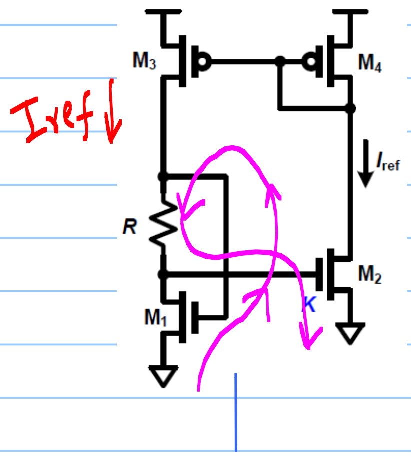
ECE 511 – Lecture 14

Note Title 3/7/2013

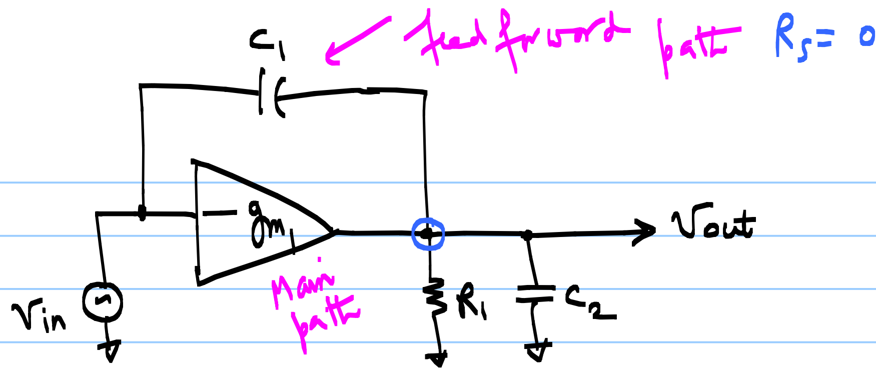
$\lambda = 0$



$$V_{GS_1} - I_{ref} R = V_{GS_2}$$

$$\sqrt{\frac{2 I_{ref}}{W/L}} + \cancel{V_{THN}} - I_{ref} R = \sqrt{\frac{2 I_{ref}}{K W/L}} + \cancel{V_{THN}}$$

$$\sqrt{\frac{2 I_{ref}}{W/L}} \left(1 - \frac{1}{\sqrt{K}}\right) = I_{ref} \cdot R$$



$$v_{in}(\overbrace{-g_m + sC_1}^{0})$$

$$\boxed{-g_{m1} v_{in}} - \frac{v_{out}}{1/sC_2} - \frac{v_{out}}{R_1} - \frac{(v_{out} - v_{in})}{1/sC_1} = 0$$

$$\Rightarrow \quad (-g_{m1} + sC_1)\, v_{in} = v_{out}\left[\frac{1}{R_1} + sC_2 + sC_1\right]$$

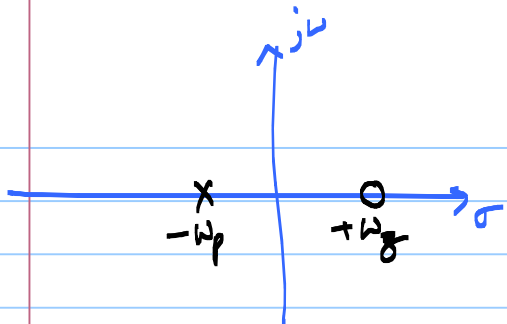
$$\Rightarrow \quad \frac{v_{out}}{v_{in}}(s) = \frac{-(g_{m1} - sC_1)}{1/R_1 + s(C_1 + C_2)}$$

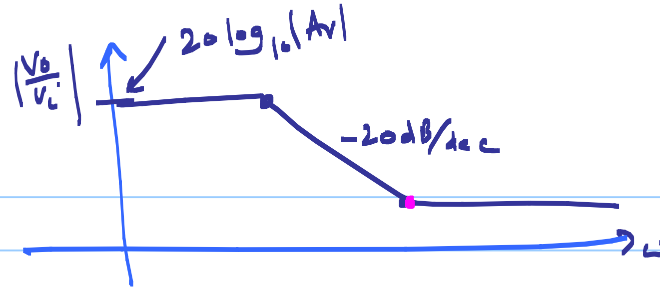
$$= -g_{m1}R_1 \cdot \frac{\left(1 - \frac{sC_1}{g_{m1}}\right)}{1 + sR(C_1 + C_2)} = \boxed{A_v \frac{(1 - s/\omega_z)}{(1 + s/\omega_p)}}$$

$A_v = -g_{m1}R_1$

$\omega_z = + g_{m1}/C_1$ "RHP"

$\omega_p = \dfrac{1}{R_1(C_1 + C_2)}$

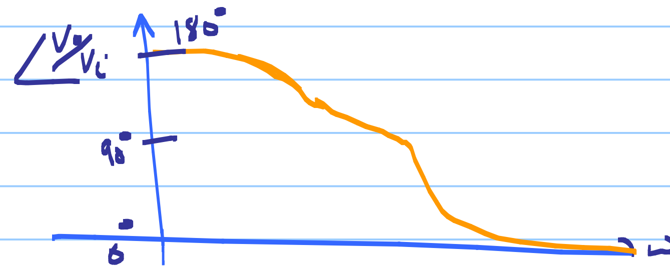


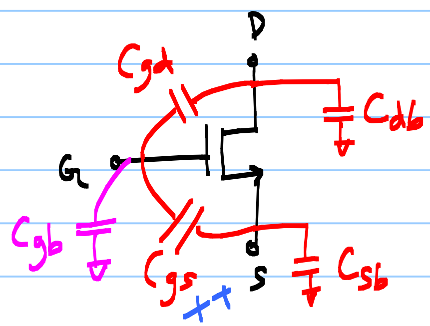


$$\angle \frac{V_o}{V_i} = -\tan^{-1}\left(\frac{\omega}{\omega_z}\right) - \tan^{-1}\left(\frac{\omega}{\omega_p}\right)$$

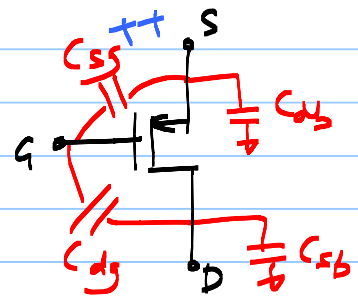
RHP zero looks like

~ pole





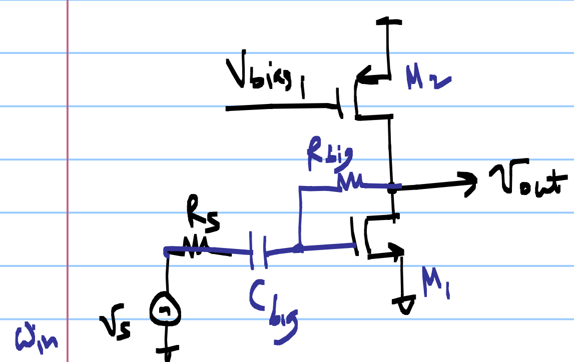
D
Cgd
Cdb
G
Cgb
Cgs
S
Csb

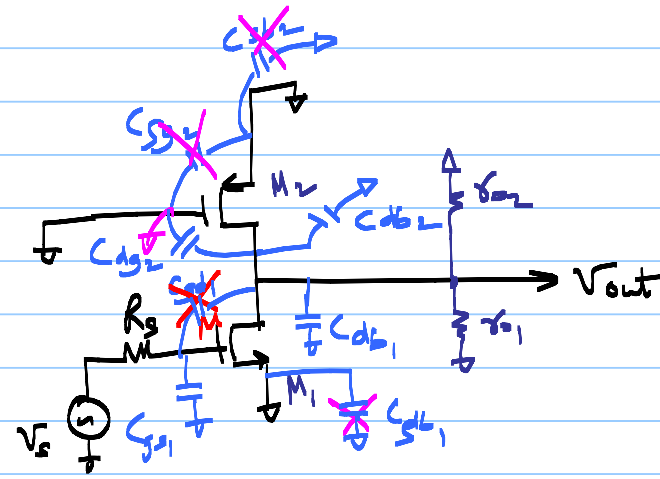


S
Css
Cdb
G
Cdg
D
Csb

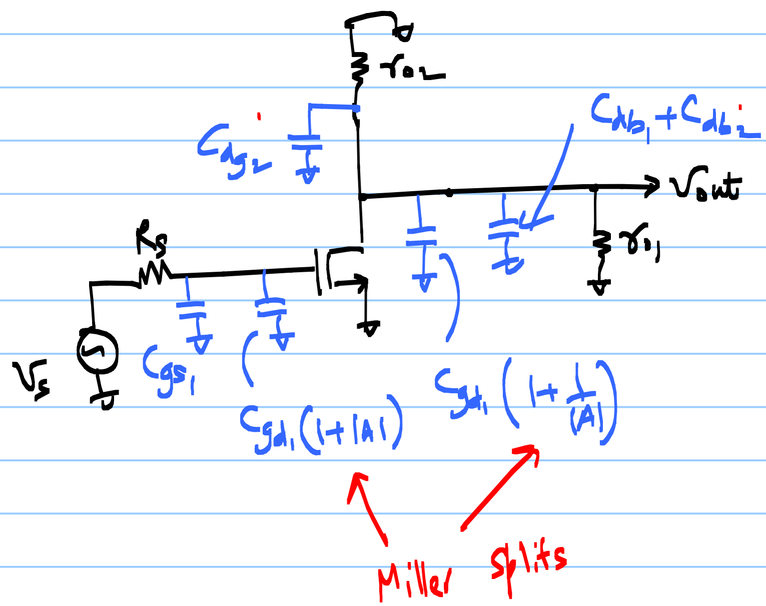
CS Stage

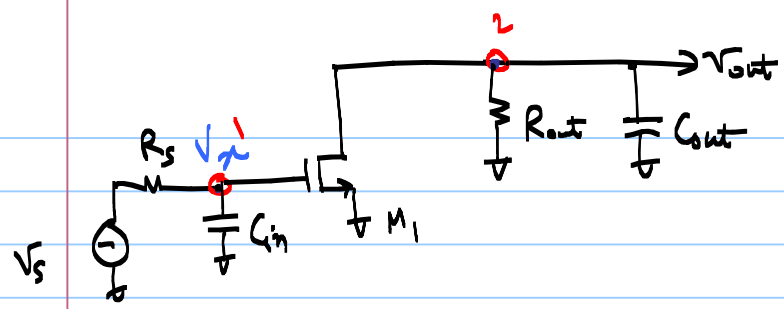
$$\omega_{in} \gg \frac{1}{R_{big} C_{big}}$$





Using Miller's Approx.





Small signal R & C's

$R_{out} = r_{o_1} \| r_{o_2}$

$C_{in} = C_{gs_1} + C_{gd_1}(1+|A|)$

$C_{out} = C_{gd_1}\left(1+\frac{1}{|A|}\right) + C_{db}$

$A = -g_{m_1} R_{out}$

$$\omega_{in} = \frac{1}{R_s C_{in}} = \frac{1}{R_s\left[C_{gs_1} + (1+|A|)C_{gd_1}\right]}$$

$$\omega_z = \frac{g_{m1}}{C_{gd_1}}$$

RHP zero

$$\omega_{out} = \frac{1}{R_{out} C_{out}} = \frac{1}{(r_{o_1}\|r_{o_2})\left[C_{gd_1} + C_{db}\right]}$$

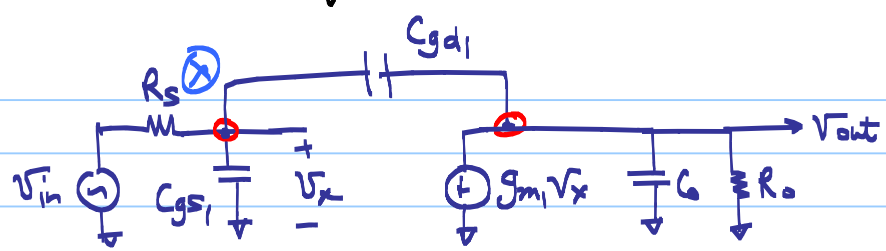
Miller misses this zero!

$$\frac{V_{out}}{V_{in}}(s) = \frac{A_v \left(1 - \frac{s}{\omega_z}\right)}{\left(1+ s/\omega_{in}\right)\left(1+ s/\omega_{out}\right)}$$

Draw the equivalent circuit

$R_o = r_{o_1} \| r_{o_2}$

$C_o = C_{db} + C_{dg_2}$



① ⇒ $$\frac{V_x - V_{in}}{R_S} + V_x C_{gs_1} s + (V_x - V_{out}) C_{gd_1} s = 0$$

② ⇒ $$(V_{out} - V_x) C_{gd_1} s + g_{m_1} V_x + V_{out}\left(\frac{1}{R_o} + sC_o\right) = 0$$

Solve for V_x & substitute in ①

$$V_x = -\frac{V_{out}\left(C_{gd_1} s + 1/R_o + C_o s\right)}{g_{m_1} - sC_{gd_1}}$$

$\xi \rightarrow$ Zeta

$$\frac{V_{out}}{V_{in}}(s) = \frac{(C_{gd_1} s - g_{m_1}) R_o}{R_s R_o \xi s^2 + \underbrace{[R_s(1+g_{m_1}R_o)C_{gd_1} + R_s C_{gs_1} + R_o(C_{gd_1} + C_{db})]}_{\frac{1}{\omega_{p1}}} s + 1}$$

$$\xi = C_{gs_1} C_{gd_1} + C_{gs_1} C_o + C_{gd_1} C_o$$

2^{nd}-order TF $\Rightarrow$ 2 nodes interacting thru C_{gd_1}

$$N^r = (sC_{gd_1} - g_{m_1}) R_o = \underbrace{-g_{m_1} R_o}_{A_v} \left(1 - \frac{s}{\omega_z}\right), \quad \omega_z = \frac{g_{m_1}}{C_{gd_1}}$$

$$D(s) = \frac{s^2}{\omega_n^2} + 2\zeta \frac{s}{\omega_n} + 1$$

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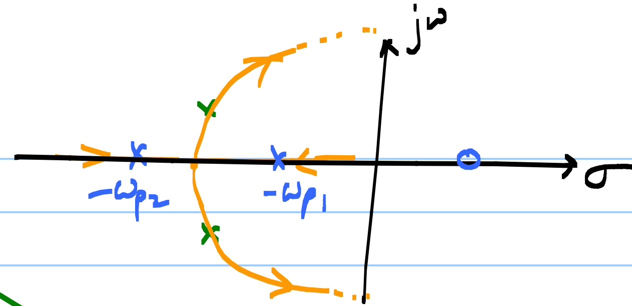

If we have $|\omega_{p_1}| \ll |\omega_{p_2}|$ $\rightarrow$ $\frac{1}{\omega_{p_1}} \gg \frac{1}{\omega_{p_2}}$

$$D(s) = \left(\frac{s}{\omega_{p_1}} + 1\right)\left(\frac{s}{\omega_{p_2}} + 1\right)$$

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

$$\simeq \frac{s^2}{\omega_{p_1}\omega_{p_2}} + \boxed{\frac{1}{\omega_{p_1}}} \cdot s + 1$$

Coeffⁿ of 's'

$$\omega_{p_1} = \frac{1}{\underbrace{R_s(1+g_{m_1}R_o)C_{gd_1}}_{\substack{\text{Miller input cap} \\ R_s C_{in}}} + R_s C_{gs_1} + \underbrace{R_o(C_{gd_1}+C_o)}_{\text{Extra term}}}$$