EE2019 28/02/2019

Note Title

$$V_{o2}\left[G_{o1}G_{o2} + s\left[G_{o2}(C_{o1}+C_c) + G_{o1}(C_{o2}+C_c) + C_c g_{m2}\right] + s^2\left[C_{o1}C_{o2} + \cancel{C_c^2} + C_c(C_{o1}+C_{o2}) - \cancel{C_c^2}\right]\right]$$

$$= V_{in}\, g_{m1}(g_{m2} - sC_c)$$

$$\frac{V_{o2}}{V_{in}} = \frac{g_{m1}g_{m2}\left(1 - \frac{C_c}{g_{m2}}s\right)}{\left[C_{o1}C_{o2} + C_c(C_{o1}+C_{o2})\right]s^2 + \left[G_{o1}(C_{o2}+C_c) + G_{o2}(C_{o1}+C_c) + C_c g_{m2}\right]s + G_{o1}G_{o2}}$$

$$= \frac{g_{m1}g_{m2}}{G_{o1}G_{o2}} \frac{\left(1 - \frac{C_c}{g_{m2}}s\right)}{\frac{C_{o1}C_{o2} + C_c(C_{o1}+C_{o2})}{G_{o1}G_{o2}}s^2 + \left(\frac{C_{o2}+C_c}{G_{o2}} + \frac{C_{o1}+C_c}{G_{o1}} + \frac{C_c g_{m2}}{G_{o1}G_{o2}}\right)s + 1}$$

at $s = 0$

$$\frac{V_{o2}}{V_{in}} = \frac{g_{m1} g_{m2}}{G_{o1} G_{o2}} = g_{m1} R_{o1} \cdot g_{m2} R_{o2} = A_o \rightarrow \text{dc gain}$$

$$\frac{V_{o2}}{V_{in}} = A_o \frac{N(s)}{D(s)}$$

Zeroes $\rightarrow$ roots of $N(s)$

Poles $\rightarrow$ roots of $D(s)$

$$\frac{V_{o2}}{V_{in}} = \frac{g_{m1} g_{m2}}{G_{o1} G_{o2}} \frac{\left(1 - \frac{C_c}{g_{m2}} s\right)}{\frac{C_{o1} C_{o2} + C_c (C_{o1} + C_{o2})}{G_{o1} G_{o2}} s^2 + \left(\frac{C_{o2} + C_c}{G_{o2}} + \frac{C_{o1} + C_c}{G_{o1}} + \frac{C_c g_{m2}}{G_{o1} G_{o2}}\right) s + 1}$$

$\frac{V_{o2}}{V_{in}}$ has first order $N(s)$ & second order $D(s)$

$$N(s) \downarrow \text{One zero} \qquad D(s) \downarrow \text{Two poles}$$

we can write,

$$\frac{V_{o2}}{V_{in}} = A_o \cdot \frac{(1 - s/\omega_z)}{(1 + s/\omega_{p_1})(1 + s/\omega_{p_2})}$$

Ignoring R.H.P. zero for now, we will find the roots of $D(s)$

$$\text{roots of } D(s) = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$$

$$ax^2 + bx + c = 0$$

roots are x_1 & x_2

if $x_2 >> x_1$

for x_1, $ax^2 << bx + c$ so we can ignore ax^2

$$bx_1 + c = 0 \Rightarrow x_1 = -\frac{c}{b}$$

for x_2, $ax^2 + bx >> c$ so we can ignore, c

$$ax_2^2 + bx_2 = 0 \Rightarrow x_2 = 0 \text{ \& } x_2 = -\frac{b}{a}$$

$$x_2 = -\frac{b}{a}$$

assume, $x_1 = -1$ & $x_2 = -100$

$$(x+1)(x+100) = x^2 + 101x + 100$$

$$a = 1, \quad b = 101, \quad c = 100$$

$$x_1 = -\frac{c}{b} = -\frac{100}{101} \simeq -1$$

$$x_2 = -\frac{b}{a} = \frac{101}{1} \approx 100$$

$$\frac{V_{o2}}{V_{in}} = \frac{g_{m1} g_{m2}}{G_{o1} G_{o2}} \frac{\left(1 - \frac{C_c}{g_{m2}} s\right)}{\frac{C_{o1} C_{o2} + C_c (C_{o1} + C_{o2})}{G_{o1} G_{o2}} s^2 + \left(\frac{C_{o2} + C_c}{G_{o2}} + \frac{C_{o1} + C_c}{G_{o1}} + \frac{C_c g_{m2}}{G_{o1} G_{o2}}\right) s + 1}$$

$$a = \frac{C_{o1} C_{o2} + C_c (C_{o1} + C_{o2})}{G_{o1} G_{o2}}, \quad b = \frac{C_{o2} + C_c}{G_{o2}} + \frac{C_{o1} + C_c}{G_{o1}} + \frac{C_c g_{m2}}{G_{o1} G_{o2}}$$

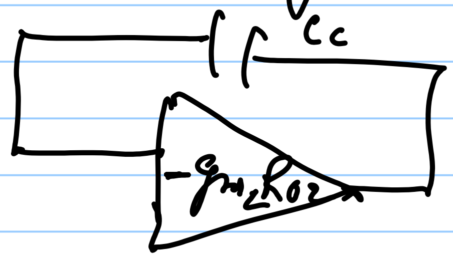
$$c = 1$$

$$\omega_{p_1} = -\frac{c}{b} \quad \& \quad \omega_{p_2} = -\frac{b}{a}$$

$$\omega_{p_1} = \frac{1}{\frac{C_{o2} + C_c}{G_{o2}} + \frac{C_{o1} + C_c}{G_{o1}} + \frac{C_c g_{m2}}{G_{o1} G_{o2}}}$$

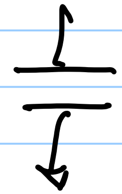
$$= \frac{1}{(C_{o2} + C_c) R_{o2} + (C_{o1} + C_c) R_{o1} + g_{m2} R_{o2} (R_{o1} C_c)}$$

$g_{m2} R_{o2}$ = gain of 2^{nd} stage



2nd stage amp

$\Rightarrow$



$g_{m2} \cdot R_{o2} C_c$

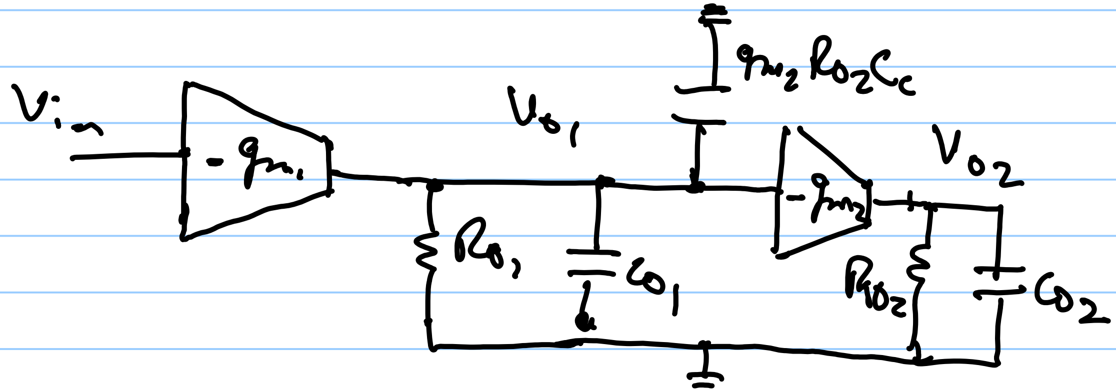
$$g_{m2} R_{o2} R_{o1} C_c >> (C_{o2}+C_c) R_{o2} \; \& \; (C_{o1}+C_c) R_{o1}$$

$$\omega_{p1} = \frac{-1}{(C_{o2}+\cancel{C_c}) R_{o2} + (C_{o1}+\cancel{C_c}) R_{o1} + g_{m2} R_{o2} (R_{o1} C_c)}$$

$$\omega_{p1} = \frac{-1}{g_{m2} R_{o2} (R_{o1} C_c)}$$

ωp_1 without miller compensation

$$\omega p_1 = -\frac{1}{R_{o1} C_{o1}}$$



$$a = \frac{C_{o1} C_{o2} + C_c (C_{o1} + C_{o2})}{G_{o1} G_{o2}}, \quad b = \frac{C_{o2} + C_c}{G_{o2}} + \frac{C_{o1} + C_c}{G_{o1}} + \frac{C_c g_{m2}}{G_{o1} G_{o2}}$$

$c = 1$

$$\omega_{p_2} = -\frac{b}{a} = \frac{\dfrac{C_{o2}+C_c}{G_{o2}} + \dfrac{C_{o1}+C_c}{G_{o1}} + \dfrac{C_c\, g_{m2}}{G_{o1} G_{o2}}}{\dfrac{C_{o1} C_{o2} + C_c (C_{o1}+C_{o2})}{G_{o1} G_{o2}}}$$

$$\omega_{p_2} = -\frac{G_{o1}(C_{o2}+C_c) + G_{o2}(C_{o1}+C_c) + C_c\, g_{m2}}{C_{o1} C_{o2} + C_c (C_{o1}+C_{o2})}$$

original ω_{p_2} (without compensation)

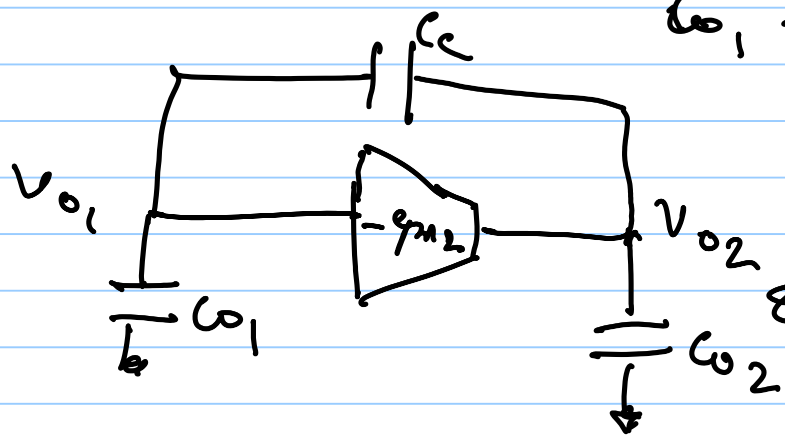
$$\omega_{p_2} = -\frac{1}{R_{o2} C_{o2}} = -\frac{G_{o2}}{C_{o2}}$$

$$w_{p_2} = \frac{-h_{o1}\frac{(C_{o2}+C_c)}{(C_{o1}+C_c)} + h_{o2} + \frac{C_c}{C_{o1}+C_c}g_{m_2}}{\frac{C_{o1}C_{o2}}{C_{o1}+C_c} + \frac{C_c(C_{o1}+C_{o2})}{C_{o1}+C_c}}$$

$$= \frac{-h_{o1}\frac{(C_{o2}+C_c)}{C_{o1}+C_c} + h_{o2} + \frac{C_c}{C_{o1}+C_c}g_{m_2}}{\frac{C_{o1}C_{o2}}{C_{o}+C_c} + \frac{C_c C_{o1}}{C_{o1}+C_c} + \frac{C_c C_{o2}}{C_{o}+C_c}}$$

$$= \frac{}{\frac{C_c C_{o1}}{C_{o1}+C_c} + \frac{C_{o2}}{C_{o1}+\cancel{C_c}}(\cancel{C_{o1}+C_c})}$$

$$\omega_{p_2} = - \frac{G_{o1} \frac{(C_{o2}+C_c)}{C_{o1}+C_c} + G_{o2} + \frac{C_c}{C_{o1}+C_c} g_{m_2}}{C_{o2} + \frac{C_c C_{o1}}{C_{o1}+C_c}}$$



$\leftarrow C_{eff} = C_{o2} \parallel \left(\frac{C_c C_{o1}}{C_c + C_{o1}} \right)$

ω_{p_2} without miller compensation $\omega_{p_2} = - \frac{1}{R_{o2} C_{o2}} = - \frac{G_{o2}}{C_{o2}}$