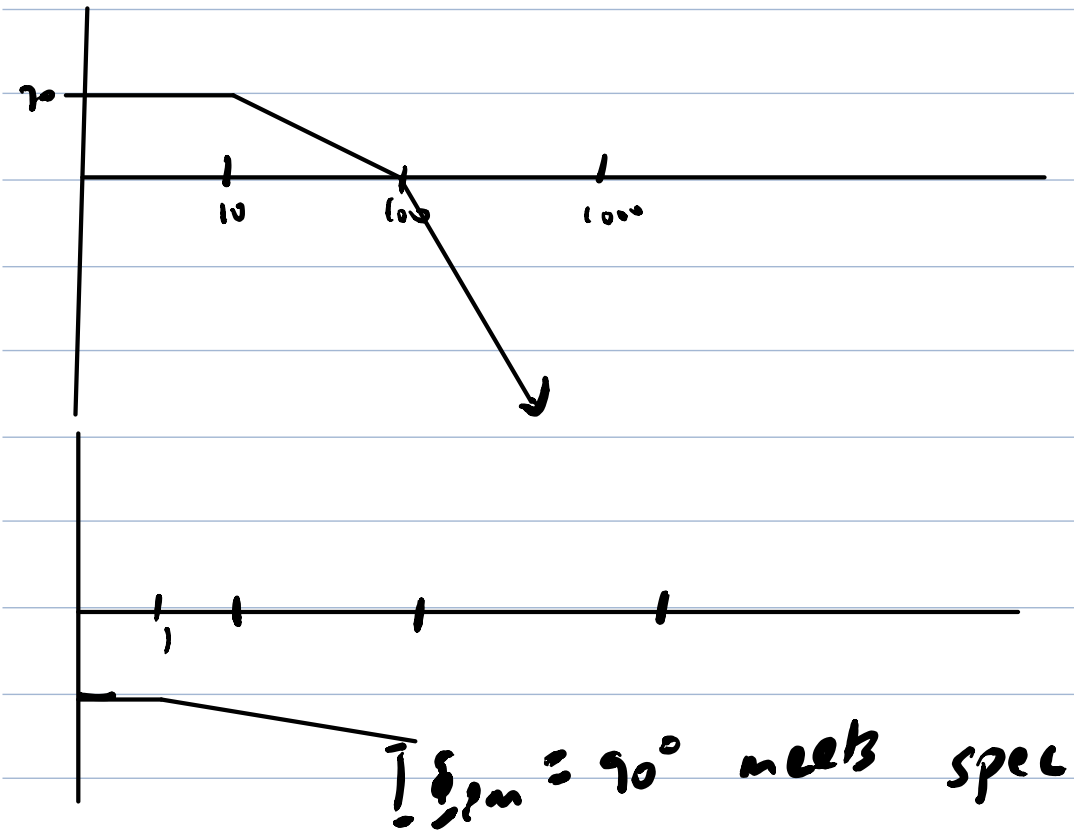
$$P(s) = \frac{10^8}{(s+10)(s+10^3)^2}$$

$$= \frac{10}{\left(\frac{s}{10}+1\right)\left(\frac{s}{10^3}+1\right)^2}$$



$\therefore \phi_{pm} = 90°$ meets spec

$K=1 \qquad |C(j\omega_c)|_{dB} \simeq 0$

$\angle 100 \qquad T_i = 10$

T_i

(may decrease K to meet ϕ_{pm}^{des})

What if we wanted $\phi_{pm} = 45°$

$$\angle KP(j\omega) = \begin{cases} 0 & \omega < 10 \\ -90° & 10 < \omega < 10^2 \\ 90° - 90°\log\omega & 10^2 < \omega < 10^4 \\ -270° & \omega > 10^4 \end{cases}$$

Solve $90° - 90° \log\omega = -130°$

$\Rightarrow \omega = 278$

$|P(j278)|_{dB} = -9dB$

$|C(j278)| = 9\,dB$ $\qquad K = \sqrt{10}$

$$K\left|1 + \frac{1}{T_i \cdot 278j}\right| = 9$$

$\frac{10}{T_i} < 278$ $\quad T_i = 10$

Lead - lag design

$P(s) = \frac{1}{s(s+1)(s+20)}$ $\qquad$ 10% ramp error

45° pm at least

$\phi_{pm}^{des} = 45° = 20° + 25°$

$e_{ss} = \lim_{s\to 0} \frac{1}{s^2} \cdot s \cdot \frac{1}{1 + K\frac{1}{s(s+1)(s+20)}} = \frac{20}{K} \Rightarrow K = 200$

$\angle KP(j1.77) = -155°$

$|KP(j1.77)|_{dB} = 9$

Desire $|C(j1.77)| = -9dB$

$20\log|\alpha| = -9$

$\Rightarrow \alpha = \frac{1}{\sqrt{10}}$

$\frac{10}{T_i \cdot 5.6} < 1.77$ $\quad T_i = 20$ works.

$$\alpha = \frac{1+\sin(25°)}{1-\sin(25°)} = 2.46$$

$$|C(j\omega_m)|_{dB} = \sqrt{\alpha} \qquad T = \frac{1}{\omega_m \sqrt{\alpha}}$$

$$\omega_m = 2.3$$