



PROCESS CONTROL

PID

Process Control System



MATRIX

CP3720

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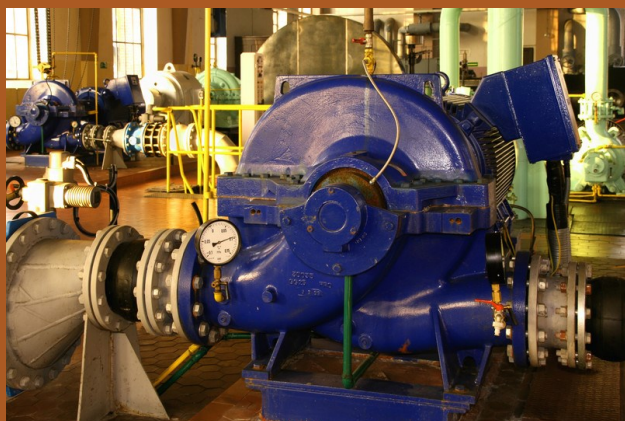
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Worksheet 1

Understanding the drive

Process control Worksheets



In Process Control pumps for water, oil, food-stuffs, air and other materials are at the heart of every system. Understanding how to control driving devices is an important part of understanding how to understand how to control processes.

This photograph shows a pump in a water pumping station.

	Flow	Level	Temperature	Pressure
Drive system	Water pump	Water pump	Heater	Air pump
Loss actuator	Variable valve	Variable valve	Baffle	Digital valve with manual adjuster
Loss method	Restriction	Fluid leakage	Heat loss	Air leakage

Over to you:

- 1) Make sure that you have read the Process Control Reference Manual and understood how your system works, have installed drivers, software etc.
- 2) For the system you are using open the Manual application. E.g.: Open_Flow_manual.bat'.
- 3) Press the 'GO' button in the top left hand corner. If your unit is connected properly and the drivers are installed then the 'APPLICATION', 'COMMUNICATIONS' lights should illuminate.
- 4) If you are using the Flow or level apparatus you will need to calibrate and zero the sensor.
- 5) On all the systems there is a loss adjustment mechanism: e.g. a valve. Adjust this so that there is no LOAD.
- 6) Slide the DRIVE slider so that it is off - at position

0. Press the RUN button. Your system is now running but the drive is off.
- 7) Move the drive slider up to 50% and monitor what is happening in your system. Try different % drives.
- 8) Adjust the LOAD so that there is some load in the system and the system is stable. With Level and Flow load is regulated by a mechanical valve with many settings. With Temperature this is a fan and a baffle that you adjust manually. With Pressure this is an on/off valve with an adjustable air loss aperture.
- 9) With the LOAD at this given level, vary the DRIVE output upwards between 0 and 100% in 10% steps. Let the system settle and make a note of the values in the values in the table and graph on the next page.

Worksheet 1

Understanding the drive

Process control Worksheets

Flow

LOAD %:

Drive output %	Manual reading l/h
10	
20	
30	
40	
50	
60	
70	
80	
90	
100	

Level

LOAD %:

Drive output %	Manual reading mm
10	
20	
30	
40	
50	
60	
70	
80	
90	
100	

Temperature

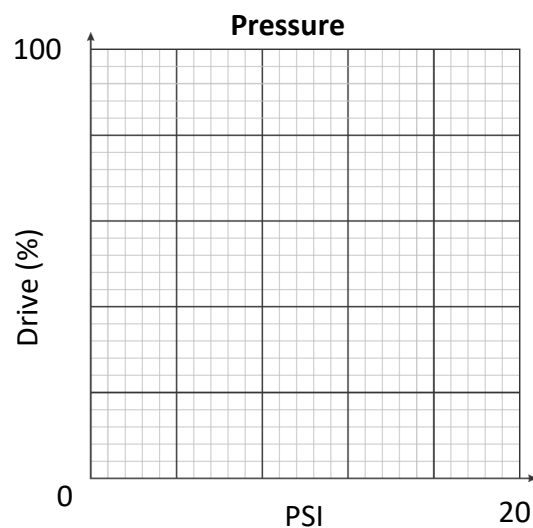
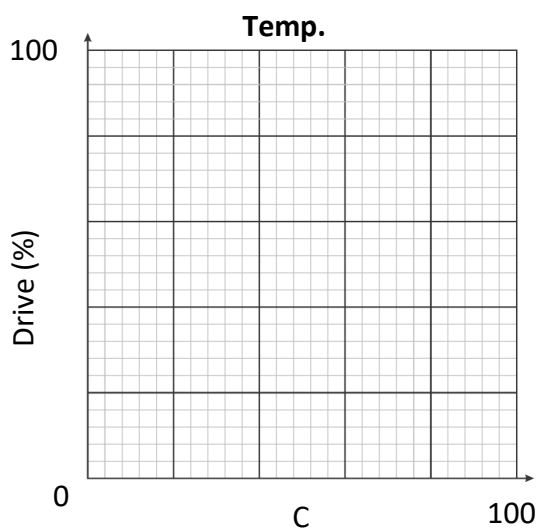
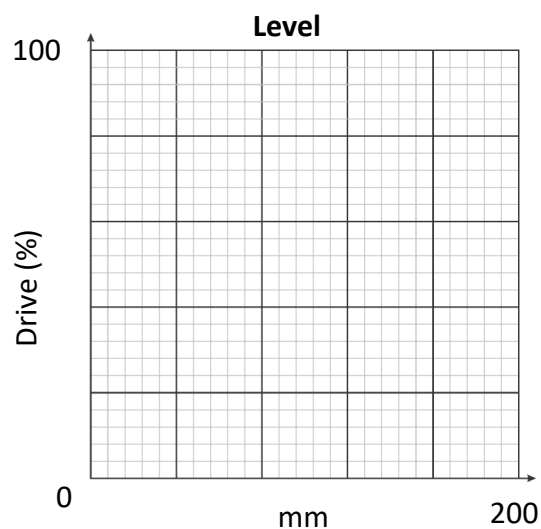
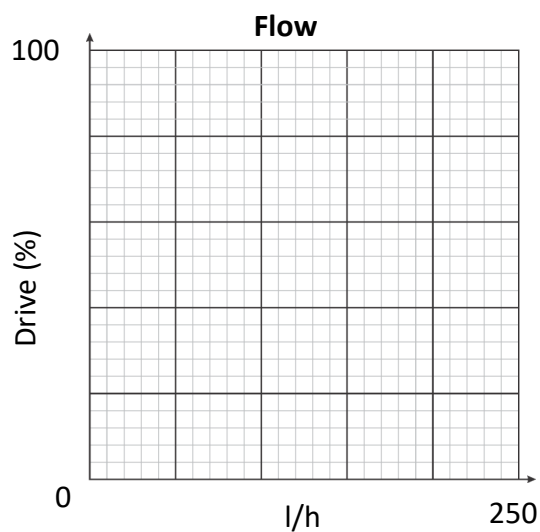
LOAD %:

Drive output %	Manual reading C
10	
20	
30	
40	
50	
60	
70	
80	
90	
100	

Pressure

LOAD %:

Drive output %	Manual reading psi
10	
20	
30	
40	
50	
60	
70	
80	
90	
100	



Worksheet 1

Understanding the drive

Process control Worksheets

So what?

Range

These experiments show you that a system with a given load has a certain RANGE. The output does not go down to 0 or up to infinity. It has a minimum rate that can be achieved and a maximum rate that can be achieved.

The range is determined by several things:

- The capability of the drive: the power of the pump, or heater
- The natural load in the system: friction in pipes, heat load
- The purposeful load in a system - the leakage, the cooling effect of the fan. You choose this load.

Drive

The system will have a certain power. How much power is important for the overall performance of the system. However for the purposes of the system equations the thing that is really important is the percentage of drive in the system: from 0% power to 100% power. This is specified as a percentage.

Output scaling factor

Each system has a maximum system value. The maximum value of the drive is 100%. The Output scaling factor for each system is defined as the ratio of max drive to maximum system value. The maximum system value for Pressure is the point at which the pump can supply no more air in the system: around 20 psi. For temperature this is around 100C: the max we want the temperature to go up to. For level this is 200mm - the level at which the overflow pipe

takes water out of the cylinder. For flow this is around 250l/h - the maximum achievable.

Over to you:

For each system calculate the Output Scaling Factor.

Flow:

OSF: _____

Level:

OSF: _____

Temperature

OSF: _____

Pressure

OSF: _____

For each system experiment with the values of load so that you understand how each system works.

Worksheet 2

Understanding the sensors

Process control Worksheets



Sensor outputs need to be converted by computers to values that make sense in our control equation. For some systems this is taken care of in the sensor itself. Other systems need calibration. All systems need checking to make sure that the sensor value is correct.

This photograph shows a typical flow rate sensor like the one in the Flow rig.

Over to you:

- 1) Make sure that you have read the Process Control Reference Manual section on Sensors and their operation. This tells you how each sensor is calibrated.
- 2) Open the Manual application by running 'Open ManualControl.bat'.
- 3) Press the GO button in the top left hand corner.
- 4) Adjust the LOAD so that there is some load in the system. With Pressure, Level and Flow this is a mechanical valve. With Temperature this is a fan and a baffle that you adjust manually.
- 5) The procedure for zeroing and calibrating the sensor for each Process Control system is slightly different. Follow the relevant one to make sure that your system is calibrated.

Flow:

- 1) The Scaling factor can be calculated from the datasheet as shown in the Reference document.
- 2) For several values of drive make a note of the software reading and the Rotameter sensor reading. Making a graph and measuring the slope to determine the Calibration factor you need.
- 3) Adjust the Calibration factor property in the software and verify that the software now gives the same reading as the Rotameter.

Level:

- 1) Open the valve to empty the level tank.
- 2) Start with a low scaling factor - say 0.001 and enter this in the Properties.
- 3) Open the valve until the gauge reads 0.
- 4) Click Zero on the software.
- 5) For any value of pressure read the level manually on the gauge and read the value from the software. Enter a calibration factor in the software properties and repeat the process to verify that this is accurate. The Sensor has a 24bit (0 to 16 million) so the numbers here

Worksheet 2

Understanding the sensors

Process control Worksheets

will be very small.

Temperature:

- 1) The scaling factor here is 1. Enter this value in the software properties.
- 2) Use the manual thermocouple and meter to verify that this is accurate.

Pressure:

- 1) Start with a low scaling factor - say 0.001.
- 2) Open the valves until the gauge reads 0.
- 3) Click Zero on the software.
- 4) For any value of pressure read the pressure manually on the gauge and read the value from the software. Adjust the calibration factor in the software properties by the ratio of gauge reading to software pressure reading. The Sensor has a 24bit (0 to 16 million) so the numbers here will be very small.
- 5) Repeat the process to verify that the pressure reading is accurate.

Over to you:

Note the values of the sensor Scaling Factor and Calibration Factor if relevant.

Flow:

SF: _____

CF: _____

Level:

SF: _____

CF:: _____

Temperature

SF: _____

Pressure

SF: _____

CF: _____

For each system experiment with the values of load so that you understand how each system works.

Worksheet 3

ON/OFF control systems

Process control Worksheets



Some control systems can make effective use of simple On/Off control techniques. Here we evaluate the technique for the Flow system.

The photograph shows valves and pumps in a gas distribution system.

Over to you:

- 1) Load the ON/OFF application. E.g.: 'Open On-OffControl.bat'. This is an application that allows you to see the effects of simple on/off feedback control on the system.
- 2) Press the GO button in the top left hand corner.
- 3) Set the LOAD to a certain value. Select a Set point value.
- 4) Press RUN and monitor the output.
- 5) Select other set points and losses and see how the output changes.
- 6) Make some notes and compare how successful it is to use this technique to operate the different systems.
- 7) Understand the Hysteresis property and how it changes the output..

So what?

You should have made some observations:

- It is possible to use this technique to roughly control the process.
- The output is not in any way 'smooth' or accurate.
- There is an error between the Set Point

and the Process Value. This error is positive for low values and negative for high values.

- The ON/OFF frequency can change with Set point.

Conclusion

To a point this works - it allows some adjustments of value. But it is not satisfactory and the operational life of drive systems may be reduced by operating them in this way.

Worksheet 4

System time constant

Process control

Worksheets



When designing a digital PID system we need to set some basic parameters around the timings of measurements in the system. This depends on the response time of the system itself.

Photograph shows a pipe-fed hydroelectric plant

Over to you:

- 1) For the system you are using open the Manual application. E.g.: 'Open ONOffControl.bat'.
- 2) Press the GO button in the top left hand corner.
- 3) Adjust the LOSS so that there is a no loss in the system.
- 4) Set the DRIVE to around 50% of the scale.
- 5) Run the application and stop it as soon as the output reaches the set point.
- 6) Zoom in on the graph and measure the time taken for the output to rise from its starting position to 63% of its set point.

So what?

The time constant of a system is the time taken to get from 0% to 63% of the final output step change.

For the Flow system this is very fast: the pump is powerful and water is reasonably incompressible.

For the temperature system this is quite slow.

For practical digital control systems the interval between samples should be around a tenth of

the time constant.

Measure the time constant and calculate the ideal sampling frequencies for each system:

Flow:

Level:

Temperature

Pressure

The sampling time in your system can make a big difference in how your system operates.

Worksheet 5

P controller

Process control

Worksheets



There is a much better way of controlling systems than simple on/off control: proportional control where we vary the power being supplied to the process depending on the difference between the desired output and the actual flow rate. In this worksheet you will explore the creation of a Proportional controller for flow based systems.

Photograph shows a water pump in a factory.

Over to you:

- 1) Load the PID application. E.g.: 'Open PIDControl.bat'.
- 2) Refer to the Reference document and make sure you are familiar with how the software works.
- 3) In the Properties section turn Integral wind up off. Turn Derivative filter off. You will use these later.
- 4) In the Properties section enter the values for Output scaling factor that you calculated earlier.
- 5) In the Properties section enter the values for Sensor scaling factor that you measured earlier.
- 6) In the properties section enter the Calibration factor you measured earlier - if it is needed.
- 7) In the Properties section enter a Control frequency that is appropriate based on the system time constant.
- 8) Press the GO button in the top left hand corner and check your computer is communicating with the unit with the Application and Communications LEDs green.

- 9) Set the load quantity so that there is a loss in the system.
- 10) This software is a full PID controller. For now we are going to concentrate on the P term. So firstly reduce Ki and Kd to 0 which takes them out of our equation and select a starting value of Kp as 1. On the screen you can see the control equation with the P, I and D terms.
- 11) Select RUN.
- 12) Move the set point to around half way up the scale.
- 13) When the value settles make a note of the Set point and the output value for each system.

So what?

You have just witnessed a simple Proportional controller in action. What the software does is take the Process Value and subtract the Set Point from it to give an Error value. It then applies the Proportional P multiplier to this value and then the Scaling Factor multiplier (and calibration if there is any) to this value and then sets the Pulse Width Modulation drive of the pump to this value. This can be expressed



Worksheet 6

P controller

Process control Worksheets

Flow

Set point:

Final output

Level

Set point:

Final output

Temperature

Set point:

Final output

Pressure

Set point:

Final output

mathematically as:

Error = Set Point - Process Value

PWM % = Scaling Factor x Proportional factor x
Error

Very often you will see this expressed in a different way by engineers:

$$O(t) = K_f \times K_p \times e(t)$$

Where:

O(t) shows PWM as the letter 'O' and the '(t)' implies that this is varying in time.

K_f is the Scaling Factor for the PWM drive

K_p is the value of the Proportional multiplier

e(t) is the error and once again the '(t)' implies that this is varying in time.

Worksheet 6

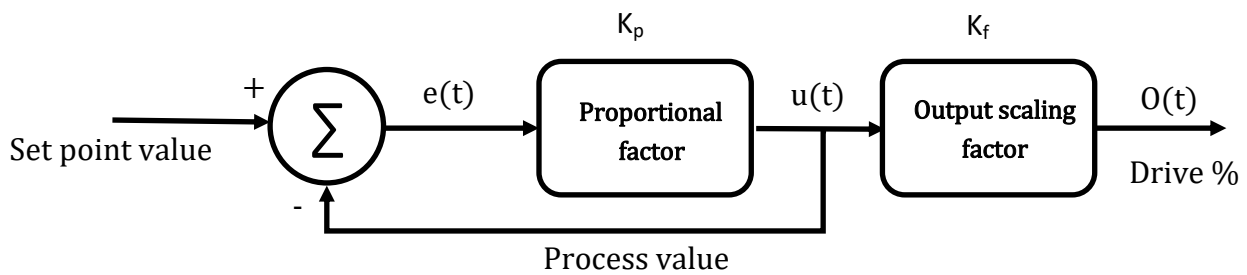
P controller

Process control

Worksheets

$$O(t) = K_f \times K_p \times e(t)$$

Control Function



Block Diagram

So what?

The system we have created can be expressed as a mathematical equation. This is sometimes referred to as the Control Function.

This is also sometimes expressed in diagrammatic form. This diagram is shown above and it is known as a Block Diagram.

The Block Diagram shows the flow of signals in a system and it is used by engineers as a shorthand way of explaining the signal flow and the mathematical processes in the system.

In the block diagram the Greek letter Epsilon (Σ) in the circle is used to mean that the incoming signals are summed. The '+' and '-' signs denote whether the value or the negative equivalent of the value are summed. The rectangular boxes denote multiplications to the signals.

When discussing control systems we are often as much concerned with the mathematical part of the problem as opposed to the mechanics of

converting the mathematical result into a driving signal and this part of the problem is left out of the mathematics. This means that the system above is most often described mathematically like this:

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

The key problem with Proportional only controllers is that the error is never zero: if it was then the output drive would be 0 and the flow would stop.

The pseudocode needed to set up a system like this is shown below:

```
PWM_out = Scale_factor x Kp x error
```

Worksheet 6

P controller

Process control Worksheets

Over to you:

You need to get a feel for this system and the various values of K_p and how the value chosen affects the system performance.

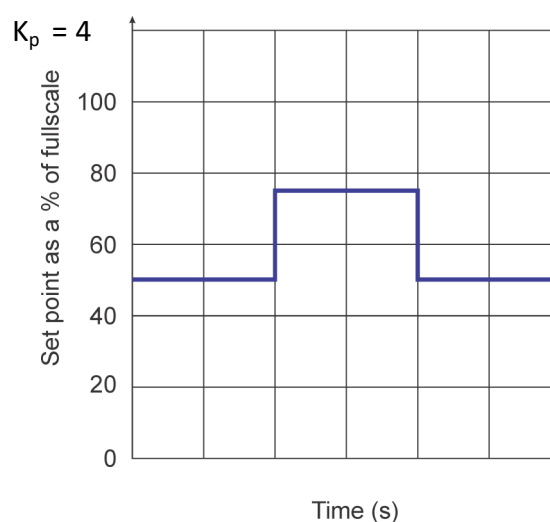
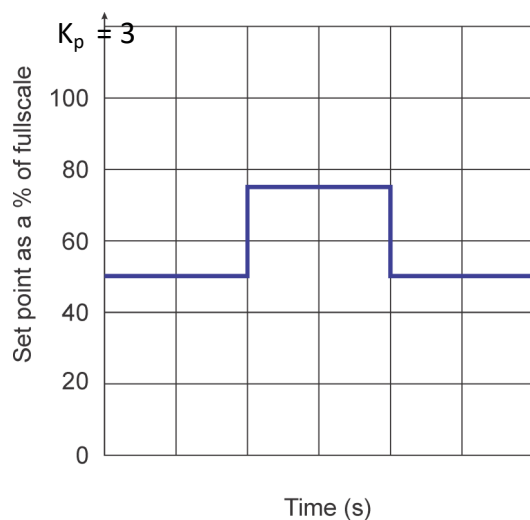
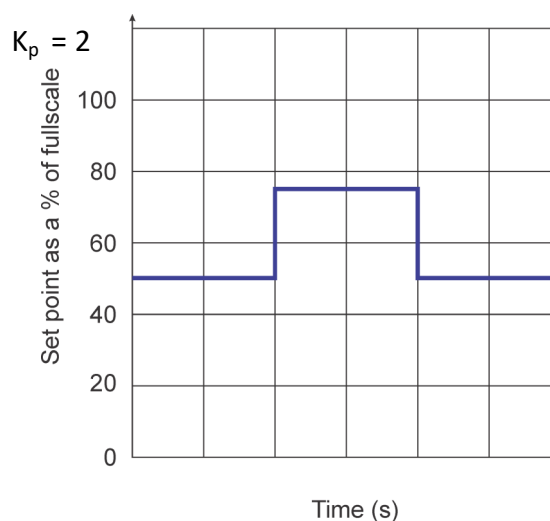
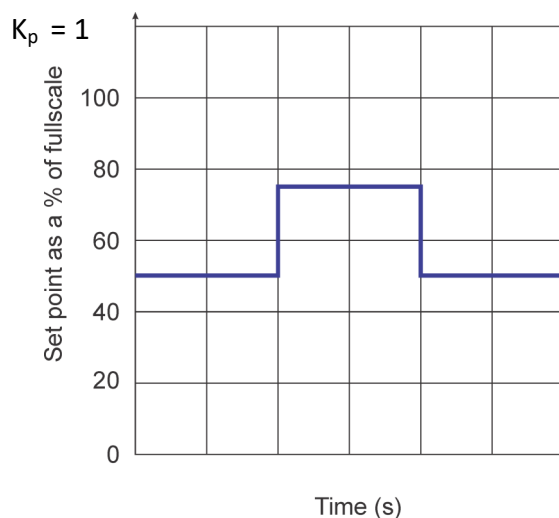
- 1) Adjust the system so that the set point is 50% of full scale.
- 2) Once the system has settled adjust the set point to 75% of full scale.
- 3) Then adjust it for 50% again.
- 4) Repeat this for values of K_p (Proportional value) of 1, 2, 3, 4 and sketch the results below for each of Temperature, Pressure, Level and Flow.
- 5) For each of the high set points make a note of

the final settled value.

So what?

You should see that there is always an offset in a P only controller. The offset is determined by the value of K_p : the higher the value of K_p , the smaller the error.

Higher values of K_p also give more instability.



Worksheet 6

PI controller

Process control Worksheets



The problem with the P only controller is that there is always an offset required. This problem can be solved by adding an Integral term that corrects the long term error in output.

Photo shows pumps in a boiler room.

Over to you:

- 1) Load the PID application for the equipment you are working on. E.g.: 'Flow_PID.bat'.
- 2) Refer to the Reference document and make sure you are familiar with how the software works.
- 3) In the Properties section turn Integral wind up off. Turn Derivative filter off. You will use these later.
- 4) In the Properties section enter the values for Output scaling factor that you calculated earlier.
- 5) In the Properties section enter the values for Sensor scaling factor that you calculated earlier.
- 6) In the properties section enter the Calibration factor you calculated earlier - if it is needed.
- 7) In the Properties section enter a Control frequency that is appropriate based on the system time constant.
- 8) Press the GO button in the top left hand corner and check your computer is communicating with the unit with the Application and Communications LEDs green.
- 9) Alter Kp to 1 and Ki to around 10.
- 10) Select RUN.
- 11) As before move the Set point between 50% of full scale and 75% of full scale.
- 12) For varying values of Kp and Ki make a note of the performance of the system on the small graphs on the next page.

Worksheet 7

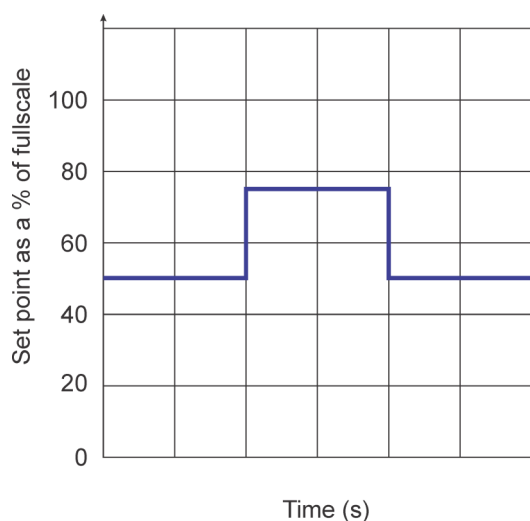
PI controller

Process control

Worksheets

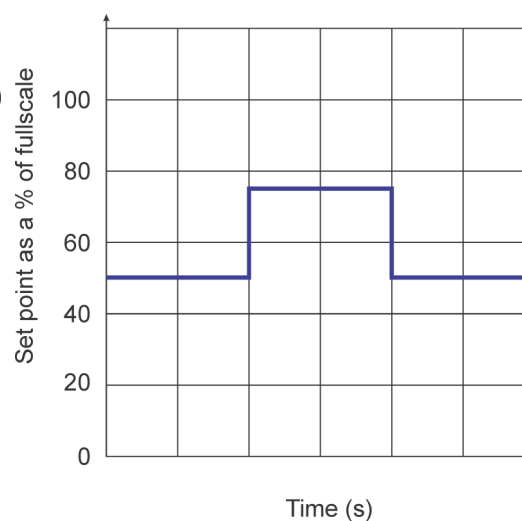
$K_p = 1$

$K_i = 20$



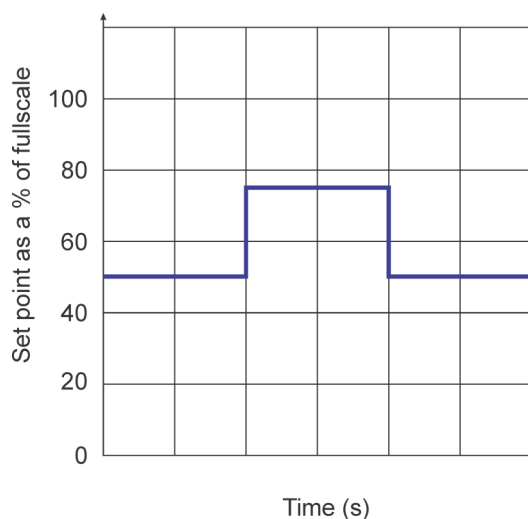
$K_p = 1$

$K_i = 20$



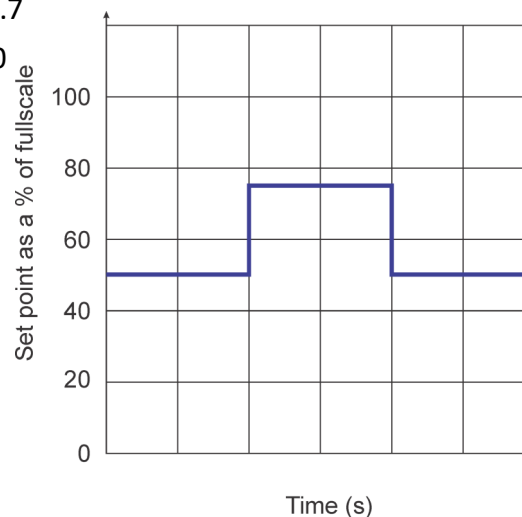
$K_p = 1$

$K_i = 30$



$K_p = 0.7$

$K_i = 40$



So what?

You have just witnessed a simple Proportional Integral (PI) controller in action. This takes the P only controller in the previous worksheet and adds an additional term to the system. The great thing about the PI controller is that it takes the error in the system down to close to zero and hence solves the major problem with the Proportional only controller. The PI controller also takes into account the past history of the system in terms of boosting drive to the pump if the pump is not having the desired effect.

The Integral term applies a correction to the

system that is not only proportional to the error but also proportional to the time for which the error has existed: the longer the error has persisted the greater the effect.

In practice this is achieved by an integration: for a given time we add the error multiplied by the time the error has persisted for and multiply this by a new factor: K_i

Mathematically this is expressed as:

$$K_I \int_0^t e(t) dt$$

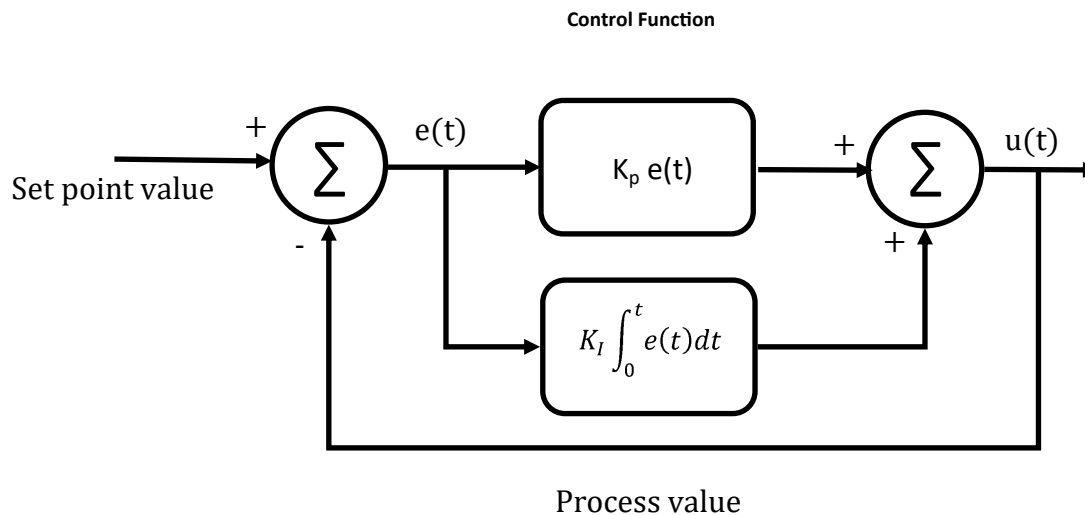
Worksheet 7

PI controller

Process control

Worksheets

$$u(t) = K_P e(t) + K_I \int_0^t e(t) dt$$



Block Diagram

Mathematically the overall Control function has changed as you can see above - it now has an Integral term in it.

The block diagram has also changed: the error is fed into two processes - one for the Proportional term and one for the Integral term. They are summed to give an output function which is fed to the PWM drive process. Note that for clarity we are leaving the PWM process out of the

block diagram.

Programmatically using pseudocode we can simply develop a program to do this as shown below.

The problem with the PI controller is that there is an overshoot - the output value is more than the setpoint for a certain time. For some systems that's fine - for others it is not.

```
Previous error = Error
Error = Process_value - Set_value
Integral = Integral + error
PWM_out = Scale_factor x (Kp x error + Ki x Integral)
```

Worksheet 7

PID controller

Process control Worksheets



There are situations where we need to control a pump to deliver a required amount of liquid quickly without any overshoot. For example with a prepaid petrol pump. The PI system falls short of requirements here but adding a differential term can help.

Over to you:

- 1) Load the PID application for the equipment you are working on. E.g.: 'Flow_PID.bat'.
- 2) Refer to the Reference document and make sure you are familiar with how the software works.
- 3) In the Properties section turn Integral wind up off. Turn Derivative filter off. You will use these later.
- 4) In the Properties section enter the values for Output scaling factor that you calculated earlier.
- 5) In the Properties section enter the values for Sensor scaling factor that you calculated earlier.
- 6) In the Properties section enter a Control frequency that is appropriate based on the system time constant.
- 7) Press the GO button in the top left hand corner and check your computer is communicating with the unit with the Application and Communications LEDs green.
- 8) Alter the value of K_p to 1, K_i to 20 and K_d to 0.02.
- 9) Select RUN.
- 10) As before move the Set point between 50%

of full scale and 75% of full scale.

- 11) For varying values of K_p , K_i and K_d make a note of the performance of the system on the small graphs on the next page.

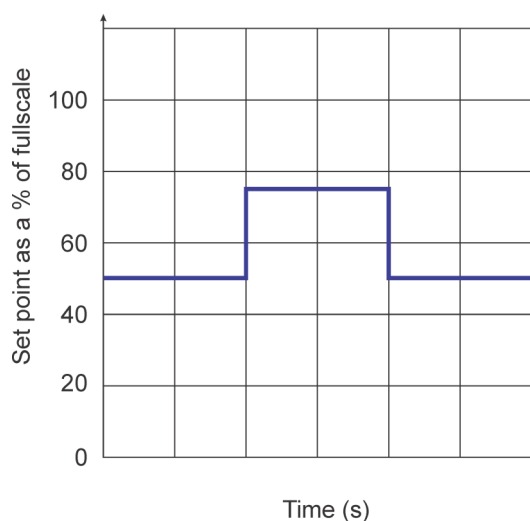
Worksheet 8

PID controller

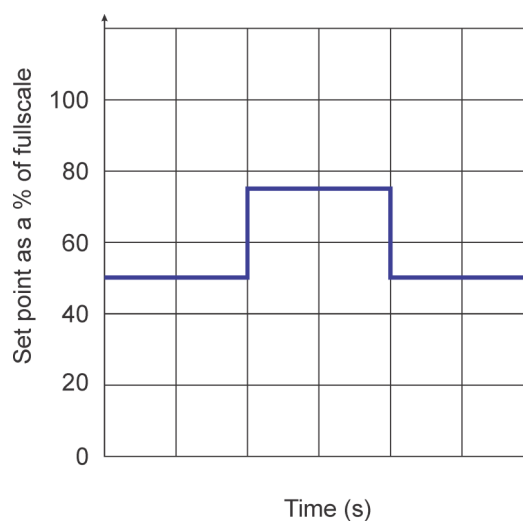
Process control

Worksheets

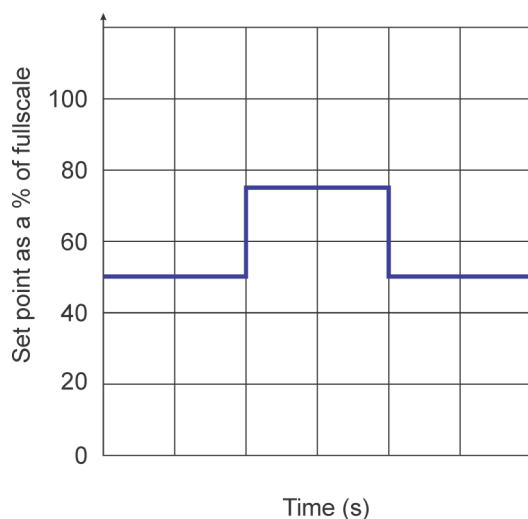
$K_p = 1$
 $K_i = 20$
 $K_d = 0.02$



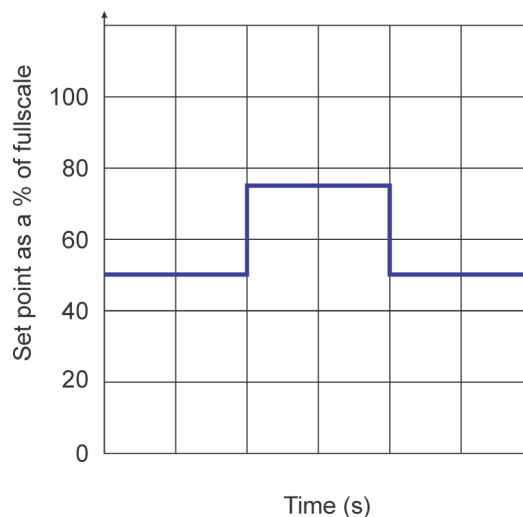
$K_p = 1$
 $K_i = 20$
 $K_d = 0.04$



$K_p = 1$
 $K_i = 20$
 $K_d = 0.06$



$K_p = 1$
 $K_i = 20$
 $K_d = 0.08$



So what?

You have just witnessed a full Proportional Integral Differential (PID) controller in action. This takes the PI controller in the previous worksheet and adds an additional term to the system.

The problem with a PI only controller is that the system does not take into account the rate of change of the system error. If the error is falling fast then we might want to slow the pump up a

bit. The Derivative term applies a correction to the system that proportional to the rate of change of error.

In practice this is achieved by an differentiation term in the equation.

Mathematically this is expressed as:

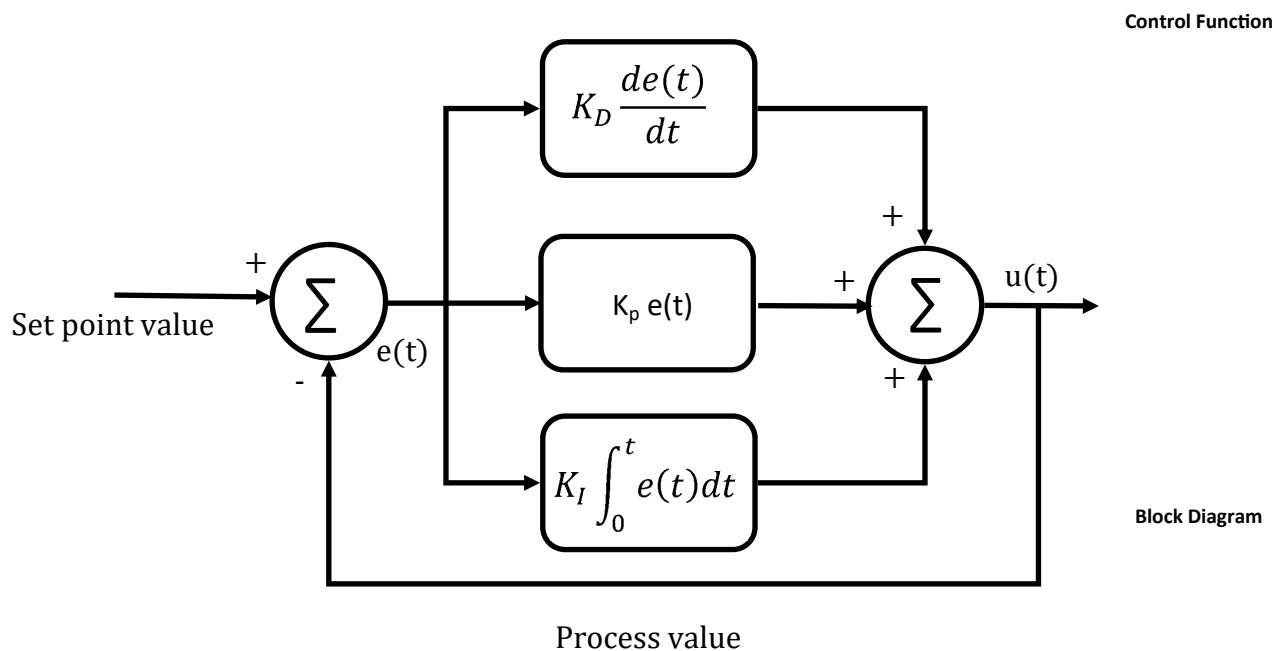
$$K_D \frac{de(t)}{dt}$$

Worksheet 8

PID controller

Process control

Worksheets



Mathematically the Control function has changed as you can see above - it now has an Derivative term in it.

The block diagram has also changed: the error is fed into two processes - one for the Proportional term and one for the Integral term. They are summed to give an output function which is fed to the PWM drive process.

Programmatically using pseudocode we can simply develop a program to do this as shown below.

So what?

You have now got a feel for the effects of each of the terms in P, I and D. but how do we work out the values we need?

```
Previous error = Error
Error = Process_value - Set_value
Integral = Integral + error
Differential = error - last error
PWM_out = Scale_factor x (Kp x error + Ki x Integral + Kd x Differential)
```

Worksheet 8

Zeigler Nichols algorithm

Process control

Worksheets

Control type	K_P	K_I	K_D
PID classic	0.6 K_u	1.2 K_u/T_u	0.075 $K_u T_u$
P	0.5 K_u		
PI	0.45 K_u	0.54 K_u/T_u	
PD	0.8 K_u		0.1 $K_u T_u$
Some overshoot	$K_u/3$	$(2/3) K_u/T_u$	$(1/9) K_u T_u$
No overshoot	0.2 K_u	$(2/5) K_u/T_u$	$(1/15) K_u T_u$

So You should now have some idea of how K_p , K_i , and K_d and their values affect a system's performance. But what are the right values? The Zeigler Nichols algorithm helps you define vales for different control systems.

Over to you:

First you need to gather some information about your system. To do this:

- 1) With the same settings as in the previous experiment set K_p to 1, K_i to 0, K_d to 0.
- 2) Press the RUN button.
- 3) Slowly increase P to a point of 'neutral stability': this is defined as a value when the output starts oscillating in a predictable and stable way. This is the critical or ultimate gain and we define this as ' K_u '.
- 4) Stop the system by clicking on the stop button when you have gathered a number of cycles of 'stable instability'.
- 5) Click on the graph area. Use the scroll wheel on the mouse to zoom into the graph. Measure the time between the instability peaks. This is the neutral stability period or T_u .

So what?

Ziegler Nichols was a famous engineer in the 1940's who did a lot of research on control systems. He came up with a method of approximating the solution to the problem of selecting values of P, I and D for control systems based on their behaviour in terms of

K_u and T_u .

This table is shown below.

Over to you:

Using a spreadsheet and the values of K_u and T_u you measured calculate the values of K_p , K_i , and K_d for the different types of control system shown in the table.

As this is a discrete system you will need to divide the value of K_i by the sample frequency and you will need to multiply the value of K_d by the sample frequency.

Very the Set point between 50% and 75% (lower for the temperature apparatus) of full scale as before and verify that this works for the Flow system for PID classic.

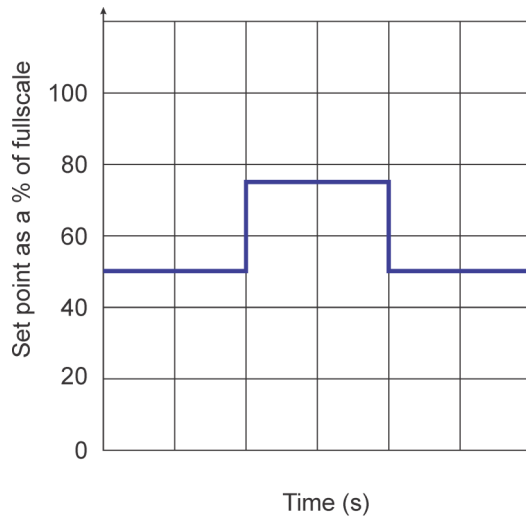
Worksheet 9

Zeigler Nichols algorithm

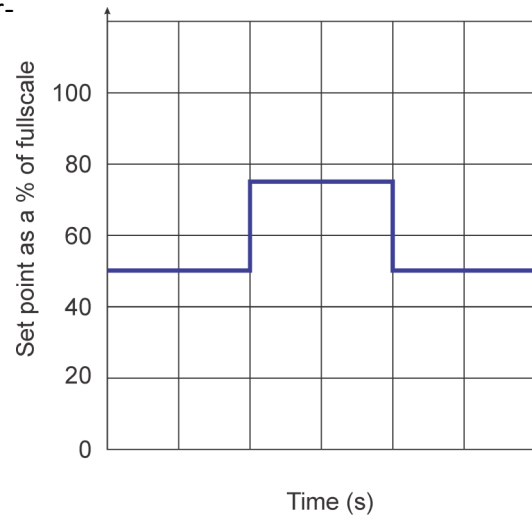
Process control

Worksheets

PID classic



No over-shoot



Worksheet 10

Integral wind up

Process control Worksheets

As you have seen a properly tuned PID control system provides a great solution. If everything in your system runs perfectly then this works really well. In practice there are some 'real world' problems that we sometimes need to take care of before the system will be fit for purpose.

Photograph shows a partially blocked pipe.

Over to you:

- 1) Set the system up with the PID classic values for K_p , K_i , and K_d that you deduced in the Zeigler Nichols calculations in the previous worksheet.
- 2) Choose a suitable DRIVE and LOAD for your system.
- 3) Run the system and notice how the integral term appears on your graph: the yellow line.

So what?

For some systems the Integral term builds up to a point where it significantly increases the time a system takes to settle down. A fault in the system like a blocked pipe or loose wire, can result in a very large accumulated value for the Integral component that can take some time to clear. This is called Integral wind up. Because of this many systems introduce a variation to the controller that limits the value the of the Integral component. This is called Integral clamping as the Integral is clamped to a value we can set.

Over to you:

- 1) The software has a facility to allow you to clamp the value of the Integral. Select 'Integral clamp' to YES .
- 2) Repeat steps 1 to 3 and compare the results

when the system was unclamped. Take screen grabs or export the data to Excel and compare the two sets of information.

- 3) For the system you are using does the integral clamp produce a better control system?

So what?

The Integral clamp allows system designers to allow for problems in the control process that might affect the performance of the system. If there is a problem in the system and the integral value is allowed to rise to any value then when the problem with the system is fixed the system will take a long time to return to its operational state. By limiting the value the integral term can assume the system is made more robust.

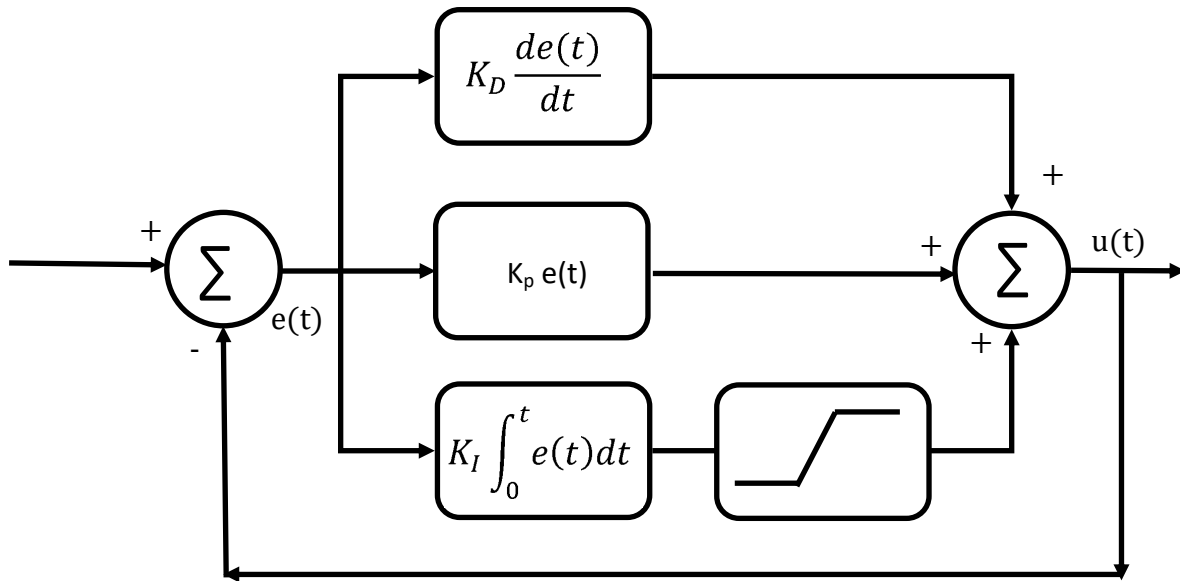
This necessitates an additional term to our block diagram which you can see below

You can also see how this would be implemented in code.

Worksheet 10

Integral wind up

Process control Worksheets



```

Previous error = Error
Error = Process_value - Set_value
Integral = Integral + error
If Integral = Max_Clamp_Value
    Integral = Max_Clamp_Value
EndIf
If Integral Min_Clamp_Value
    Integral = Min_Clamp_Value
EndIf
Differential = error - last error
PWM_out = Scale_factor x (Kp x error + Ki x Integral + Kd x Differential)

```


Worksheet 11

Derivative filter

Process control Worksheets

A key problem with some control systems is noise. If there is some noise in the system path then the Differential component can introduce large amounts of feedback which amplifies the noise terms. This is so bad in some systems that PID control is not possible: we need a mechanism to limit the effects of noise.

Photograph shows remote pumping station in Canada.

Over to you:

- 1) Set the system up with the PID classic values for K_p , K_i , and K_d that you deduced in the Zeigler Nichols calculations in the previous worksheet.
- 2) Choose a suitable DRIVE and LOAD for your system.
- 3) Run the system and look at the derivative term on your graph - the blue line.

So what?

Some systems are noisy and some are not. The derivative term is problematic in control systems because it amplifies any noise that is present in the system. Often that noise is down to the nature of sampling in a digital system. Differential terms are usually the most problematic terms in PID systems and this is why a great many systems are simply PI controllers leaving out the differential term altogether. However with a little adjustment it is possible to make some improvements to the differential.

Over to you:

- 1) In the properties section adjust the Derivative filter term to YES.
- 2) Adjust the Derivative Filter term to 10.
- 3) Repeat steps 1 to 3 and compare the results

when the system was unclamped. Take screen grabs or export the data to Excel and compare the two sets of information.

- 4) For the system you are using does the integral clamp produce a better control system?

So what?

A small low pass filter added to the system alters the frequency of the signals that are fed back to the error signal. This makes the system much more stable and cuts down the noise in the system.

You can see how this affects the block diagram below

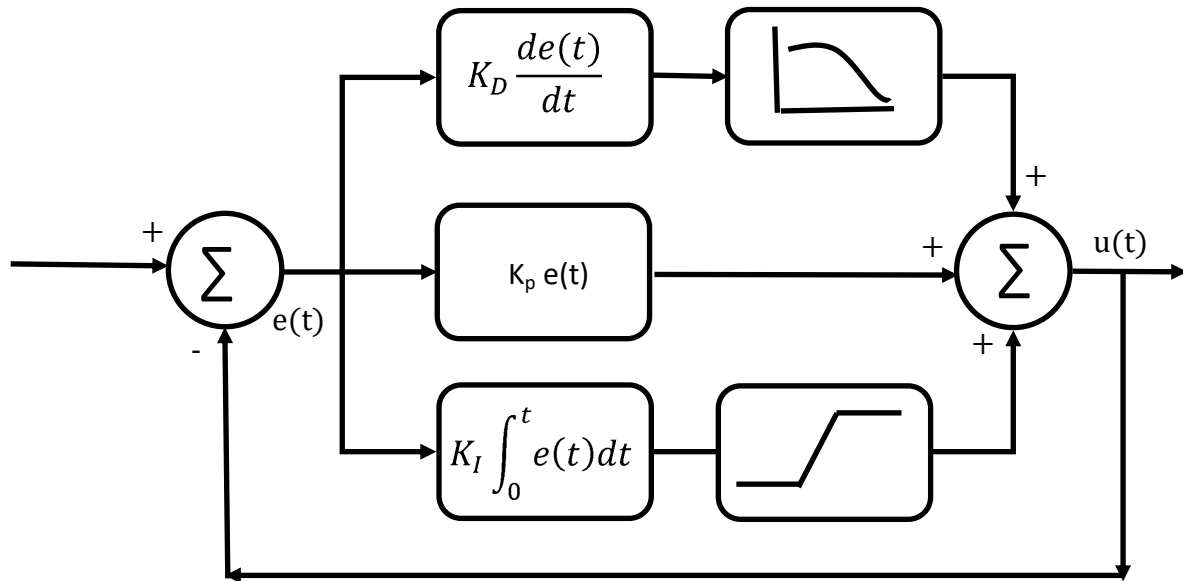
You can see how this is implemented in code below.

Worksheet 11

Derivative filter

Process control

Worksheets



//DFC is the Derivative Filter Coefficient

```
output = last_output + DFC (output - last_output)
Differentialterm = Kd * output
Last_output = output
```

Worksheet 12

Manual tuning

Process control Worksheets

Most of the time the Zeigler Nichols 'rule of thumb' calculations can give us good approximations to getting a stable system using P, I and D control. ZN also includes values for 'no overshoot'. In practice these do not always work for control systems.

Over to you:

Calculate the Ziegler Nichols values for 'no overshoot' and enter them into the system.

On some systems the ZN values for 'no overshoot' don't produce the results we want.

Manually adjust the values of K_p , K_i , and K_d to give a typical no overshoot result.

Make a note of your results.

Interfacing with MATLAB/LabView

Process control Worksheets

The worksheets above make use of off the shelf software that controls the system. This is fine for simple systems. In practice if you are a design engineer you will need to design control software from scratch understanding the transfer function of the control system.

Photograph shows a design engineer in a lab..

- 1) Familiarise yourself with the contents of the Process control reference guidebook.
- 2) Familiarise yourself with the list of API commands in the reference guidebook.
- 3) Construct a Matlab/Labview program that simply turns the pump and valve on and reads the flow meter.
- 4) Read worksheets 1 to 6. Replicate these functions in Matlab / Labview so that you understand the scaling factor of the pump, the calibration of the flow sensor and the operation of the Valve.
- 5) Using your knowledge of Laplace construct an S plane model for the PID system described by the block diagram in Worksheet 9.
- 6) Modify your program to implement integral clamping and derivative filtering.

Version control

Process control Worksheets

19 11 20 first release

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