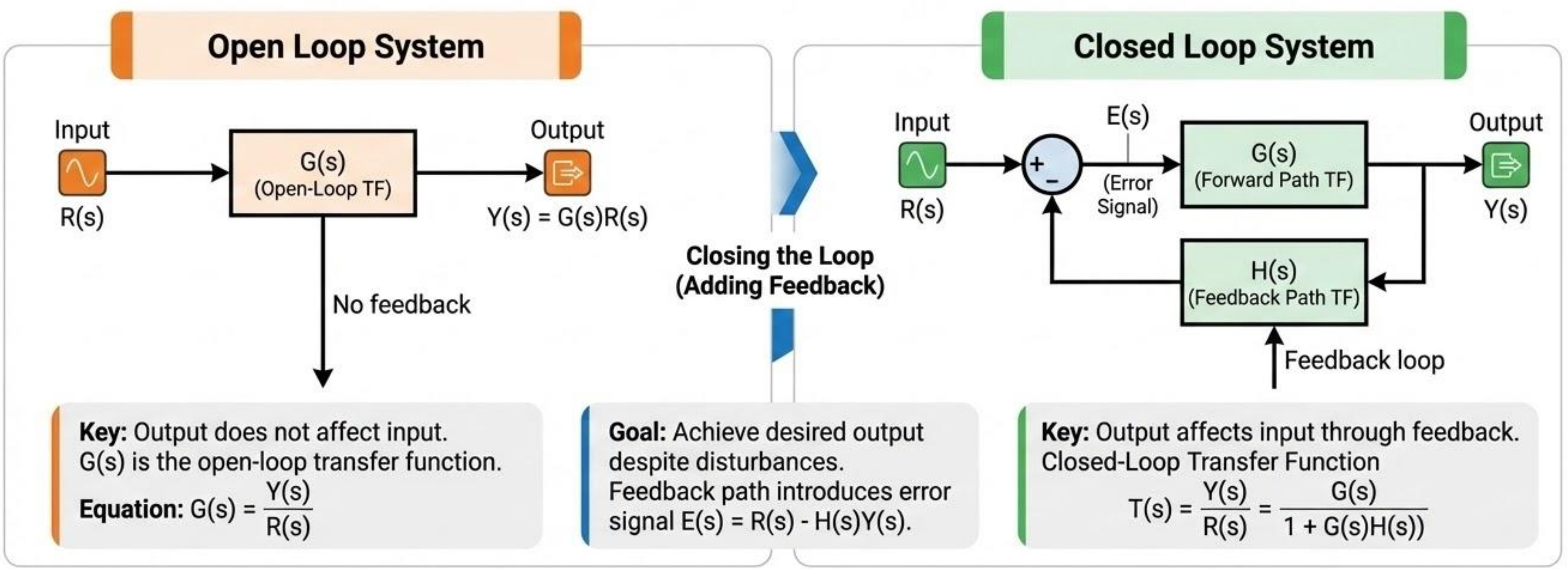
Smart Throttle Control

Basics of Control Theory, Matlab and Simulink (2)

Open to Closed Loop



Summary

- **Open Loop:** Simple, stable, but sensitive to disturbances. (G(s))
- **Closed Loop:** Better performance, robust to disturbances, potential for instability. (T(s) = G(s) / (1 + G(s)H(s)))
- **Conversion:** Add feedback path H(s), re-evaluate transfer function.

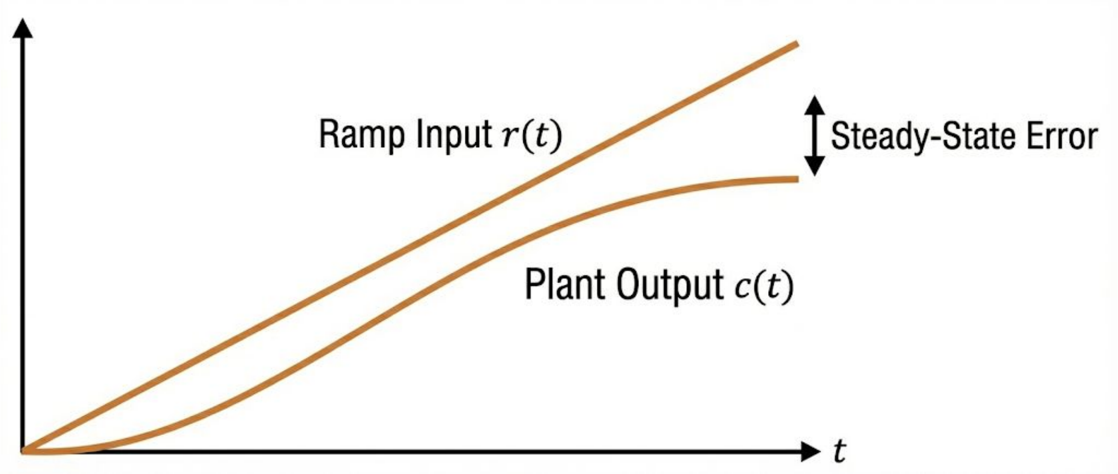
Response vs Transfer Function

Response - How does your system reacts with time to an input

Types - Impulse, Step, Ramp, Parabolic..

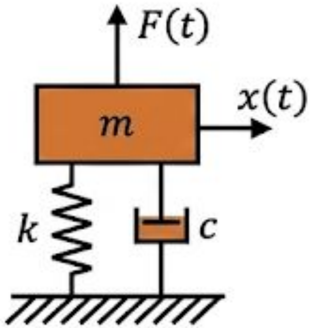
Transfer Function - Output/Input in a different and easier to manipulate dimension

Types - 0th order, 1st order, second order..



Response to Transfer Function

1. Simple Plant Equations



Governing Differential Equation:

$$m^*x''(t) + c^*x'(t) + k^*x(t) = F(t)$$

2. Laplace Transform & Transfer Function

Apply **Laplace Transform** (with zero initial conditions):

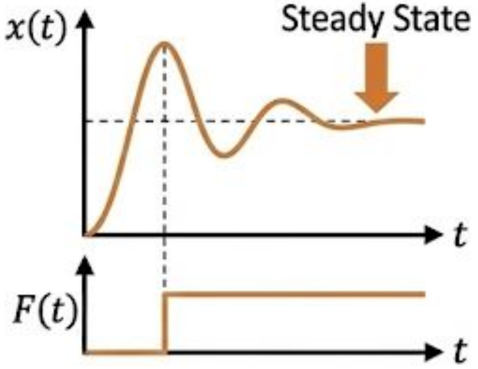
$$L(m^*x''(t) + c^*x'(t) + k^*x(t) = F(t)\}$$

$$\rightarrow (ms^2 + cs + k)X(s) = F(s)$$

Transfer Function $H(s)$ = Output/Input:

$$H(s) = \frac{X(s)}{F(s)} = \frac{1}{ms^2 + cs + k}$$

3. Step Response



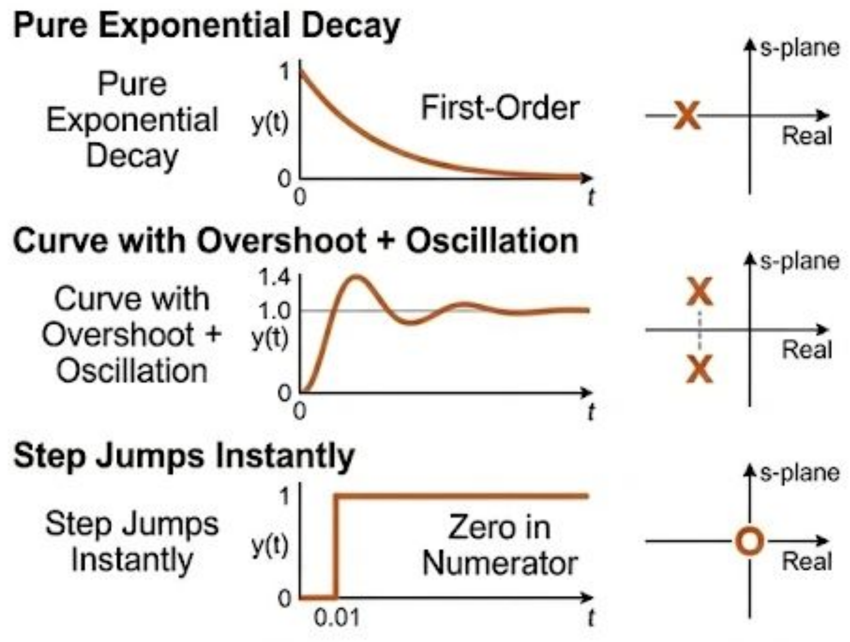
Input Step $F(t) = u(t)$

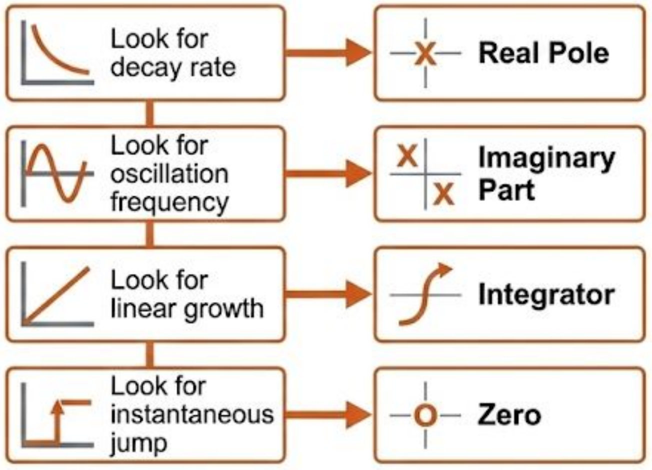
$$\rightarrow X(s) = H(s) * \frac{1}{s}.$$

Inverse Laplace gives $x(t)$.

Correlation

Major step responses

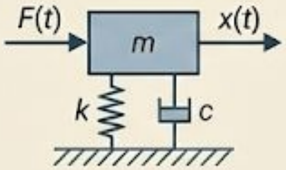




Every distinct shape tells you about its transfer function

Modeling of a Plant

Equation Based (Laplace Transform)

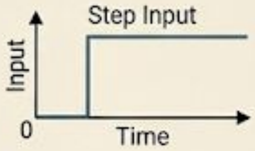


1. Physical System
2. Differential Equation
3. Laplace Transform
4. Transfer Function

VS

Response Based (Estimation)

1. Unknown System



2. Apply Test Input

3. Observe Output

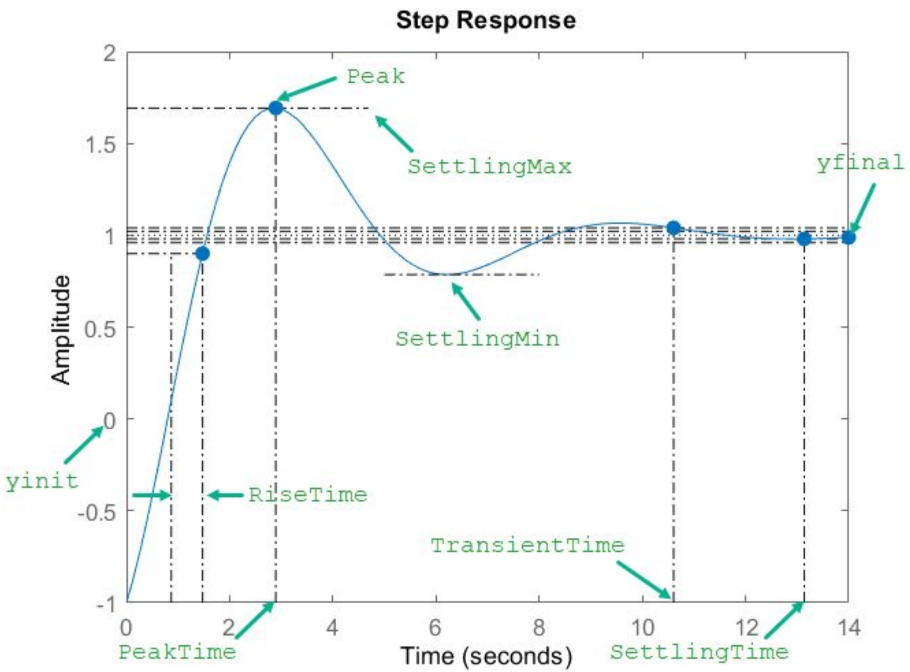
4. Estimate Parameters

Step Response

Things to look out for:

- Rise time
- Settling time
- Steady state error
- overshoot

Have to minimise all these components for a better response



Step Response

First Order Response

$$\frac{C(s)}{R(s)} = \frac{\frac{1}{sT}}{1+\frac{1}{sT}} = \frac{1}{sT+1}$$

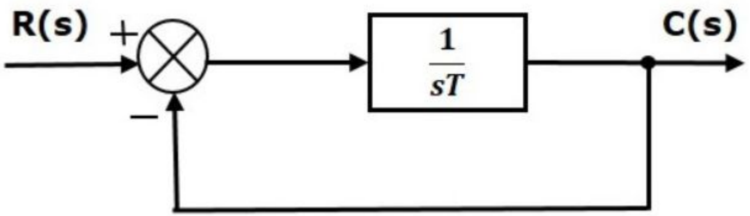
Since r(t) = u(t), using laplace transform

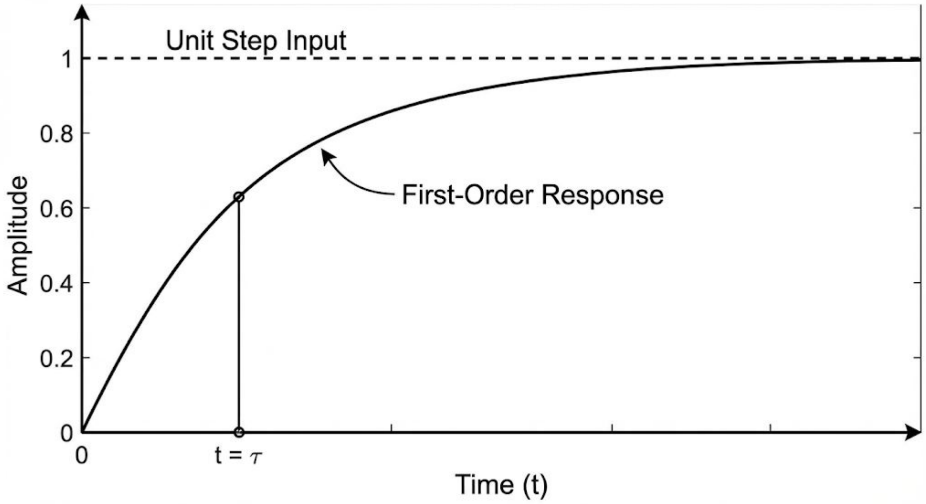
Substitute, $R(s) = \frac{1}{s}$ in the above equation.

$$C(s) = \left(\frac{1}{sT+1}\right)\left(\frac{1}{s}\right) = \frac{1}{s\,(sT+1)}$$

Apply inverse Laplace transform on both the sides.

$$c(t) = \left(1 - e^{-\left(\frac{t}{T}\right)}\right) u(t)$$

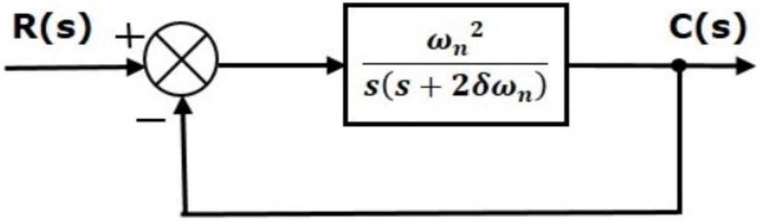




Step Response

Second Order Response

$$\frac{C(s)}{R(s)} = \frac{\left(\frac{\omega_n^2}{s(s+2\delta\omega_n)}\right)}{1+\left(\frac{\omega_n^2}{s(s+2\delta\omega_n)}\right)} = \frac{\omega_n^2}{s^2+2\delta\omega_n s+\omega_n^2}$$



If we consider delta = 0 (Good/Bad)???

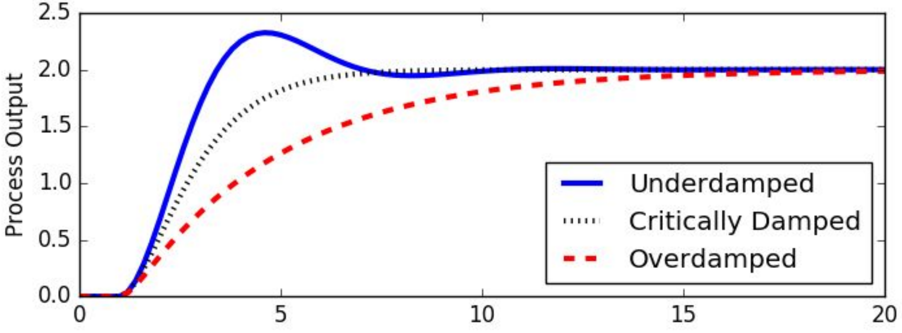
$$C(s) = \left(\frac{\omega_n^2}{s^2+\omega_n^2}\right)\left(\frac{1}{s}\right) = \frac{\omega_n^2}{s(s^2+\omega_n^2)}$$

Apply inverse Laplace transform on both the sides.

$$c(t) = (1-\cos(\omega_n t))\,u(t)$$

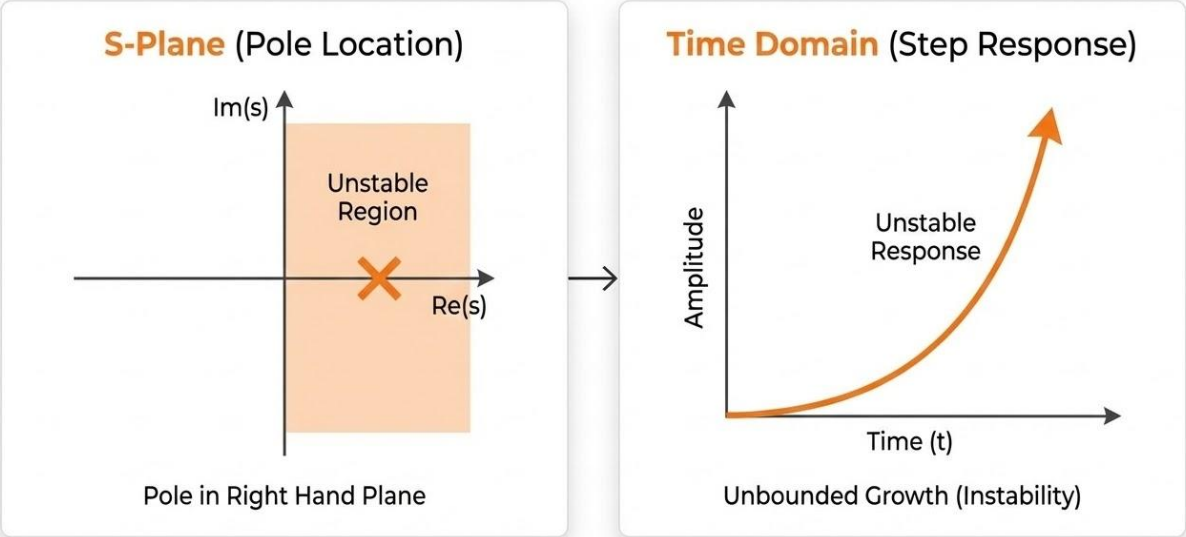
If delta = 1

$$C(s) = \left(\frac{\omega_n^2}{(s+\omega_n)^2}\right)\left(\frac{1}{s}\right) = \frac{\omega_n^2}{s(s+\omega_n)^2}$$



Stability

When poles come to the right hand plane



Example:

G(s) = 1 / (s - 1)

Inverse laplace is with unit response is -

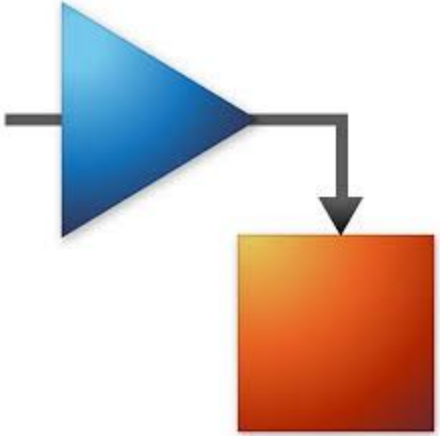
$e^t * u(t)$

Control Using Matlab

Moving on to

Control Using Simulink

Moving on to



Thank You !!!