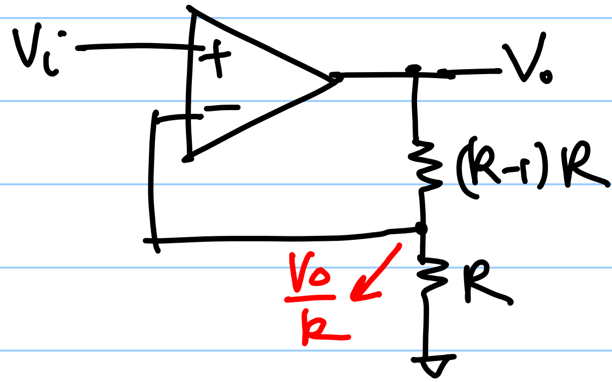
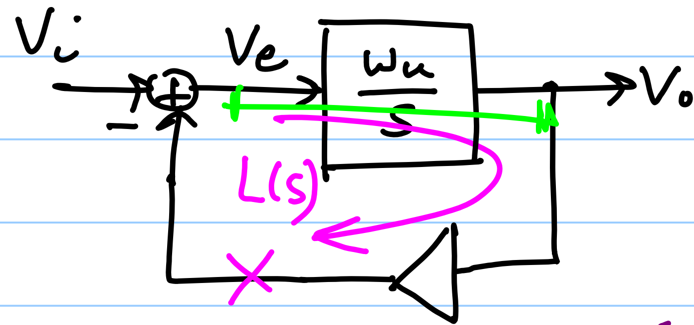
# ECE 511 - Lecture 25

Note Title 4/29/2014




$\Longleftrightarrow$




$1/k \Leftarrow \beta \Leftarrow$ feedback ratio

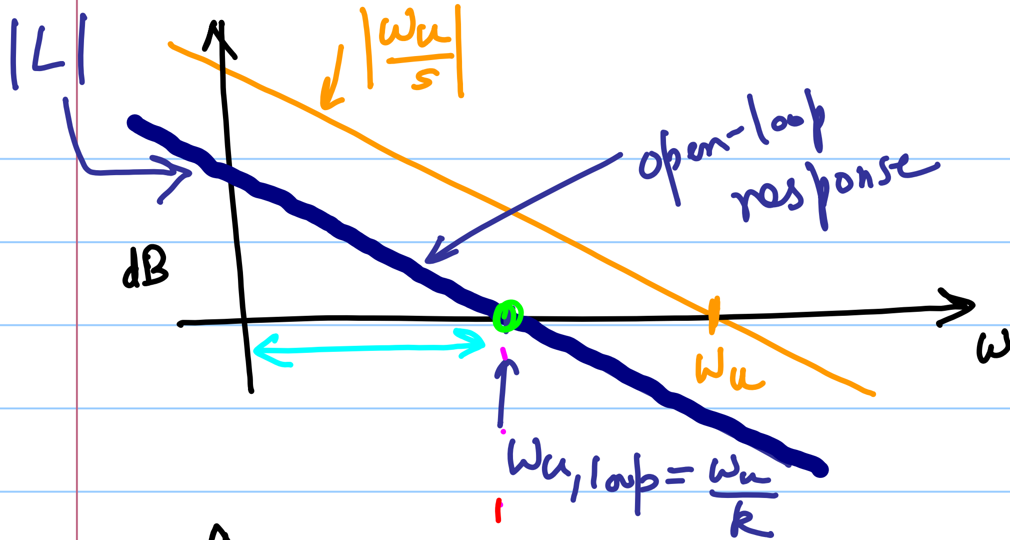
(open) Loop-response $\boxed{L(s) = \frac{\omega_u}{k \cdot s}}$

Closed-loop Transfer function

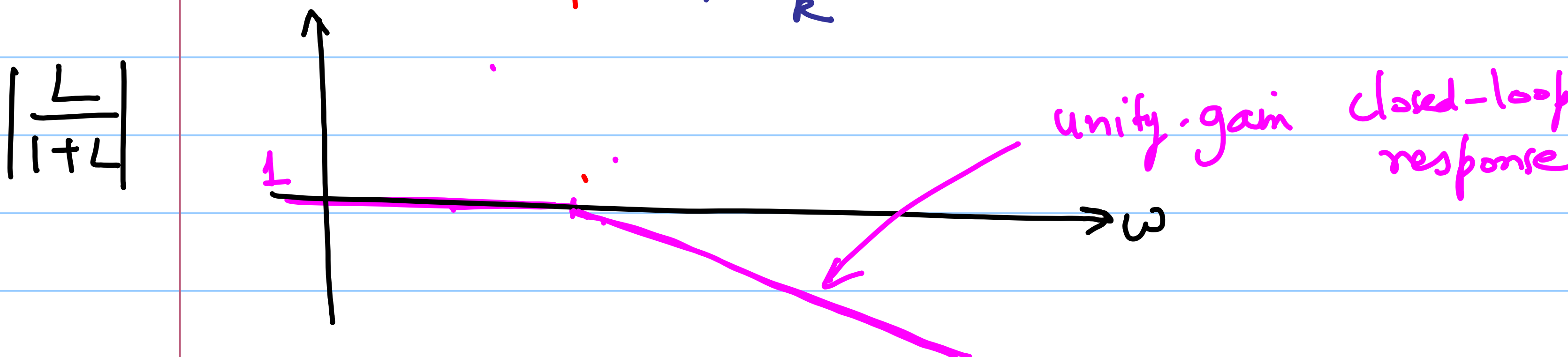
$$\frac{V_o}{V_i} = \frac{\frac{\omega_u}{s}}{1 + L(s)} = \frac{\underbrace{k \cdot L(s)}_{\text{forward path response}}}{1 + \underbrace{L(s)}_{\text{loop-response}}}$$

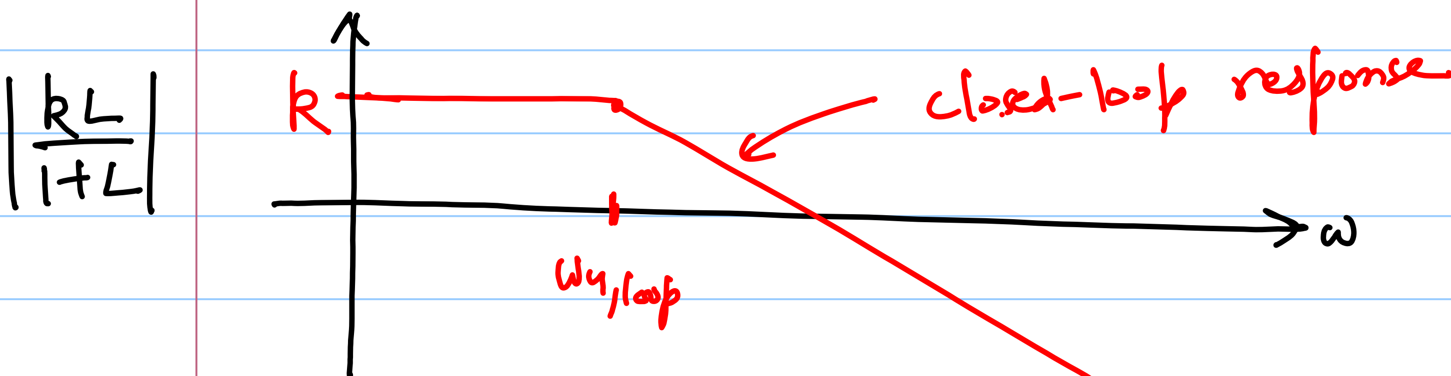
$$= k \cdot \left(\frac{L}{1+L}\right)$$

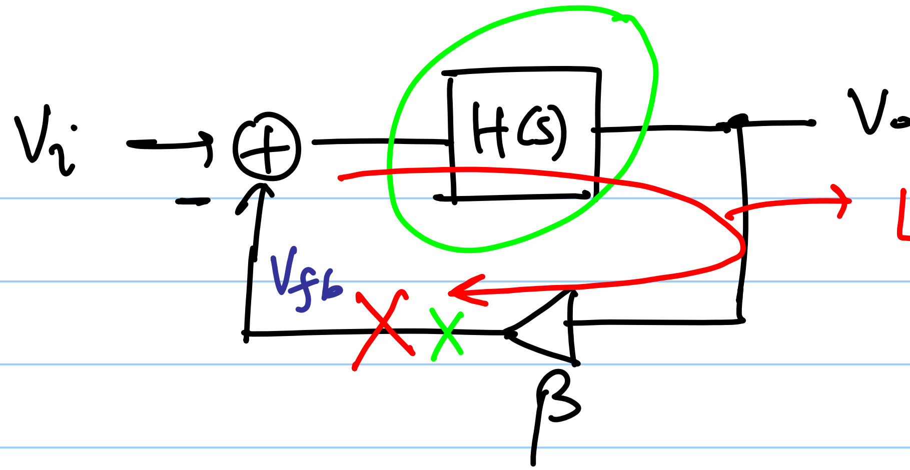
$$L(s) = \frac{\omega_u}{k \cdot s}$$




$$\left|\frac{L}{1+L}\right| = \begin{cases} \simeq 1 & \text{for } |L| \gg 1 \\ \simeq L & \text{for } |L| \ll 1 \end{cases}$$






$L(s) = \beta H(s)$

$$(V_i - V_{fb}) H(s) = V_o(s)$$

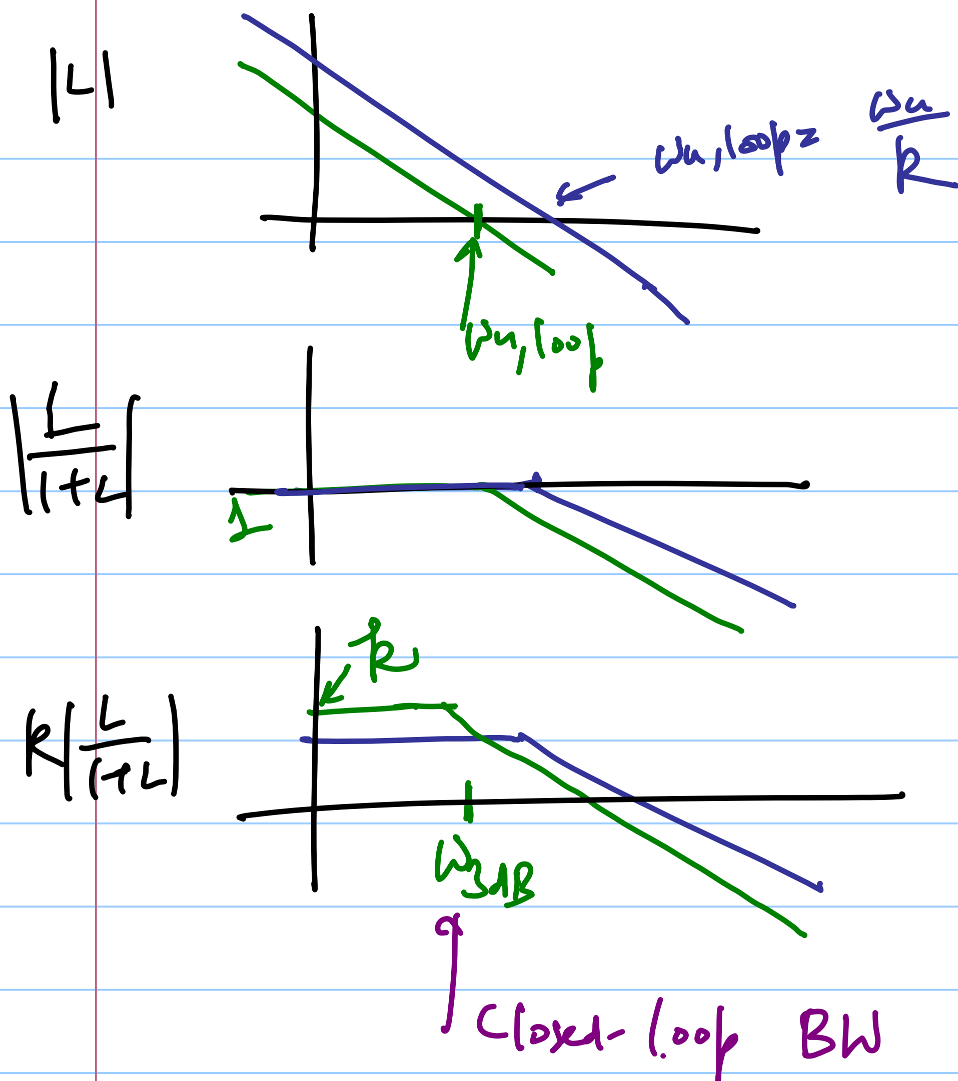
$$[V_i(s) - \beta V_o(s)]\, H(s) = V_o(s)$$

$$H(s) \cdot V_i(s) = V_o(s)\,[1 + \beta H(s)]$$

$$H_{CL}(s) = \frac{V_o}{V_i}(s) = \frac{H(s)}{1 + \beta H(s)}$$

FWD PATH

$$= \frac{\text{FWD-PATH}}{1 + \text{LOOP-GAIN}}$$




open-loop

k ↑ by 2

UGF

closed-loop

$\boxed{\text{HINT}}$

## Multiple-Poles:

$$\boxed{\beta = 1/k}$$

Closed-loop Transfer function

$$\frac{V_o(s)}{V_i(s)} = \frac{H(s)}{1 + \underbrace{\beta H(s)}_{L(s)}} = \frac{k \cdot L(s)}{1 + L(s)}$$

× Instability if $D^r = 1 + L(s) = 0$

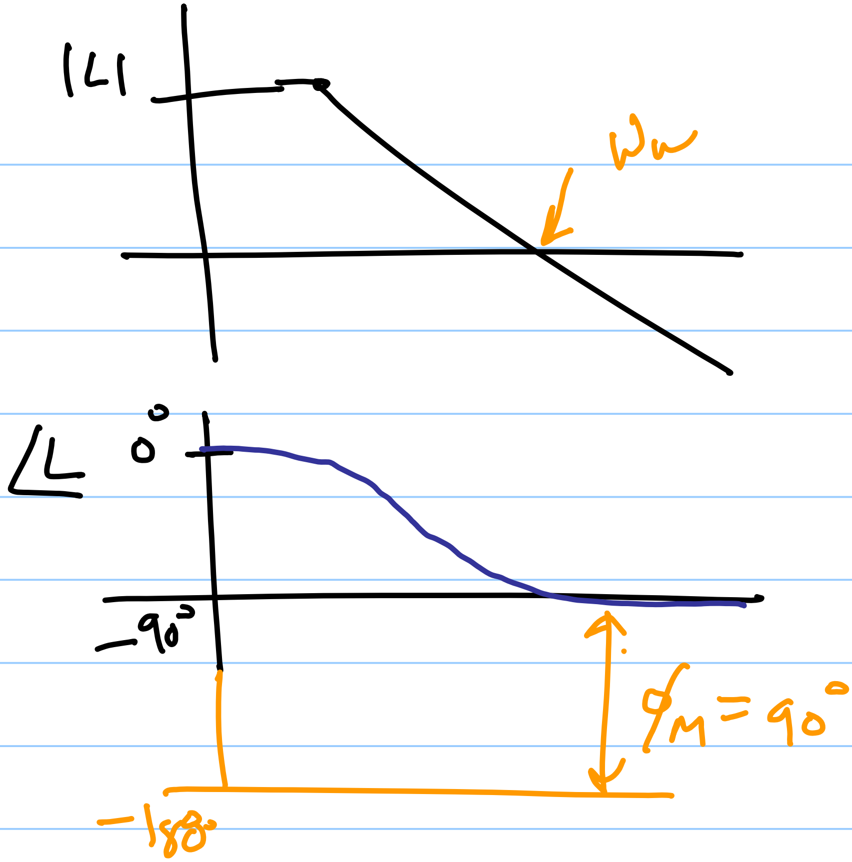
$L(s) = -1$

$\hookrightarrow \quad L(j\omega) = -1$

$\Rightarrow \quad |L| = 1$ and $\angle L = -\pi$ or $180^\circ$

" $|L| = 1$ & $\angle L = -180^\circ$

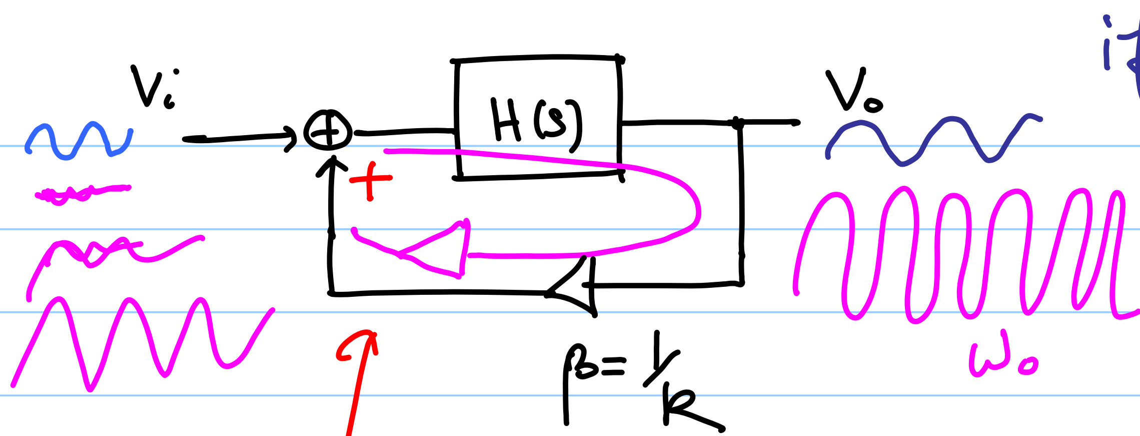
Barkhausen's Criterion"




1st-order system

Single pole system

↳ unconditionally stable

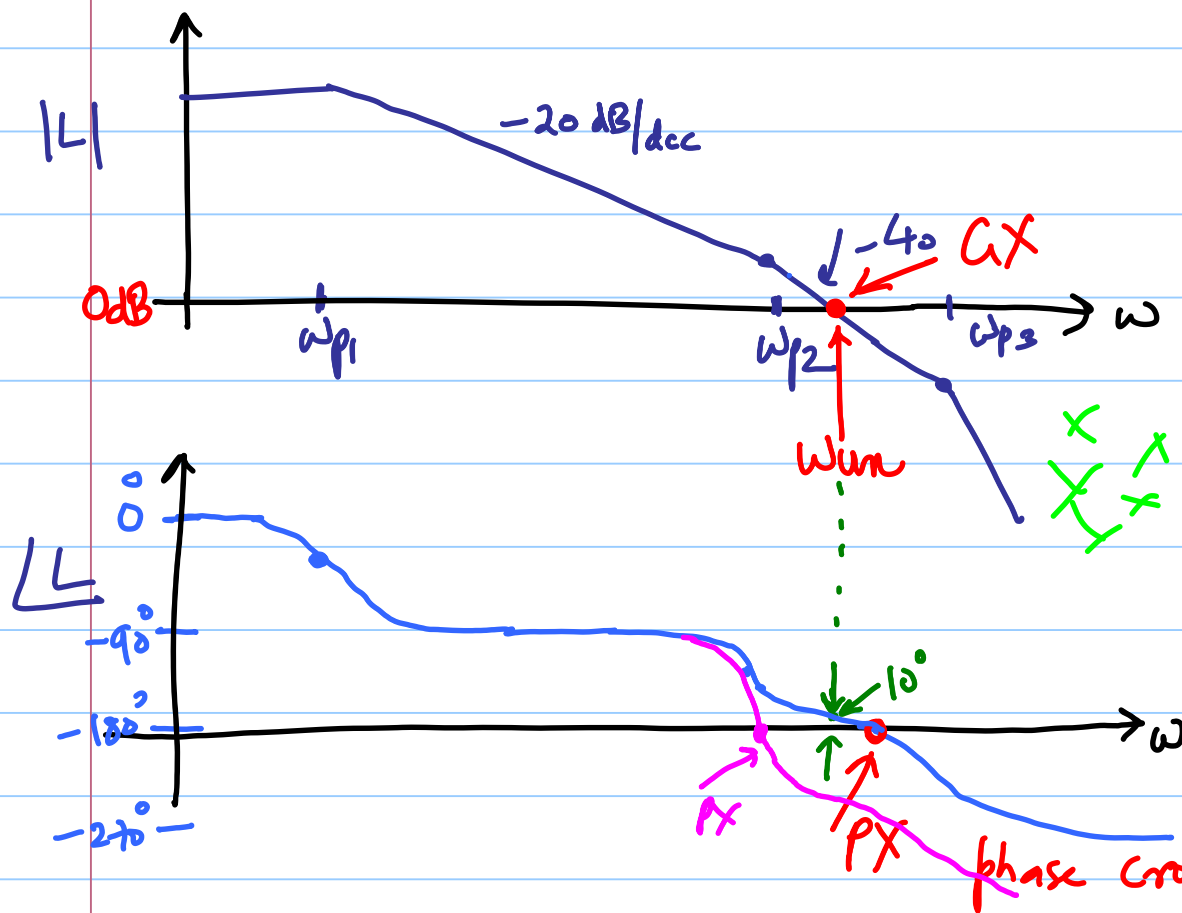



looks like a +ve feedback system

if at some $\omega = \omega_o$

$$\beta H(\omega_o) = 1 \angle -\pi$$

open-loop response

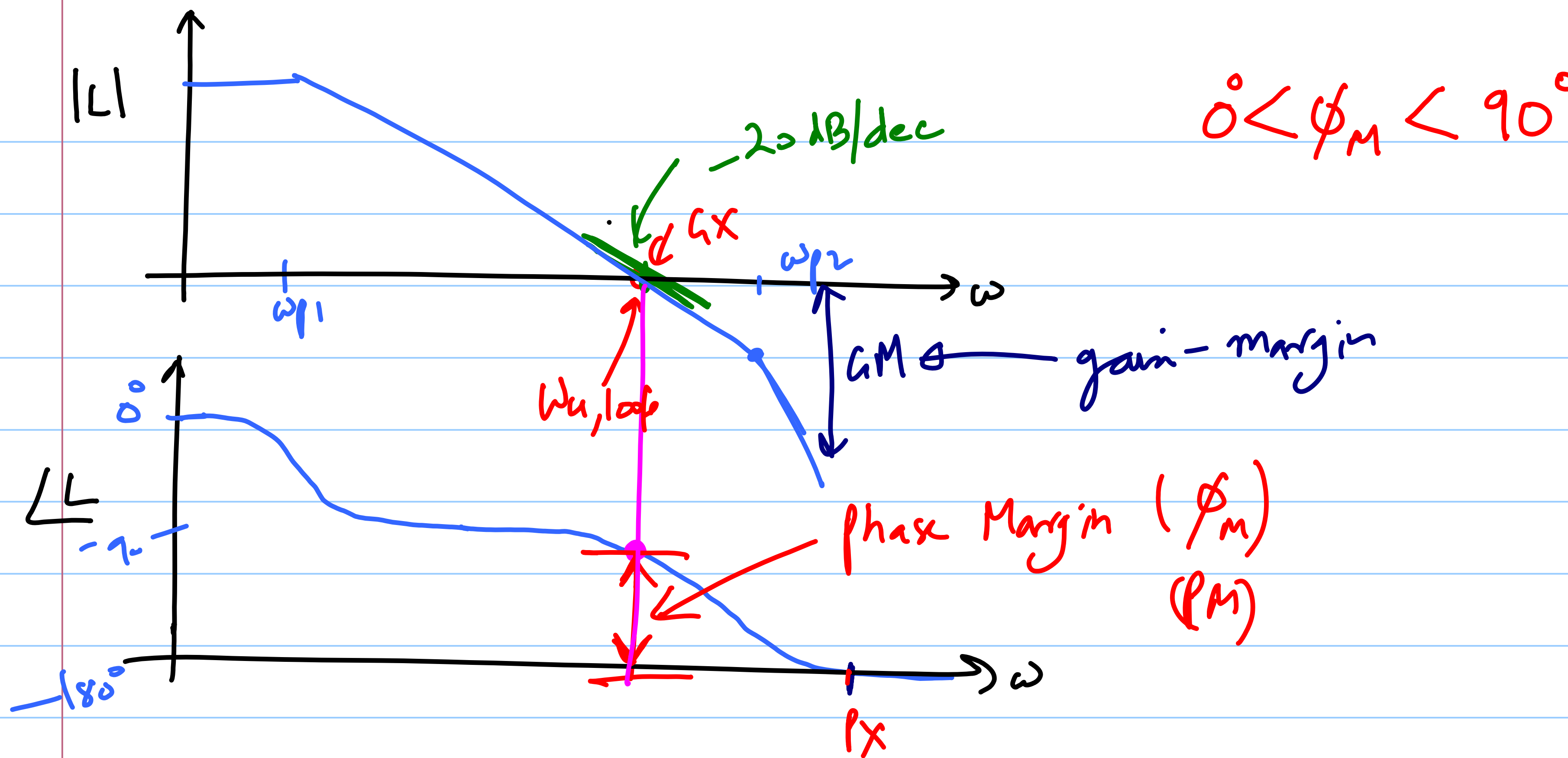



gain-crossover point

phase crossover point

for stability

"GX < PX"



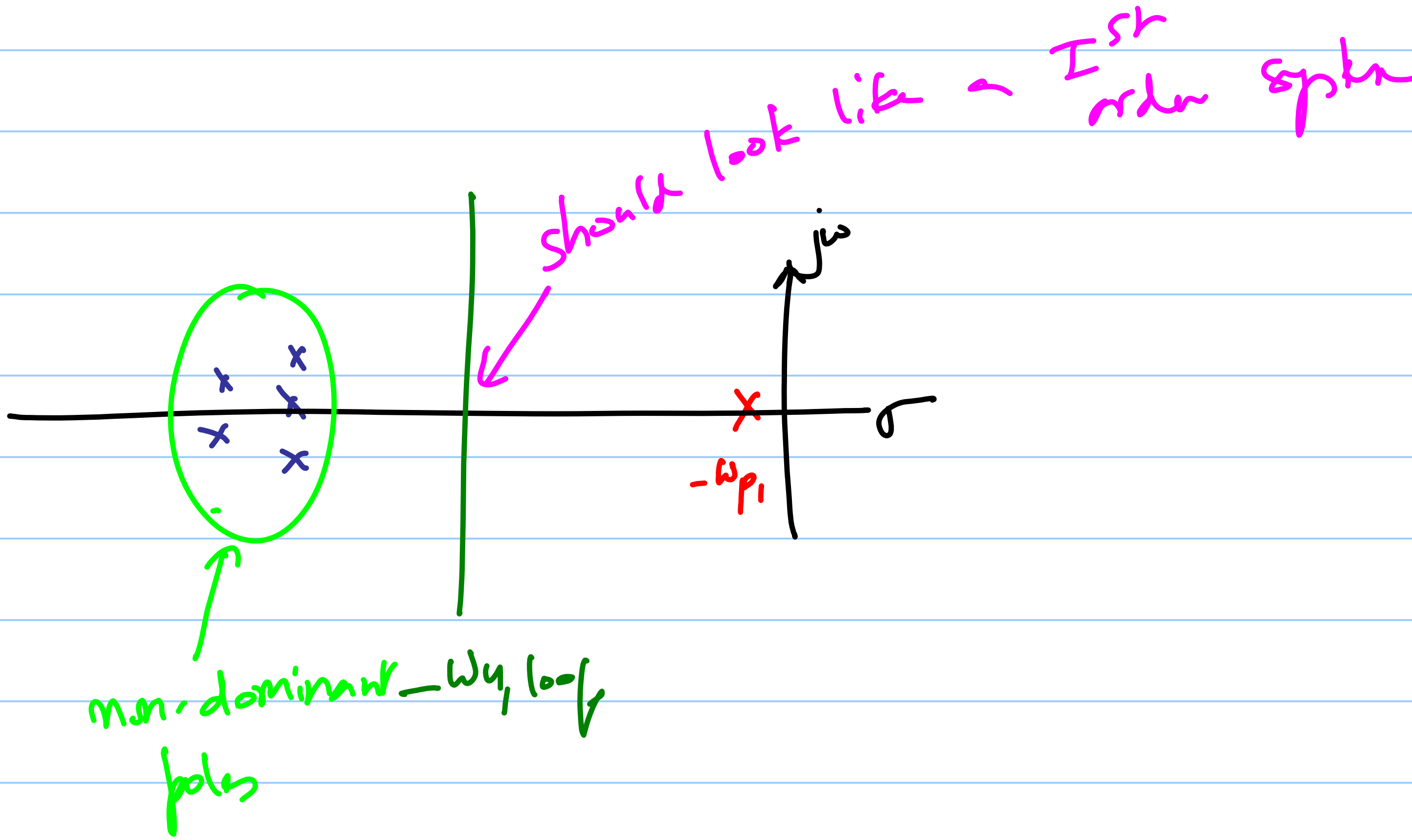

for stability:

① the magnitude plot must have a slope of $-20\frac{dB}{dec}$ around the unity-gain frequency

↳ the feedback-system is made to look like

② a first-order system around its unity gain crossover point.

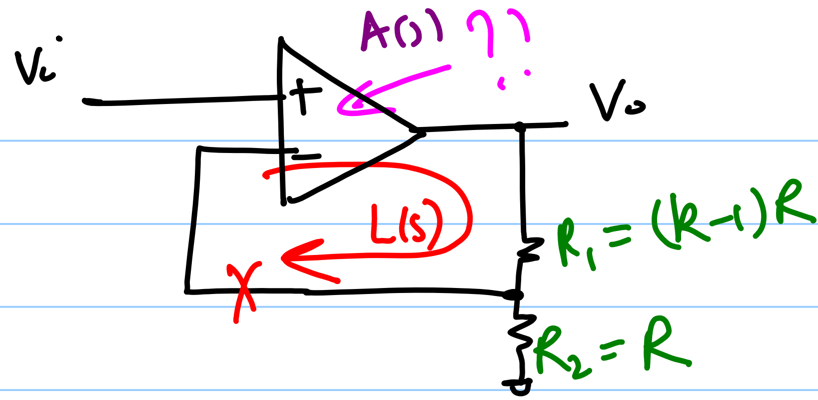
③ PM is a valuable metric



for opamps

* $PM > 45^{\circ}$ for stable system with less ringing

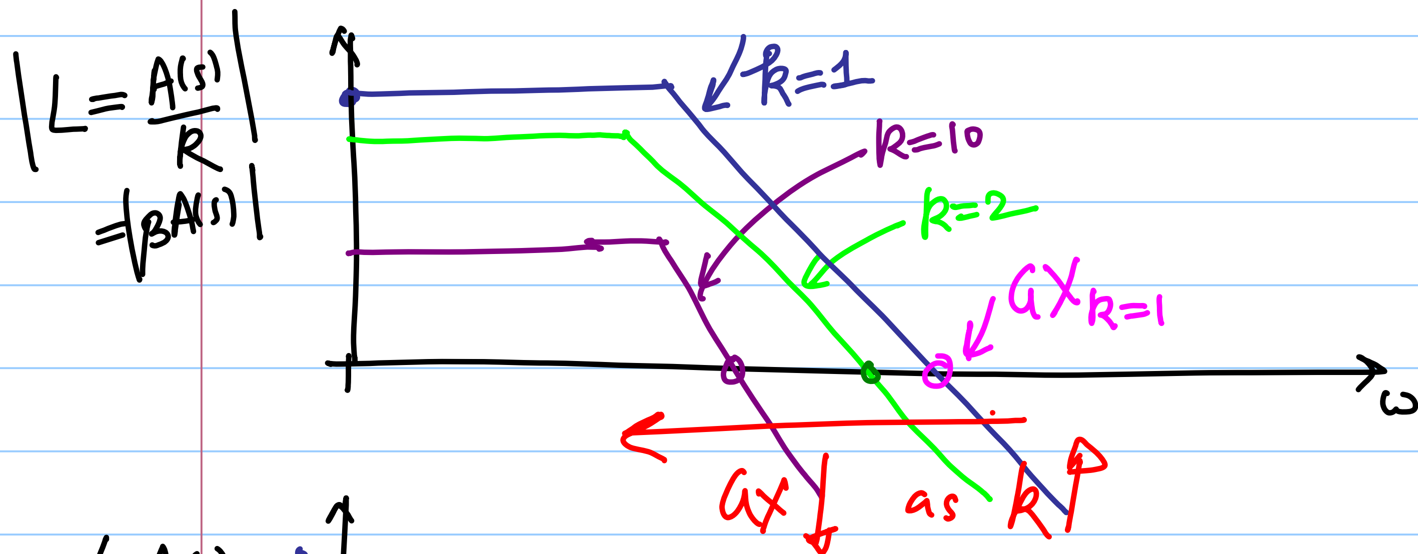
$\boxed{PM = 60^{\circ}}$ is generally the best situation

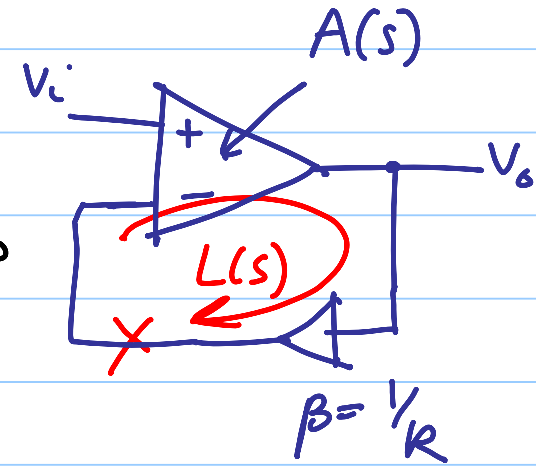


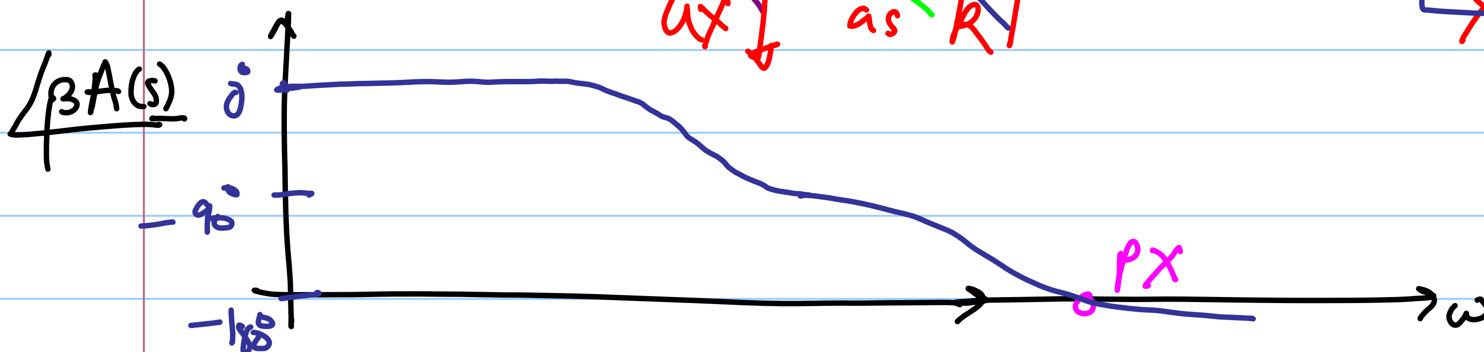

$L(s)$ changes with "$k$" $= 1/\beta$

open loop gain $\quad L(s) = \dfrac{A(s)}{k}$

Closed loop gain $\simeq k \geq 1$



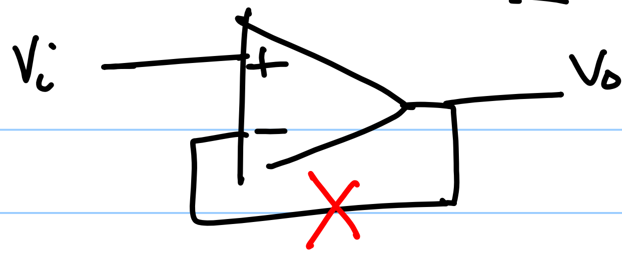

$k \geq 1$

$\Rightarrow \beta \leq 1$

* Sufficient to stabilize for the unity-gain feedback case

If the opamp is stable for $k=\beta=1$

$\Rightarrow$ stable for $\forall\, k>1$ (or $\beta<1$)




stabilize for this case

$\phi_M = 60^\circ$