

## Laboratory Tutorial#6: PID Control

Finally, we've made it to the last lab. In this lab, you will build a PID controller. You will demonstrate how the proportional, integral and derivative components each contribute.

### 6.1 New Equipment: PID Unit (PID150Y)

There is one piece of new equipment that you will use in this lab: the PID unit. It is shown in Figure 6.1. Its purpose is to serve as a controller in the experiment, taking the error signal 'e' and producing a command voltage  $V_{com}$ . In principle, the PID unit creates the following mathematical relationship (in the time domain) between the command voltage and error signal:

$$V_{com} = K(s_p e + s_i \frac{1}{T_i} \int e dt + s_d T_d \frac{de}{dt}) \quad (6.1)$$

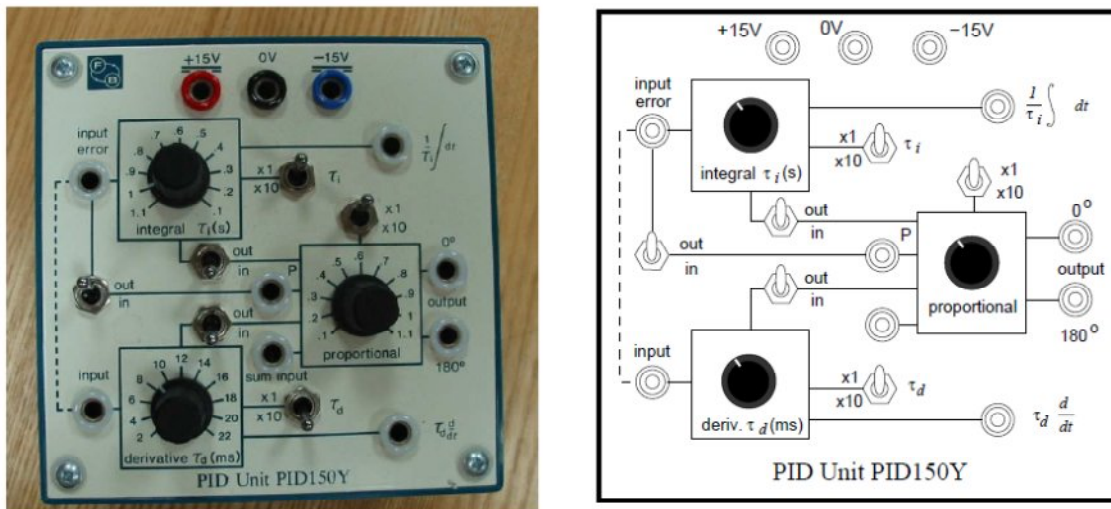


Figure 6.1: PID unit.

The error signal is to be connected to the port named "input error" and the commanded voltage appears at output port labelled as  $0^\circ$ . If, for some reason, you need  $-V_{com}$  instead of  $V_{com}$  the inverted output voltage can be obtained from the port labelled  $180^\circ$ .

There are several toggle switches on the PID unit. Three of the switches have positions labelled "in" and "out". The purposes of these three switches are for turning on or off (respectively) the individual proportional, integral, and derivative actions of the PID unit. The variables  $s_p$ ,  $s_i$ , and  $s_d$  in equation (6.1) represent the states of these switches. If a switch is turned on (i.e. "in"), the corresponding switch variable is set to 1, which is otherwise 0.

Taking the time derivative of a signal is inherently messy. Even a small amount of noise riding on top of an electric signal can have a derivative much larger than the underlying signal, making the final output meaningless. The PID unit has a low pass filter whose purpose is to attenuate much of the error from the differentiator. Furthermore, if you want to take a derivative, you must explicitly connect the error signal to the port simply labelled "input" near the bottom left corner of the PID unit. Later on in the lab, we will simply make an electrical connection between the "input error" port and the "input" port as indicated by the dashed curve on the console of the unit.

The three other toggle switches each have positions labelled “x 1” and “x 10”. They determine whether the number pointed to by the corresponding dial gets multiplied by 1 or 10. There are three dials on the PID unit that allow you to adjust parameters  $K$ ,  $T_i$ , and  $T_d$ . The range of values you can set are outlined in the table-6.1.

Component	Switch X 1	Switch X 10
Proportional Gain, $K$	0.1 to 1	1 to 10
Integral Action Time, $T_i$	0.1s to 1s	1s to 10s
Derivative Action Time, $T_d$	1ms to 22ms	10ms to 220ms

Table-6.1: PID parameters’ range

Finally, there are ports on the PID unit that will allow you to monitor the signal from the integrator and differentiator separately.

## 6.2 Position Control

### 6.2.1 Set-Up

After arriving in the lab, you should set up your equipment exactly as you did in the previous lab (Lab #4). Once you have it working as you did before, proceed with the experiments.

### 6.2.2 Experiment #1: Proportional Control

Disconnect the op-amp output from the servo-amp input. In this gap, place the PID unit as shown in Figure 6.2. Connect the output of the op-amp to the input of the PID unit, and connect the output of the PID unit to the appropriate input of the servo-amp. Don't forget to provide power to the PID unit. Turn the integrator and differentiator both off (switches in the “out” position). Set the gain on the proportional dial to 1. Turn on the power. See what happens.

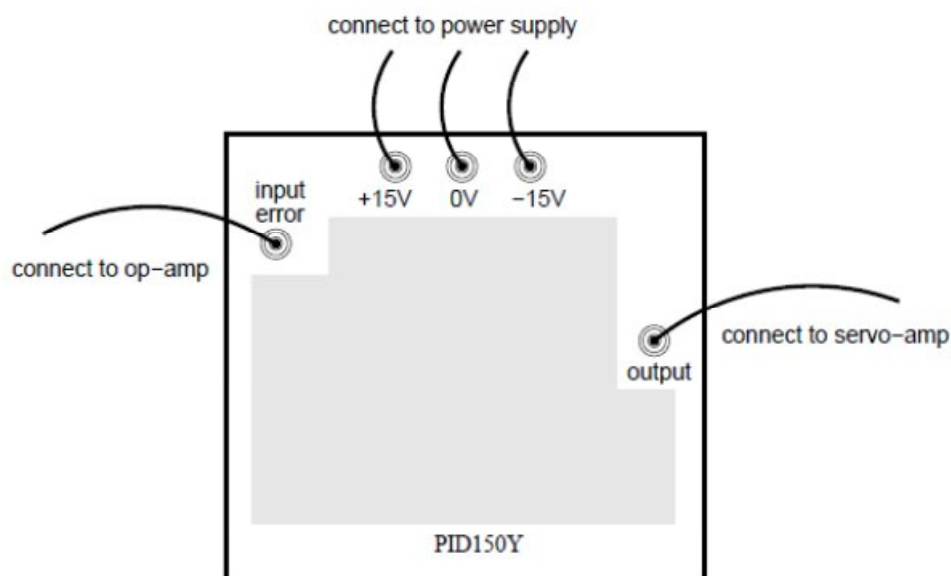


Figure 6.2: External connections of PID unit (without derivative).

Set the dial of the input potentiometer to  $90^\circ$  (abruptly). This is the way we will create our step inputs. Apply few more step inputs and observe the performance. Simply by observing the dial of the output potentiometer as it goes back and forth between  $0^\circ$  and  $90^\circ$ , estimate the amount of

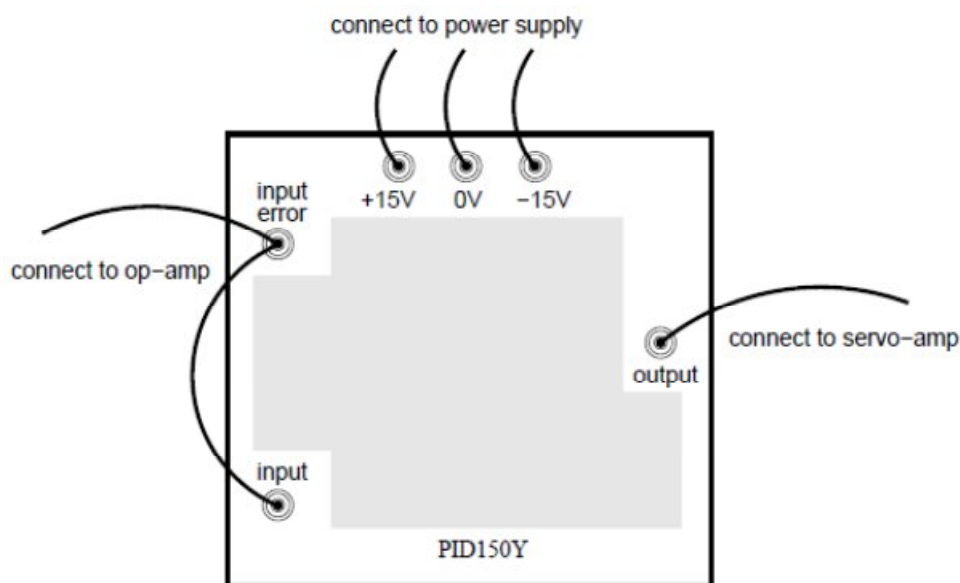
overshoot in the closed loop system. Also, measure the steady state error. Rather than try to read the difference in the input and output potentiometer dial angles, perhaps the best way to measure the error is to simply measure the voltage at the output of the op-amp (the output of the comparator). This is the error that the controller actually sees.

### 6.2.3 Experiment #2: Proportional + Integral Control

Now, turn on ("in") the integral part of the PID module, and set the dial so that  $T_i = 1$  sec. Do not modify the proportional part of the control signal; leave the derivative component off. Perform several  $90^\circ$  step inputs. Observe how the overshoot and steady state error are affected by the integral action. Again, you should be able to observe the overshoot by sight. However, to observe the error, you should measure the error signal voltage at the output of the op-amp. Furthermore, to see the integrator work, you may wish to observe the commanded signal at the output of the PID unit.

### 6.2.4 Experiment #3: Proportional + Integral + Derivative Control

To include the derivative action, you need to connect ports labelled "input error" and "input" as shown in Figure 6.3. Also, flip the derivative switch to "in," and set the derivative time scale to  $T_d = 0.2$  ms. Do not modify the proportional or integral components of the signal. Perform several  $90^\circ$  step inputs. Observe how the overshoot and steady state error are affected by the derivative action.



**Figure 6.3:** External connections of PID unit (with derivative).

## 6.3 Speed Control

Set up your equipment exactly as you did in the Lab #5 (closed loop speed control). Once you have it working as you did before, repeat the same experiments of section 6.2.

**Comments/Observations**