EE2019 Analog Systems & Lab

Note Title 3/12/2020

$$V_{o2}\left(G_{o2}+(C_{o2}+C_c)s\right)\left(G_{o1}+(C_{o1}+C_c)s\right) = g_{m1}(g_{m2}-C_c s)V_i - \underline{V_{o2}C_c s(g_{m2}-C_c s)}$$

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

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

$$\Rightarrow V_{o_2}\Big[G_{o_2} G_{o_1} + \big(G_{o_2}(C_{o_1}+C_c) + G_{o_1}(C_{o_2}+C_c) \big) s + C_{o_1} C_{o_2} s^2 + C_c C_{o_1} s^2 + C_{o_2} C_c s^2 + \cancel{C_c s^2} + C_c g_{m_2} s - \cancel{C_c s^2} \Big]$$

$$= g_{m_1}(g_{m_2} - C_c s) V_i$$

$$V_{o_2}\Big[(C_{o_1} C_{o_2} + C_c C_{o_1} + C_{o_2} C_c) s^2 + G_{o_2}(C_{o_1}+C_c) + G_{o_1}(C_{o_2}+C_c) + C_c g_{m_2} + G_{o_1} G_{o_2} \Big]$$

$$= g_{m_1}(g_{m_2} - C_c s) V_i$$

$$\frac{V_{o2}}{V_i} = \frac{v_o}{v_i} = \frac{g_{m_1} g_{m_2}\left(1 - \frac{C_c}{g_{m_2}}\right)}{\left[(C_{o_1}C_{o_2} + C_c C_{o_1} + C_{o_2}C_c)s^2 + \left(G_{o_2}(C_{o_1}+C_c) + G_{o_1}(C_{o_2}+C_c) + C_c g_{m_2}\right)s + G_{o_1}G_{o_2}\right]}$$

$$= \frac{g_{m_1} g_{m_2}}{G_{o_1} G_{o_2}} \frac{\left(1 - \frac{C_c}{g_{m_2}} s\right)}{\frac{C_{o_1}C_{o_2} + C_c C_{o_1} + C_{o_2}C_c}{G_{o_1}G_{o_2}} s^2 + \left(\frac{C_{o_1}+C_c}{G_{o_1}} + \frac{C_{o_2}+C_c}{G_{o_2}} + \frac{C_c\, g_{m_2}}{G_{o_1}G_{o_2}}\right)s + 1}$$

$$= A_o \frac{1 - s/\omega_z}{(1 + s/\omega_{p_1})(1 + s/\omega_{p_2})} = A_o \frac{N(s)}{D(s)}$$

It has two poles and one zero

Zero is in R.H.P.

$$\omega_z = \frac{g_{m2}}{C_c}$$

Roots of D(s) are poles.

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

Since after compensation, $\omega_{p_1} \ll \omega_{p_2}$

$$ax^2 + bx + c = 0 \Rightarrow x^2 + \frac{b}{a}x + \frac{c}{a} = 0$$

assume x_1 & x_2 are two roots

$$(x - x_1)(x - x_2) = 0$$

$$x^2 - (x_1 + x_2)x + x_1 x_2$$

$$x_2 >> x_1$$

$$x_1 + x_2 \approx x_2$$

$$x^2 - x_2 x + x_1 x_2 = 0$$

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

$$x_1 x_2 = \frac{c}{a} \Rightarrow x_1 = \frac{1}{x_2} \times \frac{c}{a} = -\frac{c}{b}$$

$$\underbrace{\frac{C_{o_1} C_{o_2} + C_c C_{o_1} + C_{o_2} C_c}{G_{o_1} G_{o_2}}}_{a} s^2 + \underbrace{\left(\frac{C_{o_1} + C_c}{G_{o_1}} + \frac{C_{o_2} + C_c}{G_{o_2}} + \frac{C_c \, g_{m_2}}{G_{o_1} G_{o_2}} \right)}_{b} s + \underbrace{1}_{c}$$

$$\omega_{p_1} = \frac{c}{b} = \frac{1}{\frac{C_{o_1} + C_c}{G_{o_1}} + \frac{C_{o_2} + C_c}{G_{o_2}} + \frac{C_c \, g_{m_2}}{G_{o_1} G_{o_2}}}$$

$$\omega_{p_1} = \frac{G_{o1} G_{o2}}{\underbrace{G_{o2}(C_{o1}+C_c) + G_{o1}(C_{o2}+C_c)}_{\text{can be ignored}} + \underbrace{C_c\, g_{m2}}_{\text{dominant}}}$$

$$\omega_{p_1} \approx \frac{G_{o1} G_{o2}}{C_c\, g_{m2}} = \frac{1}{\underbrace{(g_{m2} R_{o2})(R_{o1} C_c)}_{\text{miller effect}}}$$

Pole before compensation $\quad \omega_{p_1} = \dfrac{1}{R_{o1} C_{o1}}$

ωp_1 is shifted to lower frequency after compensation

$$\omega p_2 = \frac{b}{a} = \frac{\dfrac{C_{o1}+C_c}{G_{o1}} + \dfrac{C_{o2}+C_c}{G_{o2}} + \dfrac{C_c\, g_{m2}}{G_{o1}G_{o2}}}{\dfrac{\overline{C_{o1}C_{o2}} + C_c C_{o1} + \overline{C_{o2}C_c}}{G_{o1}G_{o2}}}$$

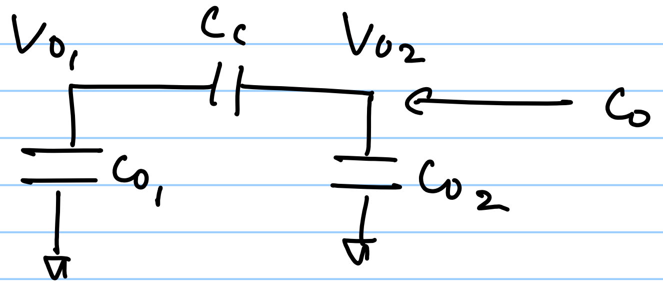
$$= \frac{\overbrace{G_{o2}(C_{o1}+C_c) + G_{o1}(C_{o2}+C_c)}^{\text{ignore}} + C_c\, g_{m2}}{G_{o2}(C_{o1}+C_c) + C_c C_{o1}}$$

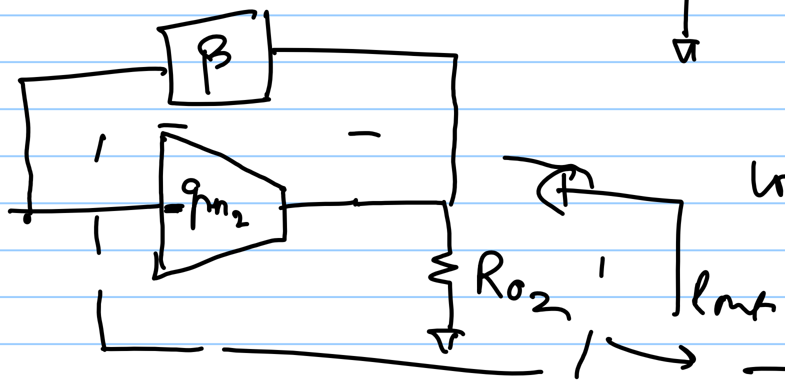
dominant

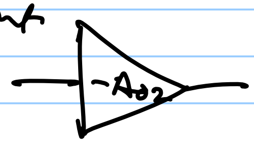
$$= \frac{C_c\, g_{m_2}}{C_{o_2}(C_{o_1}+C_c) + C_c C_{o_1}} = \frac{\frac{C_c}{C_{o_1}+C_c}\, g_{m_2}}{C_{o_2} + \frac{C_c C_{o_1}}{C_{o_1}+C_c}}$$

β

$$C_o = C_{o_2} + \frac{C_c C_{o_1}}{C_{o_1}+C_c} \Rightarrow$$







loop gain $= -\beta\, g_{m_2} R_{o_2}$

$A_{o_2} = g_{m_2} R_{o_2}$

effective Rent