

Paul Austin Assignment 2

by Paul Austin

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P Number: P148321

Module: Instrumentation and Control

Assignment Title:

“Practical Exercise: Characteristics of a
Proportional Control System”

Lecturer: Dr Stephen Mosey

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2. Abstract

Using the LJ Create 1750 Transducer and Instrumentation Trainer the task is to simulate and evaluate the following control systems:

1. Proportional Control.
2. Proportional and Integral Control.
3. Proportional and Derivative Control.
4. Proportional and Integral Derivative Control.

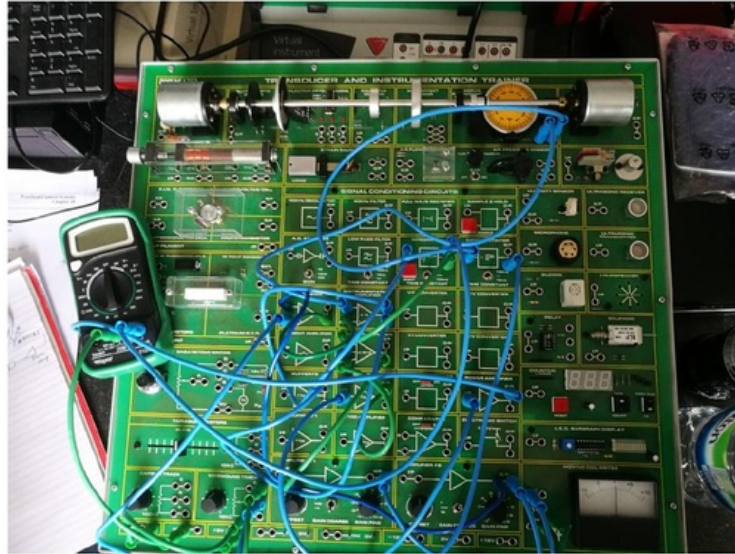


Figure 1: Image showing layout of the LJ Create 1750 Transducer and Instrumentation Trainer.

As can be seen from above, the Proportional Control unit is housed in the centre of the LJ Create 1750 Transducer and Instrumentation Trainer. The "Wirewound Track" (10k Ω Resistor) is used as a command input. The "Differential Amplifier" is used to inject a step voltage. This is generated by the "Amplifier #2" offset voltage.

The Integral Control can then be added by connecting the Integrator into the circuit between the "Instrumentation Amplifier" (used in this instance for error detection) and the "Summing Amplifier".

The Derivative Control can also be added via the "Summing Amplifier". This is done using the "Inverter" in the circuit between the "Differentiator" and "Summing Amplifier" to provide negative feedback.

This report will outline the methodology for this detailing how the equipment was used and the results obtained.

3. Introduction

Industry today is progressively looking towards intuitive methods for reducing cost & increasing the efficiency of work. Amongst the many ways in which such initiatives can be implemented is the automation of tasks rather than having them carried out through human interaction. Control systems are designed into engineering systems to allow for a greater level of controlled automation and optimisation.

Why use control systems?

1. To allow for a level of accuracy within the system.
2. To ensure operational boundaries or safety limits are not exceeded.

There are two types of Control Systems:

1. Feedback – Closed Loop System.
2. No Feedback – Open Loop System.

A Feedback (Closed Loop) System includes:

1. On / Off.
2. 3 State Control.
3. Proportional Control (P).
4. Proportional Integral Control (PI).
5. Proportional Integral Derivative (PID) Control.

Proportional Control is the difference between the start point and a process variable, deviation should not be large or sudden. The PI allows for a variable within the controller to be turned back to a set point should an error occur. The Derivative controller is usually used either with a Proportional Control (Proportional Derivative → PD) or with the Proportional Integral (PID). This gives the advantage of improving the response of the system.

4. Method

Prior to the commencement of any testing a series of steps for each procedure were carried out in order to calibrate the LJ Create 1750 Transducer and Instrumentation Trainer for each test.

4.1. Calibration

4.1.1 Proportional Control.

- Press the left hand side of the mounting plate of the Servo Potentiometer – release it to engage with the drive shaft.
- Set “Amplifier #1 – Gain Course” control to 10 and “Gain Fine” to 0.1. This gives an overall gain of 1.0.
- Remove the power connection to the Motor and switch on the power supply.
- Set “Amplifier #2 – Gain Course” control to 100 and “Gain Fine” to 1.0. Adjust the “Offset” control to provide an output of +3V.
- Return the “Gain Course” control to 1.
- Transfer the “Moving Coil Meter” to Terminal B of the “10k Ω wirewound resistor” and adjust it to its central position to provide a 0V output.
- Zero the setting of the “Servo Potentiometer” lining up with the pointer.
- Transfer the “Moving Coil Meter” to the output of the “Power Amplifier”.
- Adjust “Amplifier #1 – Offset” to 0V.
- Reconnect the Motor.

4.1.2 Proportional and Integral Control.

- Remove the power connection to the motor.
- Zero the setting of the “Servo Potentiometer” lining up with the pointer.
- Ensure the “Potentiometer” is engaged with the drive shaft.
- Set “Amplifier #1 – Gain Course” control to 10 and “Gain Fine” to 0.1. This gives an overall gain of 1.0.
- Switch on the Power Supply.
- Transfer the “Moving Coil Meter” to Terminal B of the “10k Ω wirewound resistor” and adjust it to its central position to provide a 0V output.
- Transfer the “Moving Coil Meter” to the output of the “Power Amplifier”.
- Adjust “Amplifier #1 – Offset” to 0V.
- Transfer the “Moving Coil Meter” to the output of “Amplifier #2”.
- Set the “Gain Course” control to 100 and “Gain Fine” to 1.0 and adjust the “Offset” control to provide an output of +3V.
- Return the “Gain Course” control to 1.

4.1.3 Proportional and Derivative Control.

- Remove the power connection to the motor.
- Zero the setting of the "Servo Potentiometer" lining up with the pointer.
- Ensure the "Potentiometer" is engaged with the drive shaft.
- Set "Amplifier #1 – Gain Course" control to 10 and "Gain Fine" to 0.1. This gives an overall gain of 1.0.
- Switch on the Power Supply.
- Transfer the "Moving Coil Meter" to Terminal B of the "10kΩ wirewound resistor" and adjust it to its central position to provide a 0V output.
- Transfer the "Moving Coil Meter" to the output of the "Power Amplifier".
- Adjust "Amplifier #1 – Offset" to 0V.
- Transfer the "Moving Coil Meter" to the output of "Amplifier #2".
- Set the "Gain Course" control to 100 and "Gain Fine" to 1.0 and adjust the "Offset" control to provide an output of +3V.
- Return the "Gain Course" control to 1.

4.1.4 Proportional and Integral Derivative Control.

- Remove the power connection to the motor.
- Zero the setting of the "Servo Potentiometer" lining up with the pointer.
- Ensure the "Potentiometer" is engaged with the drive shaft.
- Set "Amplifier #1 – Gain Course" control to 10 and "Gain Fine" to 0.1. This gives an overall gain of 1.0.
- Switch on the Power Supply.
- Transfer the "Moving Coil Meter" to Terminal B of the "10kΩ wirewound resistor" and adjust it to its central position to provide a 0V output.
- Transfer the "Moving Coil Meter" to the output of the "Power Amplifier".
- Adjust "Amplifier #1 – Offset" to 0V.
- Transfer the "Moving Coil Meter" to the output of "Amplifier #2".
- Set the "Gain Course" control to 100 and "Gain Fine" to 1.0 and adjust the "Offset" control to provide an output of +3V.
- Return the "Gain Course" control to 1.

4.2. Proportional Control

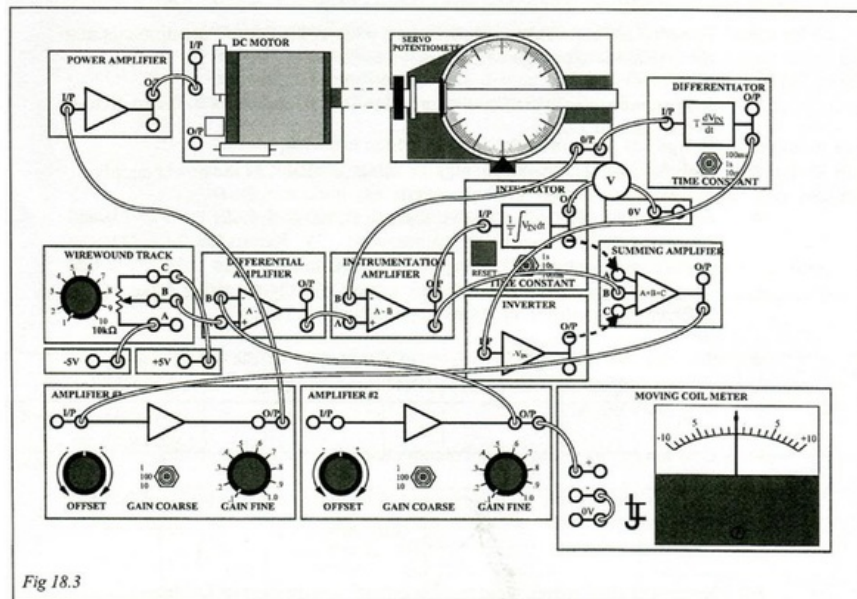


Figure 3: Image showing the layout of the Proportional Control on the LJ Create 1750 Transducer and Instrumentation Trainer.

- 4.2.1 With the power supply switched on, rotate the "10kΩ wirewound resistor" slowly over its full turn.
- 4.2.2 Record the Maximum "Servo Potentiometer" reading when "Amplifier #1 – Gain Fine" is 1.0.
- 4.2.3 Return the "10kΩ wirewound resistor" to its central position.
- 4.2.4 Set "Amplifier #1 – Gain Fine" to 0.5 and repeat 4.2.2 to 4.2.3.
- 4.2.5 Record the full range of travel of the "Servo Potentiometer" against settings of 1-10 for the "10kΩ wirewound resistor" command input and plot the graph of the Dial Reading against the Control Setting.
- 4.2.6 Repeat 4.2.5 in the reverse direction and record these readings.
- 4.2.7 Set "Amplifier #1 – Gain Fine" to 1.0. Using the input command control, return the Servo Potentiometer dial to 0°.
- 4.2.8 Moving the "Servo Potentiometer" by hand, record the range that it can be moved without the system automatically returning the "Servo Potentiometer" back.
- 4.2.9 Repeat 4.2.8 with "Amplifier #1 – Gain Fine" set to 0.5 and 0.1.
- 4.2.10 Set "Amplifier #1 – Gain Fine" to 0.1.
- 4.2.11 Switch the "Gain Course" control of "Amplifier #2" from 1 to 100 – record the effect on the output shaft position. Return the control to 1 and repeat this process several times.
- 4.2.12 Repeat 4.2.11 with "Amplifier #1 – Gain Fine" set to 0.5 and 1.0.

¹ LJ Create Curriculum Manual.

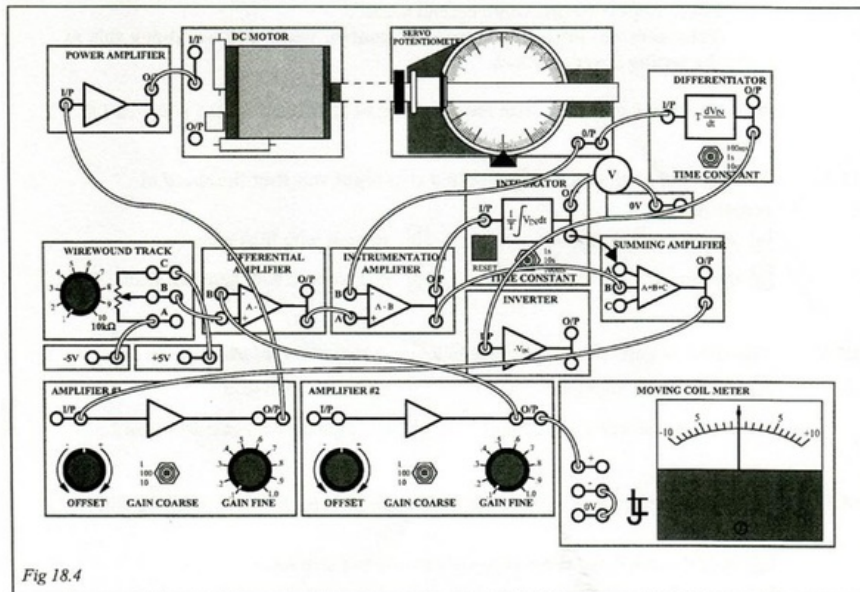


Figure 4: Image showing layout of the Proportional Integral Control on the LJ Create 1750 Transducer and Instrumentation Trainer.

- 4.3.1 With power to the motor, ensure the "Integrator Constant" time is set to 1s.
- 4.3.2 Press and hold the "RESET" button.
- 4.3.3 Connect the "Integrator Output Lead" to the "Summing Amplifier" (as shown in diagram above) and release the "RESET" button.
- 4.3.4 Record the effect on the "Servo Potentiometer" dial when a step input is applied by switching "Amplifier #2 – Gain Course" to 100, and then by switching it back to 1.
- 4.3.5 Record the long term effect on the "Integrator Output Voltage" using a digital voltmeter as well as the dial setting.
- 4.3.6 Repeat 4.3.4 with "Amplifier #1 – Gain Course" set to 0.5 and then 1.0.

² LJ Create Curriculum Manual.

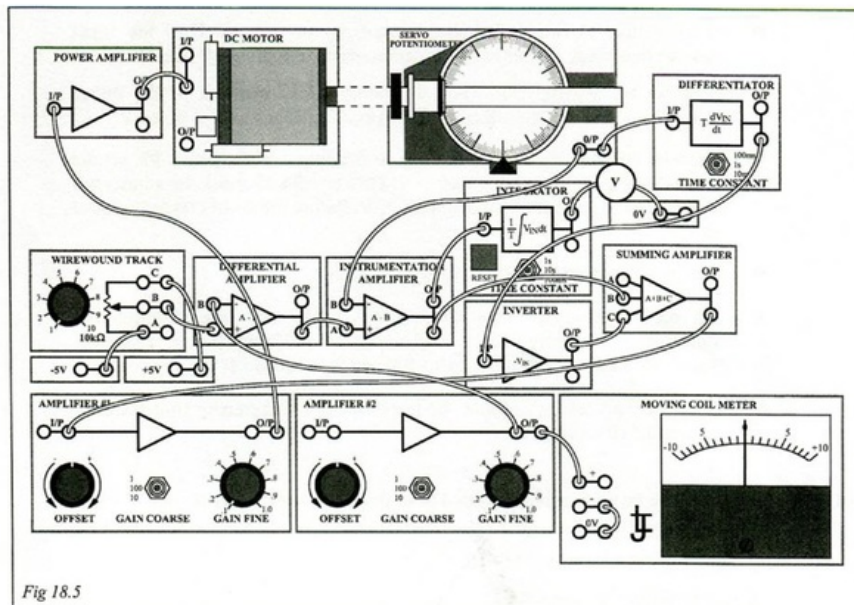


Fig 18.5

3

Figure 5: Image showing the layout of the Proportional and Derivative Control on the LJ Create 1750 Transducer and Instrumentation Trainer.

- 4.4.1 With power to the motor, ensure the "Differentiator" time is set to 1s.
- 4.4.2 Record the effect on the "Servo Potentiometer" dial when a step input of +3V is applied by switching "Amplifier #2 – Gain Course" to 100, and then by switching it back to 1.
- 4.4.3 Repeat 4.4.2 and record the response for the "Differentiator" time constant settings of 100ms and 10ms.
- 4.4.4 With the "Differentiator" time constant set to 10ms, record the effect of manually moving the output from its stable position by approximately 1 quarter turn of the "Hall Effect Disk".

³ LJ Create Curriculum Manual.

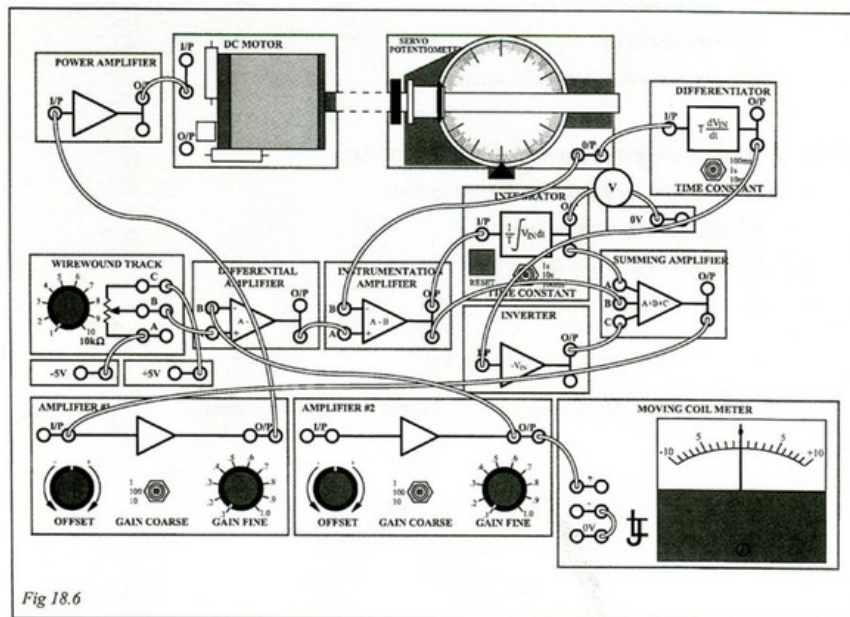


Figure 6: Image showing the layout of the Proportional and Integral Derivative Control on the LJ Create 1750 Transducer and Instrumentation Trainer.

- 4.5.1 Record the effect of applying a 3V step input utilising all combinations of “Integrator” and “Differentiator” time constants.
- 4.5.2 Record the effects and determine the optimum response.



⁴ LJ Create Curriculum Manual.

5. Results

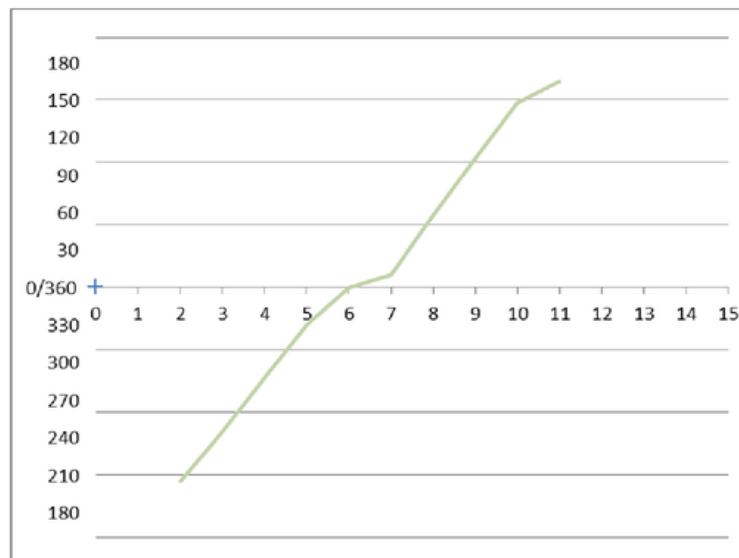
5.1. Proportional Control.

Positive	Negative
140°	213°

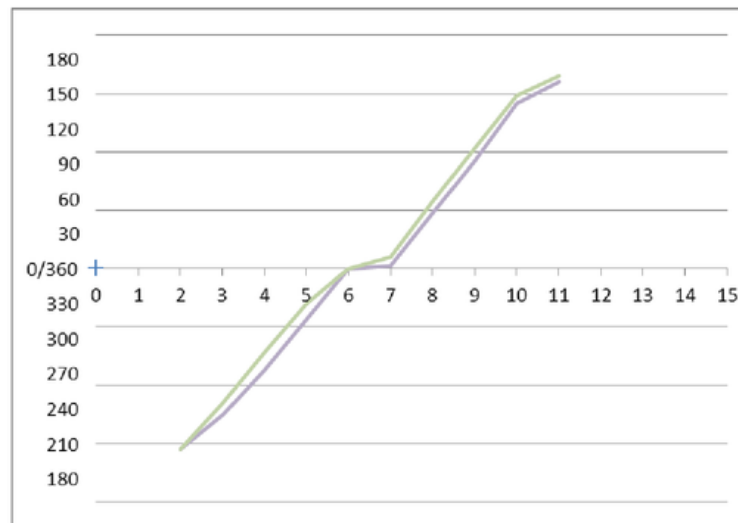
Table 2: Maximum "Servo Potentiometer reading with positive and negative voltage.

Control Setting	1	2	3	4	5	0W	6	7	8	9	10
Dial Reading (Deg)	Continuous Rotation	205	245	288	220	0/360	12	58	103	148	165
Confirming Readings (Deg)	Continuous Rotation	205	235	273	317	0/360	2	48	92	142	160

Table 3: Full range of travel for the "Servo Potentiometer" set against the setting of the "10k Ω wirewound resistor", readings also show the reverse direction of travel for the "Servo Potentiometer".



Graph 1: Showing Dial Reading associated with Control Setting.



Graph 2: Showing Dial Reading associated with Control Setting with Confirming Readings overlaid.

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

Table 4: Results of deadband compared to amplifier gain.

Amplifier	1 to 100	100 to 1	1 to 100	100 to 1	1 to 100
Gain	Clockwise	Anti-Clockwise	Clockwise	Anti-Clockwise	Clockwise
0.1	318	280	330	275	335
0.5	348	247	5	250	0
1.0	0	250	0	250	0

Table 5: Results of the effect on "Gain Course" of "Amplifier #2" on the output shaft position (Deg).

5.2. Proportional and Integral Control.

- 5.2.1 The effect on the "Integrator" output voltage is that it is still varying after 2 minutes.
- 5.2.2 The "Servo Potentiometer" dial moves rapidly towards a target, then overshoots and returns.
- 5.2.3 The response was faster when "Amplifier #1" gain was set to 5 compared with the gain being set to 1.
- 5.2.4 This also caused continuous oscillation.
- 5.2.5 Setting gain to 10 had no effect on speed, it remained the same, also with continuous oscillation.
- 5.2.6 The time constant with the fewest number of overshoots was 10 seconds.

5.3. Proportional and Derivative Control.

5.3.1 After the step input has been applied in both directions, the “Servo Potentiometer” reading may not return to 0 with no tendency to re-adjust to correct the error.

5.4. Proportional and Integral Derivative Control.

Test	Integrator time constant	Differentiator time constant	Continuous running (Yes/No)	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	N/A

Table 6: Results showing the effect of applying a 3V step input to the system with all possible combinations of “Integrator” and “Differentiator” time constants.

6. Discussion

6.1. Proportional Control.

- 6.1.1 Looking at the graphs 1 to 3, it can be seen that the approximate "Control Setting" value for a "Servo Potentiometer" reading of 90° is 7.7.
- 6.1.2 From the Table 2, it can be said that a High Gain gives a Small Deadband. An example of this is where "Amplifier #1" is 5, the Deadband in degrees is 5.
- 6.1.3 From the Table 4, it can be seen that the effect of gain on the response to a step input was that the speed of the response was greatest with high gain.
- 6.1.4 The effect of the gain on the response to a step input was that the "Overshoot" was greatest with high gain.
- 6.1.5 Therefore, a proportional control system which has low gain in the feedback loop will have a large Deadband and overdamped response to a step input.

6.2. Proportional and Integral Control.

- 6.2.1 In summary, a very short time constant may result in a build up to continuous running.

6.3. Proportional and Derivative Control.

- 6.3.1 Derivative Control affects the response during the output only.
- 6.3.2 Increases the time constant of the "Differentiator" increases the damping effect.

6.4. Proportional and Integral Derivative Control.

- 6.4.1 Fast response time, no oscillations is the most desirable characteristic for a Positional Control System.

7. Conclusion

Proportional Control is the difference between the start point and a process variable, deviation should not be large or sudden. The PI allows for a variable within the controller to be turned back to a set point should an error occur. The Derivative controller is usually used either with a Proportional Control (Proportional Derivative - PD) or with the Proportional Integral (PID). This gives the advantage of improving the response of the system.

8. References

Literature Sources:

- Digital control system analysis and design, Charles L. Phillips H. Troy Nagle (Hubert Troy), London : Prentice-Hall c1984.
- Control system design and simulation, Jack. Golten Andy Verwer, London : McGraw-Hill 1991.
- Control system technology C. J. Chesmond (Colin J), London : Edward Arnold 1984.

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- PID Controller Design Approaches - Theory, Tuning and Application to Frontier Areas, Publisher: InTech, ISBN: ISBN 953-510-405-5. Accessed 1st June 2017.
- CDM-based closed-loop transfer function design for ramp input, Haeri, Mohammad, Mohammad Saleh Tavazoei. Is Part Of: Transactions of the Institute of Measurement and Control, Jul 2011, Vol.33(5), pp.558-572 [Peer Reviewed Journal].
- Controller design using closed-loop transfer function, Lozachev, G. Computational Mathematics and Modeling, 1998, Vol.9(2), pp.153-159 [Peer Reviewed Journal].

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- http://www.cds.caltech.edu/~murray/courses/cds101/fa04/caltech/am04_ch6-3nov04.pdf
- <https://www.its.bldrdoc.gov/fs-1037/dir-037/5543.htm>
- <https://www.collinsdictionary.com/dictionary/english/transfer-function>

The following was accessed on 30th May 2017:

- https://en.oxforddictionaries.com/definition/transfer_function

Document:

- LJ Create Curriculum Manual.

Paul Austin Assignment 2

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

47 /100

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PAGE 3

PAGE 4

PAGE 5



Comment 1

But which advantages and which disadvantages?

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Comment 2 | Skills for Professional Prac.

Your method section seems to have turned into an instruction manual, this is not what I wanted. A brief statement saying you were following the instructions given in the handout would have done the job better as the reader would not get bored with phrases like "....With power to the motor, ensure the "Differentiator" time is set to 1s".

PAGE 12



Comment 3 | Analysis

I am not convinced by your results for the centre position 0W in your table. These values, as they do not correspond to a marked position on the potentiometer, should be excluded.



Comment 4

A comparison would have strengthened this statement

GRADING FORM: SMU GENERIC_GJ

PAUL AUSTIN

46.70

RESEARCH-INFORMED LITERATURE



References to a limited range of mostly relevant sources. Some omissions and minor errors. Referencing conventions evident though not always applied consistently.

10.25

KNOWLEDGE AND UNDERSTANDING



Evidence of basic knowledge and understanding of the relevant concepts and underlying principles.

13.5

ANALYSIS



Evidence of some logical, analytical thinking and synthesis. Can analyse new and/or abstract data and situations without guidance. An emerging

15.3

awareness of different stances and ability to use evidence to support the argument. Valid conclusions

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.

2.55