자동제어 한방에 끝내기

6.Frequency Response

목차

Frequency domain

- Why?
- System에 진동하는 input을 넣으면?

System & Stability analysis

- Bode plot
- Stability margin
- Nyquist plot

Dynamic compensation

- Lead compensation
- Lag compensation

Dynamic Compensations

- Lead Compensation(진상 보상)

$$D(s) = \frac{Ts + 1}{\alpha Ts + 1} \quad (\alpha < 1)$$

$$= \frac{1}{\alpha}\left(\frac{s + \frac{1}{T}}{s + \frac{1}{\alpha T}}\right)$$

zero

pole

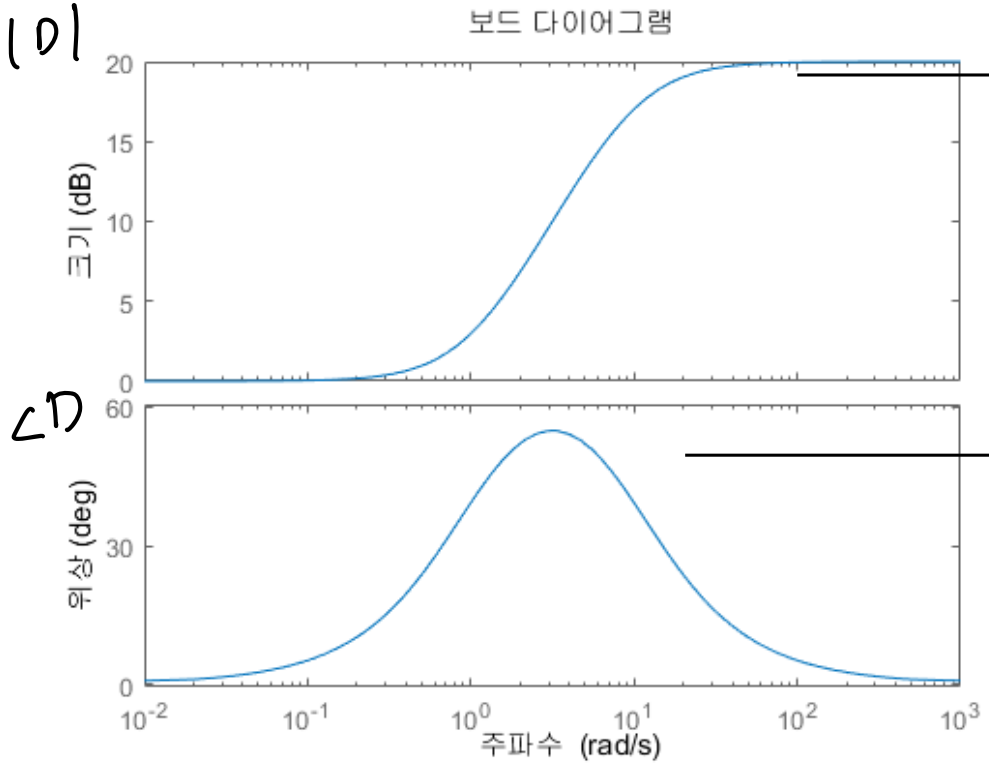
- PD 제어기의 근사 $K_d s + K_p$

- α가 작으면 작을수록 phase 증가량이 커지지만, 고주파수 대역에서 magnitude 증가량이 커진다.

- PM과 noise 민감도를 잘 고려하여 α를 설계

Dynamic Compensations - Bode

- Lead Compensation(진상 보상)



$$\log \omega_{max} = \frac{1}{2}\left(\log\frac{1}{T} + \log\frac{1}{\alpha T}\right)$$

$$\sin \phi_{max} = \frac{1-\alpha}{1+\alpha}$$

Dynamic Compensations

- Lag Compensation(지상 보상)

$$D(s) = \alpha \frac{Ts + 1}{\alpha Ts + 1} \quad (\alpha > 1)$$

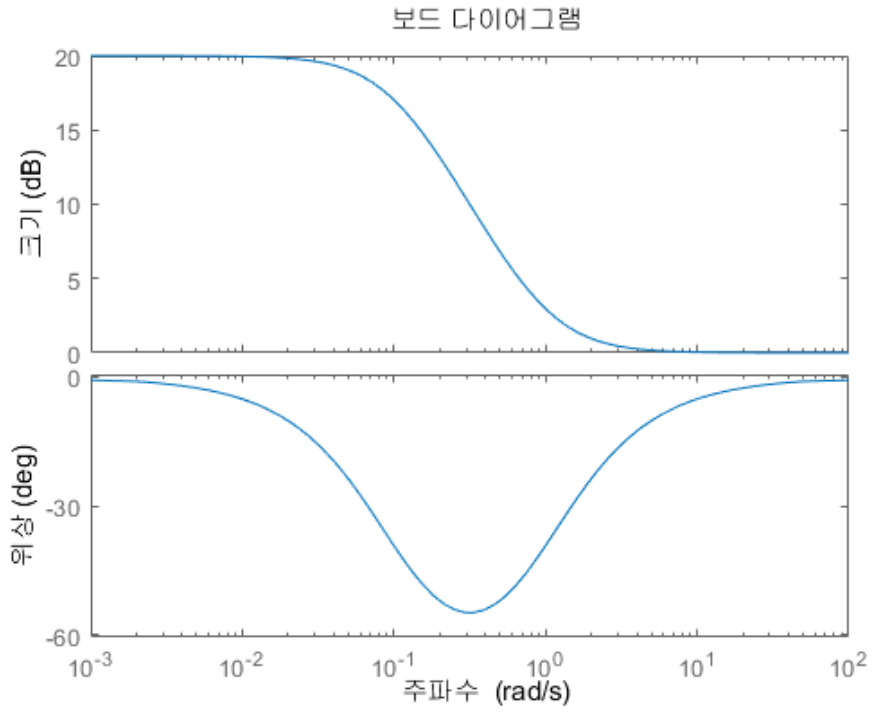
- PI 제어기의 근사 $\frac{K_I}{s} + K_P$

- α가 클수록 저주파 대역에서 gain이 커져 steady-state response를 좋게 한다.

- Phase를 늦춰 PM이 기존에 잘 확보되어 있는지 확인해야 한다.

Dynamic Compensations - Bode

- Lag Compensation(지상 보상)



PID

PI+PD

Lead-Lag Compensation

문제풀이

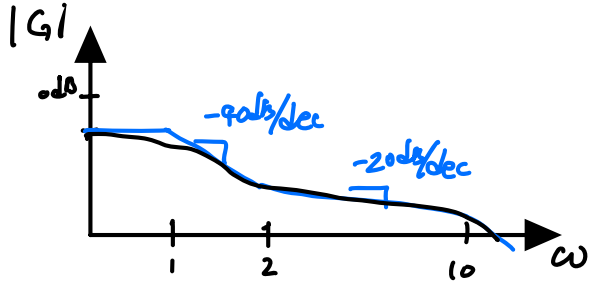
$-\frac{s+2}{(s+10)}$

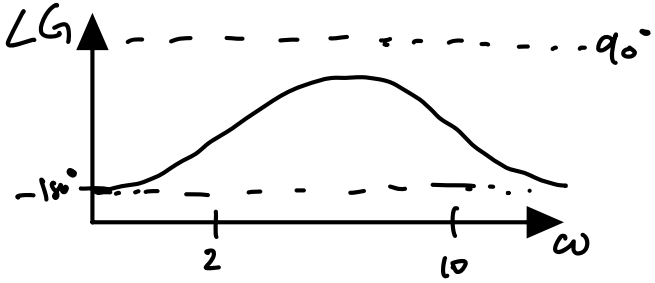
$K\,G(s) = \frac{s+2}{(s+10)(s^2-1)}$ $\qquad$ $w=0 \Rightarrow G(0) = -\frac{2}{10}$

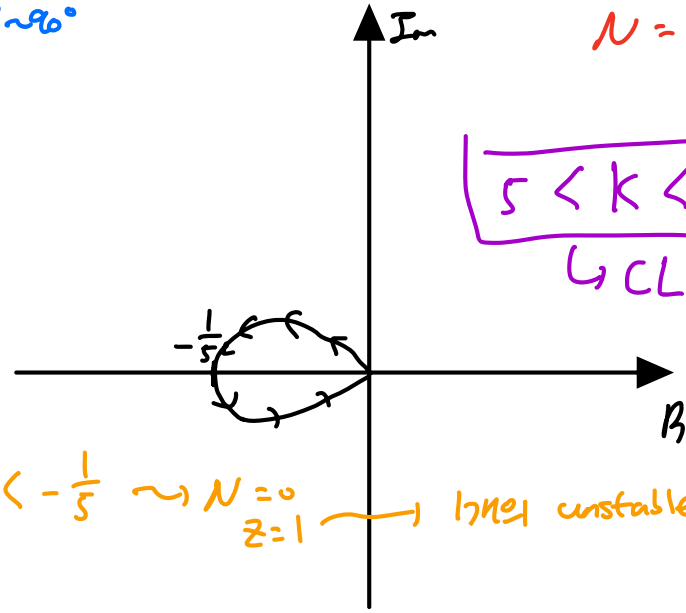
$(s+1)(s-1)$ → $180° \sim 90°$

↓

$0° \sim 90°$







$N = Z - P$

$P = 1$

$5 < K < \infty$

↳ CL system stable

$-\frac{1}{K} < -\frac{1}{5} \rightsquigarrow N = 0$, $Z = 1$ → 1개의 unstable CL pole.

$-\frac{1}{5} < -\frac{1}{K} < 0 \rightsquigarrow N = -1$

$\therefore Z = 0$ → unstable CL pole X.

$-\frac{1}{K} > 0 \rightarrow N = 0,\ Z = 1$

문제풀이

$$\frac{s+2}{s(s+10)(s^2-1)}$$

$S = \varepsilon e^{i\theta} \left(-\frac{\pi}{2} < \theta < \frac{\pi}{2}\right)$