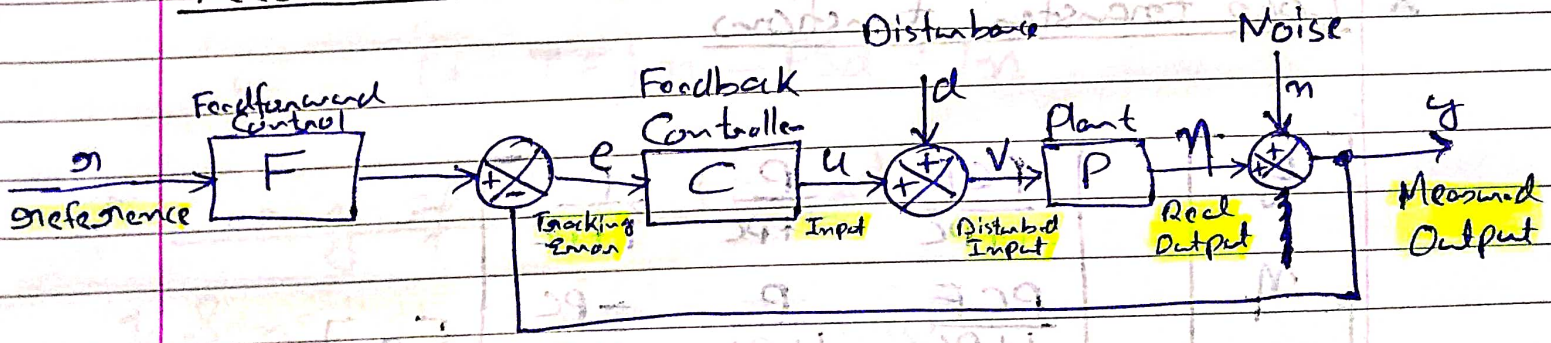
① Introduction

Control Objective	Controllers
① Stability	① Loop Shaping (lead / lag)
② Performance	② PID
③ Robust Stability	③ State feedback
④ Robust Performance	④ LQR
	⑤ LQG
	⑥ Hinf
	⑦ Lyapunov

★ Feedback Control loop



★ Types of Control problem

① Regulation problem ⇒ Determine an input such that the system maintains a reference value dispite disturbances.

② Tracking / servo problem: Find the input that allows the system output to closely follow a time varying reference signal.

★ Robustness

"A control system is robust when it is insensitive to model uncertainties"

⇒ **Robust Stability (RS)**: The system is stable for all perturbed plant about the nominal model up to the world case model uncertainty.

⇒ **Robust Performance (RP)**: The system satisfies the performance specifications for all perturbed plants about the nominal model upto the worst-case model uncertainty.

★ Loop transfer functions

$$\begin{bmatrix} y \\ \eta \\ v \\ u \\ e \end{bmatrix} = \begin{bmatrix} \frac{PCF}{1+PC} & \frac{P}{1+PC} & \frac{I}{1+PC} \\ \frac{PCF}{1+PC} & \frac{P}{1+PC} & \frac{-PC}{1+PC} \\ \frac{CF}{1+PC} & \frac{P}{1+PC} & \frac{-PC}{1+PC} \\ \frac{CF}{1+PC} & \frac{-PC}{1+PC} & \frac{-C}{1+PC} \\ \frac{F}{1+PC} & \frac{-P}{1+PC} & \frac{-1}{1+PC} \end{bmatrix} \begin{bmatrix} \mathcal{R} \\ d \\ n \end{bmatrix}$$

⇒ A performant controller minimizes the error between reference and Plant output:

$$E = r - y = \left(1 - \frac{PCF}{1+PC}\right) r + \left(\frac{-P}{1+PC}\right) d + \left(\frac{PC}{1+PC}\right) n$$

★ The Gang of Six

Let,

$$S(s) = \frac{1}{1+PC} \quad \& \quad T(s) = \frac{PC}{1+PC}$$

$$\begin{bmatrix} y \\ \eta \\ v \\ u \\ e \end{bmatrix} = \begin{bmatrix} TF & PS & S \\ TF & PS & -T \\ CFS & PS & -T \\ CFS & -T & -CS \\ FS & -PS & -S \end{bmatrix} \begin{bmatrix} r \\ d \\ n \end{bmatrix}$$

$$E = (1 - TF) r - PSd + Tn$$

★ Gang of four (F = 1)

1. Sensitivity = $S(s) = \frac{1}{1 + P(s)C(s)}$

2. Complementary Sensitivity = $T(s) = \frac{P(s)C(s)}{1 + P(s)C(s)}$

3. Load Sensitivity = $P(s)S(s) = \frac{P(s)}{1 + P(s)C(s)}$

{How does disturbance affect the output}

4. Noise Sensitivity $= C(s)S(s) = \dfrac{C(s)}{1 + P(s)C(s)}$

{How does noise affect the input}