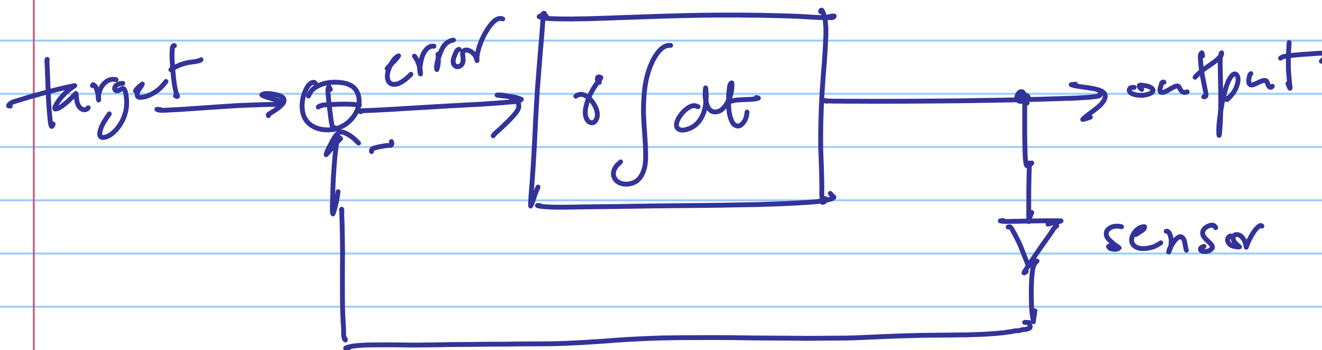
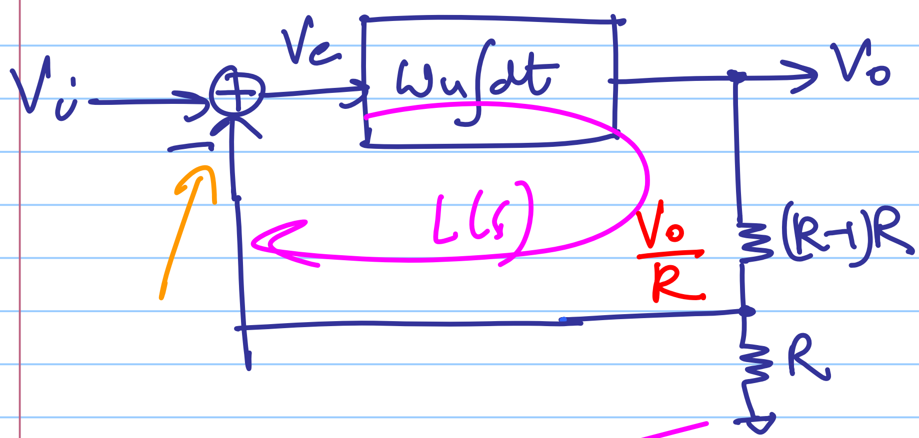
ECE 511- lecture 25

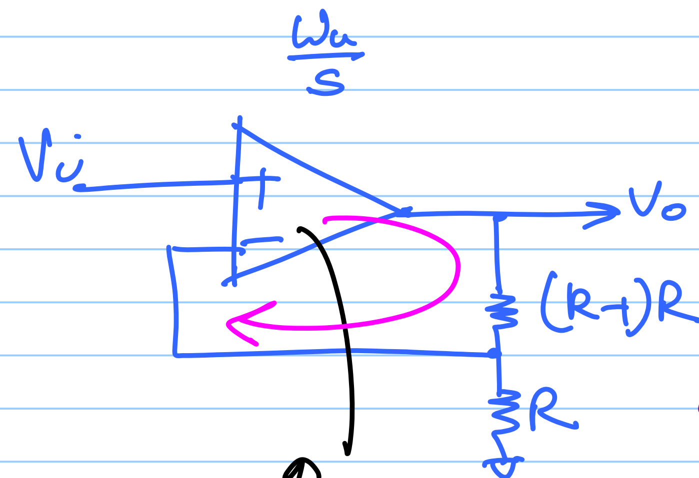
Note Title 4/23/2015

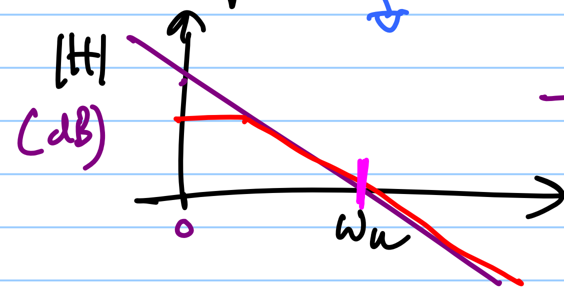


In steady state
error $\rightarrow 0$

Ex. Negative feedback amplifier (with precise gain)







desired V_i

sensed value → $\frac{V_o}{R}$

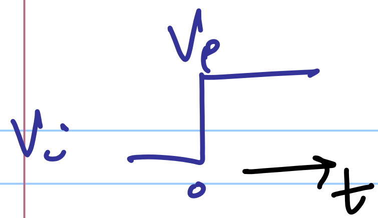
In steady-state, error → 0

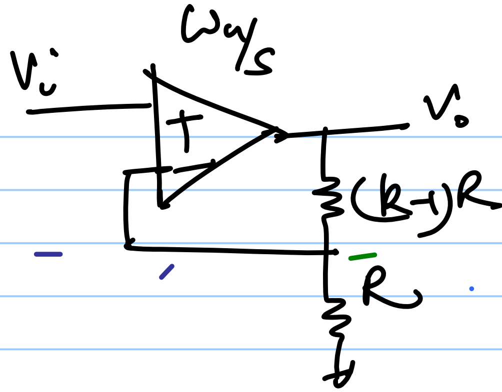
$\frac{V_o}{k} \longrightarrow V_i$

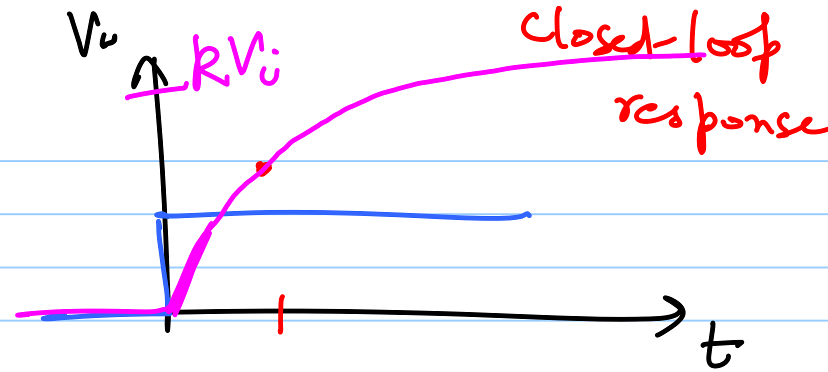
$\Rightarrow \quad V_o \longrightarrow k V_i$

ideal closed-loop gain

$= \dfrac{1}{\text{feedback ratio}}$







$$0.7\tau = \frac{0.7}{\omega_{3dB}}$$

$$V_o(s) = \frac{\omega_u}{s}\left[V_i(s) - \frac{V_o(s)}{k}\right]$$

$$\frac{V_o}{V_i}(s) = \frac{k}{1 + \frac{ks}{\omega_u}}$$

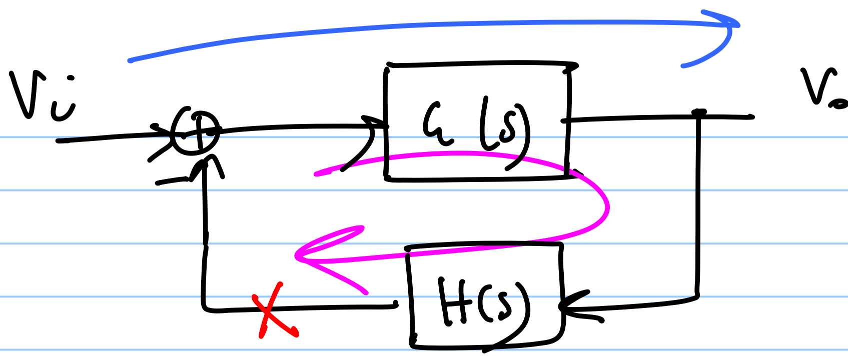
closed-loop gain

$$\omega_{3dB} = \frac{\omega_u}{k}$$

$$\boxed{\omega_u} = k \times \omega_{3dB}$$

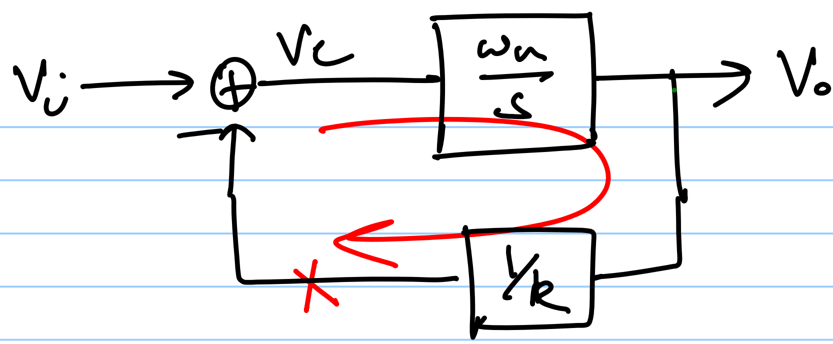
$\uparrow$ $\downarrow$

gain × BW tradeoff



$$\frac{V_o}{V_i}(s) = \frac{G(s)}{1+\underbrace{G(s)\,H(s)}_{\text{loop-gain}}} = \frac{1}{H(s)} \cdot \frac{1}{1+\frac{1}{G(s)\,H(s)}}$$ loop-gain

$$\cong \begin{cases} \dfrac{1}{H(s)} = k, & |L| = |GH| \gg 1 \\ G(s), & |L| = |GH| \ll 1 \end{cases}$$

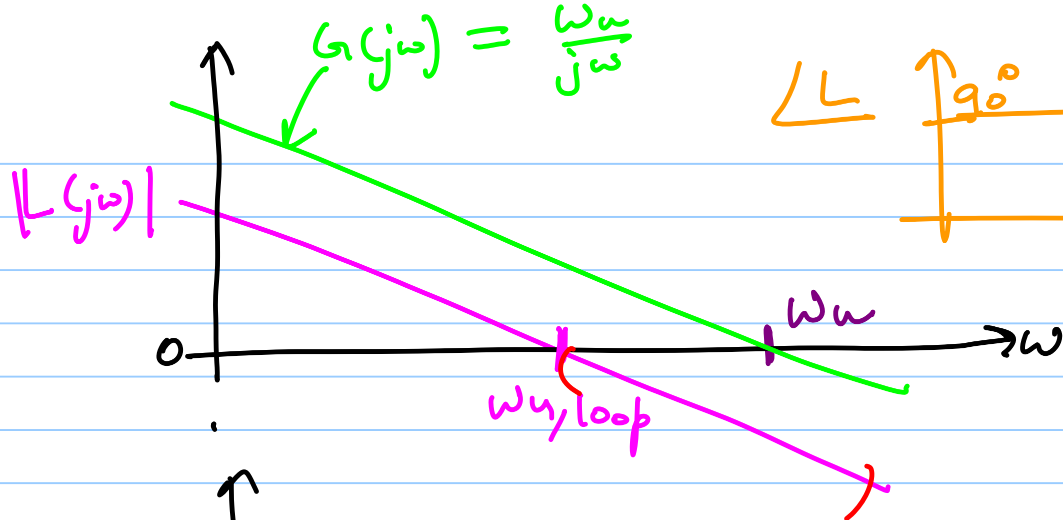


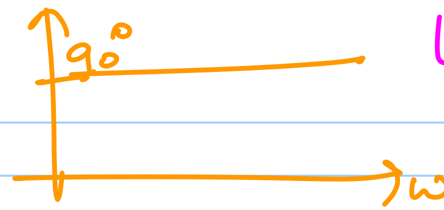
$\omega_u \Rightarrow$ unity-gain frequency of the integrator controller

$$L(s) = \frac{\omega_u}{ks}$$

for $|L| = 1$, $\quad \omega_{u,loop} = \frac{\omega_u}{k}$

unity loop-gain frequency





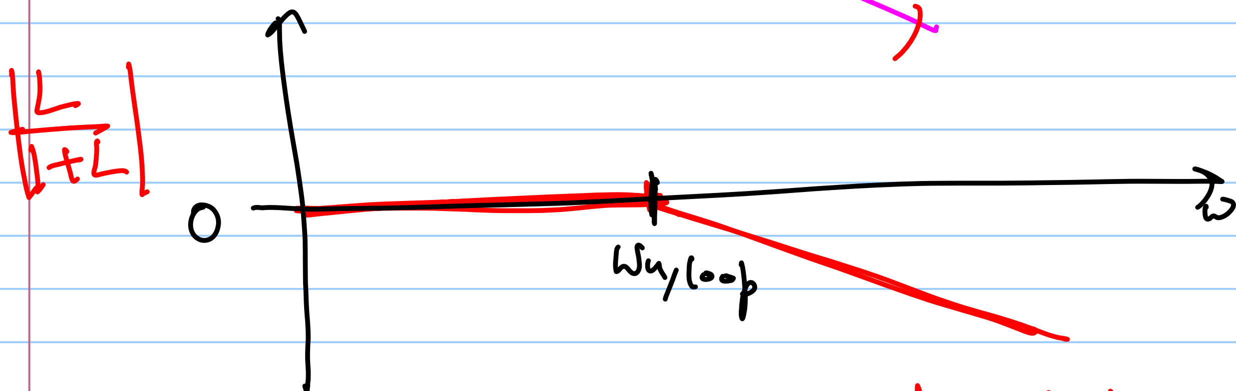
$L(j\omega) = \frac{\omega_u}{k(j\omega)}$

for $|L| >> 1$

$\left|\frac{L}{1+L}\right| \simeq 1$

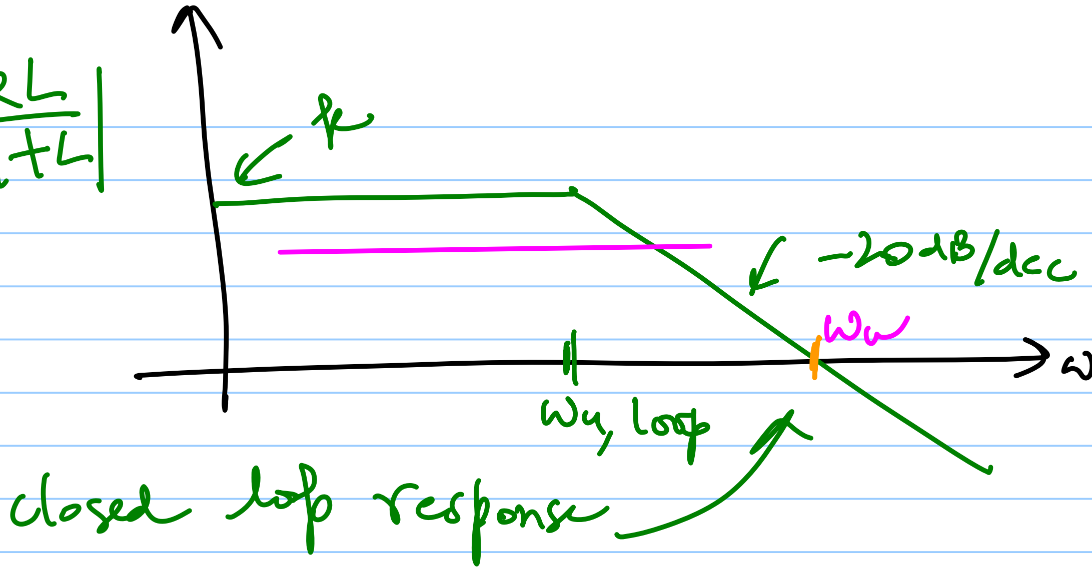
for $|L| << 1$

$\left|\frac{L}{1+L}\right| \simeq |L|$

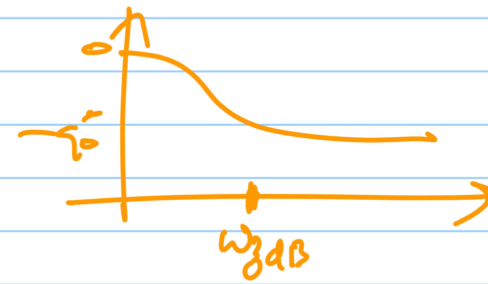


unity-gain closed-loop response

$$\left|\frac{KL}{1+L}\right|$$



$$\frac{KL}{1+L} = \frac{G}{1+GH}$$



$$\frac{1}{s} = \frac{1}{j\omega}$$

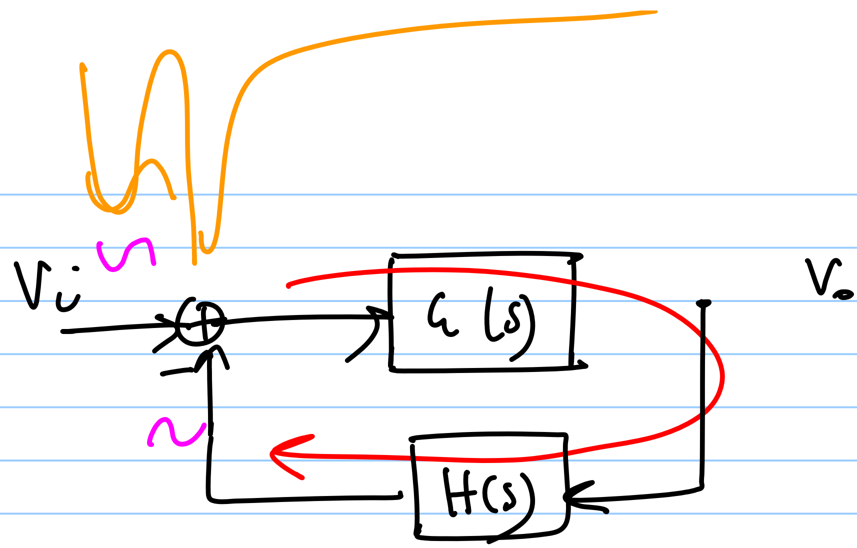
$$= \frac{1}{\omega} \cdot e^{-j\pi/2}$$

$$\frac{V_o}{V_i}(j\omega) = \frac{G}{1+GH} = k \cdot \frac{L(j\omega)}{1+L(j\omega)}$$

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

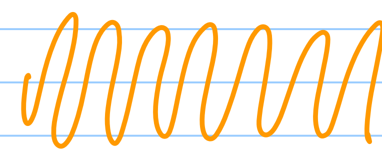
$$= \begin{cases} |L(j\omega)| = 1 \\ \& \ \angle L(j\omega) = \pi \end{cases}$$

Barkhausen's criterion for instability

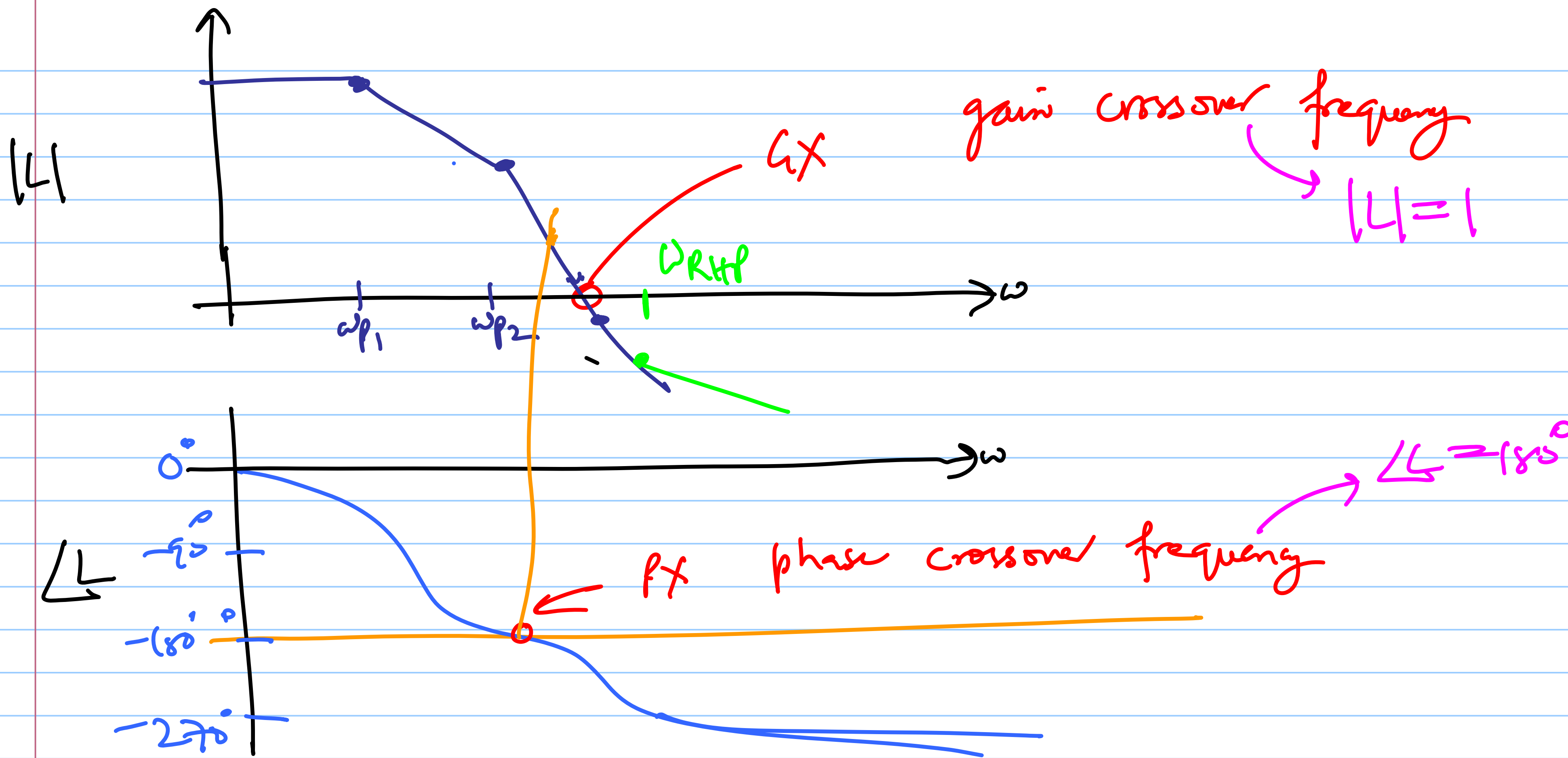


$|L(j\omega)| = 1$

$\angle L(j\omega) = 180^\circ$ ← excess phase shift



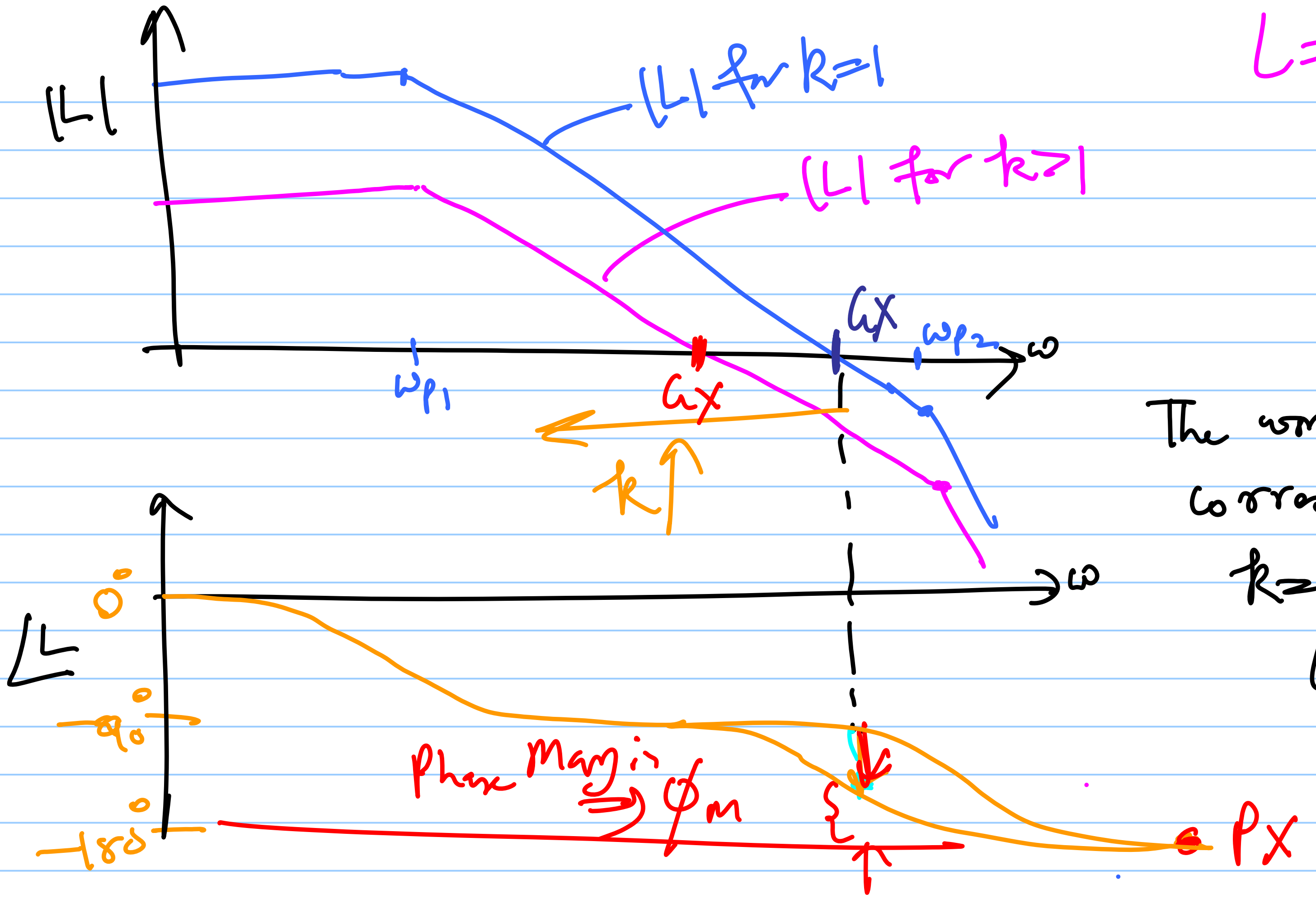
first-order system → unconditionally stable


|L|
ωp1
ωp2
ω
ωRHP
GX
gain crossover frequency
|L|=1
∠L
0°
-90°
-180°
-270°
ω
PX
phase crossover frequency
∠L=-180°

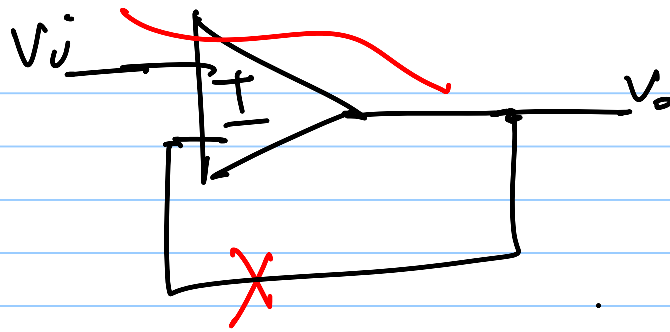
for stability $GX < PX$

frequency

$L = \frac{G(s)}{k}$



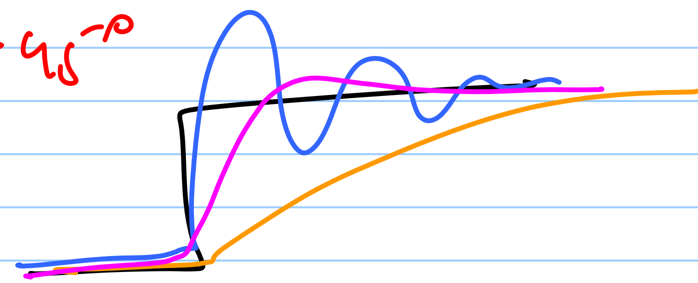
The worst case stability corresponds to k=1 (unity gain)



PM

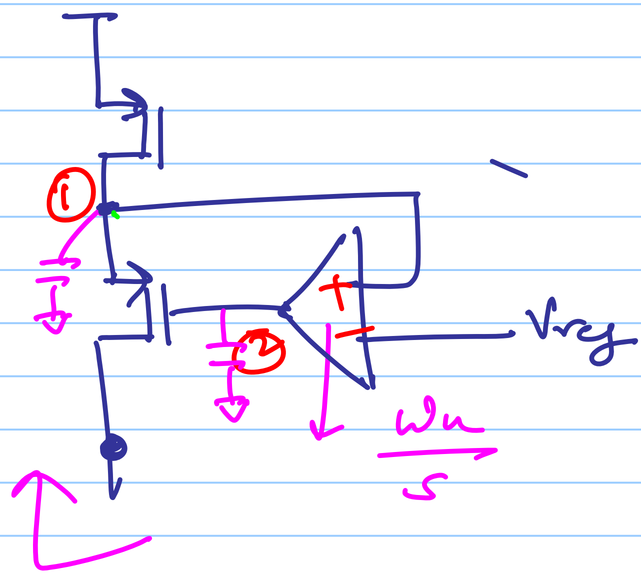
PM $\geq 45^\circ$

Use Stability Analysis



PM $\geq 60^\circ$ is optimal for ~ 2^{nd} order system regulated drain

→ used in Gain enhancement opamp



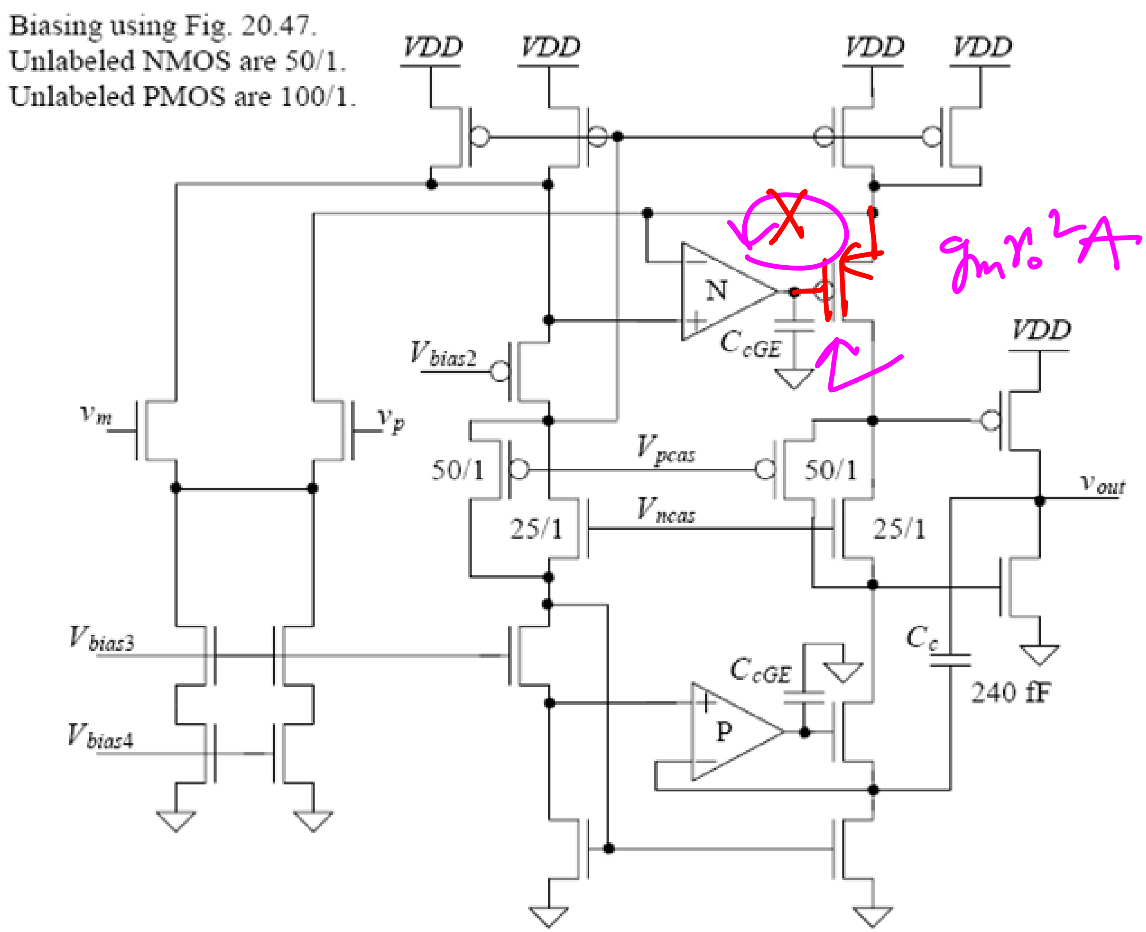
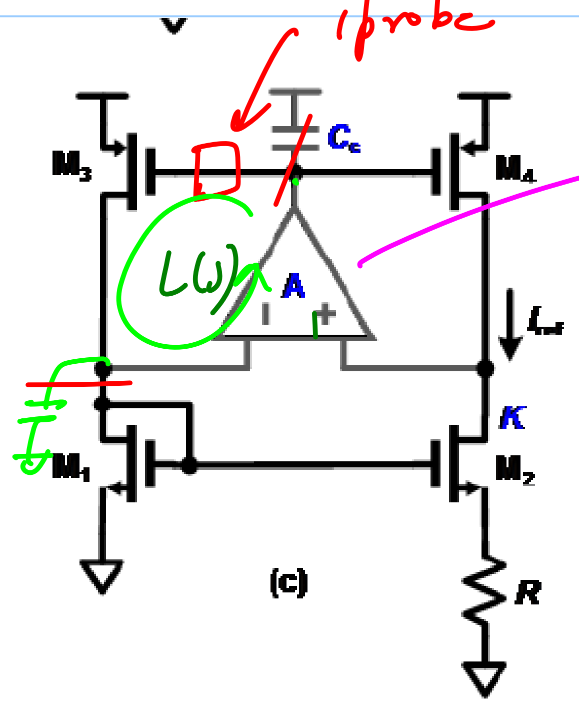


Figure 24.51 Folded-cascode op-amp with class AB output buffer and gain-enhancement.

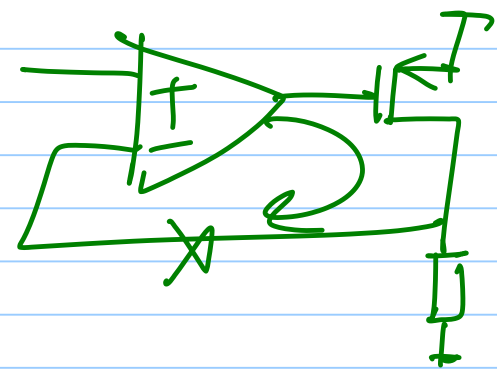
iprobe

stability analysis

PM > 60°



Verilog-A



L(s)