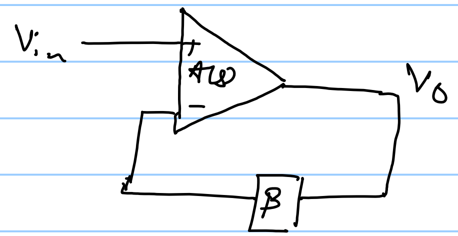
Second order system



$$A(s) = \frac{A_o}{(1+s/\omega_{p_1})(1+s/\omega_{p_2})}$$

$$\frac{V_o}{V_{in}} = \frac{A(s)}{1+A(s)\beta} = \frac{\frac{A_o}{(1+s/\omega_{p_1})(1+s/\omega_{p_2})}}{1+\frac{A_o\beta}{(1+s/\omega_{p_1})(1+s/\omega_{p_2})}}$$

$$= \frac{A_o}{(1+s/\omega_{p_1})(1+s/\omega_{p_2})+A_o\beta}$$

$$= \frac{A_0}{(1+s/\omega_{p_1})(1+s/\omega_{p_2}) + A_0\beta}$$

$$= \frac{A_0}{1 + s/\omega_{p_1} + s/\omega_{p_2} + \frac{s^2}{\omega_{p_1}\omega_{p_2}} + A_0\beta}$$

$$= \frac{A_0}{\frac{s^2}{\omega_{p_1}\omega_{p_2}} + \left(\frac{1}{\omega_{p_1}} + \frac{1}{\omega_{p_2}}\right)s + (1+A_0\beta)}$$

$$= \frac{A_0\,\omega_{p_1}\omega_{p_2}}{s^2 + (\omega_{p_2}+\omega_{p_1})s + (1+A_0\beta)\omega_{p_1}\omega_{p_2}}$$

$$= \frac{A_0}{1+A_0\beta}\;\frac{(1+A_0\beta)\,\omega_{p_1}\omega_{p_2}}{s^2+(\omega_{p_1}+\omega_{p_2})s+(1+A_0\beta)\omega_{p_1}\omega_{p_2}}$$

$$\frac{v_o}{v_{in}} = K \frac{\omega_n^2}{s^2 + 2\xi \omega_n s + \omega_n^2}$$

$$K = \frac{A_0}{1 + A_0 \beta}$$

$$\omega_n^2 = (1 + A_0\beta)\,\omega_{p_1}\omega_{p_2} \Rightarrow \omega_n = \sqrt{(1 + A_0\beta)\,\omega_{p_1}\omega_{p_2}}$$

$$2\xi\omega_n = \omega_{p_1} + \omega_{p_2}$$

$$\xi = \frac{\omega_{p_1} + \omega_{p_2}}{2\sqrt{(1 + A_0\beta)\,\omega_{p_1}\omega_{p_2}}} = \frac{1}{2\sqrt{1 + A_0\beta}} \sqrt{\frac{\omega_{p_1}^2 + \omega_{p_2}^2 + 2\omega_{p_1}\omega_{p_2}}{\omega_{p_1}\omega_{p_2}}}$$

$$= \frac{1}{2\sqrt{1 + A_0\beta}} \sqrt{\frac{\omega_{p_1}}{\omega_{p_2}} + \frac{\omega_{p_2}}{\omega_{p_1}} + 2}$$

Case-1 $\omega_{p_1} = \omega_{p_2}$

$$\xi = \frac{1}{\cancel{2}\sqrt{1+A_0\beta}} \cancel{2} = \frac{1}{\sqrt{1+A_0\beta}}$$

$A_0\beta >> 1$

$\xi \to 0$ unstable.

<u>Case-2</u> $\omega_{p_1} << \omega_{p_2}$

$$= \frac{1}{2\sqrt{1+A_0\beta}} \sqrt{\frac{\omega_{p_1}}{\omega_{p_2}} + \frac{\omega_{p_2}}{\omega_{p_1}} + 2}$$

$$= \frac{1}{2\sqrt{1+A_0\beta}} \sqrt{\frac{\omega_{p_2}}{\omega_{p_1}}}$$

Assume $\omega_{p_2} = \omega_{ugb} = (1+A_0\beta)\,\omega_{p_1}$

$$\xi = \frac{1}{2\,\cancel{1+A_0\beta}} \sqrt{\cancel{(1+A_0\beta)}} = \frac{1}{2}$$

$$\xi = 0.5$$

<u>Case-3</u> for $PM = 60^\circ$

$$PM = 180^\circ - 90^\circ - \tan^{-1}\frac{\omega}{\omega_{P_2}}$$

$$\tan^{-1}\frac{\omega}{\omega_{P_2}} = 30^\circ$$

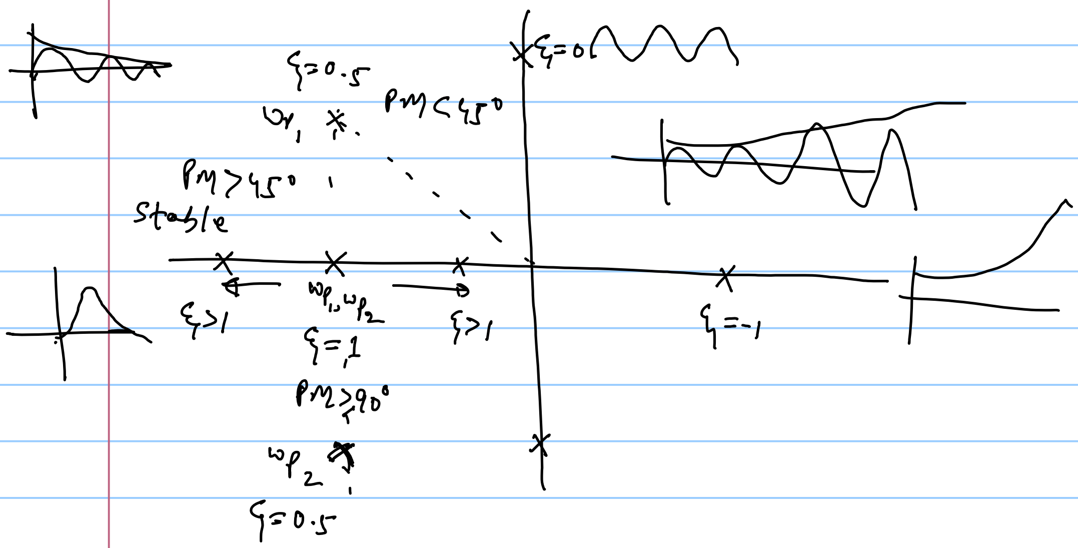
$$\frac{\omega_{ugb}}{\omega_{P_2}} = \tan 30 = \frac{1}{\sqrt{3}}$$

$$\omega_{P_2} = \sqrt{3}\,\omega_{ugb}$$

$$\omega_{P_1} = \frac{\omega_{ugb}}{1+A_0\beta} \Rightarrow \xi = \frac{1}{2\sqrt{\cancel{1+A_0\beta}}} \sqrt{\sqrt{3}\,\cancel{(1+A_0\beta)}}$$

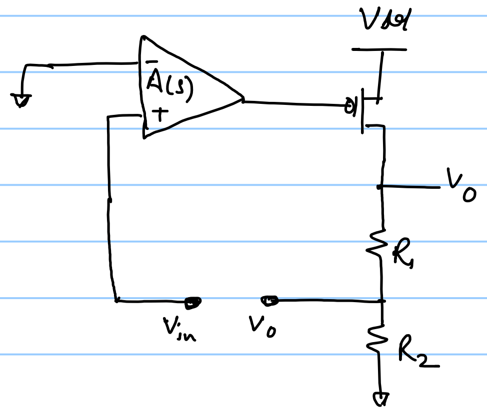
$$\xi = 0.65$$

Phase Margin $\approx 90\xi - 100\xi$



<u>Stabilizing a system</u>

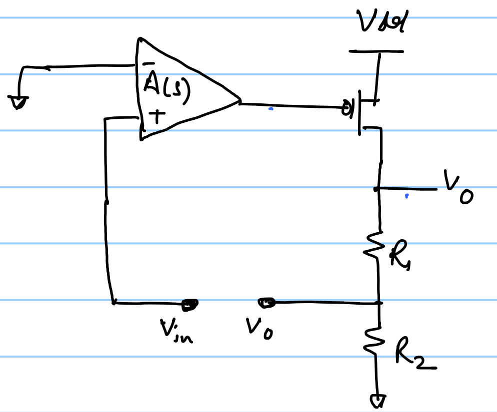
compensation techniques.

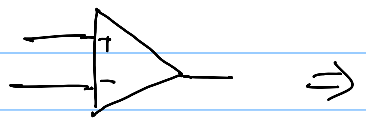


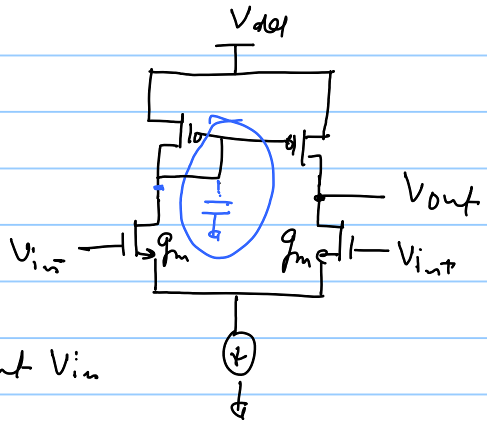
How to Analyse the stability (Loop gain analysis)

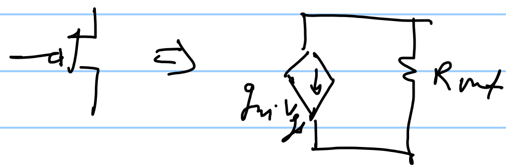
<u>Step-1</u> Break the Loop.

Step-2 Find poles (and zeroes)

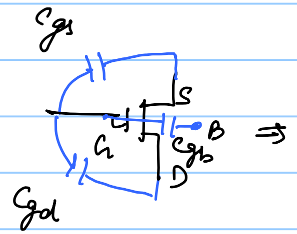




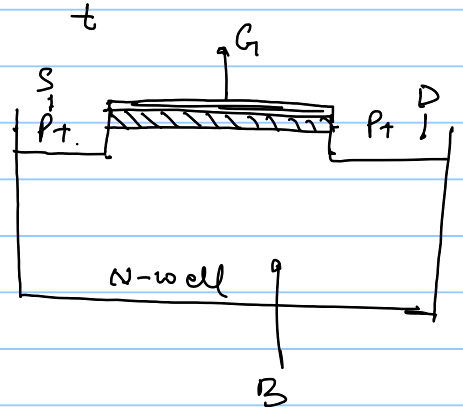




$V_{out} = A V_{in} = g_m R_{out} V_{in}$



$$C = \frac{\varepsilon A}{t}$$



C_{gb} is the dominant capacitor.

Since Gate is the common terminal to all the three capacitors, we get maximum capacitance at gate.