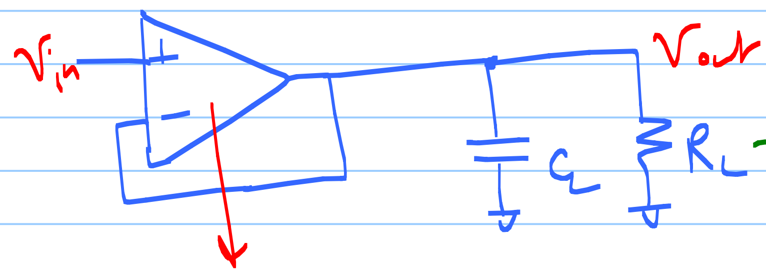
ECE 5410 - Lecture 23.

Note Title 4/25/2011



$\Rightarrow$ 10kΩ

heavy load

Large Cap

Small Resistor

$$A_v = -g_m \cdot \underline{\underline{R_{out}}}$$

↓ 10MΩ

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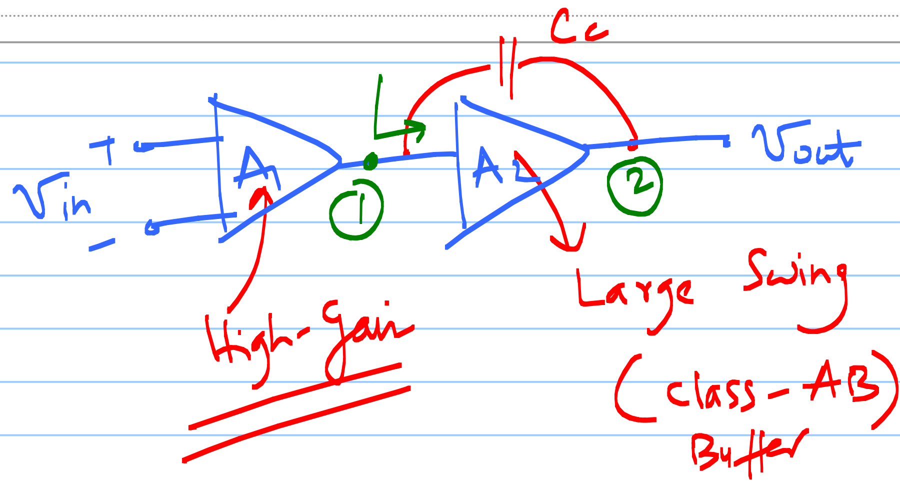
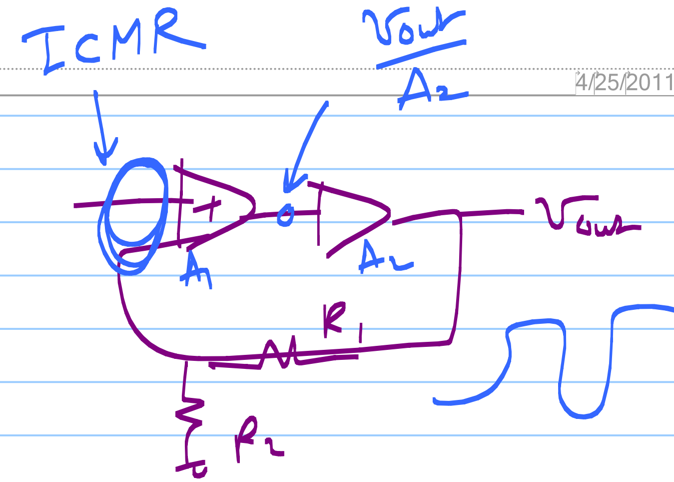
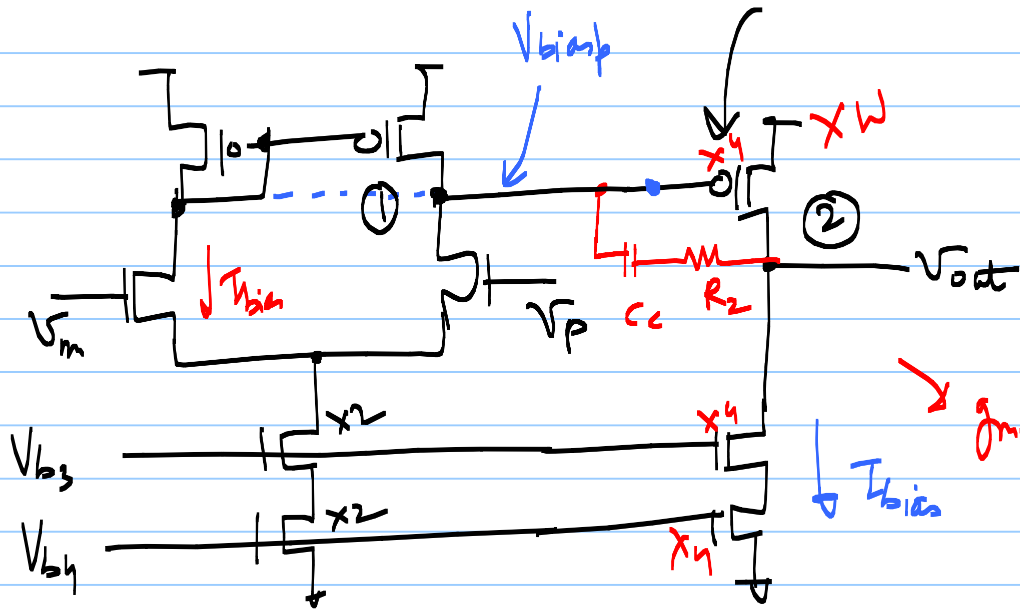
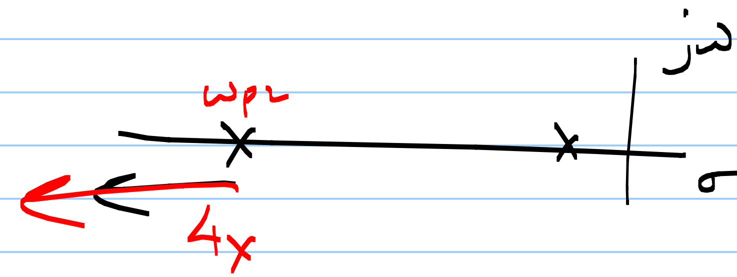




CMRR





$g_{m2} = 4\, g_{m1}$

$$f_{un} = \frac{g_{m1}}{2\pi C_c}$$

$\omega_{p2} \uparrow\uparrow$

$A_1 = g_{m1} R_1$

Cascode Compensation (Indirect)

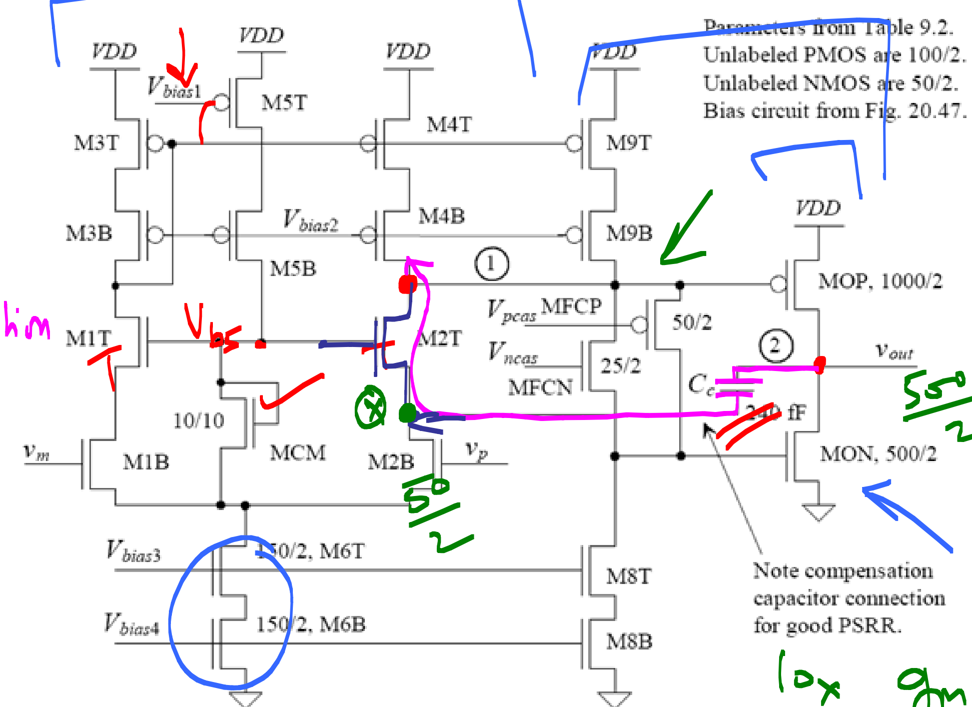


Figure 24.29 A CMOS op-amp with output buffer.

* Not Miller Compensated !

* LHP zero

Class-AB output stage

$10\times\, g_{m2}$

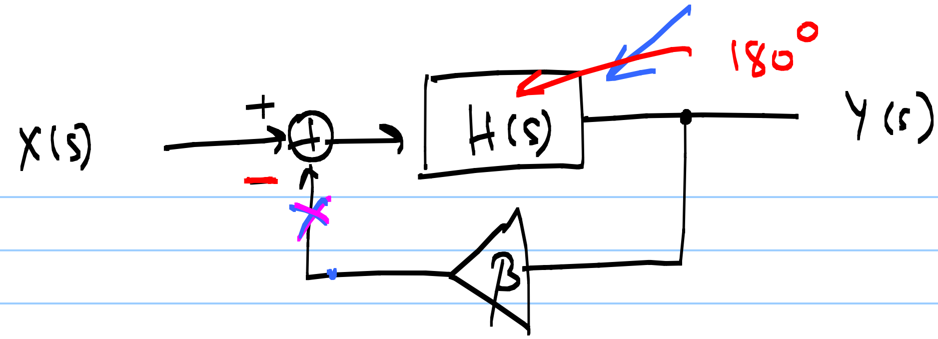
$$* \left[\omega_{p2} = \frac{g_{m2}\,(g_{mca} R_1)}{C_L} \right.$$

→ High-Speed Compensation

* Smaller C_c → f_{un} ↑↑

* Be careful about $\underline{\underline{\omega_{px}}}$

$$\omega_{un} = \frac{g_{m1}}{C_c}$$



closed-loop response

$$\frac{Y}{X}(s) = \frac{H(s)}{1+\beta H(s)}$$

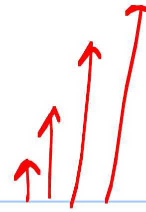
open-loop response

$\beta < 1$, constant

If $\underline{\beta H(s)} = -1 \Rightarrow$ closed-loop gain $= \infty$, with $s = j\omega_1$

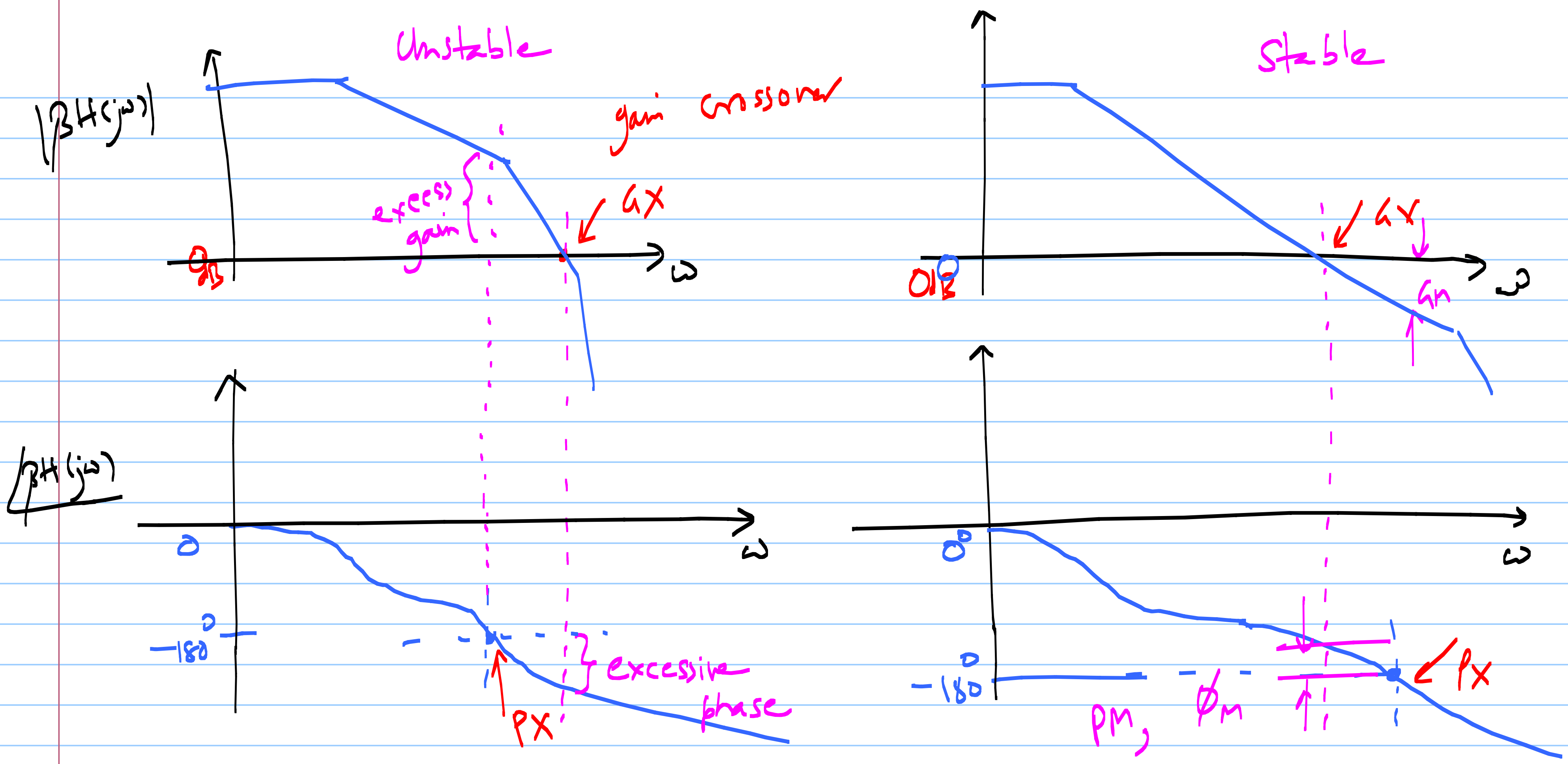
↳ circuit can amplify its own noise & start oscillation.

$$\begin{cases} |\beta H(j\omega_1)| = 1 \\ \angle \beta H(j\omega_1) = -180^\circ \end{cases} \longleftarrow \text{Barkhausen's Criterion}$$



$$|\beta H(j\omega_0)| \geq 1$$

$\rightarrow$ overall 360° phase-shift in the loop

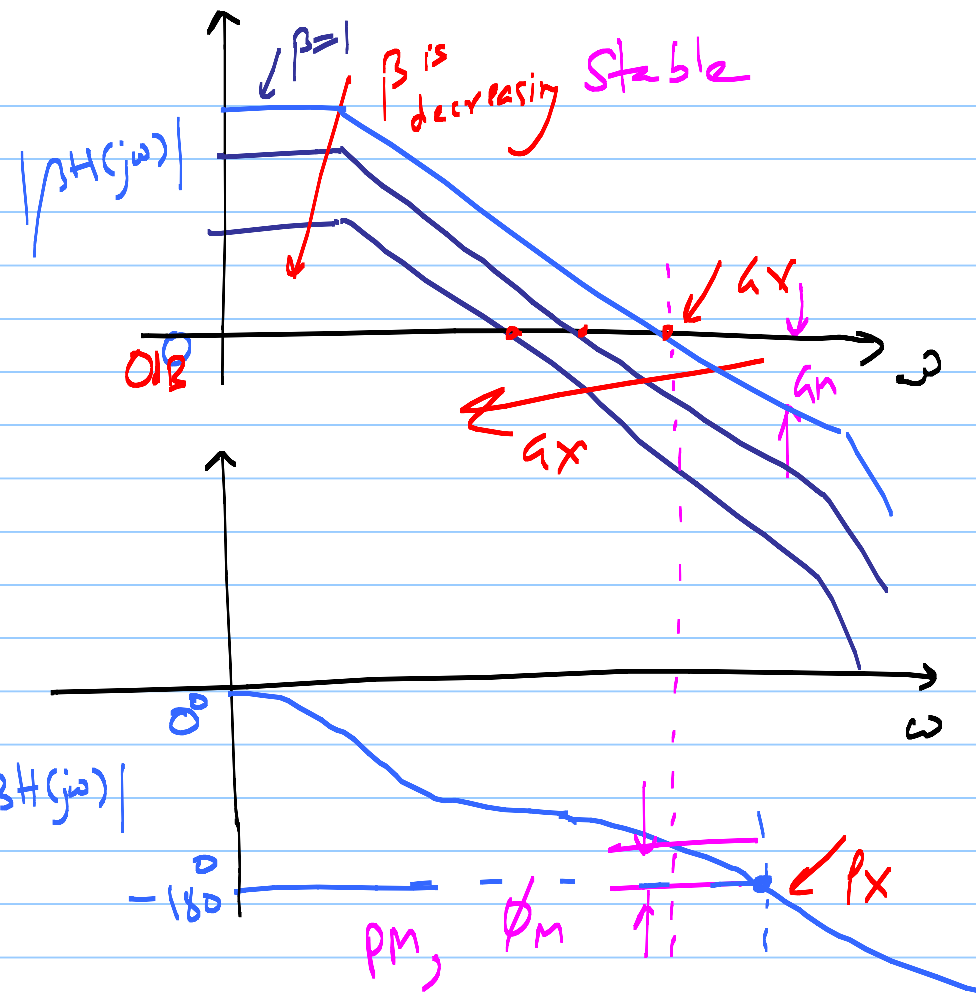


Unstable
Stable
|βH(jω)|
∠βH(jω)
gain crossover
GX
excess gain
0dB
ω
0
-180°
PX
excessive phase
GX
GM
0dB
0°
-180°
PM, φm
PX

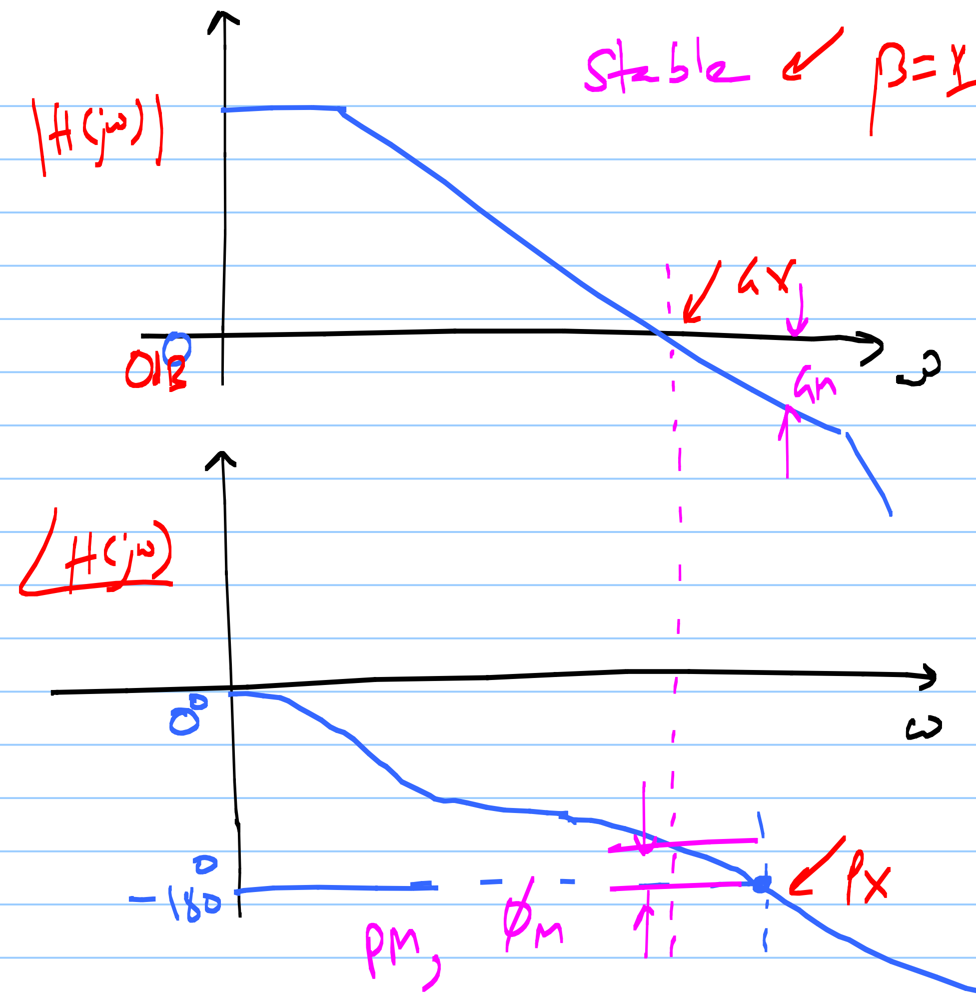
* for stable system GX should occur before PX.

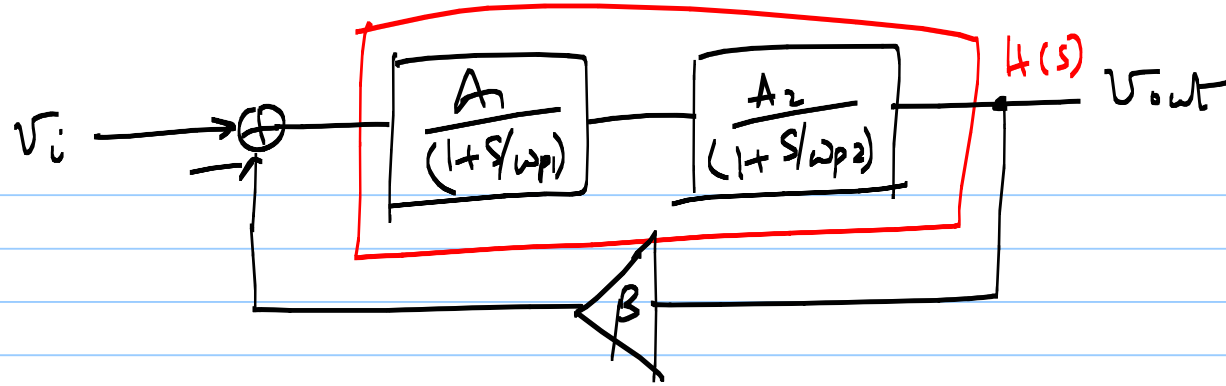
$\beta \in [0, 1]$

→ Looking for $\beta = 1$ is sufficient to test stability



* The worst case stability is for $\beta = 1$.

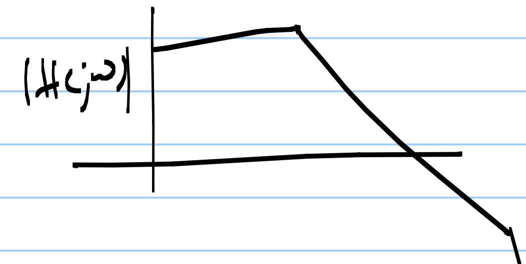




$A_o = A_1 A_2$

$\left.\begin{array}{l}\omega_{p1}\\ \omega_{p2}\end{array}\right\}$ open loop poles

$$\frac{V_o}{V_i}(s) = \frac{k}{1 + \frac{k}{A_o} + s\left(\frac{1}{\omega_{p1}} + \frac{1}{\omega_{p2}}\right) + \frac{s^2}{\omega_{p1}\omega_{p2}} \cdot \frac{k}{A_o}}$$



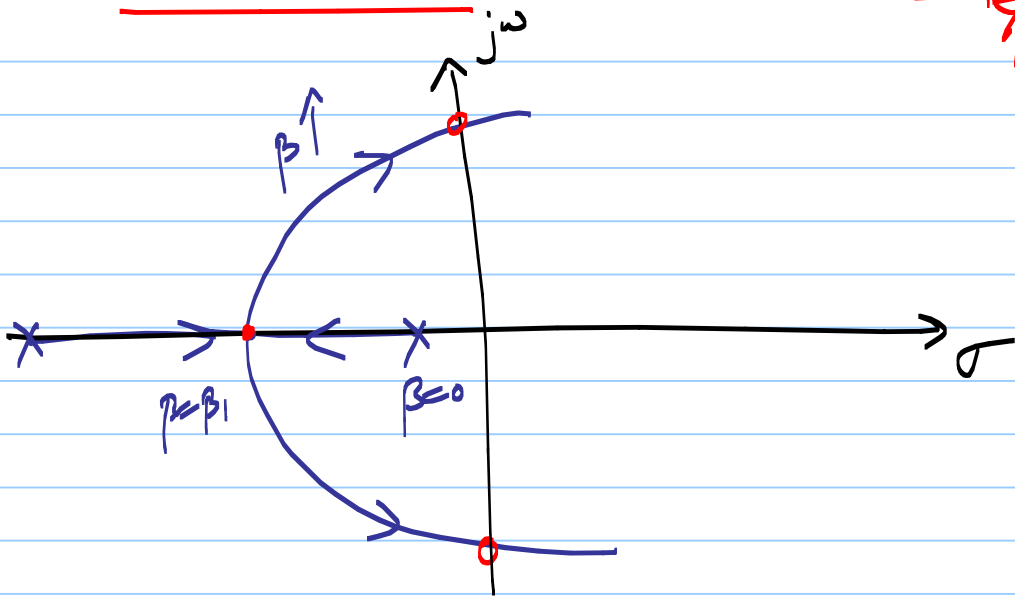
$k = 1/\beta \leftarrow$ ideal

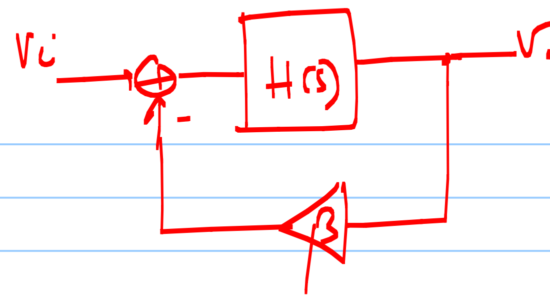
closed-loop gain

$$\text{DC gain} = \frac{k}{1+k/A_o} \longrightarrow \underline{\underline{k}} \quad \text{as} \quad \frac{A_o}{k} \gg 1$$

$$\beta A_o \gg 1$$

Root locus





locus of the roots of the closed loop system as β is varied.

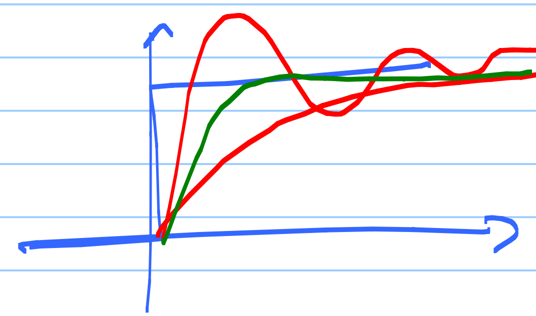
$$\frac{v_o}{v_i}(s) = \frac{k}{1 + \frac{k}{A_o} + s\left(\frac{1}{\omega_{p1}} + \frac{1}{\omega_{p2}}\right) + \frac{s^2}{\omega_{p1}\omega_{p2}} \cdot \frac{k}{A_o}}$$

$$\frac{v_o}{v_i}(s) = \frac{k}{(s/\omega_o)^2 + \left(\frac{s}{\omega_o Q}\right) + 1} = \frac{k}{(s/\omega_o)^2 + 2\zeta\left(\frac{s}{\omega_o}\right) + 1}$$

damping factor $\leftarrow \zeta = \frac{1}{2Q} \leftarrow$ pole Quality factor $\simeq \frac{Y}{X} = \frac{g_m}{R_e}$

$\omega_o = \sqrt{\omega_{p1}\omega_{p2}} \leftarrow$ natural frequency

$$\zeta = \frac{1}{2}\sqrt{\frac{k}{A_0}}\left[\sqrt{\frac{\omega_{p2}}{\omega_{p1}}} + \sqrt{\frac{\omega_{p1}}{\omega_{p2}}}\right] \leftarrow \text{Damping factor}$$



$\zeta > 1 \leftarrow$ overdamped

$\zeta = 1 \leftarrow$ critically damped

$\zeta < 1 \leftarrow$ underdamp

$*$ $\zeta = \frac{1}{\sqrt{2}}$ (fastest) Best settling time

$$\omega_{p2} = \frac{2 A_0 \omega_{p1}}{k}$$

$$= 2\,\omega_{un}$$

$$\phi_m \simeq 90^\circ - \tan^{-1}\left(\frac{\omega_{un}}{\omega_{p2}}\right)$$

$$= \underline{\underline{63.5^\circ}}$$

$\underline{\underline{45^\circ - 65^\circ}}$

If $\phi_m = 60^\circ \Rightarrow \zeta = 0.66$