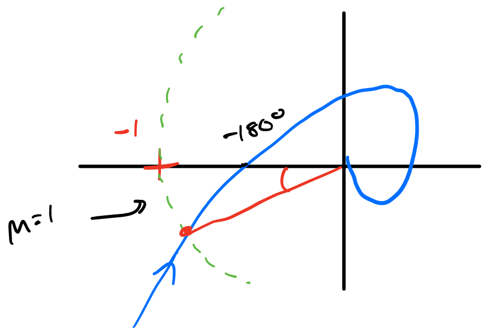
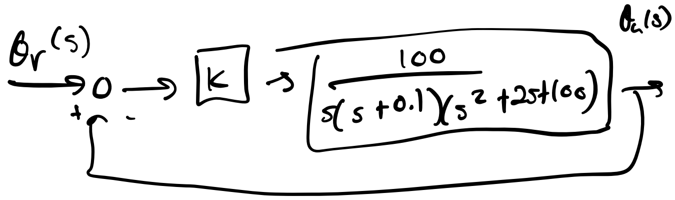
Design using freqency response

- "shape" OL freq. response to achieve specifications
- choose crossover frequency ω_c ($M=1$) to achieve desired response speed
- adjust phase @ ω_c to achieve desired damping (& overshoot, amplification, etc)



- adjust high freq. gain to achieve sufficient gain margin
- SOON: adjust low freq. gain to achieve SS error

Compensation approach example:



Requirements: $PM \geq 50°$, $GM \geq 10dB$

unity gain:
with $D(s) = K = 1$

$GM = 13.1$ dB, $PM = 4.5°$, $\omega_c = 1$ r/s

- phase margin too small

If speed of response not important, could lower crossover freq.

→ $K = 0.011$: $GM = 52$, $PM = 50.1°$
but $\omega_c = 0.08$, simple but slow!

PD control: $D(s) = \underbrace{K_d\left(s + \frac{K_p}{K_d}\right)}_{\text{Gain \& zero term}}$ $-z_{pd}$

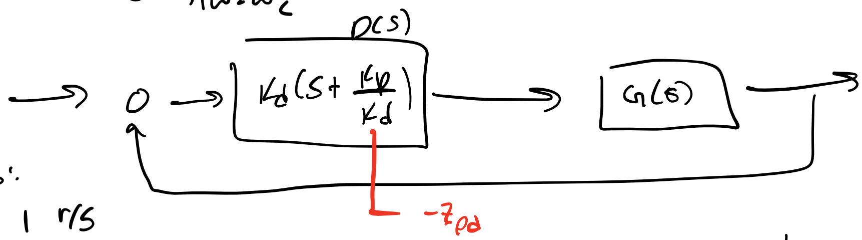
→ can be used to add phase (to improve PM)

→ can cause noise w/ high gain @ high freq

→ can worsen SS error by lowering low freq. gain when high phase added

→ want PD phase = 50° at desired ω_c

$$\angle D(j\omega)\big|_{\omega=\omega_c} = 0.8727$$

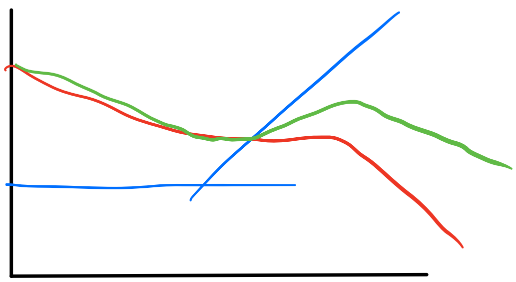


for this:
$\omega_c = 1$ r/s

want $\angle D(j\omega_c) = 50° = \overset{(\varphi_{des})}{0.8727} = \mathrm{atan}\left(\dfrac{\omega_c}{z_{pd}}\right)$ ← 1

$$\tan(\varphi_{des}) = \frac{\omega_c}{z_{pd}}$$

$$z_{pd} = \frac{\omega_c}{\tan(\varphi_{des})} = \frac{1}{\tan(0.8727)} \cong 0.839$$



$K_d \rightarrow M = D \cdot G = 1$ @ $\omega = \omega_c$

$$D(s) = K_d(s+0.839)$$

$$|D(j\omega_c)G(j\omega_c)| = 1 = K_d \frac{100\sqrt{0.839^2+1^2}}{1 \cdot \sqrt{0.1^2+1^2} \cdot \sqrt{99^2+2^2}}$$

$$= 1.31\,K_d = 1 \rightarrow K_d \cong 0.76$$

$$\rightarrow D(s) = 0.76(s+0.839)$$