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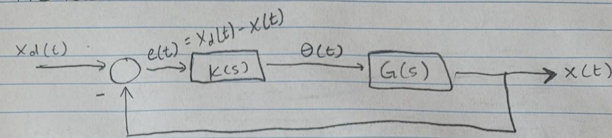
Pre-lab

2)



3) $\begin{cases} E(s) = X_d(s) - X(s) \\ \Theta(s) = K(s) * E(s) \end{cases}$

$$\Rightarrow \frac{\Theta(s)}{X_d(s)} = \frac{K(s)}{1 + K(s)G(s)}$$

4) In specification 3:

$$\theta(t)\Big|_{t=0} < 30° \quad \text{or} \quad \frac{\pi}{6} \text{ rad}$$

$$\theta(s) = \frac{K(s)}{1 + K(s)G(s)} * X_d(s) = \frac{1}{s} * \frac{K(s)}{1 + K(s)G(s)}$$

$$\begin{cases} G(s) = \frac{7}{s^2} \\ K(s) = \frac{K \prod_{i=1}^{M} (s - z_i)}{\prod_{j=1}^{n} (s - p_j)} \end{cases}$$

z_i , p_j - zeros, poles
K - control gain

$$\theta(t)\Big|_{t=0} = \lim_{s \to \infty} s * \theta(s) = \lim_{s \to \infty} \frac{K(s)}{1 + K(s)G(s)}$$

$$= K$$

$\therefore K < \frac{\pi}{6}$

5) $$\frac{X(s)}{X_d(s)} = \frac{\Theta(s)G(s)}{X_d(s)}$$

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

pole > zero
reduces
~~damping~~
inc damp factor

For lag compensator
When dom. poles
go closer to zero

move
poles
behind
zero
reduces
ss error

6) from specification 1

$$2 \le T_s \le 4\,s$$

$T_s = \frac{4.6}{\sigma}$ σ - real part of pole / dominant pole

$$\Rightarrow 1.15 \le \sigma \le 2.3$$

7) dominant poles:

compare the real parts of poles since
the real part determines how fast the response decreases

ex) poles: $-\zeta\omega_n \pm j\omega_n\sqrt{1-\zeta^2}$

$-a_r$

step response:

$$C(s) = \frac{A}{s} + \frac{B(s+\zeta\omega_n) + C\omega_d}{(s+\zeta\omega_n)^2 + \omega_d^2} + \frac{D}{s+a_r}$$

$$c(t) = Au(t) + e^{-\zeta\omega_n t}(B\cos\omega_d t + C\sin\omega_d t) + De^{-a_r t}$$

if $a_r \gg \zeta\omega_n$

8) if Type1 or Type2 specification 1 is met
$K(s)\,G(s)$ should be at least type 1

control design:

$$K(s) = \frac{Ks}{s+p}$$

$$K(s)G(s) = 7K / s(s+p) \qquad \begin{matrix} K>0 \\ p>0 \end{matrix}$$

In practice, zero and pole cancellation is not allowed unless the pole is strictly in LHP. Also, since the poles at zero indicates the type of system, we usually do not cancel the pole at zero