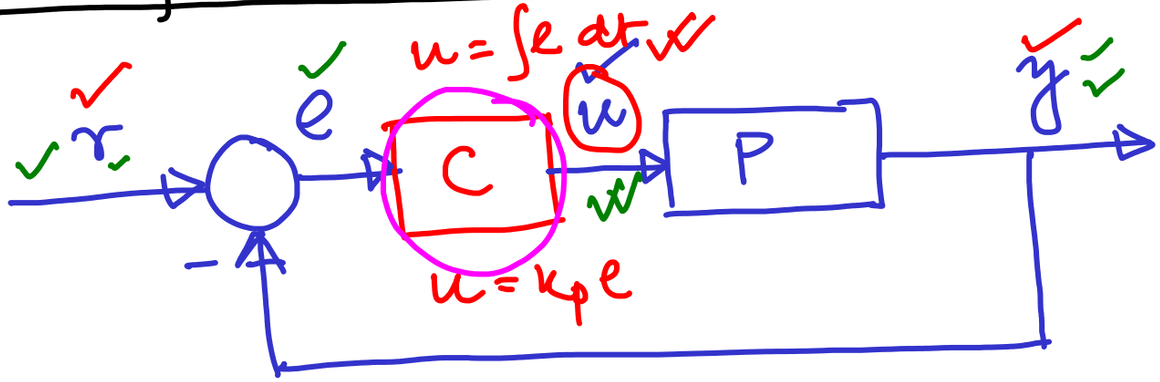
Simple forms of feedback

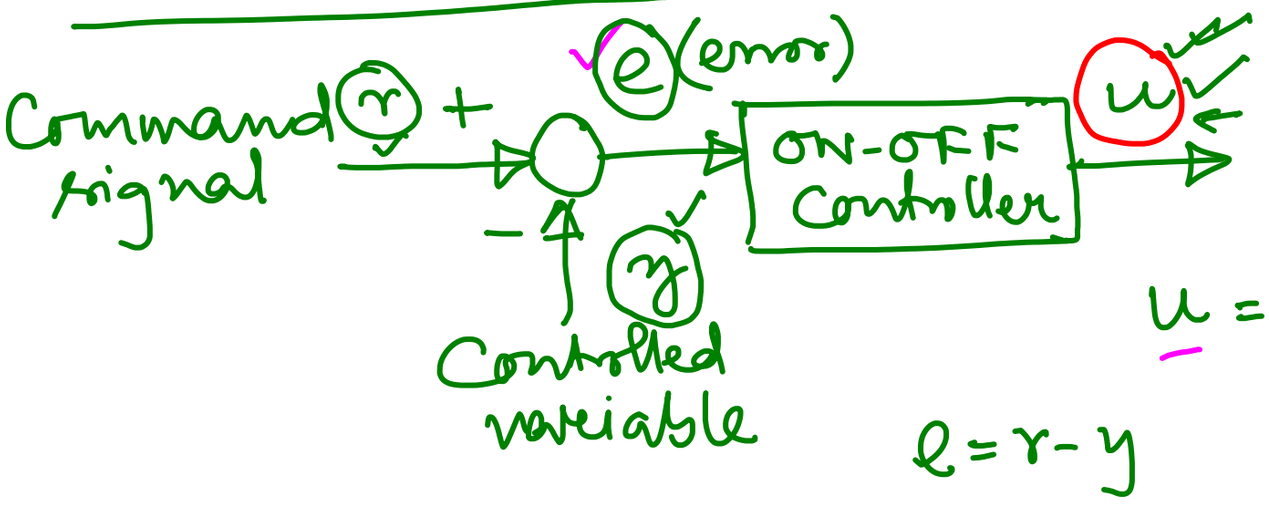


Error signal
$e = r - y$

The idea of feedback to make corrective actions based on the difference between the desired and the actual values of a quantity can be obtained in different ways.

- ON-OFF control
- PID control
  (Proportional-integral-derivative)

ON-OFF Control

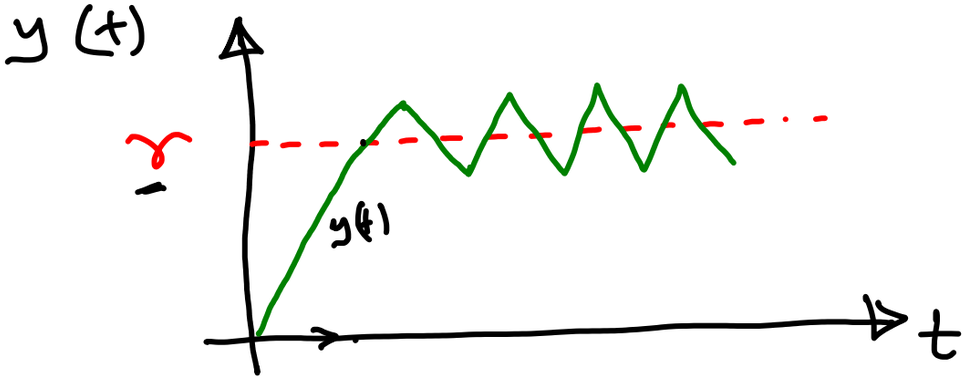


$$u = \begin{cases} u_{max} & \text{if } e > 0 \\ u_{min} & \text{if } e < 0 \\ = u & = \\ = 0 & \end{cases}$$

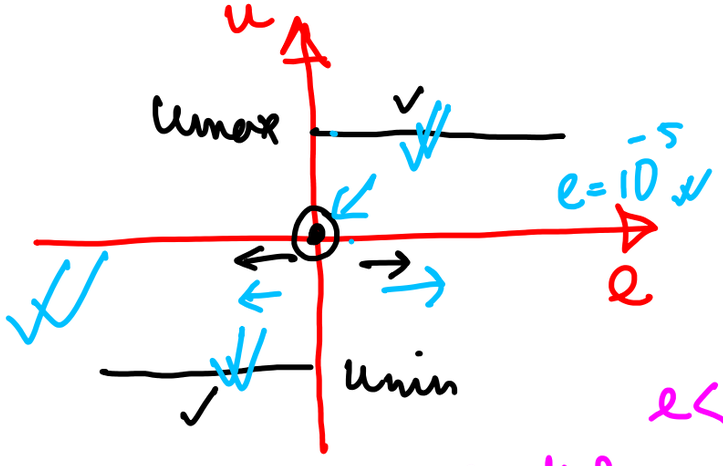
$e = r - y$

$e = 0$

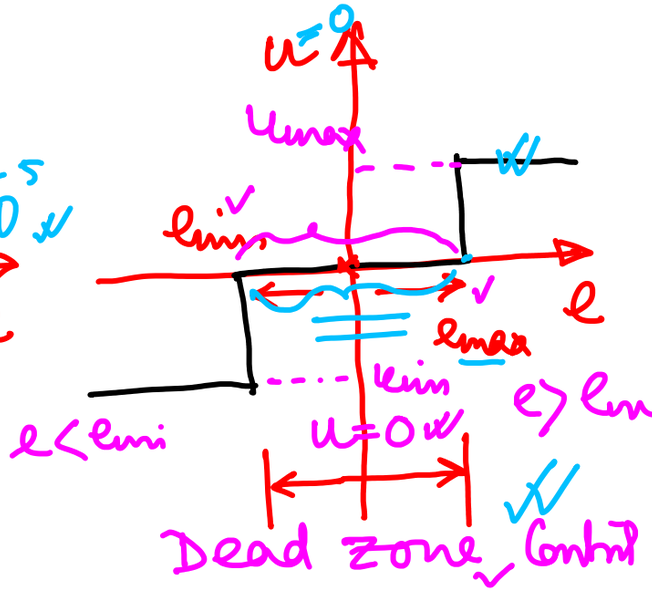
- simple, no parameter to choose
- typically results in oscillation of controlled variable



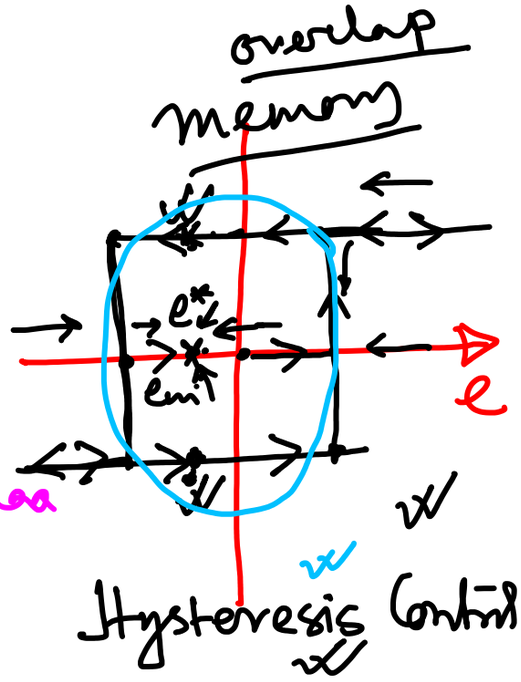
- Control variable is not defined when the error is zero.



ON - OFF Control



Dead zone Control



Hysteresis Control

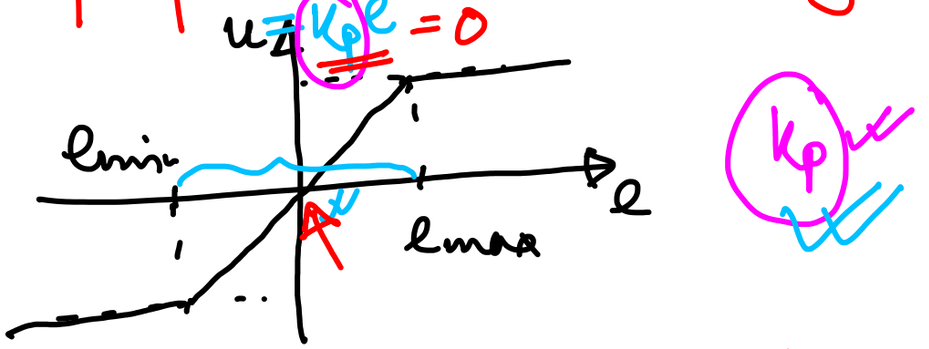
- ON-OFF Control overreacts
- A small change in the error makes the actuated variable change over the full range.

PID Control

- The above disadvantage can be avoided in proportional control.

$$u = \begin{cases} u_{max} & \text{if } e \geq e_{max} \\ K_p e & \text{if } e_{min} < e < e_{max} \\ u_{min} & \text{if } e \leq e_{min} \end{cases}$$

- K_p is the proportional controller gain.



- the interval (e_{min}, e_{max}) is called the proportional band.

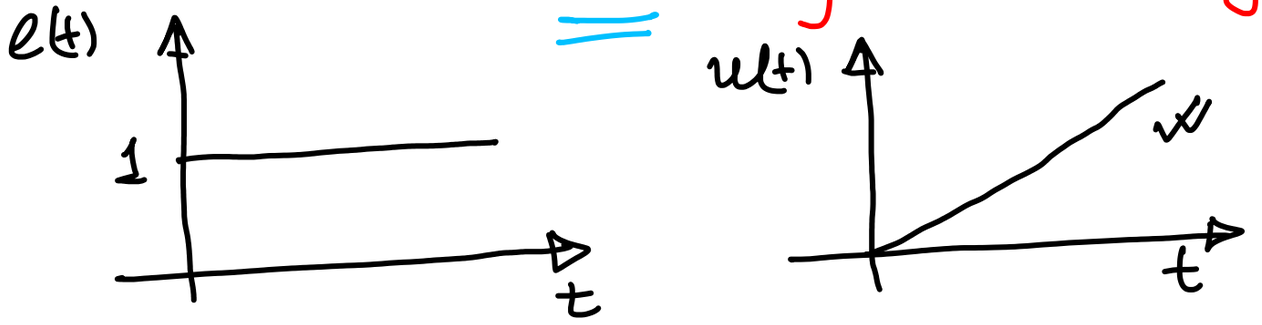
- Controlled variable deviates from the reference. In order to maintain it, e should not be equal to zero since some control input required.

(drawback of proportional controller)

- This can be avoided by making the control action proportional to the integral of the error.

$$u(t) = K_i \int_0^t e(\tau)\, d\tau$$

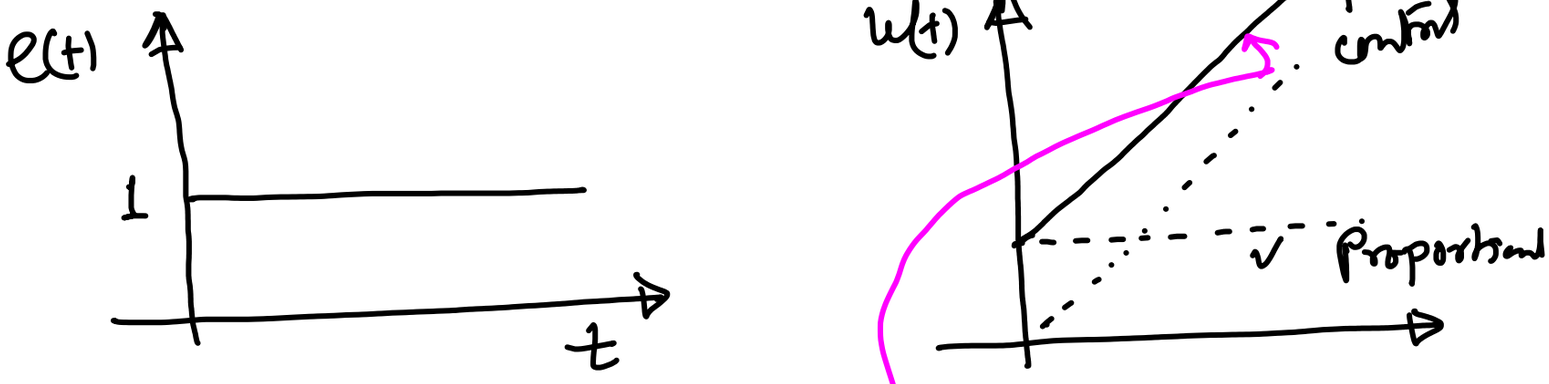
- K_i Integral Control gain.

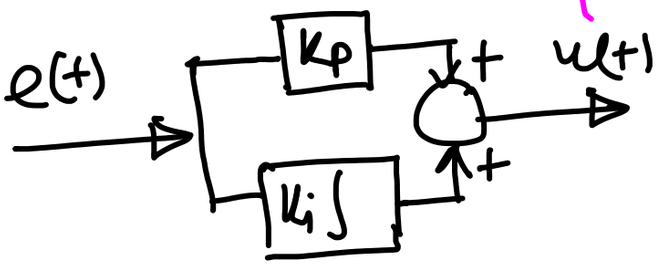


- The steady-state error becomes zero.

P-I (Proportional-Integral) Control

P+I



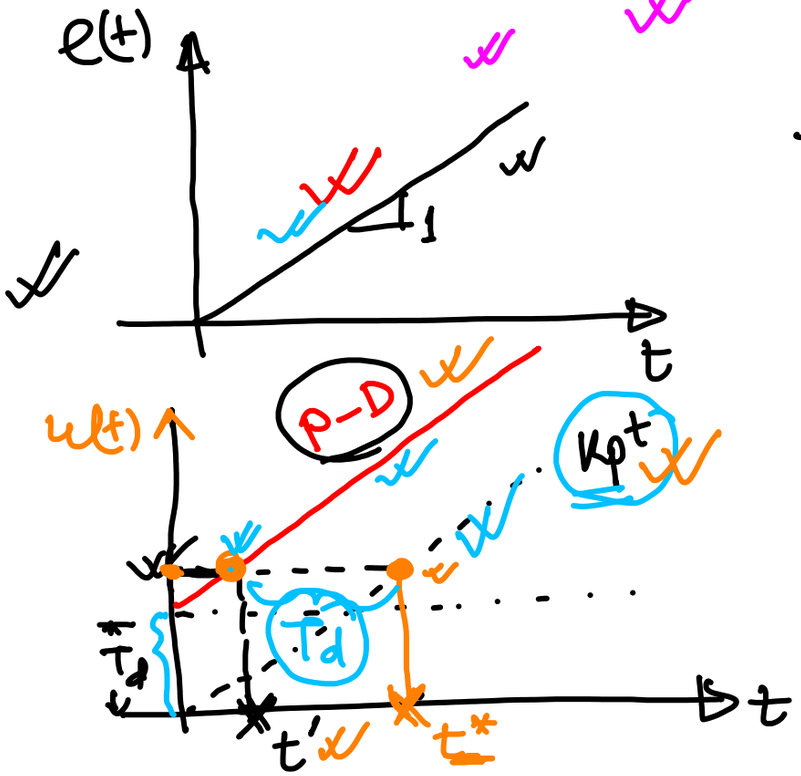


An additional refinement is to provide the controller with an anticipative ability by using a prediction of the error

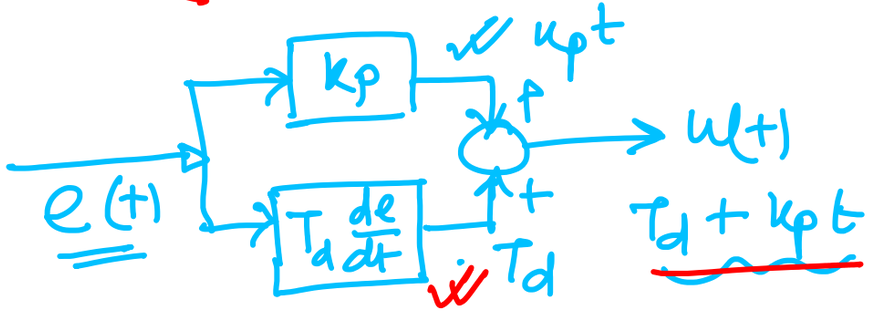
$$e(t+T_d) \approx e(t) + T_d \frac{de(t)}{dt}$$

$= 0$

— It predicts the error T_d time units ahead.

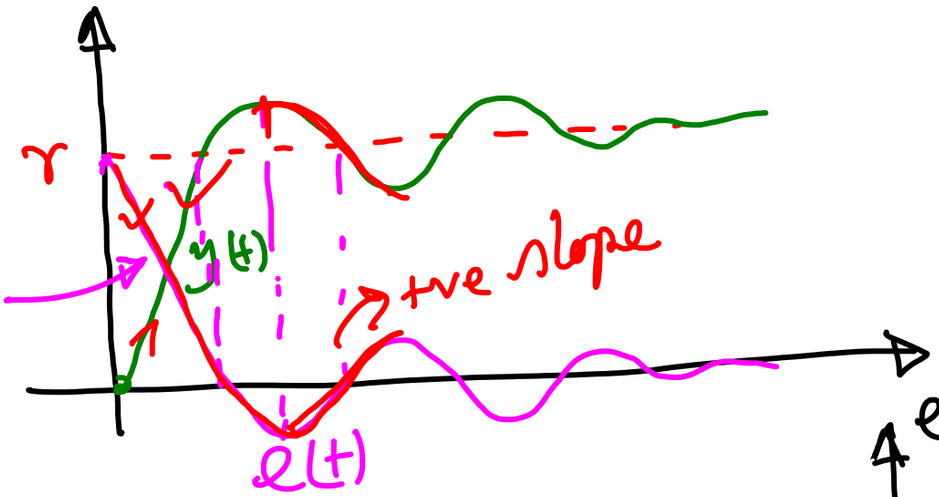


— PD (proportional + derivative)



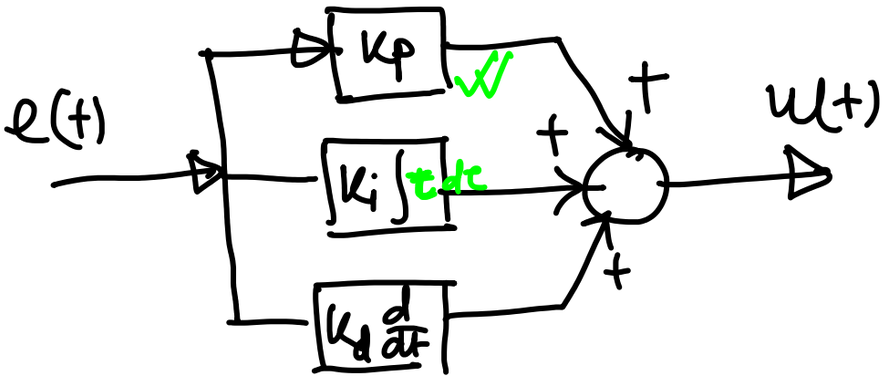
$T_d \frac{de(t)}{dt}$

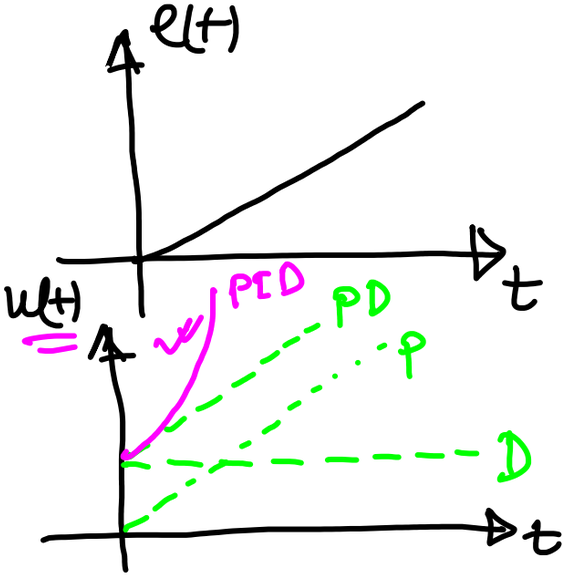
-ve slope

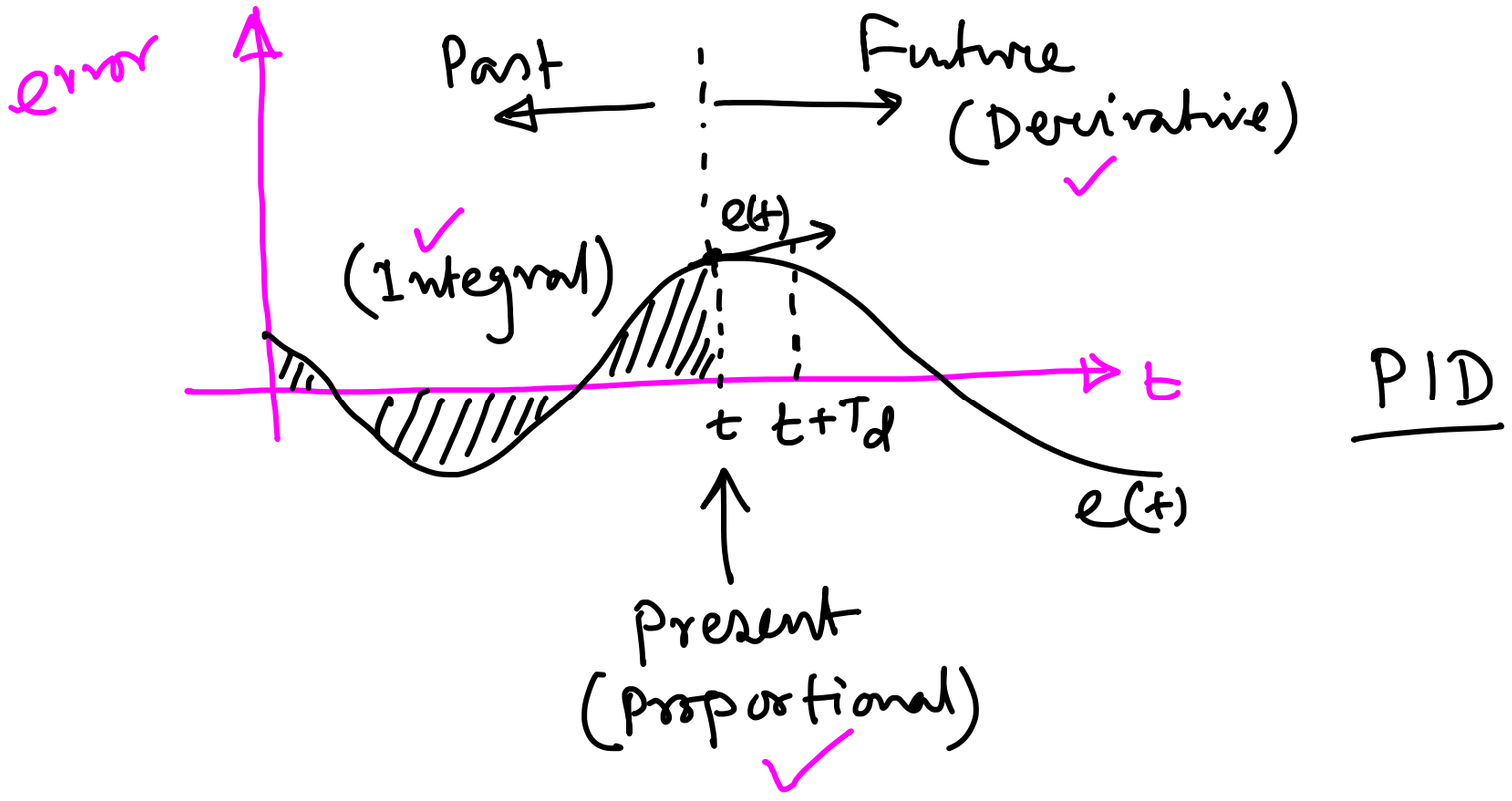


$e = r - y$

PID






error
Past
Future
(Derivative)
e(t)
(Integral)
t
t
t+Td
e(t)
Present
(Proportional)

PID