MTRE4002 Feedback Control Laboratory

Lab #2 PID Control using MATLAB/Simulink Simulations

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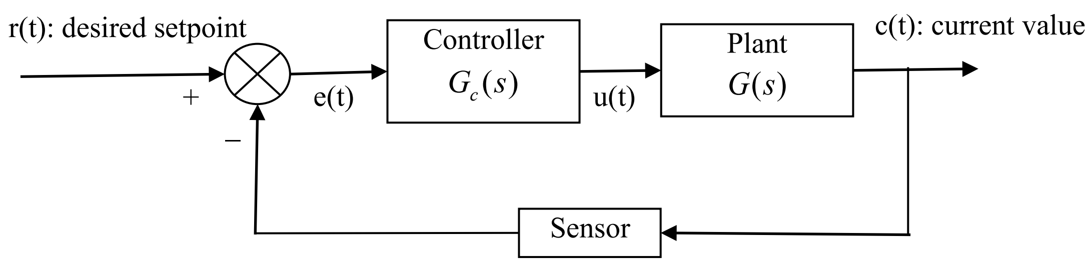
Objective

In this lab, students are required to create PID controllers using MATLAB/Simulink, simulate the behaviors of a feedback control system, measure and assess various performance specifications under different controller parameters.

Background knowledge

1. **Feedback control systems**

   A typical feedback control is presented below:



Where, the plant is a system (for example, a DC motor) to be controlled, and the controller provides the excitation for the plant and is designed to control the overall system behavior.

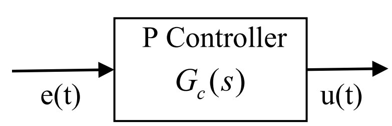
2. **PID Controller**

A proportional–integral–derivative controller (PID controller) is a generic controller widely used in industrial control systems – a PID is the most commonly used feedback controller. A PID controller calculates an "error" value as the difference between a measured process variable and a desired setpoint. The controller attempts to minimize the error by adjusting the process control inputs.

There are four kinds of variants of PID control:

- P control
- PI control
- PD control
- PID control

3. **P Control (Proportional Control)**



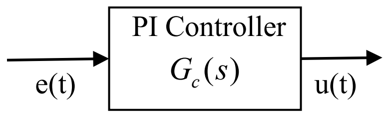
For a proportional controller, its input/out relationship can be described with the following equation.

$u(t) = k_p e(t)$ where k_p is the **proportional gain**

Accordingly, the transfer function of the controller is

$$G_c(s) = \frac{U(s)}{E(s)} = k_p$$

4. **PI Control (Proportional–Integral Control)**



For a PI controller, its input/out relationship can be described with the following equation.

$$u(t) = k_p e(t) + k_i \int e(t)dt$$

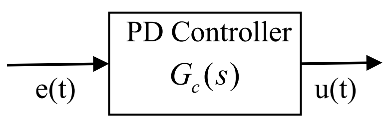
where k_p is the proportional gain

k_i is the **integral gain**

Accordingly, the transfer function of the controller is

$$G_c(s) = \frac{U(s)}{E(s)} = k_p + \frac{k_i}{s}$$

5. **PD Control (Proportional– Derivative Control)**



For a PD controller, its input/out relationship can be described with the following equation.

$$u(t) = k_p e(t) + k_d \frac{de(t)}{dt}$$

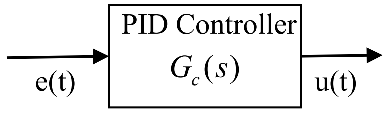
where k_p is the proportional gain

k_d is the **derivative gain**

Accordingly, the transfer function of the controller is

$$G_c(s) = \frac{U(s)}{E(s)} = k_p + k_d s$$

6. **PID Control (Proportional–Integral–Derivative Control)**



For a PID controller, its input/out relationship can be described with the following equation.

$$u(t) = k_p e(t) + k_i \int e(t)dt + k_d \frac{de(t)}{dt}$$

where k_p is the **proportional** gain

k_i is the **integral gain**

k_d is the **derivative gain**

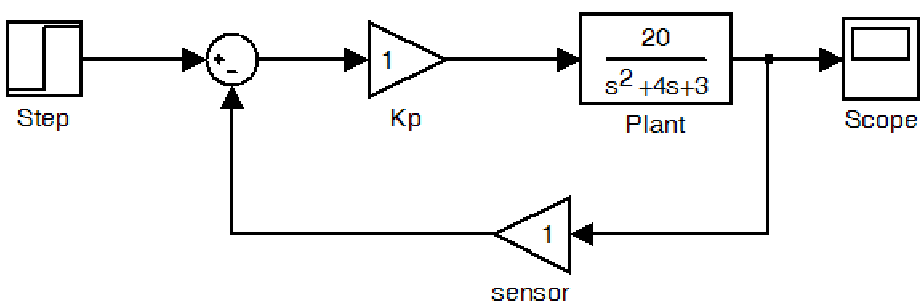
Accordingly, the transfer function of the controller is

$$G_c(s) = \frac{U(s)}{E(s)} = k_p + k_i \frac{1}{s} + k_d s$$

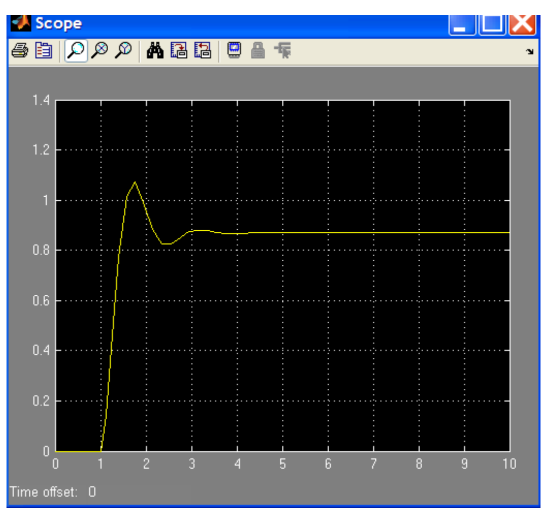
Lab Procedures

1. P controller

Please follow the instructor step by step to create the following Proportional control system in Simulink.



Run the above Simulink model, double-click the "Scope" block and you may get the following response curve.



From the above step response curve, you may measure various performance specifications such as rise time, peak time, and percent overshoot.

Please set the proportional gain according to Table 1, run the Simulink model, measure the response curve and complete the table:

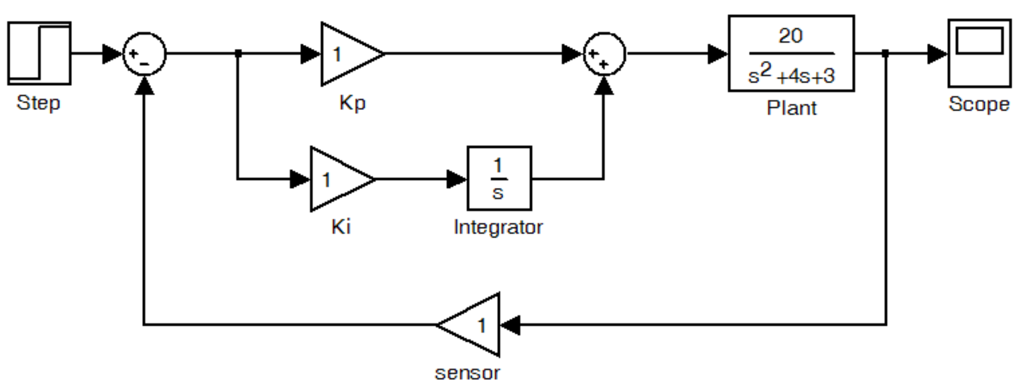
Table 1 Effects of Proportional Gain

Proportional Gain (k_p)	Rise Time (T_r)	Peak Time (T_p)	Setting Time (T_s)	Percent Overshoot (%OS)	Steady-state Error (e_{ss})	Is it a stable system? (Yes/No)	Type of the System (Under/Over/ Critically Damped System?)
0.1							
1							
5							
10							
20							
100							
1000							

Based on the information in the above table, please draw a conclusion.

2. PI controller

Please follow the instructor step by step to create a PI control system in Simulink, as indicated below.



Please set the proportional gain and integral gain according to Table 2, run the Simulink model, measure the response curve and complete the table:

Table 2 Effects of Integral Gain

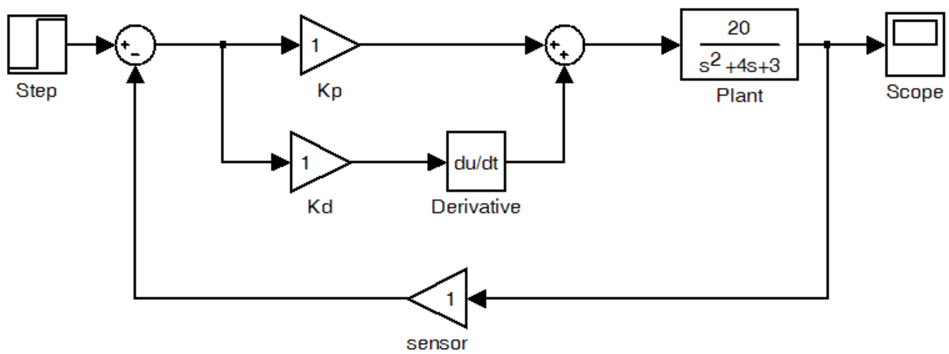
Proportional Gain (k_p)	Integral Gain (k_i)	Rise Time (T_r)	Peak Time (T_p)	Setting Time (T_s)	Percent Overshoot (%OS)	Steady-state Error (e_{ss})	Is it a stable system? (Yes/No)	Type of the System (Under/Over/ Critically Damped System?)
1	1							
1	2							
1	4							
1	10							
1	100							

1	1000							
1	10000							

Based on the information in the above table, please draw a conclusion.

3. PD controller

Please follow the instructor step by step to create a PD control system in Simulink, as indicated below.



Please set the proportional gain and derivative gain according to Table 3, run the Simulink model, measure the response curve and complete the table:

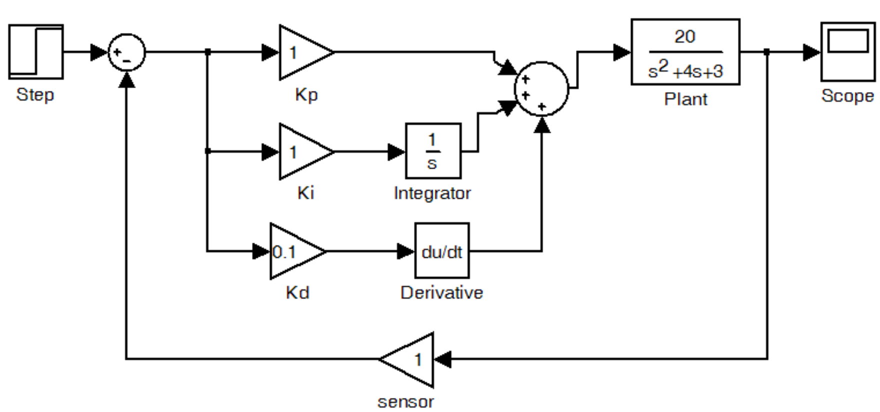
Table 3 Effects of Derivative Gain

Proportional Gain (k_p)	Derivative Gain (k_d)	Rise Time (T_r)	Peak Time (T_p)	Setting Time (T_s)	Percent Overshoot (%OS)	Steady-state Error (e_{ss})	Is it a stable system? (Yes/No)	Type of the System (Under/Over/ Critically Damped System?)
1	0.01							
1	0.1							
1	0.3							
1	0.5							
1	1							
1	10							
1	100							

Based on the information in the above table, please draw a conclusion.

4. PID controller

Please follow the instructor step by step to create a PID control system in Simulink, as indicated below.



Please set the proportional gain, integral gain and derivative gain according to Table 4, run the Simulink model, measure the response curve and complete the table:

Table 4 Effects of Derivative Gain

Proportional Gain (k_p)	Integral gain (k_i)	Derivative Gain (k_d)	Rise Time (T_r)	Peak Time (T_p)	Setting Time (T_s)	Percent Over shoot (%OS)	Steady -state Error (e_{ss})	Is it a stable system? (Yes/No)	Type of the System (Under/Over/ Critically Damped System?)
1	0.5	0.1							
1	1	0.1							
1	5	0.1							
1	0.5	0.5							
1	0.5	1.5							
1	0.5	5							
1		100							

Based on the information in the above table, please draw a conclusion.

Lab report requirements

(1) The lab report should be an official technical report, including the information such as experiment objectives, background information of PID control, experimental data and curves, and conclusions.

(2) For each controller (P, PI, PD or PID), you need to present its Simulink model, the response curves, the completed table, and draw a conclusion based on the data in the table.

(3) Each student needs to submit his/her independent lab report.