

LEVEL 4 ASSESSMENT SPECIFICATION

Student name:	Dafydd Adams	Student ID number:	
Programme:	HNC Instrumentation Engineering		
Module:	Instrumentation, Automation and Control		
Module code:	PCEE4009	Contribution to Overall Module Assessment (%):	50%
Lecturer:	Jason Pointer	Internal Verifier:	Nigel Richards
Assignment Title:	Control Systems	Word count (or equivalent):	2000
Submission deadline:	15/05/25	Return date of provisional marks & written feedback:	29/05/25
Submission method:	All written assessments, where practical and possible, must be submitted via Turnitin unless otherwise instructed by the Lecturer. (Please DO NOT put this assessment specification into Turnitin or it will match many similarities with other students' submissions.) Alternative submission method (if applicable): Late submission of the assessment will result in a late penalty mark: Work which is submitted up to 1 week late will be capped at 40% for the first attempt and will be awarded a mark of 0% for re-assessment. Late submission penalties may be lifted only if there is an approved extenuating circumstances claim. Work submitted more than 1 week late will be considered as a non-submission and will not be marked. The work may be considered as a submission for reassessment if offered by an Examining Board or if there is an approved extenuating circumstances claim.		
Academic honesty / referencing:	Academic honesty is required. In the main body of your submission you must give credit to authors on whose research and ideas your work is based. Append to your submission a reference list that indicates the books, articles, etc. that you have used, cited or quoted in order to complete this assessment.		

Module Learning Outcomes (from module syllabus)

3. Demonstrate an understanding of control strategy & tuning methods to meet an industrial application process.

STUDENT FEEDBACK FORM

This section details the *extent* to which the assessment criteria are demonstrated by you, which in turn determines your mark. The marks available for each category of skill are shown. Lecturers will use the space provided to comment on the achievement of the task(s), including those areas in which you have performed well and areas that would benefit from development/improvement.

Generic Assessment Criteria	Marks available	Marks awarded
1. Engagement with Literature Skills	20	11.6
Engagement with an appropriate range of literature, including sources retrieved independently. Referencing may show minor inaccuracies or inconsistencies.		
2. Knowledge and Understanding Skills	40	25.4
Task 1 - 50%. Task 2 - 66%. Task 3 - 70%. Task 4 - 68%. Competent knowledge of the underlying concepts and principles is accurate with a good understanding of the concepts of each task but in places there needs to be more detail.		
3. Cognitive and Intellectual Skills	10	4.8
Limited attempt at evaluation of the underlying concepts and principles for tasks 2 and 3.		
4. Practical Application Skills	20	16.4
Task 1 - 82%. Task 2 - 82%. An excellent application of practical work for tasks 2 and 3, very good use of Scilab to obtain the required test results for the position controller and tuned system.		
5. Transferable Skills for Life and Professional Practice	10	6.2
Work is accurate, coherent, fluent, well-structured and organised.		

Assessment Mark (Assessment marks are subject to ratification at the Exam Board. These comments and marks are to give feedback on module work and are for guidance only until they are confirmed.)

Late Submission Penalties (tick if appropriate)

Up to 1 week late (40% Max)

Over 1 week late (0%)

64%



CONTROL SYSTEMS

PCEE 4011

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Introduction

Control Systems play a crucial role within industry and are responsible for the control of a wide range of products and these systems can be either open or closed loop systems. Examples of a closed loop system include thermostats, cruise control systems, industrial processes etc. ✓

Task 1 – Control types

a) Open-Loop System

An open-loop system 'does not monitor or measure the condition of its output signal as there is no feedback' (Electronics Tutorial, 2025). Below is an example of an open-loop drying system.

Open-loop Drying System

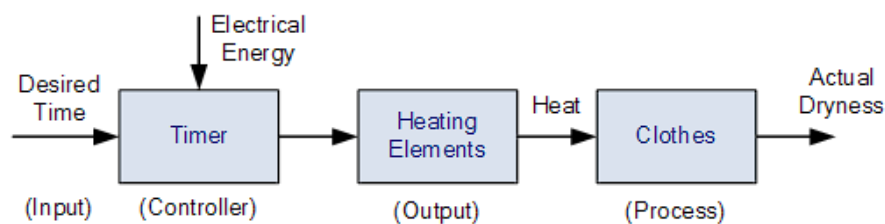


Figure 1 - Open-loop drying system (Electronics Tutorial, 2025)

This type of system will follow the input signal regardless of the output. This can lead to errors in the intended outcome, in the above example the heating element could be turned off after a set period even though the clothes could still be wet, another outcome is drying for longer than required. Although there are flaws to open-loop systems they are generally cheaper than a closed-loop system and less complex due to the lack of sensors and feedback mechanisms and are commonly used in timer central heating systems. ✓

b) Closed-Loop System

'A closed loop system incorporates feedback to adjust its control actions based on the output. This means the system continuously monitors its output and makes necessary adjustments to the input control, ensuring the desired output level is maintained' (RT Engineering, 2023). ✓

Closed-loop Control

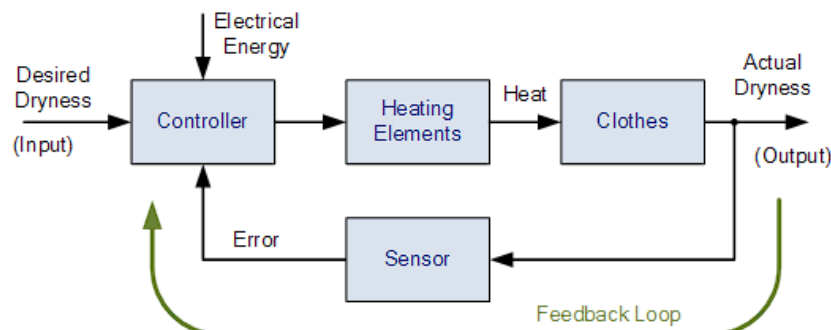


Figure 2 - Closed-loop system (Electronics Tutorial, 2025)

This example system uses a sensor to check the dryness of the clothes and relays this information to the controller. The controller will then modify the output in response to the feedback, increasing either duration or heating output if the clothes are wet and reducing temperature if the clothes are nearly dry. ✓

Compared to an open-loop system a closed-loop can reduce the error by changing the input automatically using the feedback thus providing better performance and robustness. A closed loop system can calculate the error between the set point and actual output in 2 ways positive feedback and negative feedback. Negative feedback is predominantly used as it is designed to bring the system into equilibrium at the set point. This is a desirable quality in most control systems.

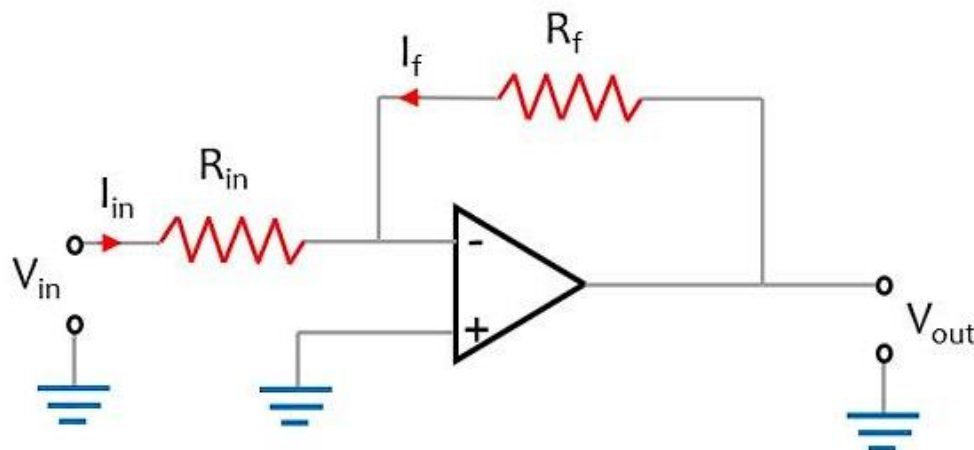


Figure 3 - Negative Feedback (Circuit Globe, 2025)

Positive feedback will however push the system further away from equilibrium and can lead to uncontrolled oscillations. Positive feedback is used within the below op – amp.

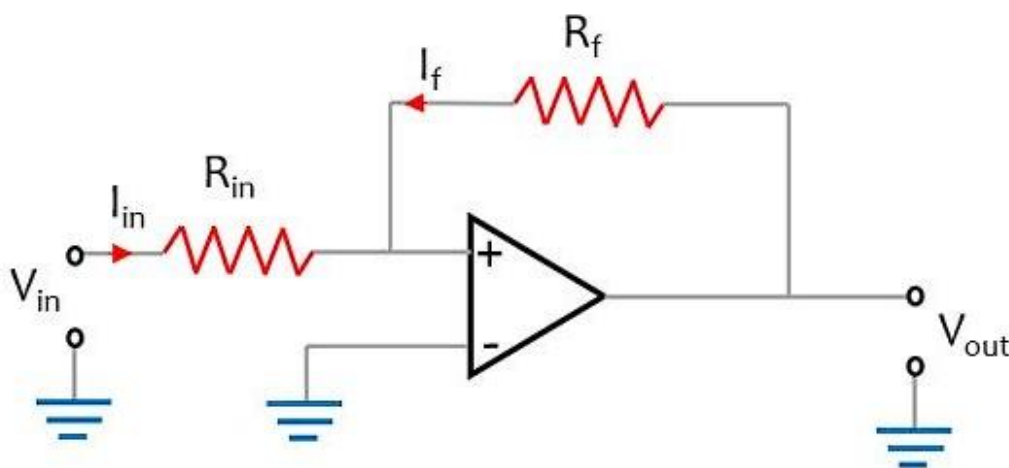


Figure 4 - Positive Feedback (Circuit Globe, 2025)

These are amplifier circuit not really relative to the assignment.
Have not shown how the equation for a closed loop system can be derived.

c) Three Term Control

A three term control also known as a proportional-integral-derivative (PID) controller (Dwyer Omega, 2025) is a type of closed loop system used to regulate a wide variety of process variables such as temperature and pressure.

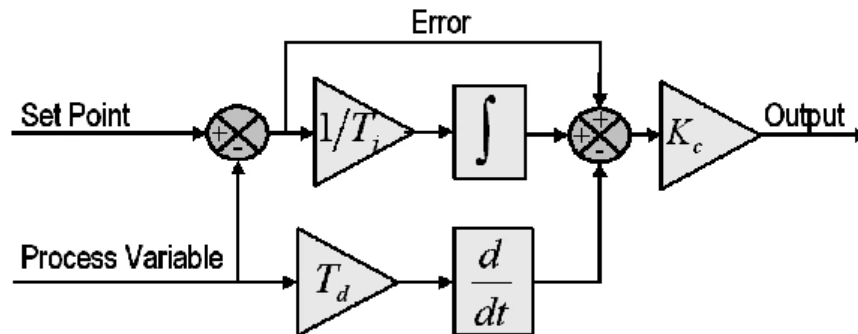


Figure 5 - PID Control (National Instruments, 2025)

The error seen above relates to the proportional part of a PID and looks at the current error between the setpoint and the output. The integral part denoted above by $\int$ sums up the error over time causing the integral component to increase over time unless the error is 0. This removes steady state error which can occur in systems using only proportional error feedback. Derivative denoted above by d/dt slows the output if the process variable is increasing rapidly as it is proportional to the rate of change of the process variable. The greater the derivative parameter T_d the faster the overall response of the system (National Instruments, 2025).

Tuning a PID controller can be done using various methods such as the Ziegler-Nichols Rule, Tyreus-Luyben and Rivera, Morari and Skogstad (Omega, 2025).

Verg brief.

2) Position Servo Control

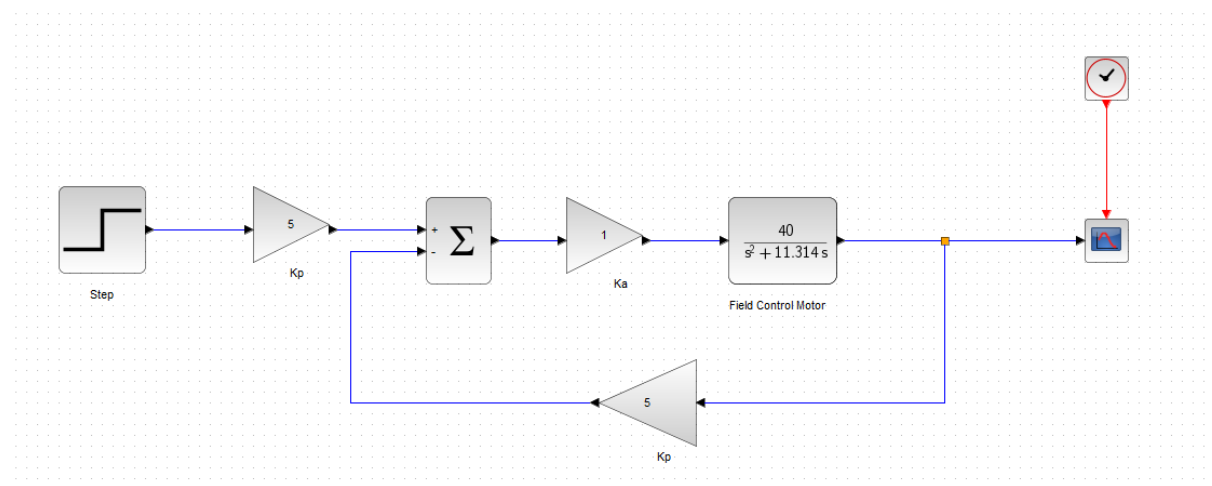


Figure 6 - Scilab Control Motor

a) Servo Control

The above figure was used within Scilab using the parameters stated below

$K_a = 1$

$$K_p = 5V/r$$

$$K_f = 6mA/V$$

$$I = 1.5 \times 10^{-4} \text{ Kg m}^2$$

Below are 2 equations used to solve the above question.

$$\frac{\theta_o(s)}{\theta_i(s)} = k_{ss} \frac{\omega_n^2}{s^2 + 2\zeta\omega_n s + \omega_n^2}$$

$$\frac{\theta_o(s)}{\theta_i(s)} = \frac{\frac{K_p K_A K_F}{I}}{s^2 + \frac{Bs}{I} + \frac{K_p K_A K_F}{I}}$$

Figure 7 - Second Order System Equation

Figure 8 - Block Diagram transfer Function

Substitute the above values from the question into the Block diagram transfer function. The calculations are seen in the photo below with an example for Critically Dampened.

$$\frac{\theta_o(s)}{\theta_i(s)} = \frac{\left(\frac{5 \times 1 \times 6 \times 10^{-3}}{1.5 \times 10^{-4}} \right)}{s^2 + \left(\frac{Bs}{1.5 \times 10^{-4}} \right) + \left(\frac{5 \times 1 \times 6 \times 10^{-3}}{1.5 \times 10^{-4}} \right)}$$

$$= \frac{200}{s^2 + 6666.67Bs + 200}$$

$$\omega_n^2 = 200 \quad \checkmark$$

$$2\zeta\omega_n = 6666.67B$$

$$\omega_n = \sqrt{200} = 14.142 \text{ rad/sec} \quad \checkmark$$

Critically dampened

$$B = 2\zeta\omega_n I$$

$$= 2 \times 1 \times 14.14 \times 0.0002 \quad \checkmark$$

$$= 0.00424 \quad \checkmark$$

Try using Equation Editor.

Figure 9 - Calculations

To find the following conditions, no dampening, under dampened, critically dampened and over dampened the below values of ζ .

No Dampening $\zeta = 0$

Under Dampened $0 < \zeta < 1$

Critically Dampened $\zeta = 1$

Over Dampened $\zeta > 1$

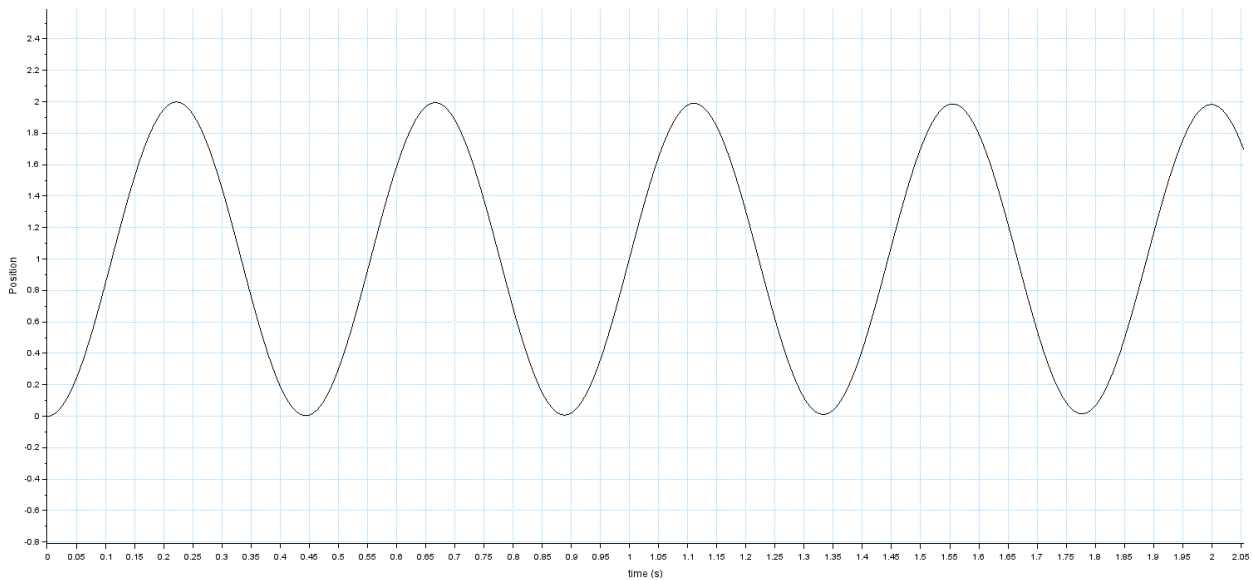


Figure 10 - No Dampening

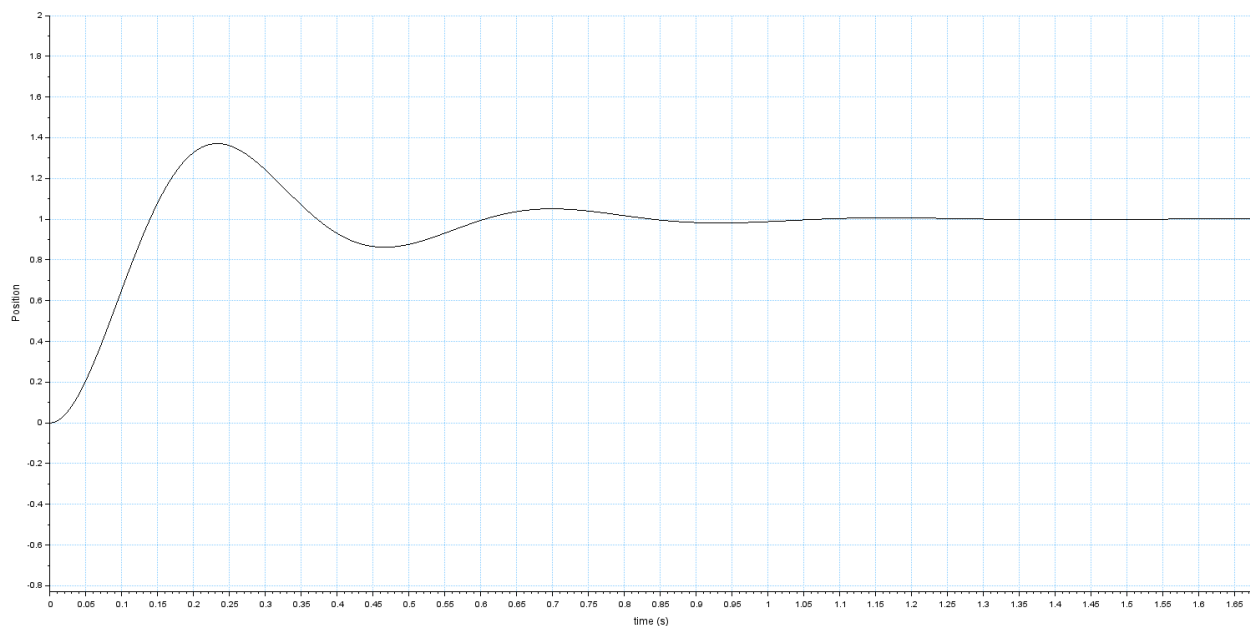
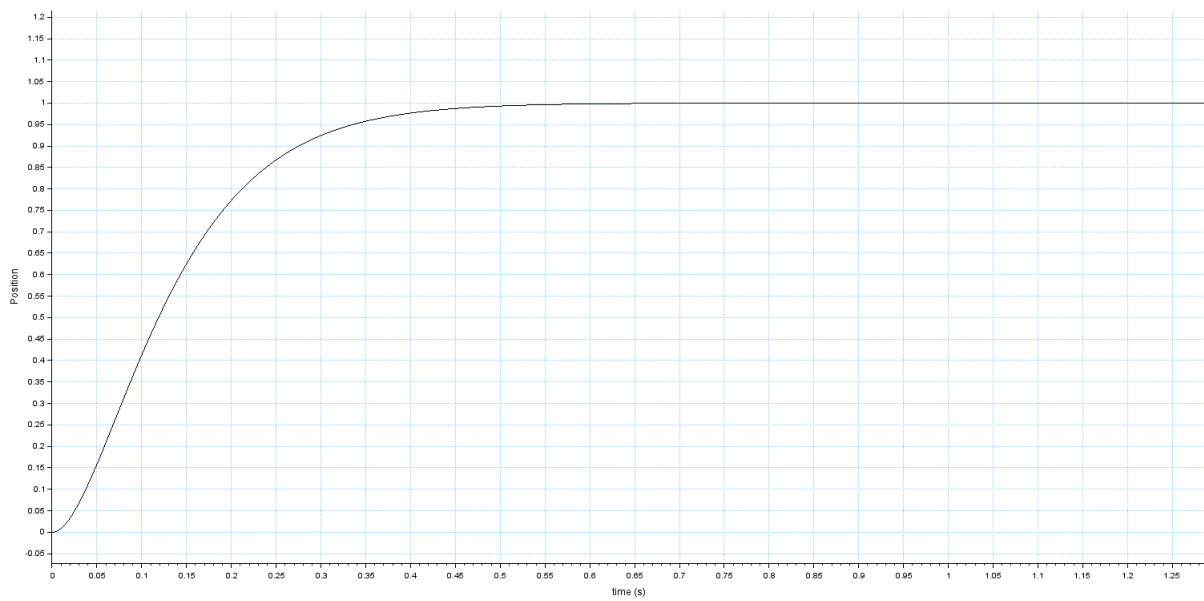
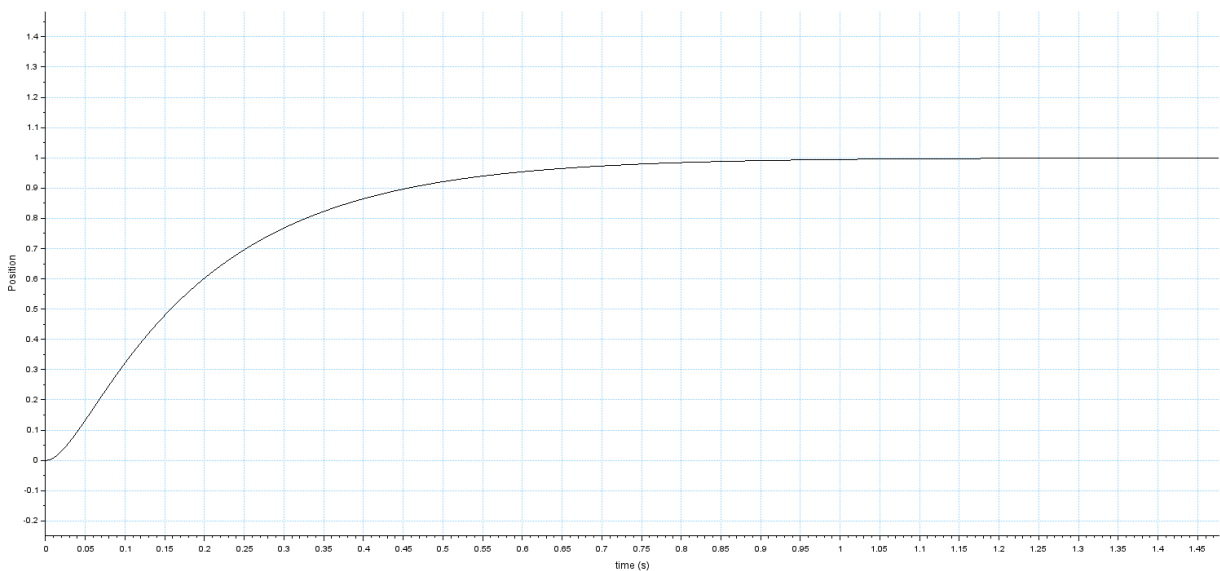


Figure 11 - Under Dampened

*Figure 13 - Critically Dampened**Figure 12 - Over Dampened*

The table below shows the values used for the above graphs.

Damping Conditions	B	B/I
No Damping $\zeta = 0$	0	0
Under Damped $\zeta = 0.3$	0.00127	8.485
Critically Damped $\zeta = 1$	0.00424	28.284
Over Damped $\zeta = 1.5$	0.00636	42.426

b) Under Dampened Condition

Rise time is the time difference between 10% and 90% of the final value. For the under dampened curve, the value is 0.09s. The peak time refers to the time taken to reach the peak value for the first time which for this curve is 0.24s. Maximum overshoot is the deviation of the response from the final value at it's peak which for this curve is 0.37. The settling time is the time taken for the curve to reach within usually 2 or 5% of the final value and can be referred to as having reached a steady state which in this case was 0.55s. (TutorialsPoint, 2025). When the ζ value is decreased further the oscillation increases which causes a decrease in both the rise time, and peak time but will cause an increase in the Maximum overshoot and the settling time as the system is in greater oscillation.

Need to include some examples showing different damping ratios.

3) Tuning

a) 2 Tuning Techniques

One way to tune a control system is the closed loop method by Ziegler-Nichols which is also referred to as ultimate cycle method. This method involves placing the system into maximum oscillation and from this the ultimate gain and period of the system. These are then used to calculate the optimal PID controller gains which are then input into the PID control. This method however is not perfect and can require some fine tuning for optimum performance of the system. It does however provide a good base to begin fine tuning (Bennett, et al., 2025).

Another method is the Cohen-Coon tuning method which works well for processes that require fast adjustment. The first step is to do an output step change test. This involves changing the controller output and then waiting for the system to stabilise. The gain is calculated and the maximum slope of the process variable measured at the point of inflection. A line is then drawn from the process variable curve at this point back to the original value and the time difference is then noted, this is the dead time which needs to be in minutes. Then find 63% of the total change of the process variable and calculate the time taken to reach it. The time constant will be the difference between time taken to reach 63% and the end of the dead time, this is also measured in minutes. The above steps are then repeated another 3 times to provide an average value of the characteristics. Use the above equations to calculate each section (Option Controls, 2011).

www.opticontrols.com	Controller Gain	Integral Time	Derivative Time
P Controller:	$K_c = \frac{1.03}{g_p} \left(\frac{\tau}{t_d} + 0.34 \right)$		
PI Controller:	$K_c = \frac{0.9}{g_p} \left(\frac{\tau}{t_d} + 0.092 \right)$	$T_I = 3.33 t_d \frac{\tau + 0.092 t_d}{\tau + 2.22 t_d}$	
PD Controller:	$K_c = \frac{1.24}{g_p} \left(\frac{\tau}{t_d} + 0.129 \right)$		$T_D = 0.27 t_d \frac{\tau - 0.324 t_d}{\tau + 0.129 t_d}$
PID Controller: (Noninteracting)	$K_c = \frac{1.35}{g_p} \left(\frac{\tau}{t_d} + 0.185 \right)$	$T_I = 2.5 t_d \frac{\tau + 0.185 t_d}{\tau + 0.611 t_d}$	$T_D = 0.37 t_d \frac{\tau}{\tau + 0.185 t_d}$

Figure 14 - Cohen Coon Equations (Option Controls, 2011)

b) PID Tuning

As explained above the ultimate cycle involves placing the system into oscillation which involves putting the integral and derivative to 0 and the gain is then adjusted until the system is in full oscillation. Below are various screenshots from this process.

The below screenshot has the gain at 10.

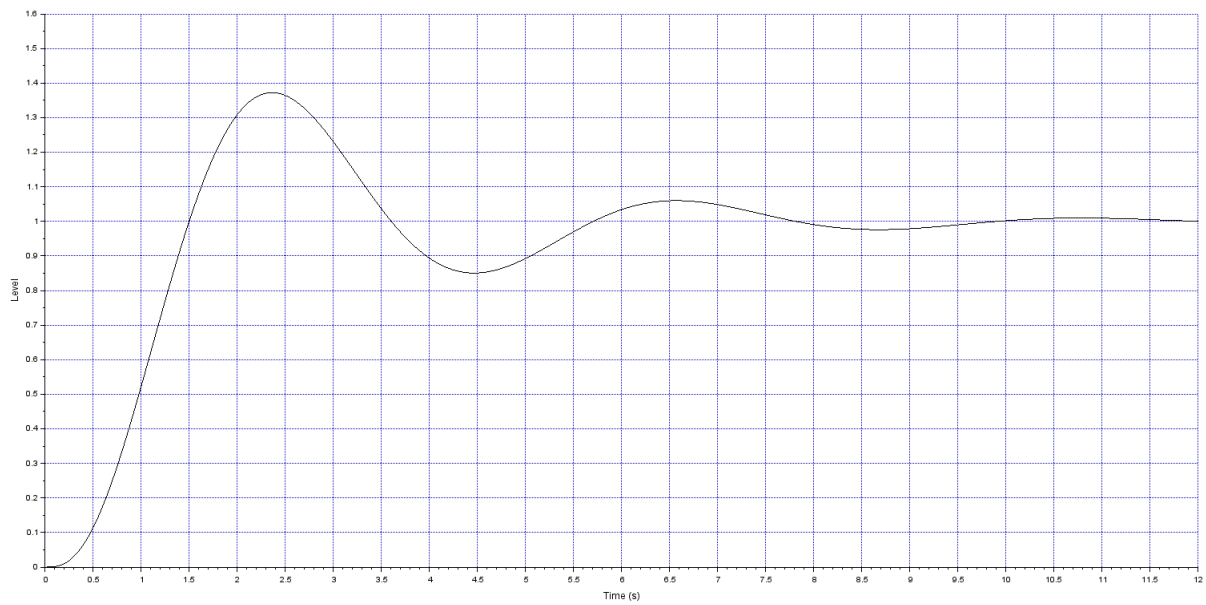


Figure 15 - Tuning with gain = 10

Gain below is at 30.

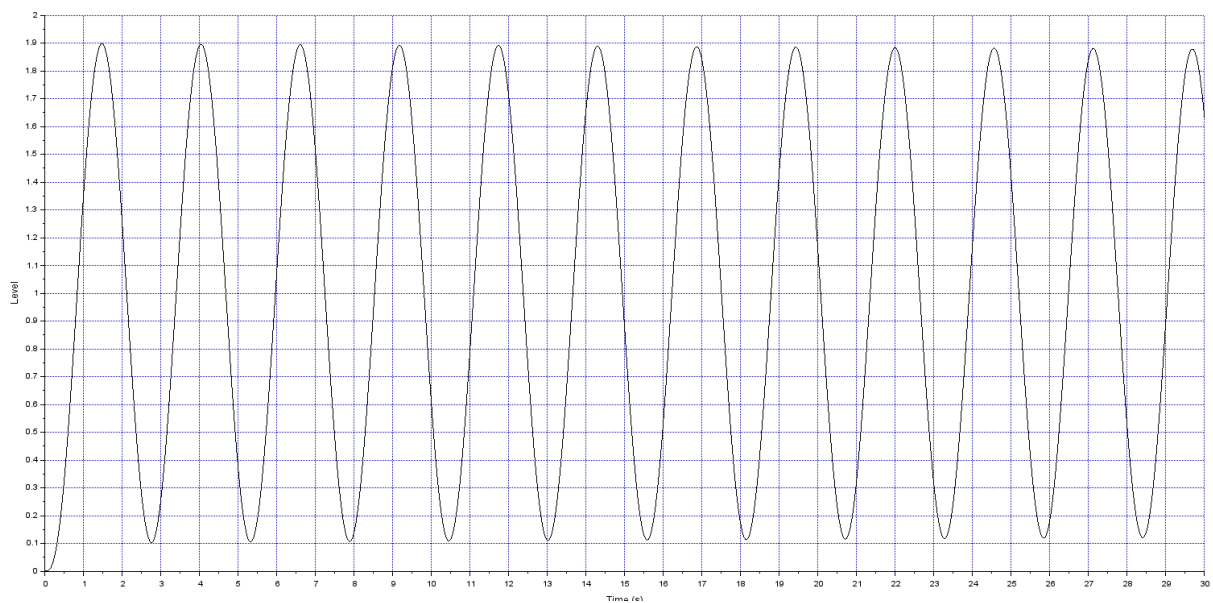


Figure 16 - Tuning with gain = 30

Tuning with gain at 31.

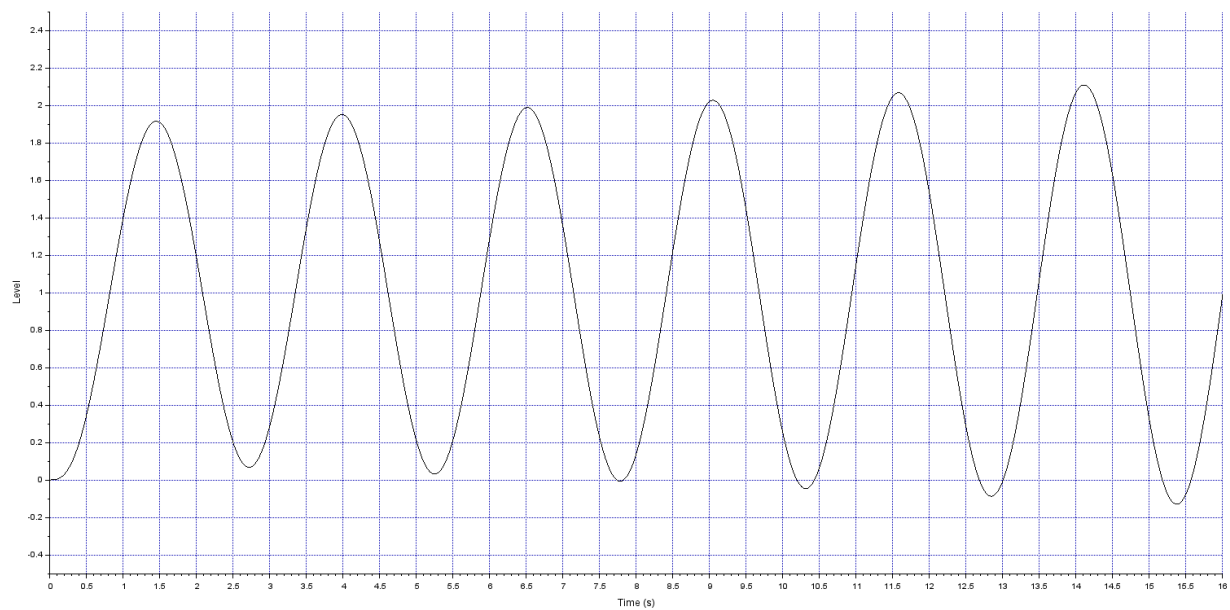


Figure 17 - Tuning with gain = 31

The above screenshot with a gain of 31 has the oscillations increasing and therefore a figure of 30.05 was tried for the gain which provided a good stable oscillation seen below.

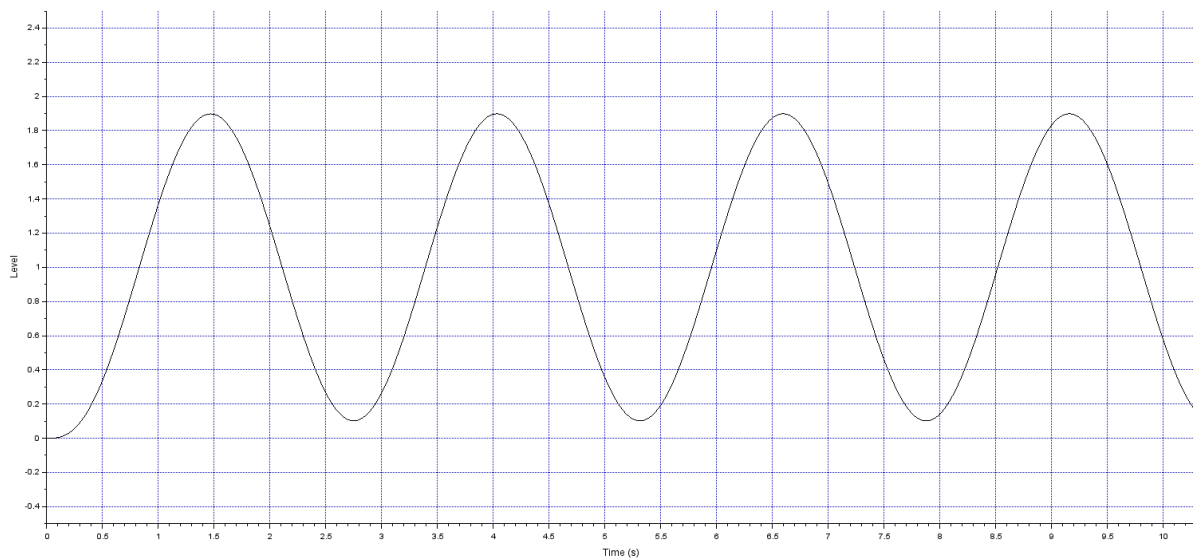


Figure 18 - Tuning with Gain = 30.05

Once the system was at full oscillation the time between each peak was calculated and the below screenshots show the first and second peak.

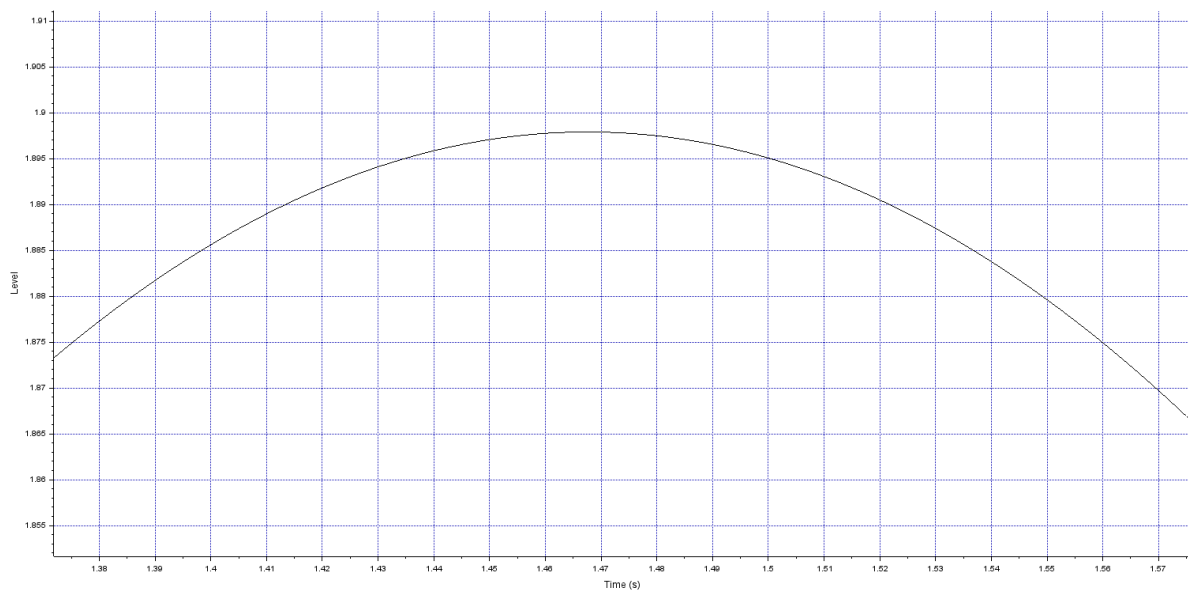


Figure 19 - 1st peak

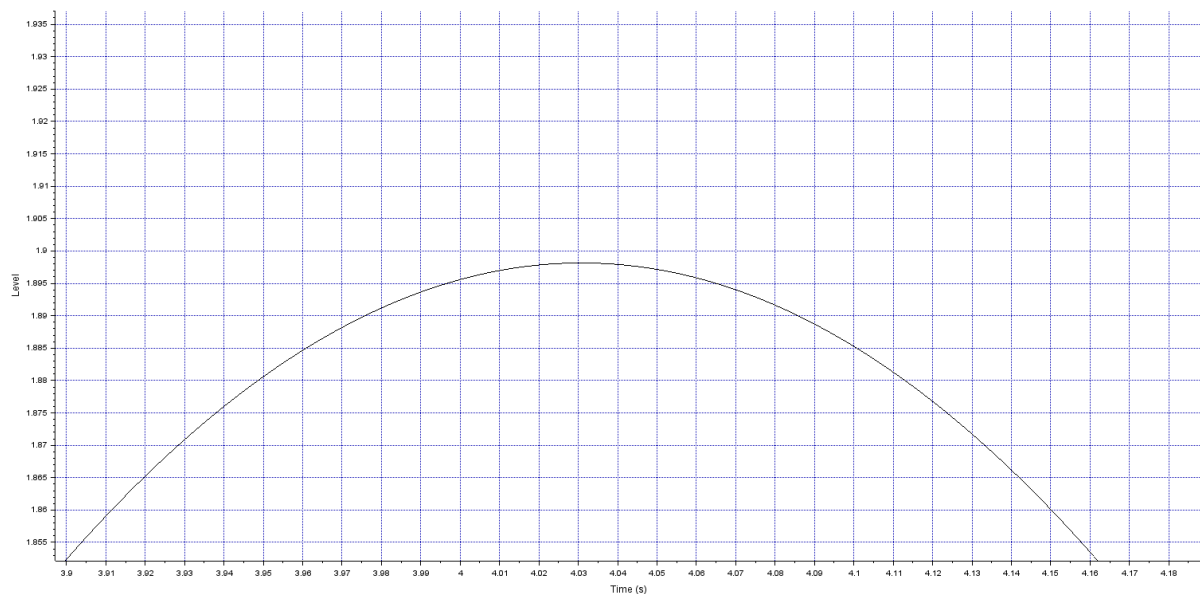


Figure 20 - 2nd peak

The period between each peak is 2.56s. The Kpu for this system is going to be 30.05 and the Tu is 2.56s. The Kp is then calculated as 18.03 (30.05 x 0.6).

$$T_i = T_u / 2 = 2.56 / 2 = 1.28s$$

$$T_d = T_u / 8 = 2.56 / 8 = 0.32s$$

$$1/T_i = 0.78125$$

These are then input into the below model.

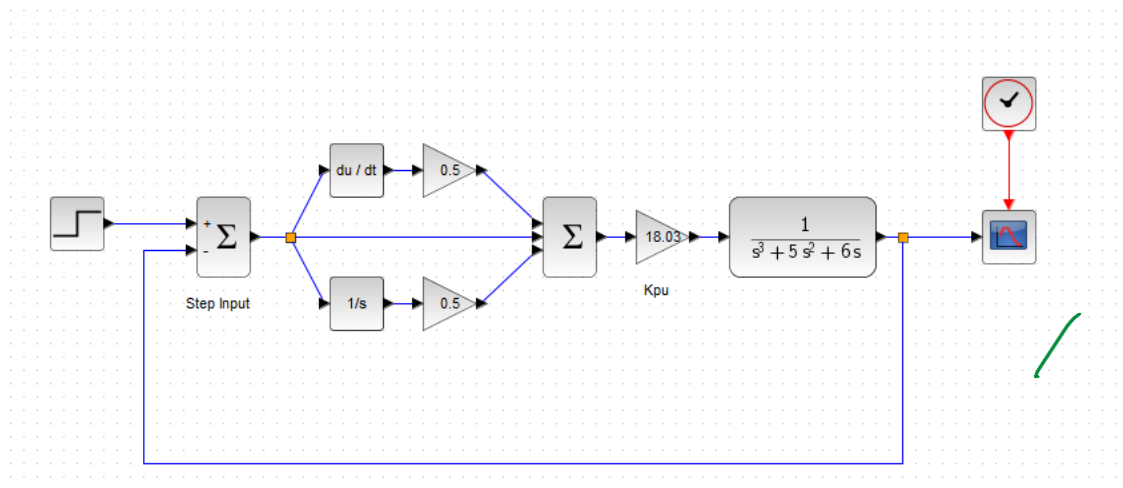


Figure 22 - PID controller model

The above model shows 0.5 on both as these are the final values used. The graph created from using the calculated values above is seen in figure 21.

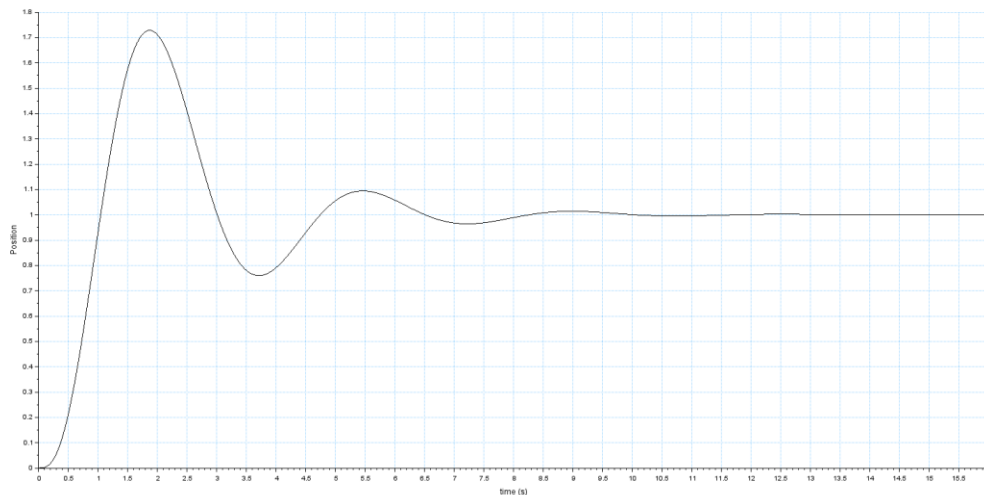


Figure 21 - Calculated PID response

As stated in the discussion above although a good starting point, the Ultimate cycle method can be fine-tuned for better performance. The calculated value for the integral section was changed from 0.78125 to 0.5 and the below response was found. This response is an improvement as it has a smaller overshoot and a quicker stabilisation time.

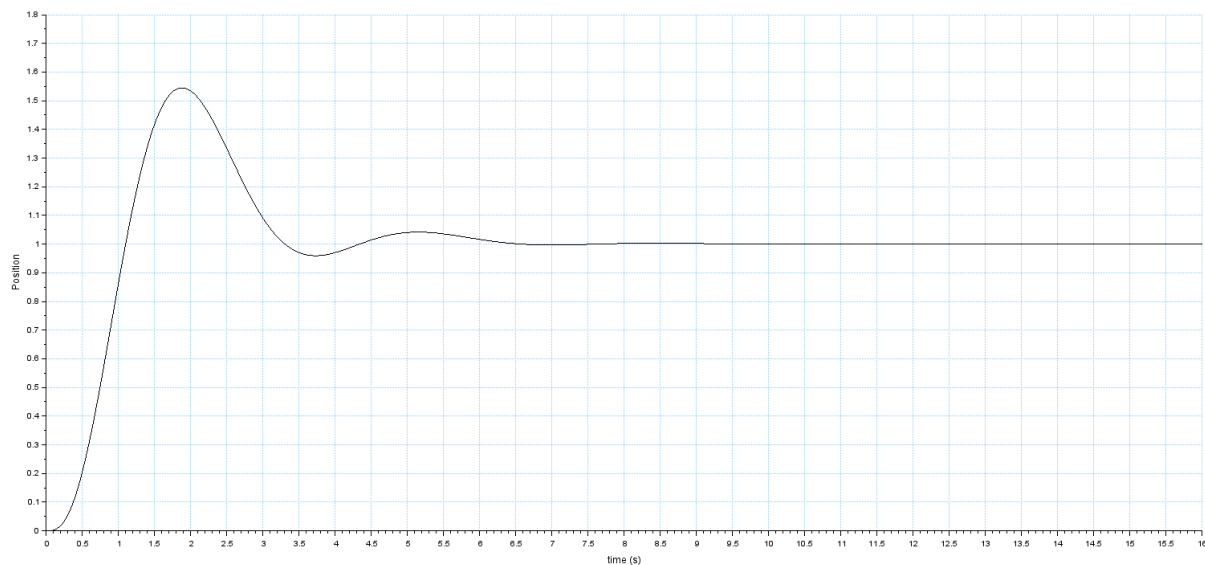


Figure 23 - Adjusted integral section

The derivative section was then updated from 0.32 to 0.5 providing a smoother response but a slightly slower response time.

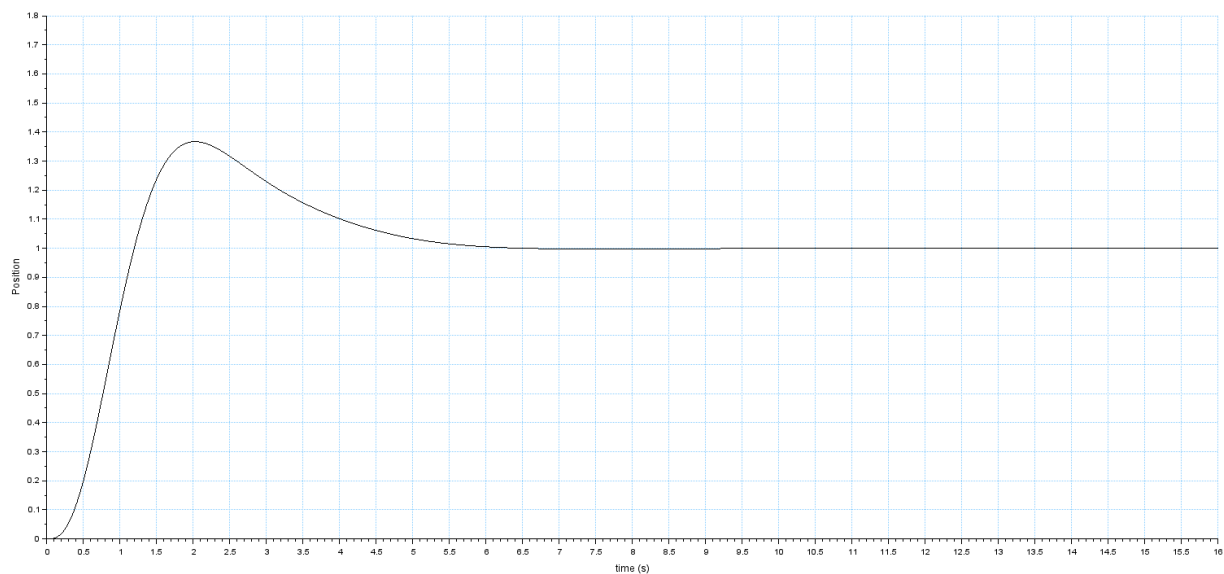


Figure 24 - Adjusted Derivative section

As can be seen adjustments after the ultimate cycling method can be performed to adjust the tuning to match the required system with some systems unable to have any overshoot whilst others that can handle it can be adjusted for a quicker response time.

4) Computerised Control Systems

This section is a report on the differences between a PLC, Direct Digital Control (DDC) and Distributed Control System (DCS). A PLC is a small device which uses a CPU to monitor inputs and adjust outputs based off this information. They can be used to control various components such as valves, chiller units and can provide the logic for temperature control systems. An example of a PLC can be seen below.



Figure 25 - Siemens SIMATIC S7-1200 (RS Components, 2025))

This PLC has 6 inputs and 4 outputs and uses either PROFINET or Ethernet to communicate, other larger PLCs are available. Positives of PLCs are that they can withstand harsh environments which is a benefit for some companies due to their working environments but due to the limited number of I/O ports incorporating them into a SCADA system provides wider control when an operation line requires controlling from one location. PLCs are programmed in various languages (Instruction Listing, Structured Text etc.) depending on the manufacturer or system it is utilised within and although very similar to a DDC they are generally quicker, more reliable and more accurate in completing their activities (Banelec Control, 2021). PLCs are therefore used in systems such as manufacturing to automate processes and production lines.

A DDC is used primarily in building automation and in systems such as HVAC control as it uses digital devices to control processes such as fan speed. This system 'measures environmental conditions and compares the measurements to the desired settings' (University of Michigan, 2025). A DDC works by having a central master station providing information about HVAC units or any other variables being monitored, this information is relayed via a communication protocol e.g Modbus and LonWorks from all the various sensors deployed (Erickson, 2025). This main computer allows for easy control over variables such as fan speed and temperature across the site whilst also providing trends over time to allow engineers to change settings more maximum efficiency. Below an example of a DDC can be seen.



Figure 26 - DDC Controller (Instrumentation Tools, 2025)

A DDC is preferred to a PLC with regards to building management as the need for such fine processing control isn't generally a necessity with temperature specifications usually 18-25°C, it also worth noting that a DDC is a cheaper alternative to a PLC where system control is less critical.

A distributed control system is a 'digital automated industrial control system (ICS) that uses geographically distributed control loops throughout a factory, machine or control area. The goal of a DCS is to control industrial processes to increase their safety, cost-effectiveness and reliability.' (Gillis, 2025).

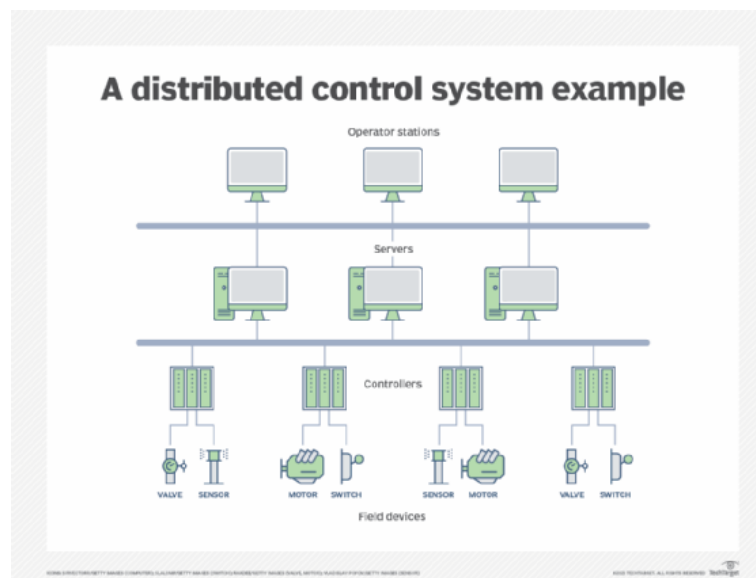


Figure 27 - DCS Example (Gillis, 2025)

A DCS works by having multiple servers around the factory connected by a high speed data transfer network. Although the controllers work independently, they are controlled by a central supervisory control operated by a trained individual. A DCS functions in a similar fashion to a SCADA system but are used more locally. The composition of a DCS involves the sensors or devices connecting to a nearby controller which then relays the information to the servers and then operator stations. These small systems within the DCS operate independently of each other which allows the DCS to continue even if a section stops working. DCS systems are primarily used for complex processes where continuous control and monitoring are required (Confluent, 2025). A DCS provides benefits over a

PLC system as it has servers which can collect data providing the opportunity to analyse this data and optimise performance and wit historic data prior to a failure potentially avert such instances in the future by seeing the changes occurred in the leadup to the failure. This can allow a change of component and avert any stoppages to the system. A DCs can also 'help organizations meet regulatory requirements and maintain a safer working environment. This is because continuous monitoring of critical parameters. When thresholds are exceeded, it will trigger alerts and enable fast response to developing issues (Illumin, 2025).

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Would like to see some text books.