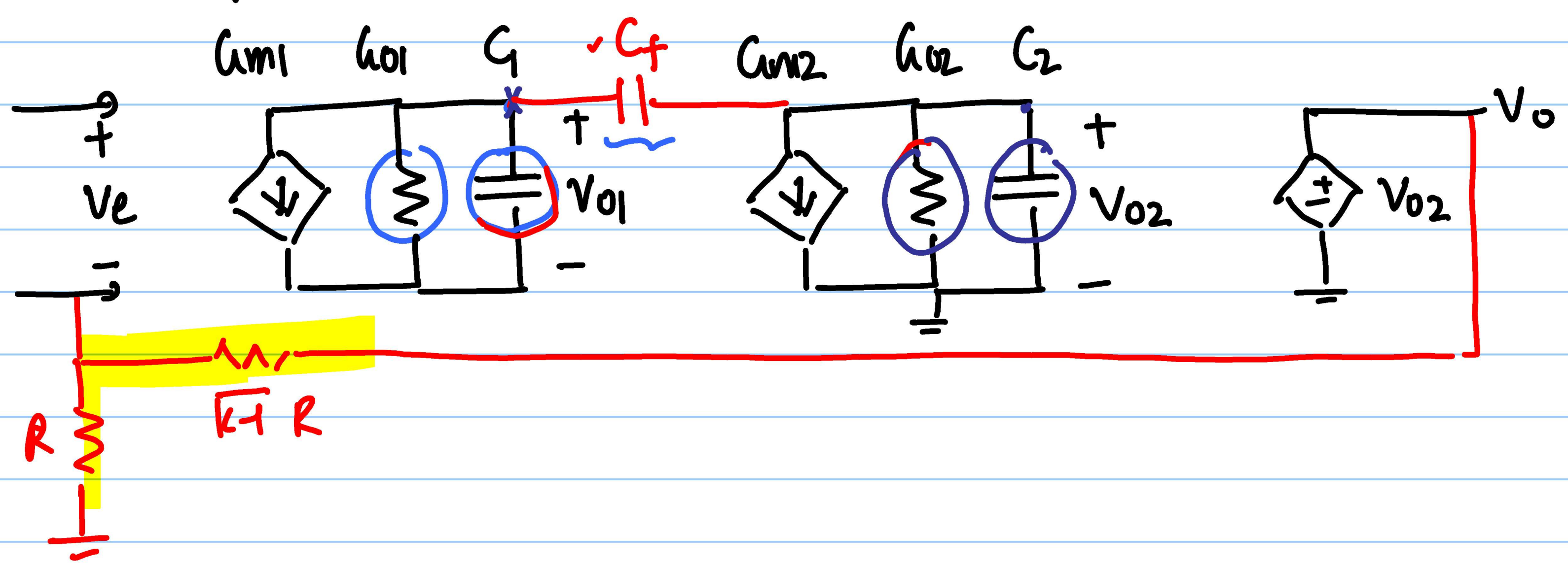
Note Title 25-02-2022

Lecture #19

Miller Compensation



$$\frac{V_o}{V_e} = \frac{G_{m1} G_{m2} \left(1 - s C_f / G_{m2}\right)}{s^2 (C_1 C_f + C_2 C_f + C_1 C_2) + s\left(C_f G_{m2} + C_f (G_{o1} + G_{o2})\right) + s C_1 G_{o2} + s C_2 G_{o1} + G_{o1} G_{o2}}$$

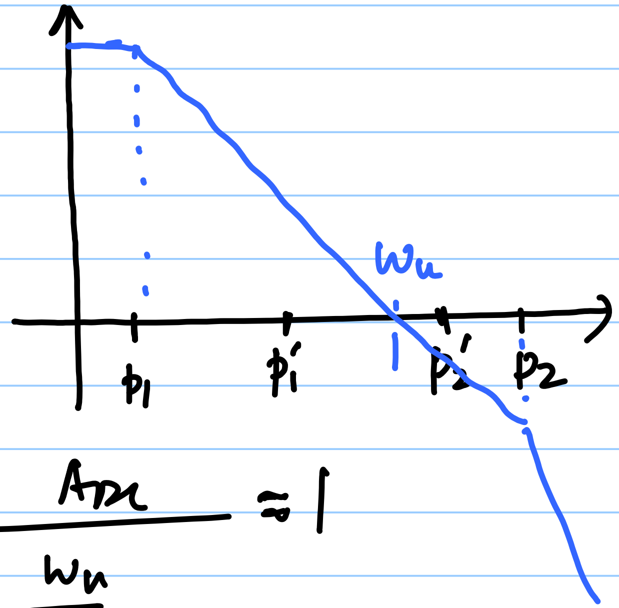
$$s_1 = -p_1 = -\frac{G_{o1} G_{o2}}{C_f (G_{m2} + G_{o1} + G_{o2}) + C_1 G_{o2} + C_2 G_{o1}}$$

$$s_2 = -p_2 = -\frac{C_f (G_{m2} + G_{o1} + G_{o2}) + C_1 G_{o2} + C_2 G_{o1}}{C_1 C_2 + C_1 C_f + C_2 C_f}$$

$$s_1 = -p_1 = -\frac{G_{o1}}{C_f\left(\frac{G_{m2}}{G_{o2}} + \frac{G_{o1}}{G_{o2}} + 1\right) + C_1 + C_2\frac{G_{o1}}{G_{o2}}} \doteq \frac{-G_{o1}}{C_1 + C_f\left(1+\frac{G_{m2}}{G_{o2}}\right) + (C_f + C_2)\frac{G_{o1}}{G_{o2}}}$$

$$s_2 = -p_2 = -\frac{G_{o2} + G_{o1}\frac{(C_2+C_f)}{(C_1+C_f)} + \frac{C_f}{C_1+C_f}G_{m2}}{C_2 + \frac{C_1 C_f}{C_1+C_f}}$$

$$\frac{V_o}{V_e} = \frac{A_{DC}}{\left(1+\frac{s}{p_1}\right)\left(1+\frac{s}{p_2}\right)}$$



$$\left|\frac{V_o}{V_e}\right| \doteq 1$$

$$\Rightarrow \frac{A_{DC}}{\sqrt{1+\left(\frac{w_u}{p_1}\right)^2}\sqrt{1+\left(\frac{w_u}{p_2}\right)^2}} = 1 \xRightarrow{p_1 \ll w_u \ll p_2} \frac{A_{DC}}{\frac{w_u}{p_1}} \approx 1$$

$$\Rightarrow w_u = A_{DC} \cdot p_1$$

$$\omega_u = A_{DC} \cdot p_1$$

$$\frac{V_o}{V_e} \longrightarrow LG = \frac{\frac{G_{m1}}{G_{o1}} \cdot \frac{G_{m2}}{G_{o2}} \times \frac{1}{K}}{\left(1+\frac{s}{p_1}\right)\left(1+\frac{s}{p_2}\right)}$$

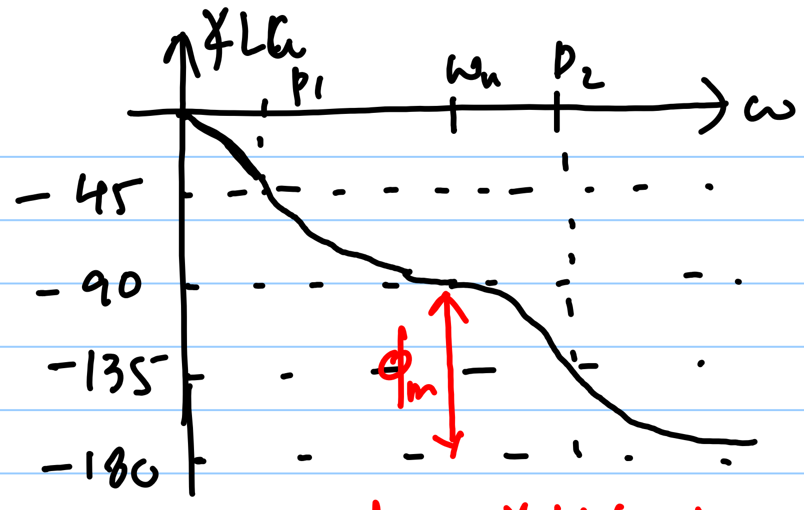
$$\Rightarrow \omega_u = \frac{G_{m1}}{G_{o1}} \frac{G_{m2}}{G_{o2}} \cdot \frac{1}{K} \cdot p_1$$

$$= \frac{G_{m1}}{\cancel{G_{o1}}} \frac{G_{m2}}{G_{o2}} \cdot \frac{1}{K} \cdot \frac{\cancel{G_{o1}}}{\underbrace{\left\{C_1 + C_f\left(1+\frac{G_{m2}}{G_{o2}}\right)\right\} + (C_2+C_f)\frac{G_{o1}}{G_{o2}}}}$$

$$\approx \frac{G_{m1} \cdot \cancel{G_{m2}}}{\cancel{G_{o2}} \cdot K} \times \frac{1}{C_f \cdot \frac{\cancel{G_{m2}}}{\cancel{G_{o2}}}}$$

$$= \frac{G_{m1}}{C_f} \cdot \frac{1}{K} > \frac{G_{m1}G_{m2} / K \cdot G_{o2}}{C_1 + C_f(\quad) + C_2 + C_f(\quad)}$$

$$L_a = \frac{\frac{G_{m1}}{G_{o1}} \frac{G_{m2}}{G_{o2}} \frac{1}{K}}{\left(1+\frac{s}{p_1}\right)\left(1+\frac{s}{p_2}\right)}$$

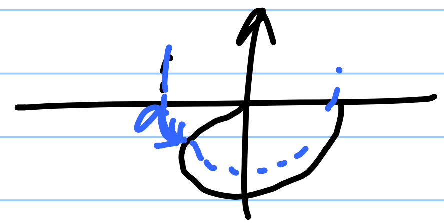


$$\omega_n = \frac{G_{m1}}{C_f \cdot K}$$

$\phi_m = \measuredangle L_a(\omega_n) - (-180^\circ)$

$$\measuredangle L_a = -\tan^{-1}\left(\frac{\omega}{p_1}\right) - \tan^{-1}\left(\frac{\omega}{p_2}\right)$$

$$\phi_m = 180^\circ - \underset{\sim}{\tan^{-1}\left(\frac{\omega_n}{p_1}\right)} - \tan^{-1}\left(\frac{\omega_n}{p_2}\right)$$



$$= 180^\circ - 90^\circ - \tan^{-1}\left(\frac{\omega_n}{p_2}\right)$$

$$= 90^\circ - \tan^{-1}\left(\frac{\omega_n}{p_2}\right),$$

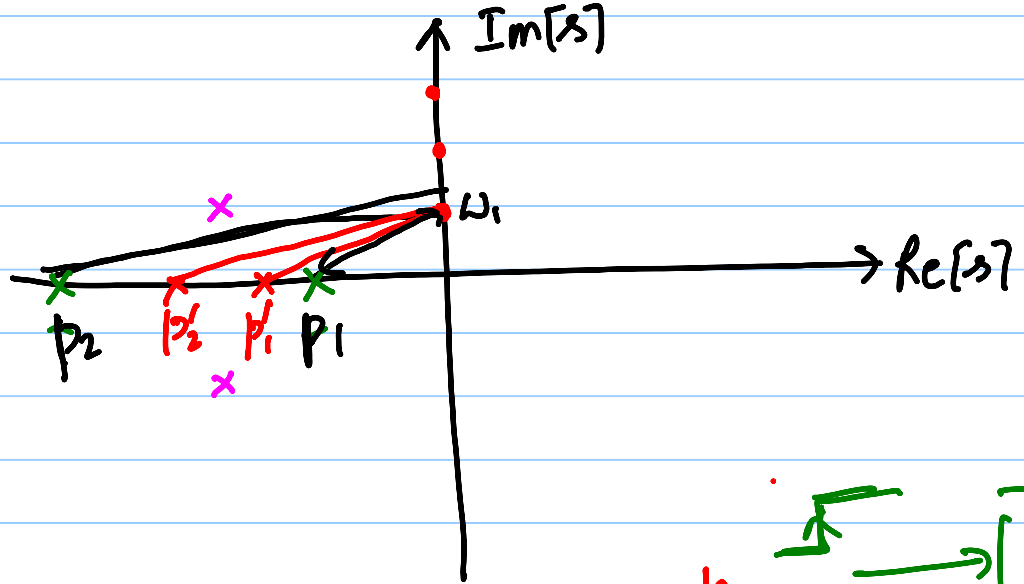
$$= \tan^{-1}\left(\frac{p_2}{\omega_n}\right)$$

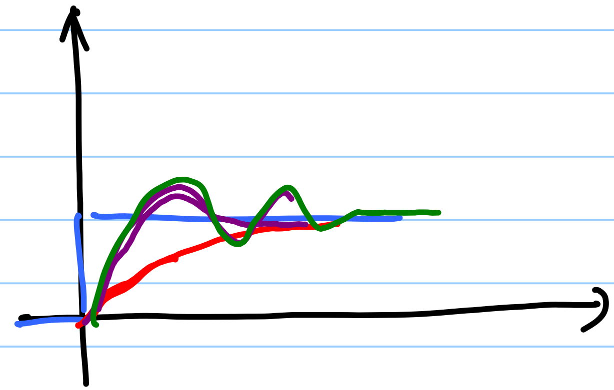
$$\frac{p_2}{\omega_n} = \frac{G_{o2} + G_{o1}\dfrac{(C_2+C_f)}{(C_1+C_f)} + \dfrac{C_f}{C_1+C_f}G_{m2}}{C_2 + \dfrac{C_1 C_f}{C_1+C_f}} \times \frac{C_f \cdot K}{G_{m1}}$$

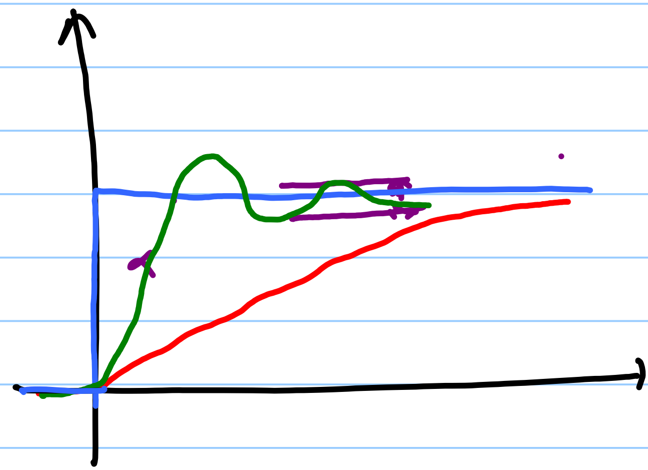
C_1, C_2, G_{o1}, G_{o2}, G_{m1}, G_{m2}

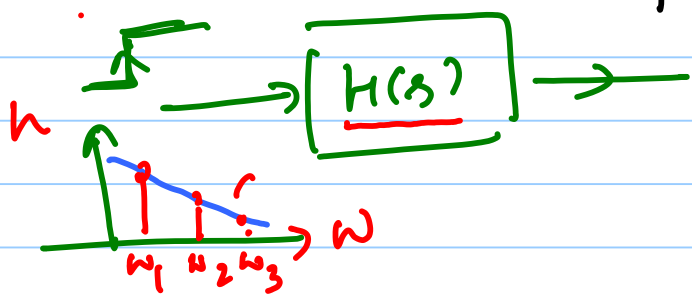
Minimum Phase Margin : 45°

How much phase margin? $\Rightarrow \phi_m$









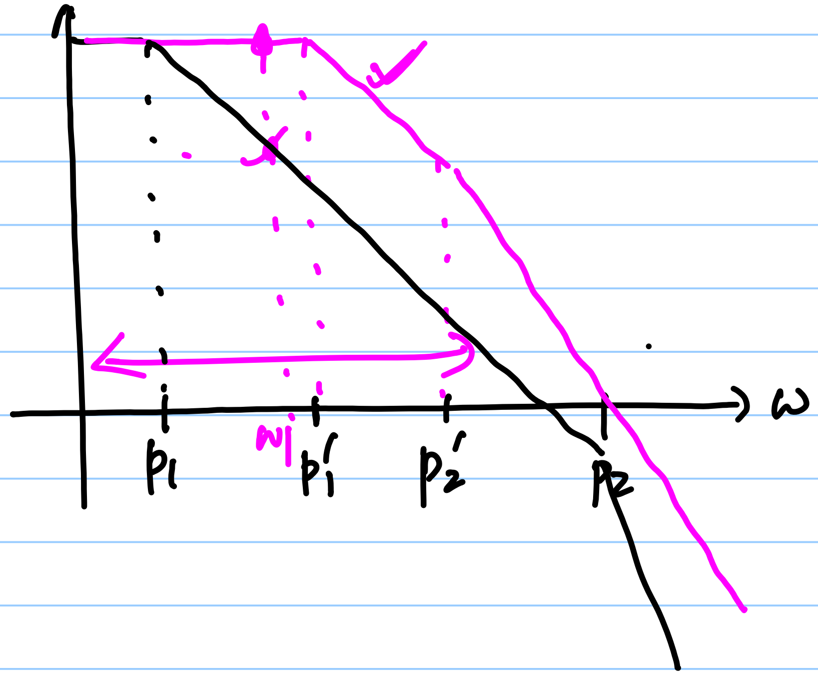
$$H(s) = \frac{1}{\left(1+\frac{s}{p_1}\right)\left(1+\frac{s}{p_2}\right)}$$

$$H(j\omega_1) = \frac{1}{\sqrt{1+\frac{\omega_1^2}{p_1^2}}\ \sqrt{1+\frac{\omega_1^2}{p_2^2}}}$$ ✓

$$= \frac{p_1 p_2}{\sqrt{\omega_1^2+p_1^2}\ \sqrt{\omega_1^2+p_2^2}}$$ ✓

$$\approx \frac{p_1 \cancel{p_2}}{\sqrt{\omega_1^2+p_1^2}\ \cancel{p_2}}$$ ✓

$$H(j\omega_1) = \frac{p_1 p_2}{\sqrt{\omega_1^2+p_1^2}\ \sqrt{\omega_1^2+p_2^2}}$$ ✓



Ex.

G_{m1}	G_{m2}	G_{o1}	G_{o2}	C_1	C_2	K
1mS	10mS	0.01mS	0.1mS	100pF	10pF	1

$s_1 = -p_1 = -\frac{G_{o1}}{C_1} = -10^5$ rad/s.

$s_2 = -p_2 = -\frac{G_{o2}}{C_2} = -10^7$ rad/s.

$A_{DC} = 10000$, $\phi_m = 76^0 \Rightarrow$ $\frac{p_2}{\omega_u} = 4$

Dominant pole compensation, addition cap @ V_{o1} node = ,

$C_f = 51.8pF$

$p_1' \approx 2 \times 10^3$ rad/s, $p_2' = \underline{7.97} \times 10^7$ rad/s