

Instrumentation and control assignment 1 JTyrrell

by Jake Tyrrell

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Instrumentation and Control (QinetiQ)

Assignment 1

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P148324

07/04/17

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1 Abstract

Advance control systems have benefitted industry tenfold over the past 20years. Proportional Integral Derivative (PID) Control Systems are now common place and continue to play a big part in automation. To make these systems more productive, they need to be adjusted and tuned to create the most efficient output for their purpose.

In this assignment task 1 will outline process of producing a control system and reigning in a PID control system to meet requirements specified by the assignment author. Task 2 part 1 will show how to achieve combining the PID controller and the transfer function together. Task 2 part 2 will show how to compress the design further into what is simply a single block controller. In the process we are continuously validating the output data against the original, to make sure it conforms to the original specification.

The outputs on the scopes will be the primary signal output for the control systems produced for Task 1, 2 part 1 and 2 part 2. The results for task 1 will also be displayed in a variety of forms to help evaluate the results and performance of the overall system.



2 Introduction

A system, or machine without smart control is only using 10 percent of its functionality. It is basically an On/Off system that will only function when the user triggers it. Examples of this range from hand drills to car air conditioning many years ago. Systems have improved vastly as technology has been enhanced and developed further. This advancement has allowed us to control the system and greatly expand on its very functionality and capacity. So an in-car, air conditioning system many years ago would have been functioned by turning a switch to the temperature you needed. A constant heat or cold would be output and the temperature would need to be manually reduced as the car interior would overheat or freeze. Now days you can use climate control which will keep the car interior at a constant and stable temperature as selected, using something called a Control Transfer Function. This is one of the many uses of a control system.

There are a lot of different types of control system:

- Proportional Control System (P)
- Proportional Integral Control System (PI)
- Proportional Derivative Control System (PD)
- Proportional Integral Derivative Control System (PID)

For this assignment a PID control system was used and was simplified throughout the tasks.

Proportional Integral Derivative Control System

The three main variable parts that are required to produce a PID are; Proportional Control, Integral Control and Derivative Control. The PID controller uses these variables as part of its control system and by combining the responses from each strengthens the overall control system.

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; [1] "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. [2] "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 helps to increase the system response by multiplying the derivative constant by the errors rate of change over time.

Author Background

At work we use PID controllers in the form of a Eurotherm; Multi-loop temperature controllers (PID). These we use to control the various conditioning units/chambers that we have throughout our facility. We provide the Eurotherm PID controllers with individually selected programmes, laid out in temperature (air) set points and differing timescales for each temperature. For example, over 24 hours the test assets conditioned might see 6 hours ambient, 6 hours at -30 degrees 6 hour at +40 degrees and 6 hours at 60 degrees. This is all controlled via the PID control system and works as described above by measuring the actual temperature and comparing it to what it should be (set point) and then changing the output of the conditioning unit to suit.

[3]



The Tasks laid out for this assignment

Task 1

An industrial process has the transfer function $G(s)$ given by the equation below, **where a , b , and c are values assigned to you shown in the table at the bottom of this page.**

$$G(s) = \frac{1}{as^2 + bs + c}$$

Using MATLAB and Simulink, design a control system capable of controlling this process. Following a unit step input, your control system should be able to bring the process under control within two seconds, with overshoot of less than 5%. Critically analyse the control system through the use of pole-zero diagrams and Nyquist diagrams.

Task 2

Using your control system from Task 1, find the closed loop transfer function of the system as a whole, i.e. the industrial process and the control system you have designed. Validate your results by comparing the results of simulations of the single transfer function and the simulation results from task 1.

Task 3

Write a report detailing the investigation and your findings. Your report should contain the following sections: abstract, introduction, method, results, discussion, conclusion, references. All references used should be cited in your text in the relevant place and listed numerically at the end of your report.

<i>Student ID</i>	<i>A</i>	<i>b</i>	<i>c</i>
<i>P148567</i>	5	1	5
P148324	5	2	3
<i>P148321</i>	3	2	2
<i>P148322</i>	2	1	5
<i>P148323</i>	5	5	2

3 Method

The idea is that this little controller will be part of a bigger system.

The different variants:

Task 1- design of PID controller

Combining the controller and the process

Task 2 part 1- simplified version of PID controller

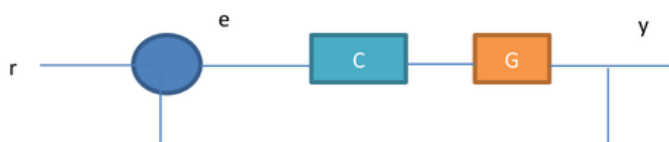
Simplifying and updating the model.

Task 2 part 2 – even more simplified version of a PID controller

Even more simplified version of the PID controller.

Task 1

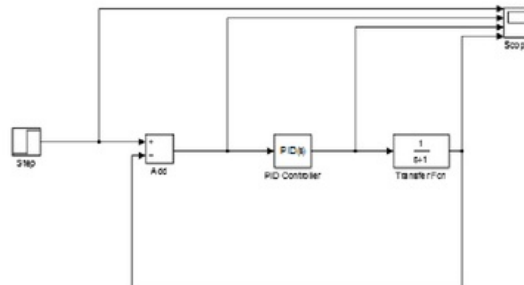
The basic schematic for a PID control system.



e = error r = reference input y = controller output

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The PID control circuit was built using Simulink in MATLAB. (below an overall schematic of the system built on Simulink)



The values shown on the scope will be the output values that provide the evidence for Task 1.

```
Command Window
New to MATLAB? Watch this Video, see Examples, or read the Documentation
>> G=tf([1], [5 2 3])

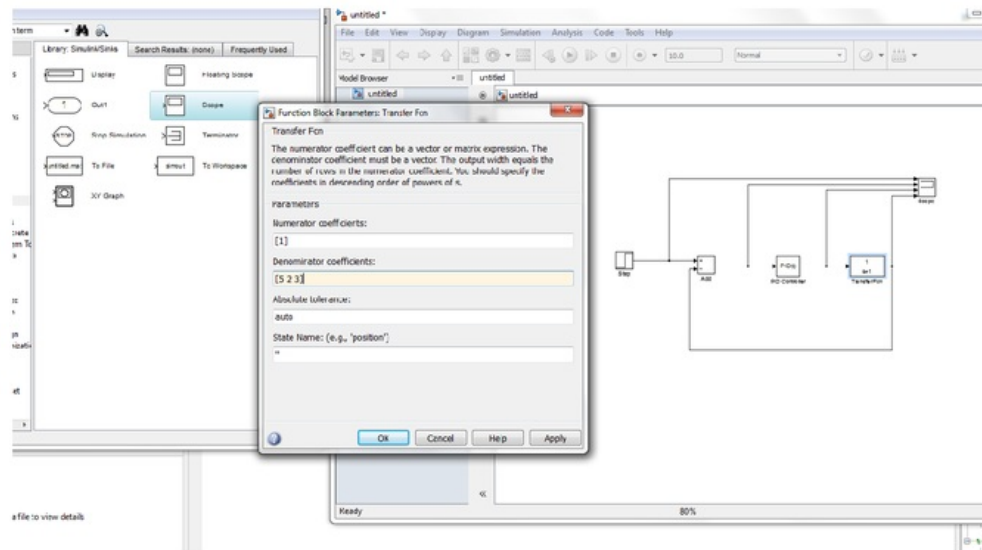
G =

      1
-----
5 s^2 + 2 s + 3

Continuous-time transfer function.

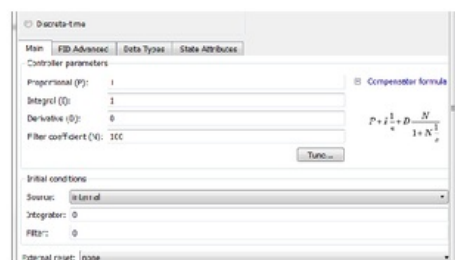
>> simulink
fx |
```

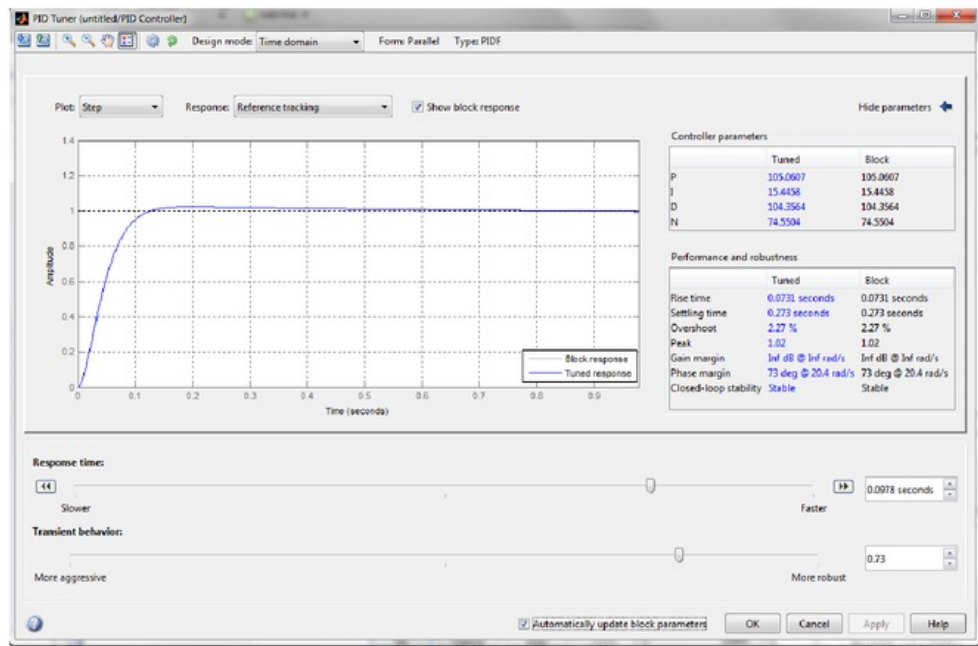
The unique numbers allocated for this assignment were inputted to create the continuous time transfer function as shown above. Simulink was then utilised to produce a control system.



The input of the Denominator Coefficients (5, 2, 3) into the function block parameters transfer box.

The Proportional, Integral and Derivative were formed by clicking on the PID controller and selecting the “tune” option that is part MATLAB’s Simulink application.





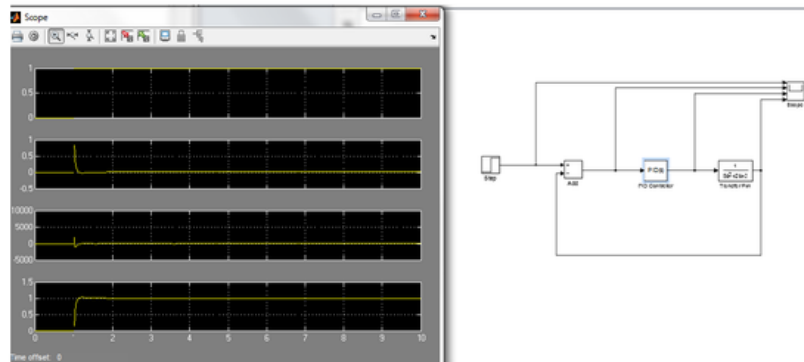
The idea of tuning the PID controller is to get the best out of the controller making it more efficient. This is done by using the built-in tuner, but can also be tuned manually by adjusting the Response Time and Transient Behaviour slide controllers to PID's overall performance.

The settings of the controller model were saved and exported to the MATLAB workspace shown below as C, but later changed to C1 due to problems (please see the discussion section).

Workspace			
Name	Value	Min	Max
C	<1x1 pid>		
G	<1x1 tf>		
xlSgRoot	'C:\Xilinx\14.7\ISE_DS...		

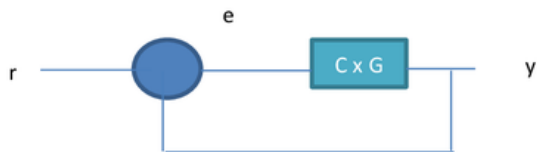
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When the system was run the following outputs were selected for the scope to understand overall what is going on in the control system and to make sure it functioning correctly. (Below) The top window is the Input Signal, 2nd down the Error, 3rd down PID output and bottom the control.

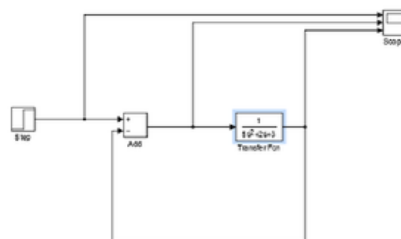


Task 2 Part 1

MATLAB's Simulink was used again to produce a slimmed down version of the original design used in task 1. The PID controller was removed from the feedback loop and amalgamated into the overall transfer function.



e = error r = reference input y = controller output



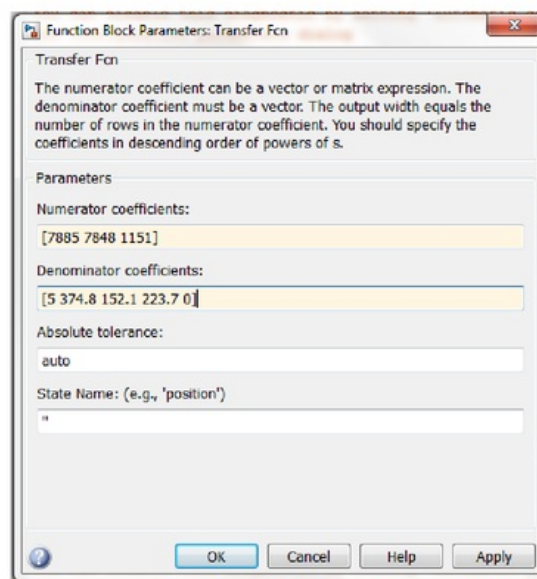
The MATLAB software processed the information inputted and calculated the function coefficients. These were used in the Transfer fcn application and inputted as parameters. (Note: the coefficients that do not exist are replaced with a 0)

```
>> (C1*G)

ans =

From input to output "ufb":
      7885 s^2 + 7848 s + 1151
-----
      5 s^4 + 374.8 s^3 + 152.1 s^2 + 223.7 s

Continuous-time transfer function.
```



the configuration parameters dialog

```
>> (C1*G)

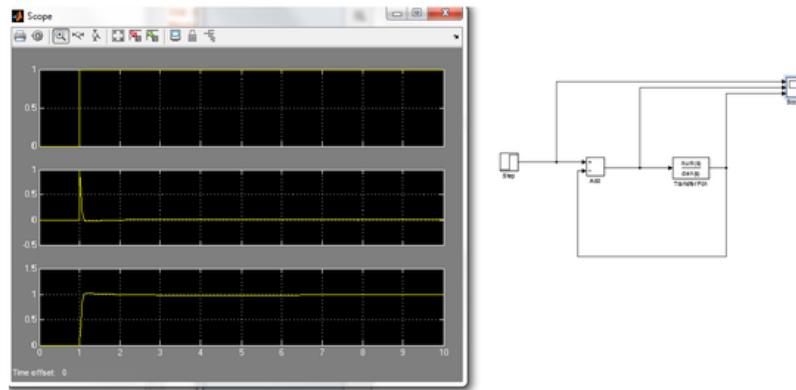
ans =

From input to output "ufb":
      7885 s^2 + 7848 s + 1151
-----
      5 s^4 + 374.8 s^3 + 152.1 s^2 + 223.7 s

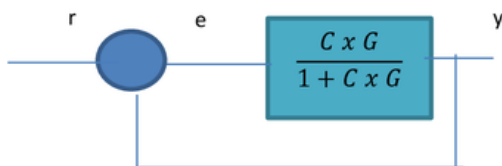
Continuous-time transfer function.
```

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The system was run, again each of the following outputs were selected for the scope to understand overall what is going on in the control system and to compare it again the original control system in task 1. (Below) The top window is the Input Signal, Middle the Error and bottom the control.



Task 2 Part 2



e = error r = reference input y = controller output

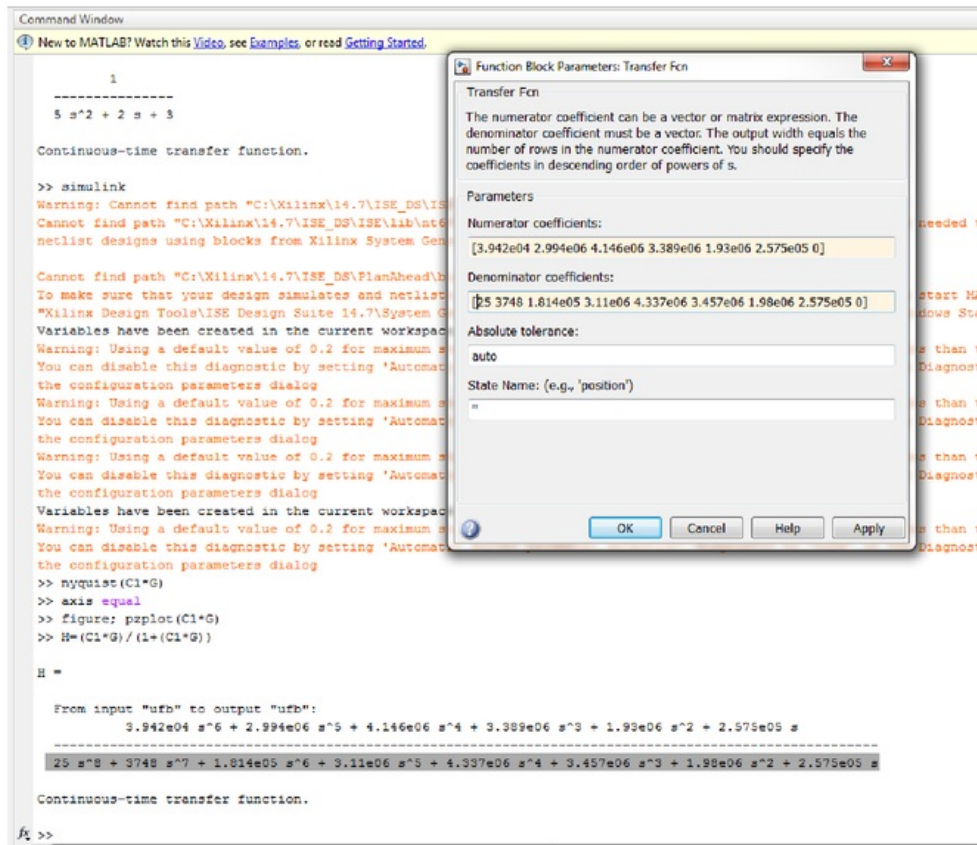
The last part of the task was to include the feedback in the transfer function, again this included the use of MATLAB's Simulink to build and simulate the system checking for the performance of the output.



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The formula (below) was calculated and used to produce the final simplified control system. The parameters calculated were entered in the Transfer fnc application.

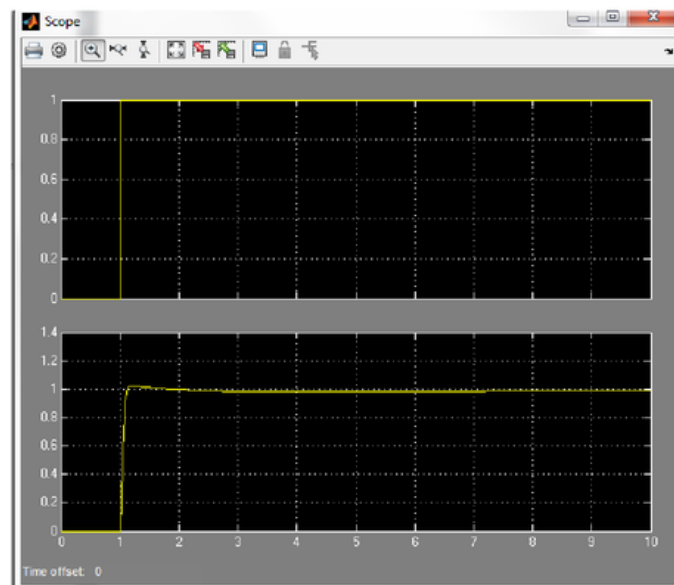
```
>> H=(C1*G)/(1+(C1*G))  
  
H =  
  
From input "u_fb" to output "u_fb":  
3.942e04 s^6 + 2.994e06 s^5 + 4.146e06 s^4 + 3.389e06 s^3 + 1.93e06 s^2 + 2.575e05 s  
-----  
25 s^8 + 3748 s^7 + 1.814e05 s^6 + 3.11e06 s^5 + 4.337e06 s^4 + 3.457e06 s^3 + 1.98e06 s^2 + 2.575e05 s  
  
Continuous-time transfer function.
```



The control system combined both the PID controller and the feedback into the transfer function.

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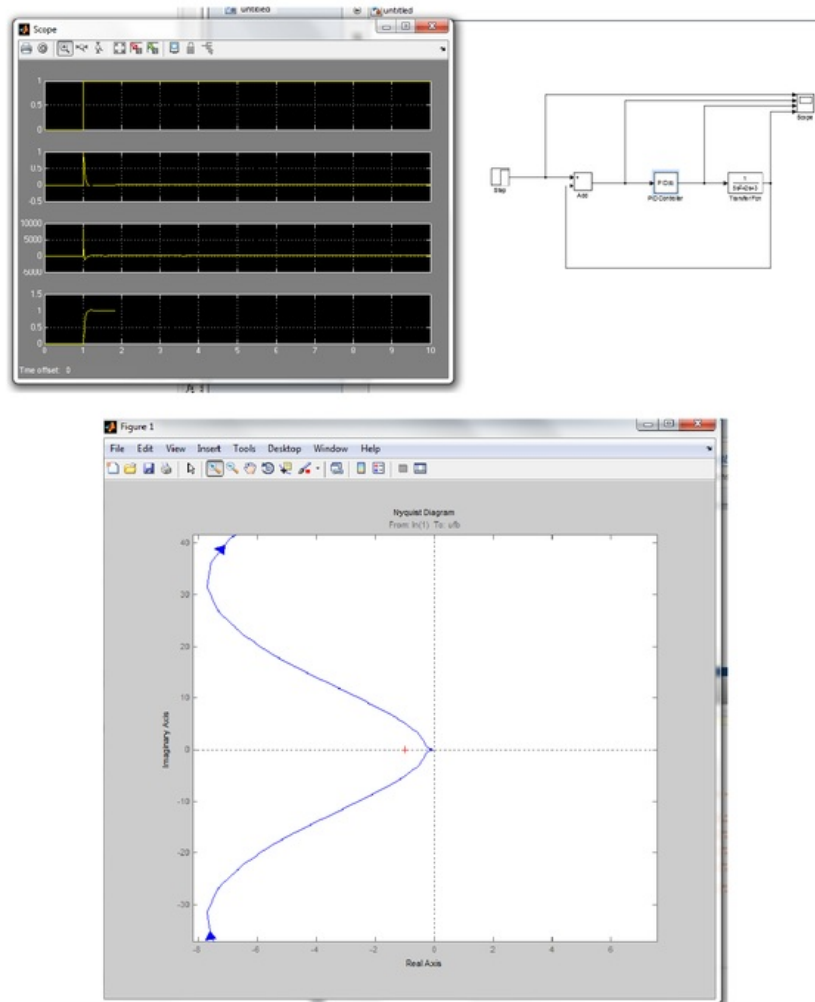
The final version of the control system was run. (Below) The top window is the Input Signal and bottom the control.

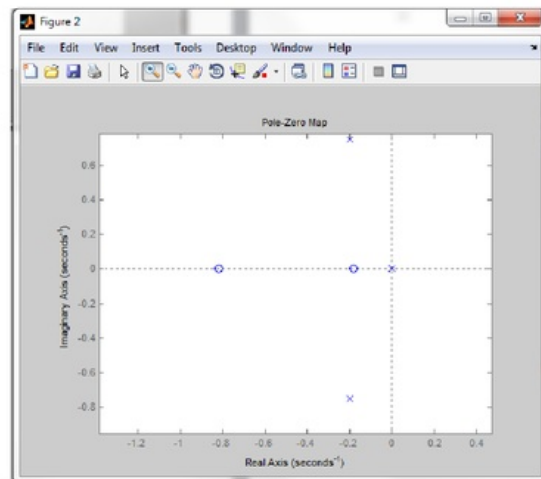


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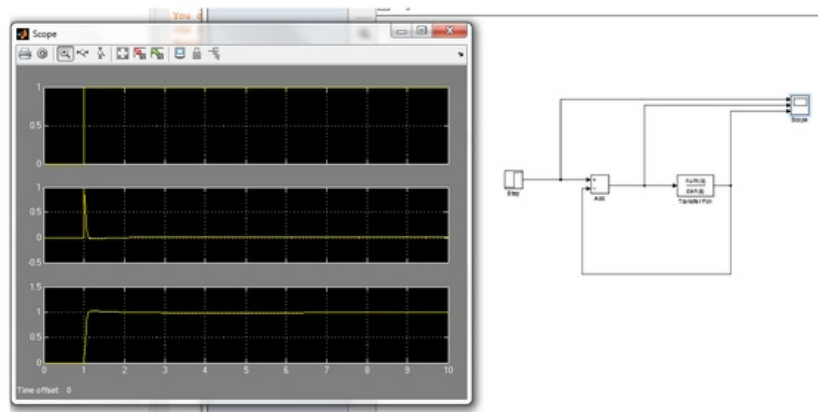
5 Results

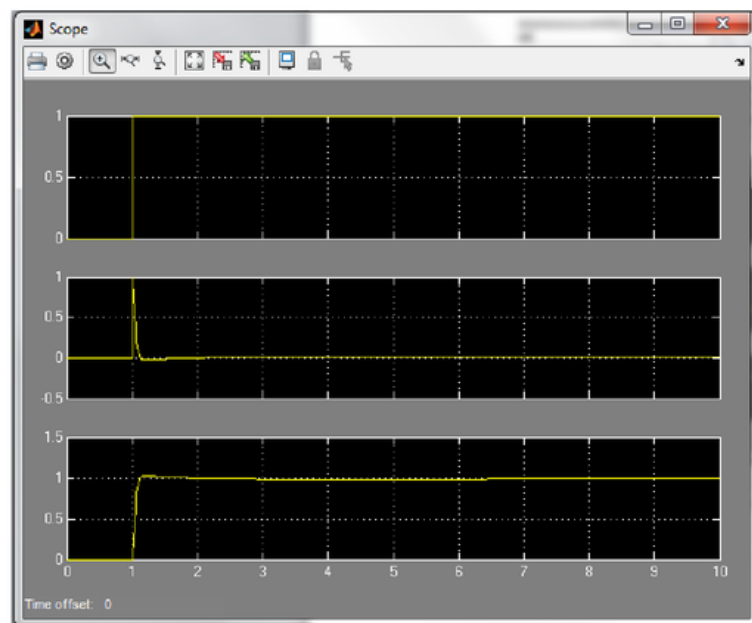
Task 1 Results



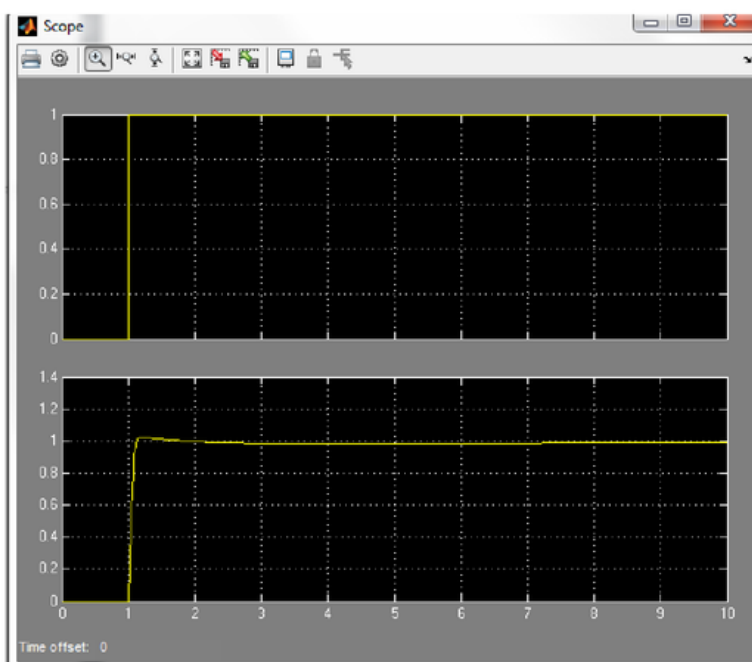


Task 2 Part 1 Results





Task 2 Part 2 Results

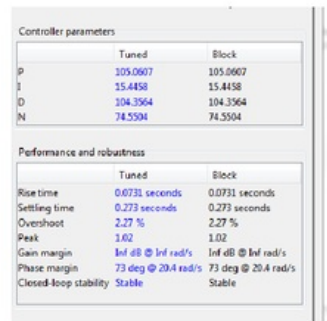


6 Discussion

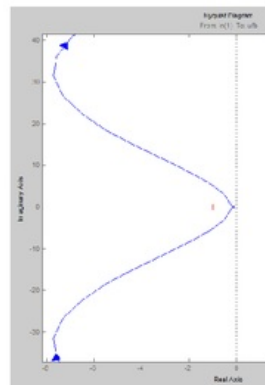
Task 1

Using MATLAB and Simulink, design a control system capable of controlling this process. Following a unit step input, your control system should be able to bring the process under control within two seconds, with overshoot of less than 5%. Critically analyse the control system through the use of pole-zero diagrams and Nyquist diagrams.

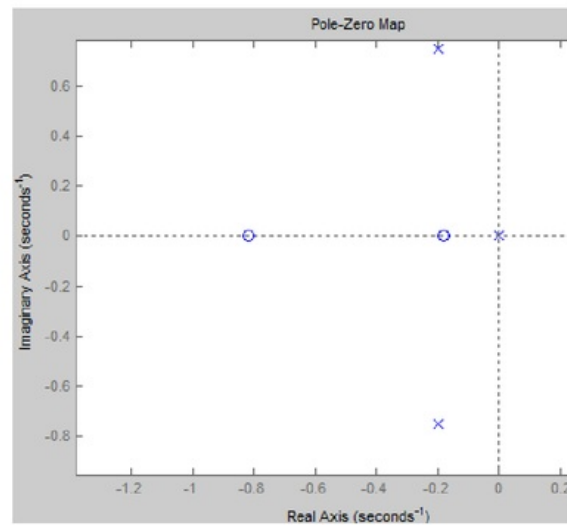
The results show exactly what is wanted in the task 1 specification. The system settling time is vastly under the 2 second time at 0.273 seconds and the control system has an overshoot of 2.27%.



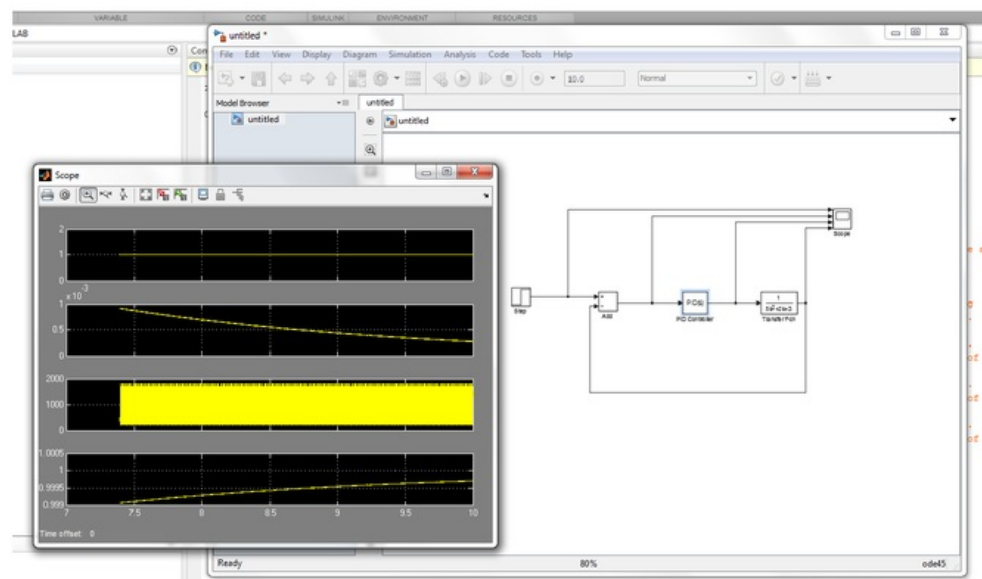
Studying the result from the Nyquist diagram I found that the control system is stable this is due to fact that when you zoom in on the diagram to the red X (-1), it is outside of the curve (see below). Stable systems do not include the point "-1" under their curve.



Again looking at the results shown in the Pole-Zero Diagram the poles are on the left hand side of the diagram indicating again that the control system is stable. If the poles were located on the right side of the diagram it would indicate that there is potentially a time signal that increases without bound meaning that the system is unstable.



During the process of producing a control system to the specification required by Task 1 there were a few bugs in the system that had to be ironed out. One of which, made the Filter Coefficient (N) very high affecting the overall output of the PID.

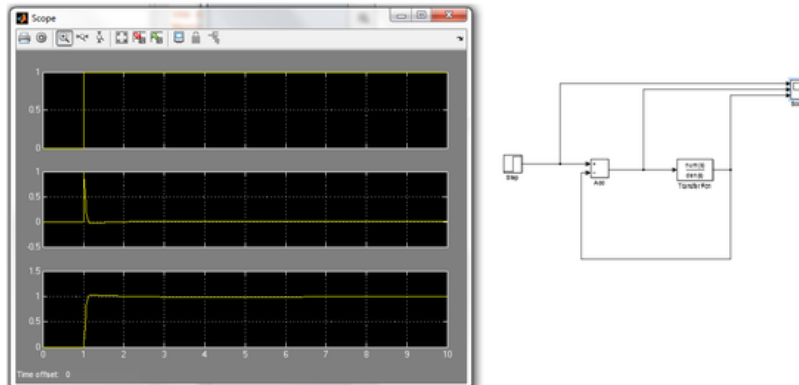


A change like this in a real control system would wreak havoc and potentially cause damage as the controller effort/output is all over the place.

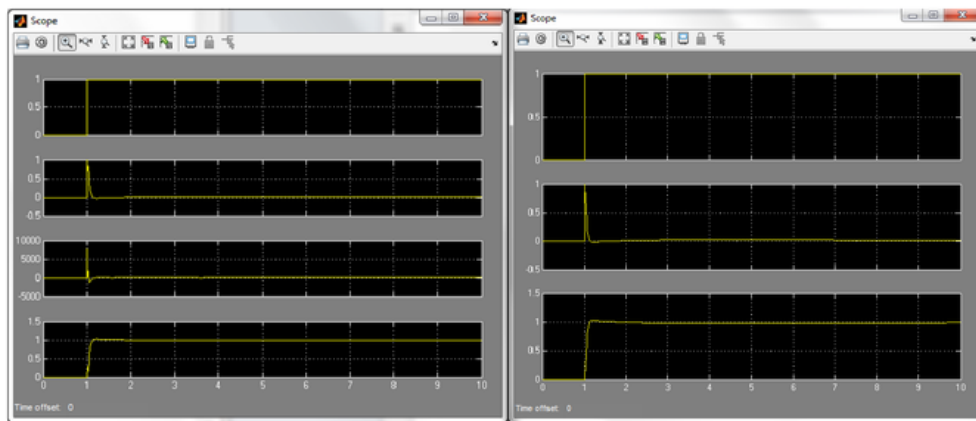
Task 2

Using your control system from Task 1, find the closed loop transfer function of the system as a whole, i.e. the industrial process and the control system you have designed. Validate your results by comparing the results of simulations of the single transfer function and the simulation results from task 1.

The results are very positive they show a stable system that has a similar output as in task 1, meaning that the slim lining of the system has been successful as it has basically produced the same output.

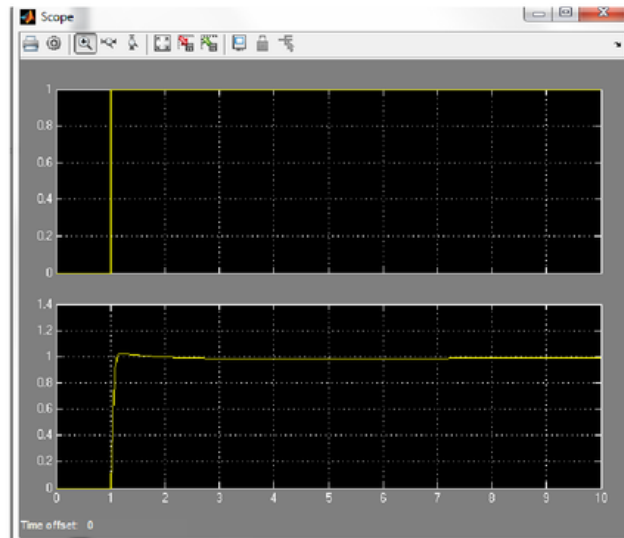


(Below) Task 1 scope results on the left and Task 2 part 1 scope results on the right.



Task 2 Part 2

Again in part 2 the results are very similar as in task 1 and task 2 part 1 giving confidence in the fact that the slimmed down version of the original control system has the same ability overall as the individual design control system.



Evaluating the output of each of the three control systems they have almost exactly the same output signal. When comparing output signal shape for each, they have the same trend as well, meaning that each control system has near enough the same performance.

7 Conclusion

Overall the results showed the output that was expected from the control systems that were produced to the specification required in the assignment. The output signal was very similar throughout each task, with all of the different changes to the system. It was the ideal result as it demonstrated that the control system could be reduced down to one simplified block with feedback on Simulink, instead of an assortment blocks that included PID's.

Although there were some problems with the MATLAB software and mistakes were made in the first task these were quickly and easily corrected and acted as a learning curve, which gave a greater understanding to the MATLAB Simulink software and the control system itself.

Ultimately the standards set in each task of the assignment were met and the results prove that a closed loop control system, (shown in task 1) can be reduced to an open loop system (shown in task 2 part 2) without any substantial effect on its overall performance.

8 Bibliography

- [1] Coulton, "Controllers," [Online]. Available: <http://www.coulton.com/article57.html>. [Accessed 21st May 2017].
- [2] Electrical4u, "Proportional, Integral and Derivative Controllers," [Online]. Available: <https://www.electrical4u.com/types-of-controllers-proportional-integral-derivative-controllers/>. [Accessed 20th May 2017].
- [3] "EuroTherm.co.uk," Eurotherm, [Online]. Available: <http://www.eurotherm.co.uk/products/temperature-controllers>. [Accessed 3rd June 2017].

9 References

- [1] Coulton, "Controllers," [Online]. Available: <http://www.coulton.com/article57.html>. [Accessed 21st May 2017].
- [2] Electrical4u, "Proportional, Integral and Derivative Controllers," [Online]. Available: <https://www.electrical4u.com/types-of-controllers-proportional-integral-derivative-controllers/>. [Accessed 20th May 2017].
- [3] "EuroTherm.co.uk," Eurotherm, [Online]. Available: <http://www.eurotherm.co.uk/products/temperature-controllers>. [Accessed 3rd June 2017].

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GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

51 /100

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Comment 1

You should have included a statement of your results in your abstract

PAGE 5



Comment 2

Thermostats usually provide on-off type control via an adjustable bi-metallic switch

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GRADING FORM: SMU GENERIC_GJ

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50.75

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.

2.35

KNOWLEDGE AND UNDERSTANDING



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

16.5

ANALYSIS



Evidence of some logical, analytical thinking and some attempts to synthesise, albeit with some

14.4

weaknesses. Some evidence to support findings/
views, but evidence not consistently interpreted.
Some relevant 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.

13

SKILLS FOR PROFESSIONAL PRAC.



Can communicate in a suitable format but with some room for improvement. Work lacks coherence in places and could be better structured. Figures should be captioned to enable you to refer to them in your text

4.5