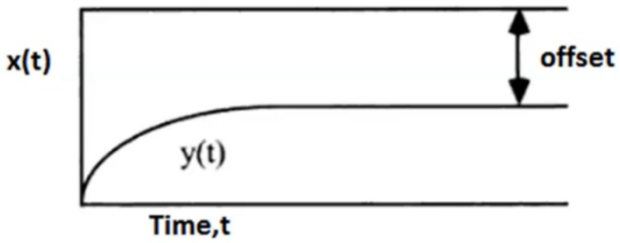
Why Derivative and/or Integral Controller?

In the previous document we have seen how proportional controller works and effects of that on the system. Now let us analyze why we need derivative and/or Integral controller.

Limitations of using Proportional controller :-

1. Proportional controller only responds to the present value of error.
2. Offset will be present when a set point change is made.
3. Proportional controller cannot keep the controlled variable on set point.
4. The smaller the gain, the larger will be the offset.
5. Steady state error will be present.

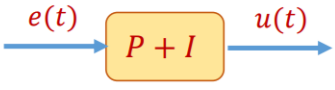


PID Controller

Proportional Control	Integral Control	Derivative Control
$e_a(t) = K_p e(t)$	$e_a(t) = K_I \int e(t)dt$	$e_a(t) = K_d \frac{de(t)}{dt}$

Integral Regulator:-

Output depends on the amplitude and duration of the error signal.



$$u(t) = K_p e(t) + K_I \int e(t)dt$$

$$u(t) = K_p e(t) + K_I \sum e(t)$$

So, the I regulator add the previous error with the current error and multiply with the gain to give the signal. That's why it solves the problem of steady state error/offset. But this makes system slow. Here comes the role of Derivative regulator in PID controller.

Derivative regulator:

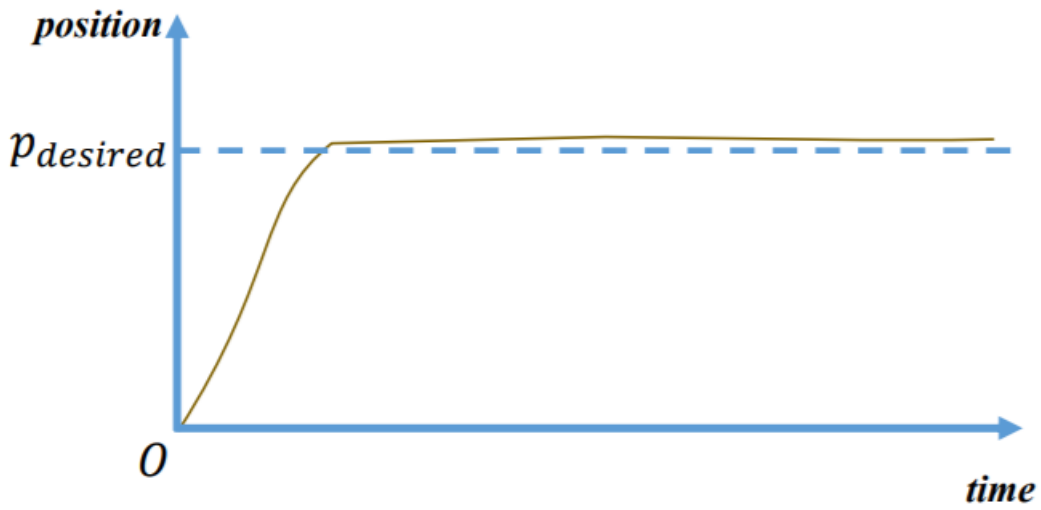
Derivative term: output depends on the rate of change of the error signal. This makes system faster.

Derivative Control

$$e_a(t) = K_d \frac{de(t)}{dt}$$

Add this term in PI controller to make it PID controller, and from this controller we can achieve our desired position by tuning the right values of the P-I-D gains.

The output of the system should be like this :-



Advantages of using Proportional Integral(PI) controller.

1. Improved Damping
2. We can achieve zero offset
3. We can decrease the steady state error in the system.

Advantages of using Proportional Derivative(PD) controller.

1. Decreases maximum peak overshoot(m_p).
2. Reduces Rise time(T_r) and Settling time(T_s).
3. Increases Bandwidth.

So if we use PID controller,

1. Kp reduces the Rise time.
2. Ki eliminates the Steady state error.
3. Kd decreases the overshoot and settling time.

PID tuning:

Parameters	Rise Time	Overshoots	Steady-State Error	Stability
K_p	Decreases	Increases	Decreases	Degrades
K_I	Decreases	Increases	Eliminate	Degrades
K_d	Minor Change	Decreases	No Effect	Improves a bit