PID Controller Design

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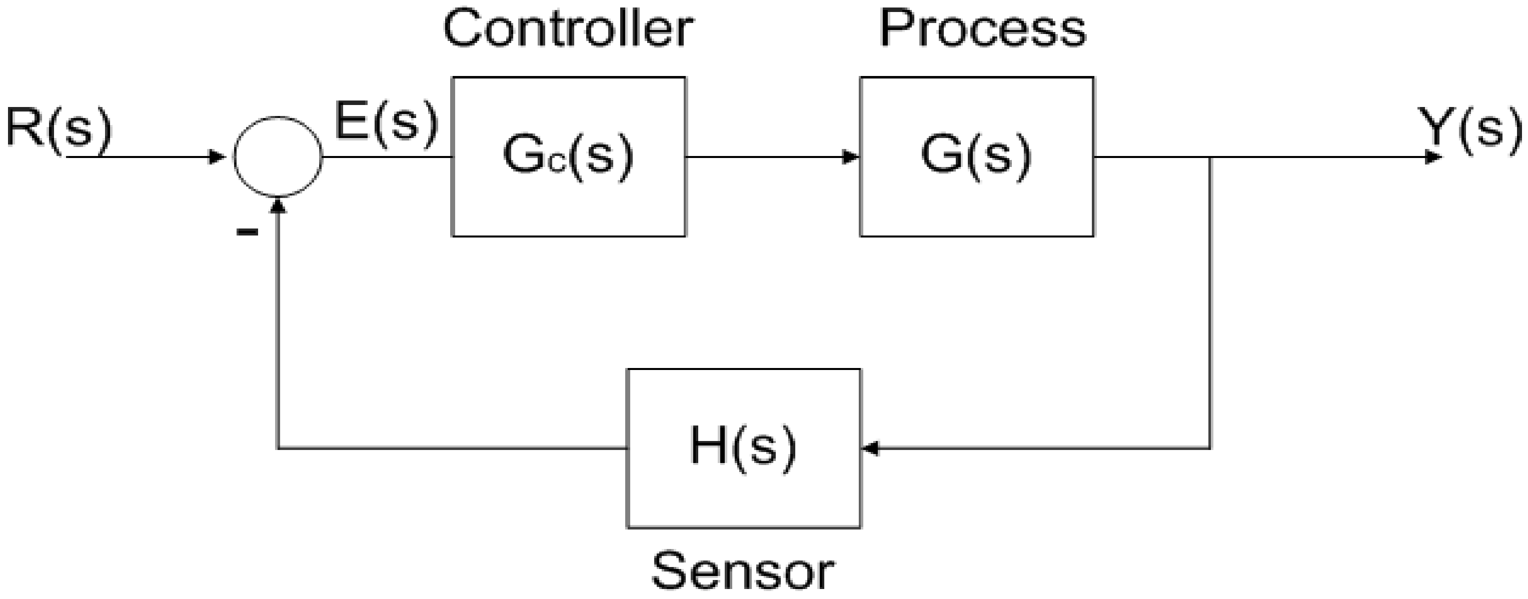
Feedback control



- Transfer function

$$\frac{Y(s)}{R(s)} = \frac{G_C(s)G(s)}{1 + H(s)G_C(s)G(s)}$$

Feedback control

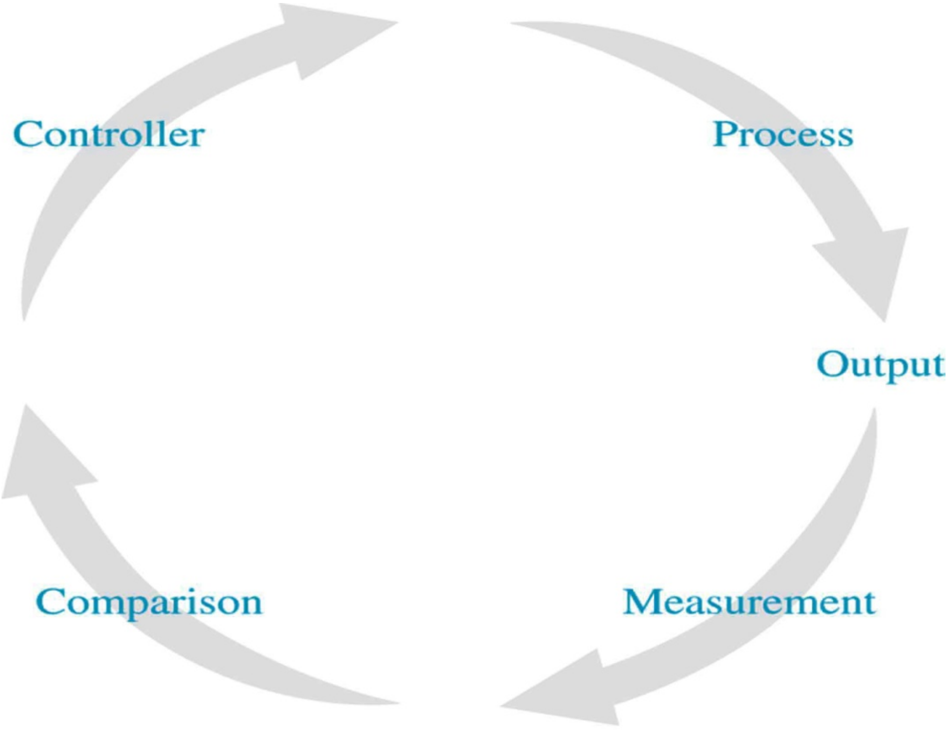
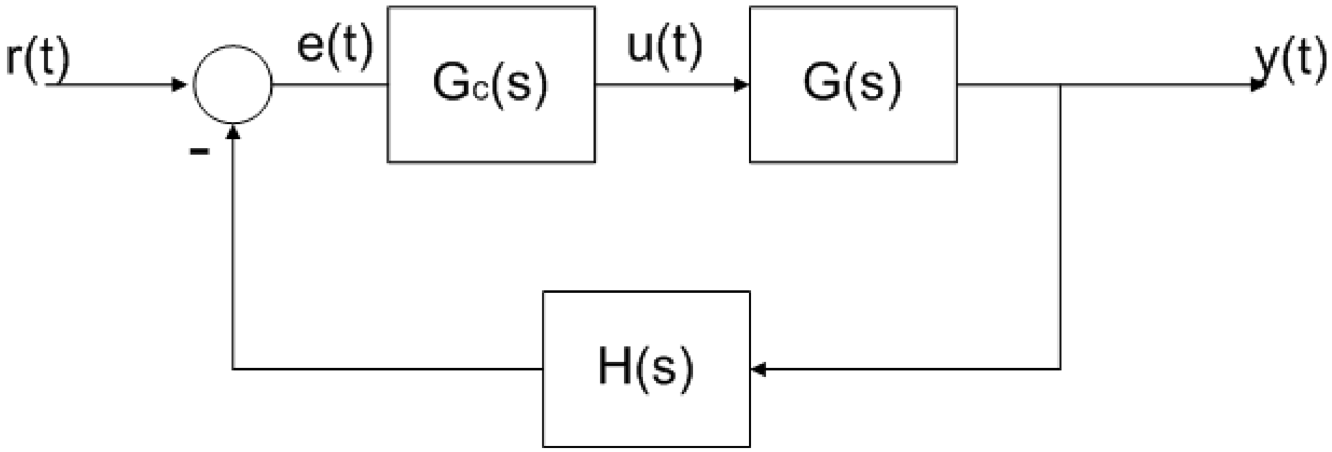


Figure 4.1 A closed-loop system.

Advantages of the closed-loop

- Decreased sensitivity of the system to variations in the parameters of the process
- Improved rejection of the disturbances
- Improved measurement noise attenuation
- Improved reduction of the steady-state error of the system
- Easy control and adjustment of the transient response

PID controller



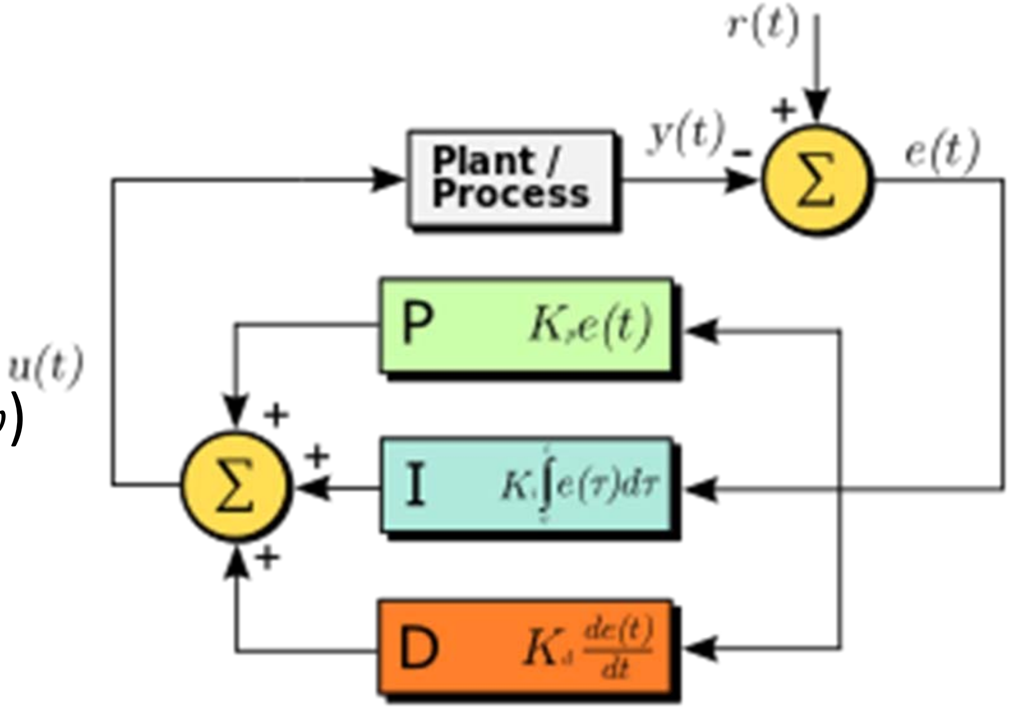
- From the block diagram,

$$u(t) = K_p e(t) + K_i \int e(t)\,dt + K_d \frac{de(t)}{dt}$$

- Taking the Laplace transform,

$$U(s) = K_p E(s) + \frac{K_i}{s} E(s) + K_d sE(s)$$

- PID controller gain:
    - Proportional gain (K_p)
    - Integral gain (K_i)
    - Derivative gain(K_d)



Advantages of the PID controller

- Attempts to minimize the error by adjusting the process control outputs
- P: depends on the ***present*** error
- I: depends on the ***accumulation of past errors***
- D: predicts ***future errors*** based on current rate of change
- Able to adjust the process by tuning the three parameters in the PID controller

Proportional term

- $P_{out} = K_p e(t)$
- A high gain

  => large change

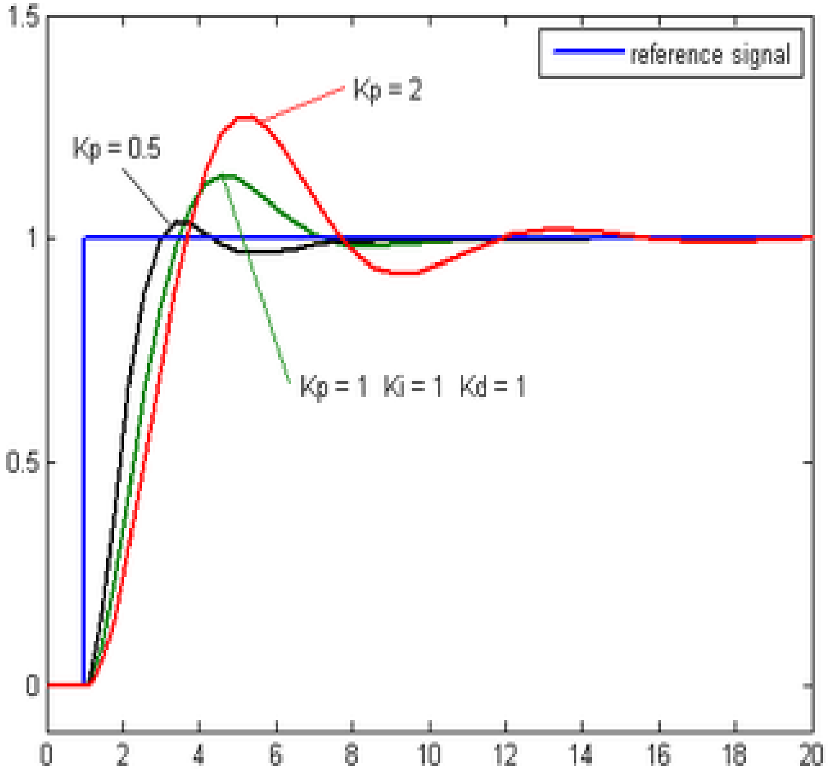
  in the output

  => makes it unstable

- A small gain

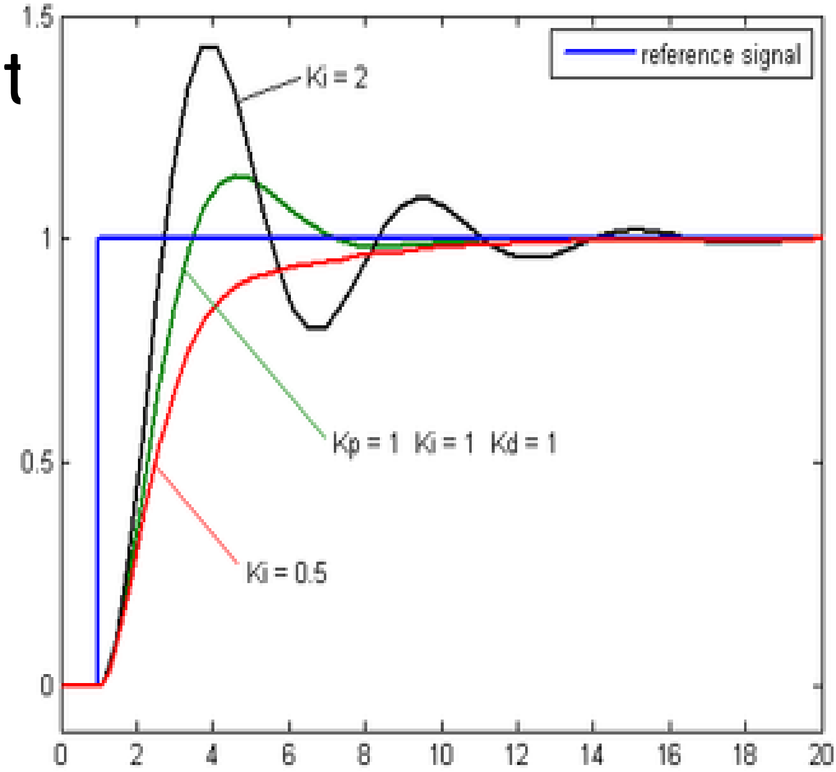
  => small output response

  to a large input error



Integral term

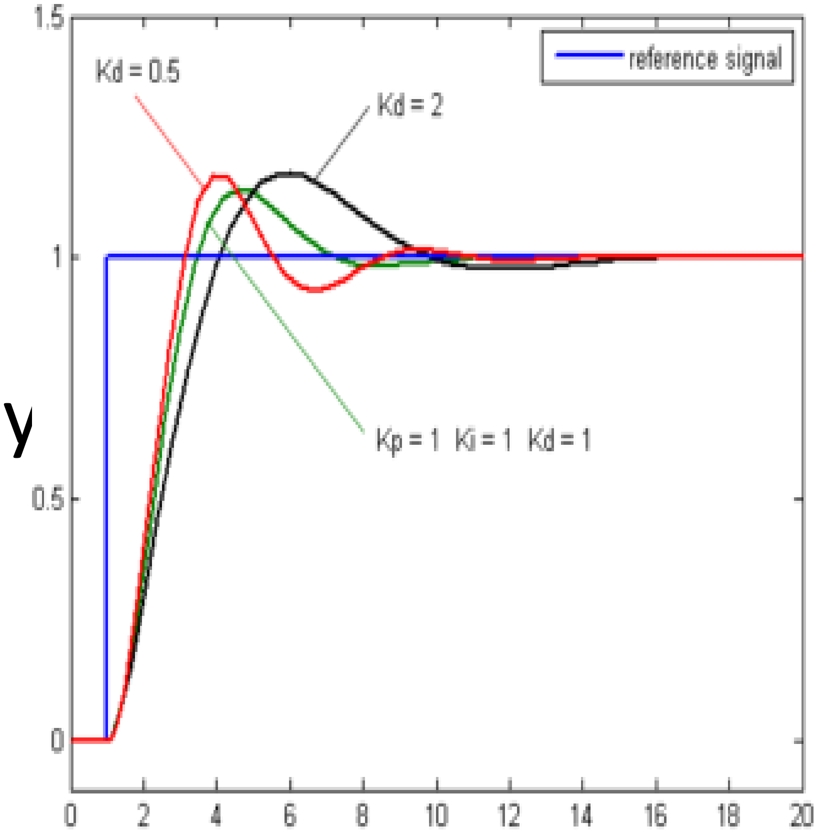
- $I_{out} = K_i \int e(\tau)d\tau$
- Accelerates the movement of the process towards the setpoint
- Able to cause the present value to overshoot the setpoint value



Derivative term

- $D_{out} = K_d \frac{de(t)}{dt}$
- Improves settling time and stability
- Has its inherent sensitivity to measurement noise

=> seldom used in practice



The effect of each controller

	Rise time	**Overshoot**	**Settling time**	**S-S error**	**Stability**
Kp	Decrease	Increase	Small change	Decrease	Degrade
Ki	Decrease	Increase	Increase	Eliminate	Degrade
Kd	Small change	Decrease	Decrease	No change	Improve if Kd is small

- Note that these correlations may not be exactly accurate, because Kp, Ki, and Kd are dependent on each other. In fact, changing one of these variables can change the effect of the other two.