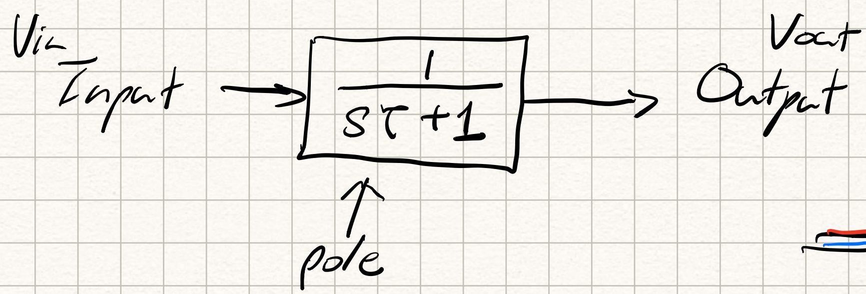
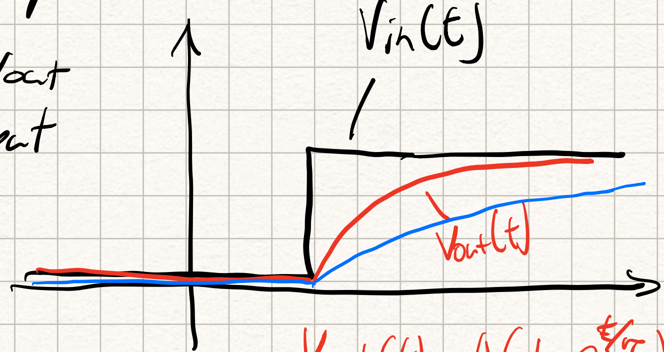
MECH 423 Lecture 18

What is a pole?

A linear delay in system response.

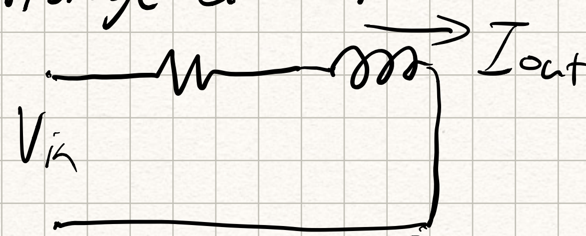




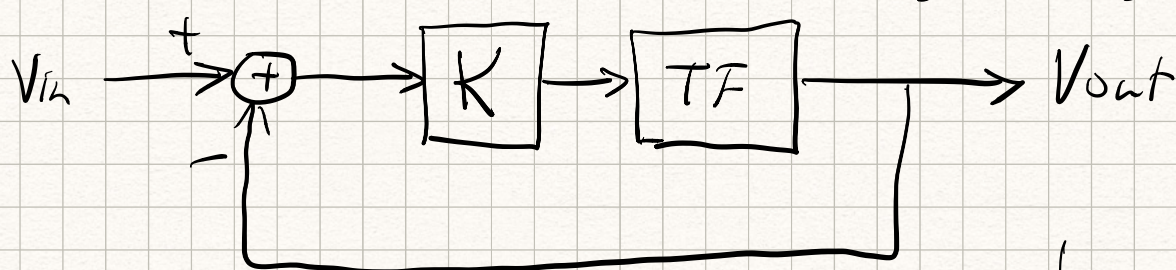
$V_{out}(t) = A(1-e^{t/\tau})$

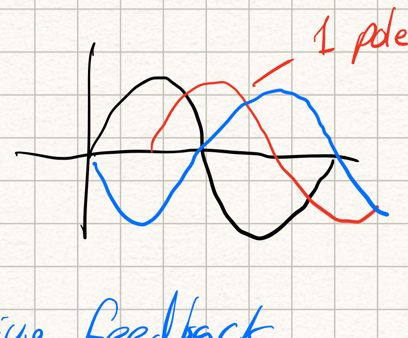
MECH Example: Flexible coupling
- Any finite stiffness

Elec Example: Energy storage element



Realistic Systems: $TF = \dfrac{1}{(\tau_1 s+1)(\tau_2 s+1)(\tau_3 s+1)(\tau_4 s+1)}$



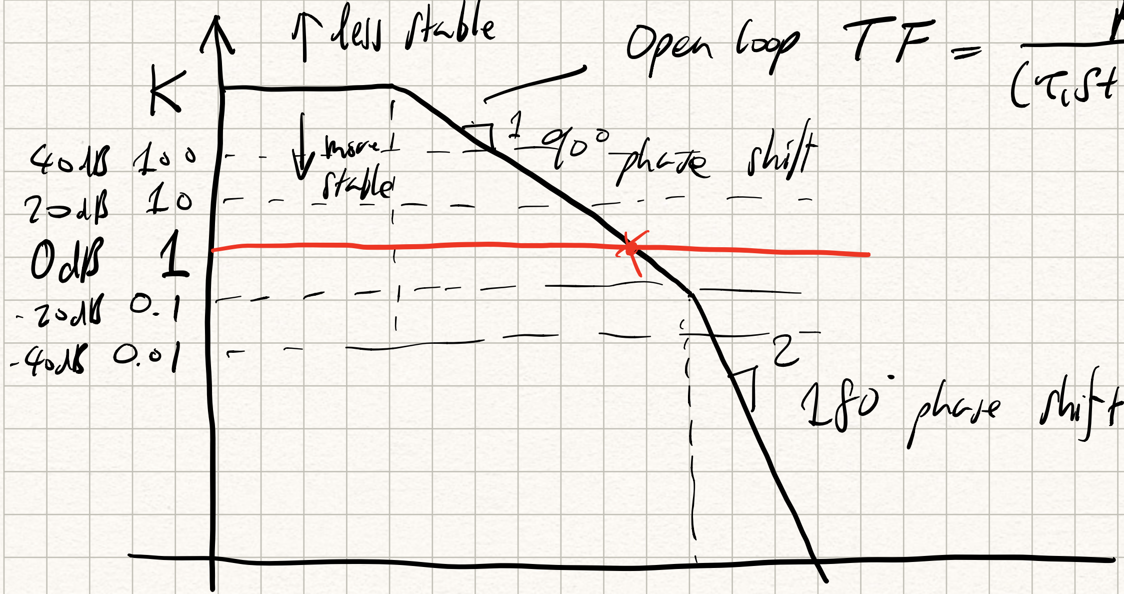


One pole: 90° of phase shift

Two poles: 180° phase shift

$\Rightarrow$ Inversion $\Rightarrow$ positive feedback

Open loop $TF = \dfrac{K}{(\tau_1 s+1)(\tau_2 s+1)(\tau_3 s+1)(\dots)}$



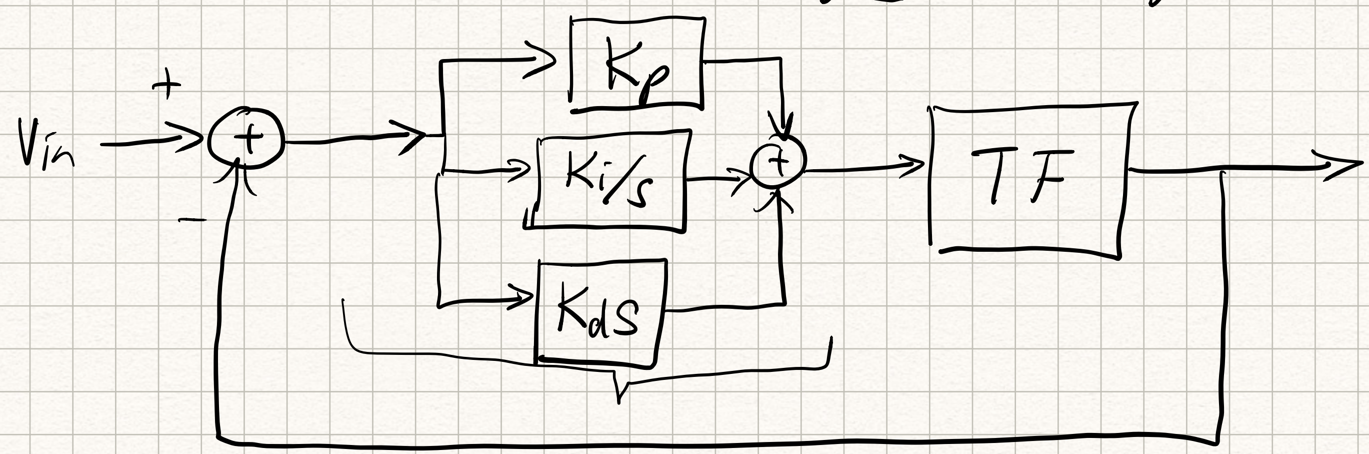
Electrical system: TF is known

Mechatronic system: TF is unknown.

(1) Measure the open loop TF — lab 3
- 2nd pole

(2) Measure the close loop TF
- Try different gain — Same as PID tuning

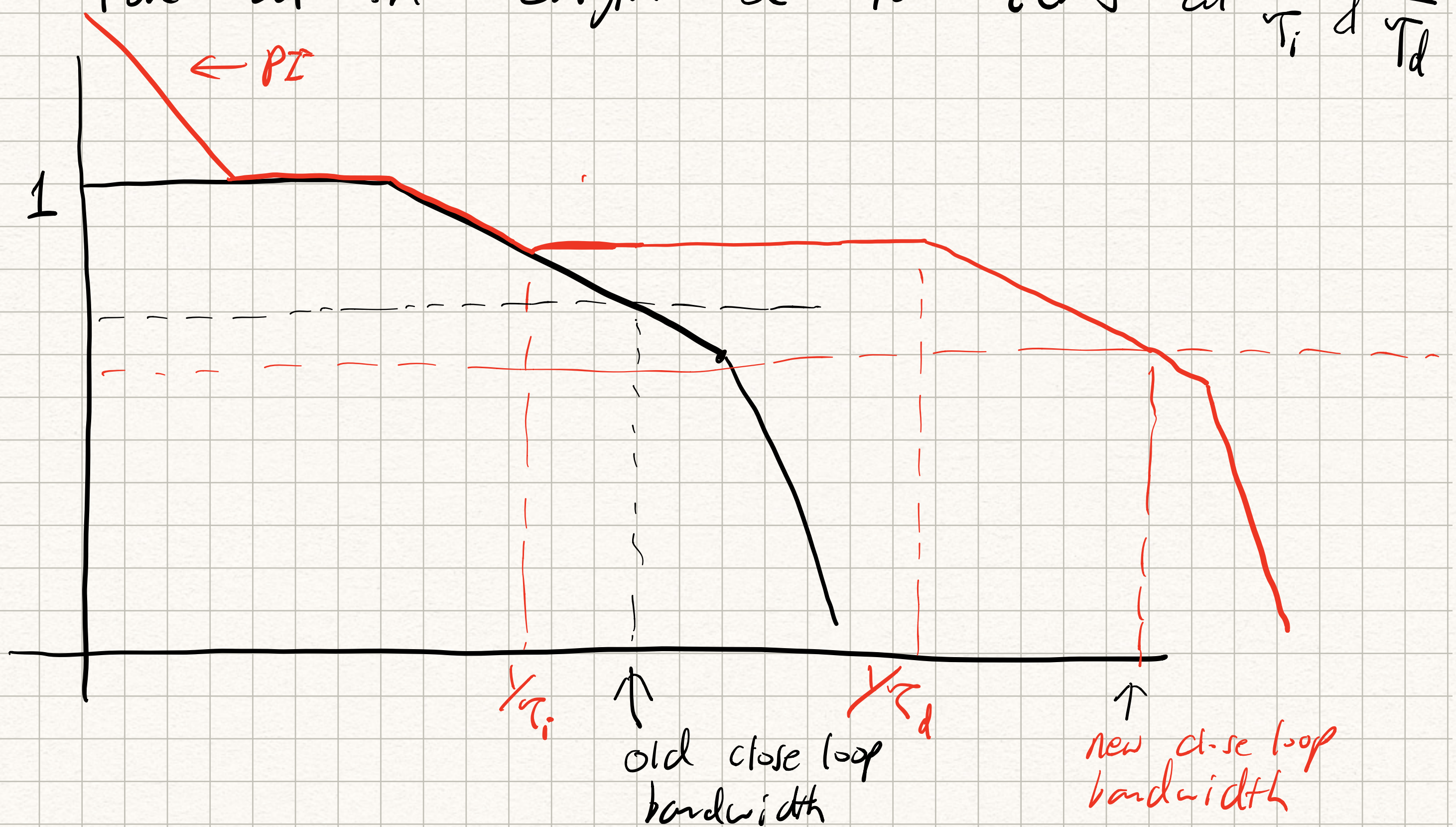
PID Control — developed for <u>digital</u> control systems



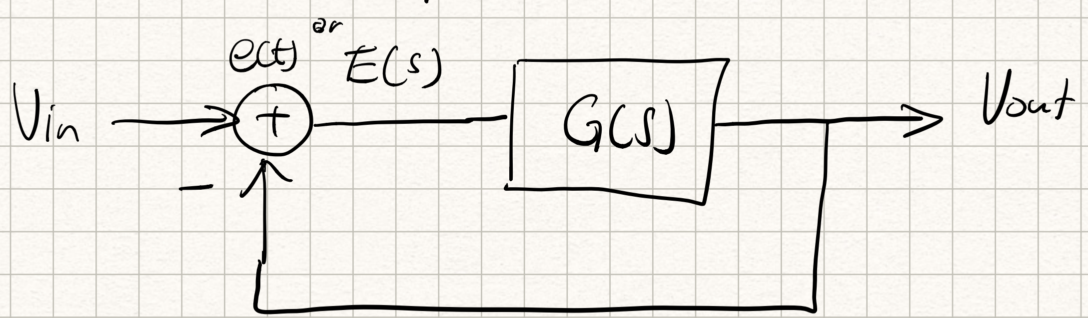
$$K_p + \frac{K_i}{s} + K_d s = \frac{K_d s^2 + K_p s + K_i}{s}$$

$$= \frac{K_c(\tau_i s + 1)(\tau_d s + 1)}{\tau_i s}$$

- Pole at the origin & two zeros at $\frac{1}{\tau_i}$ & $\frac{1}{\tau_d}$



* PID – sufficient most of the time.
  - TF is often not well known.



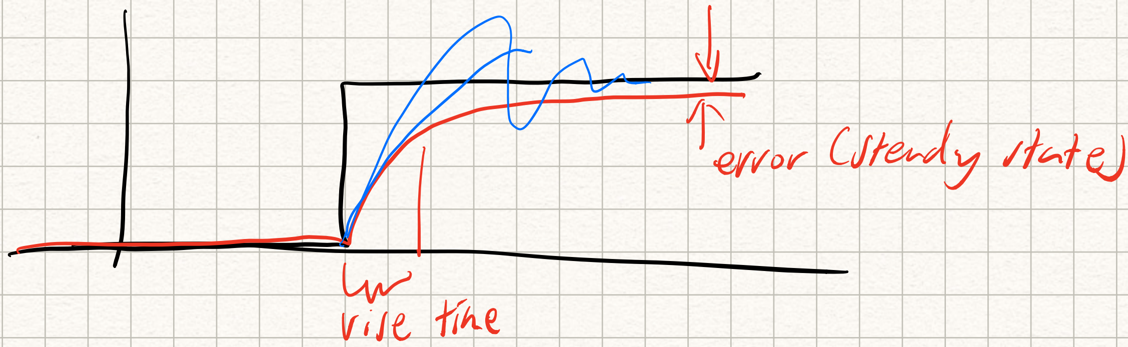
$$E(s) = V_{in}(s) - V_{out}(s)$$

$$G(s)\big(\underbrace{V_{in} - V_{out}}\big) = V_{out}$$

$$G(s)\, V_{in} = V_{out}\big(1 + G(s)\big)$$

$$\frac{V_{out}}{V_{in}} = \frac{G(s)}{1 + G(s)} \simeq 1$$

$$E(s) = V_{out} - V_{in} = \frac{1}{1 + G(s)} \simeq \frac{1}{G(s)}$$

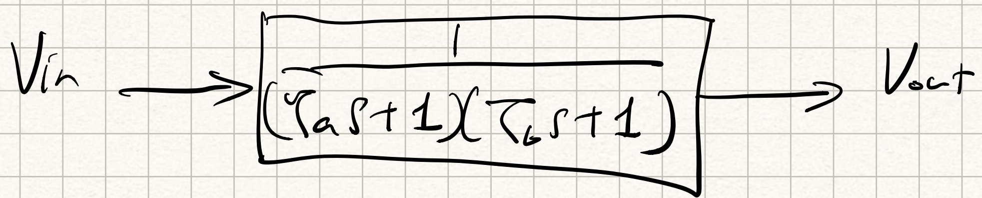


$$\text{Open loop TF} = \frac{K}{(\tau_1 s+1)(\tau_2 s+1)}$$

$$\text{Close loop TF} = \frac{1}{1+G(s)}$$

$$= \frac{1}{(\tau_1 s+1)(\tau_2 s+1)+K}$$

$$= \frac{1}{(\tau_a s+1)(\tau_b s+1)}$$

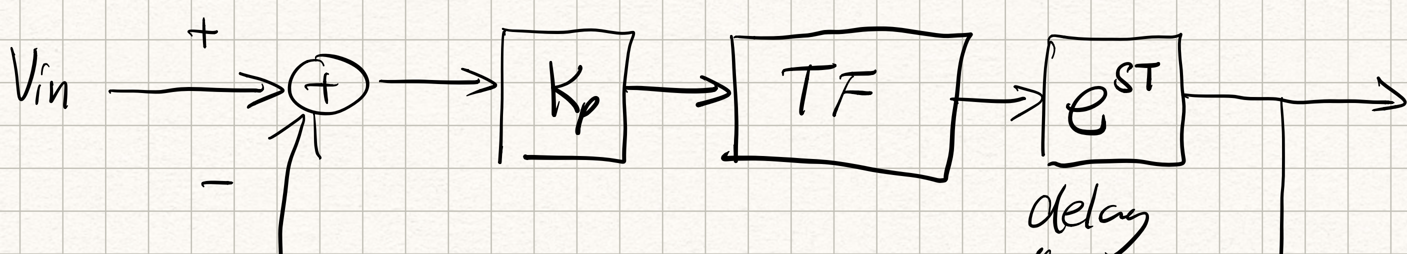


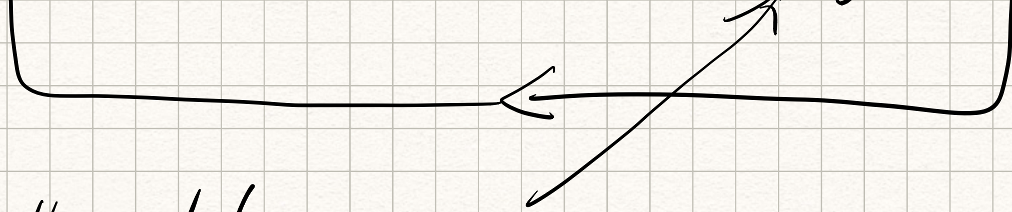
$$\boxed{n_{new} = TA\emptyset R - TA1R}$$

	S-domain	Time domain	Numerical
P	$K_p E(s)$	$K_p e(t)$	$K_p * e \quad e = n_{ref} - n_{new}$
I	$\frac{K_i}{s} E(s)$	$K_i \int e(t)\,dt$	$K_i * \sum_i e_i \Delta t = K_i(e + e_{sum})$
D	$K_d s E(s)$	$K_d \frac{de(t)}{dt}$	$K_d \frac{(e_{n-1} - e_n)}{\Delta t}$

absorb Δt here

absorb Δt into K_d





Controller delay

$T \simeq$ period of your control loop.

T should be < 1 ms.