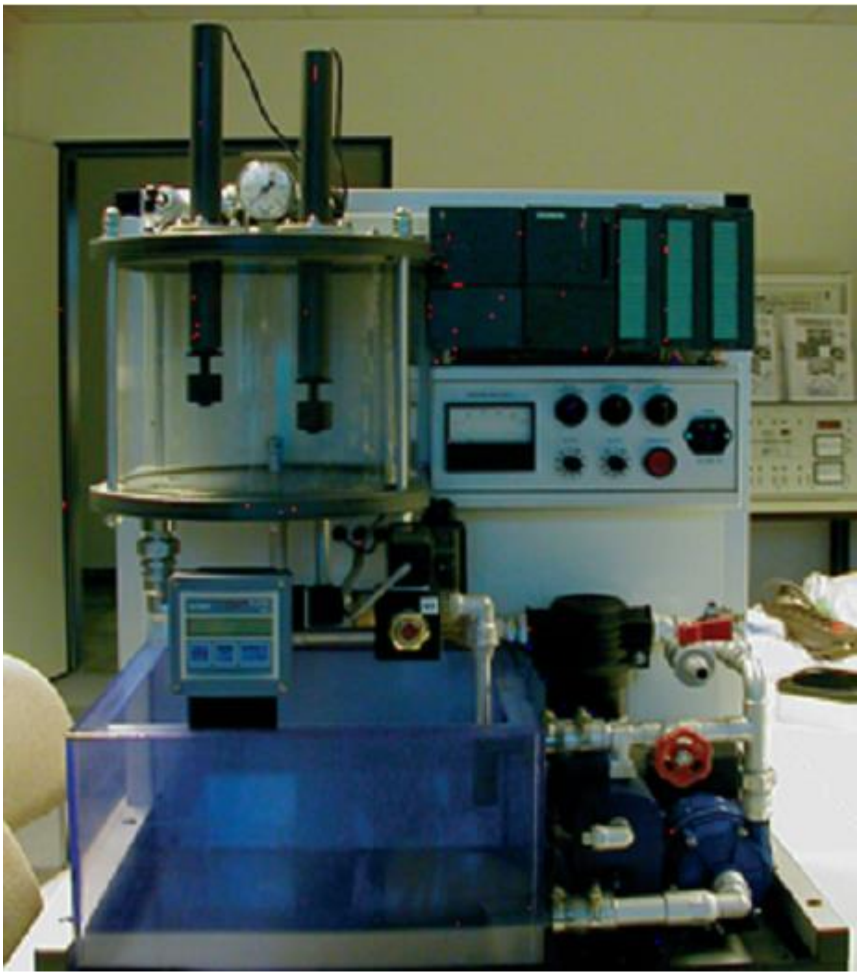
# Pressure Control System



**Contents**

## 1. Objectives

- To understand the characteristics of pressure control
- To understanding the whole procedure of the PID tuning and application by practicing the automatic PID control of the liquid flow of the pipe of the below liquid flow control experimental equipment.
  - Understand the strengths and weaknesses of the three modes of the PID.
  - Determine the model of a feedback system using block diagram algebra.
  - Establish general properties of PID feedback from the closed-loop model.

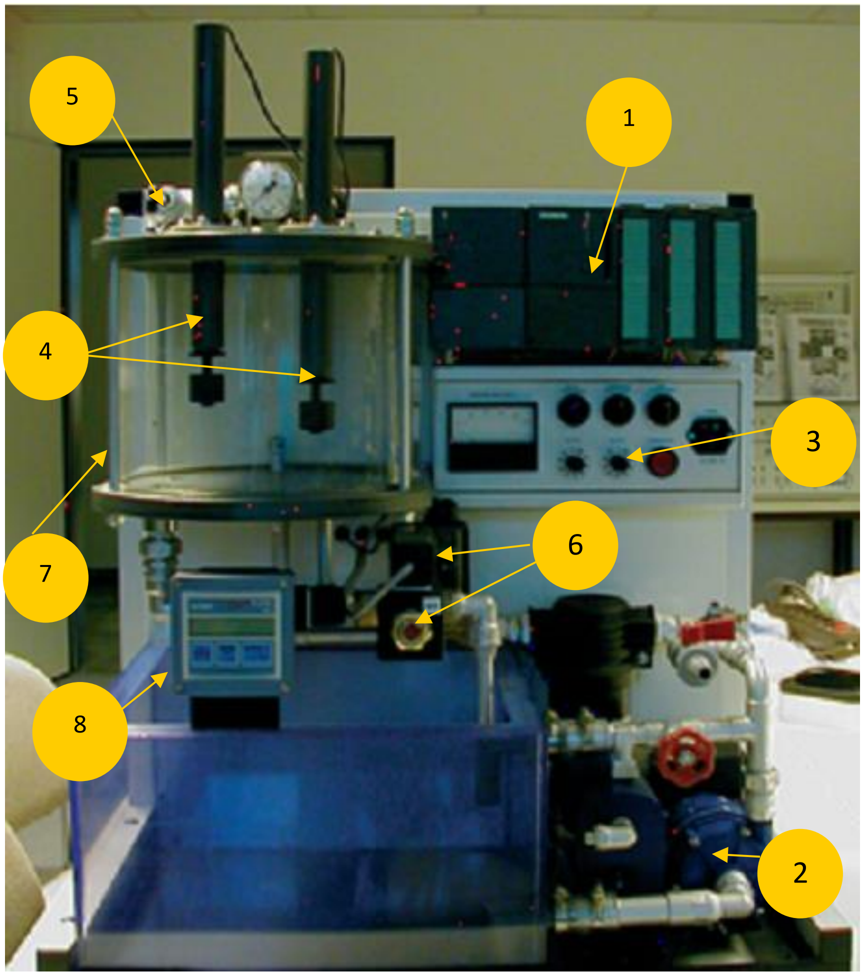
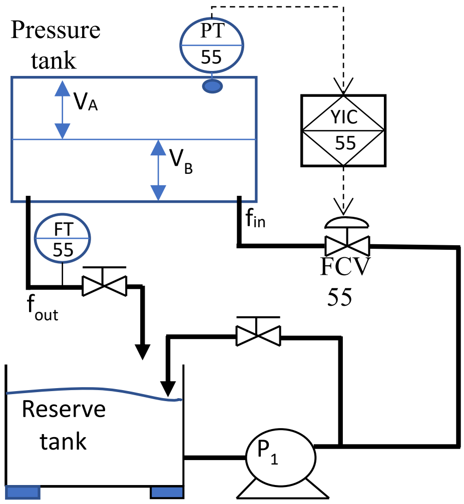



**Figure 1. Experimental Equipment for Automatic Liquid flow Control**

## 2. Theory

### 2.1 Pressure systems

Any phase of substance, solid, liquid or gas is stated by thermodynamic. The thermodynamic state of a system can be defined its pressure, enthalpy, and volume. If a gas phase alone is present, pressure and temperature are directly proportional but pressure and volume are inversely proportional (PV=nRT). The pressure is one criterion for boiling point of substance, saturated temperature of water is directly proportional with saturated pressure. Most of the processes handling the phase are normally related to both pressure and temperature. Since most of pressure used in industry is really high to drive the mass and energy to process, it is extremely important to attach the correct significance to the pressure measurement for safety.



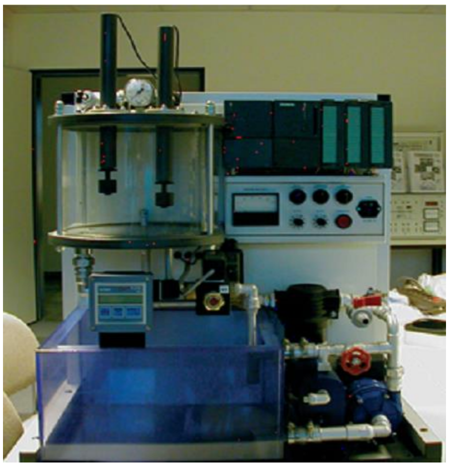



**Figure 2. Equipment and P&ID diagram of pressure control systems**

Mathematical model is created as

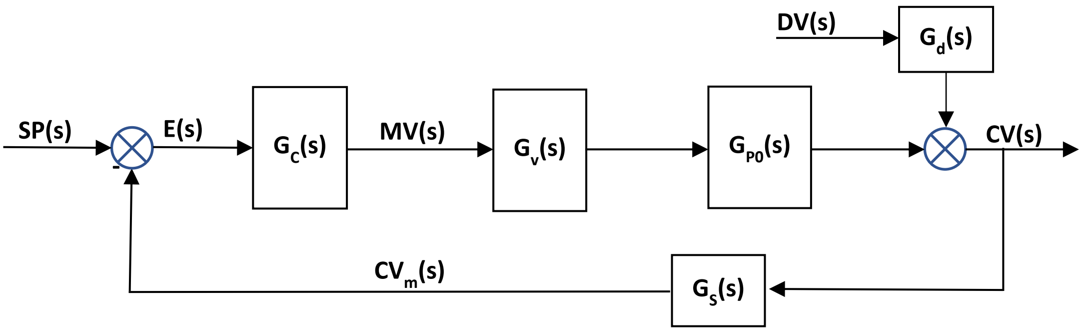



**Figure3. Block diagram of mathematical model**

Where,

$$G_{p0} = \frac{K_{p0}}{\tau_{p0}s + 1}; G_v = \frac{K_v}{\tau_v s + 1}; G_s = \frac{K_s}{\tau_s s + 1}; G_d = \frac{K_d}{\tau_d s + 1}$$

And,

$$CV_m(s) = \left(\frac{K_{p0}}{\tau_{p0}s + 1} \times \frac{K_v}{\tau_v s + 1} \times \frac{K_s}{\tau_s s + 1}\right) MV(s) + \left(\frac{K_d}{\tau_d s + 1} \times \frac{K_s}{\tau_s s + 1}\right) DV(s)$$

$$\approx \frac{K_p e^{-\theta_p s}}{\tau_p s+1} MV(s) + \frac{K_d e^{-\theta_d s}}{\tau_d s+1} DV(s) \quad (1)$$

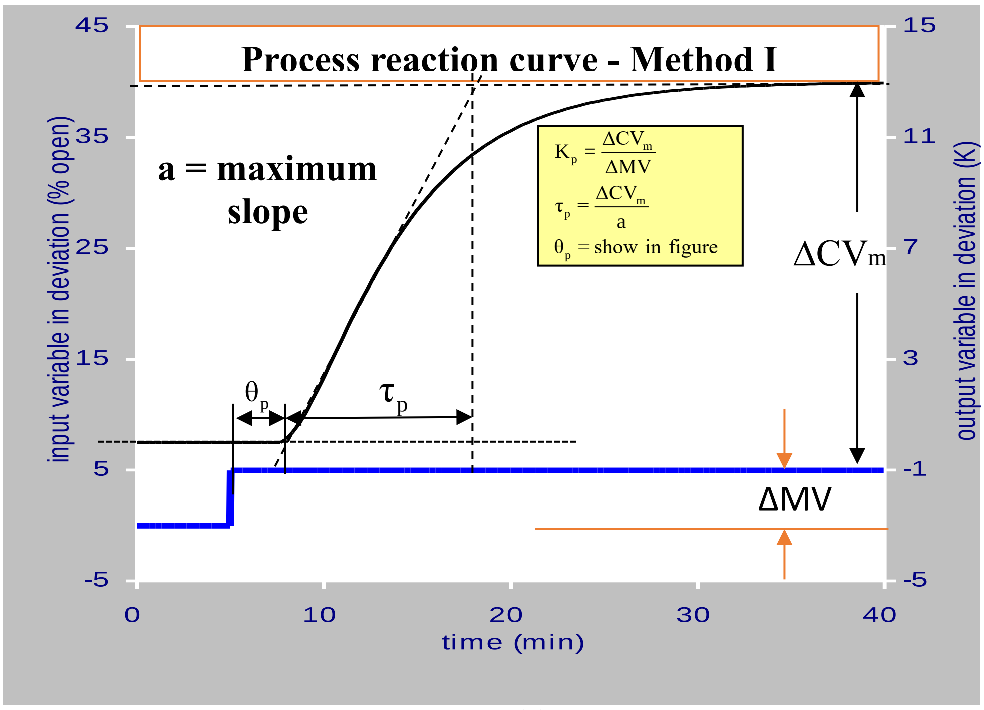
$$CV_m(s) = G_p(s) \times MV(s) + G_d(s) \times DV(s) \quad (2)$$

When DV(s) = 0:

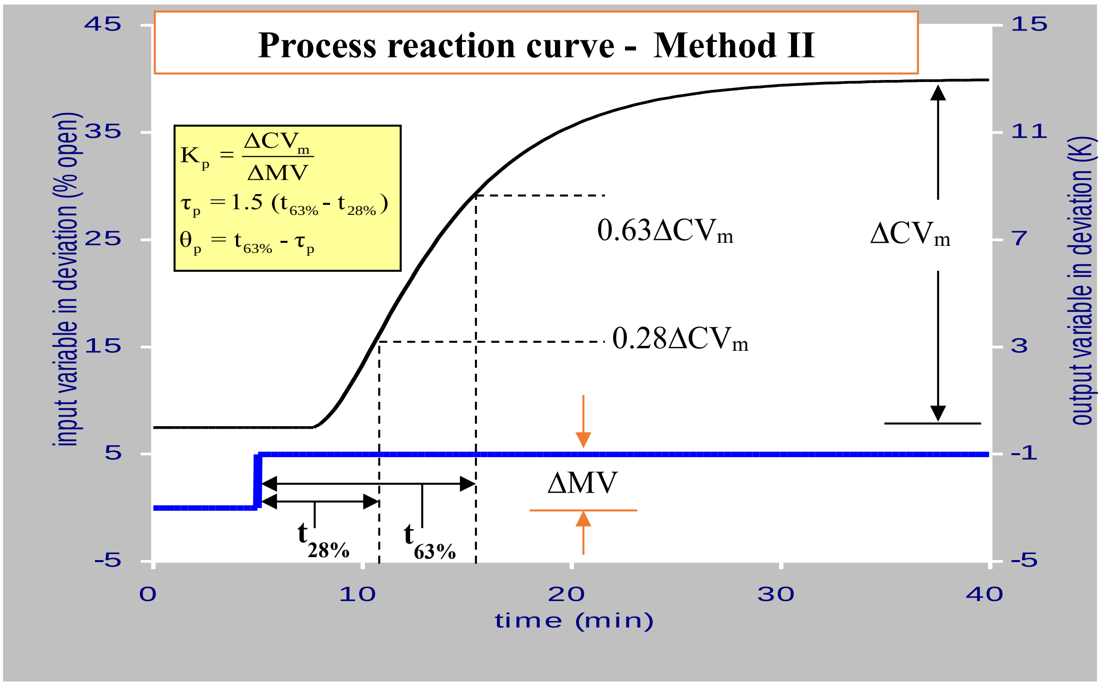
$$G_p(s) = \frac{CV_m(s)}{MV(s)} = \frac{K_p e^{-\theta_p s}}{\tau_p s + 1} \quad (3)$$

$K_p$: Process gain.
$\tau_p$: Effective process time, time constant (s).
$\theta_p$: Effective process dead time, time delay (s).
The transfer function corresponding to the three model parameters is equation (3). This is called the first order plus time delay model (FOPTD).

**2.2 Development of mathematical model of process by open loop test method (semi-empirical model)**




(a)




**(b)**

**Figure 4. Reaction curve of MV(t) and $CV_m$(t) applied by step function.**

First of all, the process dynamics should be identified in the form of the model to determine $K_c$, $T_i$(or $K_i$) and $T_d$ (or $K_d$) of the PID controller appropriately. From figure 3 MV(t) is being applied by step function when is no process disturbance or process is stable. The $CV_m$ response on figure 4 is called "Reaction curve", which $K_p$, $\tau_p$ and $\theta_p$ duration can be find out as:

- Keep the process steady state. Next, enter a step-wise process input of which the magnitude is ΔMV. Then, the following process reaction curve will be obtained.

- Draw a tangent line at the inflection point of the process reaction curve as shown in Figure 4 and obtain the model parameters of $K_p$, $\tau_p$, $\theta_p$ as shown in Figure 4.

### 2.3 Closed-loop Control System

In Closed-loop control (Figure 5), the objective is to reduce the error signal to zero where

$$e(t) = sp(\tau) - cv(\tau) \tag{4}$$

The PID controller ($G_c(s)$) adjusts the control output (mv(t), co($\tau$) to derive the process output (cv(τ), pv(τ)) to the setpoint (sp(τ)). $G_p(s)$ denotes the process. mv(τ) is the process input, equivalently, the control output (co(τ)). The setpoint is a desired process output (sp(τ). When the process input (mv(τ)) varies for the variation of the process output (pv(τ)) it is called closed-loop control system. The liquid level of the automatic liquid level control system corresponds to the process output.

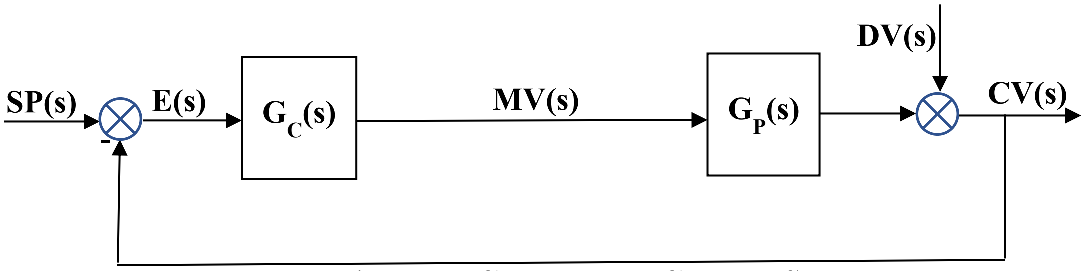



**Figure 5. Closed-loop Control System**

**PID (Proportional-Integral-Derivative) Controller**

PID Controller is composed of the following three parts.

Proportional (P): $mv_P(t) = K_c e(\tau)$ (5)

Integral (I) : $mv_I(t) = \frac{K_c}{\tau_i}\int_0^\tau e(\tau)dt = K_I \int_0^\tau e(\tau)d\tau$ (6)

Derivative (D) : $u_D(\tau) = k_c \tau_d \frac{de(\tau)}{d\tau} = K_D \frac{de(\tau)}{d\tau}$ (7)

The output of the PID controller is the linear combination of the three parts (proportional part, integral part and derivative part of the control error) as shown below.

$$mv(\tau) = mv_P(\tau) + mv_I(\tau) + u_D(\tau) = K_c e(\tau) + K_I \int_0^\tau e(\tau)d\tau + K_D \frac{de(\tau)}{d\tau} \quad (8)$$

Where, $K_c$, $\tau_c$ and $\tau_d$ are the proportional gain, integral time, derivative time, respectively. τ is time. Determining the parameters of $K_c$, $\tau_c$ and $\tau_d$ appropriately to achieve high control performance is called PID tuning.

**Digital PID calculation**

Now we derive a transfer function for a digital PID controller (see Appendix part 3), where, the sampling period is Δτ.

- Discrete transfer function of a proportional part. The proportional of e(t) in continuous time can be approximated by:

$$mv_P(\tau) = K_c e(\tau) = K_c e(k) \quad (9)$$

Where e(k) is the error at the *k*th sampling instant for k=1,2,…

Taking the z-transform,

$$MV_P(z) = K_c e(\tau) = K_c E(z) \quad (10)$$

- Discrete transfer function of an integral part. The integral of e(τ) in continuous time can be approximated by a summation in to the integral

$$mv_I(\tau) = \frac{K_c}{\tau_i}\int_0^\tau e(\tau)dt = K_I\int_0^\tau e(\tau)d\tau \approx \frac{K_c}{\tau_i}\Delta t\sum_{k=0}^{n} e(k) \qquad (11)$$

Taking the z-transform,

$$MV_I(z) = \frac{K_c}{\tau_i}\Delta\tau\left(\sum_{k=0}^{n} z^{-k}\right)E(z) \qquad (12)$$

When n is large then,

$$MV_I(z) = \frac{1}{(1-z^{-1})}\frac{K_c}{\tau_i}\Delta\tau E(z) \qquad (13)$$

- Discrete transfer function of a derivative part. This expression is known as the backward-difference approximation of t (equivalent to a first-order Taylor series)

$$MV_D(\tau) = k_c\tau_d\frac{de(\tau)}{d\tau} \approx k_c\tau_d\frac{e(k)-e(k-1)}{\Delta\tau} \qquad (14)$$

Taking the z-transform,

$$MV_D(z) = k_c\tau_d\frac{1-z^{-1}}{\Delta\tau}E(z) \qquad (15)$$

And,

$$MV_{PID}(z) = MV_P(z)+MV_I(z)+MV_D(z)$$

$$= \left(K_c + \frac{1}{(1-z^{-1})}\frac{K_c}{\tau_i}\Delta\tau + k_c\tau_d\frac{1-z^{-1}}{\Delta\tau}\right)E(z) \qquad (16)$$

Or,

$$(1-z^{-1})MV_{PID}(z) = K_c\left(1+\frac{\Delta\tau}{\tau_i}+\frac{\tau_d}{\Delta\tau}-\left(1+\frac{2\tau_d}{\Delta\tau}\right)z^{-1}+\frac{\tau_d}{\Delta\tau}z^{-2}\right)E(z) \qquad (17)$$

Converting the controller transfer function into difference equation form gives

$MV_{PID}(k) - MV_{PID}(k-1) =$

$$K_c\left((1+\frac{\Delta\tau}{\tau_i}+\frac{\tau_d}{\Delta\tau})e(k)-\left(1+\frac{2\tau_d}{\Delta\tau}\right)e(k-1)+\frac{\tau_d}{\Delta\tau}e(k-2)\right) \qquad (18)$$

***A Digital PID calculation:***

When implementing their equations in a computer program the equations can be rewrite as shown in equation (19). *To do this calculation, previous error and control value must be stored*. The calculation also requires the scan time Δt between updates.

$$MV_{PID}(k) = MV_{PID}(k-1) + K_c\left(1+\frac{\Delta\tau}{\tau_i}+\frac{\tau_d}{\Delta\tau}\right)e(k) -$$

$$-K_c\left(1+\frac{2\tau_d}{\Delta\tau}\right)e(k-1) + K_c\frac{\tau_d}{\Delta\tau}e(k-2) \qquad (19)$$

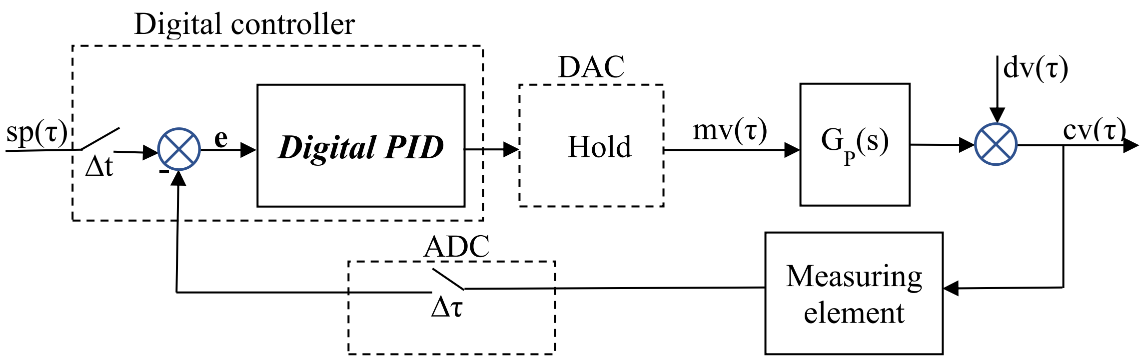



**Figure 6. Simplified block diagram for digital control**

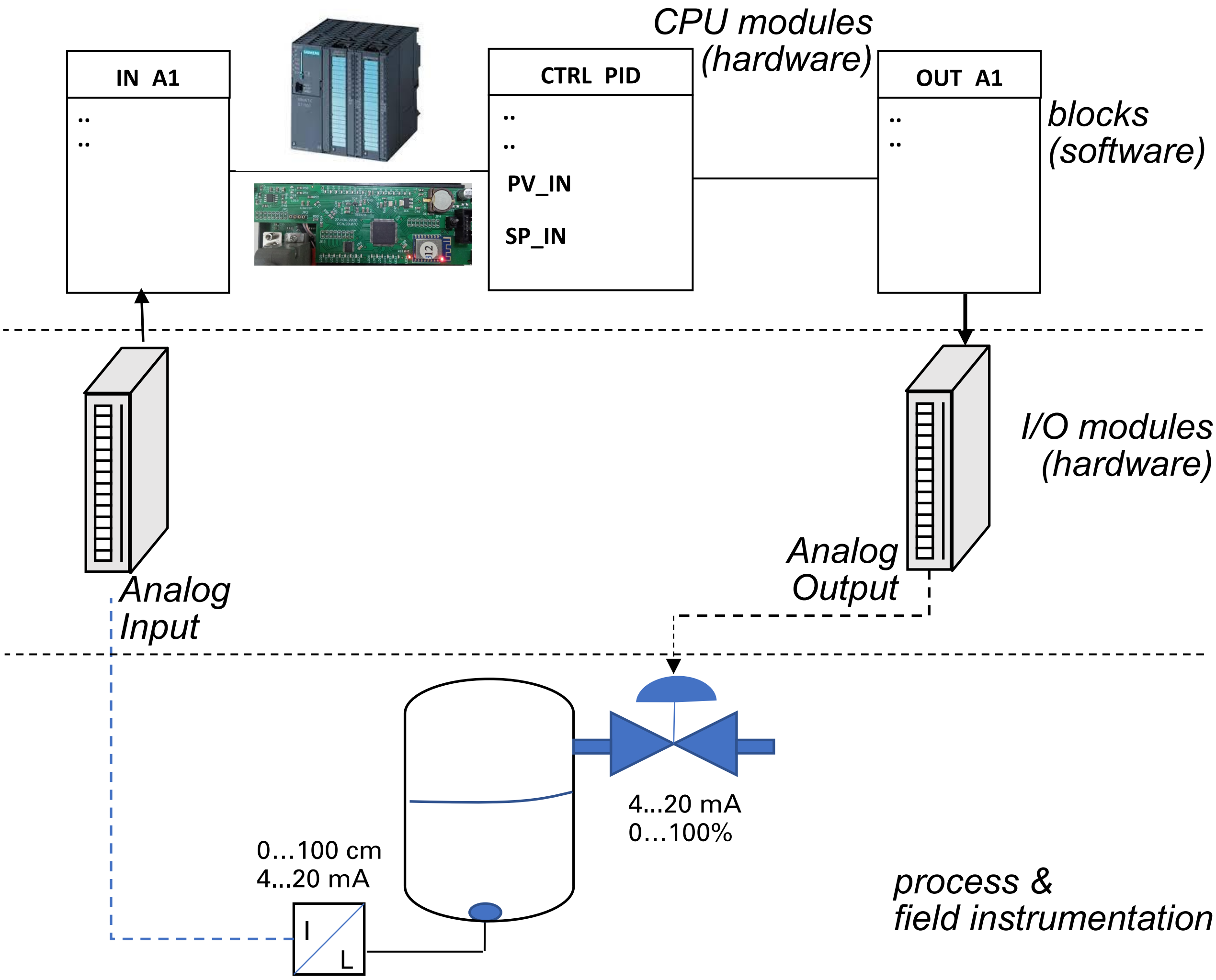



**Figure 7. Block diagram for control systems**

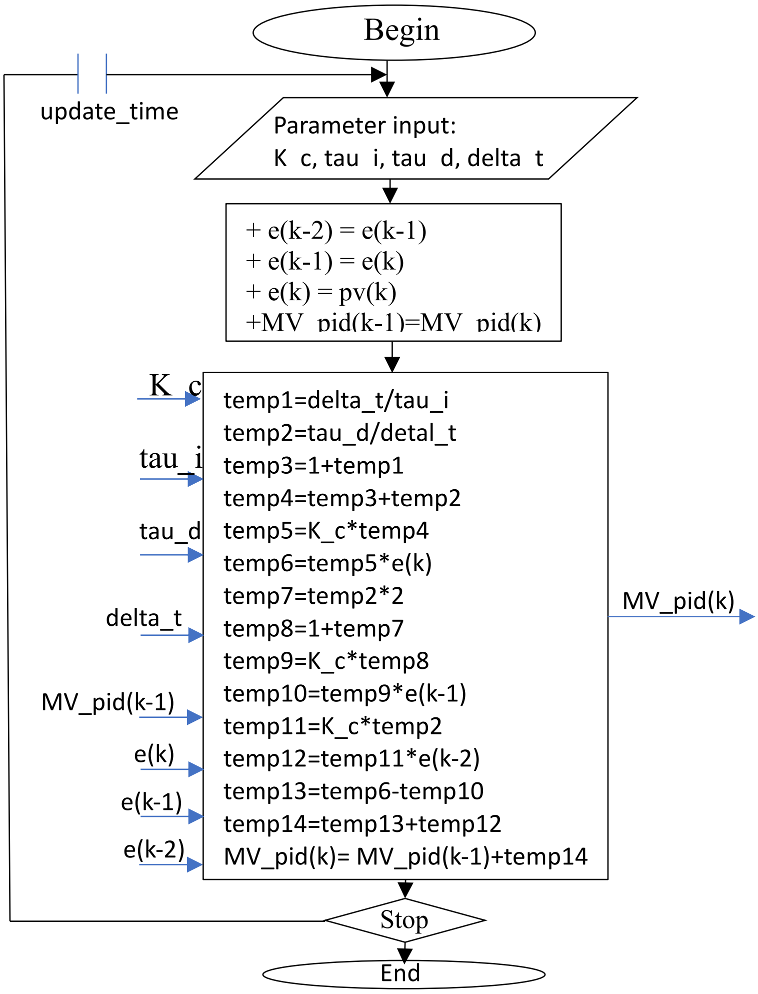



**Figure 8. Flowchart of digital PID calculation**

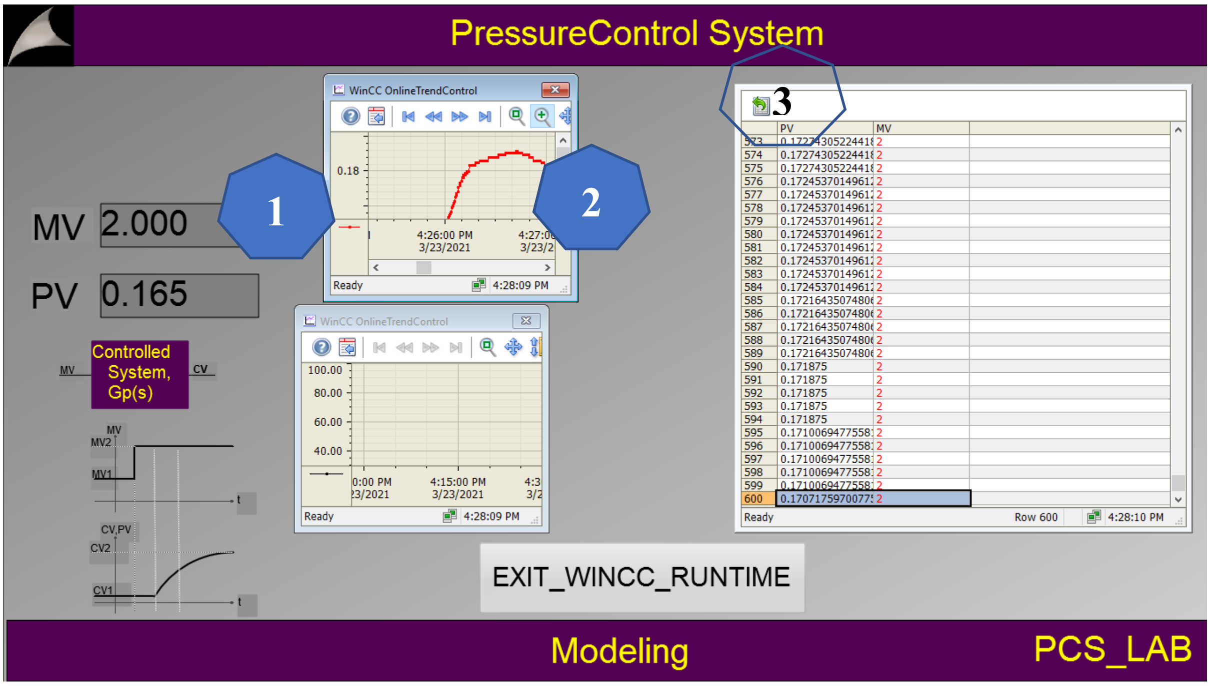



**Figure 9. Pressure control screen**

## 3. Experimental Equipment

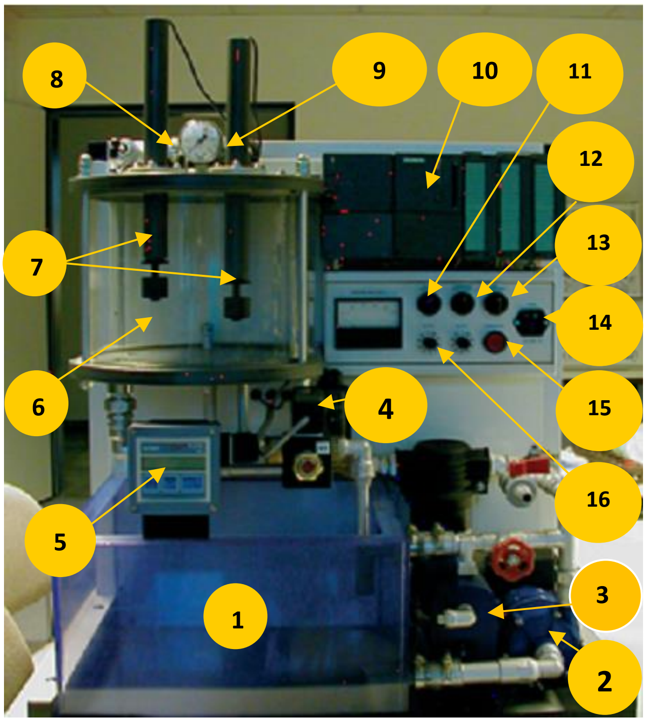



**Figure 10. Experimental Equipment**

1. Water tank; 2. Pump; 3. Compressor; 4. Control valve; 5. Flow sensor; 6. Pressure tank; 7. Limited switch; 8. Pressure sensor; 9. Pressure gauge; 10. PLC; 11. Manual/auto switch for control valve; 12. Manual/auto switch for Compressor; 13. Manual/auto switch for pump; 14. Power switch; 15. Run/Stop button and lamp; 16. Control valve adjusts.

### 3.1. Control valve

Control valve adjusts the valve opening in proportional to the electrical current (4…20 mA, 0…100%) set by the level control screen (Figure 9) or Control valve adjusts (Figure10).

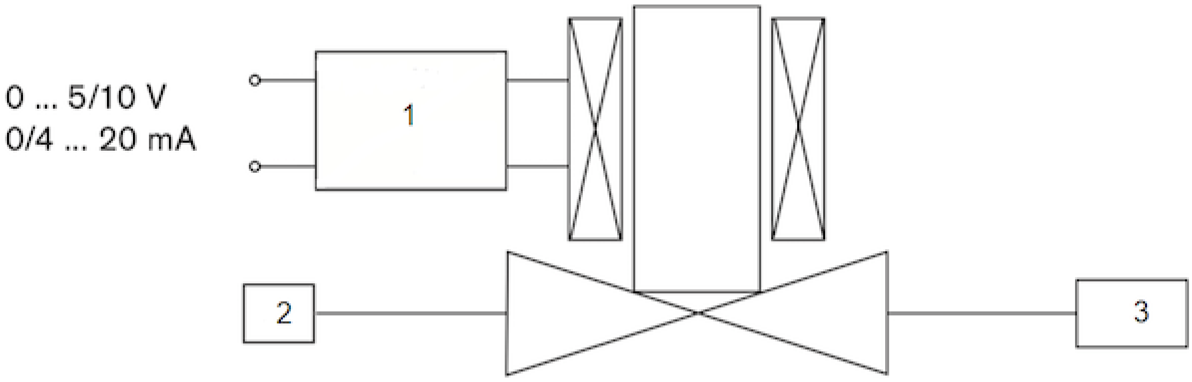



**Figure 11. Operation of control valve**: 1. Setpoint signal; 2. manipulated variable; 3. Controlled variable.

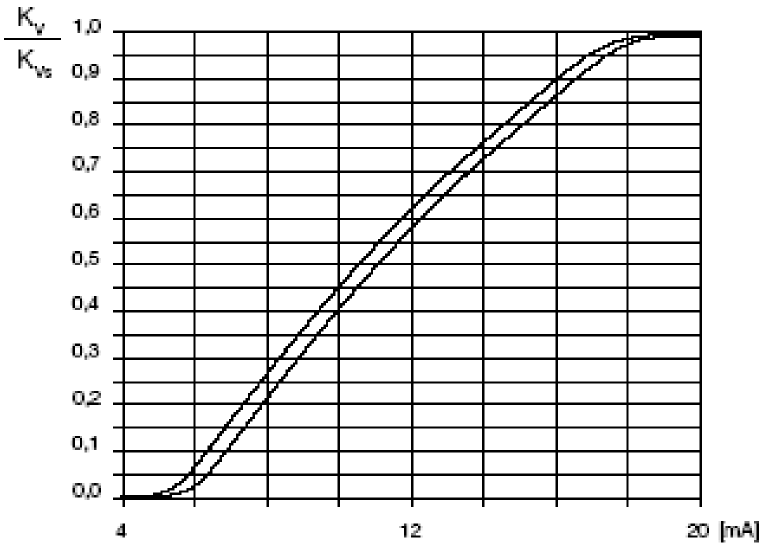



Figure 12. Proportional valve characteristics

### 3.2. Pressure sensor

The measurement range of the pressure sensor is 0…1 bar. It outputs 4…20 mA in proportional to 0…1 bar.

### 3.3. Flow sensor

The measurement range of the pressure sensor is 0…25 l/min. It outputs 4…20mA in proportional to 0…25 l/min.

## 4. Pressure and MV relationship

4.1 Start experiment

| Step | Action | Remarks |
|---|---|---|
| 1 | Open the power switch (14, Figure 10); Set the pump (2, Fig.10) to manual mode; Set control valve (8, Fig.10) to auto mode | Switch power switch (14, Figure 10) to “ON”; Switch Manual/auto switch for pump (2, Figure 10) to “MAN”; Switch Manual/auto switch for control valve (19, Fig.10) to “AUTO” |
| 2 | Open the Pressure control screen (Fig.9) | By double click on the “flow_scada” icon on desktop |
| 3 | At the “Pressure control screen”, | Set MV = 8% (1, Fig.9) |

| | | |
|---|---|---|
| | manually open control valve (8, Fig.10) | |
| 4 | Observe Process value (PV) from the “Pressure control screen” and wait until it has to a constant value ($p_s$) (4, Fig.9) | Record PV and perfect Table 4.1 |
| 5 | At the “Pressure control screen”, apply a step change to the control valve (4, Fig.10) by an additional 1% | Set MV = MV+1 (1, Fig.9) |
| 6 | Observe Process value (PV) from the “Pressure control screen” and wait until it has to a constant value (2, Fig.9) go to Step 4 until MV=50% | |

### 4.2 Results analysis

From the experimental data in the % of the MV from 8 to 50 %, the nonlinear regression analysis is working to determine the relationship between the pressure and MV. Refer to **Appendix part 4**

## 5. Process Modeling

### 5.1 Start experiment

| Step | Action | Remarks |
|---|---|---|
| 1 | Open the power switch (14, Figure 10); Set the pump (2, Fig.10) to manual mode; Set control valve (8, Fig.10) to auto mode | Switch power switch (14, Figure 10) to “ON”; Switch Manual/auto switch for pump (2, Figure 10) to “MAN”; Switch Manual/auto switch for control valve (19, Fig.10) to “AUTO” |
| 2 | Open the Pressure control screen (Fig.9) | By double click on the “flow_scada” icon on desktop |
| 3 | At the “Pressure control screen”, | Set MV = 8% (1, Fig.9) |

| | | |
|---|---|---|
| | manually open control valve (8, Fig.10) | |
| 4 | Observe Process value (PV) from the "Pressure control screen" and wait until it has to a constant value ($p_s$) (4, Fig.9) | Record PV and perfect Table 4.1 |
| 5 | At the "Pressure control screen", apply a step change to the control valve (4, Fig.10) by an additional 10% | Set MV = MV+10 (1, Fig.9) |
| 6 | Observe Process value (PV) from the "Flow control screen" and wait until it has to a constant value (2, Fig.9) | This is the "Process reaction curve" |
| 7 | Get data from the recorder | Click (3, Fig.9), we have data of the process reaction curve (excel format) |

### 5.2 Results analysis

Base on the "Process reaction curve" and experimental data, identify the Process Modeling ($G_p(s)$). Refer to **<u>part 2.2 and Appendix part 5</u>**

## 6. PID tuning

After we obtain the process model, the tuning parameters of $K_c$, $\tau_i$, $\tau_d$ can be calculated by a PID tuning rule. In this work, the Ziegler-Nichols 1, Cohen-Coon, Haalman Method, DS Method**,** IMC tuning rule will be used among many available tuning rules.
Refer to **<u>Appendix part 6</u>**

## 7. Dynamic Simulation

After you define a model, you can simulate it, using a choice integration method. There are a lot of Simulink software help you to Simulink: Python, MATLAB, Mable,…. In this practice we use MATLAB software, either from the Simulink menus or by entering commands in the MATLAB command window. The menus are particularly convenient for interactive work, while the command-line approach is very useful for running a batch of simulations. Using scopes and other display blocks, you can see the simulation results while the simulation is running. In addition, you can change parameters and immediately see what happen. Because MATLAB and Simulink are integrated, you can simulate, analyses, and revise your models in either environment at any point.

Rise time, settling time, and other step-response characteristics of automatics system can get from by Simulink:

- Rise Time ($\tau_r$) — Time it takes for the response to rise from 10% to 90% of the steady-state response.
- Settling Time ($\tau_s$) — Time it takes for the error $e(\tau) = |cv(\tau) - cv_{final}|$ between the response cv($t$) and the steady-state response $cv_{final}$ to fall below 2% of the peak value of $e(\tau)$.
- Settling Min — Minimum value of $cv(\tau)$ once the response has risen.
- Settling Max — Maximum value of $cv(\tau)$ once the response has risen.
- Overshoot (POT) — Percentage overshoot, relative to $cv_{final}$.
- Undershoot — Percentage undershoots.
- Peak — Peak absolute value of $cv(\tau)$
- Peak Time — Time at which the peak value occurs.

The following figure illustrates some of these quantities on a typical second-order response (Fig.13).

The exercise in this part, refer to **Appendix Simulink and Appendix part 7**

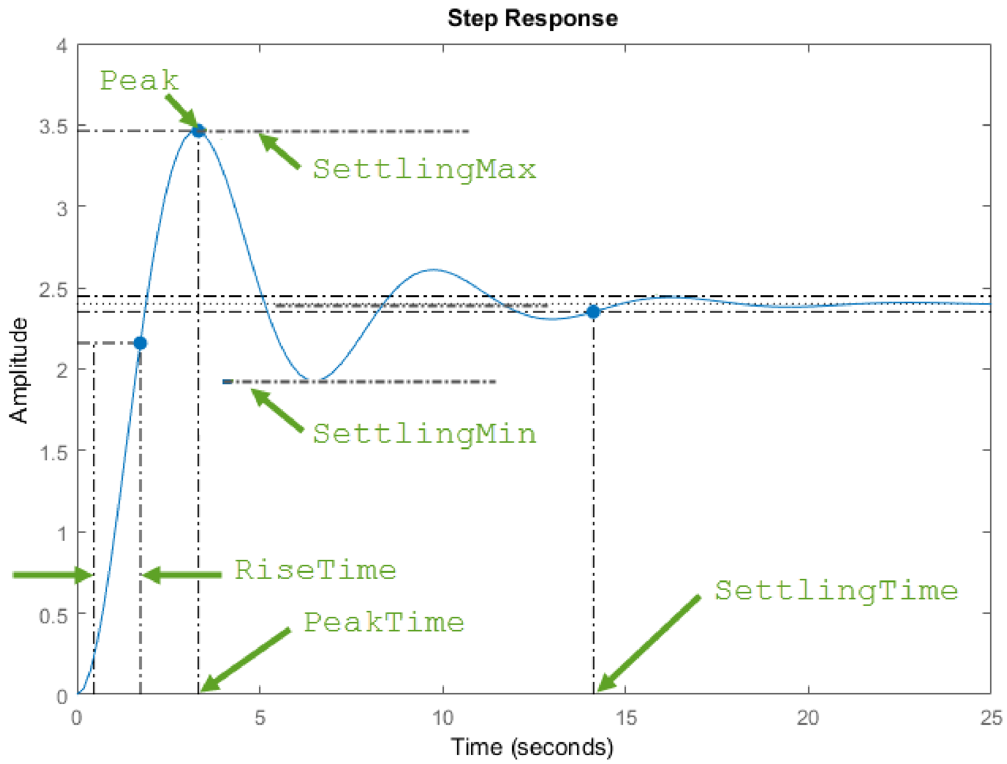



**Figure 13. Step response of second-order (Source: MathWorks)**

## 8. Process automation

From figure 7,

- A controller which receives inputs in form of digital or analog signal and process them via a programmed sequence using timers, counters, mathematical elements to generate outputs to control a determined process. There are a lot of type controller in control systems, but electronic device with microcontroller and PLC are two kind of device is use in the industry. There are two classes of PLC's: modular and compact, in form of modular, it is the one that has all the elements (Power supply, CPU, DI, DO, AI, AO, etc…) separated by functions and are interconnected via a rack or base.

- Sensor and actuators:

+ Sensors: They are to get information from the process. These elements are connected to the inputs of the PLC (DI, AI modular). There are different type of sensors:

• Proximity sensors (capacitive and inductive).

• Level sensors (Submersible pressure transmitters, level Optical, vibrating or tuning fork, ultrasonic, float, capacitance, radar, conductivity or resistance, etc…)

• Temperature sensors (Thermo-resistor, temperature gauge, pyrometer, thermocouple, etc…)

• Flow sensors (Differential Pressure Flow Meters, Positive Displacement Flow Meters, Velocity Flow Meters, Mass Flow Meters, Open Channel Flow Meters, ect…)

• Pressure sensors (Potentiometric pressure sensors, Inductive pressure sensors, Capacitive pressure sensors, Piezoelectric pressure sensors, Strain gauge pressure sensors, Variable reluctance pressure sensors)

All their elements are used to receive information from the controlled process. The dig ital signals (Proximity sensors) are connected to the digital signal input modular (DI), the analog signal (Level sensors, Temperature sensors, Flow sensors, Pressure sensors, Pressure sensors, etc…) are connected to the analog input modular (AI).

+ Actuators: They are connected to the analog signal output modular (AO) that control the components of the system to adjust them to the setpoint. Example, proportional valve, power adjust, etc…

- Human machine interfaces (HMI, PC, Display, etc…), They are used to monitor the process through information given in the PLC

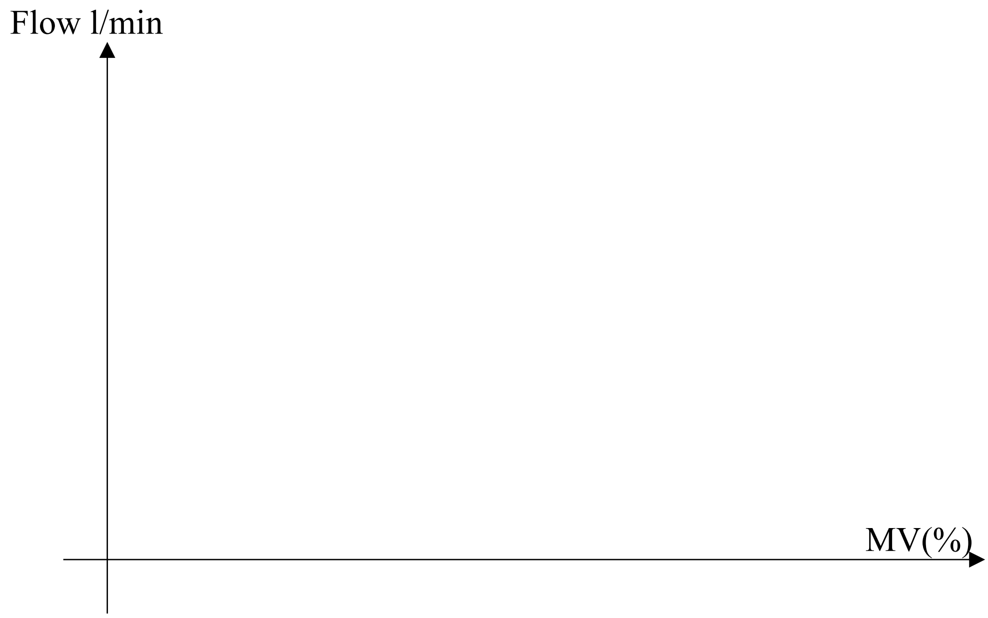
The exercise in this part, refer to **Appendix TIA portal, Cube MX and Appendix part 8**

## Appendix part 4

**Table 4.1**

| **MV(%)** | **f_out** | **$p_s$** | | | |
|---|---|---|---|---|---|
| | | **Test 1** | **Test 2** | **Test 3** | **Average** |
| **8** | | | | | |
| **9** | | | | | |
| **10** | | | | | |
| **…** | | | | | |
| **…** | | | | | |
| **50** | | | | | |

The relationships between the identified parameters (MV and pressure) are shown in Figure **Appendix A.1** and the equations (**Appendix A.1**)




$p_s$ =

## Appendix part 5

$$G_p(s) = \frac{CV_m(s)}{MV(s)} = \frac{K_p e^{-\theta_p s}}{\tau_p s + 1}$$

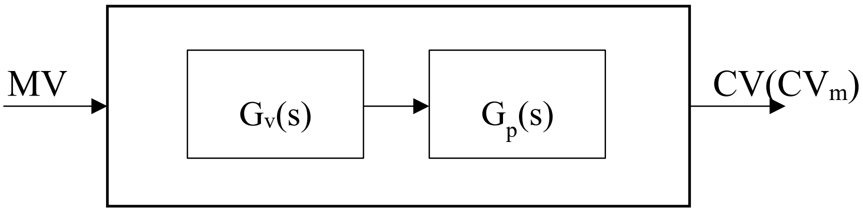



**Table 5.1**

| Par | Test 1 | Test 2 | Test 3 | Average |
|---|---|---|---|---|
| $K_p$ | | | | |
| $\tau_p$ | | | | |
| $\theta_p$ | | | | |

$G_p(s) =$

## Appendix part 6

**Note: $K = K_p$; $\tau = \tau_p$; $\theta = \theta_p$**

### Table 6.1: Ziegler-Nichols 1

| Con troller | $K_c$ | $\tau_i$ | $\tau_d$ |
|---|---|---|---|
| P | $\frac{\tau}{k\theta} =$ | - | - |
| PI | $\frac{0.9\tau}{K\theta} =$ | $3.3\theta =$ | - |
| PID | $\frac{1.2\tau}{K\theta} =$ | $2\theta =$ | $0.5\theta =$ |

### Table 6.2: Cohen-Coon

| Controller | $K_c$ | $\tau_i$ | $\tau_d$ |
|---|---|---|---|
| P | $\frac{\tau}{K\theta}\left(1+\frac{\theta}{3\tau}\right) =$ | - | - |
| PI | $\frac{\tau}{K\theta}\left(0.9+\frac{\theta}{12\tau}\right) =$ | $\frac{\theta\left(30+\frac{3\theta}{\tau}\right)}{9+\frac{20\theta}{\tau}} =$ | - |
| PID | $\frac{\tau}{K\theta}\left(\frac{16+\frac{3\theta}{\tau}}{12}\right) =$ | $\frac{\theta\left(32+\frac{6\theta}{\tau}\right)}{13+\frac{8\theta}{\tau}} =$ | $\frac{4\theta}{11+\frac{2\theta}{\tau}} =$ |

### Table 6.3: Haalman

| Con troller | $K_c$ | $\tau_i$ | $\tau_d$ |
|---|---|---|---|
| P | | - | - |
| PI | $\frac{2\tau}{3K\theta} =$ | $\tau =$ | - |
| PID | | | |

### Table 6.4: Direct Synthesis

$$G(s) = \frac{e^{-\theta s}}{\tau_c s+1} \text{ or } T(s) = \frac{K_d s e^{-\theta s}}{(\tau_c s+1)^2}$$

| Con troller | $K_c$ | $\tau_i$ | $\tau_d$ |
|---|---|---|---|
| P | | - | - |

| | | | |
|---|---|---|---|
| PI<br>(DS) | $\frac{\tau}{K(\tau_c+\theta)} =$<br>$\tau_c = \tau;\ \tau_c = 0.5\tau$ | $\boldsymbol{\tau_i = \tau =}$ | - |
| PI<br>(Chen & Seborg) | $\frac{\boldsymbol{T_i}}{(\boldsymbol{\tau_c+\theta})\mathrm{K}} =$ | $\frac{\boldsymbol{\tau^2+\theta\tau-(\tau_c-\tau)^2}}{\boldsymbol{\tau+\theta}} =$ | |

**Table 6.4: IMC**

| Con troller | $K_c$ | $\tau_i$ | $\tau_d$ |
|---|---|---|---|
| P | | - | - |
| PI | $\lambda = 1.7\theta$<br>$\frac{(2\tau+\theta)}{2K\lambda} =$ | $\tau + \frac{\theta}{2} =$ | |
| PID | $\lambda = 0.25\theta$<br>$\frac{(2\tau+\theta)}{2(\lambda+\theta)} =$ | $\tau + \frac{\theta}{2} =$ | $\frac{\tau\theta}{(2\tau+\theta)} =$ |

## Appendix part 7

### Part 7.1: Step response of process curve

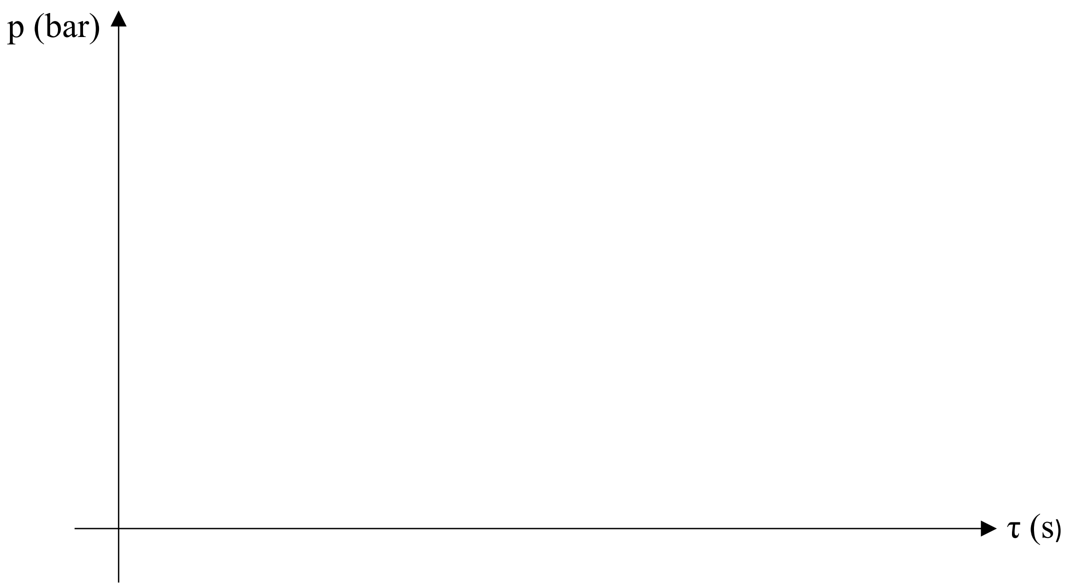



**Table 7.1: Step-response characteristics**

| Step change **(MV,%)** | **POT** | $\tau_s$ | $\tau_r$ |
|---|---|---|---|
| 0,1.1(τ) | | | |
| 0,15.1(τ) | | | |

## Appendix part 7

### Part 7.2: Step response of process curve with closed loop tuning (ZN-1)


**Table 7.2: Step-response characteristics with closed loop tuning (ZN-1)**

| Setpoint change **(Sp)** | **POT** | $\boldsymbol{\tau_s}$ | $\boldsymbol{\tau_r}$ | $\mathbf{e_\infty}$ |
|---|---|---|---|---|
| 0,09.1(τ) | | | | |
| 0,2.1(τ) | | | | |

### Part 7.2: Step response of process curve with closed loop tuning (Cohen-Coon)


**Table 7.2: Step-response characteristics with closed loop tuning (Cohen-Coon)**

| Setpoint change **(Sp)** | **POT** | $\boldsymbol{\tau_s}$ | $\boldsymbol{\tau_r}$ | $\mathbf{e_\infty}$ |
|---|---|---|---|---|
| 0,09.1(τ) | | | | |
| 0,2.1(τ) | | | | |

**Part 7.3: Step response of process curve with closed loop tuning (Haalman)**


**Table 7.3: Step-response characteristics with closed loop tuning (Haalman)**

| Setpoint change **(Sp)** | **POT** | $\boldsymbol{\tau_s}$ | $\boldsymbol{\tau_r}$ | $\mathbf{e_\infty}$ |
|---|---|---|---|---|
| 0,09.1(τ) | | | | |
| 0,2.1(τ) | | | | |

**Part 7.4: Step response of process curve with closed loop tuning (Direct Synthesis)**


**Table 7.4: Step-response characteristics with closed loop tuning (Direct Synthesis)**

| Setpoint change **(Sp)** | **POT** | $\boldsymbol{\tau_s}$ | $\boldsymbol{\tau_r}$ | $\mathbf{e_\infty}$ |
|---|---|---|---|---|
| 0,09.1(τ) | | | | |
| 0,2.1(τ) | | | | |

## Part 7.5: Step response of process curve with closed loop tuning (IMC)


**Table 7.5: Step-response characteristics with closed loop tuning (IMC)**

| Setpoint change **(Sp)** | **POT** | $\tau_s$ | $\tau_r$ | $e_\infty$ |
|---|---|---|---|---|
| 0,09.1(τ) | | | | |
| 0,2.1(τ) | | | | |

## Appendix part 8

The structure of the system is show in Fig 8.1.

**Fig.8. Experiment process pressure diagram with PLC**

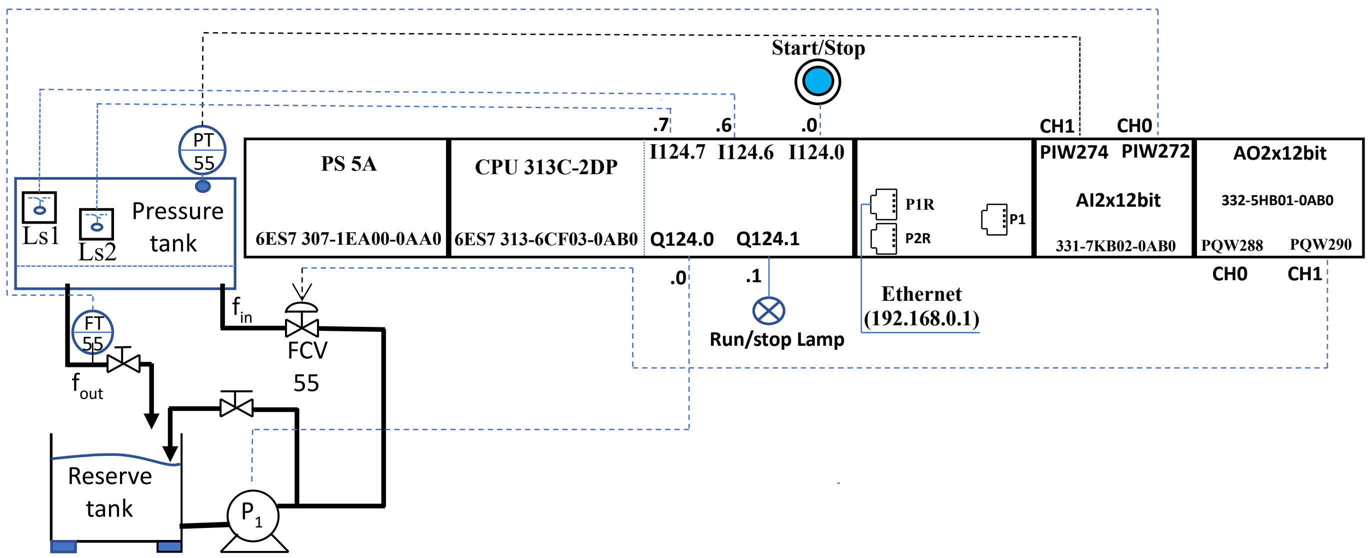



**Table 8.1: Input/output address of process pressure systems**

| Add | Equipment's |
|---|---|
| **I124.0** | S1 Start/Stop button |
| **I124.6** | LS1 high limited sensor |
| **I124.7** | LS1 low limited sensor |
| **Q124.0** | P1 Pump |
| **Q124.1** | Start/ Stop lamp |
| **AI 0 (PIW272)** | Flow transmitter 0…25 l/min, 4…20 mA |
| **AI 1 (PIW274)** | Pressure transmitter 0…1bar, 4…20 mA |

| | |
|---|---|
| **AO 1 (PQW274)** | V2 Control valve (proportional valve) |

**Exercise:** Configure hardware Siemens s7-300 PLC with TIA portal. After that, program to control system with **flowchart fig.8**

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The structure of the system is show in Fig 8.2

**Fig 8.2 Experiment process flow diagram with STM32 embedded board**

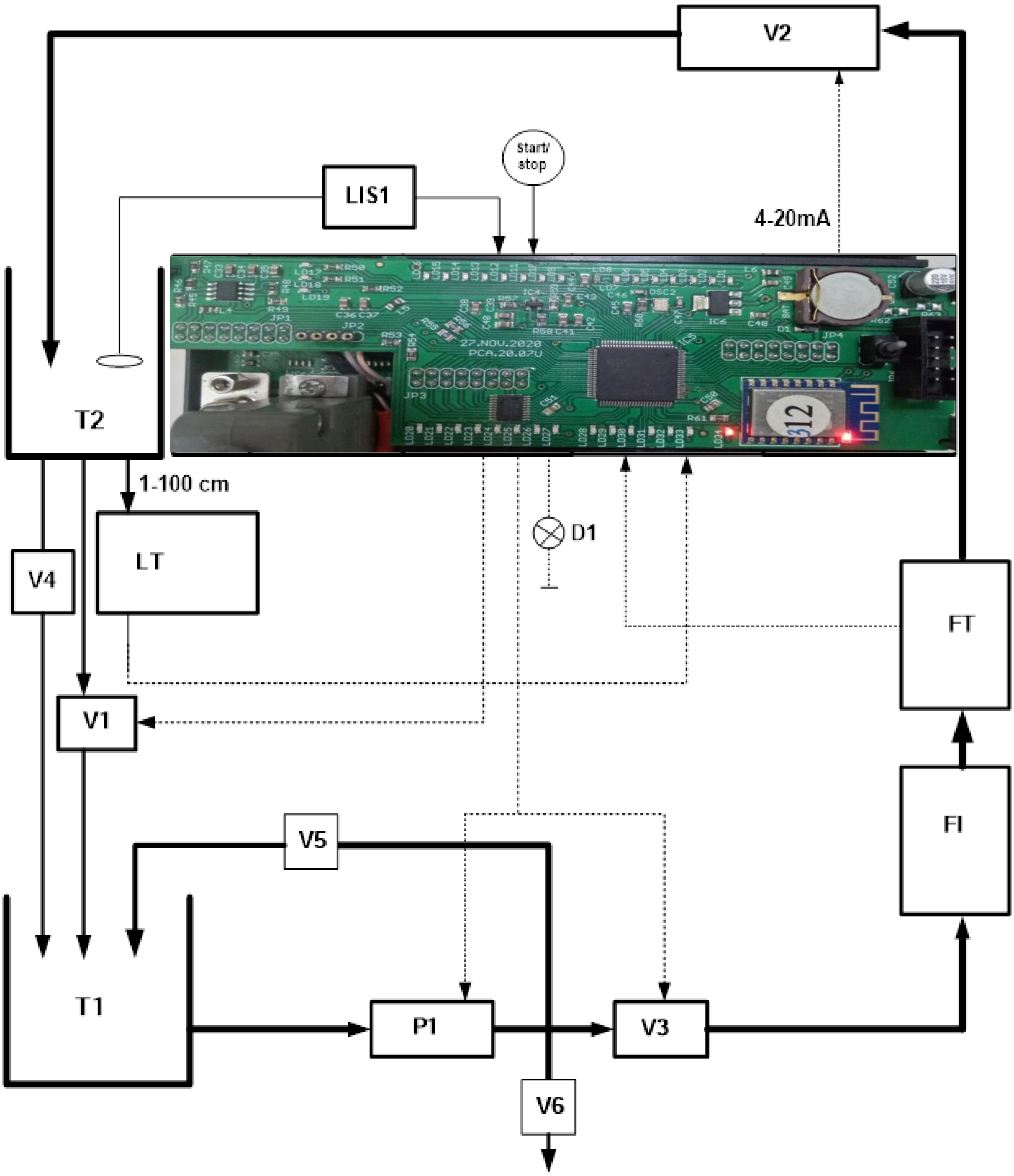

**Table 8.2: Input/output address of process flow systems**

# STM32F205VCT6

1. Input:

| No. | Sym | ARM - PIN | Note |
|---|---|---|---|
| 1 | IN1 | PD.13 | Timer 4 (Encoder) |
| 2 | IN2 | PD.12 | Timer 4 (Encoder) |
| 3 | IN3 | PD.11 | |
| 4 | IN4 | PC.6 (PB.10) | Timer 8 (Encoder) |
| 5 | IN5 | PC.7 (PE.15) | Timer 8 (Encoder) |
| 6 | IN6 | PE.14 | |
| 7 | IN7 | PA.15 (PE.12) | |
| 8 | IN8 | PC.8 (PE.13) | |
| 9 | IN9 | PB.5 | |
| 10 | IN10 | PB.4 | |
| 11 | IN11 | PB.3 | |
| 12 | IN12 | PD.7 | |
| 13 | IN13 | PD.6 | |
| 14 | IN14 | PD.5 | |

2. Output:

| No. | Sym | ARM - PIN | Note |
|---|---|---|---|
| 1 | OUT1 | PB.0 | Timer 3 |
| 2 | OUT2 | PA.7 (PB.1) | Timer 14 |
| 3 | OUT3 | PB.2 | |
| 4 | OUT4 | PE.7 | |
| 5 | OUT5 | PE.8 | |
| 6 | OUT6 | PE.9 | |
| 7 | OUT7 | PE.10 | |
| 8 | OUT8 | PE.11 | |
| 9 | OUT9 | PB.7 | |

| | | | |
|---|---|---|---|
| 10 | OUT10 | PB.6 | |
| 11 | OUT11 | PB.9 | |
| 12 | OUT12 | PE.0 (PE.6) | |

3. **Other:**

| No. | Sym | ARM - PIN | Note |
|---|---|---|---|
| 1 | AI.0 | PC.0 | Analog input CH0, 0…10Vdc, level CH |
| 2 | AI.1 | PC.3 | Analog input CH01, 0…10Vdc, flow CH |
| 3 | AO.0 | PA.4 | Analog output CH0, 0…10Vdc |
| 4 | A0.1 | PA.5 | Analog output CH1, 0…10Vdc, MV |
| 5 | TX.0 | PA.2 (UART2-TX) | Serial communications Port.0, transmitted pin |
| 6 | RX.0 | PA.3 (UART2-RX) | Serial communications Port.0, received pin |
| 7 | TX.1 | PA.0 (UART4-TX) | Serial communications Port.1, transmitted pin |
| 8 | RX.1 | PA.1 (UART4-RX) | Serial communications Port.1, received pin |
| 9 | DE.1/RE.1 | PC.5 | Serial communications Port.1, controlled pin |
| 10 | TX.2 | PA.9 (UART1-TX) | Serial communications Port.2, transmitted pin (IOT) |
| 11 | RX.2 | PA.10 (UART1-RX) | Serial communications Port.2, received pin (IOT) |
| 12 | Run-Stop | PD.2 | Run / Stop program |
| 15 | Bus-Ena | PC.12 | Exp In/Out |
| 16 | TX.3 | PC.10 (UART3-TX) | Serial communications Port.3, transmitted pin (exp) |
| 17 | RX.3 | PC.11 (UART3-RX) | Serial communications Port.3, received pin (exp) |
| 18 | POWER | PD.4 | Lose power |

4. **Led Status:**

| No. | Sym | ARM - PIN | Note |
|---|---|---|---|
| 1 | RUN | PC.1 | Run status |
| 2 | COM.0 | PC.2 | Communication status Port.0 |
| 3 | COM.1 | PA.6 | Communication status Port.1 |
| 4 | IOT | PE.5 | Communication status IOT |
| 5 | In Out | PE.4 | In/out status |

**Exercise:** Configure hardware STM32F205 with Cube MX. After that, program to control system