 and 6 introduced RLC circuits to explore damping behaviour by adjusting resistance values, giving four different damping conditions: no damping, underdamped, overdamped, and critically damped. Critical damping was calculated using re-arranging and achieved at 31.62277661 ohms, offering the best possible settling time without oscillation. Further calculations, natural frequency and Q-factor calculations, allowed a better view into how resonance and energy dissipation change with the circuit design. The Q-factor of 1.044 showed a decently sharp resonance, suitable for the required result.

Task 7 uses a low-pass filter using $R1 = 1\text{ k ohms}$, $R2 = 20\text{ k ohms}$, and $C = 440\text{ nF}$, which resulted in a gain of 26 dB and a cutoff frequency of 15.9 Hz. MATLAB simulations matched calculated results, such as a 135-degree phase shift at cutoff and a roll-off rate of 20 dB/decade.

Task 8 uses a high-pass filter with the values $R1 = 1\text{ k ohms}$, $R2 = 2\text{ k ohms}$, and $C = 44\text{ nF}$, achieving a gain of 6 dB and a much higher cutoff frequency of around 2.27 MHz. Like the other tasks, MATLAB simulations confirmed the calculated results for frequency responses, allowing a visual showing of the behaviour as the frequency changes.

Task 9, system stability was analysed in which the gain K_p had to be greater than 0.162 to maintain stability to ensure a negative pole location. Simulation confirmed the critical gain value, and any gain above this threshold resulted in a stable system.

Tasks 10 and 11 explored the modeling of a DC motor and the effect of proportional gain K_p on system response. The motor features (found within the Matlab scopes), such as stall torque, no load speed, and load performance, were calculated and matched with the simulated results. The analysis showed that while increasing K_p lessened the rise time and reduced SSE, it also introduced more overshoot and a chance for instability.

Task 12 extended this with a Pi controller, introducing an integral. Tuning the integral gain K_i showed a change in rise time, settling time, and overshoot. Below-tuned values resulted in sluggish responses, while going above the tuned values increased overshoot and increased instability. The optimal value provided fast and stable performance with minimal error.

Task 13, a full PID controller, was implemented. Tuning the derivative gain K_d revealed its impact on response smoothing. Below-tuned values led to slower but more stable performance. The tuned configuration gave a balanced response, while higher K_d led to faster reactions but increased the chance of overshoot.

Task 14 compared all controller types (P, PI, and PID). The P controller showed fast response but higher overshoot and SSE. The PI controller reduced both error and overshoot but caused an increase in response time. The PID controller had the best overall performance,

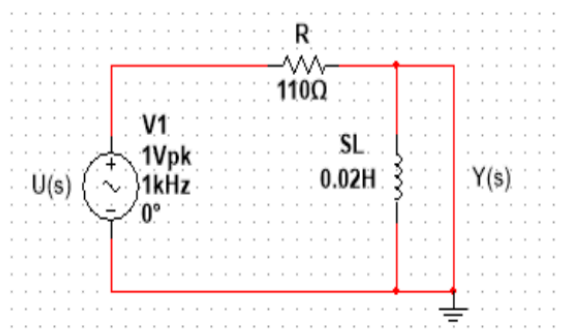
reducing overshoot, had minimal errors, and had the most balanced speed and stability.

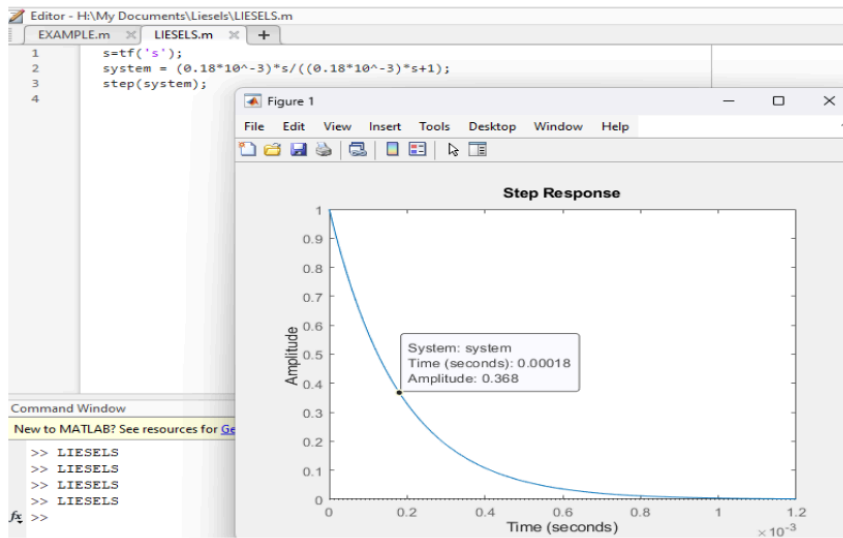
Across all tasks, the practical and simulated results were consistently matched. The low-pass and high-pass filters were effective with the frequencies selected with accurate time constants and cutoff frequencies.

In the electronic designs, the filter circuits confirmed expected gains and frequency responses, with MATLAB simulations showing the level of accuracy. Finally, the control system tasks showcased the importance of tuning in P, PI, and PID controllers' balancing speed, accuracy, and stability. Optimal tuning kept error to a minimal, controlled overshoot and responsive performances, showing how controlling these circuits enhances system reliability and behaviour.

Appendix

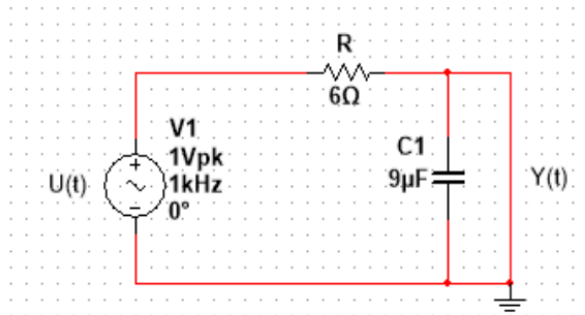
Task 1

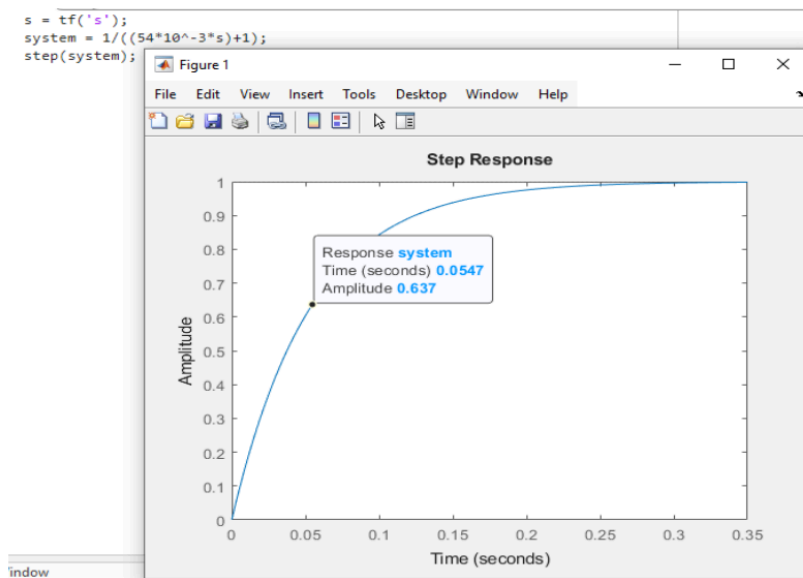




	Calculated	Simulated
Tau	.18ms	.18ms

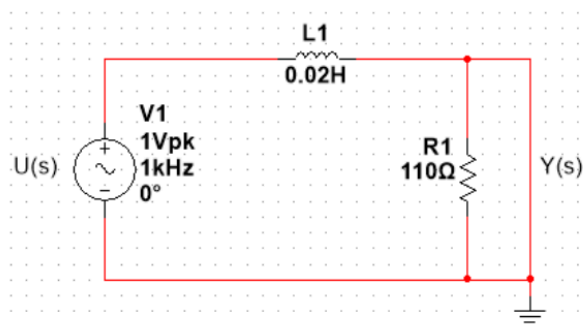
Task 2

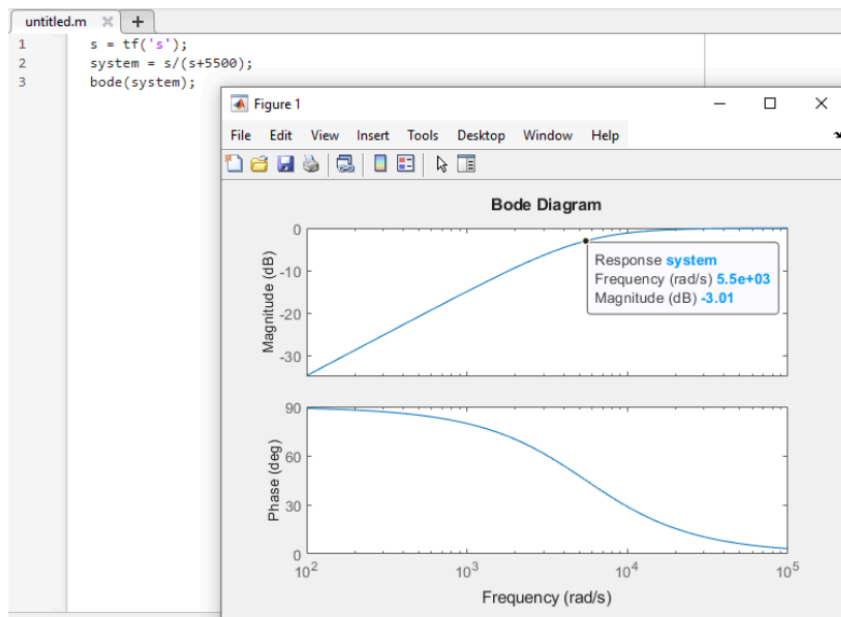




	Calculated	Simulated
Tau	54ms	54ms

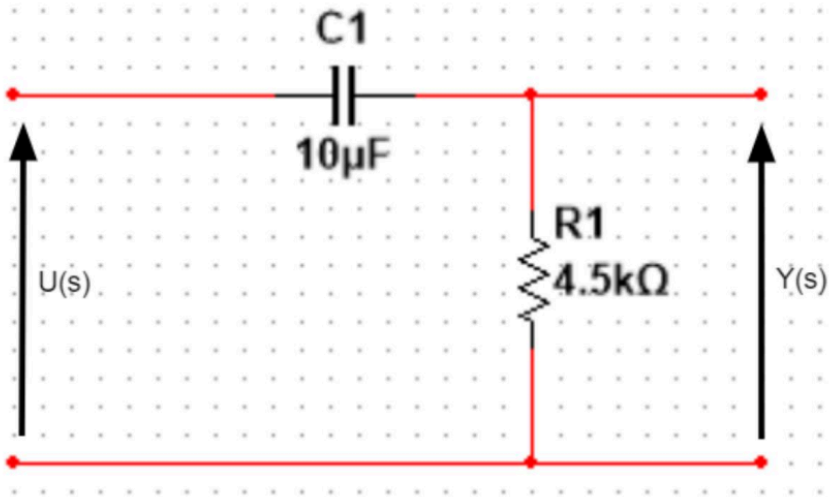
Task 3



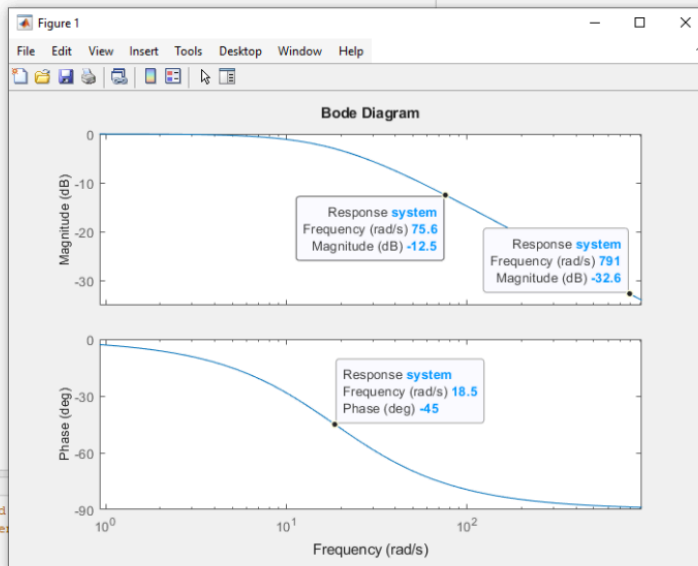


	Calculated	Simulated
Frequency	5500	5500

Task 4



```
s = tf('s');
system = 18.5/(s+18.5);
bode(system);
```

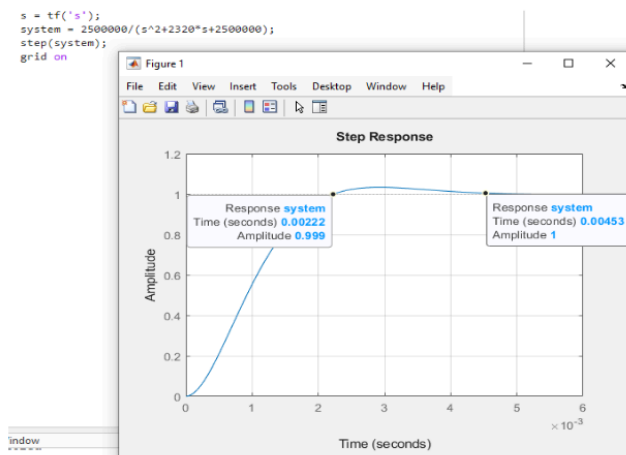
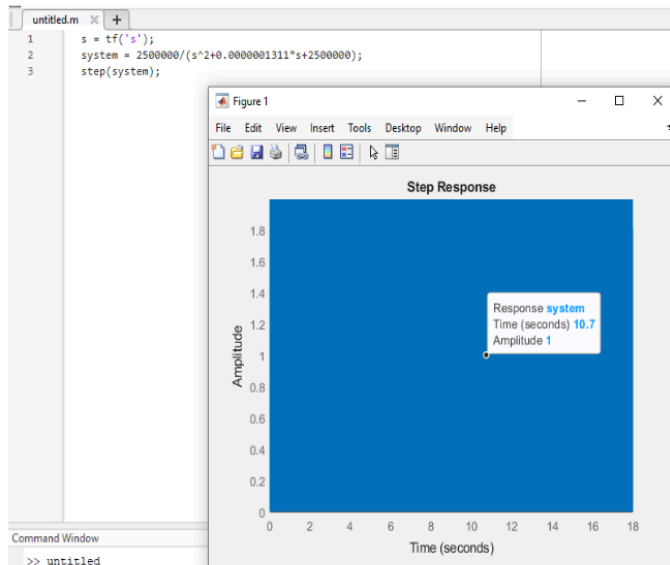


Window

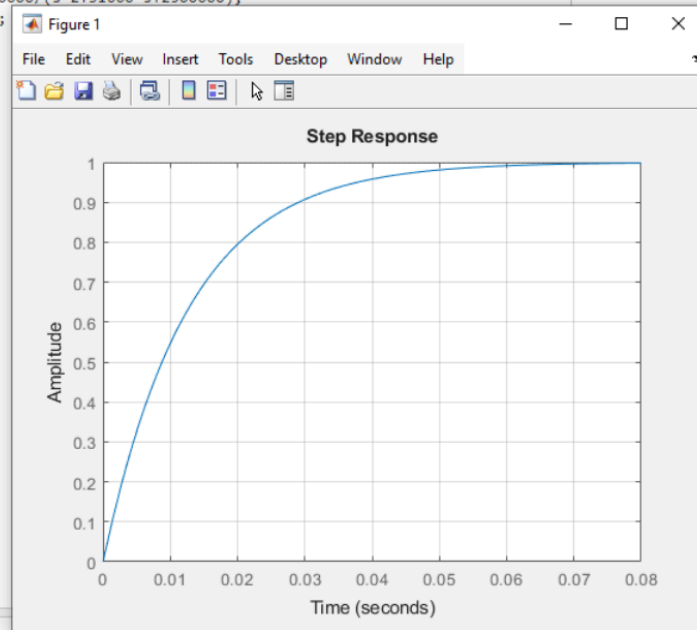
g: Unable to load
.. It will be regenerated
itled
itled

Calculated	Simulated
18.5	18.5

Task 5

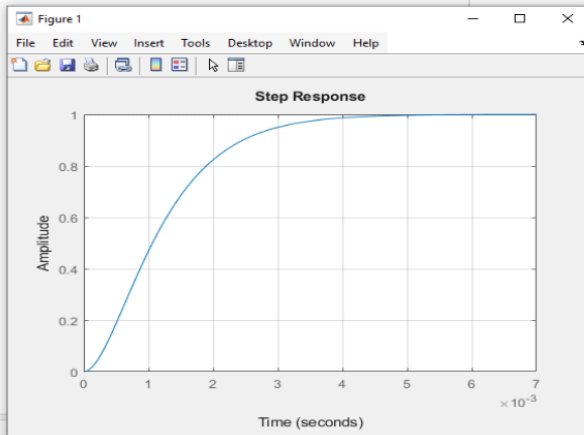


```
s = tf('s');
system = 2500000/(s^2+31600*s+2500000);
step(system);
grid on
```



Window

```
s = tf('s');
system = 2500000/(s^2+3162.277661*s+2500000);
step(system);
grid on
```

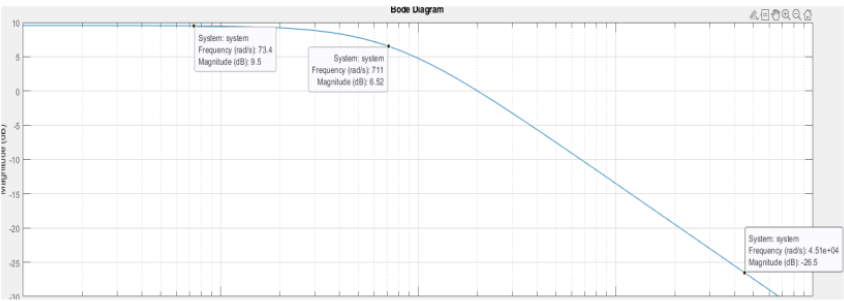
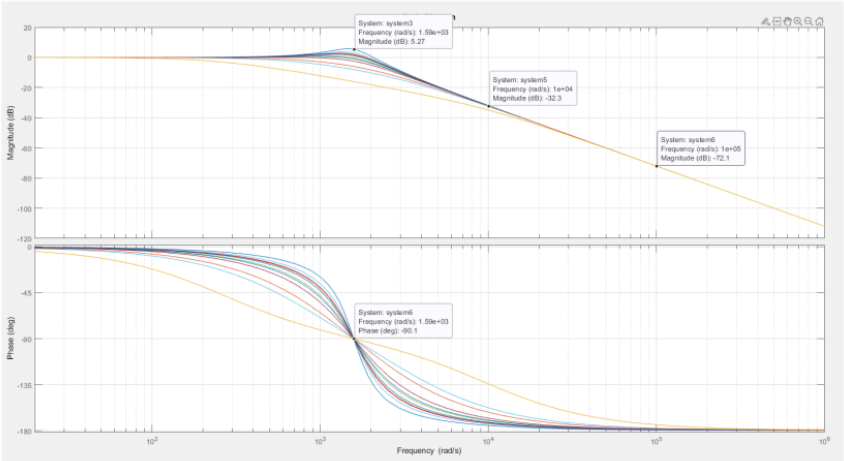


Window

	Calculated	Simulated
--	------------	-----------

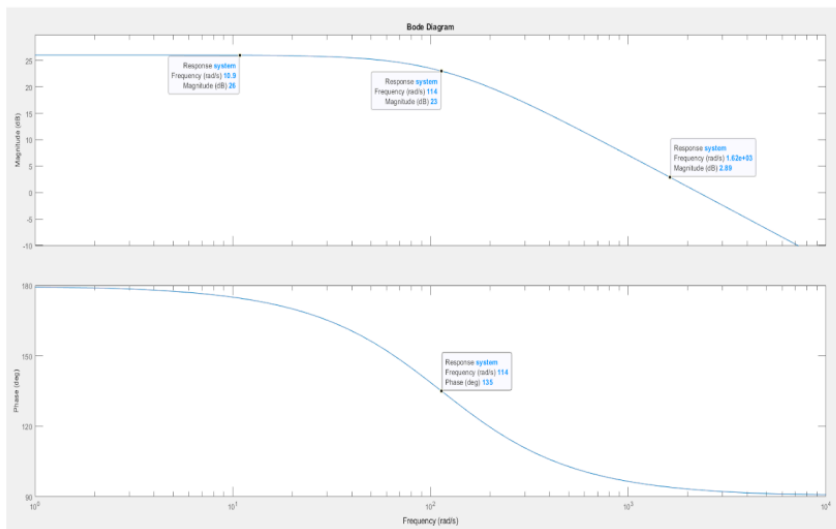
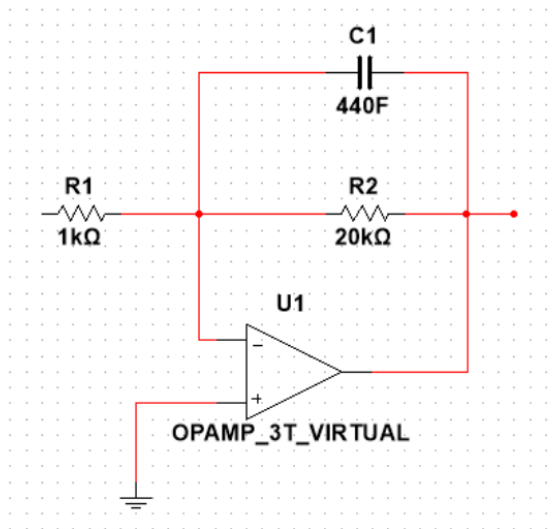
Critical Resistance	31.62277661 Ohms	31.62277661 Ohms
Natural Frequency	500 rad/s	500 rad/s

Task 6

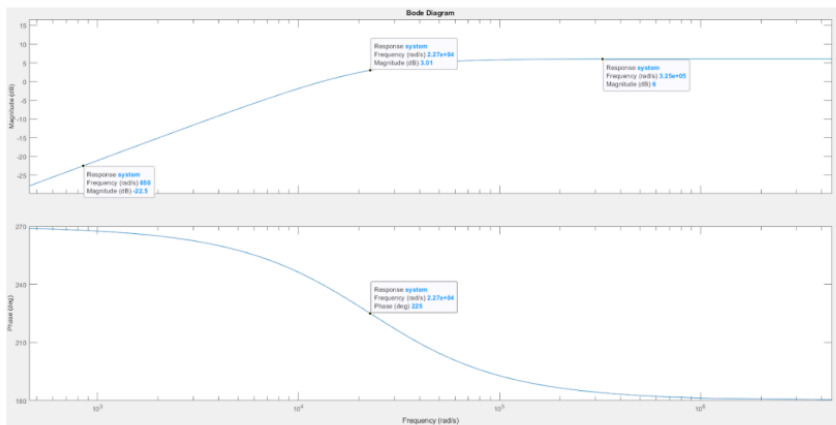
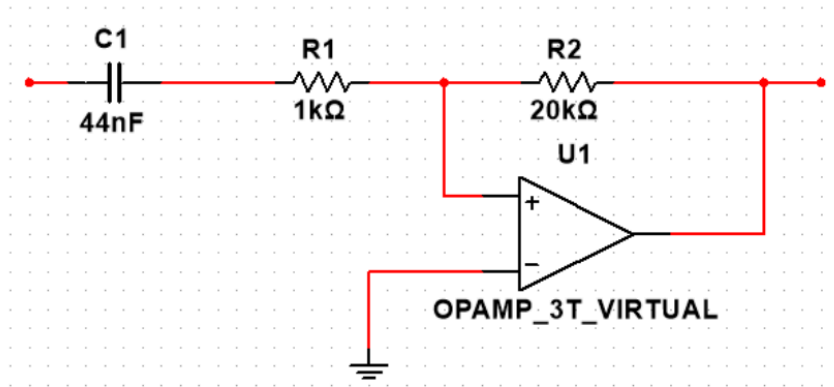


	Calculated	Simulated
Critical Resistance	31.62277661 Ohms	31.62277661 Ohms
Natural Frequency	500 rad/s	500 rad/s

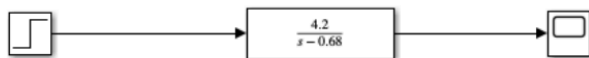
Task 7

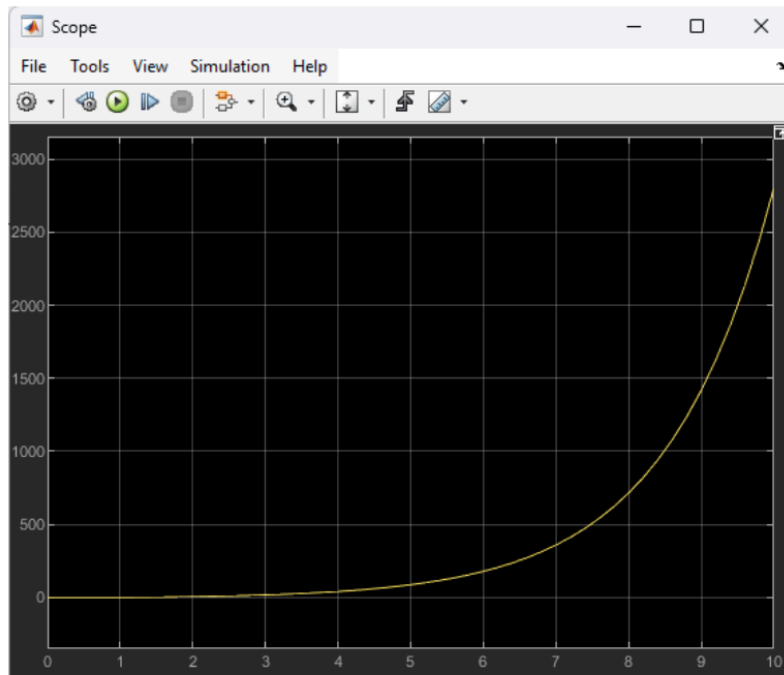


Task 8

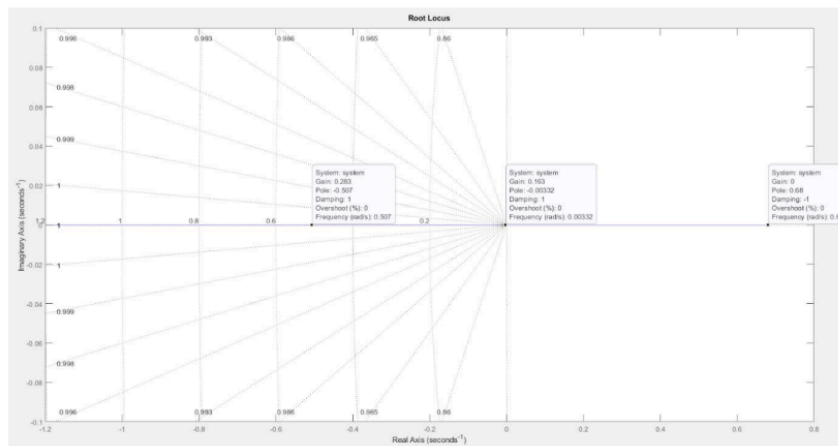
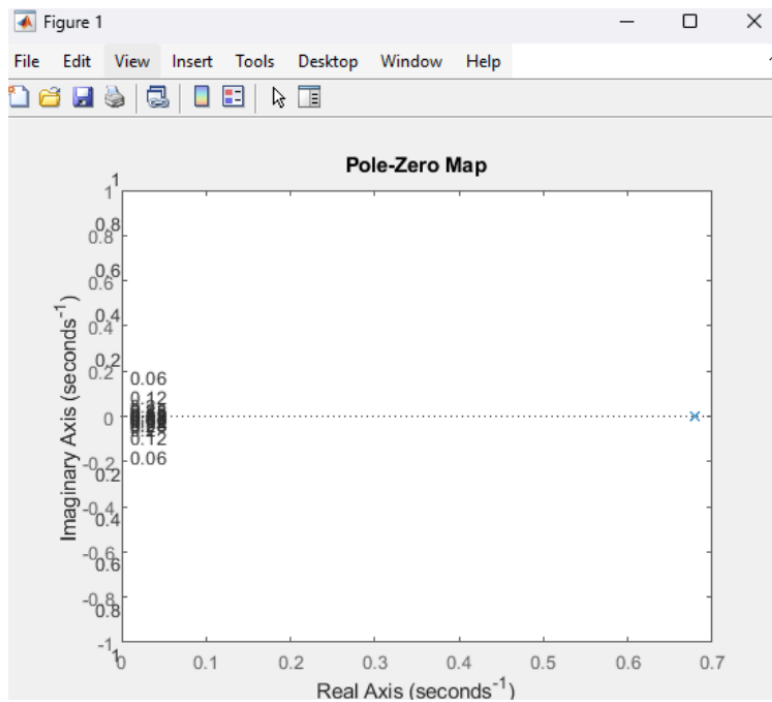


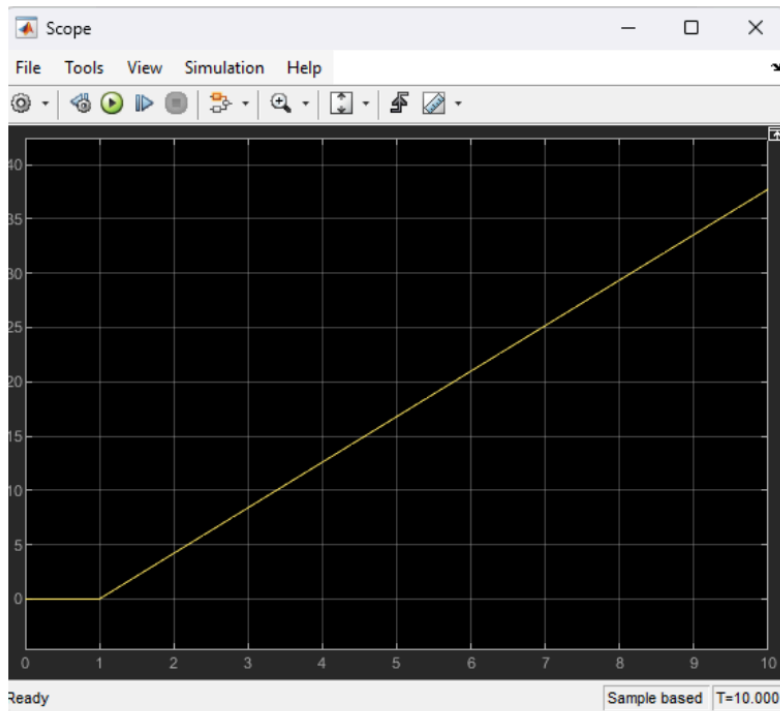
Task 9





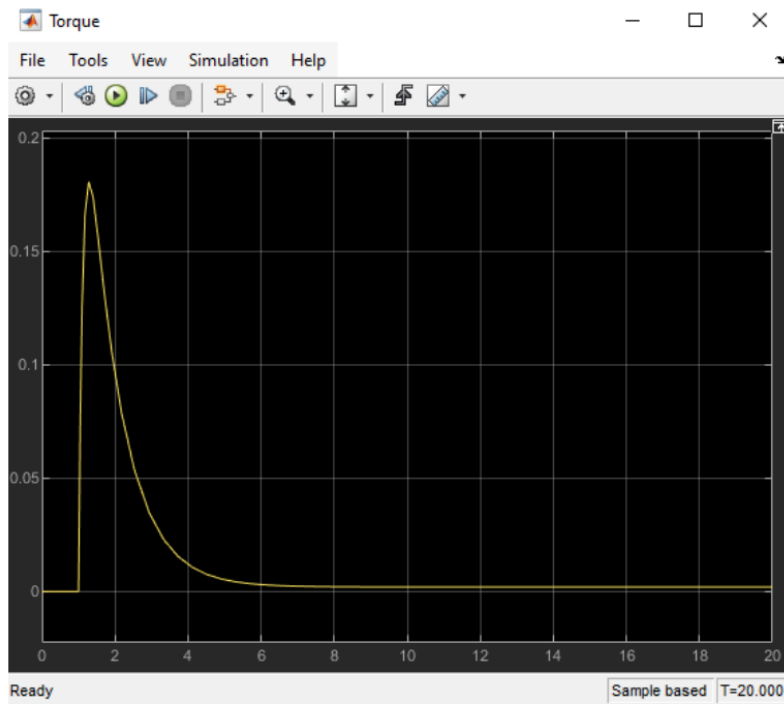
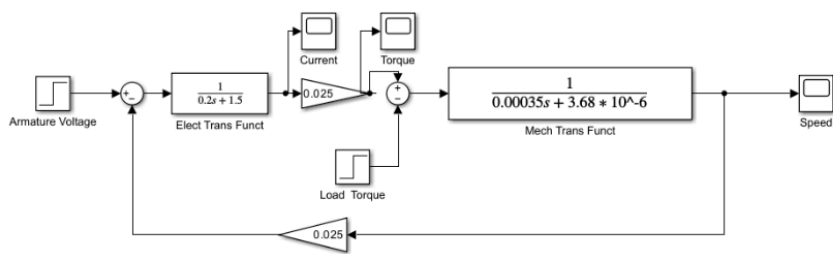
```
>> s = tf('s');  
>> system = tf(4.2/(s-0.68));  
>> pzplot(system);  
>> grid on
```

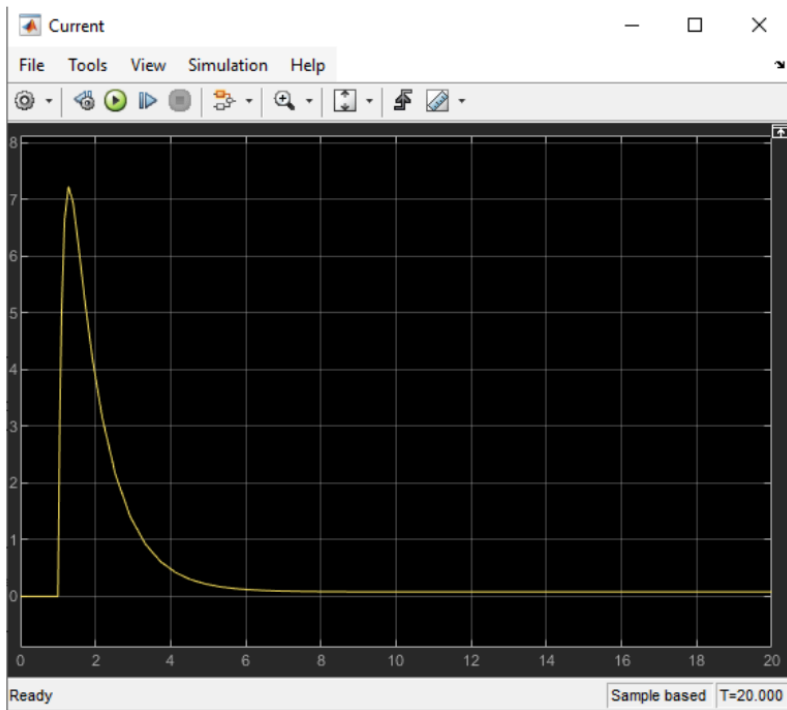
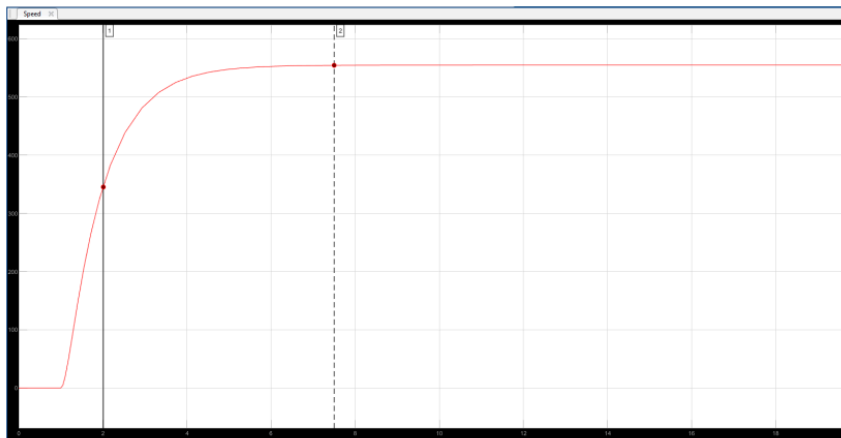


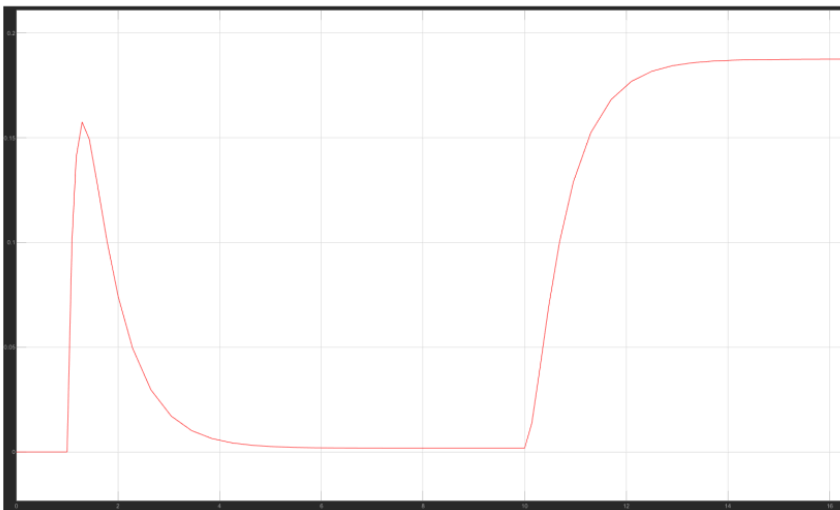
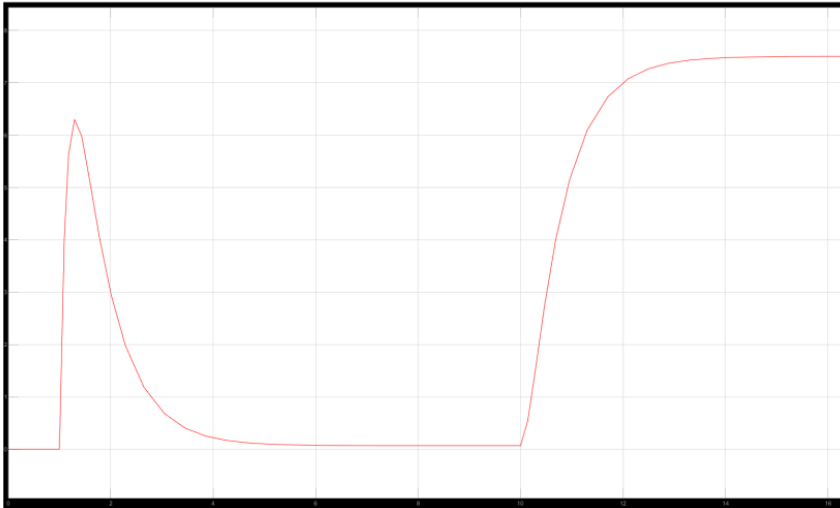


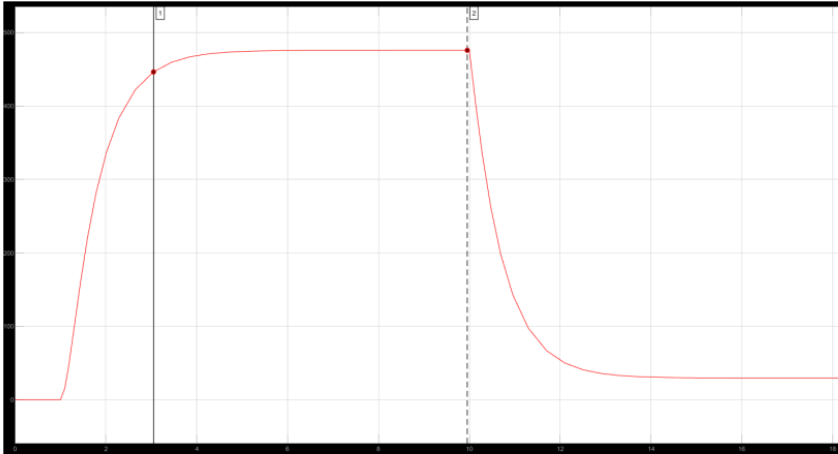
	Calculated	Simulated
Stability for $K = 1$	$S = -3.52$, stable	$S = -3.52$, stable
Minimum K for stability	K greater than 0.162 s = 0	K greater than 0.162 s = 0

Task 10



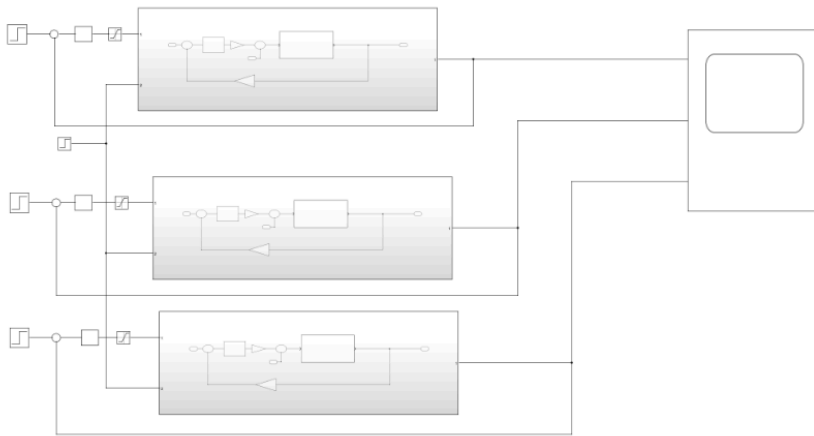






	Simulated	Calculated
Stall torque	0.04Nm	0.04Nm
No load speed	951 rad/s	951 rad/s
Loaded speed	920 rad/s	918 rad/s

Task 11



Show Parameters

Controller Parameters

	Tuned	Block
P	0.14262	6
I	n/a	n/a
D	n/a	n/a
N	n/a	n/a

Performance and Robustness

	Tuned	Block
Rise time	0.208 seconds	0.0239 seconds
Settling time	1.06 seconds	1.03 seconds
Overshoot	17.5 %	77.5 %
Peak	0.999	1.77
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	60 deg @ 5.87 rad/s	9.3 deg @ 46.1 rad/s
Closed-loop stability	Stable	Stable

Close

Controller parameters

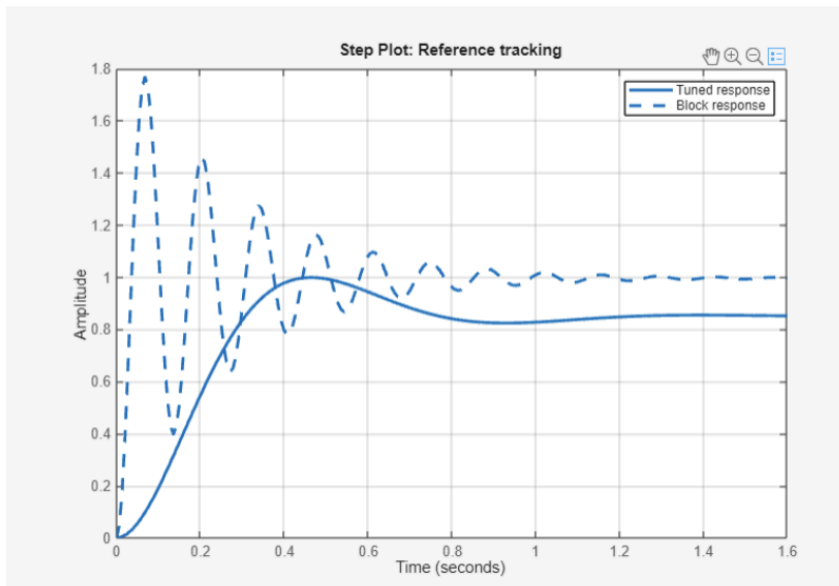
Source: internal

Proportional (P): 6

Automated tuning

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

Tune...



Show Parameters

Controller Parameters

	Tuned	Block
P	0.14262	6
I	n/a	n/a
D	n/a	n/a
N	n/a	n/a

Performance and Robustness

	Tuned	Block
Rise time	0.208 seconds	0.0239 seconds
Settling time	1.06 seconds	1.03 seconds
Overshoot	17.5 %	77.5 %
Peak	0.999	1.77
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	60 deg @ 5.87 rad/s	9.3 deg @ 46.1 rad/s
Closed-loop stability	Stable	Stable

Close

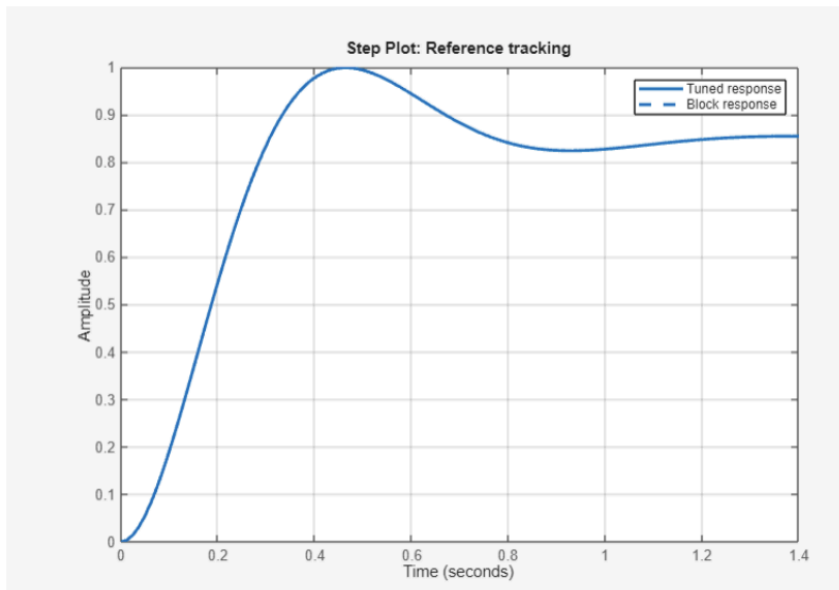
Controller parameters

Source: internal

Proportional (P): 0.14262

Automated tuning

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



Show Parameters

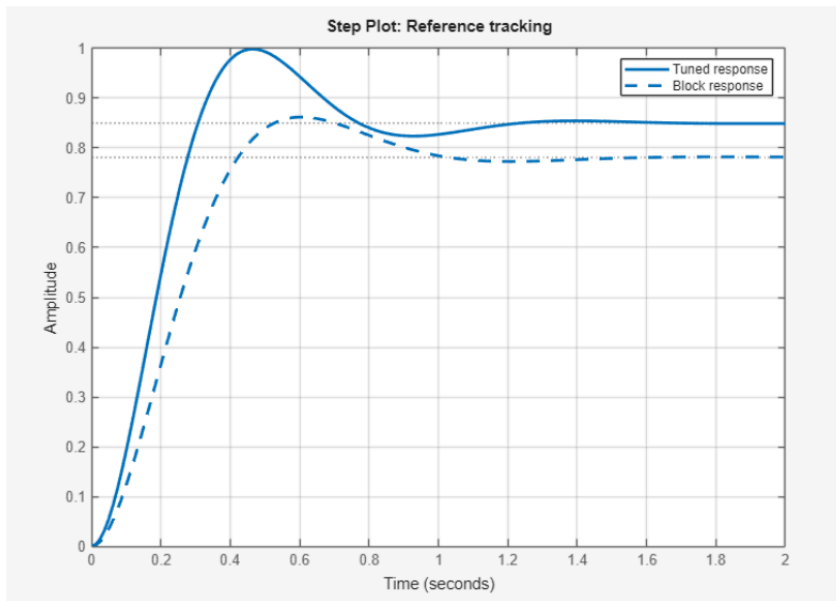
Controller Parameters

	Tuned	Block
P	0.14262	0.14262
I	n/a	n/a
D	n/a	n/a
N	n/a	n/a

Performance and Robustness

	Tuned	Block
Rise time	0.208 seconds	0.208 seconds
Settling time	1.06 seconds	1.06 seconds
Overshoot	17.5 %	17.5 %
Peak	0.999	0.998
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	60 deg @ 5.87 rad/s	60 deg @ 5.87 rad/s
Closed-loop stability	Stable	Stable

Close



Controller parameters

Source:

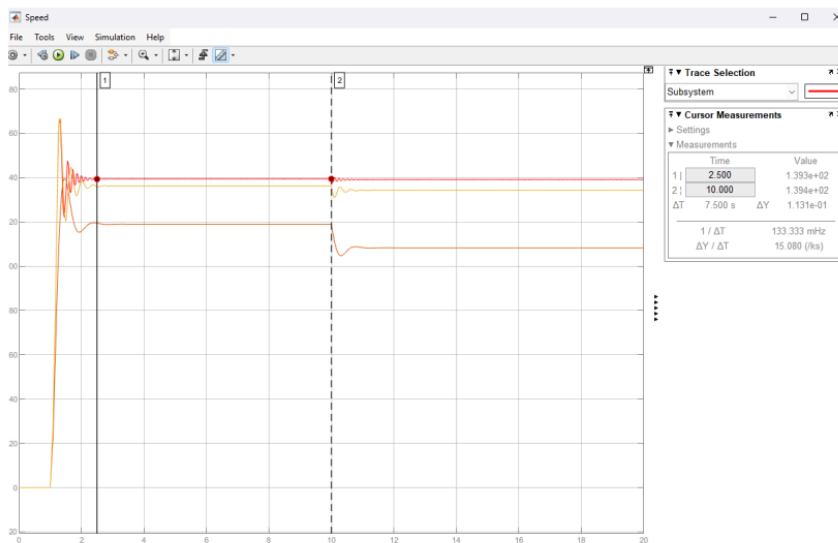
Proportional (P):

Controller Parameters

	Tuned	Block
P	0.14262	0.09
I	n/a	n/a
D	n/a	n/a
N	n/a	n/a

Performance and Robustness

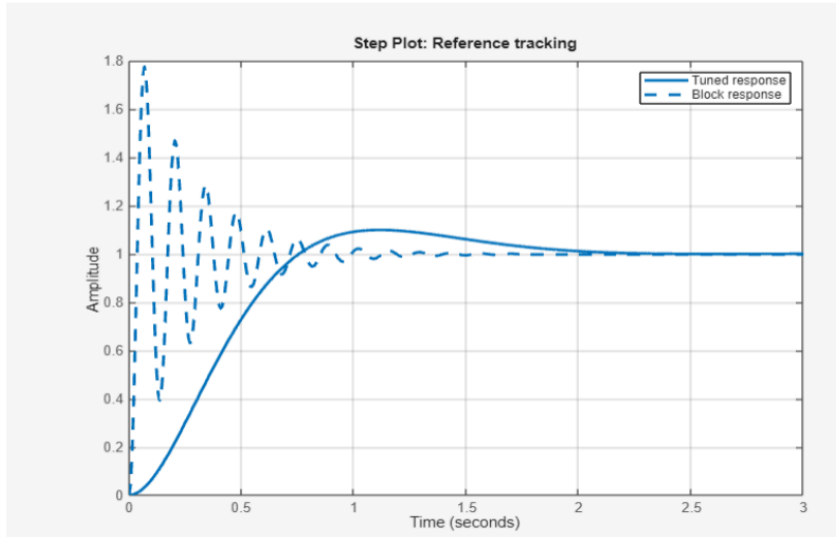
	Tuned	Block
Rise time	0.208 seconds	0.284 seconds
Settling time	1.06 seconds	0.922 seconds
Overshoot	17.5 %	10.3 %
Peak	0.999	0.862
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	60 deg @ 5.87 rad/s	75.3 deg @ 4.14 rad/s
Closed-loop stability	Stable	Stable



KP	SSE (Rads/s)	Rise Time (S)	% Overshoot
----	--------------	---------------	-------------

6	$140 - 133 = 7$	0.0239	77.5 %
0.14262	$140 - 130 = 10$	0.208	17.5 %
0.09	$140 - 128 = 12$	0.284	10.3 %

Task 12



	Tuned	Block	
P	0.043543	0.14262	▲
I	0.084532	0.03	
D	n/a	n/a	
N	n/a	n/a	
			▼

Performance and Robustness

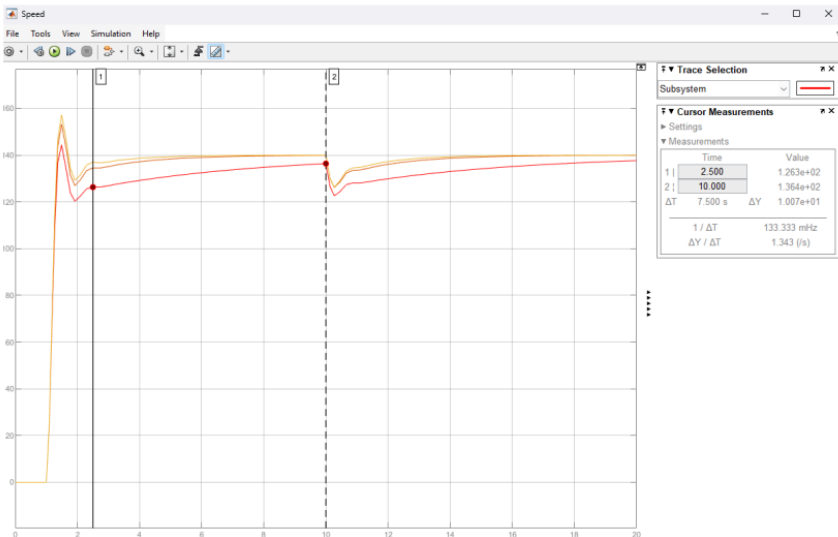
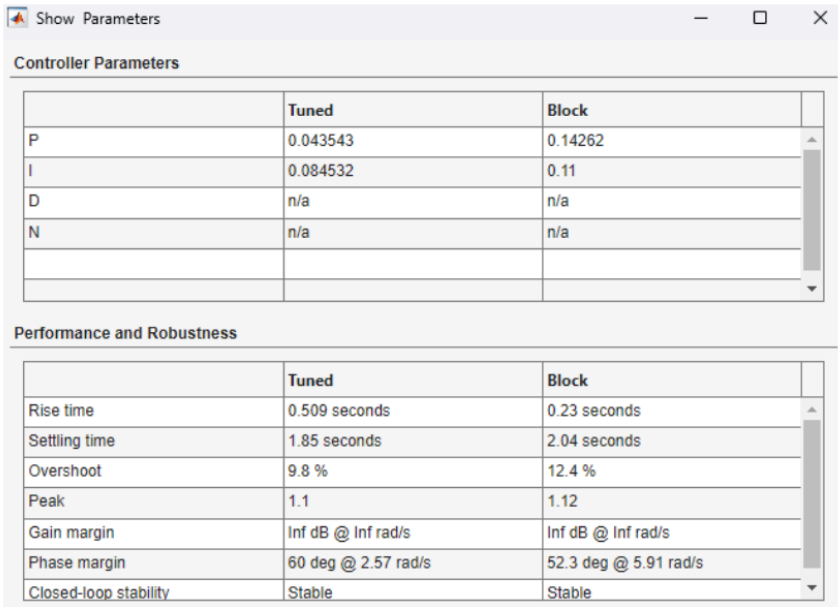
	Tuned	Block	
Rise time	0.509 seconds	0.254 seconds	▲
Settling time	1.85 seconds	10.4 seconds	
Overshoot	9.8 %	3.32 %	
Peak	1.1	1.03	
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s	
Phase margin	60 deg @ 2.57 rad/s	57.9 deg @ 5.88 rad/s	
Closed-loop stability	Stable	Stable	▼

Controller Parameters

	Tuned	Block	
P	0.043543	0.14262	▲
I	0.084532	0.084532	
D	n/a	n/a	
N	n/a	n/a	
			▼

Performance and Robustness

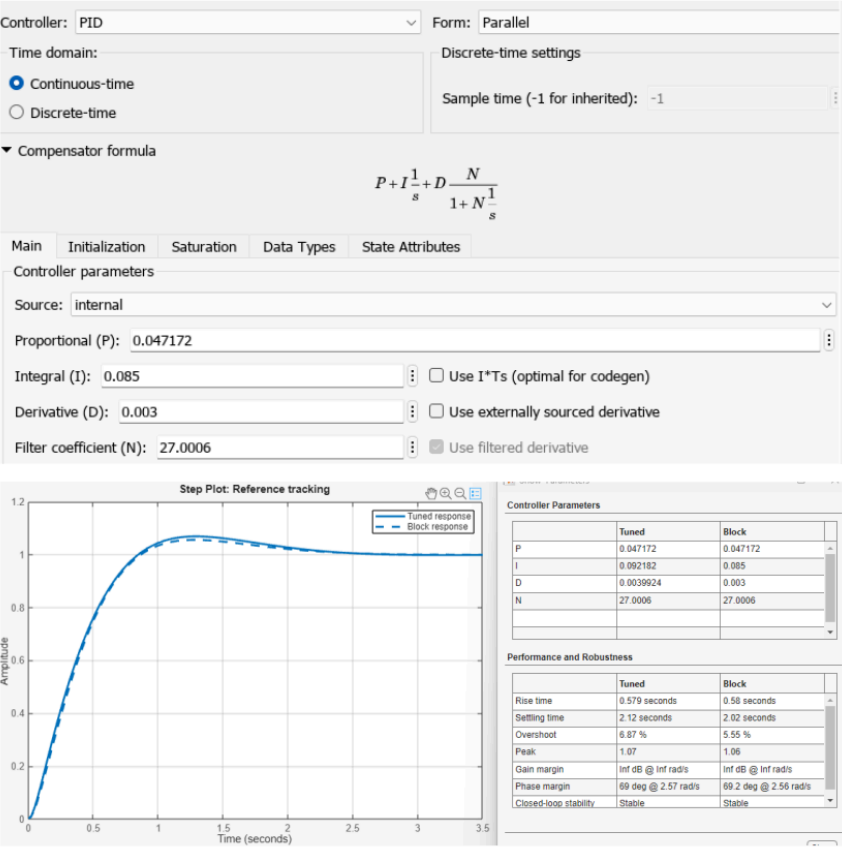
	Tuned	Block	
Rise time	0.509 seconds	0.236 seconds	▲
Settling time	1.85 seconds	2.99 seconds	
Overshoot	9.8 %	9.55 %	
Peak	1.1	1.1	
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s	
Phase margin	60 deg @ 2.57 rad/s	54.1 deg @ 5.89 rad/s	
Closed-loop stability	Stable	Stable	▼



KI	Tr (S)	Ts (S)	% Overshoot
----	--------	--------	-------------

0.03	0.254	10.4	3.32%
0.084532	0.236	2.99	9.55%
0.11	0.23	2.04	12.4%

Task 13



Step Plot: Reference tracking

Controller Parameters

	Tuned	Block
P	0.047172	0.047172
I	0.092182	0.085
D	0.0039924	0.003
N	27.0006	27.0006

Performance and Robustness

	Tuned	Block
Rise time	0.579 seconds	0.58 seconds
Settling time	2.12 seconds	2.02 seconds
Overshoot	6.87 %	5.55 %
Peak	1.07	1.06
Gain margin	Inf dB @ Inf rad/s	Inf dB @ Inf rad/s
Phase margin	69 deg @ 2.57 rad/s	69.2 deg @ 2.56 rad/s
Closed-loop stability	Stable	Stable

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

Saturation

Data Types

State Attributes

Controller parameters

Source: internal

Proportional (P): 0.047172

Integral (I): 0.092182

Derivative (D): 0.0039924

Filter coefficient (N): 27.0006

Use I*Ts (optimal for codegen)

Use externally sourced derivative

Use filtered derivative

Step Plot: Reference tracking

Amplitude

Time (seconds)

Tuned response

Block response

Show Parameters

Controller Parameters

	Tuned	Block
P	0.047172	0.047172
I	0.092182	0.092182
D	0.0039924	0.0039924
N	27.0006	27.0006

Performance and Robustness

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

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

Saturation

Data Types

State Attributes

Controller parameters

Source: internal

Proportional (P): 0.047172

Integral (I): 0.092182

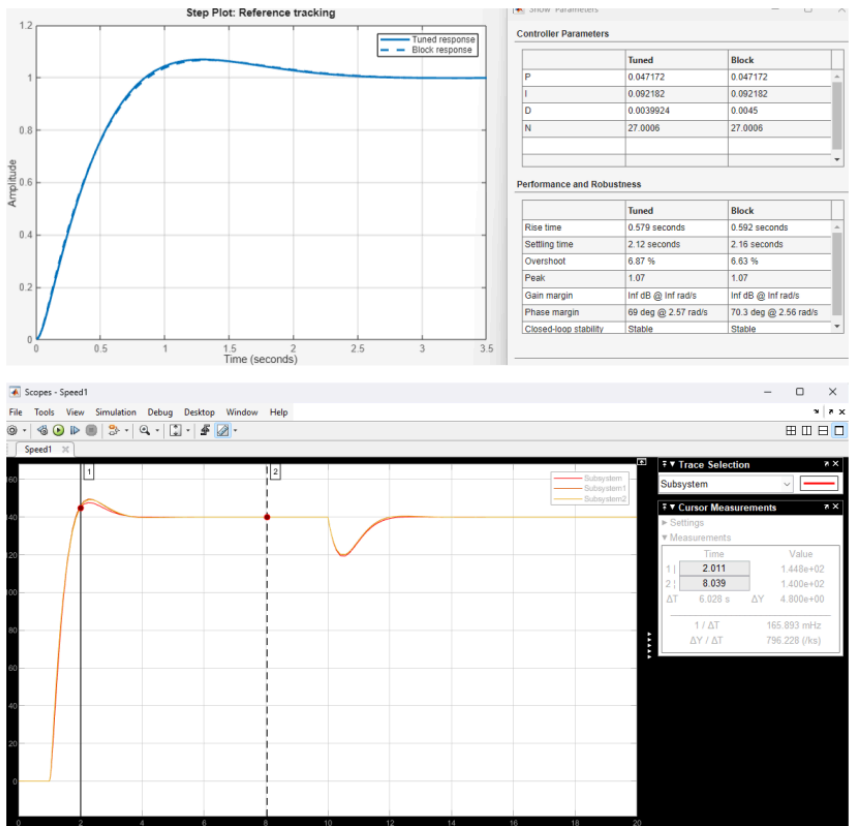
Derivative (D): 0.0045

Filter coefficient (N): 27.0006

Use I*Ts (optimal for codegen)

Use externally sourced derivative

Use filtered derivative



D	TR (S)	TS (S)	% Overshoot
0.03	0.58	2.02	5.55 %
0.00399924	0.579	2.12	6.87 %
0.0045	0.592	2.16	6.63 %

Task 14

Controller: P Form: Parallel

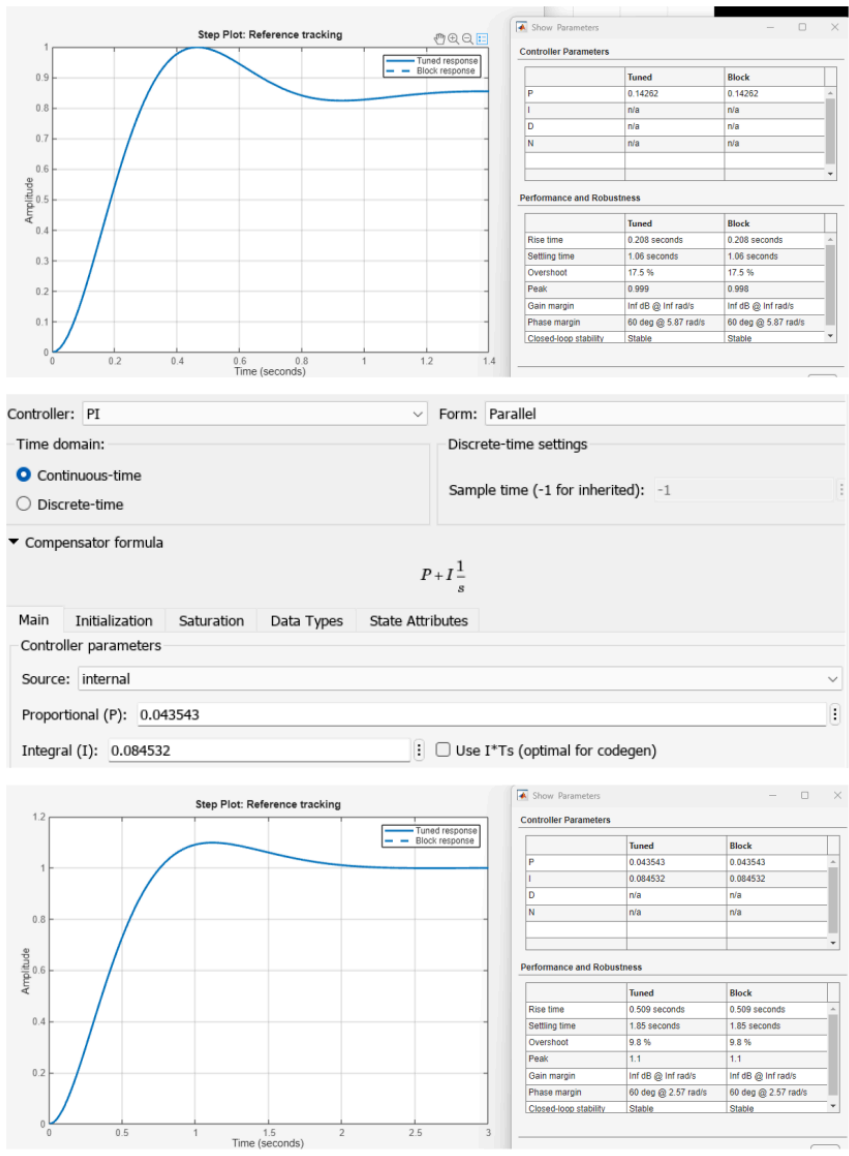
Time domain:
☒ Continuous-time
☐ Discrete-time

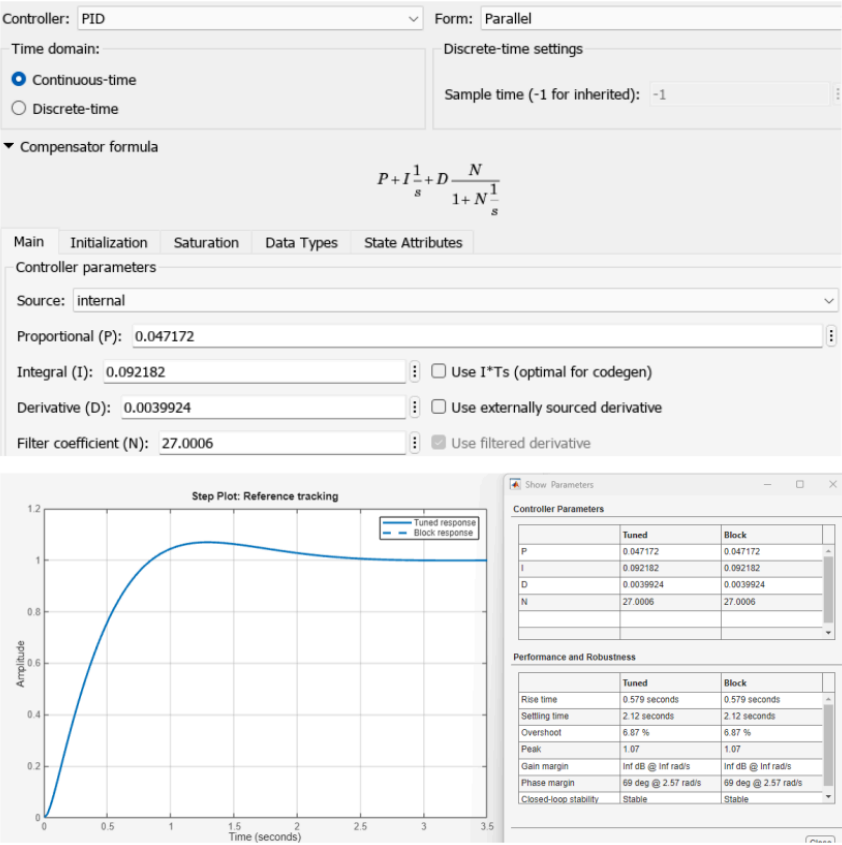
Discrete-time settings
Sample time (-1 for inherited): -1

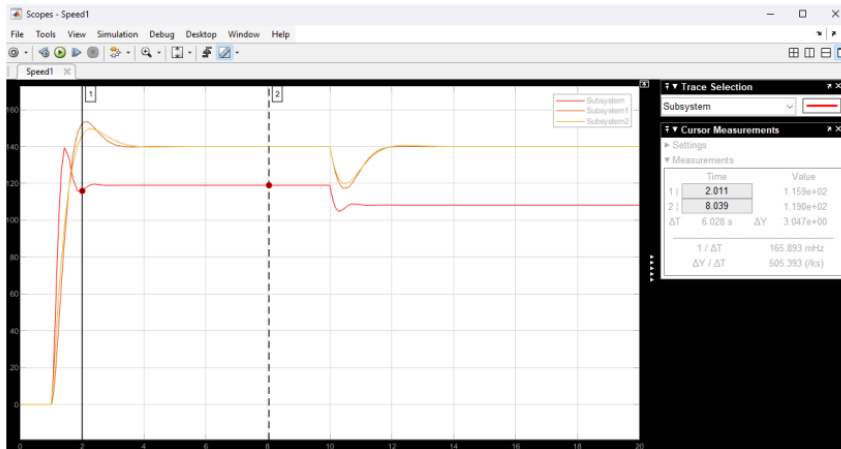
▼ Compensator formula
 P

Main Initialization Saturation Data Types State Attributes

Controller parameters
Source: internal
Proportional (P): 0.14262







Controller	TR	TS	Overshoot	SSE
P	0.208	1.06	17.5 %	140 -
PI	0.509	1.85	9.8 %	140 -
PID	0.579	2.12	6.87 %	140 -

Liesel Assignment

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

35/100

PAGE 1

PAGE 2



Comment 1

Some inaccuracy and no need to describe each task, simply outline the three sections.

PAGE 3



Comment 2

Use meaningful headings

PAGE 4

PAGE 5



Comment 3

All figures need a title.

PAGE 6

PAGE 7



Comment 4

Incorrect. This is a dc transient!



Comment 5

s is a variable, you are mistaken in your formatting, which casts doubt on understanding.



Comment 6

s not 5, again some fundamental errors which could confuse a non-technical reader.



Comment 7

Mathematical derivation is incorrectly written.

PAGE 8



Comment 8

Operation?



Comment 9

Avoid using words in equations, use the WORD equation tool, do not skip steps, this formatting is confusing and contains errors.

PAGE 9



Comment 10

Incorrect analysis for this task.

PAGE 10



Comment 11

Source should be DC. And Laplace model is $1/sC$



Comment 12

K?

PAGE 11



Comment 13

Completely wrong.

PAGE 12



Comment 14

Circuit incorrect.



Comment 15

Source? Units?

PAGE 13

PAGE 14



Comment 16

Too brief and too vague.



Comment 17

Circuit incorrect.



Comment 18

Too brief and too vague.



Comment 19

Needed for what?



Comment 20

Incorrect.



Comment 21

Incorrect throughout.



Comment 22

These numbers are meaningless.



Comment 23

Incorrect results table.



Comment 24

You should explain in terms of results and look for trends.



Comment 25

Makes no sense!



Comment 26

Zoom in on the locus and explain how the frequency parameters change.



Comment 27

Completely wrong!



Comment 28

Avoid vague terms such as decent, you are looking for trends.

PAGE 25



Comment 29

Needs explanation.

PAGE 26



Comment 30

Incorrect TF.

PAGE 27



Comment 31

Response is correctly annotated.



Comment 32

Op-amp purpose?

PAGE 28

PAGE 29

PAGE 30



Comment 33

Too vague.



Comment 34

Explain what you are doing.

PAGE 31

PAGE 32



Comment 35

These images need titles and an explanation.

PAGE 33

PAGE 34



Comment 36

OK, relate this to the root locus plot.



Comment 37

A circuit diagram is needed to show these parameters.



Comment 38

Does not match your tabulated results.



Comment 39

Incorrect voltage used.

PAGE 35



Comment 40

Do you mean omega? w?



Comment 41

Correct block diagram built.

PAGE 36



Comment 42

Missing measurment.

PAGE 37

PAGE 38

PAGE 39



Comment 43

Where are the measurments?



Comment 44

Incorrect to your calculations, also no cursor measurments on simulation, so impossible to tell.
Casts doubt over the process.



Comment 45

That is the next task, stick to commenting on this task.

PAGE 40



Comment 46

These blocks need explaining.

PAGE 41



Comment 47

Above what?

PAGE 42

PAGE 43

PAGE 44

PAGE 45

PAGE 46

PAGE 47



Comment 48

Simply pasting a batch of screenshots does not make for a report.

PAGE 48



Comment 49

line up with what? Vague language is used throughout this report.

PAGE 49



Comment 50

OK, also show the proportional gain equation.

PAGE 50

PAGE 51

PAGE 52

PAGE 53



Comment 51

Same comment as previous task.

PAGE 54

PAGE 55

PAGE 56



Comment 52

Same comment as previous two tasks.

PAGE 57

PAGE 58



Comment 53

Same comment as previous three tasks, also avoid writing results in lines of text, that is the purpose of a results table.



Comment 54

Descriptive in nature, these superficial statements about simulation matching calculations are redundant. Focus on the trends and make recommendations.

PAGE 83

PAGE 84

PAGE 85

PAGE 86

PAGE 87

PAGE 88

PAGE 89

PAGE 90

PAGE 91

PAGE 92

PAGE 93

PAGE 94

PAGE 95

PAGE 96

GRADING FORM: NEW CSG-RUBRIC

SAMUEL SHEPHERD

35

1. ENGAGEMENT WITH LITERATURE



NA

0

2. KNOWLEDGE AND UNDERSTANDING



Many errors exist from fundamental equations and principles, to complete misunderstanding or lack of effort. Poor evidence of knowledge. 8/30

8

3. COGNITIVE AND INTELLECTUAL



Attempt at analysis made, errors exist and for the most part evaluation is descriptive, too brief and vague. Severly lacking attention to detail, read the assignment brief! 10/30

10

4. PRACTICAL APPLICATION



Although poorly explained and containing errors, most calculations and simulations are present and correlate accurately. Adequate use of MATLAB evident. 12/30

12

5. TRANSFERABLE SKILLS



Mostly effective communication in the written work, however see comments above. Mathematical work is very poorly presented. Lack of attention to detail throughout.

5