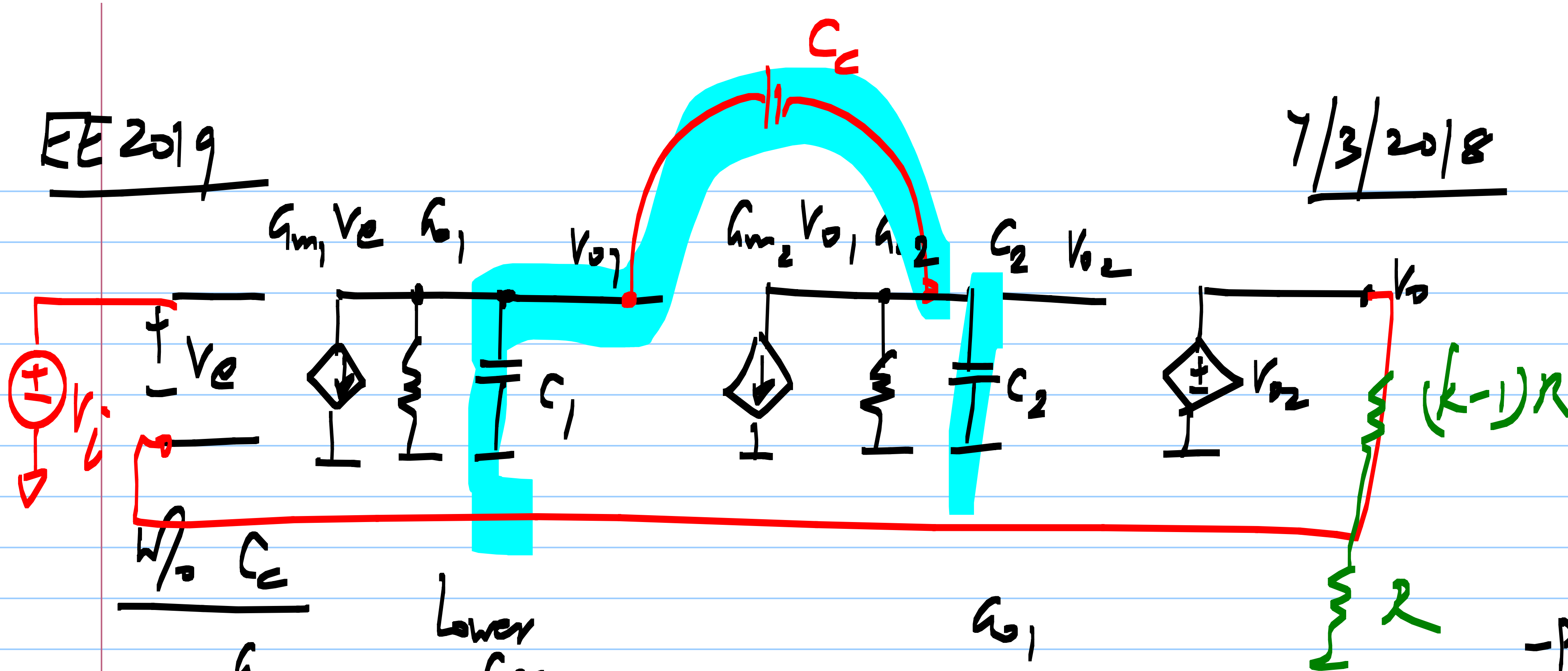
EE 2019 7/3/2018



w/o C_c

$-\dfrac{G_{o_1}}{C_1}$ Lower freq $\longrightarrow$

$-\dfrac{G_{o_2}}{C_2}$ higher freq $\longrightarrow$

$$-\frac{G_{o_1}}{C_c\left(\frac{G_{m_2}}{G_{o_2}}+1+\frac{G_{o_1}}{G_{o_2}}\right)+C_1+C_2\cdot\frac{G_{o_1}}{G_{o_2}}}=-p_1$$

$$-\frac{G_{m_2}\cdot\frac{C_c}{C_c+C_1}+G_{o_2}+G_{o_1}\cdot\frac{C_c+C_2}{C_c+C_1}}{C_2+C_c\cdot C_1/C_c+C_1}=-p_2$$

$$\frac{V_o}{V_e} = \underbrace{\frac{G_{m1} G_{m2}}{G_{o1} G_{o2}}}_{A_o} \frac{\left(1 - s/z_1\right)}{\left(1 + s/p_1\right)\left(1 + s/p_2\right)}$$ RHP zero

Ignoring the zero:

$$\underbrace{\frac{V_1}{V_e} = A_o \cdot \frac{1}{\left(1+\frac{s}{p_1}\right)\left(1+\frac{s}{p_2}\right)}}.$$

$$\omega_{u,\text{opA}} = A_o \cdot p_1 = \frac{G_{m1} G_{m2}}{G_{o1} G_{o2}} \cdot \frac{G_{o1}}{C_c\left(\frac{G_{m2}}{G_{o2}} + \cancel{1} + \cancel{\frac{G_{o1}}{G_{o2}}}\right) \cancel{+ C_1} \cancel{+ C_2 \frac{G_{o1}}{G_{o2}}}}$$

$$= \frac{G_{m1}}{C_c}$$

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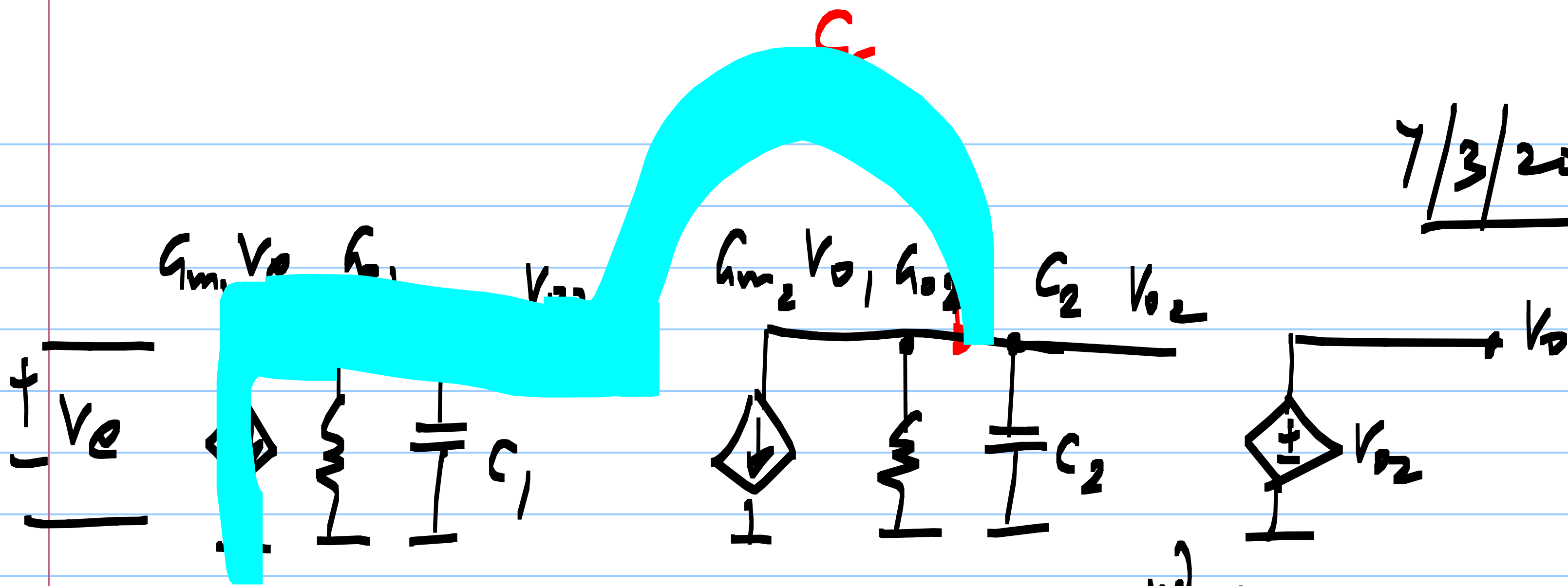
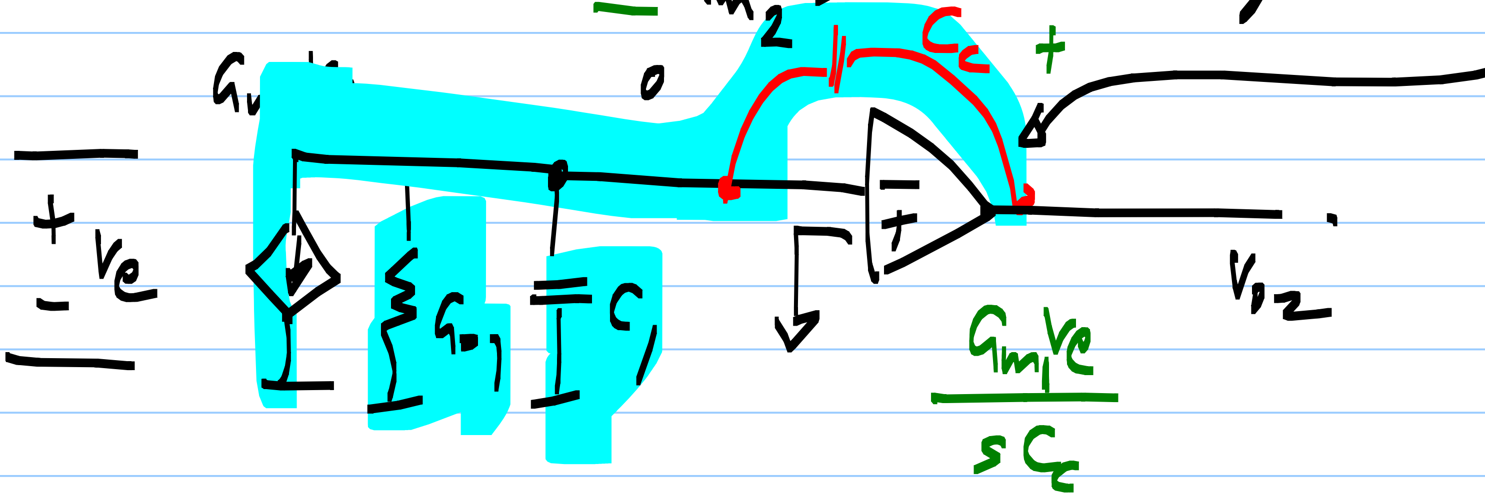
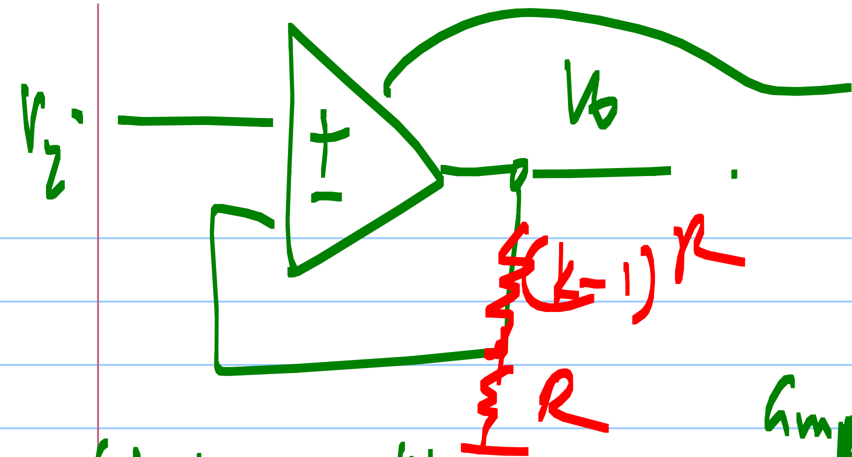


$G_{m_2} \to \infty$ 2^{nd} stage — ideal opamp



$\frac{V_{o2}}{V_e} =$



Two stage opamp:

$$A(s) = \frac{A_0\left(1 - s/z_1\right)}{\left(1 + s/p_1\right)\left(1 + s/p_2\right)}$$

$$\omega_{u,loop} = \omega_{u,OPA} = \frac{G_{m1}}{C_c}$$

$$-\pi/2$$

$$\text{Phase lag @ } \omega_{u,loop} = -\tan^{-1}\frac{\omega_{u,loop}}{p_1} - \tan^{-1}\frac{\omega_{u,loop}}{p_2}$$

$$\phi_M = 180^\circ - 90^\circ - \tan^{-1}\frac{\omega_{u,loop}}{p_2} = 90^\circ - \tan^{-1}\frac{\omega_{u,loop}}{p_2}$$

$$= \tan^{-1}\left(\frac{p_2}{\omega_{u,loop}}\right)$$

$$\tan\phi_M = \frac{p_2}{\omega_{u,loop}} = \frac{p_2}{\omega_{u,OPA}} =$$

$$\tan\phi_M = \frac{p_2}{\omega_{u,loop}} = \frac{p_2}{\omega_{u,opA}} = \frac{G_{m_2}\left(C_c/(C_c+C_1)\right)}{G_{m_1}/C_c \cdot \left[C_2 + \frac{C_c C_1}{C_c+C_1}\right]}$$

Quadratic for C_c.

$G_{m_1} = 1\,mS$

$G_{m_2} = 10\,mS$

$C_1 = 10\,pF$

$C_2 = 20\,pF$

$$\tan\phi_M = \frac{G_{m_2}}{G_{m_1}} \cdot \frac{C_c^2}{(C_2 C_c + C_1 C_c + C_1 C_2)}$$

$$= \frac{G_{m_2}}{G_{m_1}} \cdot \frac{(C_c/C_2)^2}{\frac{C_c}{C_2} + \frac{C_1}{C_2} \cdot \frac{C_c}{C_2} + \frac{C_1}{C_2}}$$

$$\tan\phi_M = \frac{G_{m_2}}{G_{m_1}} \cdot \frac{C_c^{\,2}}{(C_2C_c + C_1C_c + C_1C_2)}$$

$$= \frac{G_{m_2}}{G_{m_1}} \cdot \frac{(C_c/C_2)^2}{\frac{C_c}{C_2} + \frac{C_1}{C_2}\cdot\frac{C_c}{C_2} + \frac{C_1}{C_2}}$$

$G_{m_1} = 1\,mS$; $C_1 = 10\,pF$

$G_{m_2} = 10\,mS$; $C_2 = 20\,pF$

For 76° PM : $C_c = 16.8\,pF$

For 60° PM : $C_c = 9\,pF$

$$\left(\frac{C_c}{C_2}\right)^2 \cdot \frac{G_{m_2}}{G_{m_1}} = \left(\frac{C_c}{C_2}\right)\left(1 + \frac{C_1}{C_2}\right)\cdot \tan\phi_M + \frac{C_1}{C_2}\cdot \tan\phi_M$$

Increasing $C_1 \longrightarrow 80\,nF$

$$\omega_{u,opA} = 1.25\ Mrad/s$$

with Miller comp.

$$\frac{G_{m,1}}{C_C} = 60\ Mrad/s$$

2 stage opamp:

$$A(s) = \frac{A_0 \left(1 - s/z_1\right)}{\left(1 + s/p_1\right)\left(1 + s/p_2\right)}$$

$$-\tan^{-1} \frac{G_{m1}/C_c \cdot 10}{G_{m2}/C_L} \sim 6^\circ$$

Phase lag: $\underbrace{-\tan^{-1} \frac{\omega_{u,loop}}{p_1}}_{76^\circ} - \tan^{-1} \frac{\omega_{u,loop}}{p_2} - \overbrace{\tan^{-1} \frac{\omega_{u,loop}}{z_1}}^{\omega_{u,loop}/k}$

$$\phi_M = \overbrace{90^\circ - \tan^{-1} \frac{\omega_{u,loop}}{p_2}}^{\omega_{u,loop}/k} - \overbrace{\tan^{-1} \frac{G_{m1} \cdot 10}{G_{m2}}}$$

$/k$ for $\omega_{u,loop}/k$

Chose $G_{m2} > G_{m1}$