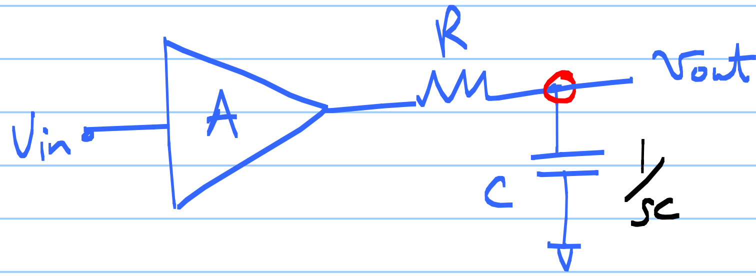
ECE 5411 – Lecture 16.

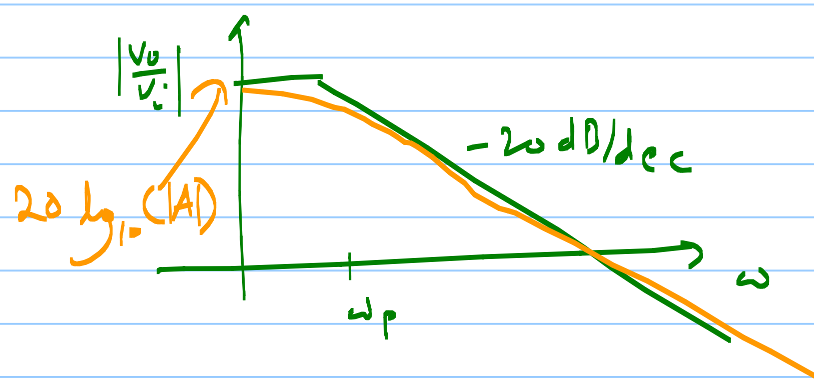
Note Title 3/21/2011

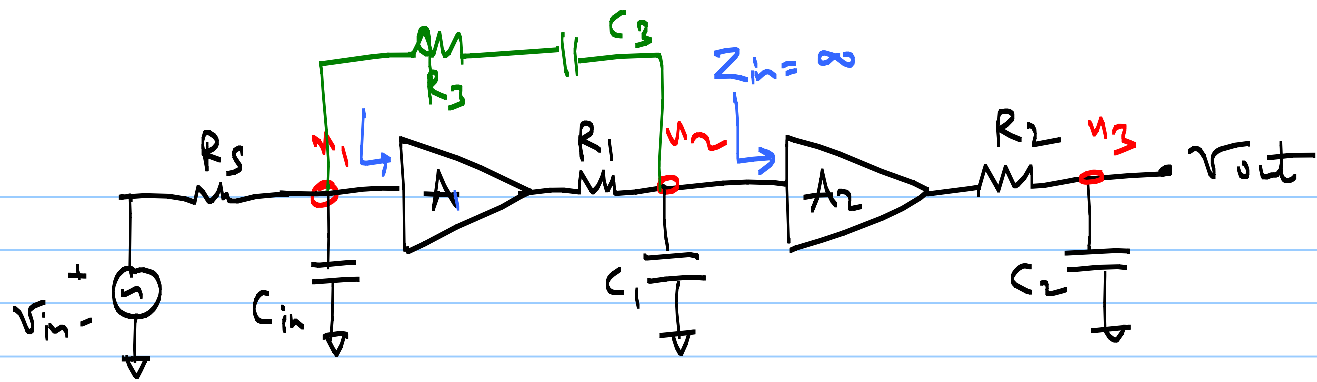


$$\frac{v_{out}}{v_{in}}(s) = \frac{A}{1 + sRC} = \frac{A}{1 + s/\omega_p}$$

$$\omega_p = \frac{1}{RC} = \frac{1}{\tau}$$

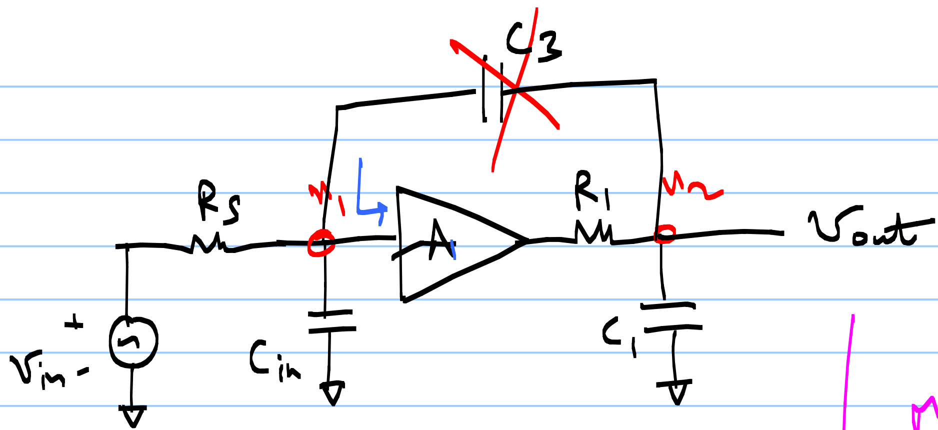
$s = j\omega$
$= j2\pi f$



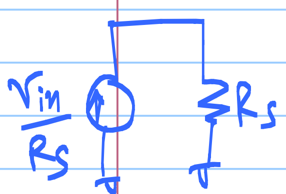


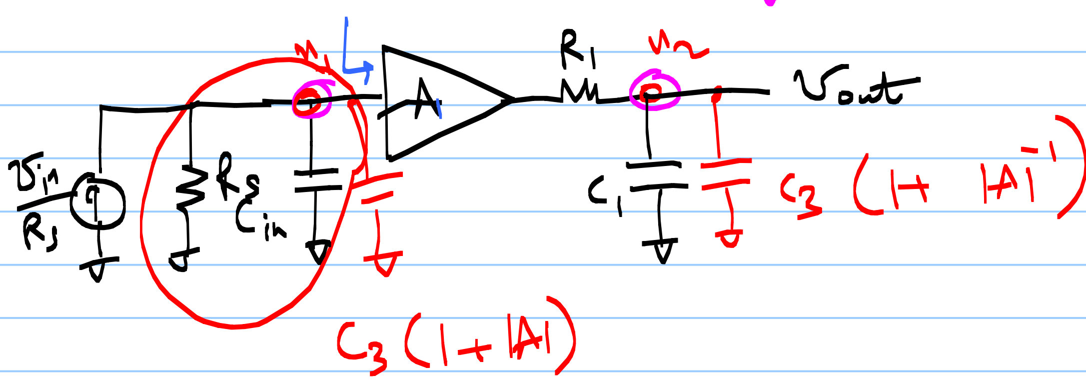
$$\frac{V_{out}}{V_{in}}(s) = \frac{1}{1 + s\underbrace{R_S C_{in}}_{\tau_1}} \cdot \frac{A_1}{1 + s\underbrace{R_1 C_1}_{\tau_2}} \cdot \frac{A_2}{1 + s\underbrace{R_2 C_2}_{\tau_3}}$$

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



Miller transformation

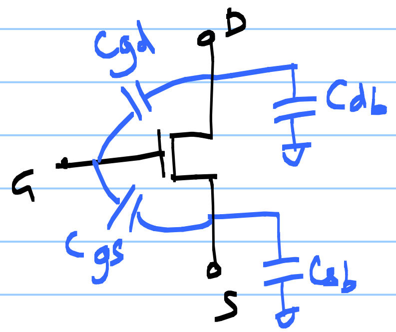


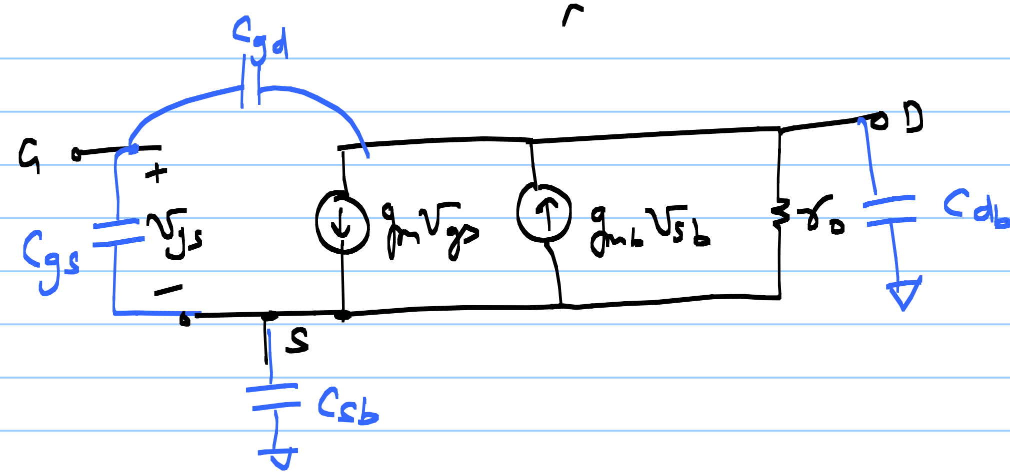


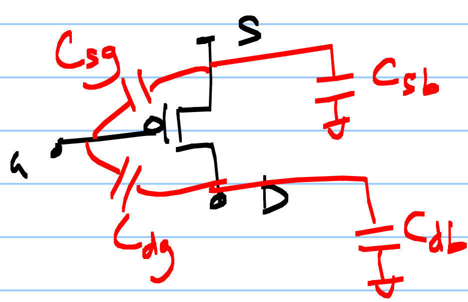
$$\omega_{in} = \frac{1}{R_s\left[C_{in} + C_3(1+|A|)\right]}$$

$$\omega_{out} = \frac{1}{R_1(C_1 + C_3)}$$

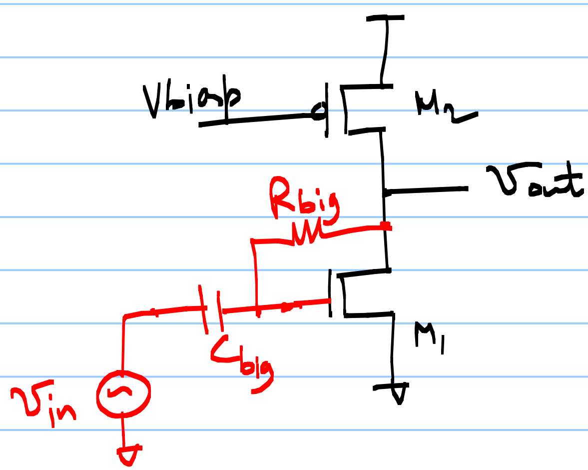
devices are in saturation





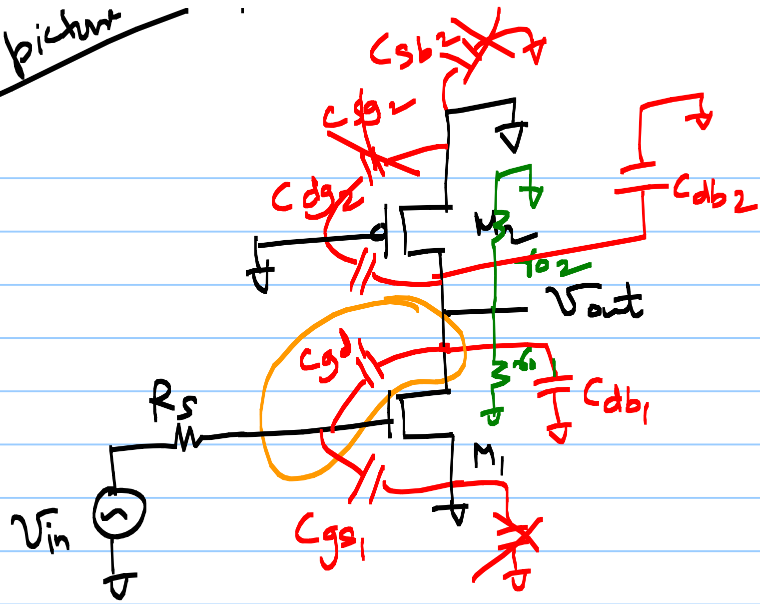


CS Stage



$$\omega_{DC} = \frac{1}{R_{big} C_{big}} \ll \omega_{in}$$

Ac picture



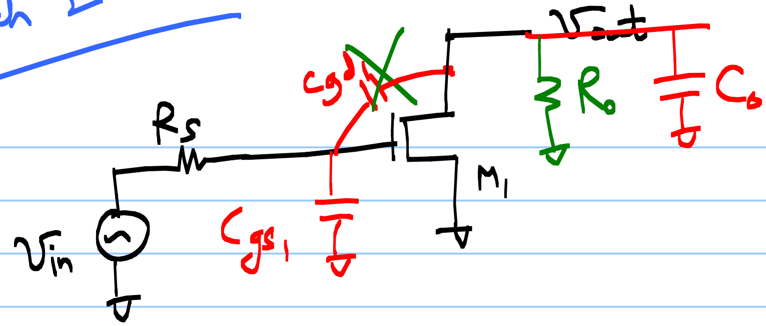
$A_v = -g_{m_1}(r_{o_1} \| r_{o_2})$ Low-freq gain

"Grounded Caps"

C_{gs_1}, C_{db_1}, C_{dg_2}, C_{db_2}

$C_{gd_1} \Rightarrow$ between input and output

Approach 2

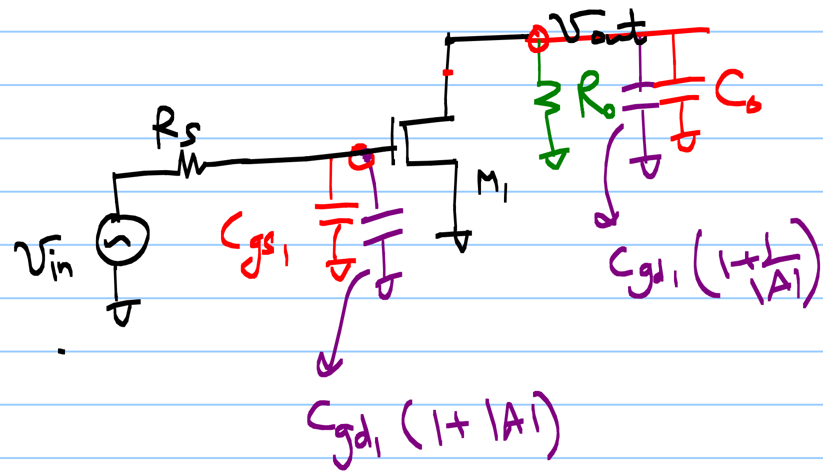


$C_{db} = C_{db_1} + C_{db_2}$

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

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

$|A| = g_{m_1}(r_{o_1} \| r_{o_2})$



poles

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

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

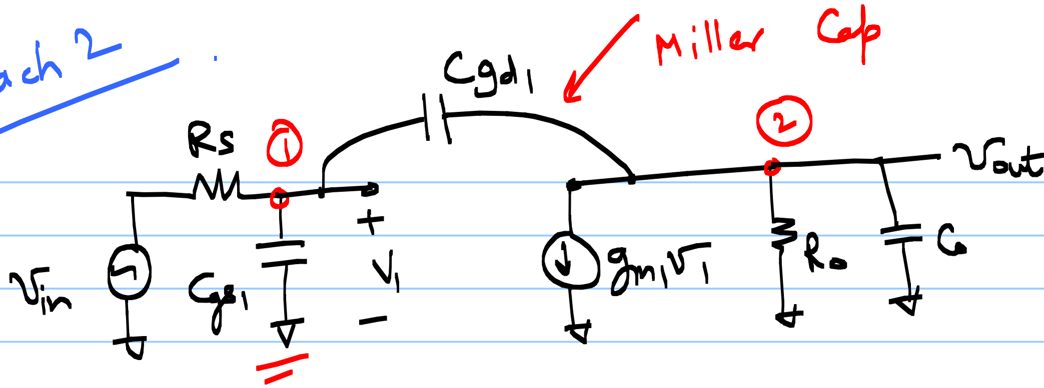
$$\frac{V_{out}}{V_{in}}(s) = \frac{A_v}{\left(1+\frac{s}{\omega_{in}}\right)\left(1+\frac{s}{\omega_{out}}\right)}$$

$$f_{in} = \frac{\omega_{in}}{2\pi}$$

$$f_{out} = \frac{\omega_{out}}{2\pi}$$

* Error in estimating the zero location.

Approach 2



$R_o = r_{o1} \| r_{o2}$

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

Nodal analysis

① $\Rightarrow$ $$\frac{v_x - v_{in}}{R_s} + v_x C_{gs1} s + (v_x - v_{out}) C_{gd1} s = 0$$

② $\Rightarrow$ $$(v_{out} - v_x) C_{gd1} s + g_{m1} v_x + v_{out}\left(\frac{1}{R_o} + C_o s\right) = 0$$

Solve for v_x and substitute in ②

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

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

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

$$N = (sC_{gd_1} - g_{m_1})R_o = 0$$

$$\omega_z = +\frac{g_{m_1}}{C_{gd_1}}$$ RHP zero

$$f_z = \frac{\omega_z}{2\pi} = \frac{g_{m_1}}{2\pi C_{gd_1}}$$

$$D = R_S R_o \xi\, s^2 + \left[R_s(1+g_{m1}R_o)C_{gd1} + R_s C_{gs1} + R_o(C_{gd1}+C_o)\right]s + 1 \longrightarrow (3)$$

Assume that $|\omega_{p1}| \ll |\omega_{p2}| \Rightarrow \frac{1}{|\omega_{p1}|} \gg \frac{1}{|\omega_{p2}|}$

$$D = \left(\frac{s}{\omega_{p1}}+1\right)\left(\frac{s}{\omega_{p2}}+1\right)$$

$$= \frac{s^2}{\omega_{p1}\omega_{p2}} + \left(\frac{1}{\omega_{p1}} + \cancel{\frac{1}{\omega_{p2}}}\right)s + 1 \longrightarrow (4)$$

Coeff^n of 's'

$$\boxed{\omega_{p1} = \frac{1}{R_s(1+\underbrace{g_{m1}R_o}_{|A|})C_{gd1} + R_s C_{gs1} + R_o(C_{gd1}+C_o)}}$$

$|A| \leftarrow$ Miller gain in C_{gd1}

with Miller appx. $\Longrightarrow$ $$\omega_{in} = \frac{1}{R_s C_{gs_1} + (1+|A|) R_s C_{gd_1}}$$

2nd pole:

$$\omega_{p2} = \frac{1}{\omega_{p1}} \times \frac{1}{R_s R_o \xi}$$

$\xi \rightarrow$ Xi

ksai

$$= \frac{1}{\omega_{p1}} \times \frac{1}{R_s R_o \left[C_{gs_1} C_{gd_1} + C_{gs_1} C_o + C_{gd_1} C_o \right]}$$

$$= \frac{R_s (1 + g_{m_1} R_o) C_{gd_1} + R_s C_{gs_1} + R_o (C_{gd_1} + C_o)}{R_s R_o \left[C_{gs_1} C_{gd_1} + C_{gs_1} C_o + C_{gd_1} \cdot C_o \right]}$$

$$\Rightarrow \quad \omega_{p2} = \frac{R_S(\cancel{1+g_{m1}R_o})C_{gd1} + \cancel{R_S}C_{gs1} + \cancel{R_o(C_{gd1}+C_o)}}{\cancel{R_S}R_o\left[C_{gs1}C_{gd1} + C_{gs1}C_o + \cancel{C_{gd1}C_o}\right]}$$

Assumption

$$* \text{ If } \quad \underline{C_{gs1}} \gg (1+g_{m1}R_o)C_{gd1} + \frac{R_o}{R_S}(C_{gd1}+C_o)$$

↳ Miller Cap is very small compared to C_{gs1}

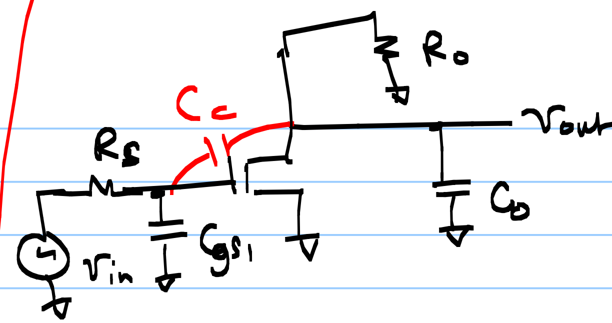
$$\omega_{p2} \simeq \frac{1}{R_o(C_{gd1}+C_o)}$$

Same as ω_{out}

↳ Valid only when C_{gs1} dominates the response

↳ otherwise not!

$$\boxed{\begin{aligned} \Rightarrow\ \omega_z &= \frac{g_{m_1}}{C_c} \qquad\qquad |\omega_{p_1}| \ll |\omega_{p_2}| \\ \omega_{p_1} &= \frac{1}{R_s[(1+|A_v|)C_c + C_{gs_1}] + R_o[C_c + C_o]} \\ \omega_{p_2} &= \frac{R_s(1+g_{m_1}R_o)C_c + R_sC_{gs_1} + R_o[C_c + C_o]}{R_sR_o[C_{gs_1}C_c + C_{gs_1}C_o + C_cC_o]} \end{aligned}}$$



$C_c = C_{gd_1} + C_c'$

* for $\overset{C_{gd_1}}{C_c} \simeq 0$, and a large C_o

$$\omega_{p_1} \simeq \frac{1}{R_sC_{gs_1} + R_oC_o}, \qquad \omega_{p_2} = \frac{\cancel{R_s}\cancel{C_{gs_1}} + \cancel{R_oC_o}}{\cancel{R_s}R_o \cdot \cancel{C_{gs_1}}C_o} \simeq \frac{1}{R_oC_o}$$

* Now, increase C_c

Consider when, $C_c >> C_{gs1}$

$$\omega_{p1} \simeq \frac{1}{R_S(1+|A|)C_c + R_o(C_c + C_o)}$$

$$\omega_{p2} \simeq \frac{\cancel{R_S}(1+g_{m1}R_o)\cancel{C_c}}{\cancel{R_S}R_o\cancel{C_c}[C_o + C_{gs1}]} \simeq \boxed{\frac{g_{m1}}{C_o + C_{gs1}}}$$

	$C_c = 0$	Typical Case: $C_c >> C_{gs_1}$, $C_c \simeq C_o$
ω_{p_1}	$\simeq \dfrac{1}{R_s C_{gs_1} + R_o C_o}$	$\simeq \dfrac{1}{\underline{\underline{R_s(1+\lvert A\rvert)C_c}} + R_o[C_c + C_o]}$ $\downarrow$
ω_{p_2}	$\simeq \dfrac{1}{\underline{R_o C_o}}$	$\simeq \dfrac{g_{m_1}}{C_o + C_{gs_1}} \simeq \dfrac{g_{m_1}}{C_o} = \underline{\underline{g_{m_1} R_o}} \left[\dfrac{1}{\underline{R_o C_o}}\right]$ $\uparrow$
ω_z	$\simeq \dfrac{g_m}{C_{gd_1}}$	$\dfrac{g_m}{C_c}$

Pole Splitting