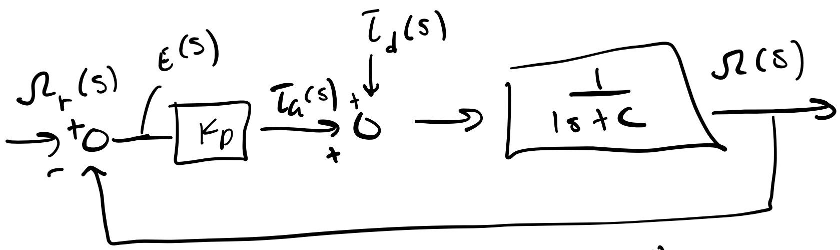
- Block diagrams reduction, FVT
- 2DOF, Transfer function
- Laplace, partial fractions
- Some time domain specs (qualitative)

- Review HWs

1st Order system: Proportional Control

cont. from Lec 12:



Error due to disturbance: $\tau_d = 1(t)$

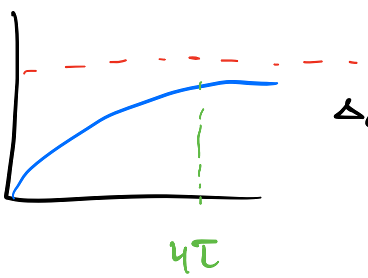
$$\frac{E(s)}{T_d(s)} = \frac{\frac{1}{Is+C}}{1 + \frac{K_p}{Is+C}} = \frac{1}{Is+C+K_p}$$

$$E(\infty) = \lim_{s\to 0}\left[\cancel{s}\cdot\frac{1}{I\cancel{s}+C+K_p}\cdot\frac{1}{\cancel{s}}\right]$$

$$E(\infty) = \frac{1}{C+K_p}$$ Goes to 0 as $K_p \to \infty$

Design example: $t_s \leftarrow$ Set

$e(\infty) \leftarrow T_d \; (\tau_d(t) = 3\cdot 1(t))$



$$\Delta_{cl}(s) = s + \frac{C+K_p}{I}$$

$$\tau = \frac{I}{C+K_p}$$

$$t_s \le 4\tau \rightarrow \boxed{K_p \ge \frac{4I}{t_s} - C}$$

$$\tau_d(t) = 3 \cdot 1(t) \to \frac{3}{s}$$

$$e(\infty) = \frac{3}{c+K_p} \to \boxed{K_p \geq \frac{3}{e(\infty)} - c}$$

$I = 0.05$

$c = 0.025$

$t_s \leq 0.1\ s$

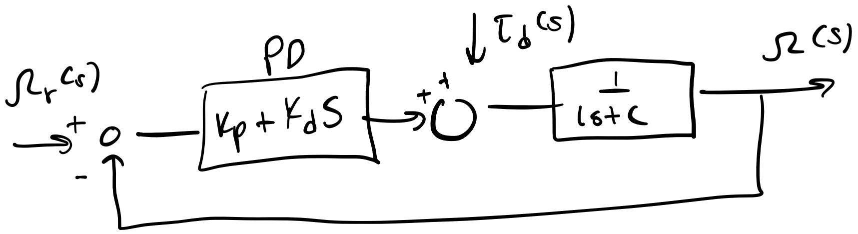
$e(\infty) \leq 2$ (rad)

$\boxed{K_p \geq 1.975}$

$K_p \geq 1.475$

will satisfy t_s exactly, with better error

what about adding derivative control?



$$\frac{\Omega(s)}{\Omega_r(s)} = \frac{K_p + s K_d}{(I+K_d)s + (c+K_p)} \leftarrow \Delta_{CL}$$

will NOT speed up

$$\Delta_{CL}(s) = s + \frac{c+K_p}{I+K_d}, \qquad \tau = \frac{I+K_d}{c+K_p}$$

Look @ Error:

$$\frac{E(s)}{\Omega_r(s)} = \frac{1}{1 + \frac{K_p + sK_d}{Is+c}} = \frac{Is+c}{Is + sK_d + (c+K_p)}$$

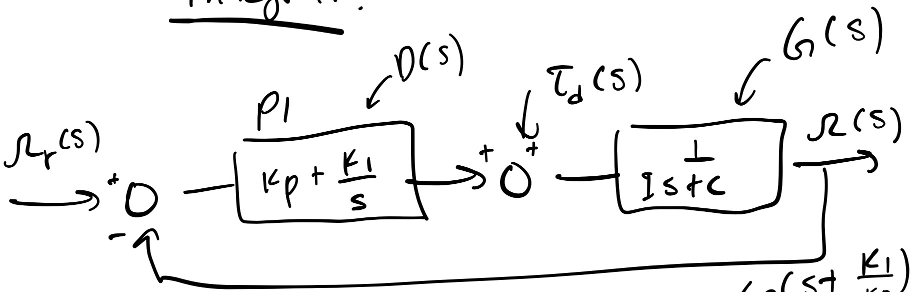
$\tau_d(t) = 1(t)$

$$e(\infty) = \lim_{s \to 0} \left[\cancel{s} \cdot \frac{\cancel{Is}+c}{\cancel{s(I+K_d)} + (c+K_p)} \cdot \frac{1}{\cancel{s}} \right]$$

$$e(\infty) = \frac{c}{c+K_p} \leftarrow K_d \text{ does not help}$$

1st ORDER: Don't use derivative

Integral:



$$K_p + \frac{K_1}{s} = \frac{K_p s + K_1}{s} \nearrow = K_p\left(s + \frac{K_1}{K_p}\right)/s$$

adds another pole, increasing order of system

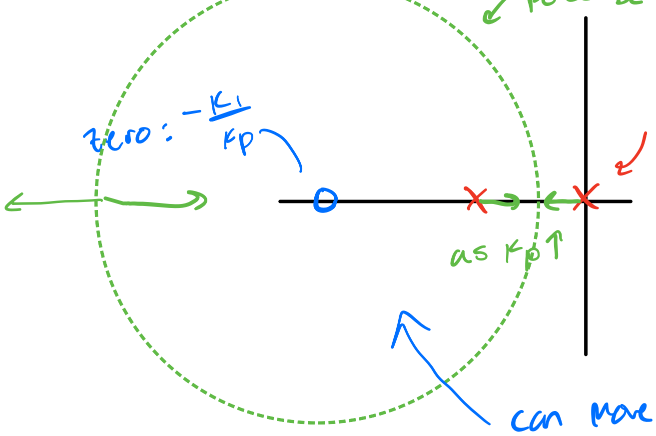
$$\frac{\Omega(s)}{\Omega_r(s)} = \frac{D(s)\,G(s)}{1 + D(s)\,G(s)} = \frac{sK_p + K_1}{Is^2 + (c+K_p)s + K_1}$$

$$\Delta_{CL} = s^2 + \frac{c+K_p}{I}s + \frac{K_I}{I}$$

closed loop

Roots can be real or complex conj.

poles become complex conjugate



can move zero to change size of circle, move poles