

Assignment 2

by Jake Tyrrell

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Instrumentation and Control (QinetiQ)

Assignment 2

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1 Abstract

This report is an evaluation of different control methods. These control methods were built on an electrical training aid with guidance from it's manual. Each of these control methods were tested and analysed, making use of the components on the training aid and an external multi meter. All of the controllers had their own positives and negatives that were noted throughout testing. The evaluation showed each method not to be perfect, but had the characteristics that would be valuable and fitting for various different control systems used all over the world.

2 Introduction

The basic idea of a control system is to monitor an input to be able to control the output. This is used every day by most of the population with things like air conditioning and the heating in homes. It is also used by planes, ships and cars in things like navigation, engine maintenance and cruise control. The list is endless. There are many different control systems that are used and each type is selected due to its suitability to the projected role and potential adaptability. The control methods that will be evaluated in this report are:

1. Proportional Control System (P)
2. Proportional Integral Control System (PI)
3. Proportional Derivative Control System (PD)
4. Proportional Integral Derivative Control System (PID)

2.1 What are the different control methods?

2.1.1 Proportional

Proportional control is a system in which the output signal of the controller is directly proportional to the systems error.

$$A(t) = K_p \times e(t)$$

Equation 1 Proportional Control [1]

[2] "With proportional control, the actuator applies a corrective force that is proportional to the amount of error:

$$\text{Output}_p = K_p \times E$$

Output_p = system output due to proportional control

K_p = proportional constant for the system called **gain**

E = error, the difference between where the controlled variable should be and where it is. E

= $SP - PV$."

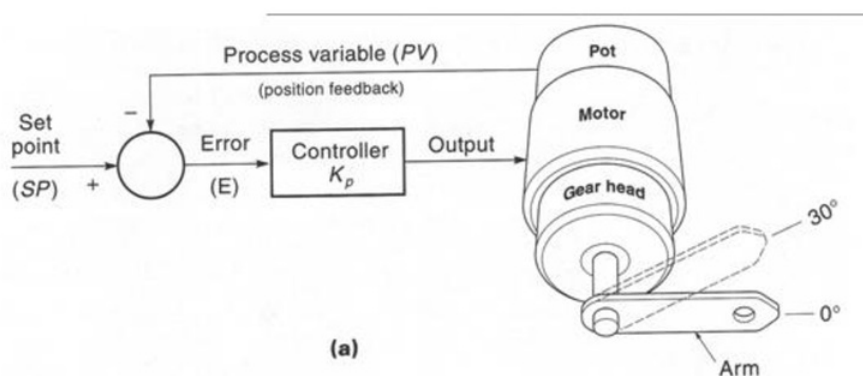


Figure 1 Graphic representation of Proportional Control [2]

2.1.2 Proportional Integral

A proportional integral controller uses the integral of the error signal to correct the output signal. [2]
“The introduction of integral control in a control system can reduce the steady-state error to zero. Integral control applies a restoring force that is proportional to the sum of all past errors, multiplied by time.”

$$A(t) = K_i \int_0^t e(t)dt + K_p e(t)$$

Equation 2 Proportional Integral control [1]

2.1.3 Proportional Derivative

The idea of proportional derivative control is to reduce the overshoot [1] “the output (also called the actuating signal) is equal to the summation of proportional and derivative of the error signal.”

$$A(t) = K_d \frac{de(t)}{dt} + K_p e(t)$$

Equation 3 Proportional Derivative control [1]

2.1.4 Proportional Integral Derivative

The Proportional Integral Derivative control is combined to strengthen the overall system.

[3] “Proportional Control (P) at its very simplest, produces an output that is proportional to the error signal received. An example of a proportional control system is a house thermostat;
[4] “Proportional controls are designed to eliminate the cycling associated with on-off control. A proportional controller decreases the average power used by the heater as the temperature approaches setpoint. This has the effect of reducing the heat that is added to the process so that the temperature approaches the setpoint without overshoot. This proportioning action can be accomplished by turning the output on and off for short periods of time.”

Integral Control (I) works by making sure the signal that is output is proportional to the integral of the error signal received.

Derivative Control (D) is never used on its own and usually used with proportional and proportional integral systems. [1] “In a derivative controller the output (also called the actuating signal) is directly proportional to the derivative of the error signal.”

Using these the PID controller produces a response signal that is proportional to the signal error received, it compares the set point with the actual value. To get the output the error is then multiplied with the proportional constant. The Proportional control has a limitation which is that an offset will exist between the set point and the variable. This is where the Integral control comes in to play. The error is integrated over a time period until it falls to 0. Finally, the Derivative controller

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helps to increase the system response by multiplying the derivative constant by the errors rate of change over time.””

$$e_a(t) = e(t) + T_d \frac{de(t)}{dt} + K_i \int e(t) dt$$

Equation 4 Proportional Integral Derivative control [1]

3 Method

Throughout the testing we used a circuit trainer system, this was specifically a [5]” Digiac 1750 Transducer + Instrumentation Trainer” depicted in Figure 2 The construction of each circuit and process of testing each control system was laid out in the user manual [6] “LJ create Practical control systems, chapter 18”.

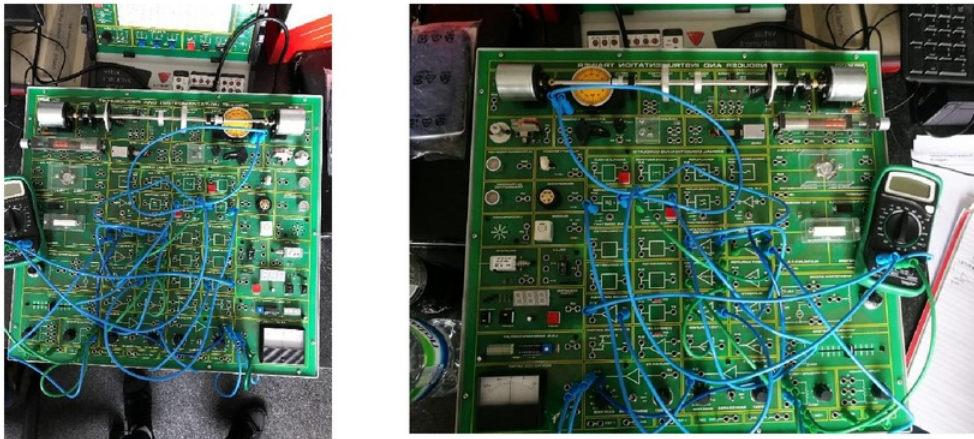


Figure 2 LJ Create Digiac 1750

An external multi metre was used to get results that were needed in certain tests. The team of three were allocated roles and checked and double checked the trainer configuration and the readings of each test. The results were recorded in the allocated tables in the user manual. On some of the readings taken a second lot of readings were taken going in the reverse direction. This was to check for hysteresis.

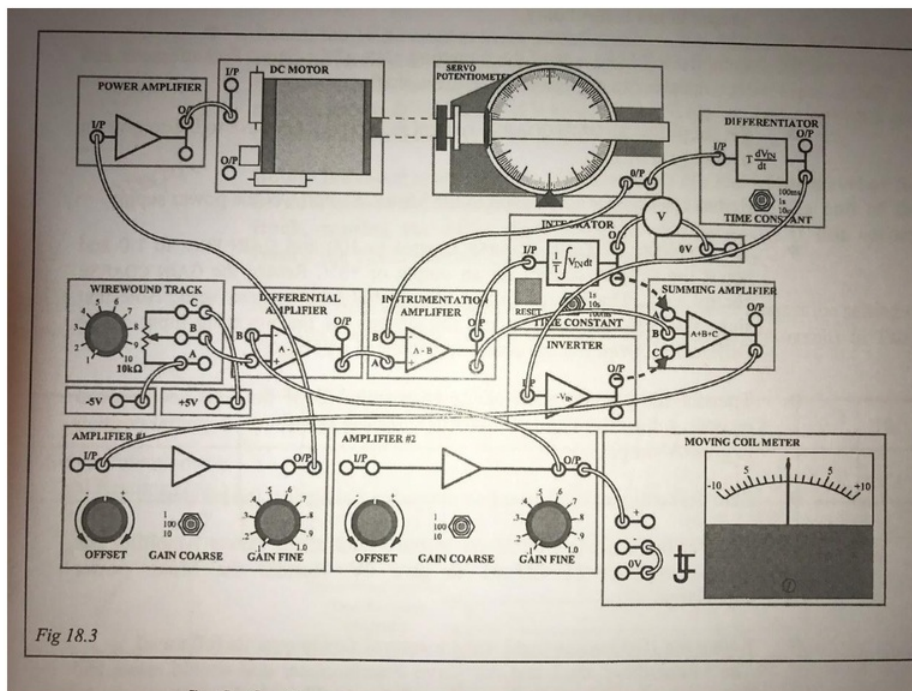


Figure 3 Proportional control setup [6]

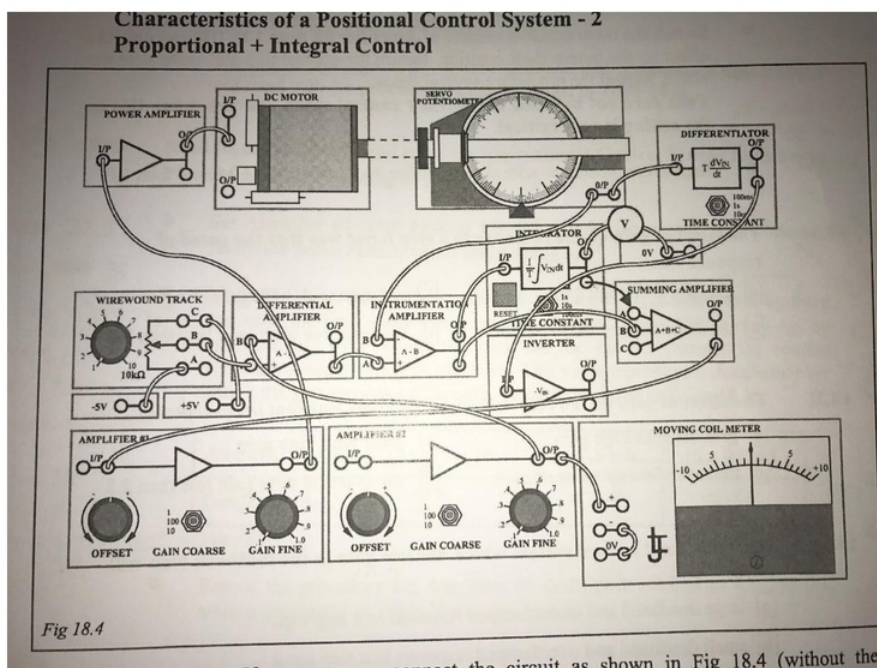


Figure 4 Proportional Integral control setup [6]

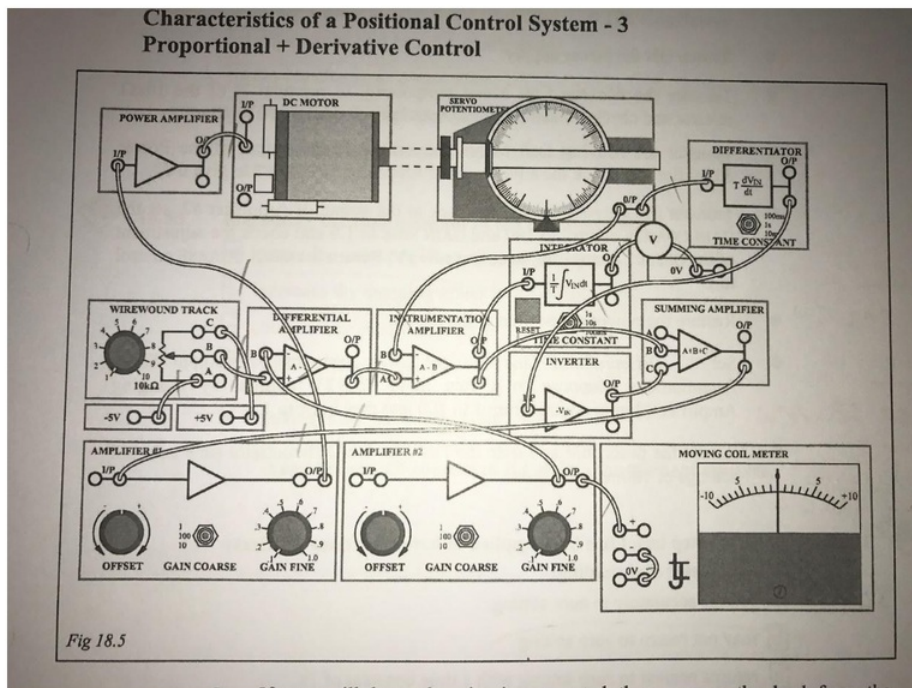


Figure 5 Proportional Derivative control setup [6]

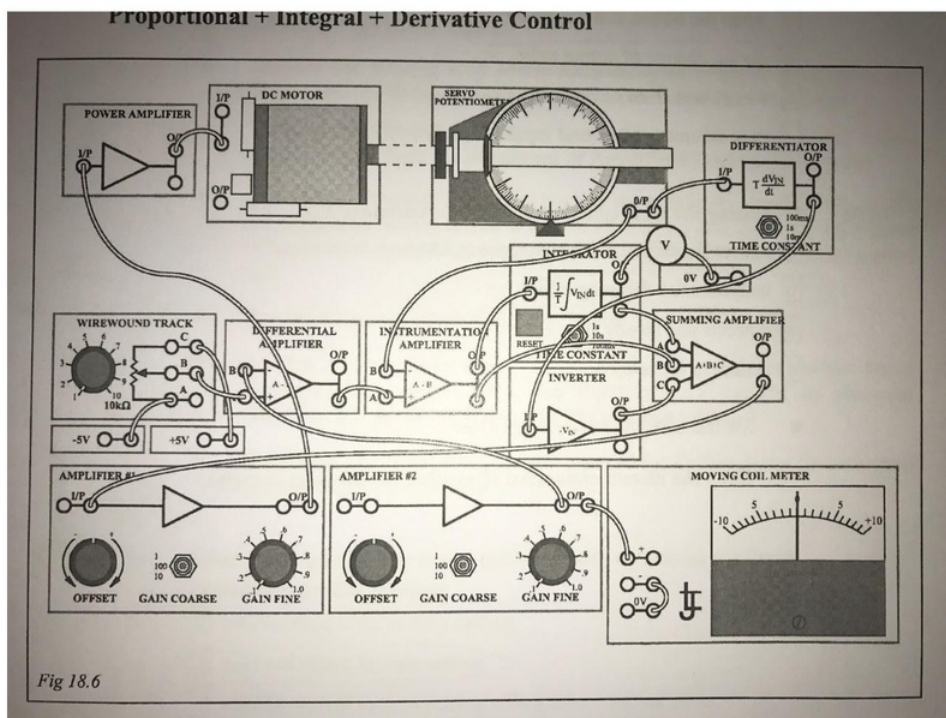


Figure 6 Proportional Integral Derivative control setup [6]

4 Results

These were the results for each of the four controller methods. Notes were taken during the tests and graphs and tables have been produced from these notes.

4.1 Proportional

The 10 kilo Ohm wirewound resistor was rotated as specified in the control manual [6]. The motor drive shaft and servo potentiometer dial moved very slowly at the start and then a little faster. The results of the two readings are listed in Table 1.

Amplifier #1 Gain = 1.0	Positive	Negative
Maximum Dial Reading (degrees)	140	213

Table 1 Proportional results - gain = 1

The instructions of the control manual [6] were followed resetting the resistor and changing the gain to 5. The full range of travel was recorded in Table 2 for the input control.

Control Setting	1	2	3	4	5	0V	6	7	8	9	10
Servo-Potentiometer Dial Reading (degrees)	Continuous	205	245	288	330	0/360	12	58	103	148	165
Reverse direction Servo-Potentiometer Dial Reading	Continuous	205	235	273	317	0/360	2	48	92	142	160

Table 2 Servo-Potentiometer dial reading - gain = 5

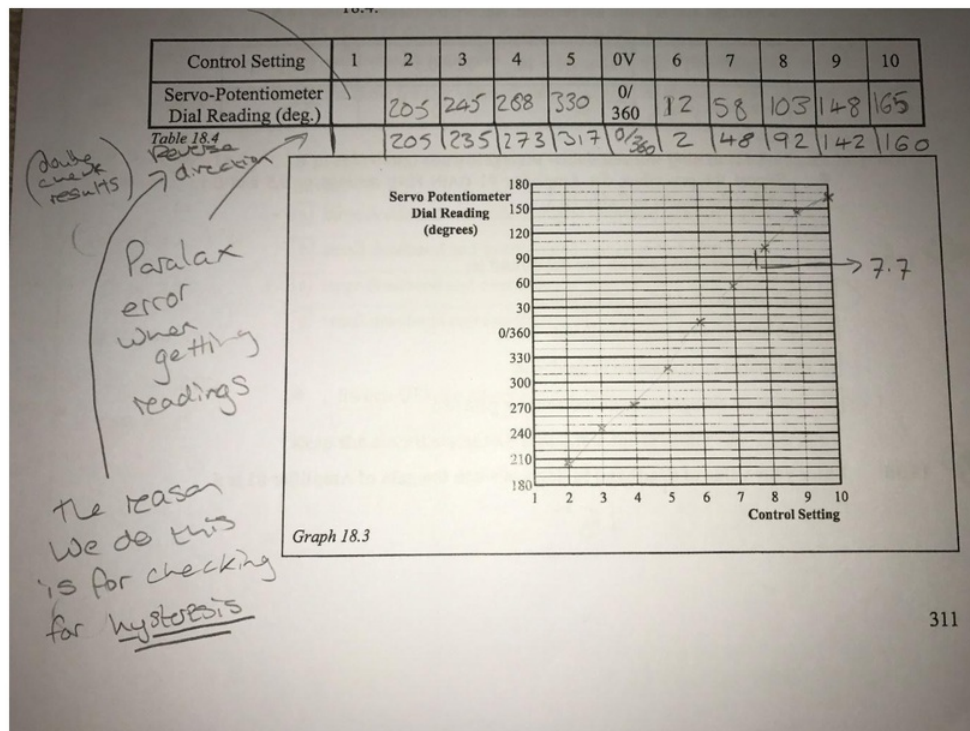


Figure 7 Servo Potentiometer readings plotted graph

The deadband/no responsive values were recorded for each of the gains displayed in Table 3.

Amplifier #1 Gain	$10 \times 1.0 = 10$	$10 \times 0.5 = 5$	$10 \times 0.1 = 1$
Deadband (degrees)	8°	15°	80°

Table 3 Deadband results for each gain

	Switch to 100	Switch back to 1
Amplifier #1 Gain Fine 0.1	From 318 to 280 = 38°	From 280 to 330 = 50°
Amplifier #1 Gain Fine 0.1	From 330 to 275 = 55°	From 275 to 335 = 60°
Amplifier #1 Gain Fine 0.5	From 348 to 247 = 99°	From 247 to 5 = 118°
Amplifier #1 Gain Fine 0.5	From 5 to 250 = 245°	From 250 to 0 = 110°
Amplifier #1 Gain Fine 1.0	From 0 to 250 = 250°	From 250 to 0 = 250°

Amplifier #1 Gain Fine 1.0	From 0 to 250 = 250°	From 250 to 0 = 250°
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Table 4 Proportional response

4.2 Proportional Integral

	Switch to 100	Switch back to 1
Multi-metre reading	From -2.78 to 3.35 then dropped	From -2.71 to 3.6 then dropped
Servo-potentiometer movement	From 355 to 250 (clockwise)	From 250 to 0 (anti clockwise)

Table 5 Proportional Integral readings

With the gain set at 0.5 the servo potentiometer continuously rotated and the reading from the multi metre could not be taken.

With the gain set at 1.0 the servo potentiometer continuously rotated and the reading from the multi metre could not be taken.

4.3 Proportional Derivative

	1s	100ms	10ms
1 to 100	0 to 288 clockwise	320 to 285 clockwise	322 to 275 clockwise
100 to 1	288 to 320 Anti clockwise	285 to 322 Anti clockwise	275 to 335 Anti clockwise

Table 6 Proportional Derivative readings

4.4 Proportional Integral Derivative

Test	Integrator Time Constant	Differentiator Time Constant	Continuous Y/N	Response Time Slow/Medium/Fast	Number of Oscillations
1	10s	1s	No	Slow	0
2		100ms	No	Medium	0
3		10ms	No	Fast	2
4	1s	1s	No	Slow	1
5		100ms	No	Medium	1
6		10ms	No	Fast	2
7	100ms	1s	No	Slow	6
8		100ms	No	Fast	1
9		10ms	Yes	Fast	0

Table 7 Proportional Integral Derivative readings

5 Discussion

5.1 Proportional

In the first test the control of dial was proportional to the movement of the wirewound resistor although at the very start it was slow. The results in Table 1 show that a higher reading for the negative then the positive.

In Table 2 and Figure 7 the servo-potentiometer dial readings were recorded in the forward and reverse directions. This was to check for hysteresis. The results are similar with an average difference of 9.44° between them, it would only take a discrepancy in the reading of the measurement for example, **parallax error to create this difference.**

The approximate control setting for the Servo Potentiometer dial reading at 90° was read as 7.7. This was taken from the graph depicted in Figure 7. The accuracy of this reading may be brought into question, but with the time and materials available, it was the only way to take the reading. It was taken by plotting the results shown in Table 2 on a scatter graph and taking the most accurate reading corresponding to the convergence of the lines.

The results for the Deadband are shown in Table 3. Deadband is the [7] “minimum percentage of a given range or amount by which a measured value must vary in order for the device or computer to register a change. For example, if you obtain a device that has a range of 0-100 Volts, and you have set a deadband of 1%, then the incoming voltage must vary by at least 1 Volt in order to realize a change of value.” The type of deadband that is relevant to our findings is called Device Deadband it means [7] “The device itself will not send a value change unless the variation exceeds the deadband limit.”

To put this into perspective the device deadband we are measuring for on the Digiac 1750 Transducer + Instrumentation Trainer is the measured amount of movement in the servo potentiometer. Once the hall effect disk (connected to the Servo potentiometer) was moved past the deadband threshold it would return to zero.

The results in Table 3 show that the higher the gain the smaller the deadband is. The response from the step input was recorded in Table 4. It showed that the higher the gain the quicker the proportional controller was to respond, but tended to over dampen the responses to the step input.

5.2 Proportional Integral

The team thought that adding the integral control would stabilise the output of the servo potentiometer. From the results shown in Table 5 the most stable output is the lower gain of 1 whereas the other gains tested produced a continuous rotation. The gain at 5 compared to the gain at 1 had a quicker response. There was not a difference in response between the gain set at 10 and the gain set at 5. With the gain set to 1 there was 6 overshoots counted. The time constant with the least amount of overshoots was 10s

The time constant was changed to 100ms and the Hall effect disc was moved to around 10° on the servo potentiometer dial, when released it built up to run continuously until the experiment was stopped. This continuous rotation is caused by error in the output of the controller. It can be noted that the higher the gain the quicker the response, but this is at the cost of stability.

5.3 Proportional Derivative

The main point noted in the results (Table 6) is that on all differentiator time constants 1s, 100ms and 10ms the servo potentiometer does not return to its zero setting and doesn't re adjust to correct the known error. By increasing the time constant the dampening effect is increased so the less travel on the hall effect disc.

5.4 Proportional Integral Derivative

The last test was on the PID the setup is depicted in Figure 6. The testing was carried out by keeping the integrator time constant the same whilst changing the differentiator time constant. This was carried out on each integrator constant. Once it was completed checks were made to compare response times to make sure the right reading was taken.

The results shown in Table 7 have a running theme that the higher the differentiator time constant the slower the response time. There were 2 medium response times noted both with the differentiator time constant set to 100ms with the integrator constant either 10ms or 1s. There were 4 fast response times noted, all but one at 100ms differentiator time constant. These all had either 1 or 2 oscillations apart from one which continuously ran.

The 100ms differentiator time constant shows the most stable results for each integrator time constant. They all had medium to fast response times, didn't continuously run and had little to no oscillation which makes them desirable.

6 Conclusion

The proportion controller's downfall is that they are not very accurate. A high gain will have the benefit of a small deadband, but has the drawback of an underdamped step input response. The accuracy of the output will vary depending on the gain, but overall proportional controllers are very stable. With the addition of the integral control the accuracy got worse. The most stable output was with a low gain (x1), but high gain (x10) produce a fast response time with the cost of stability. The proportional derivative controller gave out a quicker response, with differentiator time constant increased so too did the dampening effect which stops the oscillation, but it could not readjust back to the zero setting. Finally, the full Proportional integral derivative controller showed promising results. The trend in Table 7 suggested that the most stable responses are from when the differentiator time constant is at 100ms it produces a medium to fast response with hardly any oscillation. The other results showed traits that were good on the response time, but not very good on the oscillation, or would continually run. Each type of controller has its positives and negatives. Controller are chosen on which best suits the system it is controlling. One system may need accuracy; another may need response time whereas a certain system might need both.

On reflection of testing. Whilst there was a clear process to follow the testing was under a time restraint and performed over two separate periods of time within a team of three. Accuracy was important with parallax error mentioned in 5.1 Proportional. The readings taken were double checked by another team member and rechecks if there was a suspicious result.

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Assignment 2

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

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Comment 1
multi-meter

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Comment 2
This difference is due to the hysteresis of the control system, not due to your ability to make measurements

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GRADING FORM: SMU GENERIC_GJ

JAKE TYRRELL**56.85****RESEARCH-INFORMED LITERATURE**

"Inclusion of a wide range of research-informed literature, including sources retrieved independently. Selection of relevant and credible sources. Very good use of referencing conventions, consistently applied.

16.75**KNOWLEDGE AND UNDERSTANDING**

Knowledge is accurate with a good understanding of the field of study.

16.8**ANALYSIS**

Evidence of some logical, analytical thinking and synthesis. Can analyse new and/or abstract data and situations without guidance. An emerging awareness of different stances and ability to use evidence to support the argument. Valid conclusions.

15.6**PRACTICAL APPLICATION AND DEP.**



A good and appropriate application of standard methods, materials, tools and/or techniques. Good appreciation of the context of the application, with some use of examples, where relevant.

5.1

SKILLS FOR PROFESSIONAL PRAC.



Can communicate effectively in a suitable format, but may have minor errors. Mostly coherent work and is in a suitable structure.

2.6