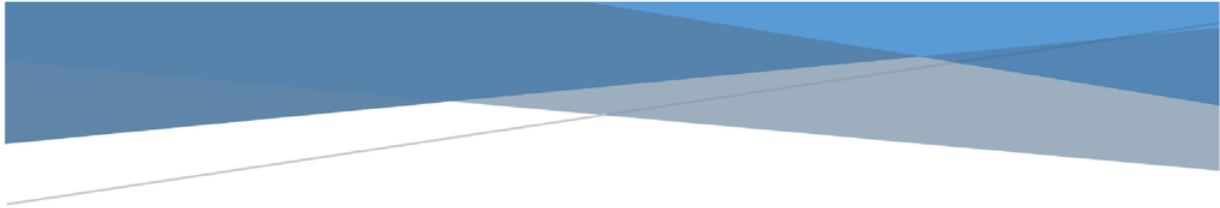


PSDE5011 Assignment 1

by Nathan Smith

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HND ELECTRICAL & ELECTRONIC ENGINEERING

PSDE 5011 CONTROL & INSTRUMENTATION

ASSIGNMENT 1 CONTROL SYSTEMS ANALYSIS, MODELLING, SIMULATION & PRACTICAL TESTING

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1. Research

Flow measurement with a range of transducers and signal conditioning methods

Flow measurement is the measured value of an amount of product passing through a desired space or area, or in engineering terms the quantification of fluid movement in a bulk form. Many methods can be used to obtain a flow measurement but the assignment looks at the transducer and signal conditioning method of flow measurement. Figure 1 below shows a basic flow measurement system with the individual steps labelled and discussed below.

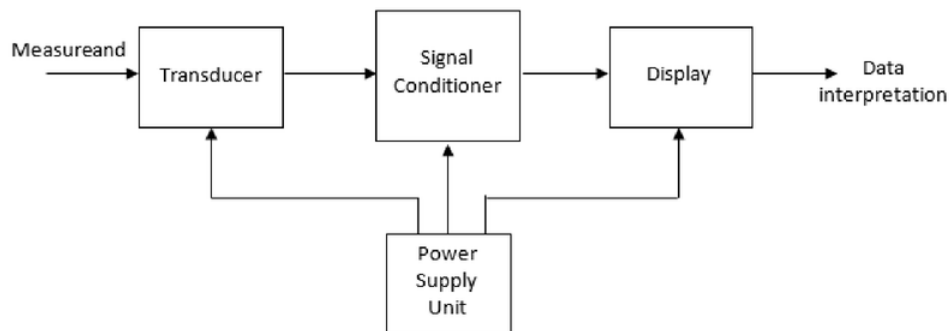


Figure 1: Basic flow system

The control loop system above in figure 1 creates a basic flow system which many control systems are based on and work from. The system consists of a transducer, this is the part of the system which receives the measureand signal and turns this physical measured signal into an electrical signal which is process through the system, there is a range of transducers as discussed below. The next part is the signal conditioning part of the system which is where the electrical signal obtained from the transducers is converted into a more usable signal through the transducer which will be used further on in the system to be displayed to the operators of the system, signal conditioning is discussed further on in this research. The next step is the display which will physically display to the operator a value or in some cases a

diagram or graph of the measurement of flow. The system has its power supply as shown in the diagram which will usually be a low voltage supply.

Flow Transducers

A transducer is a piece of instrumentation which will take a measured signal and convert this signal into an electrical signal as stated above, in an analogue or digital form to be processed and displayed to the operator as a measured value. The digital method of measurement will sample the flow at a high rate and convert this into a binary code which will be transmitted through the system and converted back into a display through this binary value. The analogue method will be measured by the voltage or current varying with the change of flow and should relate to each other in order to display an accurate measurement, some will have a linear output but others may have a nonlinear output which will be converted in the signal processing and transducer.

Flow transducers are mainly used in the measurement of liquid flow and air measurement, the different methods of flow transducers all have different principles. If the transducer is measuring the velocity, the transducer can analyse the units and calculate a flow level to determine how much flow is passing through the desired area. (PCE Instruments UK Ltd, 2018).

Ultrasonic Flow Meter

Ultrasonic flow meters use the principle of a volumetric meter which needs the presence of bubbling or particles in the flow sample. The flow meters are best suited for a soiled liquid and as used on Valero oil refinery for wastewater treatment plant flow measurement. Due to these meters looking for the particles to measure the flow, a distilled water supply or even drinking water supply may not be accurately measured with this type of transducer without adaptation. This type of meter requires low maintenance so is ideal for continuous measurement and applications where maintenance may be a big task.

The operation of this type of transducer is based on the frequency shift of the signal produced from the ultrasonic source once it is reflected from the particles or bubbles

when they are in motion. The technology works the same as a sound wave which will change its frequency once reflected in this case by a flow of product. The transducer will transmit an ultrasonic sound wave into the area of product which is being measured, in refinery cases a pipe, then the wave will be reflected at a different frequency which will be received by the transducer and will be proportional to the flow rate which is then sent through signal processing and displayed to the operator. (Omega Engineering, 2003)

Venturi Flow Meter

A venturi tube is simple and reliable transducers which is widely used in engineering processes due to the cost and dependability. The venturi tube has no flow restrictions or moving internal parts which means the flow measurement can be carried out with small pressure losses. The venturi tube uses the Bernoulli Effect by reducing the cross section flow area in the line of product flow, which will create a pressure difference. This pressure difference is then measured on the exit side of the venturi flow meter where a DP is created and Bernoulli's equation is used to calculate the pressure differential. (FlowMaxx Engineering, 2018), Figure 2 below shows the venturing flow meter principle.

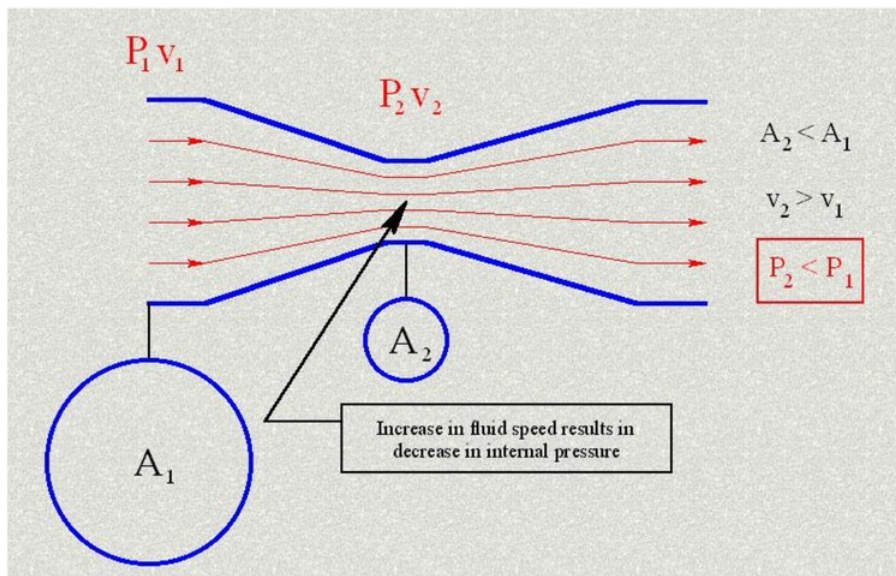


Figure 2: Venturi Principle

Pitot tube

Pitot tubes are a type of flow transducer which measures air flow and liquid flow in a variety of different ways, the Pitot tube has a low range ability and accuracy but they are a simple and reliable method of flow measurement and can operate in adverse weather conditions making them highly useful. The Pitot tube is similar to an orifice plate but it measures or detects the velocity of the flow at one point of the stream of flow. The pitot tubes can be hot tapped into pipeline making them highly useful on refineries and industrial applications. The Pitot tube was invented by Henri Pitot in 1732, the Pitot tube is designed to measure the impact and static pressure to obtain the flowrate. (Omega Engineering , 2003). Figure 3 below shows the Pitot tube.

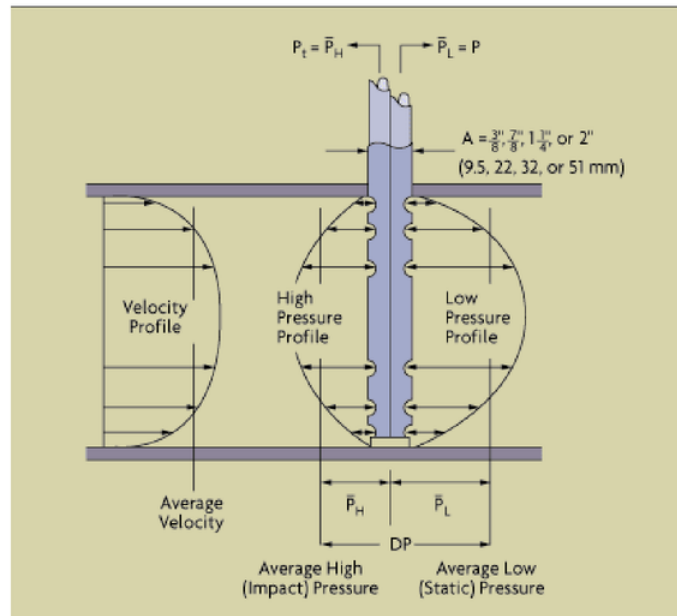


Figure 3: Pitot tube

Differential Pressure (DP) Flow meter *How does this differ from the Venturi?*

A differential pressure type flow meter uses the equation created by Bernoulli's to obtain a measurement in the flow. In a pipeline application the DP method of flow measurement will need the addition of a restriction in the pipeline to create a pressure drop in the system. As the flow rate rises this pressure drop is created and measured using the DP method. Bernoulli's equation states that the drop of pressure across the restriction on the pipe is proportional to the square of the flow rate. At low flow rates the DP method is not as accurate as at high flow rates. This type of flow measurement is low cost and can be used for multiple types of fluids but the range ability can be poor due to a nonlinear DP signal and can accuracy can deteriorate with blocking or erosion. (Universal Flow Monitors, 2012)

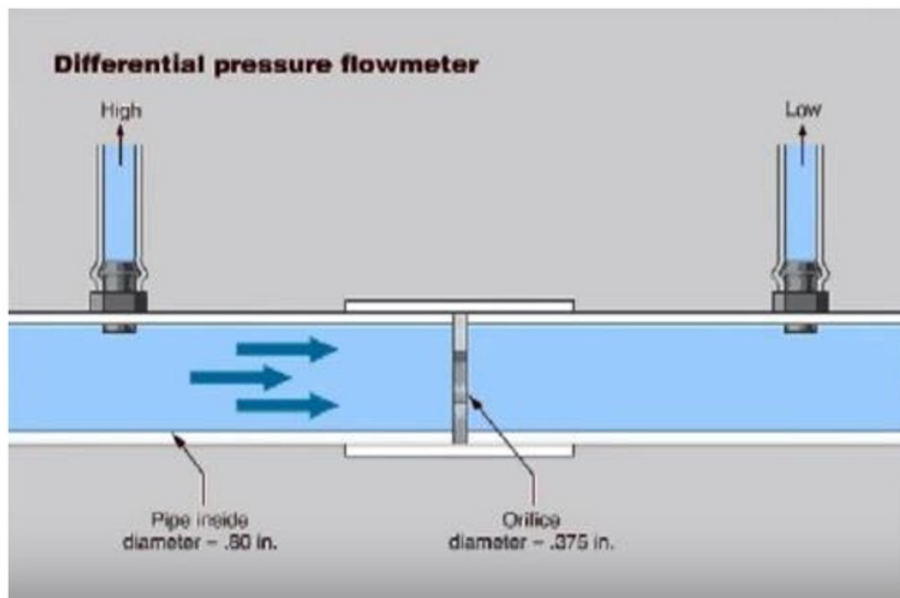


Figure 4: DP Pressure Measurement

Signal conditioning methods

Signal conditioning is the process of converting the output signal obtained from the transducer into a further electrical signal which can be used more easily and clearly. The Signal conditioning may amplify the signal which will make a small or weak signal from the transducer into a bigger and stronger signal to be displayed to the operator. The conditioner can scale the signal which will convert it into a bigger or smaller range of current or voltage. The conditioner can also filter the signal which will remove any undesirable bits of the signal and produce a cleaner purer signal. Another method is to compensate the signal which is where the conditions based upon the environment are measured and then values added or taken away from the signal. The next method of signal conditioning is to linearize the signal, this simply converts a nonlinear signal into a linear signal for easier transmission to the display. ADC methods are also used which convert an analogue signal into a digital signal which will be represented in a binary form and sent to the display device. The last method of signal conditioning is the UART method which converts a digital signal into a serial communication signal which is used when a network with a serial communication signal receiver or system is in use so they can read the measurement signal.

Flow system used in Bytronic process rig

The bytronic process control rig used for the assignment can be used to control and measure temperature, pressure and flow. This gives it a wide range of instrumentation usability and becomes a good device to be used for training and practical investigations. The process rig includes a PID control software package which can and is used in the assignment to simulate the outcome of the process rig, it features LED's and LCD screen to indicate outputs from the system and can be connected to a PC or PLC to show the results of the practical on a screen. The control rig is fully integrated and is built to be used on a workbench, it contains a process module and a control console which has an integrated supply of power. The front panel of the process rig contains a mimic of the process module on the front with switches and test points included. The flow for the system is measured and controlled with two proportional valves which will control the flow in and out of the

tank, a small needle valve which can be adjusted manually is also incorporated into the system to add some disturbance and a pressure relief valve. The data sheet attached to the appendix shows more specifications of the control rig. (Bytronic Educational Technology , 2018).



Figure 5: Bytronic Rig

This is a different piece of equipment to what you have worked on. Your system has a dc pump. What you are describing is part of the new version of the equipment available from Bytronic with a pressurized container. It is a shame you did not spot this!

The bytronic control unit control loop is shown below in figure 6. The control loop will have a set point and a process variable, the set point will be a desired value and the process variable will use the PID control to try to match this set point as smoothly and fast as possible with no overshoot or oscillations. The control rig will run at 6 pulses per turn with a output signal of 0-5v with 5v being 2L/min.

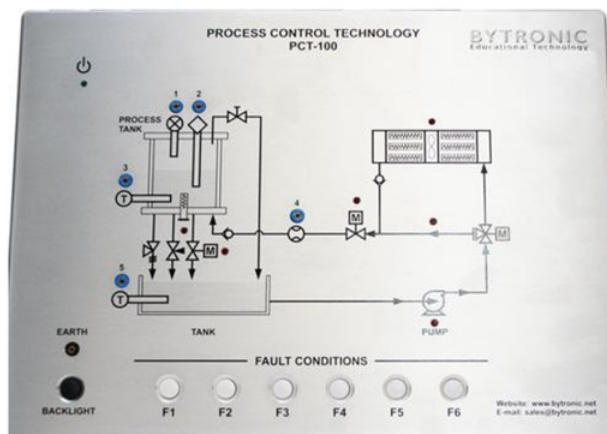


Figure 6: Process control loop

The Caldwell Method of modelling

The Caldwell method is used for modelling a system based on a process reaction curve to obtain data to be inputted into a mathematical model on mat lab with the creation of a transfer function. For a first order system, the equation used is as follows; $G(s) = \frac{1}{ts+1}$. T is found with the use of a process reaction curve as shown below in figure 7.

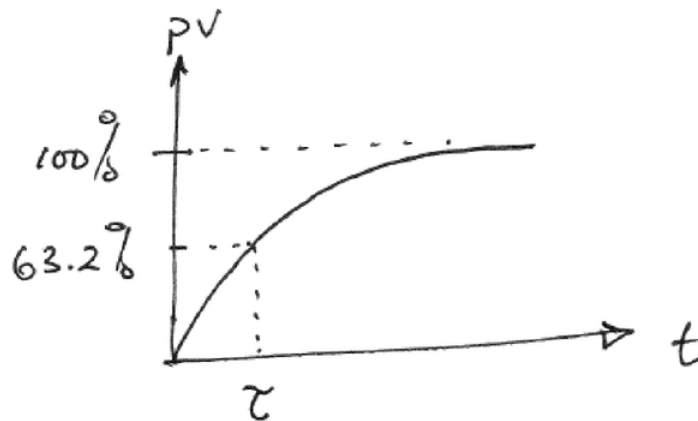


Figure 7: Process Reaction curve

This transfer function is then inputted into matlab and the response is indicated, the values of P, I & D can then be tuned or adjusted to produce a desired result.

For a second order system it uses the principle of the product of two first order systems [linked together](#), the transfer function is; $G(S) = \frac{1}{(T_1S+1)(T_2S+1)}$.

Using a process reaction curve again the Caldwell method now comes into play as it's needed to find T1 and T2. At 73% of the final value as shown in figure 8 below, the value of ty is found at, $1.32 \times (T_1 + T_2)$ which is rearranged to give the equation of; $T_1 + T_2 = \frac{T_y}{1.32}$, the fractional response is then found at the time; $\frac{T_1+T_2}{2}$. As shown below in figure 8.

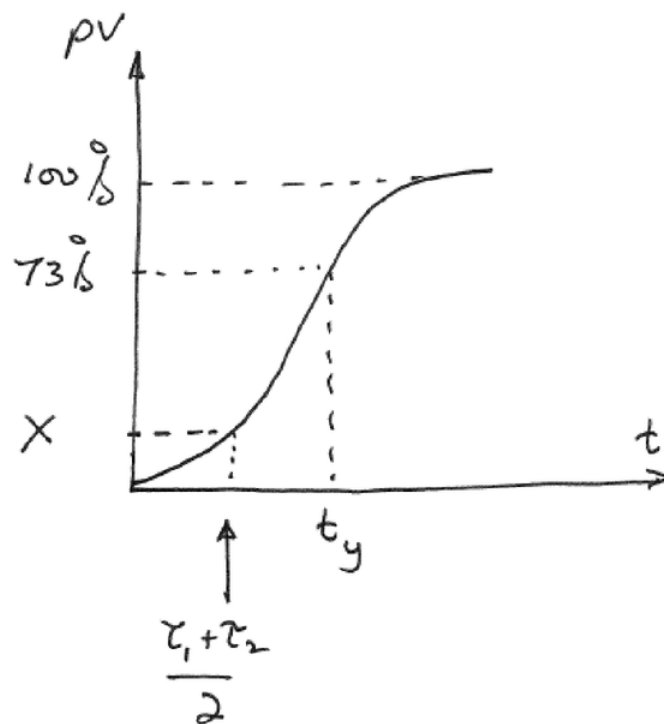


Figure 8: Second Order graph

The Caldwell reference graph is then used to find the; $\frac{T_2}{T_1 + T_2}$ and then to calculate the value for T_1 . The Caldwell reference graph is shown below in figure 9 and this equation and method is used in task 2 of the assignment to build a model in matlab for the assignment system.

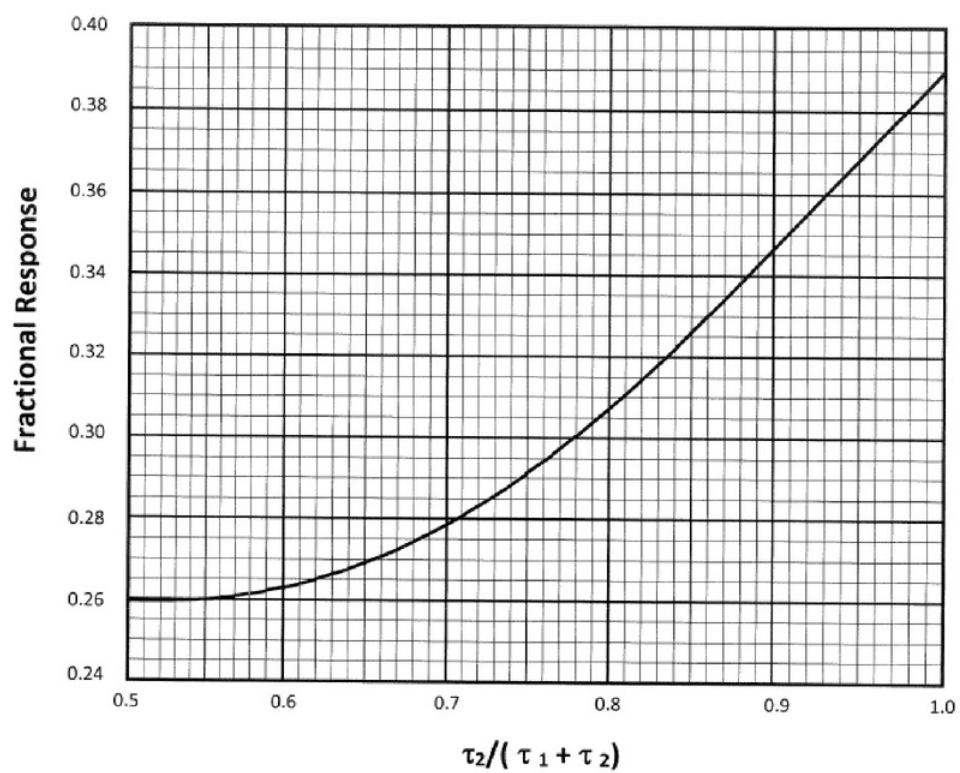


Figure 9: Caldwell Reference Graph

Ziegler-Nichols method of tuning

The Ziegler Nichols method methods of tuning which is based on the heuristic methods and is used to tune a PID controller. This method will attempt to produce good values for PI&D. The basic concept is to put the valued for I and D to zero gain and then K is increased until it reaches its ultimate gain. This tuning rule will work well with analogue systems or systems which are linear, sluggish or have a single pole lag response. The Ziegler Nichols method will presume a fictional phase adjuster that will not affect the magnitude and at the stability margin a 180 degrees phase shift surrounding the feedback loop. The Ziegler Nichols method will give a transfer function of the following; $\frac{k e^{-sT}}{(a+s)}$. This model will match the system response at a frequency 0 and at the stability limit.

Ziegler–Nichols method ^[1]			
Control Type	K_p	T_i	T_d
<i>P</i>	$0.5K_u$	-	-
<i>PI</i>	$0.45K_u$	$T_u/1.2$	-
<i>PD</i>	$0.8K_u$	-	$T_u/8$
<i>classic PID</i> ^[2]	$0.6K_u$	$T_u/2$	$T_u/8$
<i>Pessen Integral Rule</i> ^[2]	$0.7K_u$	$T_u/2.5$	$3T_u/20$
<i>some overshoot</i> ^[2]	$0.33K_u$	$T_u/2$	$T_u/3$
<i>no overshoot</i> ^[2]	$0.2K_u$	$T_u/2$	$T_u/3$

*This is the ultimate cycle method
not the process reaction method as
stated in the brief*

Figure 10: Ziegler Nichols

2. Flow Control System Modelling, Simulation and Testing

a) Using Caldwell Method

Using the bytronic flow control system with an open loop set up the first part of the task was to use the Caldwell method and develop a model to simulate the second order control system. The Caldwell method is shown above in the research and uses a process reaction curve as shown below in figure 11 and 12. The fractional response is show in the equation;

Fractional response. $T1 + t2 = ty/1.32 = 112.6/1.32 = 85.3$ m

The value for TY is taken from the value of 73% which is shown below in figure 11 at 112.6. the process reaction curve is created from the first piece of matlab code shown in figure 13. The second part of the code or matlab formulae is for the transfer function values also in figure 13.

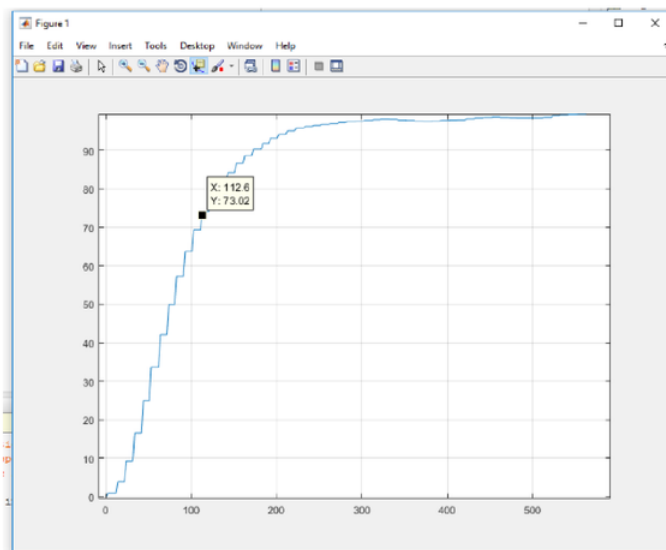


Figure 11: Process reaction curve ty

$T1+t2 = 85.3\text{ms} = 0.0853\text{ms}$ seconds

So the value of $x = 19.06/100 = 0.1906$

$85.3/2 = 42.5$

This was located on the graph as shown below in figure 12 to give the value of 'Y' to be 19.06. This value then becomes our 'X'.

$X = 19.06$

This is shown below in figure 12

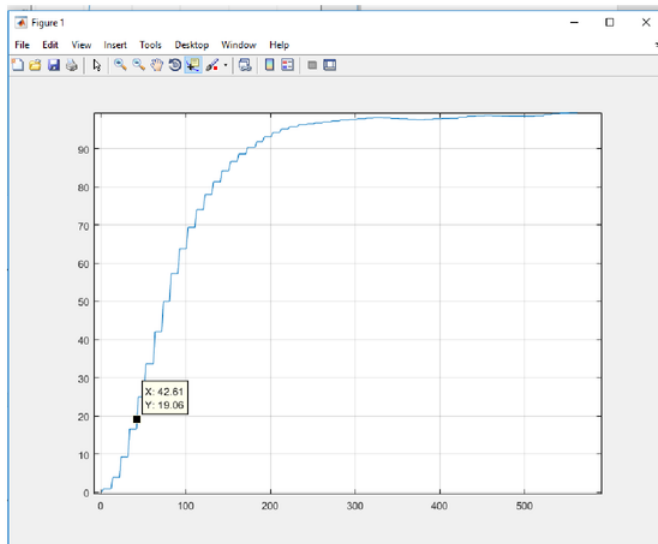


Figure 12: Process reaction curve X

From Caldwell method = 0.26

$T2/t1+t2 = 0.5$ same as on graph (the minimum value as the graph is level at 0.26 so 0.5 is the best result)

$$= t1 \ 85.3/2 = t2$$

$$= 42.65\text{ms}$$

Or 0.04265

$$\text{So } t1 \ t2 = 0.04265^2$$

$$= 0.001819$$

A transfer function was derived from this method of tuning to produce the transfer function below.

$$\text{Transfer function} = \frac{1}{0.001819s^2 + 0.0853s + 1}$$

This function then becomes out ^{spelling} mathematical model and using Simulink can be added into the system to produce results to be analysed. A code will be written into matlab with the values from the Caldwell method used to complete part B as shown below.

b) Simulink Model for System

The program matlab was opened which is a virtual design studio used to simulate and test calculated values with the use of a block diagram mode and code input mode. Part B asks for the system to be placed in an open loop system, this means it will not gain feedback from the system and the Caldwell method transfer function is used to produce a control system response. Below in figure 13 shows the code entered into matlab using the values gained for the transfer function to produce a system response in an open loop configuration. The first part of the code is for the process reaction curve and the bottom is for the values of the transfer function.

```
Editor - H:\MATLAB\Assignment1.m
Assignment1.m
1 - hold off
2 - %load data from file first into array
3 - load flow_log_2.txt;
4 - flow_rate = flow_log_2(:,1);
5 - plot(flow_rate);%blue line
6 - hold on
7 - grid on
8 - %check time column to get sample time and data length
9 - t=(0:0.001:length(flow_rate)*0.001);
10 - num1=[1];
11 - den1=[0.0018 0.0853 1];
12 - model_1 = step(98*num1,den1,t);
13 - plot(model_1);
14
```

Figure 13: Matlab code values

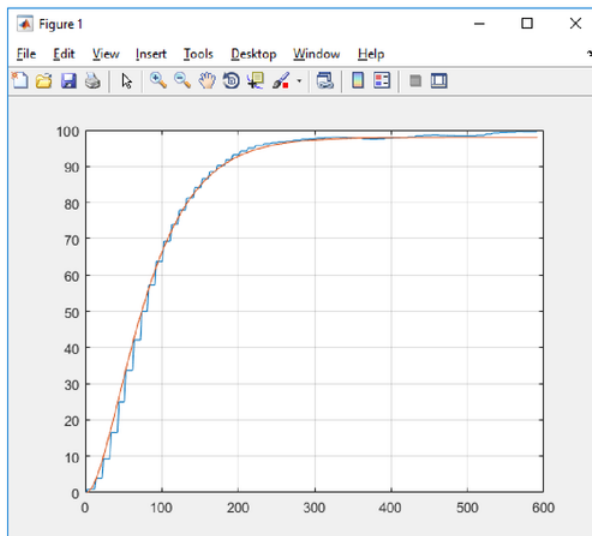


Figure 14: Process reaction curve

Figure 14 above shows the graph simulated for the process reaction curve when the model is played in matlab, this was used to gain values to calculate the transfer functions.

Below is the Simulink model designed in and open loop system for the values for the step input as calculated above and for the tuned values of the actual system response. The values can be adjusted to bring the responses closer but the introduction of a closed loop system with PID control will provide more modification to be made of the system.

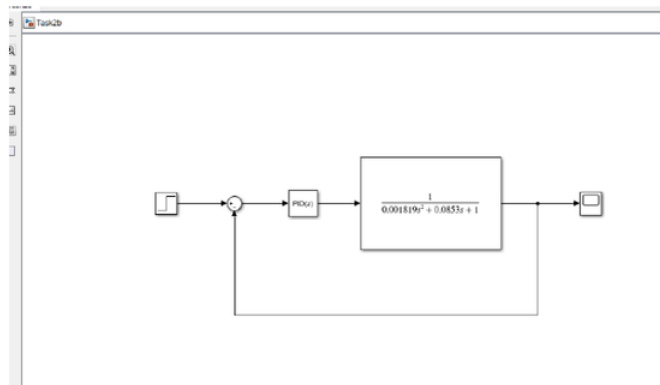


Figure 15: open loop transfer function block

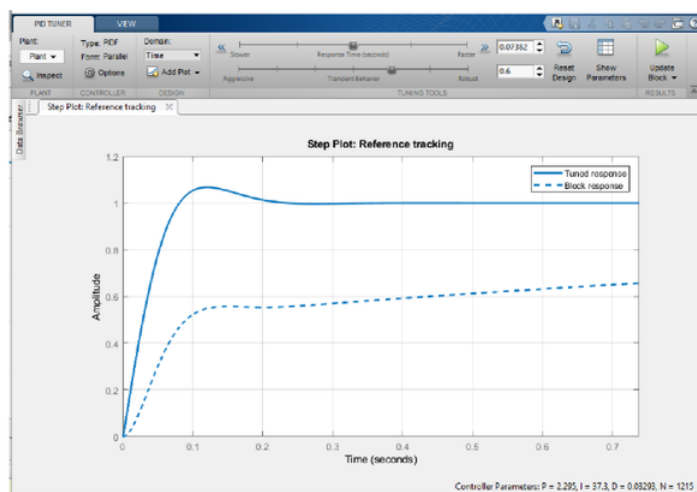


Figure 16; Tuned response v Block response for open loop

c) PID, P & PI Control

With values above for an open loop system obtained, these showed the system does not give accurate response and produces overshoot. This part of the assignment required the system to be changed to a closed loop system which meant that feedback was introduced and a PID controller was also introduced to control the system accurately. These systems are used widely in industry as it allows instrument tuning engineers to build process control system from the ease of a computer and simulate results without physically upsetting the system they are designed to control. An example would be control system in a refinery were if the values were altered or designed on a physically controller as its in service, then a wide range of process problems could occur upsetting refinery units and potentially causing a hazard to process units. This system can be built and simulated in a lab, then when the desired result is obtained it can be applied to the real world controller with limited implications.

With the Simulink model produced and the transfer functions entered the response was recorded as below with the model and values for P & I & D. the first results below are from the tuned values from the transfer function worked out, the two results after are from altering the PID settings.

Three sets of results are going to be simulated on matlab, the best results obtained will then be entered into the practical bytronic system were the control computer connected to the bytronic controller will produce a set of results based on the values for PID, this will be shown in part 'e'. This result will be shown and discussed below in part 'e' and then two more alterations to the PID settings will be made on the computer controlling the process rig to see if the change has improved the system response.

Figure 17 below shows the transfer function designed and built to create a closed loop system.

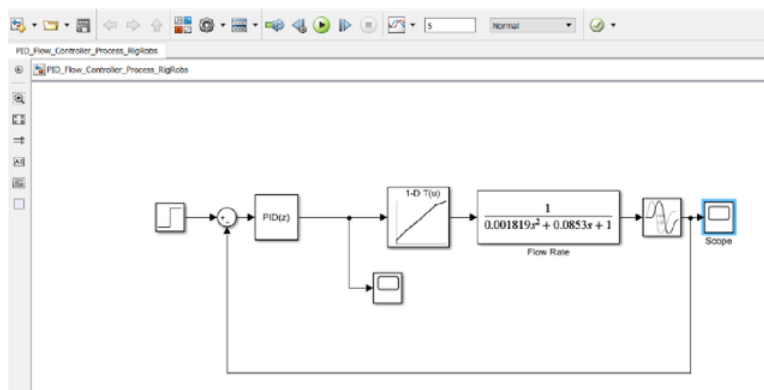


Figure 17: Closed loop control system

You have not explained the LUT

A time delay or system lag is introduced into the system and set at 0,04329 as shown below in figure 18. This is entered into the transport delay block of the system. Controlling a time delay can be challenging as the linear phase shifts may be created which will cause stability in the system so a correct time lag is essential. This time lag was obtained by using a Pico scope and the process control unit.

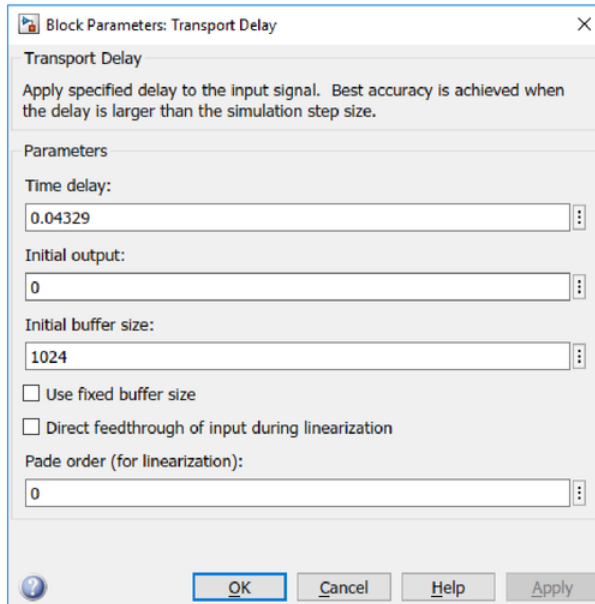


Figure 18: Time Lag

Changing the values for PID will produce different results in the system, the PID controller is designed to compute an output by summing together the PID values. The Proportional (P), in general will look at the difference between the process variable and the set point, usually increasing the P will increase the speed of response until it hits a point which is too big and cause oscillations. The integral (I) will sum the term of error over time, small values of error will cause the 'I' to rise unless it is zero. So the 'I' will try to force the steady state error to zero which is the difference between the set point and variable. The Derivative (D) will decrease the output if the variable is increasing too fast, an increase in the 'D' will cause the system to respond stronger to any error and will increase the systems response time. (National Instruments , 2011)

The first results obtained for the system response was using the transfer function worked out previously and using the auto tune button on the PID controller to produce the first set of results. Figure 19 below shows the tunes values for PID in the PID block window.

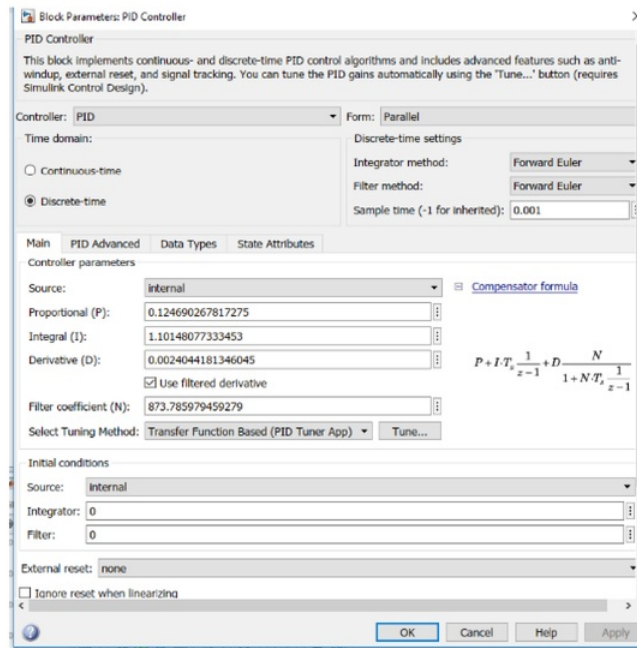


Figure 19: Transfer function PID tuned

The values were as follows, $P = 0.12469$, $I = 1.1014807$, $D = 0.0024044$. The scope was opened below in figure 20 to show an indication of how the system is performing with these values for PID. As shown below the response is smooth provides no overshoot but the response could be faster and smoother.

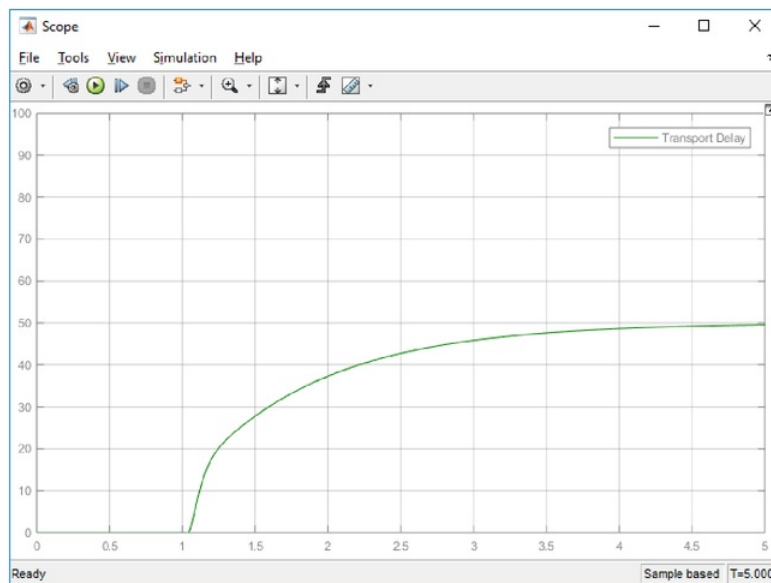


Figure 20: Response first values

The second set of results are shown below in figure 21. The PID settings were changed using a trial and error method to produce a smoother response and a better control system.

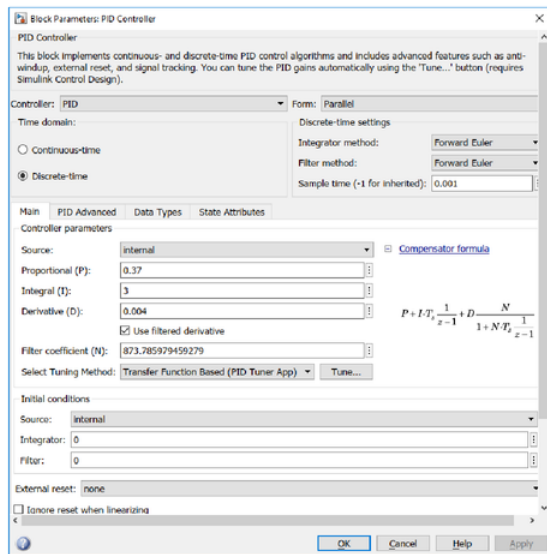


Figure 21: Second PID settings

The values were changed to the following; P = 0.37, I = 3, D = 0.004. These settings are explained above as to what effect they will have and the scope screen shot below in figure 22 shows that the response has changed and the system is performing smoother and faster.

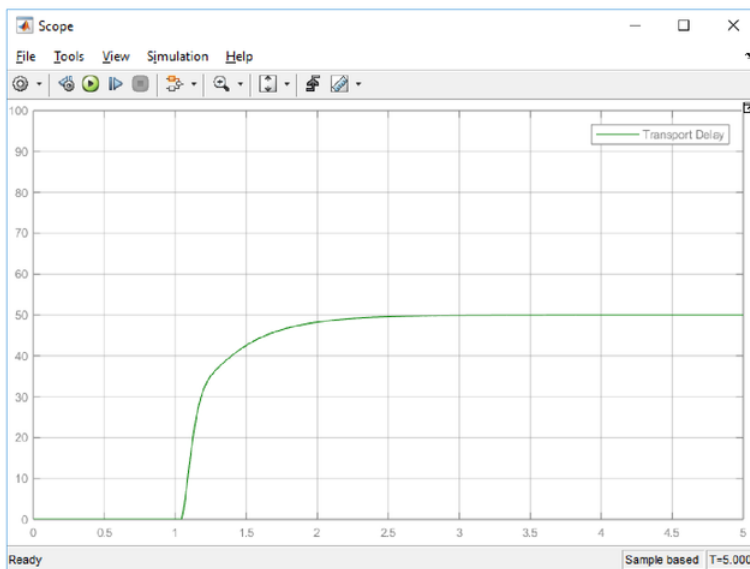


Figure 22: Second results scope

The third set of results are shown below in figure 23, these results were again used with trial and error but with this time small changes from the results obtained above as the results above were good but could be improved by a small margin.

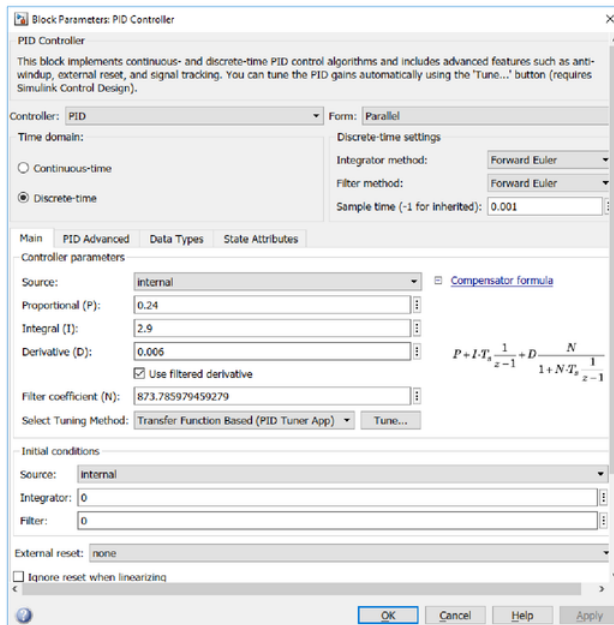


Figure 23: Third PID entered values

The values this time for PID were as follows, $P = 0.24$, $I = 2.9$, $D = 0.006$. These values were shown with the response below in figure 24 and shown an improvement on the system control. These values were the values that would be taken to the practical investigation in part 'e'.

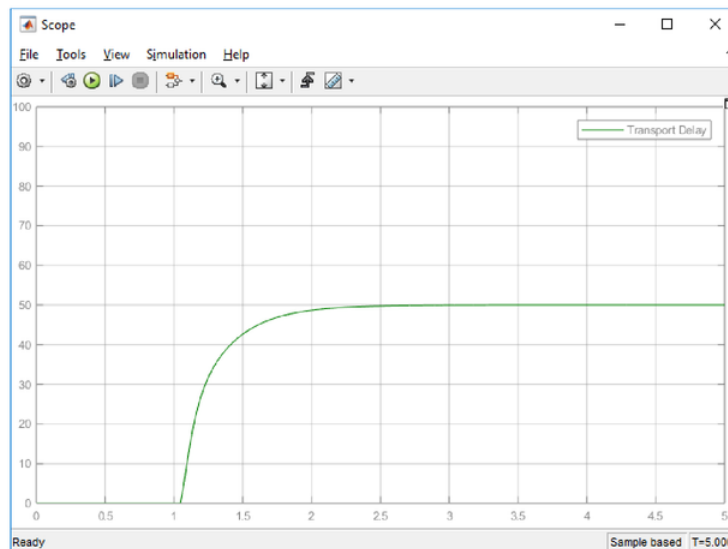


Figure 24: Response for third PID values

Figure 25 below shows the time lag used in the system as explained above of 0.043. this was obtained as stated above using the Pico scope and process control unit.

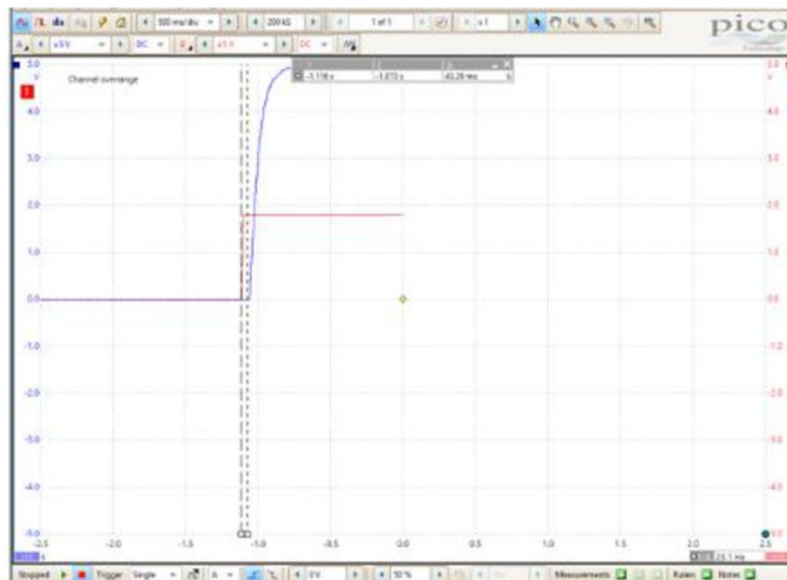


Figure 25: Time delay of 0.043

The next stage was to alter the system so that it looked at a using only a 'P', and 'PI' mode. The system block for the PID controller can be simply swapped for a 'P' or 'PI' controller by selecting the block and clicking replace. The same procedure as above was used with the 'P' setting being first. The transfer function tuned result would be used first followed by two more trial and error results to try to improve the system. The block diagram below in figure 26 was created for the 'P' controller.

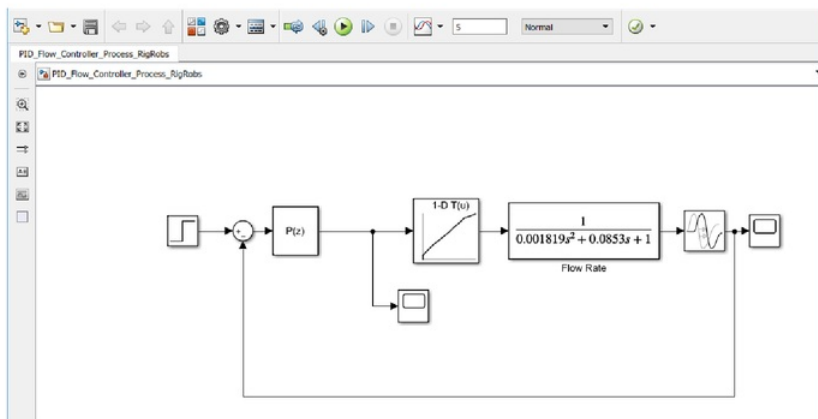


Figure 26: Block Diagram 'P';

The tune button was selected and the result for the transfer function tuned was shown below in figure 27.

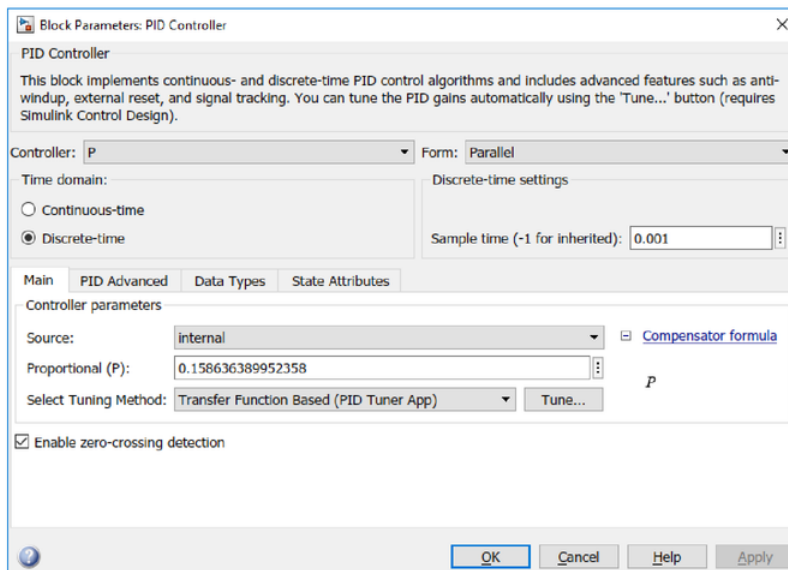


Figure 27: Tuned 'P' values

Figure 28 below shows the reaction of the control system with the value for only 'P' being used, as seen in figure 28 the output does not reach the desired value so this setting does not give a good control.

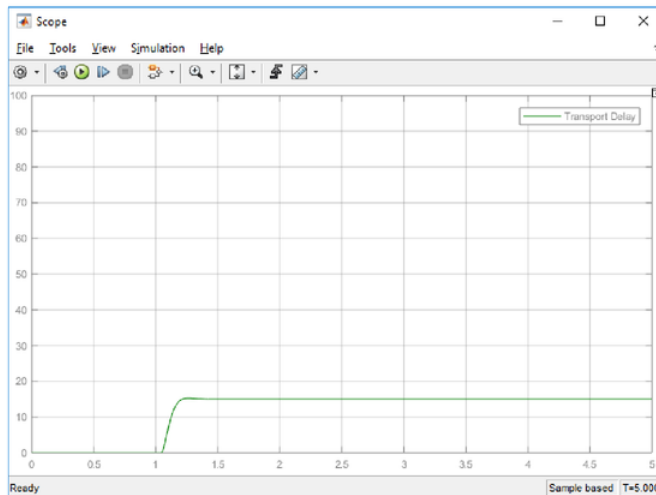


Figure 28: 'P' response from transfer function

The second simulation for 'P' controller was undertaken with a new value for the proportional, the trial and error system was used again and a new value of 1.5 was selected. Figures 29 and 30 below shows the result of this change.

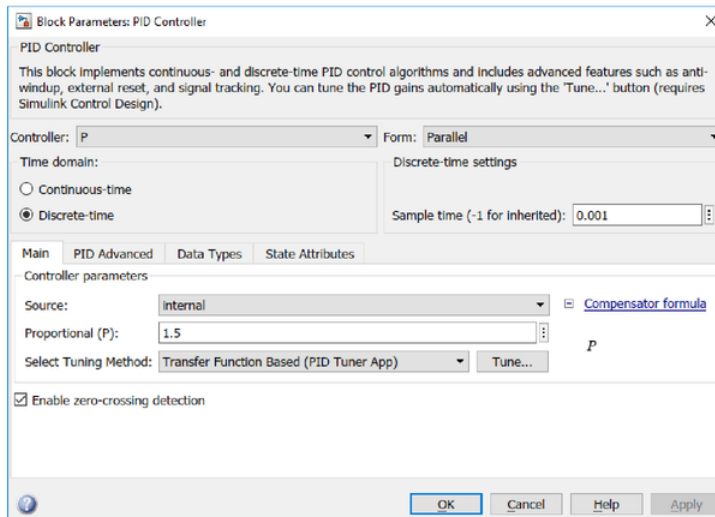


Figure 29: Second simulation for 'P'

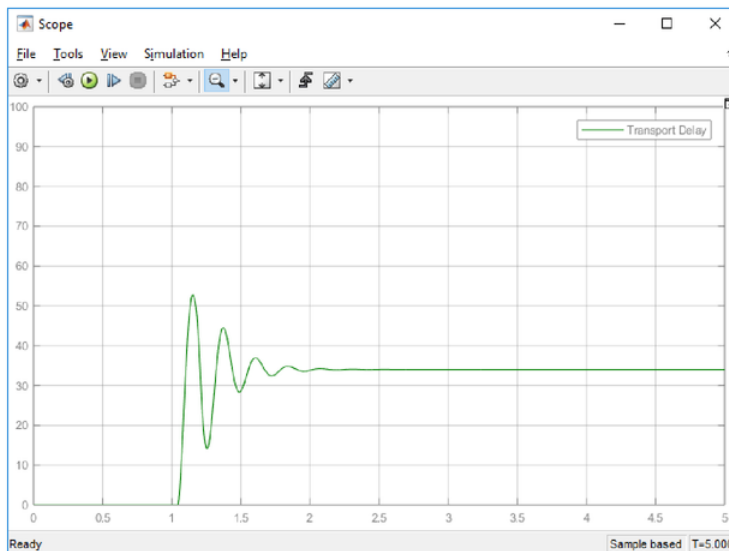


Figure 30: 2nd result for 'P' scope

As shown above in figure 30 the result has overshoot and undershoot and a oscillation effect is not very stable, this would not be good in a control system as it could cause big problems to the process it is trying to control.

The system was changed one last time to try to obtain a smooth system control with a proportional controller and the third result is shown below. The value for 'P' was changed to 1.65 as shown below in figure 31.

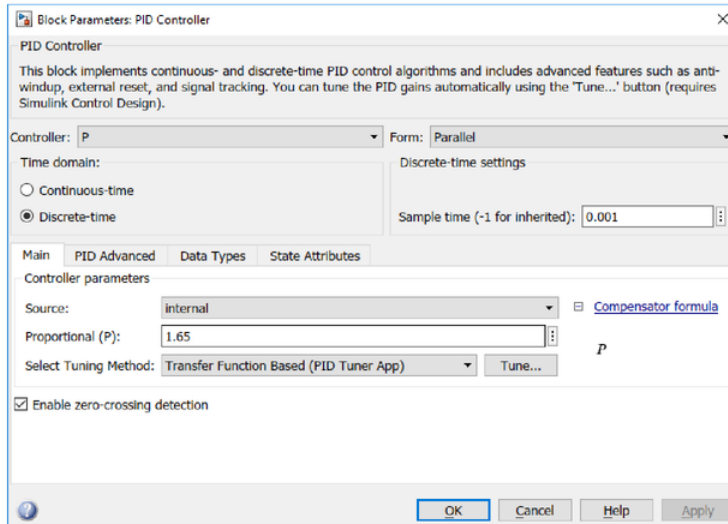


Figure 31: Final Simulation for 'P' control

The result as shown in figure 32 is that the system is creating huge oscillations so as explained above the value for 'P' has reached a point that the reaction speed is too high and is creating the oscillations.

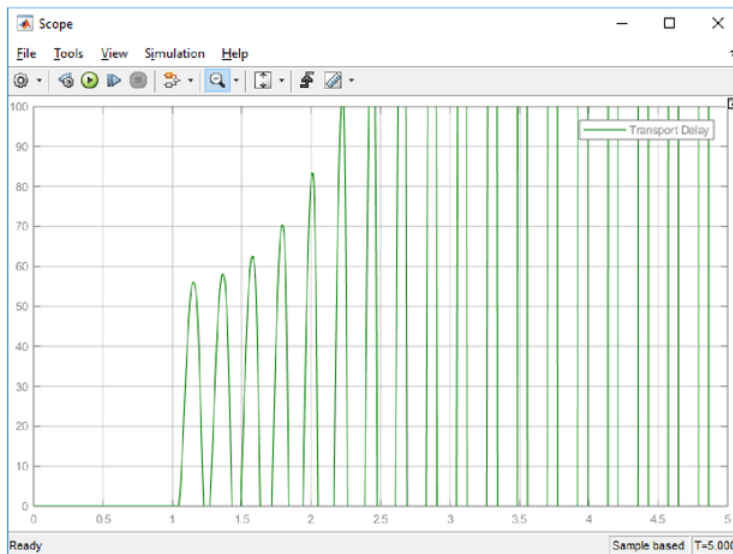


Figure 32: Final 'P' simulation scope

The above system shows that the controller does not work too well as a 'P' independent controller so the next step was to change the controller to a 'PI' controller and simulate some results.

The first results are for the system tuned with the transfer function values and are shown below in figure 33.

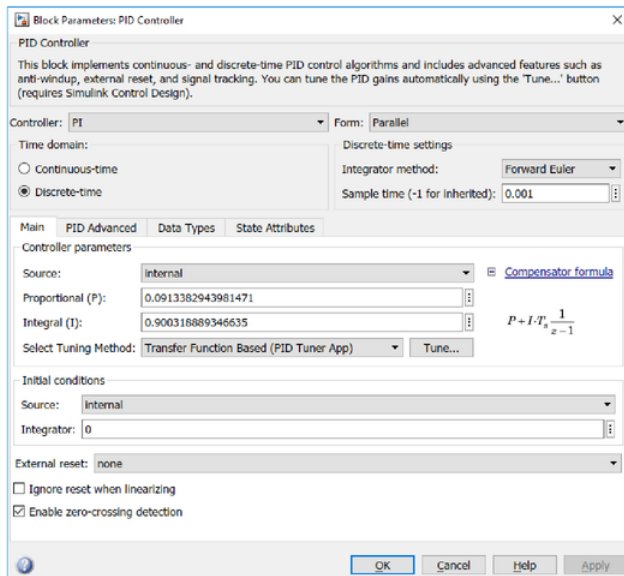


Figure 33: PI controller for transfer function tuned

Figure 34 below shows the scope of the system response, the response shows no oscillations or overshoot but the curve is not smooth and taken a long time. This will try to be improved by again trying two more values for 'PI'.

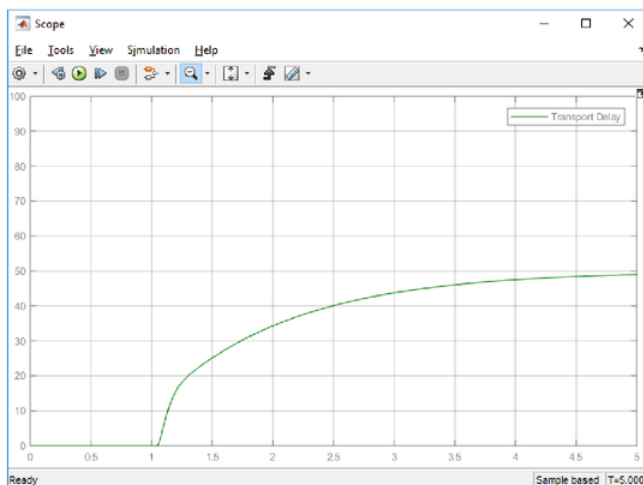


Figure 34: PI control scope from transfer function

The second simulation is shown below and the values for 'PI' are adjusted to, P = 0.15 and I = 9. Figure 35 below shows the values entered.

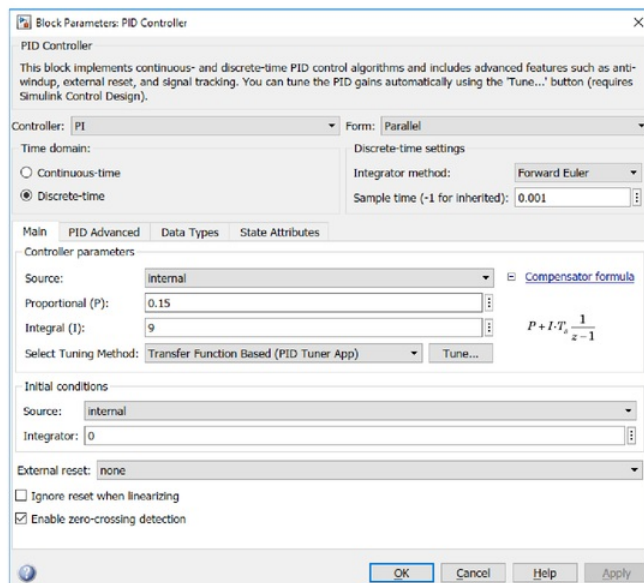


Figure 35: PI control simulation 2

The response was shown below in figure 36 and shows the control will overshoot with small oscillations which indicates that the system is not controlling well.

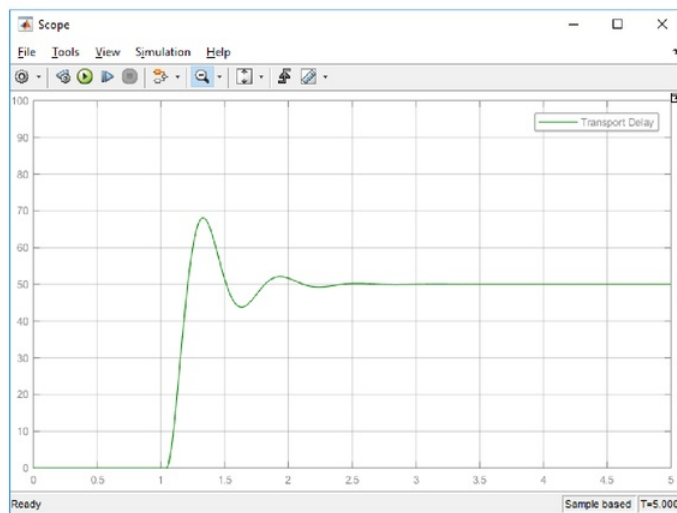


Figure 36: PI control scope simulation 2

The simulation was carried out a final time again changing the values of 'PI' to give P = 0.21 and I = 2.9. The values are entered below in figure 37.

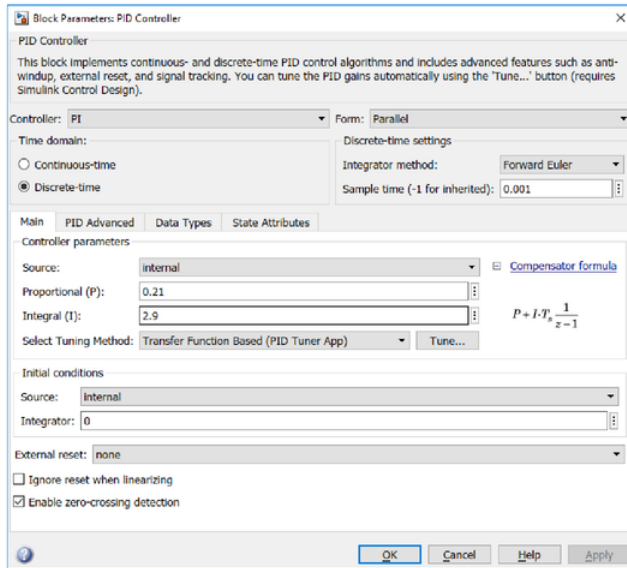


Figure 37: Third simulation for PI

Figure 38 below shows the response for changing these values and this results has shown a positive result, the response is a lot smoother and no oscillations are present. The result is not as good as the PID control above.

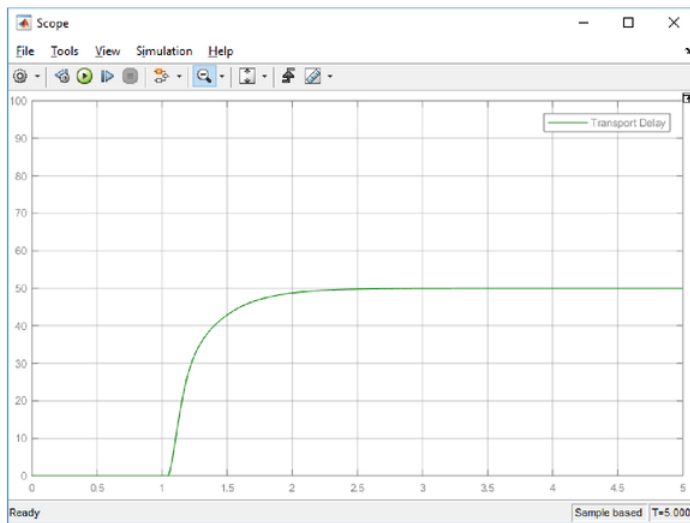


Figure 38: Third simulation for PI scope

d) Practical deployment of PID

This stage of the assignment looks at taking the best results simulated for the PID controller and inputting them into the bytronic control rig computer to practically test. The values for P, I and D were entered into the control rigs panel as shown below in figure 39. The rig and the control computer are then connected and the computer will display the response of the control rig as a real work application.



Figure 39: Bytronic control rig PID data entry

As seen above in figure 39 the machine allows values for 'Kp', 'Ki' and 'Kd' to be entered, they are entered as per the simulation and the result is shown below in figure 40. The values were $K_P = 0.24$, $K_I = 2.9$, $K_D = 0.006$.

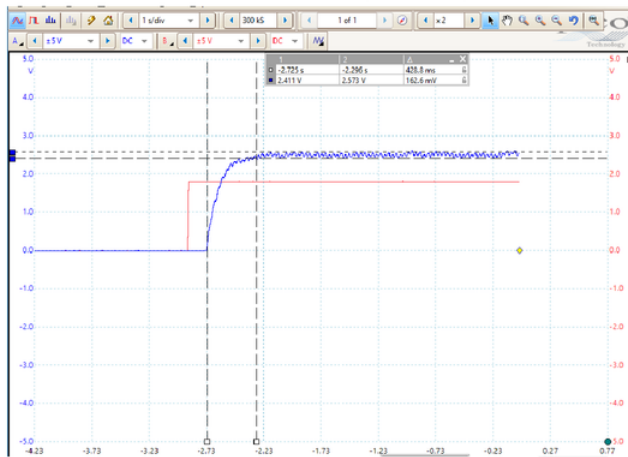


Figure 40: PID first result on test rig

The above results show that the best simulated values from the simulations have proved to work successfully on a practical deployment as the response is smooth and fast with no overshoot and very small movements in the output signal.

The same procedure as above parts is to be used to change the value for PID twice to see if any improvements can be made and what effect doing this has on the performance.

Figure 41 below shows the values changed by a very small margin to 'Ki' and 'Kd' and the response is shown to have changed very little but the output is slightly worse than before making this not worth changing. The values changed to were, $K_P = 0.24$, $I = 3.5$, $D = 0.01$.

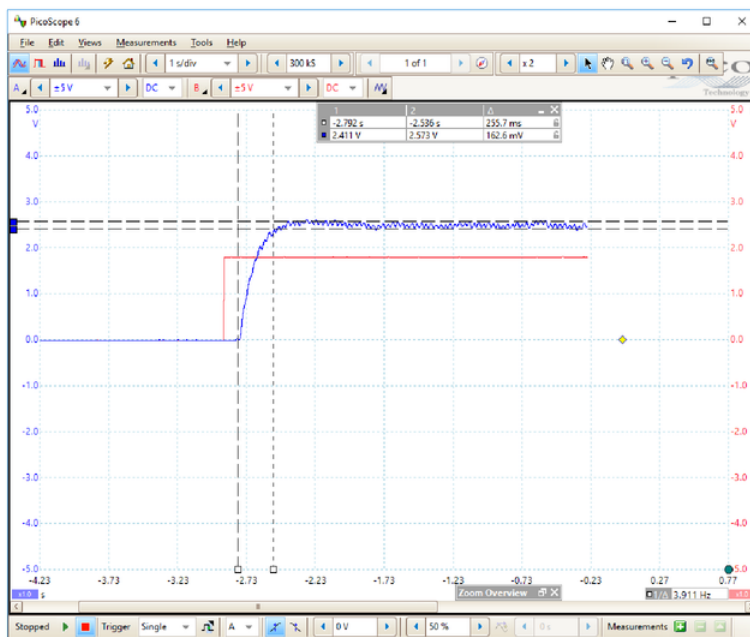


Figure 41: PID control on process rig values changed

The values were changed again a final time to try to improve the first response and are shown in figure 42 below for the values of $P = 0.24$, $I = 3.3$, $D = 0.020$. The result again didn't change much and was not as good as the initial values so it would not be worth changing the values.

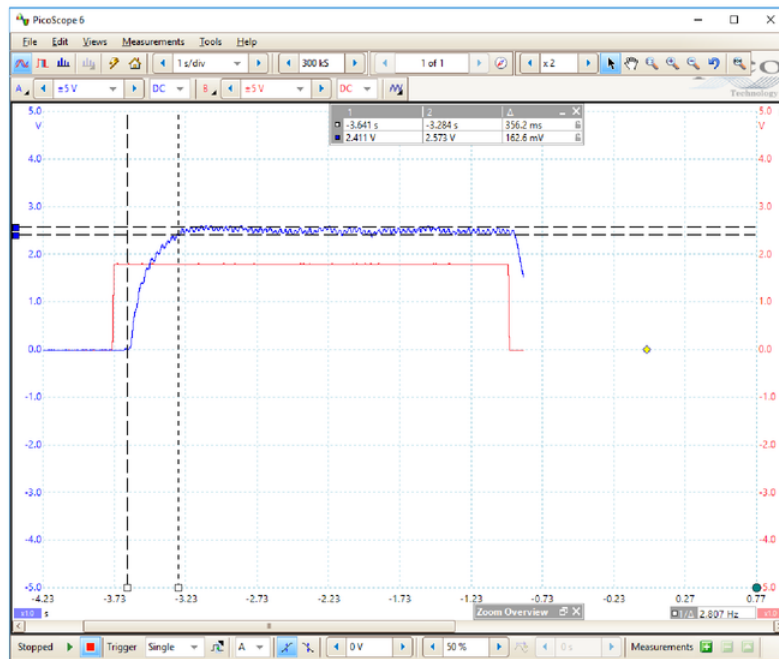


Figure 42: PID settings changed final time on process rig

e) Zielger-Nichols method of tuning

The Zielger-Nichols method is a way of tuning the control system as an alternative to the Caldwell method used above, as described and shown in the research this will be used with the values from the process reaction curve to calculate the required values. Figure 43 below shows the results of the Ziegler Nichols method calculated into a table in figure 44 and shown on the process reaction curve in figure 43.

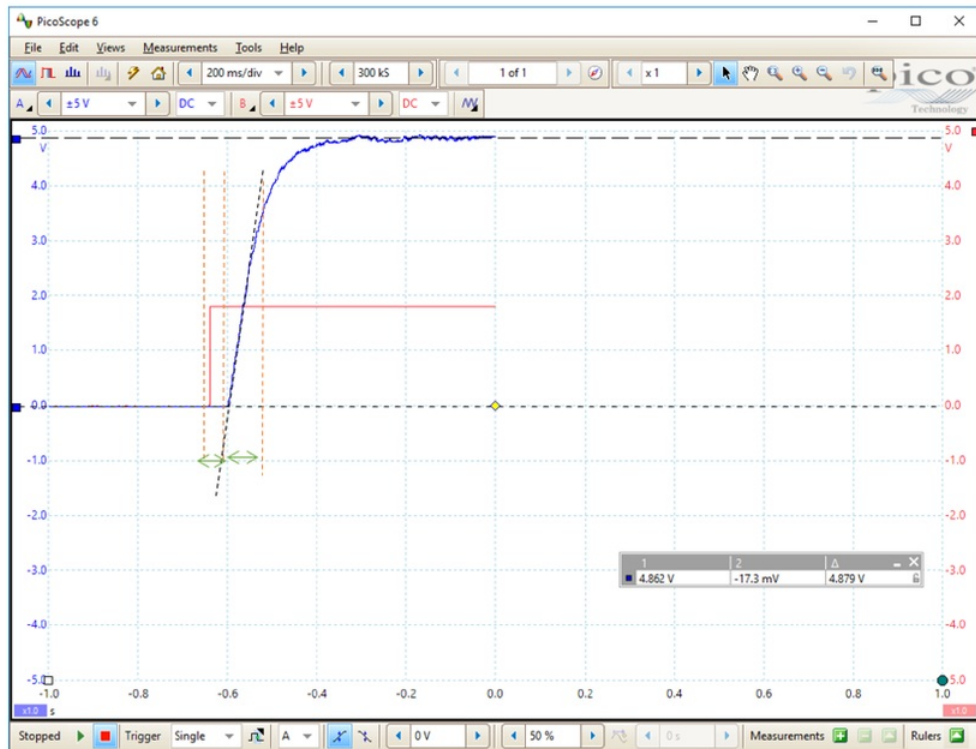


Figure 43: Process reaction curve, Zielger-Nichols

Process reaction curve

$$T = 0.09s$$

$$L = 0.04$$

$$R = 100/T = 100/0.09 = 1111.1$$

Control Mode	Kp	Ki	Kd
P	$100/(1111.1 \cdot 0.04) = 2.25$		
PI	$0.9 \cdot 100/(1111.1 \cdot 0.04) = 2.025$	$2.025/(3.33 \cdot 0.04) = 15.2027$	
PID	$1.2 \cdot 100/(1111.1 \cdot 0.04) = 2.7$	$2.7/(2 \cdot 0.04) = 33.75$	$0.5 \cdot 2.7 \cdot 0.04 = 0.054$

Figure 44: Zielger-Nichols Calculations

With the results obtained it is clear that the model approach would give better results than the Zielger-Nichols method so it was decided in the lecture not to add this back into the system or practical controller.

Why didn't you use these values of Kp, Ki and Kd in the practical PID controller? Your decision makes no sense as these values may have worked?

3. Conclusions and recommendations

Overall the assignment and tasks proved to be a success with lots of learning points and good practical results, the conclusions will be set out by each task then with an overall conclusion of how the tasks are compared. Recommendations will be set out at the bottom.

Task 1 looked at research into instrument and control systems with flow being the main topic for research with the addition of research on the control rig used in the assignment and the two methods of providing open loop control over a system. The first part of the research gained insight and knowledge from reputable sources on different types of flow transducers and signal conditioning methods. Using these sources along with classroom notes a great deal of information was learnt and built on during this research, this research also allowed a practical way of thinking approach to be applied when using and designing the control systems in task 2. The second part of the research was to research the Bytronic process rig used in the assignment which provided a great deal of understanding into the operation and use of control rig, this was then used in task 2 when operating the control rig. The last part of the task was to research the Caldwell and Zielger-Nichols methods of tuning a controller which provided the equations and information needed to be built upon in task 2 to complete the assignment. Overall task 1 set out good underpinning knowledge on the systems used to complete the assignment.

Task 2 was the simulation, testing and practical aspect of the instrument and control assignment. This section of the assignment first looked at calculating and developing a model using the Caldwell method control an open loop process system, the system designed and applied provided a good model but the closed loop system used further on in the task proved to be better this and would be the control of choice. The second part took these results and compared them to simulated adjusted results which didn't improve the system much. A mathematical analysis was then carried out to comment on the performance of the system.

The next step was to introduce a 'P', 'PI', 'PID' controllers to provide a more advanced control to the system, these systems worked well with the models produced being best for the PID system which provided a good smooth fast response and when tested on the control rig proved to also work well. The next step

was to practically apply the PID values and as stated above the model used provided good positive response and could be used in a real world scenario due to its good quality control. The last part of task 2 was to apply the Zielger-Nichols method of tuning which proved to not provide good results or a good model so would not be used as a control method due to the poor results. The research part helped make this part easier to calculate and understand.

Overall the assignment was a success, the PID method of closed loop control has proved to be the best method to provide control on a control system and as experience has shown in real work scenarios, PID is the first choice for many applications in industry. With further time and experience better terminology could be used in certain aspects of the assignment as well with more advancements to descriptive parts of the tasks.

A recommendation would be to add basic research into the level and temperature aspects of the bytronic control rig to add further instrumentation knowledge of the apparatuses.

4. Citation List

Works Cited

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technology

*Good range of sources although
more were expected at this level.
However, your listing method is not
correct. Select Harvard as your
method of referencing within MS
Word next time*

5. Appendices

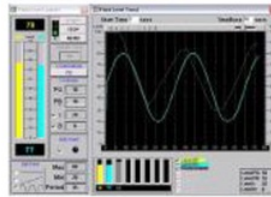
BYTRONIC
Educational Technology

Process Control Technology PCT-100



Key Features:

- Control and measurement of Temperature, Level, Pressure and Flow
- PID control PC SCADA type software with Control and Data Acquisition
- LCD meters and LEDs provides instant information
- Mimic of the rig on the control console
- Test and measurement points for the transducers and fault insertion switches
- Connection to PC through a USB
- Control console can be connected to either PC or a PLC
- Clear process tank and pipes



The PCT-100, Process Control Technology unit, is a fully integrated, self-contained bench top apparatus consisting of a Process Module, and a Control Console with a built in power supply. A Windows based software with full control and data acquisition is included. A number of experiments in process control are included covering Flow, Level, Pressure, Temperature.

The control console is easily connected to a PC using the USB connection or to a PLC using D type connectors. The console has a mimic of the process module on the front and includes fault switches, and test points from all of the transducers. Level is measured using a 0 to 10V Magnetostriuctive sensor; pressure is measured using a Gage 0 to 5bar sensor and Flow using A turbine flow rate sensor. PT1000 are used to measure temperature in both the sump and process tank. A diverter valve can be used to direct the liquid through a forced air-cooling process to cool the liquid in the system. Two proportional valves are used to control flow into and out of the process tank, a manually adjustable needle valve is used to add disturbances to the system and a pressure relief valve fitted for safety.

Data is displayed on the five LCD displays fitted to the process module, and through the software data can be monitored, saved or printed. The software has a PID controller with Supervisory Control and Data Acquisition and trending features.

Curriculum Coverage

- | | | | |
|------------------------------------|--|---|--|
| • Introduction | • Final value theorem | • Process models from time domain tests | • Pulse transfer functions |
| • On/off control | • The Routh-Hurwitz test | • PID controllers | • Z transform initial and final value theorems |
| • Open loop control | • Bode plots | • Proportional control term | • Stability of sampled data control systems |
| • Closed loop control | • Bode phase lag versus frequency plot | • Integral control term | • Inverse Z transformations |
| • Basic control principles | • Nyquist plots | • Derivative control term | • Digital controllers |
| • 1st. order systems | • Process modelling | • Multi term control | • Digital three term controller |
| • Transfer functions | • Process models from step data tests | • Ziegler Nichols tuning | • The effects of sampling time |
| • Block diagrams | • Process models from frequency response tests | • Digital control | • Use of simulation |
| • Assessment of system performance | | • The analysis of digital control systems | |
| • Transient responses | | | |
| • Control system instability | | | |

Labworks:

- | | | |
|-------------------------------------|----------------------------|---|
| • Proportional control | • Ziegler / Nichols tuning | • Bode plots |
| • Proportional and integral control | • Temperature control | • Flow loop model using Caldwell's method |
| • Saturation and integral windup | • Fluid level control | • Flow loop model using Sundaresan's method |
| • Three term or PID control | • Open loop control | • Design of controller for PCT-100 flow loop. |

Process Module			
Sump tank volume	8 litres		
Process tank volume	4.5 litres		
Maximum flow rate	≥ 3 litres per minute		
Heating element power	48v dc 400W		
Control elements	2 x 24V d.c. proportional valves 1 x Manually adjustable disturbance needle valve with incremental markings 1 x Finger type drain valve		
Pressure transducer	0 to 5 bar		
Level transducer	Magnetostrictive position sensor		
Flow transducer	Turbine flow rate sensor		
Operating pressure	14 bar maximum		
Burst pressure	170 bar		
Operating temperature	-20°C to 100°C (ambient +80°C for cable)		
Input power	5 to 24 VDC @ 8mA		
Accuracy	±3% of reading		
Repeatability	0.3% of full scale		
Flow range	Litres per minute 0.5 to 5		
Temperature transducers	2 x Pt1000 Platinum Resistance Thermometers		
Pump	24v and 7 litres per minute open flow rate with 1.5 bar safety cut-out		
Safety switch	3 bar Cracking Valve		
Cooling system	Radiator with Forced Air Cooling		
Number of LCD displays	5 x Fluid level: process tank and sump tank temperature: pressure level and flow rate		
Indicators	4 x Heater on: drain valve open: diverter solenoid active and cooler active		
Connections	2 x 25 way 'D' connectors 1 x Power connector for the heater		
Control Console			
Fault switches	6 x Illuminated push to latch, (self resetting on power off)		
Front of console	Graphical representation of process module		
Test points	5 x Heater output, level output, sump tank and process tank temperature output, flow rate		
Indicators	6 x Heater on: drain valve open: flow and diverter solenoid active: pump active and cooler active		
Connections	2 x 25 way 'D' Connectors for connection to process module/rig 1 x 9 way 'D' Connector and 1 x 15way 'D' connector for connection to PLC 1 x Power connector for heater 1 x USB connection for PC 1 x Mains power connector		
Power supply voltage	100-250V AC @ 50/60Hz		
Software			
<i>Windows based SCADA type software and interface with data logging, printing and saving features</i>			
Weight and Dimension:			
Un-Packed		Packed	
Approximate Dimensions (mm)	Module (Rig) - 1030W x 750H x 380D Control Console - 340W x 250H x 200D	Approximate Dimensions (mm)	Module (Rig) - 1100L x 650H x 460D Control Console - 500L x 380H x 500D
Approximate Weights	Module (Rig) - 34Kg Control Console - 10Kg	Approximate Weights	Module (Rig) - 39Kg Control Console - 12Kg
Required		Ordering Information	
<i>A suitable PC with Minimum: Pentium processor, 1GB RAM, 20GB HDD, CDROM Drive, USB 2 interface and Windows XP or above</i>		Model Number: PCT-100	
<i>Consists of:</i>		1 x Process module 1 x Control console with power supply 1 x Set connecting cables, USB, Power cord, 'D' and heater connector cables 1 x User and courseware Manual 1 x CD with Windows based SCADA type software	
Bytronic Limited 124 Anglesey Court, Towers Business Park, Rugeley, Staffordshire, WS15 1UL, United Kingdom Tel: +44 (0)3456 123 155 Fax: +44 (0)3456 123 156 Email: sales@bytronic.net Website: www.bytronic.net			

PSDE5011 Assignment 1

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

60/100

PAGE 1

Text Comment. submission date?

PAGE 2

PAGE 3

PAGE 4

PAGE 5

PAGE 6

PAGE 7

PAGE 8

PAGE 9

Text Comment. How does this differ from the Venturi method?

PAGE 10

Text Comment. This information is incorrect and does not apply to the equipment you have worked on.

PAGE 11

Text Comment. This is a different piece of equipment to what you have worked on. Your system has a dc pump. What you are describing is part of the new version of the equipment available from Bytronic with a pressurized container. It is a shame you did not spot this!

PAGE 12

Text Comment. linked together

PAGE 13

Text Comment. This is the ultimate cycle method not the process reaction method as stated in the brief

Text Comment. milliseconds

Text Comment. seconds

Text Comment. error

Text Comment. spelling

Text Comment. You have not explained the LUT

Text Comment. Why didn't you use these values of Kp, Ki and Kd in the practical PID controller? Your decision makes no sense as these values may have worked?

Text Comment. but a different method was researched!

Text Comment. Good range of sources although more were expected at this level. However, your listing method is not correct. Select Harvard as your method of referencing within MS Word next time

GRADING FORM: CSG-RUBIC

NATHAN SMITH

60

RESEARCH-INFORMED LITERATURE



Section 1: Your research - Two of your research items Venturi and DP appear to be the same, both use the Bernoulli equation. Your research into the Bytronic rig is incorrect. You are referring to a different piece of equipment. Your research into Caldwell is good but you have not read the brief carefully enough for the Ziegler Nichols method choosing to research the ultimate cycle approach

13

rather than the process reaction method. (10/20)
Section 4: Your use of Harvard for citing and listing.
Good range of sources although more were expected at this level. Citation method is correctly applied. However, your listing method is not correct. Select Harvard as your method of referencing within MS Word next time. (3/5)

KNOWLEDGE AND UNDERSTANDING

 Section 2: Explanation of the control system and model - A good explanation given but you did not explain the LUT. (10/15) **10**

ANALYSIS

 Sections 2 and 5: Analysis of model, simulation and practical testing - You have not mathematically analysed the model as required by task 2 part c . Simulation results are good but have not been analysed in any depth. Correct approach used for the practical Ziegler-Nichols tuning but values were not used in the PID controller as required by task 2 part f, and no results are given. (9/20) Section 3: Conclusions and recommendations - Satisfactory with one recommendation. (5/10) **14**

PRACTICAL APPLICATION AND DEP.

 Sections 2: Development of the model, use of Simulink – Good (10/10) Sections 2: Practical tuning – Good for the model based approach but not completed for Ziegler Nichols (3/5) Section 2: Presentation of results - Good (4/5) **17**

SKILLS FOR PROFESSIONAL PRAC.



All sections - A well structured report with mostly clear figures listed and referenced correctly. There are a number of grammatical and spelling errors.
(6/10)

6