P, I, D, PI, PD, and PID control

A **proportional-integral-derivative controller** (**PID controller**) is a control loop feedback mechanism (controller) widely used in industrial control systems. A PID controller calculates an *error* value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the *error* by adjusting the process through use of a manipulated variable.

The PID controller algorithm involves three separate constant parameters, and is accordingly sometimes called **three-term control**: the proportional, the integral and derivative values, denoted *P, I,* and *D.* Simply put, these values can be interpreted in terms of time: ***P* depends on the *present* error, *I* on the accumulation of *past* errors, and *D* is a prediction of *future* errors**, based on current rate of change. The weighted sum of these three actions is used to adjust the process via a control element such as the position of a control valve, a damper, or the power supplied to a heating element.

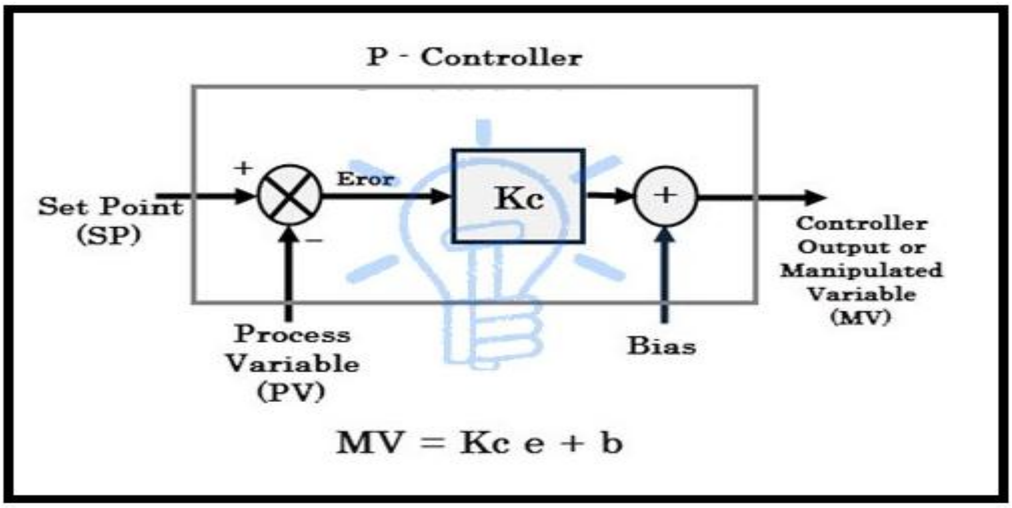
I, D, PI, PD, PID Control

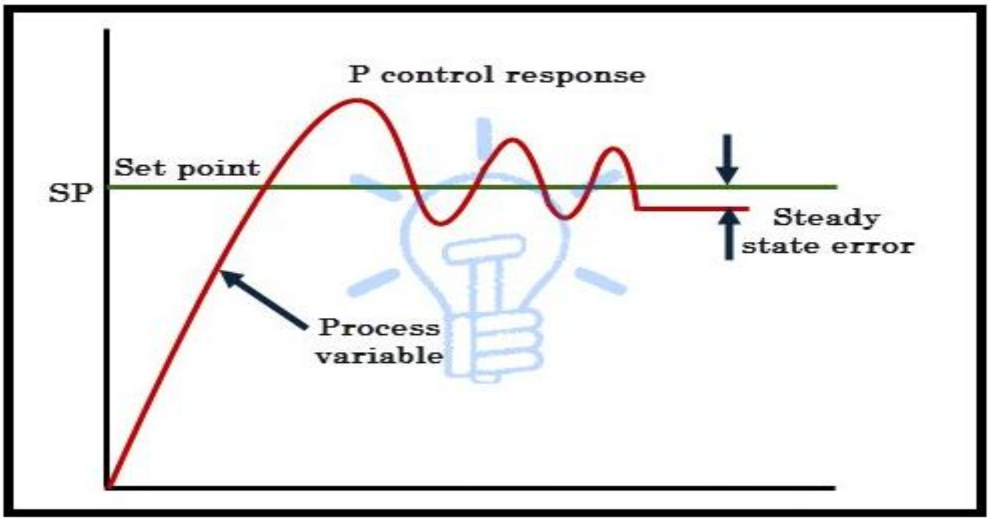
As previously mentioned, controllers vary in the way they correlate the controller input (error) to the controller output (actuating signal). The most commonly used controllers are the **proportional-integral-derivative (PID) controllers**. PID controllers relate the error to the actuating signal either in a **proportional (P)**, **integral (I),** or **derivative (D)** manner. PID controllers can also relate the error to the actuating signal using a combination of these controls.

1. P- Controller

Proportional or P- controller gives an output that is proportional to current error e (t). It compares the desired or set point with the actual value or feedback process value. The resulting error is multiplied with a proportional constant to get the output. If the error value is zero, then this controller output is zero.

This controller requires biasing or manual reset when used alone. This is because it never reaches the steady-state condition. It provides stable operation but always maintains the steady-state error. The speed of the response is increased when the proportional constant Kc increases.





Advantages of Proportional Controller

- Now let us discuss some advantages of proportional controller. Proportional controller helps in reducing the steady state error, thus makes the system more stable.
- Slow response of the over damped system can be made faster with the help of these controllers.

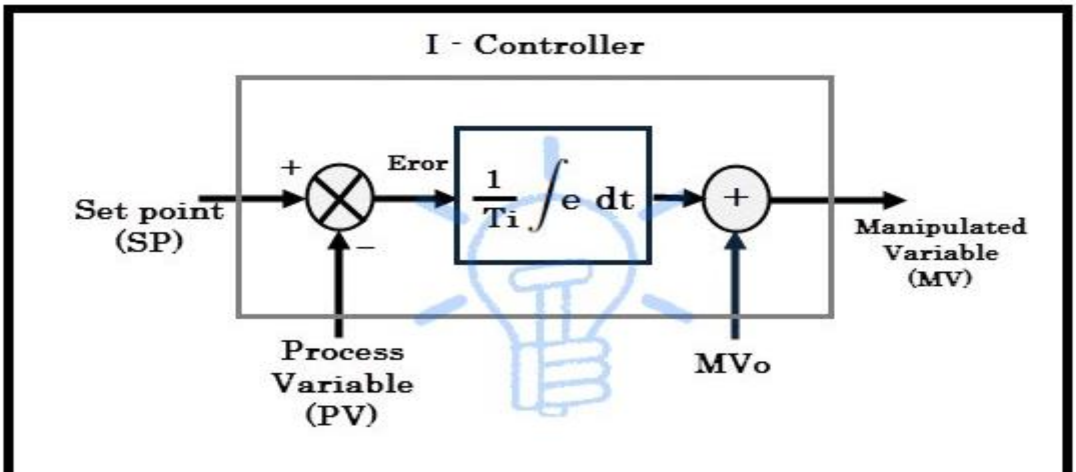
Disadvantages of Proportional Controller

- Now there are some serious disadvantages of these controllers and these are written as follows: Due to presence of these controllers we some offsets in the system.
- Proportional controllers also increase the maximum overshoot of the system.

<u>2.</u> I-Controller

Integral controller or **I-controller** is mainly used to reduce the steady state error of the system. The integral component integrates the error term over a period of time until the error becomes zero. This results that even a small error value will cause to produce high integral response.

At the zero error condition, it holds the output to the final control device at its last value in order to maintain zero steady state error, but in case of P-controller, output is zero when the error is zero.



$$MV = \frac{1}{Ti}\int e\,dt + MVo$$

If the error is negative, the integral response or output will be decreased. The speed of response is slow (means respond slowly) when I-controller alone used, but improves the steady state response. By decreasing the integral gain Ki, the speed of the response is increased.

Advantages of Integral Controller

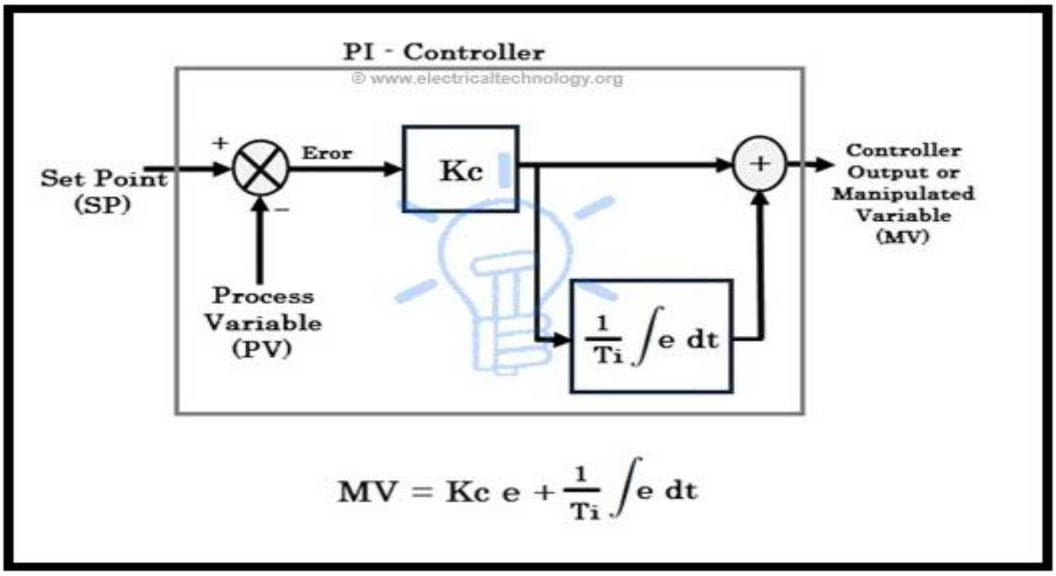
- Due to their unique ability they can return the controlled variable back to the exact set point following a disturbance that’s why these are known as reset controllers.

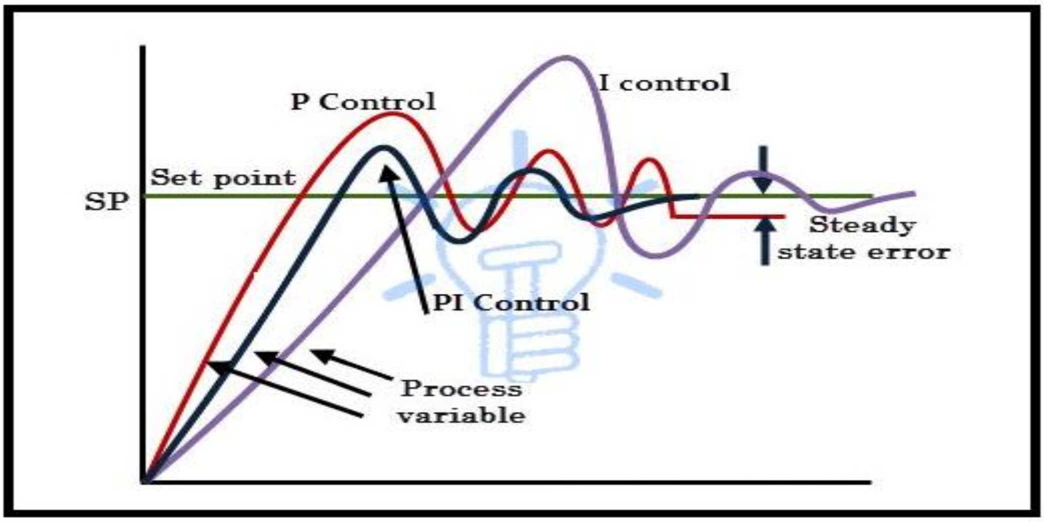
Disadvantages of Integral Controller

- It tends to make the system unstable because it responds slowly towards the produced error.

3. PI Controller

For many applications, proportional and integral controls are combined to achieve good speed of response (in case of P controller) and better steady state response (in case of I controller). Most often **PI controllers** are used in industrial operation in order to improve transient as well as steady state responses. *The responses of only I-control, only p-control and PI control are shown in below figure.*





4. *D - Controller Response*

A **derivative controller (**or simply **D-Controller)** sees how fast process variable changes per unit of time and produce the output proportional to the rate of change. The derivative output is equal to the rate of change of error multiplied by a derivative constant.

The D-controller is used when the processor variable starts to change at a high rate of speed.

In such case, D-controller moves the final control device (such as control valves or motor) in such direction as to counteract the rapid change of a process variable. It is to be noted that D-controller alone cannot be used for any control applications.

$$\text{output} = T_d \frac{de}{dt}$$

The derivative action increases the speed of the response because it gives a kick start for the output, thus anticipates the future behavior of the error.

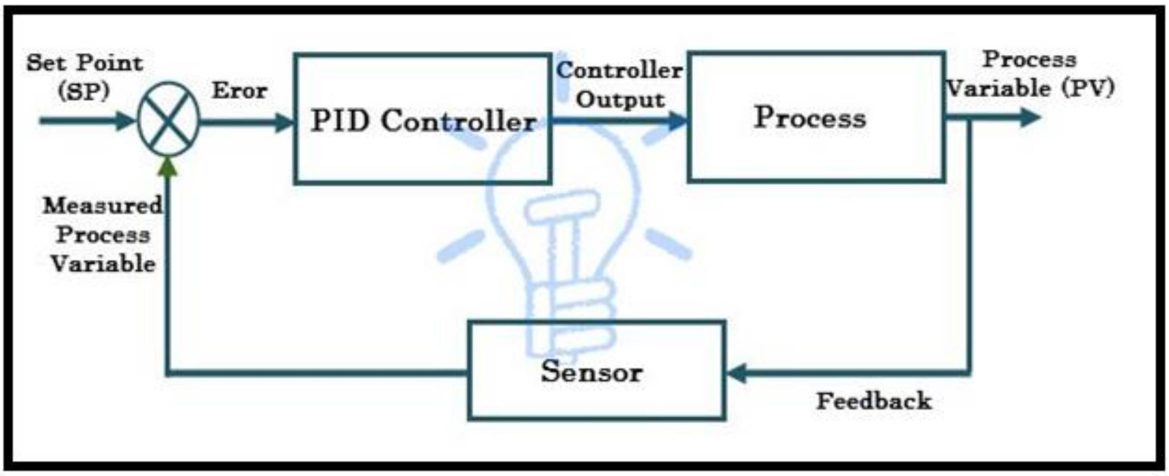
The more rapidly D-controller responds to the changes in the process variable, if the derivative term is large (which is achieved by increasing the derivative constant or time Td).

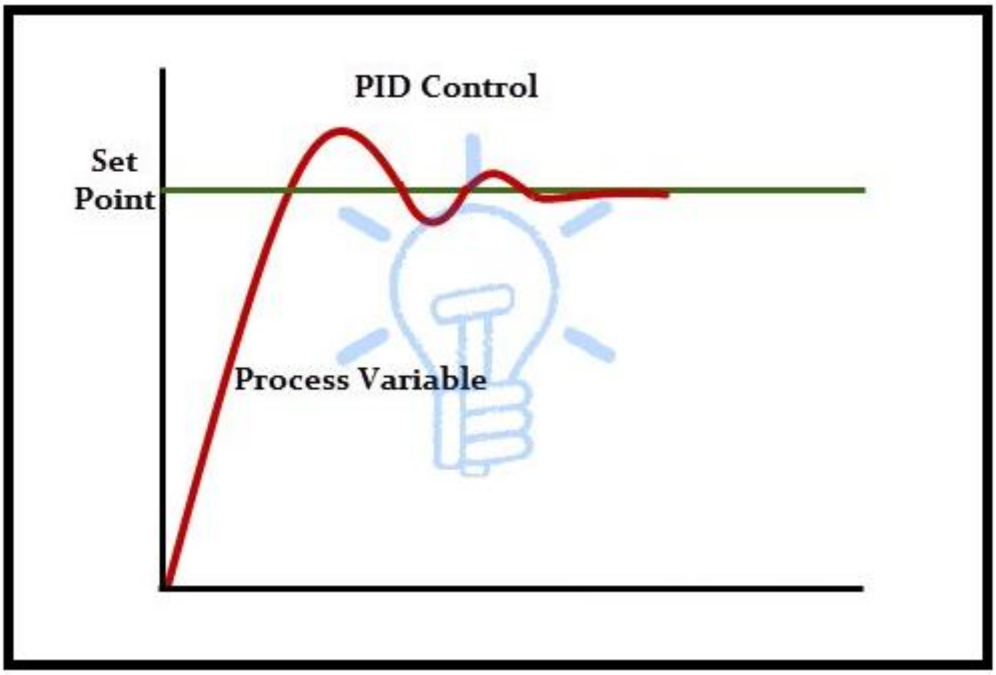
Advantages of Derivative Controller

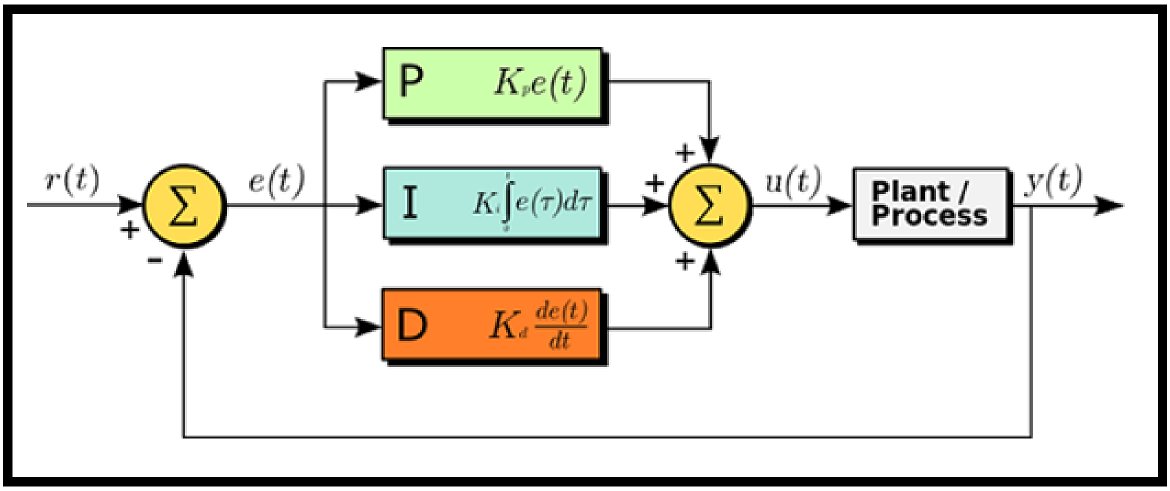
- **The major advantage of derivative controller is that it improves the transient response of the system**

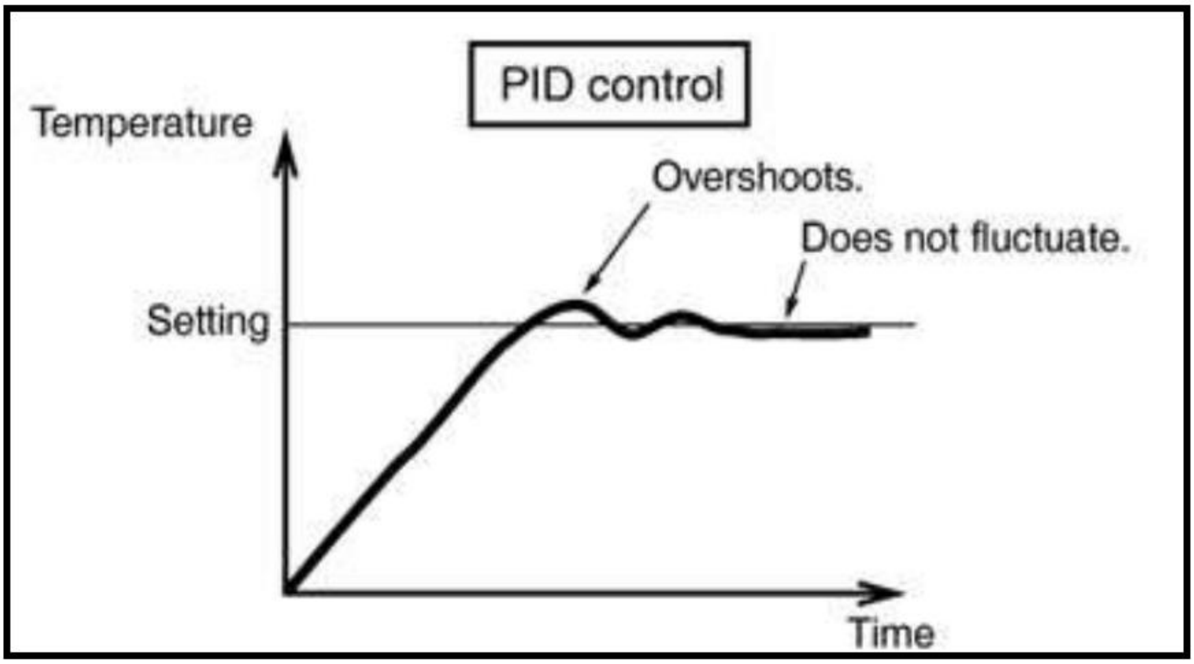
5. PID Controller

Therefore, by combining proportional, integral, and derivative control responses, a PID controller is formed. A PID controller finds universal application; however, one must know the PID settings and tune it properly to produce the desired output. Tuning means the process of getting an ideal response from the PID controller by setting optimal gains of proportional, integral and derivative parameters.



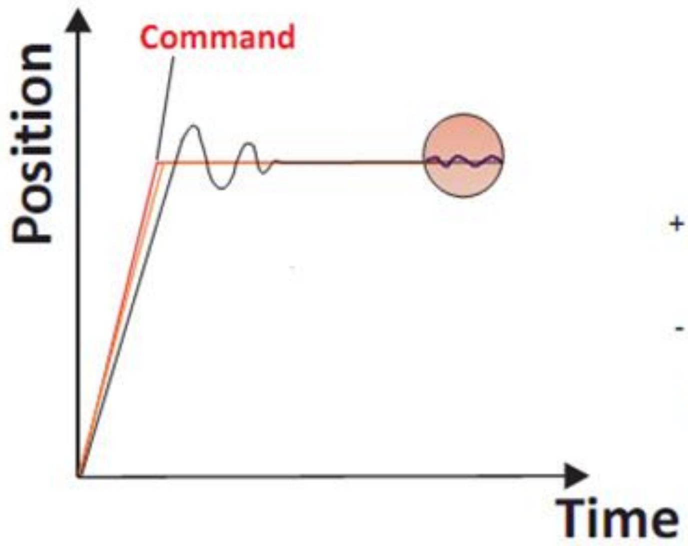



P
I
D
r(t)
e(t)
u(t)
y(t)
Plant / Process


PID control
Temperature
Overshoots.
Does not fluctuate.
Setting
Time

- **PID control** *is a feedback control method that combines* proportional, integral, and derivative actions.
- The **proportional action** provides smooth control without hunting.
- The **integral action** automatically corrects offset.
- The **derivative action** responds quickly to large external disturbances.

Hunting Cycle



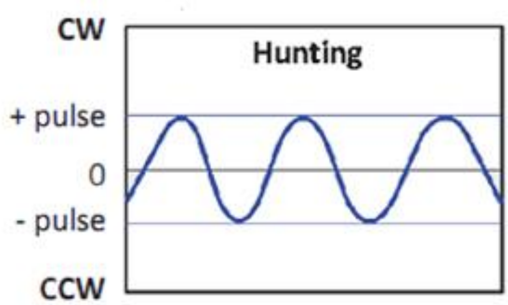


Table 1: Effect of increasing parameter independently

Parameter	**Rise Time**	**Overshoot**	**Settling Time**	**Steady-State Error**	**Stability**
K_p	Decrease	Increase	Small Change	Decrease	Degrade
K_i	Decrease	Increase	Increase	Eliminate	Degrade
K_d	Minor Change	Decrease	Decrease	No Effect	Improve if K_d small

What is tuning?

- **Tuning is adjustment of control parameters to the optimum values for the desired control response. Stability is a basic requirement.**

  However, different systems have different behaviour, different applications have different requirements, and requirements may conflict with one another.

Manual Tuning

- **The operator estimates the tuning parameters required to give the desired controller response.**
- **The proportional, integral, and derivative terms must be adjusted, or tuned, individually to a particular system using a trial-and-error method**

Table 2: Choosing a Tuning Method

Method	Advantages	Disadvantages
Manual Tuning	No math required , Online	Requires experienced personnel
Ziegler-Nichols	Proven Method, Online	Process upset, some trial-and-error, very aggressive tuning
Cohen-Coon	Good process models	Some math; offline; only good for first-order processes
Software Tools	Consistent tuning; online or offline - can employ computer-automated control system design (CAutoD) techniques;	Some cost or training involved