<center>**PROCESS CONTROL SYSTEM**</center>

INTRODUCTION

High productivity and consistent product reliability have become vital to industrial success. In particular, high reliability of the manufacturing process is important in the "process industry" as any faults in the system can produce large volumes of a defective product in a very short time. The rapid developments in the micro-electronics industry in recent years have now provided the facilities to monitor and control both the product and the manufacturing process relatively simple and at low cost. This has resulted in the proliferation of new control systems based on micro-electronics. The Bytronic Process Control Unit is specially designed to provide a training resource which can be used to cover a wide spectrum of training requirements.

Objectives of the Process Control Experiment:

1. To illustrate, at operator level, the potential advantages to be gained from the application of micro-electronics to process control.

2. To provide a controlled process in a training environment which reflects the control problems experienced in industry and on which students can carry out a detailed analysis of alternative control techniques.

3. To illustrate simply and clearly the fundamental control techniques of proportional, integral and derivative control.

4. To provide an interesting problem which reflects industrial practice on which simple or sophisticated software skills can be developed.

SYSTEM OVERVIEW

The main objectives outlined above are achieved by the provision of a unit with four main elements, namely, a 'process to control', a computer control module, a power supply unit and control software.

The first element, i.e. a 'process to control', is contained in the system rig. The unit consists of the following:

1. **A sump**, from which the fluid being processed is pumped. The temperature of

the fluid in the sump is monitored, displayed on the unit and input to the controlling microcomputer via an analogue to digital converter (ADO).

2. **A pump**, which is being used to pump the fluid round the system. The pump is driven by a DC Motor the speed of which can be controlled via the microcomputer. This gives the computer control of the flow rate. A manual flow control valve is also provided.

3. **A flowmeter**, to monitor the fluid flow rate. The output from the meter is displayed on the unit and also input to the microcomputer.

4. **A process tank**. This tank contains:

    a) a 'tank full' level switch - the output of which is displayed and also input to the microcomputer.

    b) an electric heating element, the output of which can be varied, under computer or manual control, between zero and 2.4Kw. The value is displayed on the unit and also input to the microcomputer.

    c) a temperature sensor for monitoring the temperature of the heated fluid. The output from the sensor is displayed on the unit and also input the microcomputer.

    d) a stirrer to improve the temperature distribution in the process tank.

    e) an overflow pipe through which heated fluid can be displaced and hence dispensed.

    f) a manual drain valve and a computer controlled drain valve to cycle the fluid to the sump.

5. **A cooler**. If it is required to cool the fluid instead of heating it, the fluid is diverted via either a computer or manually controlled 3-way valve to a computer controlled fan cooler. The temperature of the fluid after leaving the cooler is monitored, displayed and input to the microcomputer.

The second element, namely the computer control module (CCM), in principle, contains the electronics necessary to monitor and control the various elements of the system rig together with an interface board to link the overall system to the host microcomputer. The interfacing circuitry can be segregated into four areas:

1. **The Output Drivers** are used to control the various on/off devices such as the indicators, the cooler fan and the solenoid valves.

2. **The Signal Conditioning** which converts the signals from the flow meter and the temperature sensors into an analogue voltage prior to being input into the computer via the analogue to digital converter (ADC) and prior to supplying an analogue signal to the panel meters.

3. **The Data Acquisition and Heater Control** which serves two main functions:
    a) by using an 8-channel, 8-bk ADC, the outputs from the Signal Conditioning Board are converted-to digital form ready for use by the microcomputer.
    b) the heat input may be controlled by either an output port or a counter timer channel. The amount of power in Kw can be displayed on the system rig.

4. **The Pump Controller** serves to display, by means of 8 LEDs, the pump control byte output from the computer, convert the byte into analogue form by means of a digital to analogue converter (DAC) then amplify this signal and supply it to a MOSFET for further amplification and hence pump control. A manual pump control option is also included.
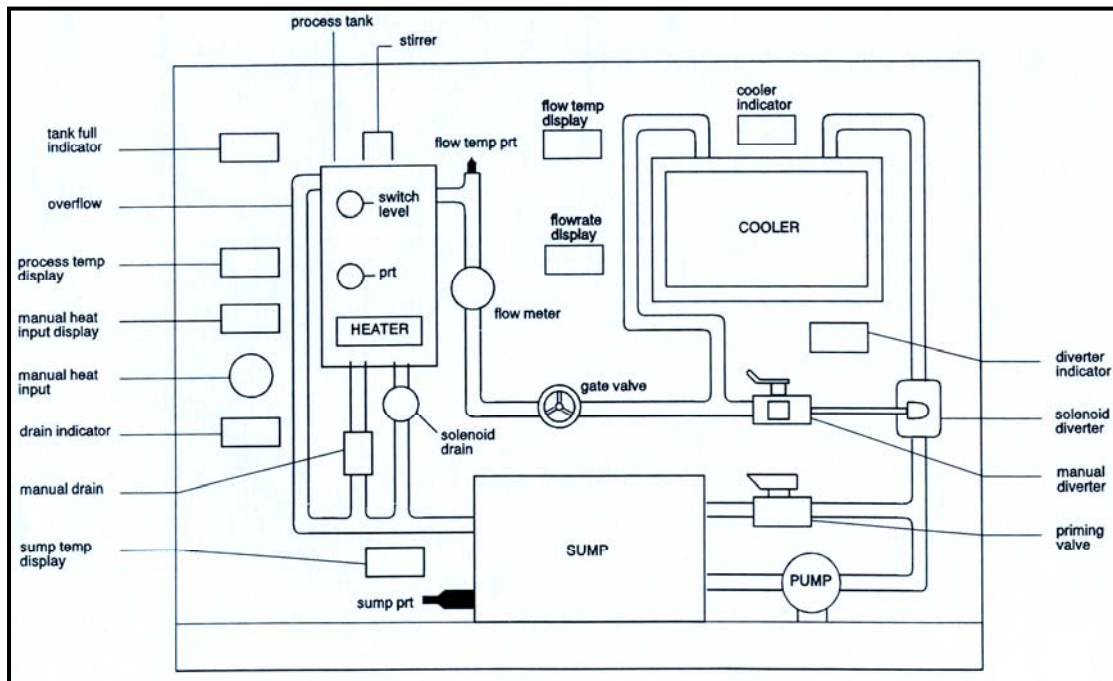

Figure 1: System Rig
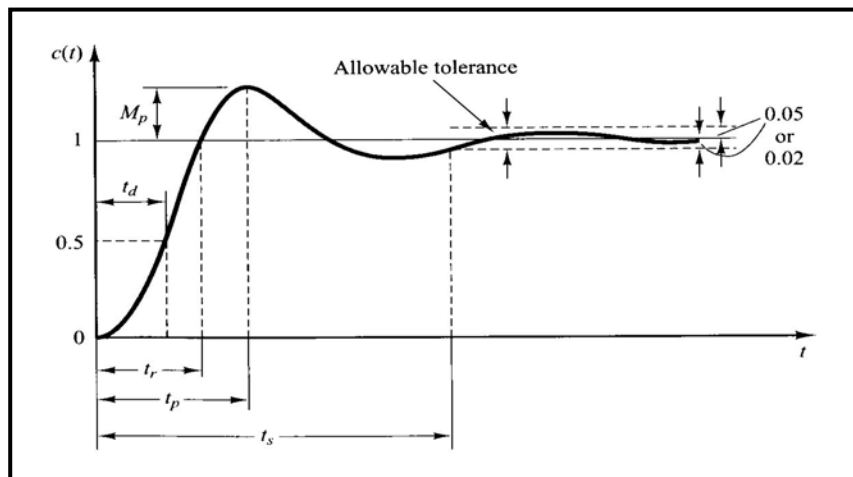
PERFORMANCE PARAMETERS

The performance of a closed-loop system is described as the characteristic behaviors of the control system beyond stability. In many practical cases the desired performance characteristics of control systems are specified in terms of time-domain quantities. In specifying the transient-response characteristics of a control system to a unit-step input, it is common to specify the following (see Figure-2),

- Delay time, t_d
- Rise time, t_r
- Peak time, t_p
- Maximum overshoot, M_p
- Settling time, t_s

A reasonable control system is expected to satisfy these criteria:

1- Minimizing the effects of disturbances on the system.
2- A rapid response and small settling time.
3- Zero steady-state error.

Figure 2: Unit step response of a second order system.

EXPERIMENT 1: Ziegler-Nichols Tuning Method for PID Controller

The process of selecting the controller parameters to meet given performance specifications is known as controller tuning. Ziegler and Nichols proposed rules for

determining values of K_p, integral time constant τ_I, and derivative time constant τ_d based on the transient response characteristics of a plant. Ziegler-Nichols ultimate oscillations method is applied in such a way; first of all, $\tau_I=\infty$ and $\tau_d=0$ are set. Using the proportional control action only, K_p is increased from 0 to a critical value K_{cr} at which the output first exhibits sustained oscillations. Thus, the critical gain K_{cr} and the corresponding period P_{cr} are experimentally determined. Ziegler and Nichols suggest setting the parameters according to the formula table shown in Table 1.

Table 1: Ziegler Nichols Tuning rule based on K_{cr} and P_{cr}.

Type of Controller	Kp	τ_I	τ_d
PD	$0.6K_{cr}$	-	$0.125P_{cr}$
PI	$0.45K_{cr}$	$0.83P_{cr}$	-
PID	$0.6K_{cr}$	$0.5P_{cr}$	$0.125P_{cr}$

Apply Ziegler-Nichols ultimate oscillations method to flow control on Bytronic Process Control Unit. Write down the K_p values tried while obtaining K_{cr} (Table 2). Obtain the K_{cr} and P_{cr} values for the system. Calculate the appropriate control parameter values using Table 1.

Table 2: Values of K_p examined while obtaining K_{cr}.

Trial No:	1	2	3	4	5
K_p					

EXPERIMENT 2: Obtaining Desired Performance

System producers offer some PID control values. ($K_p=1$, $\tau_I=1.5$, $\tau_d=0$). When applied these values performance parameters obtained are shown in Table 3. Controller parameters obtained by you in Experiment 1 will be applied to the system. Apply all types of controllers (PD, PI, PID) and decide which type of control you will use. Then compare the results of the same controller type with the producers offered and decide which one is better. Then give performance criteria and change the

controller parameters consciously to obtain the desired performance. Write down any trials on Table 3.

Table 3: Performance parameters for different controller coefficients.

Controller Parameters			% Max. Overshoot (M$_p$)	Delay Time (t$_d$)	Rise Time (t$_r$)	Settling Time (t$_s$)	Steady state error (e$_{ss}$)
P	**I**	**D**					
1	1.5	0	27	0.9 sec.	1.7 sec	12.7 sec	≈0

REPORT REQUIREMENTS:

- Write down the effects of any controller parameters on system performance. Give a summary of the procedure you followed in Experiment 2 to obtain the desired performance. Comment it using Table 3.
- Draw the system response for only proportional control (use one of the Kp values that is not equal to K$_{cr}$ in Table 2). Show performance criteria on figure.
- Draw system response for every three types of controller (3 different figures). Show performance criteria on figures.