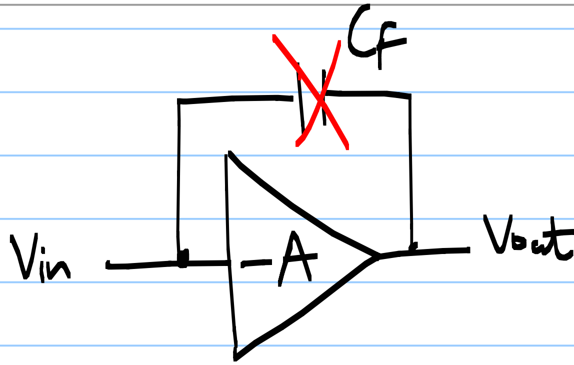
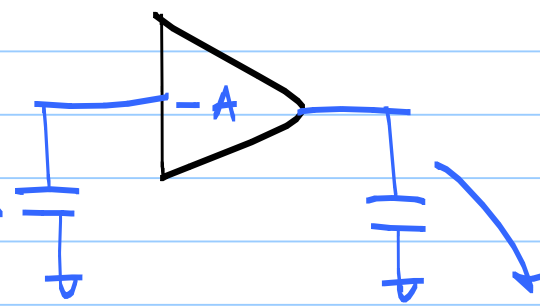
ECE 511 - Lecture 14

Note Title 3/14/2012

Miller Effect



simplify $\longrightarrow$



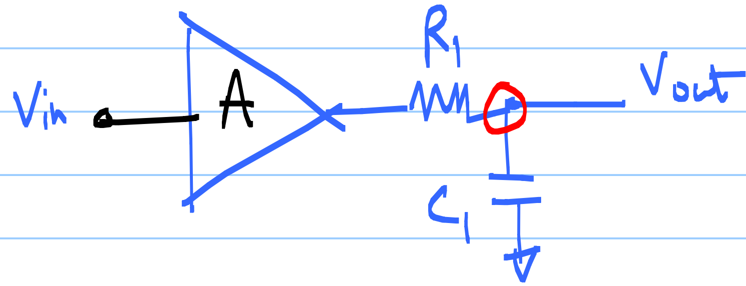
C_{in}

$= C_f(1+|A|)$

C_{out}

$\downarrow$

$C_f\left(1+\frac{1}{|A|}\right)$

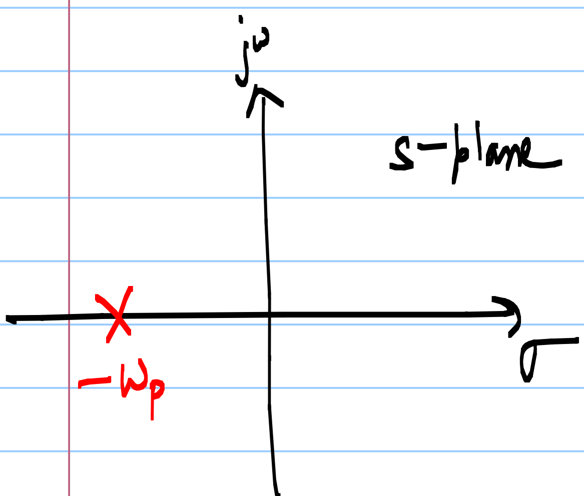


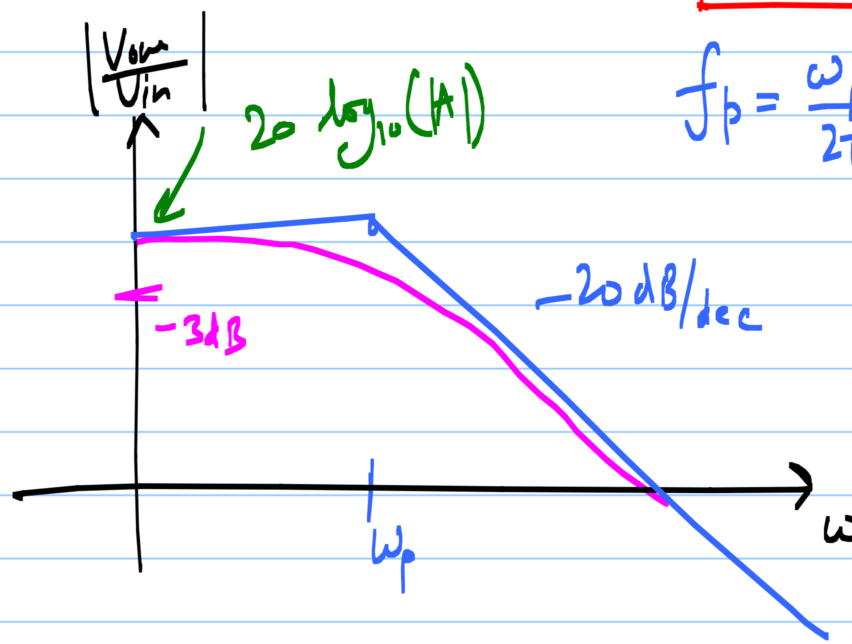
$$\frac{V_{out}}{V_{in}}(s) = \frac{A}{1+sR_1C_1} = \frac{A}{1+\frac{s}{\omega_p}}$$

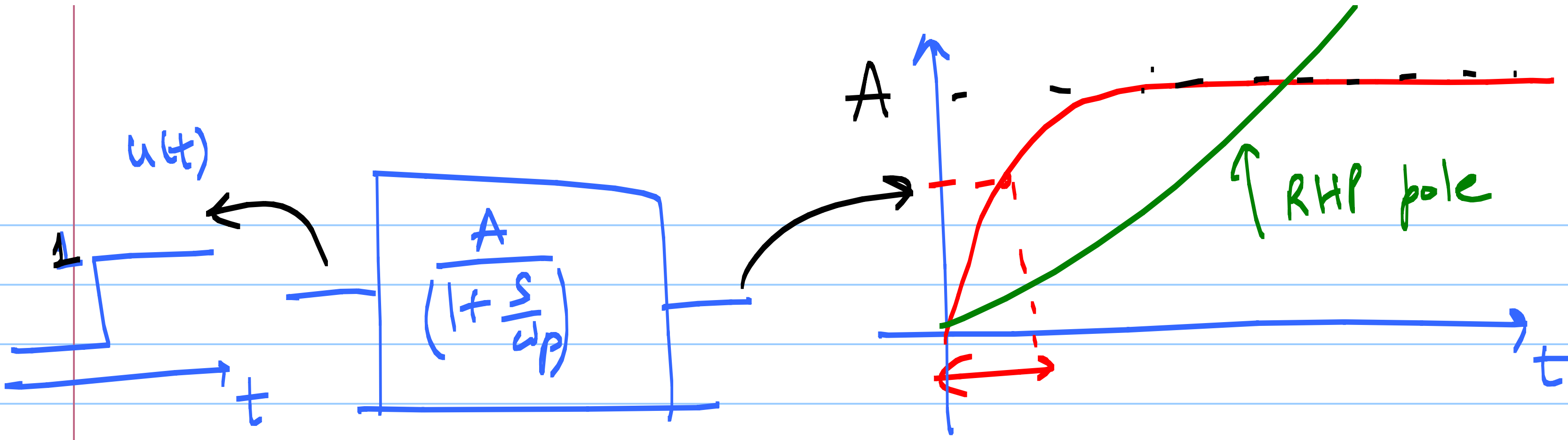
$$\boxed{\omega_p = \frac{1}{R_1C_1}}$$

"pole"

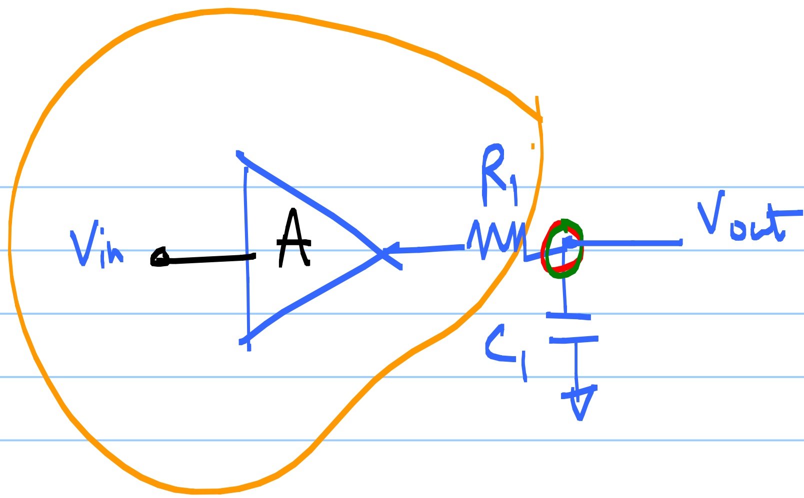
$$f_p = \frac{\omega_p}{2\pi} = \frac{1}{2\pi R_1C_1}$$



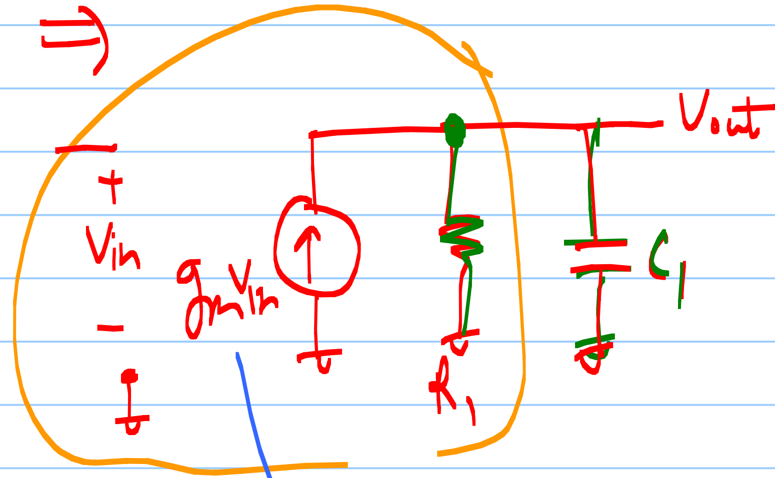




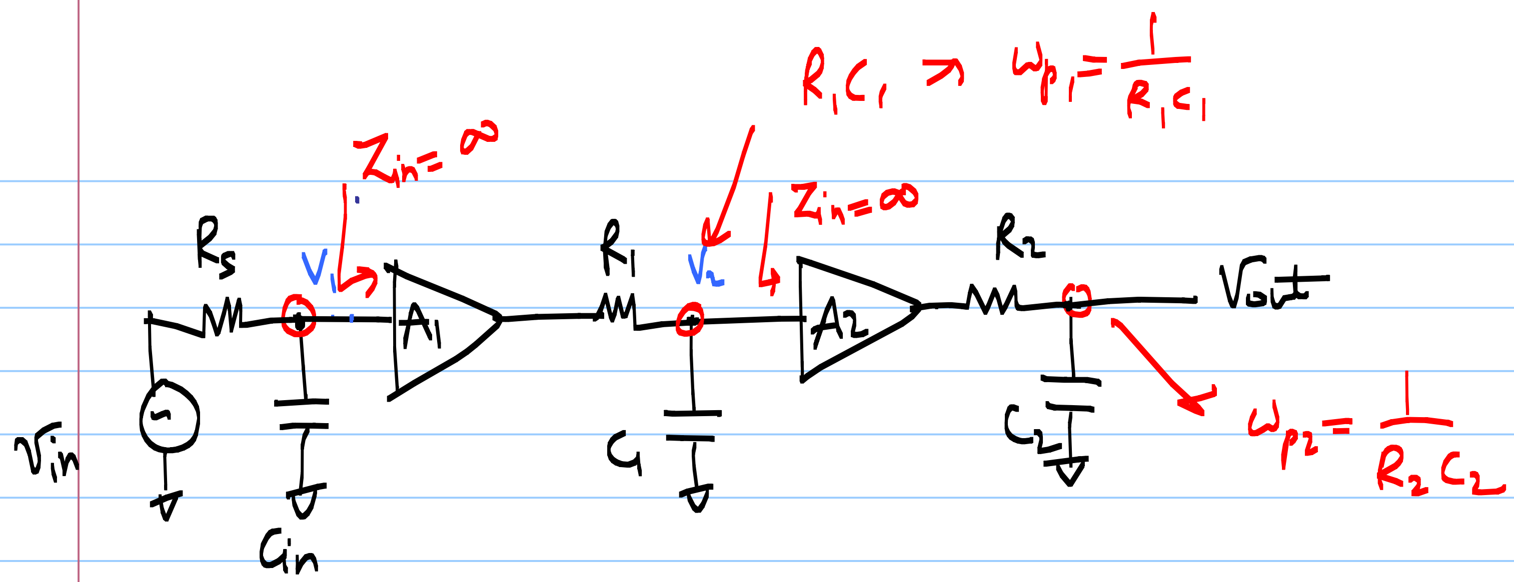
$$RC = \tau = \frac{1}{\omega_p} = \frac{1}{2\pi f_p}$$



$\Rightarrow$



$$\boxed{A = g_m R_1}$$



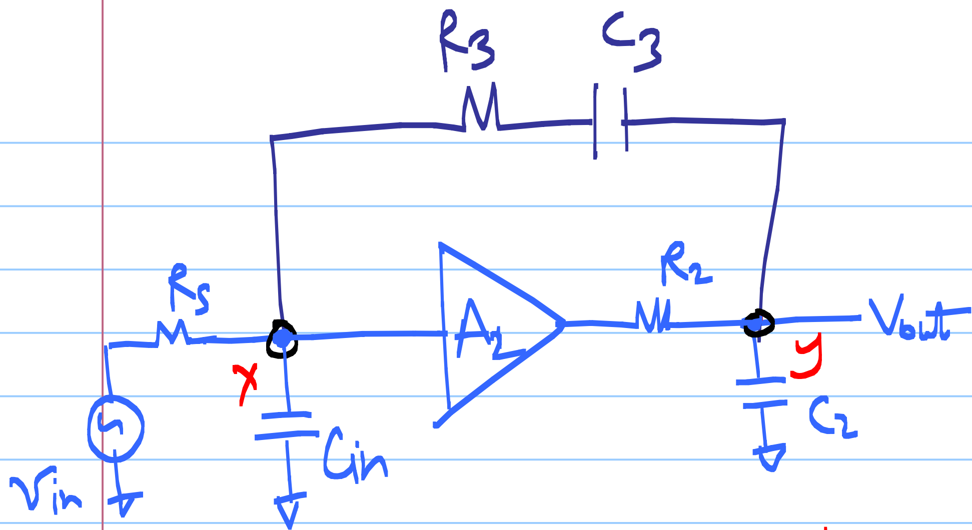
$$\frac{V_{out}}{V_{in}}(s) = \frac{1}{(1+sR_sC_{in})} \cdot \frac{A_1}{(1+sR_1C_1)} \cdot \frac{A_2}{(1+sR_2C_2)}$$

3 poles

3 poles → determined by total cap to gnd × total R to gnd at any node

for every i^{th} node $\Rightarrow$ $\omega_{p_i} = \dfrac{1}{R_i C_i} = \dfrac{1}{\tau_i}$

$$\text{Node}_i \Rightarrow \omega_{p_i} = \frac{1}{R_i C_i}$$



$$\cancel{\omega_{p_1} = \frac{1}{R_S C_{in}}}$$

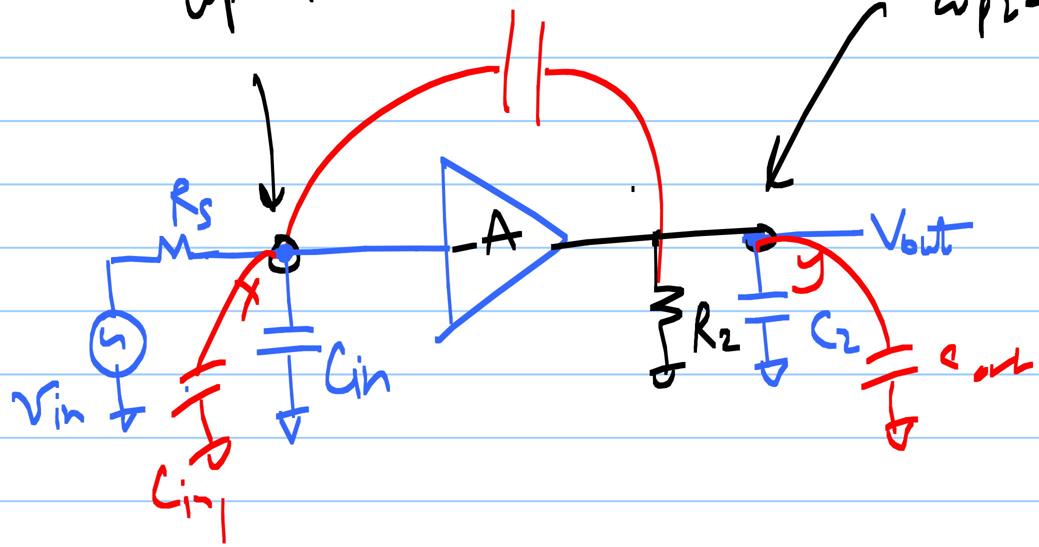
$$\cancel{\omega_{p_2} = \frac{1}{R_2 C_2}}$$

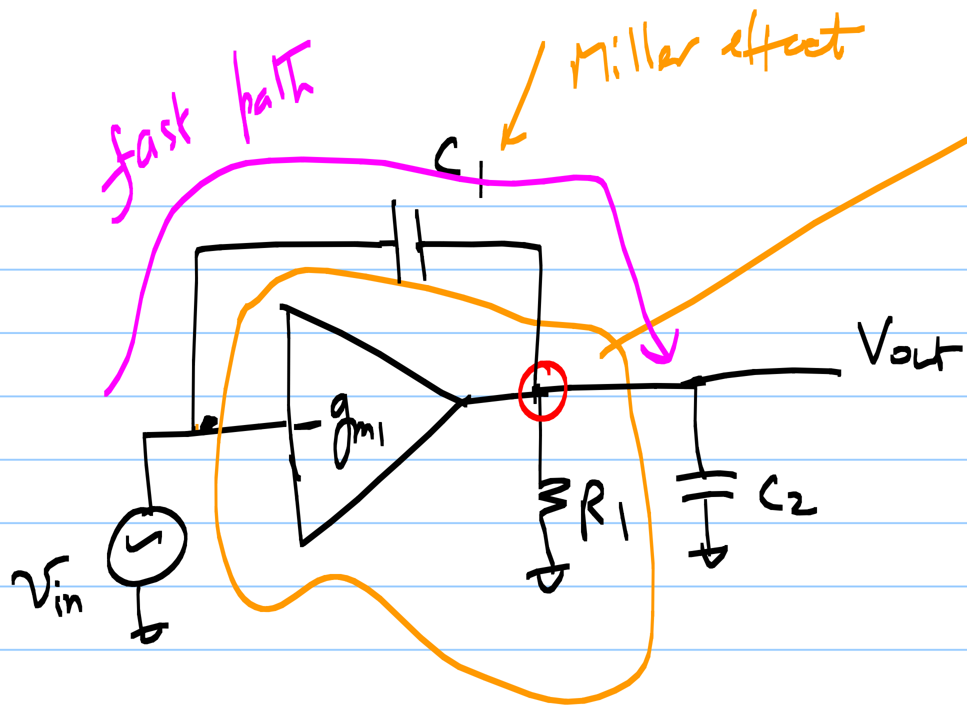
x & y are interacting thru $R_3 - C_3$ path

* All poles are contributed by all the nodes in the circuit

$$\omega_{p1} = \frac{1}{R_s(C_{in_1}+C_{in})}$$

$$\omega_{p2} = \frac{1}{R_2(C_2+C_{out})}$$





$$A_1 = -g_{m1} R_1$$

$$\omega_z = +\frac{g_{m1}}{C_1} \quad \text{RHP}$$

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

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

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

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

$$= \underbrace{-g_{m1}R_1}_{A_v} \cdot \frac{\left(1 - \frac{sC_1}{g_{m1}}\right)}{\left(1 + sR_1(C_1 + C_2)\right)}$$

ω_z

ω_p

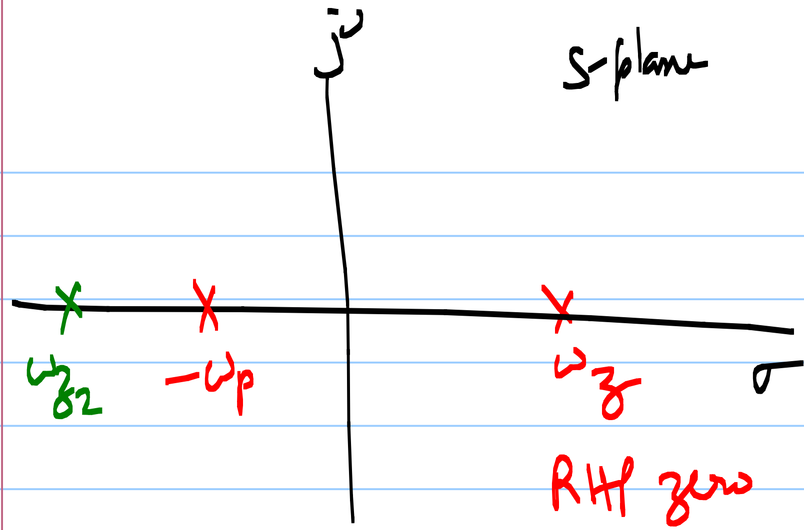
$$= \frac{A_v\left(1 - s/\omega_z\right)}{\left(1 + s/\omega_p\right)}$$

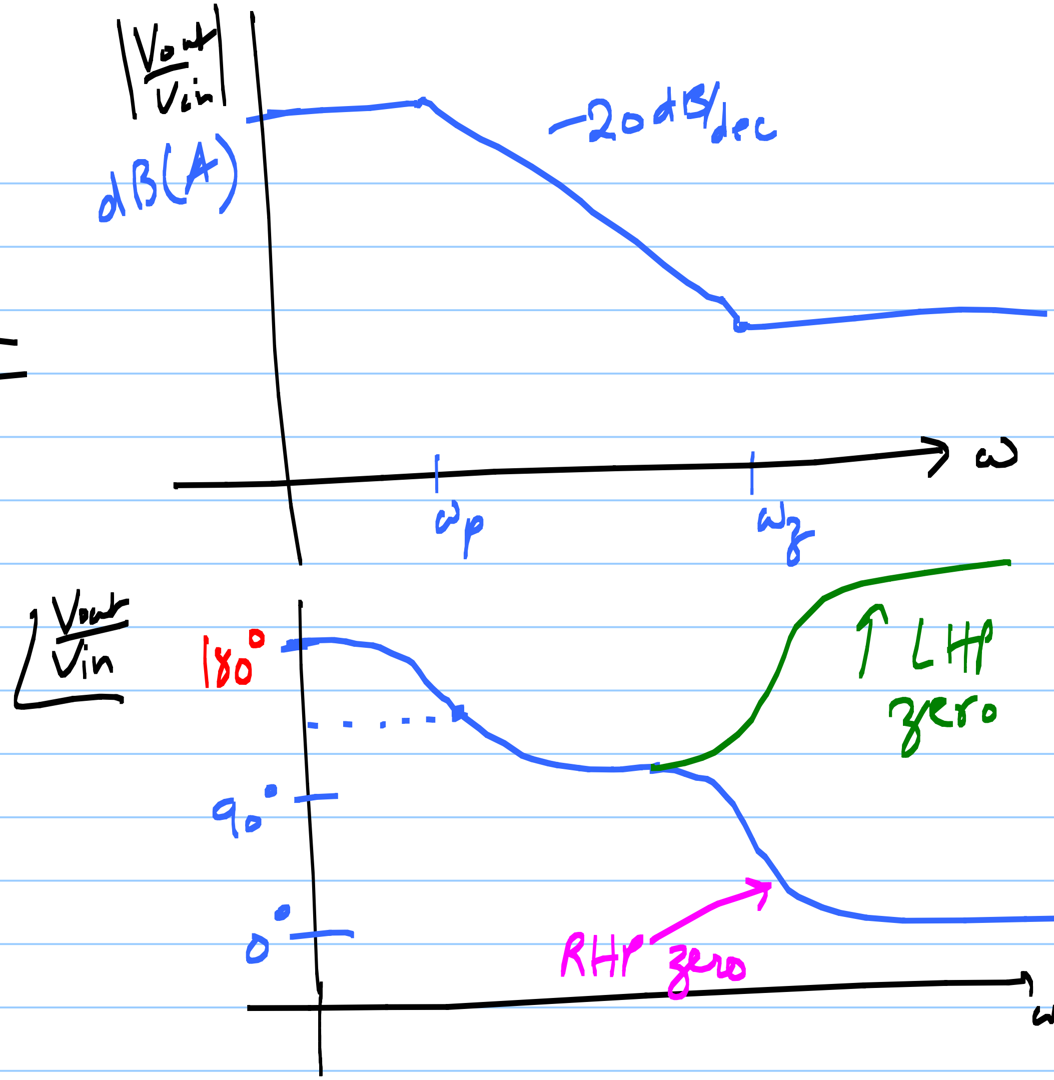
zero

pole

$$\omega_z = \frac{g_{m1}}{C_1}$$

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


jω
s-plane
σ
RHP zero


|Vout/Vin| dB(A)
-20dB/dec
ω
180°
90°
0°
LHP zero
RHP zero

$$\frac{A_v\left(1-\frac{s}{\omega_z}\right)}{\left(1+\frac{s}{\omega_p}\right)}$$

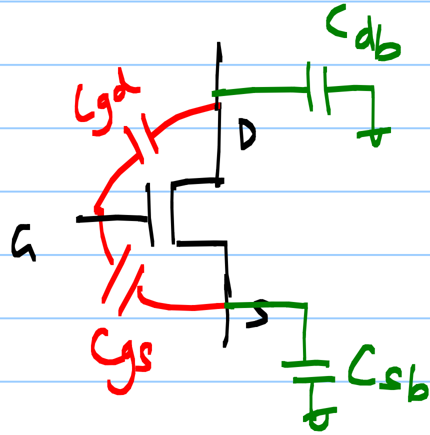
$$\sum_i \tan^{-1}\left(\frac{\omega}{\omega_{zi}}\right) - \sum_j \tan^{-1}\left(\frac{\omega}{\omega_{pj}}\right)$$

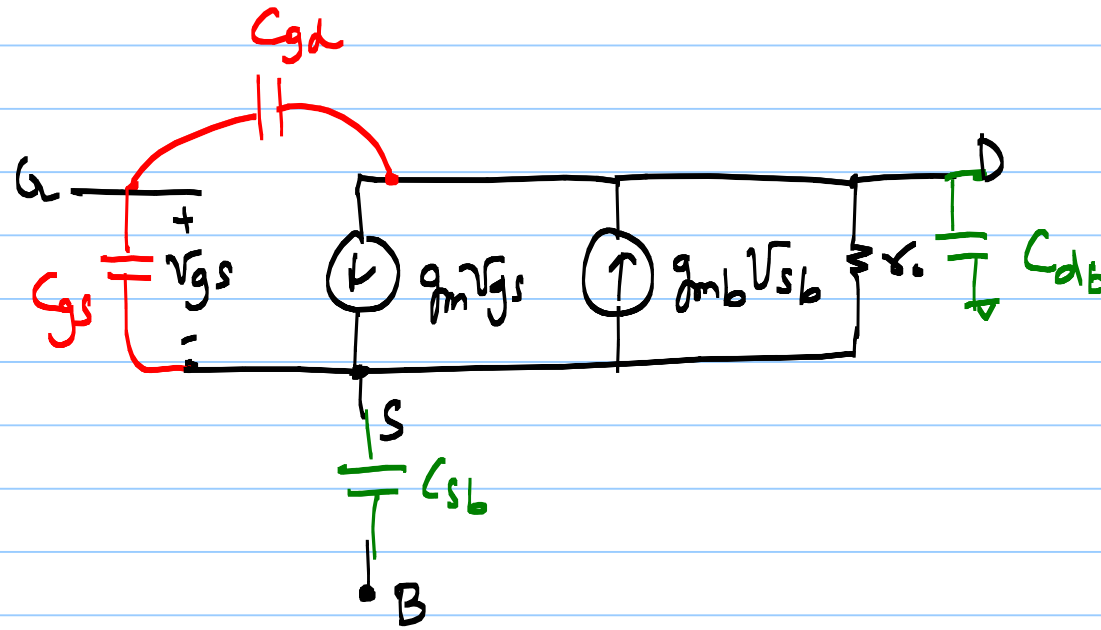
$$\angle\frac{V_{out}}{V_{in}} = -\tan^{-1}\left(\frac{\omega}{\omega_z}\right) - \tan^{-1}\left(\frac{\omega}{\omega_p}\right)$$

RHP zero pulls the phase down by total of 90°

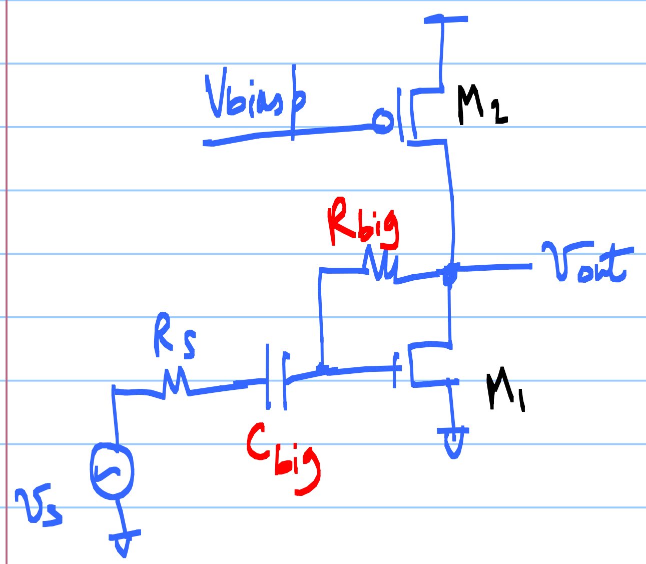
High-frequency small-signal Model

NMOS

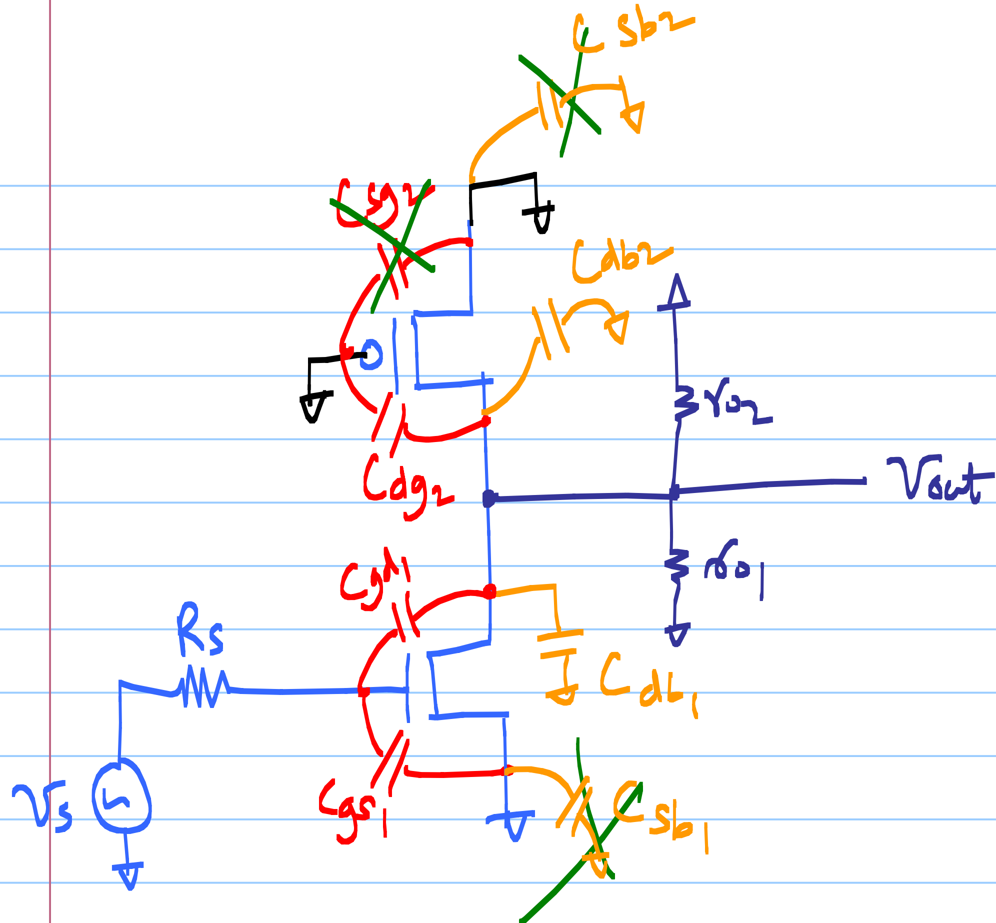




CS Stage



Ac picture with parasitics



grounded caps

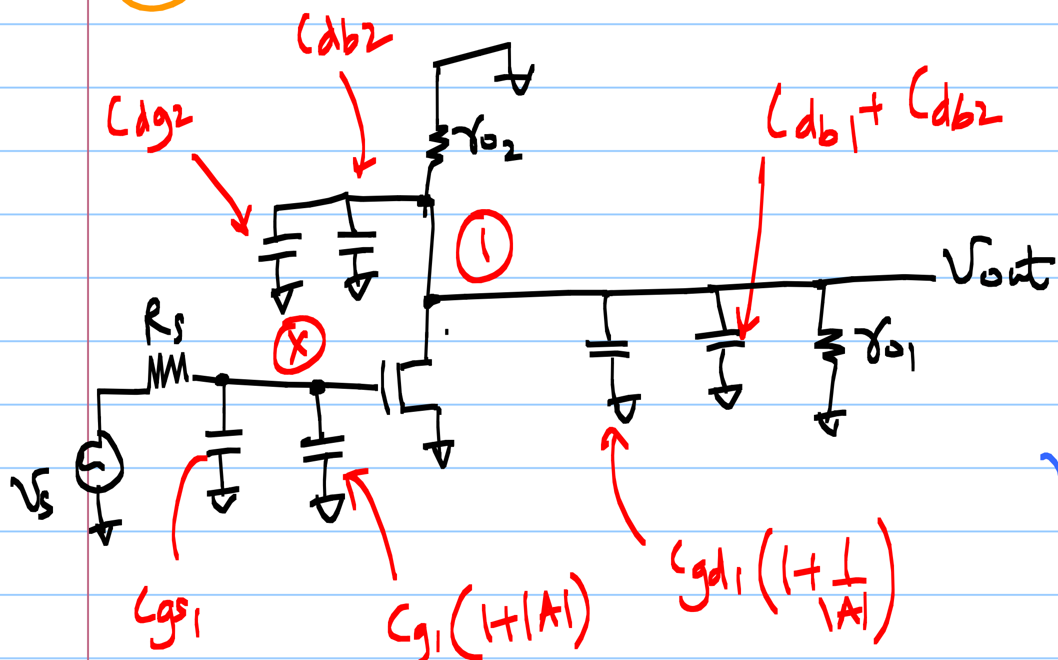
C_{gs1}, C_{db1}, C_{dg2}, C_{db2}

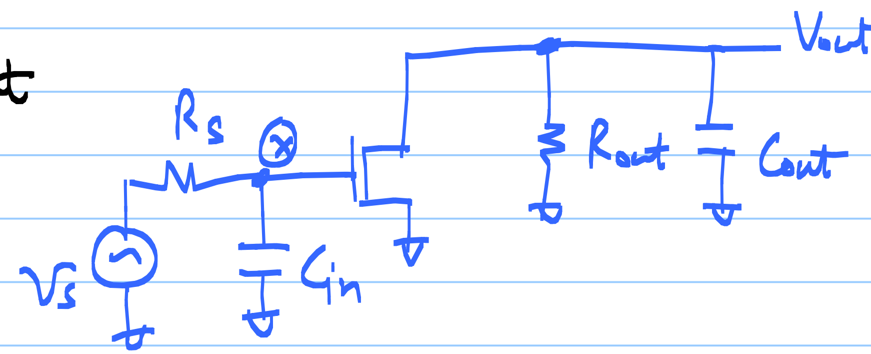
C_{gd1} ← between input & output

$$A_v = -g_{m1}(r_{o1} \| r_{o2})$$

Let's use Miller's Theorem

A





$$R_{out} = r_{o1} \,||\, r_{o2}$$

$$C_{in} = C_{gs1} + C_{gd1}(1+|A|)$$

$$C_{out} = C_{gd1}\left(1+\frac{1}{|A|}\right) + \overbrace{(C_{db1} + C_{db2})}^{C_{db}}$$

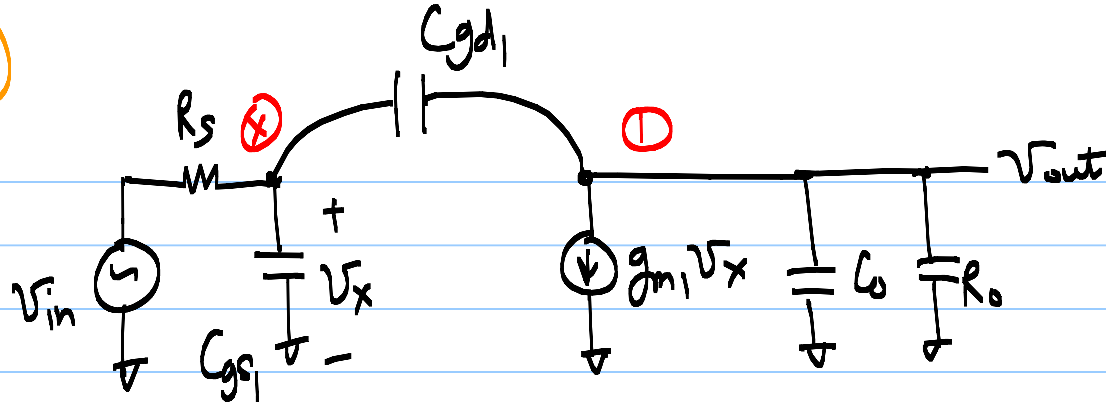
$$\omega_{in} = \frac{1}{R_s C_{in}} = \frac{1}{R_s\left[C_{gs_1} + (1+|A_v|)C_{gd_1}\right]}$$

$$\omega_{out} = \frac{1}{R_{out} C_{out}} = \frac{1}{(r_{o1} \| r_{o2})\left[C_{gd_1} + C_{db}\right]}$$

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

$\omega_z = ??$

A



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

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

$\frac{V_{out}}{V_{in}}(s) = ?$

X $$\frac{v_x - v_{in}}{R_s} + v_x C_{gs_1} s + (v_x - v_{out}) C_{gd_1} s = 0$$ ← Solve for v_x

Substitute here

1 $$(v_{out} - v_x) C_{gd_1} s + g_{m_1} v_x + v_{out}\left(\frac{1}{R_o} + C_o s\right) = 0$$

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

$$\frac{V_{out}}{V_{in}}(s) = \frac{\left(C_{gd_1}s - g_{m_1}\right)R_o}{R_sR_o\,\xi\,\boxed{s^2} + \left[R_s\left(1+g_mR_o\right)C_{gd_1} + R_sC_{gs_1} + R_o\left(C_{gd_1} + C_{db}\right)\right]\boxed{s} + \boxed{1}}$$

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