Design of PID Controller for first order and second order systems

Objectives:

i. The flow rate in the piping system of RT 578 should be controlled experimentally using PID controller.
ii. The transfer function of the flow rate system should be determined with first Ziegler-Nichols approximation method.
iii. Design a PID controller of first and second order LTI systems with oscillation (second Ziegler-Nichols) method.

Theory:

Ziegler–Nichols Rules for Tuning PID Controllers First method

This method applies if the response to a step input exhibits an S-shaped curve. Such step-response curves may be generated experimentally or from a dynamic simulation of the plant.

It is possible to apply various design techniques for determining parameters of the controller that will meet the transient and steady-state specifications of the closed-loop system, see Figure 1.

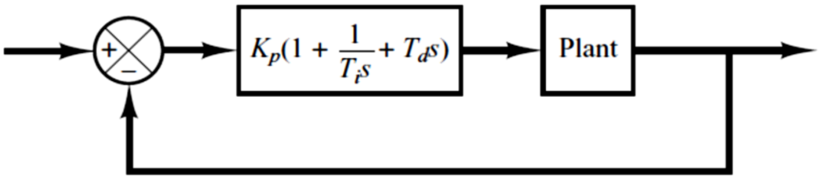


Figure 1: PID control of a plant.

The S-shaped curve may be characterized by two constants, delay time (L) and time constant (T). The delay time and time constant are determined by drawing a tangent line at the inflection point of the S-shaped curve and determining the intersections of the tangent line with the time axis and line c(t)=K, as shown in the following figure 2.

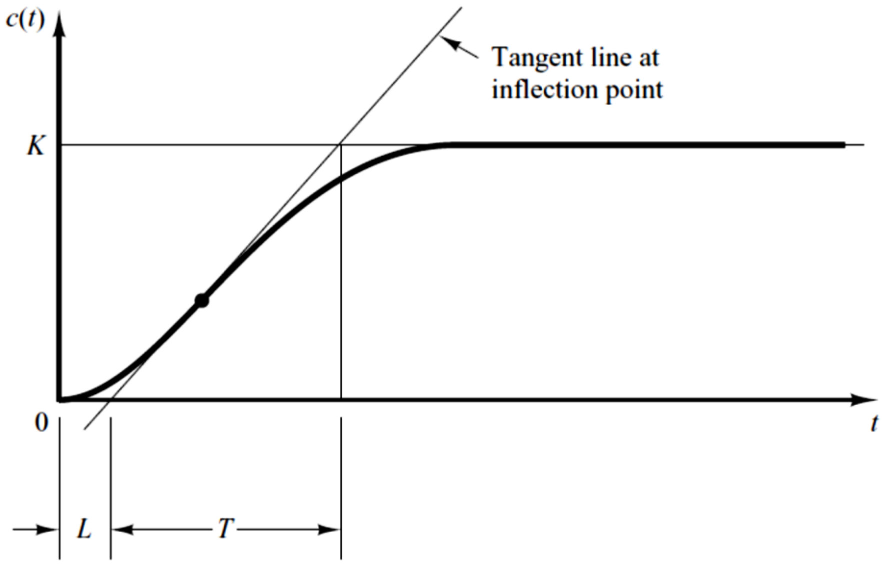


Figure 2: S-shaped response curve.

The transfer function C(s)/U(s) may then be approximated by a first-order system with a transport lag as follows:

$$\frac{C(s)}{U(s)} = \frac{Ke^{-Ls}}{Ts + 1}$$

The PID controller tuned by the first method of Ziegler–Nichols rules gives

$$G_c(s) = K_p\left(1 + \frac{1}{T_i s} + T_d s\right)$$

Where: $K_p = 1.2\frac{T}{L}$, $T_i = 2L$, $T_d = 0.5L$

K_p : Proportional gain. T_i : Integral time. T_d: Derivative time.

Procedure of the experiment:

a-Adjust the valves according to the following table:

Valve	*V4*	*V5*	*V8*	*V9*	*V11*	*V12*	*V13*	*V14*	*V15*	*V19*
Adjustment	*closed*	*closed*	*open*							

b- Set the following steps:

- Switch Cabient
- ✓ control loop → loop 3
- ✓ Jumper → flow rate
- ✓ Switch for electro-pneumatic controlV6 → control.
- ✓ Switch for pump P1: manual → 100%
- ✓ Switch for heater H2 → switched off
- Call the measurement data acquisition program (GUNT) for RT578
- ○ PID controller:
- ✓ Kp = 0.241
- ✓ Tn (Td) = 1.136
- ✓ Tv (Ti) = 0.171

- ○ The step change in reference variable of:

W = 10 % ⇒ 40 %

Where W: reference variable (blue)

X : controlled variable (red)

Y : manipulating variable (yellow)

See the results obtained in figure window of the GUNT program.

Second method

In the second method, we first set and Using the proportional control action only (see Figure 8–4), increase Kp from $0\ to \infty$ critical value Kcr at which the output first exhibits sustained oscillations. (If the output does not exhibit sustained oscillations for whatever value Kp may take, then this method does not apply.) Thus, the critical gain Kcr and the corresponding period Pcr are experimentally

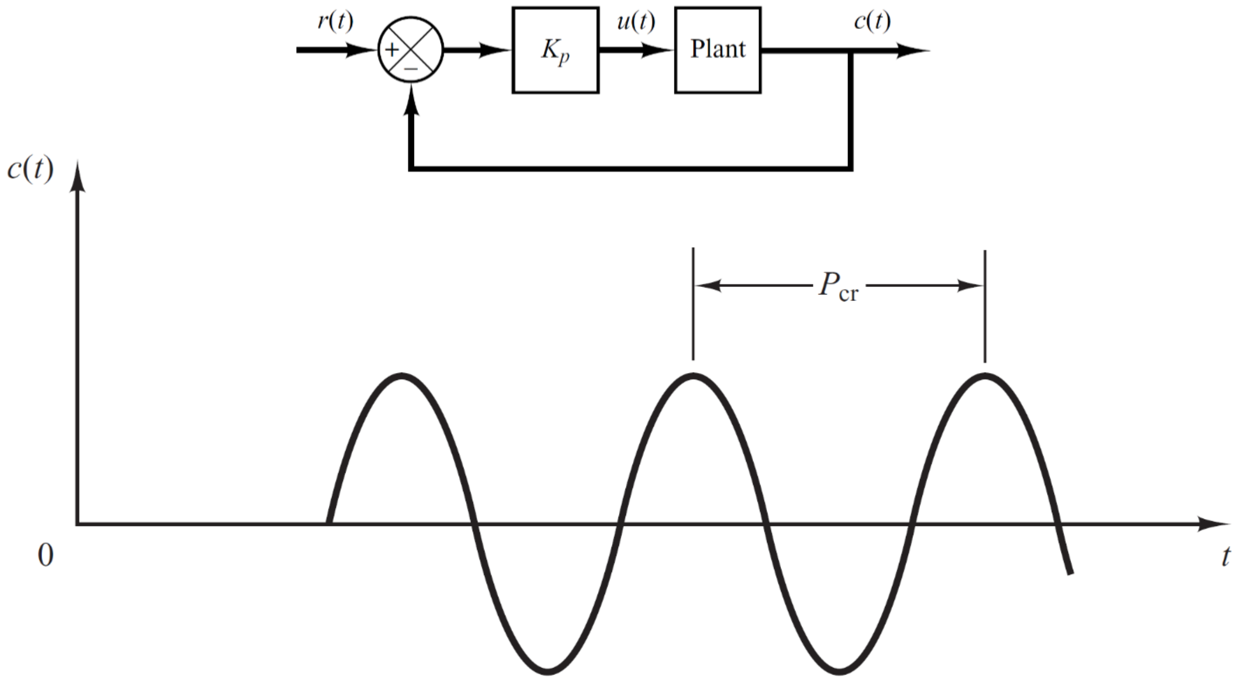


Figure 3: Sustained oscillation with period Pcr

determined (see Figure 3). Ziegler and Nichols suggested that we set the values of the parameters Kp , Ti , and Td according to the formula shown in Table 2.

Table 2 Ziegler–Nichols Tuning Rule Based on Critical Gain K_{cr} and Critical Period P_{cr} (Second Method)

Type of Controller	K_p	T_i	T_d
P	$0.5K_{cr}$	∞	0
PI	$0.45K_{cr}$	$\frac{1}{1.2}P_{cr}$	0
PID	$0.6K_{cr}$	$0.5P_{cr}$	$0.125P_{cr}$

Notice that the PID controller tuned by the second method of Ziegler–Nichols rules gives.

$$G_c(s) = K_p\left(1 + \frac{1}{T_i s} + T_d s\right)$$

iv. **OBJECTIVE OF THE EXPERIMENT:** To design a PID controller for the following second order system,
1-G(s)= 1 / (s[s+1][s+5])
2-G(s)= 5 / (s^2+6s+5)

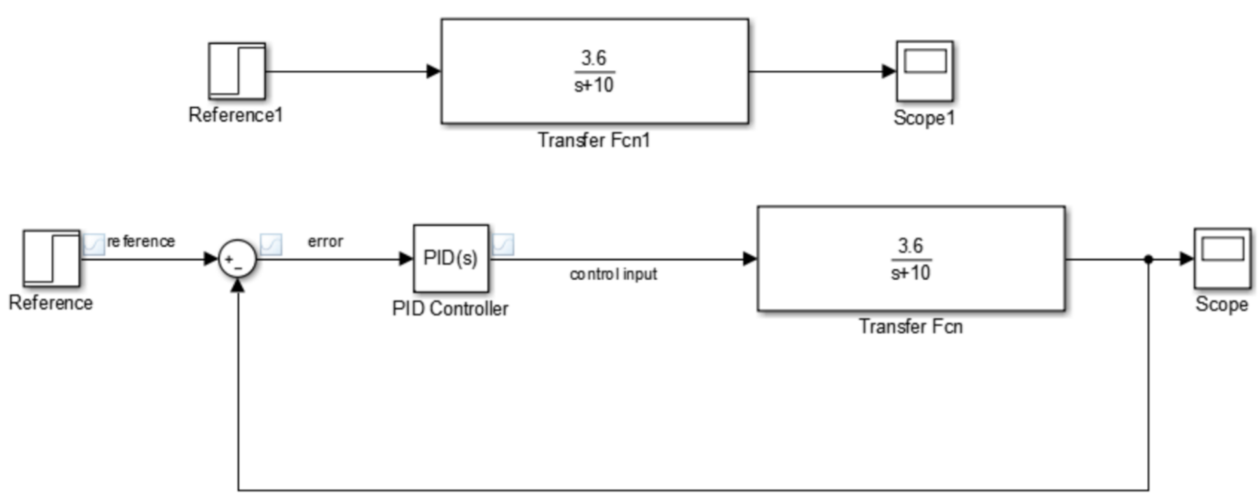
Your design should satisfy the following specifications:

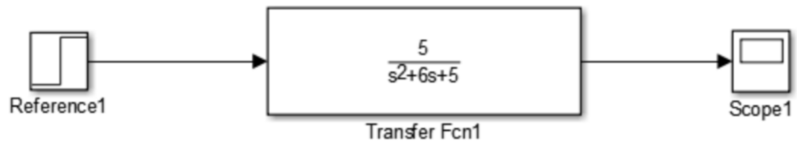
- ✓ Percentage overshoot < 15%.
- ✓ Rise time < 100 msec.
- ✓ Settling time < 500 msec.
- ✓ Zero steady-state error to a step.

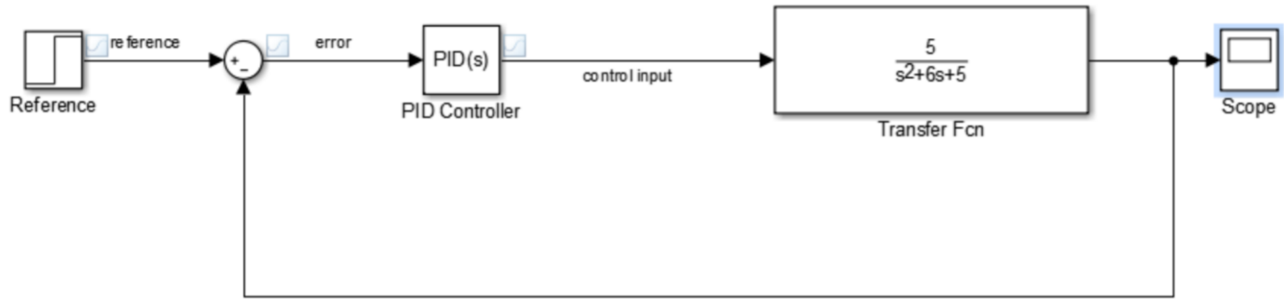
Facilities required: Computer, and Matlab Simulink package

DESIGN PROCEDURE/ DESIGN CALCULATIONS:

For first order then use Trial and Error for tuning the parameters.
For second order system G(s)= 1 /(s[s+1][s+5]).Determine the PID parameters from table 2
BLOCK DIAGRAM IN SIMULINK MATLAB:







PARAMETERS OF PID CONTROLLERS:

FIRST ORDER SYSTEM:	SECOND ORDER SYSTEM:
Kp=	Kp=
Ki=	Ki=
Kd=	Kd=

MODEL OUTPUT RESPONSE:

Figure 4: First order uncontrolled open loop response.

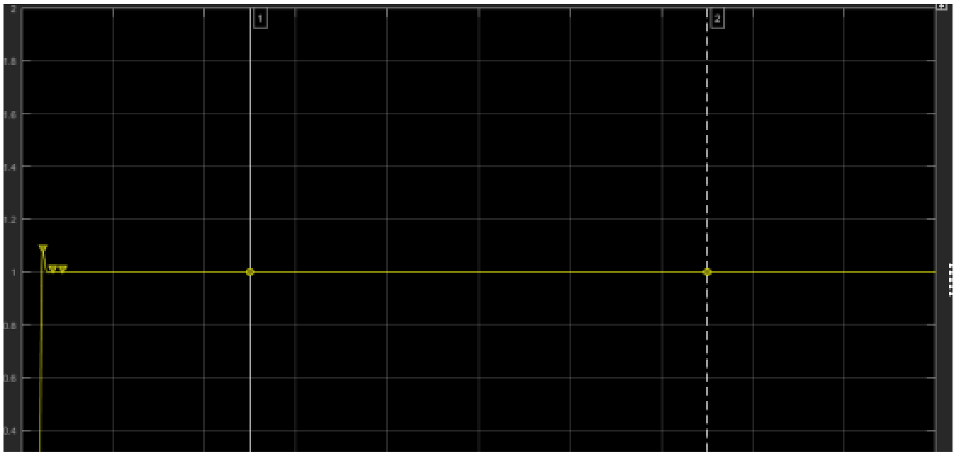


Figure 5: First order controlled closed loop response

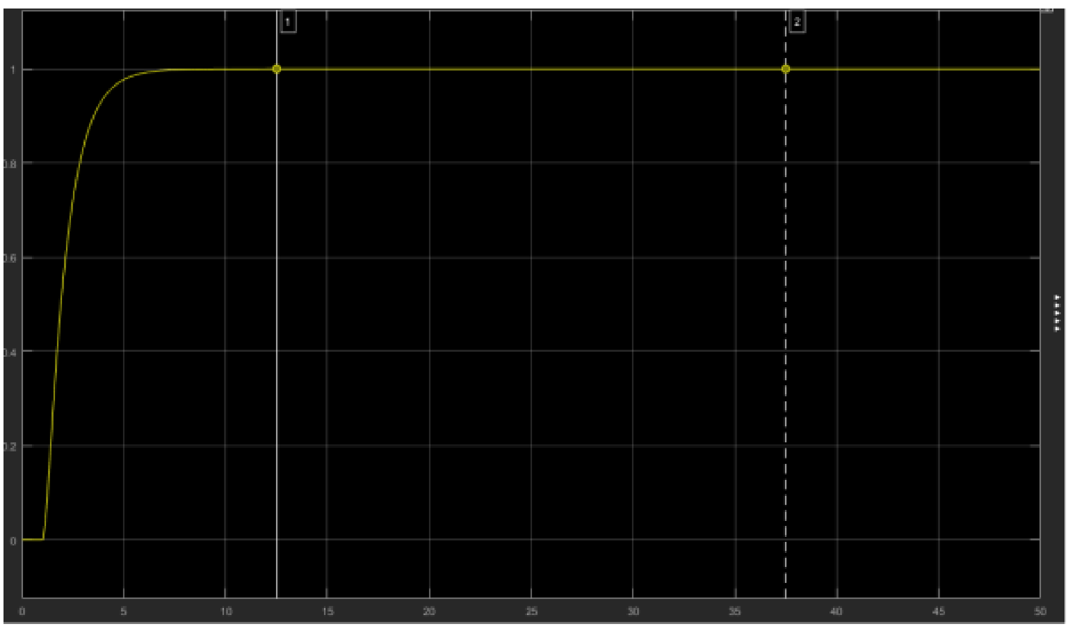


Figure 6: Second order uncontrolled open loop response

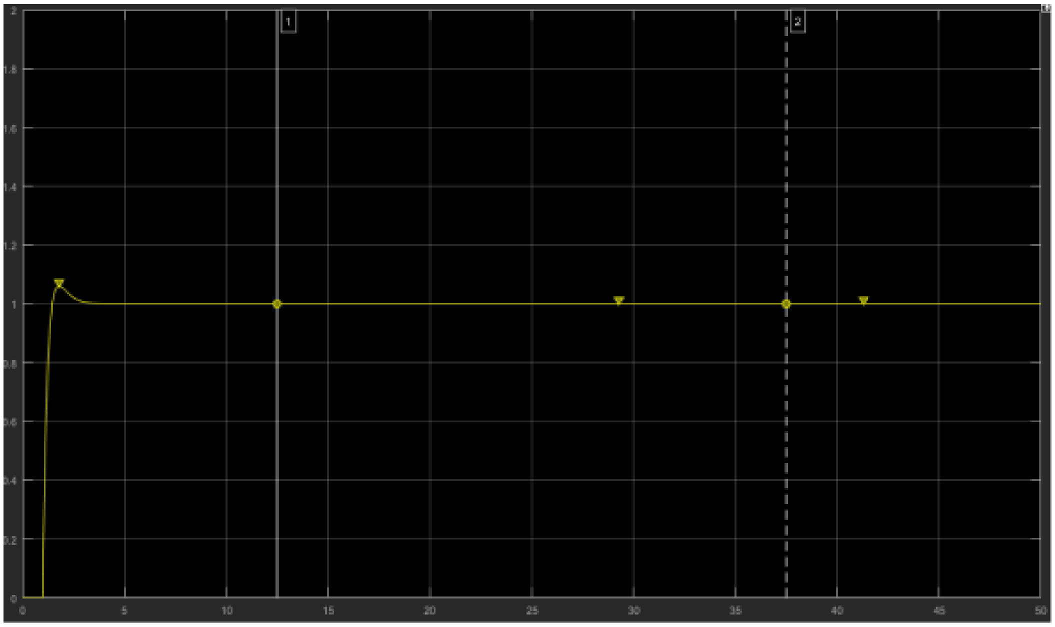


Figure 7: Second order controlled closed loop response

Lab questions:

- What is the effect of P, I and D on output response of a system?
- List the advantages of PID over PI controller.
- What is the effect of addition of poles and zeros to a system?