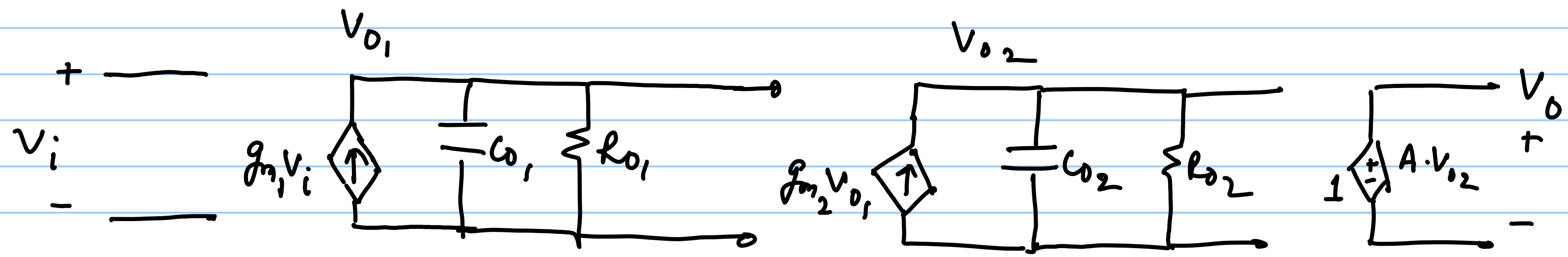
EE2019 **Analog Systems & Lab**



$$\frac{V_o(s)}{V_i(s)} = \frac{g_{m1} R_{o1}}{1 + R_{o1} C_{o1} s} \times \frac{g_{m2} R_{o2}}{1 + R_{o2} C_{o2} s}$$

$$= \frac{A_o}{(1 + s/\omega_{p1})(1 + s/\omega_{p2})}$$

$$\left[\begin{array}{l} A_o = g_{m1} R_{o1} \cdot g_{m2} R_{o2} \\ \omega_{p1} = \dfrac{1}{R_{o1} C_{o1}} \quad ; \quad \omega_{p2} = \dfrac{1}{R_{o2} C_{o2}} \end{array} \right.$$

Note Title 2/25/2020

Assume, $A_o = 1000$; $g_{m_1} = 100 \mu A/V$, $R_{o_1} = 1 M\Omega$, $g_{m_2} = 100 \mu A/V$, $R_{o_2} = 100 k\Omega$

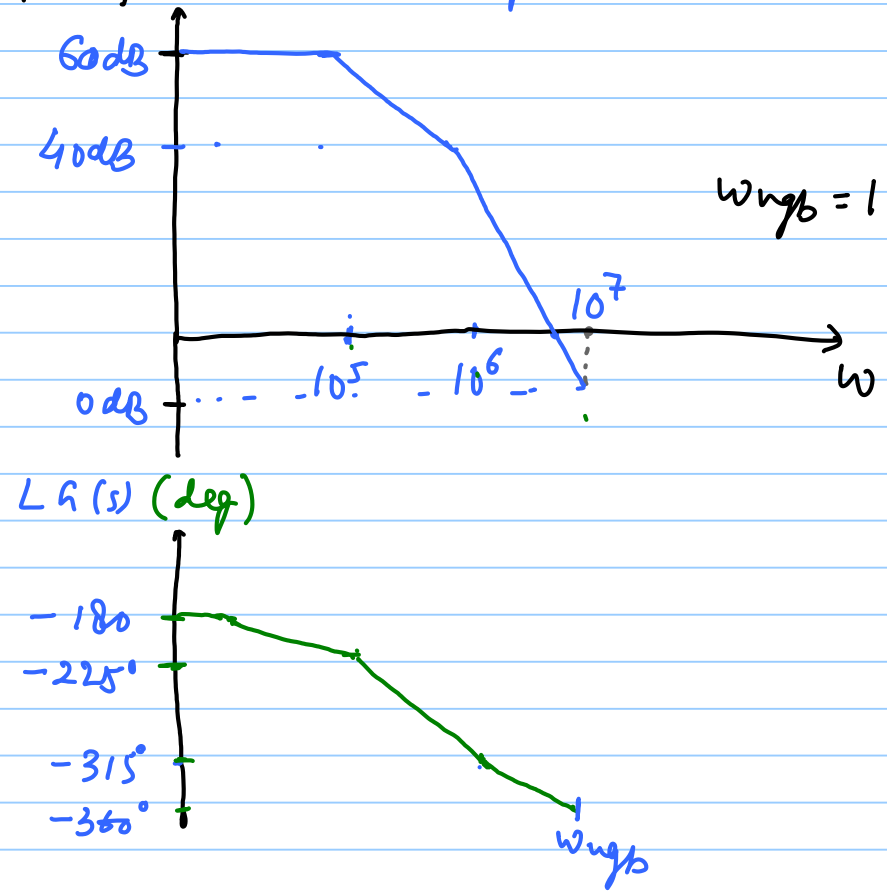
$g_{m_1} R_{o_1} = 100$, $g_{m_2} R_{o_1} = 10$ $\longrightarrow$ $A_o = 1000$

$C_{o_1} = 10pF$ & $C_{o_2} = 10pF$

$$\omega_{p_1} = \frac{1}{R_{o_1} C_{o_1}} = \frac{1}{10^6 \times 10^{-11}} = 10^5 \text{ rad/sec}$$

$$\omega_{p_2} = \frac{1}{R_{o_2} C_{o_2}} = \frac{1}{10^5 \times 10^{-11}} = 10^6 \text{ rad/sec}$$

$|A(s)| = LG(s)$ for $\beta = 1$



$\omega_{ugb} = 10^7$ rad/sec

Phase margin ≈ 0

Total phase shift due to poles $= -180^\circ$

-180° comes from $-ve$ feedback

So if this op-amp is connected in $-ve$ feedback then total loop phase shift $= -360^\circ \Rightarrow +ve$ feedback $\rightarrow$ unstable.

In order to compensate 2-stage op-amp, we target $PM \geq 60^\circ$

Before compensation

$\omega p_1 = 10^5$ rad/sec , $\omega p_2 = 10^6$ rad/sec

$$\boxed{PM = 180^\circ - \underbrace{\tan^{-1}\frac{\omega_{ugb}}{\omega_{p_1}}}_{90^\circ} - \tan^{-1}\frac{\omega_{ugb}}{\omega_{p_2}}}$$

$$\boxed{= 90^\circ - \tan^{-1}\frac{\omega_{ugb}}{\omega_{p_2}}}$$

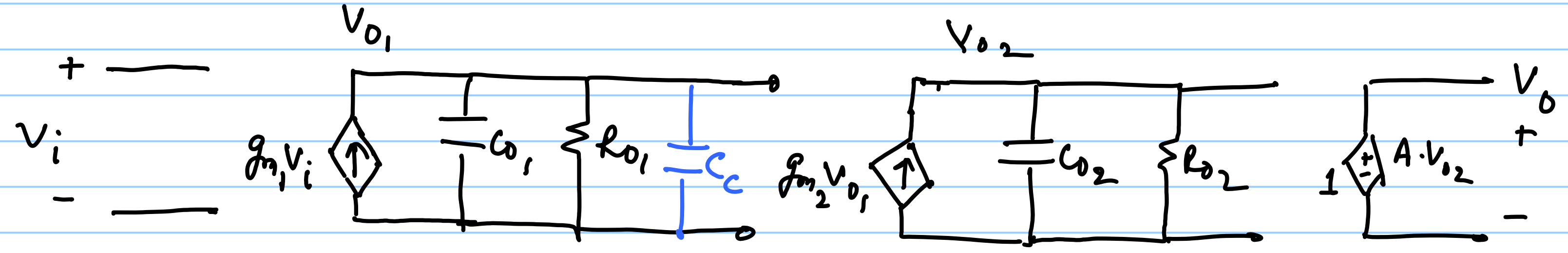
$$PM = 60^\circ$$

$$\boxed{\tan^{-1}\frac{\omega_{ugb}}{\omega_{p_2}} = 30^\circ \Rightarrow \omega_{ugb} = \frac{\omega_{p_2}}{\sqrt{3}}}$$

$$\omega_{p_1} = \frac{\omega_{ugb}}{A_0} = \frac{\omega_{p_2}}{A_0\sqrt{3}} = \frac{10^6}{10^3 \times \sqrt{3}} = \frac{10^3}{\sqrt{3}}$$

$$\omega_{p_1} = \frac{1}{R_{o1} C_{o1}}$$

For compensation, we need to increase cap at V_{o1}



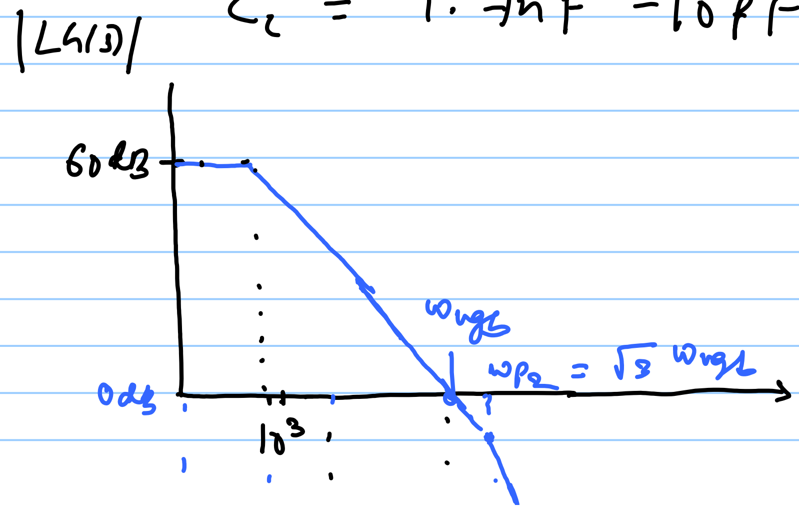
ω_{p_1} after compensation

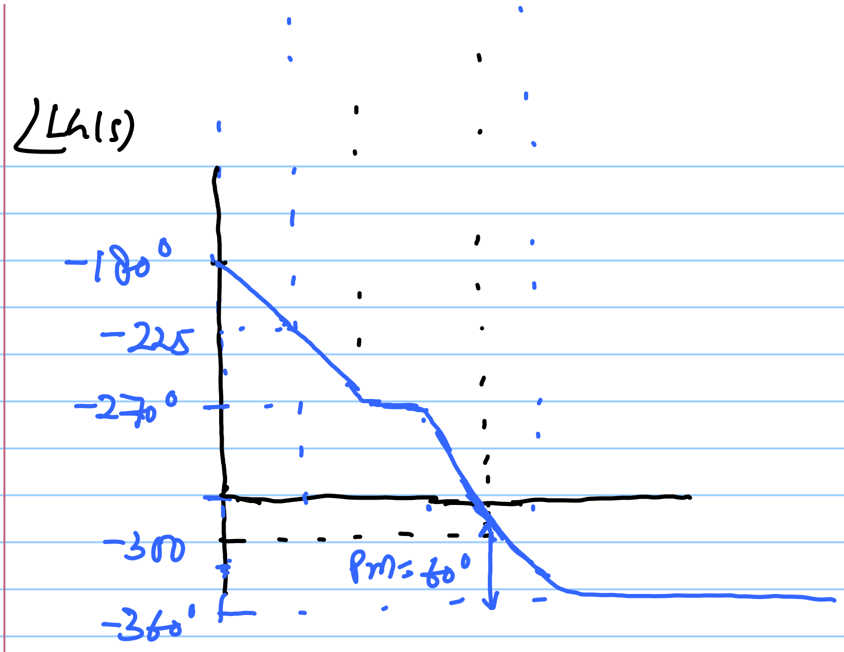
$$\omega_{p_1} = \frac{1}{R_{o1}(C_{o1}+C_c)} = \frac{10^3}{\sqrt{3}}$$

$$R_{o_2}(C_{o_1}+C_c) = \frac{\sqrt{3}}{10^3} \Rightarrow C_{o_1}+C_c = \frac{\sqrt{3}}{10^3}\left(\frac{1}{R_{o_2}}\right)$$

$$= \frac{\sqrt{3}}{10^3} \times \frac{1}{10^6} = \sqrt{3}\times 10^{-9} \simeq 1.7\,nF$$

$$C_c = 1.7\,nF - 10\,pF \simeq 1.7\,nF$$

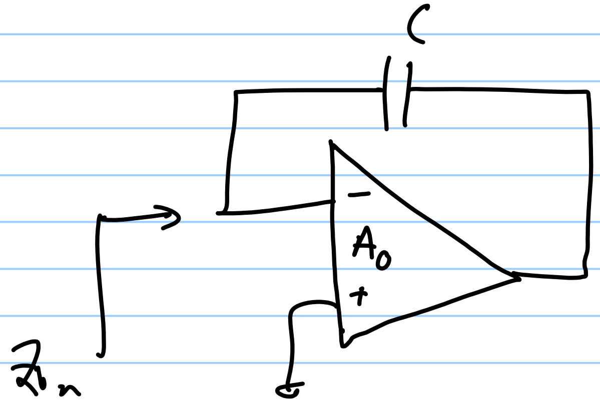




when we compensate 2-stage op-amp by adding cap, it is called

Dominant Pole compensation

Miller compensation



$$Z_{in} = \frac{1}{(1+A_0)Cs}$$