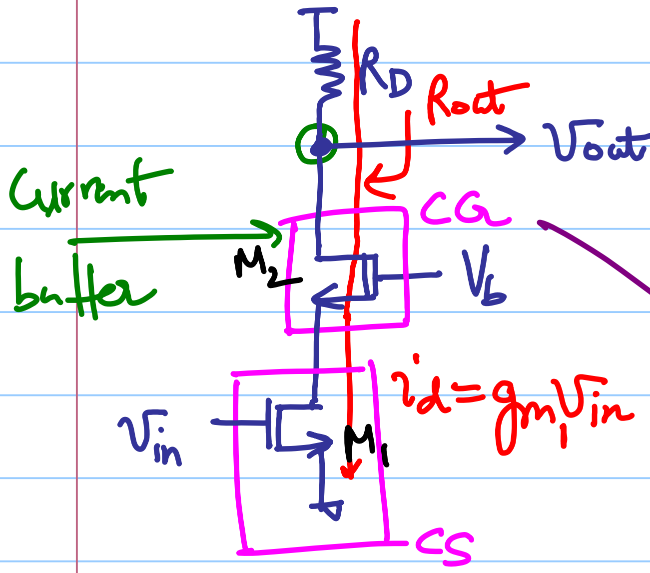
ECE 511 - Lecture 16

Note Title 3/18/2014

HW #6 due
April 1^{st}

Cascode Amplifier



Lemma:

transconductance shorting the o/p to ground

$$A_v = -g_m \cdot R_{out}$$

o/p impedance when $v_{in} = 0$

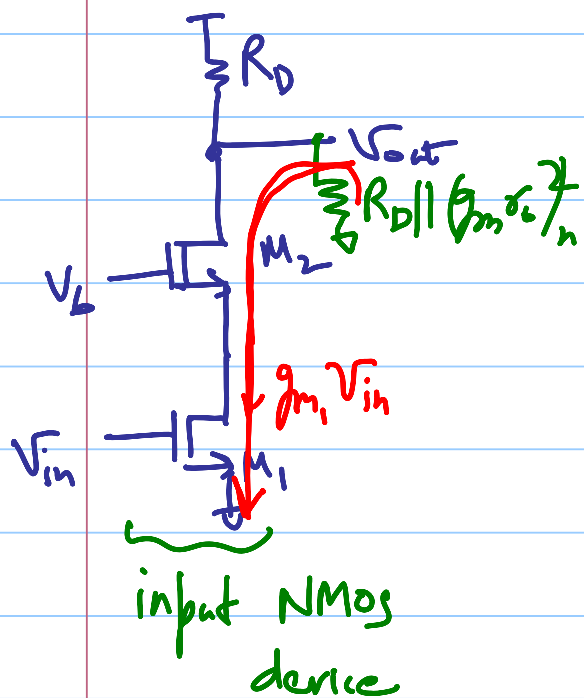
$$A_v = -g_m \cdot R_{out}$$

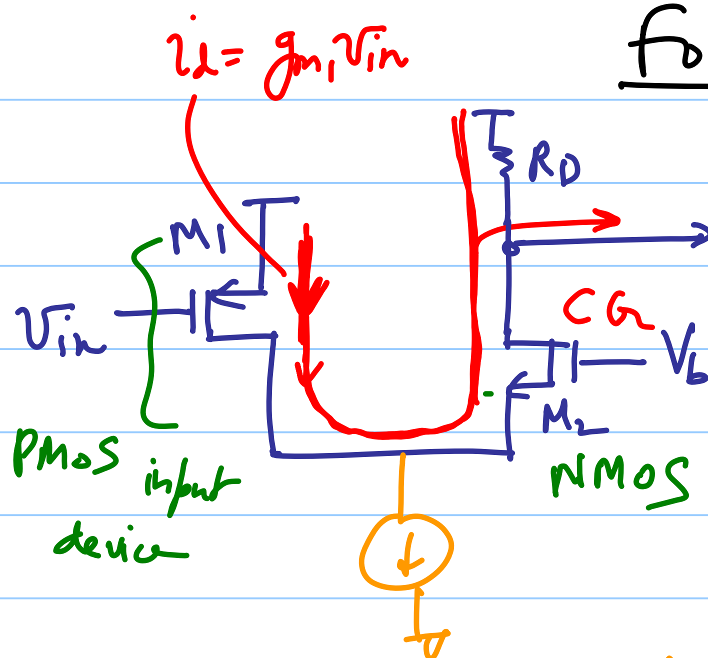
$g_m \rightarrow g_{m_1}$

$R_{out} \rightarrow R_D \,||\, (g_m r_o^2)_n$

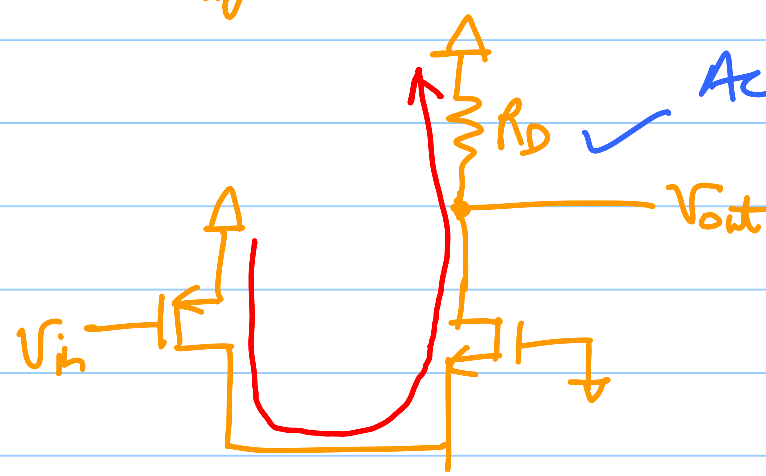
$R_D \rightarrow (g_m r_o^2)_p$ ← PMOS Cascode C.M load

Folded Cascode Amplifier

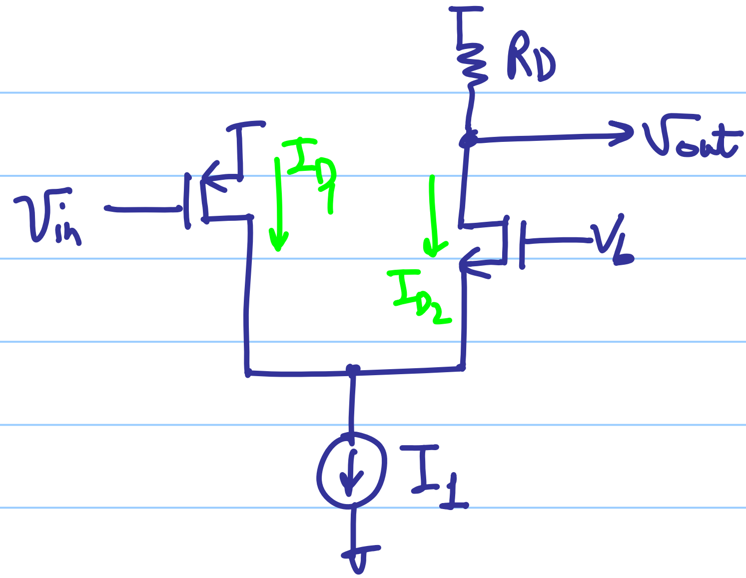




Small signal current is folded up



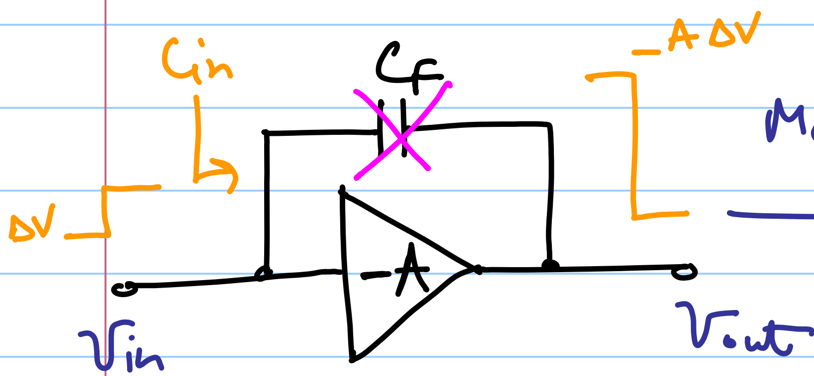
AC picture



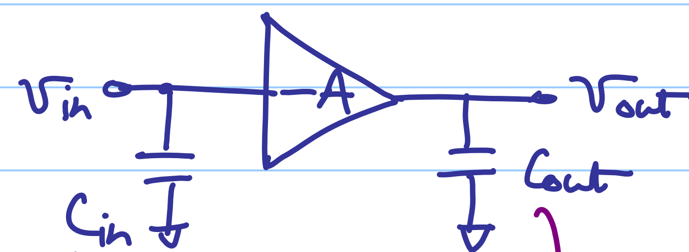
* 2x bias current
  ↓
  $(I_{D_1} + I_{D_2})$

* better headroom

Miller Effect:

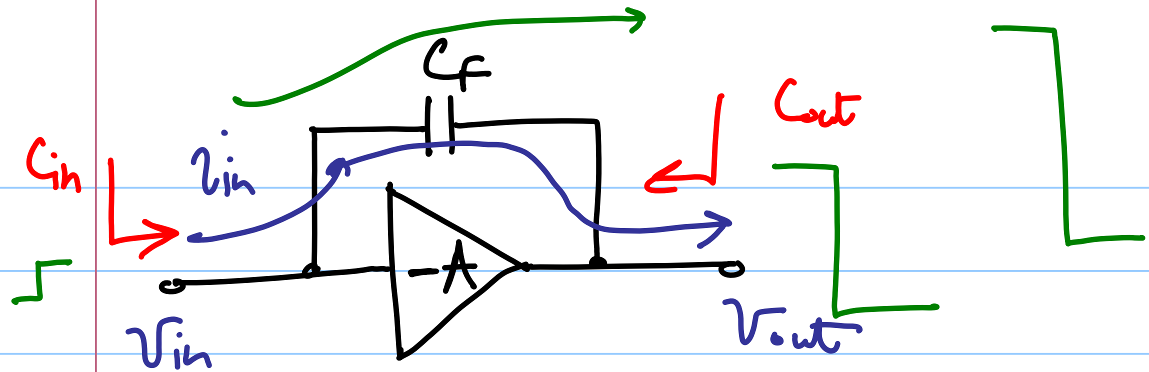


Miller Theorem



$C_f(1+|A|) \simeq |A| \cdot C_f$ $\quad |A| \gg 1$

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



Eq. input capacitance is multiplied by $|A|$

$-AV_{in}$

$$i_{in} = \frac{V_{in} - V_{out}}{1/sC_F} = sC_F(V_{in} - V_{out})$$

$$= sC_F(V_{in} + |A|V_{in})$$

$$= s\underbrace{C_F(1+|A|)}_{C_{in}} \cdot V_{in}$$

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

$$= (sC_{in})\,V_{in}$$

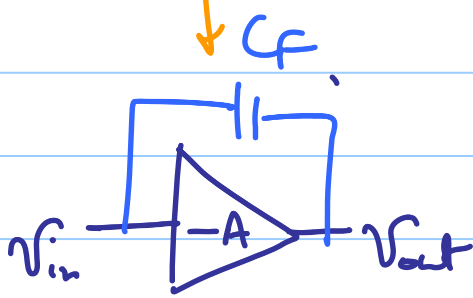
$$i_{out} = -i_{in} = -sC_F(V_{in} - V_{out})$$

$$= -sC_F\left(\frac{-V_{out}}{|A|} - V_{out}\right)$$

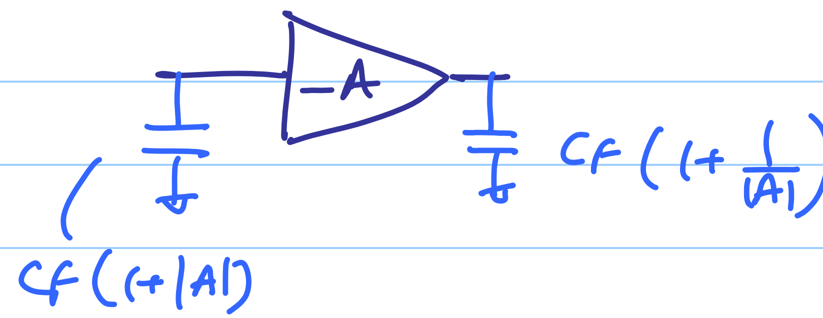
$$i_{out} = s\underbrace{C_F\left(1+\frac{1}{|A|}\right)}_{C_{out}} V_{out}$$

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

feedforward capacitor



approximation $\Rightarrow$



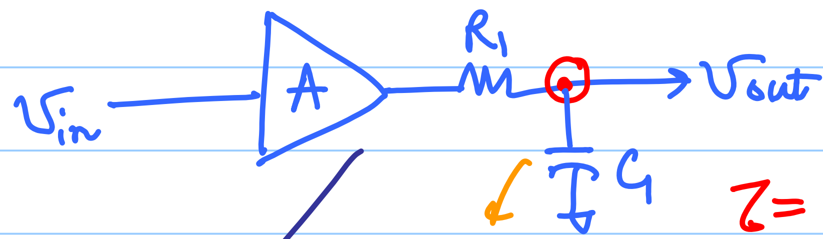
$\underbrace{\hspace{6em}}$

useful in analysis

* What happen at $\omega \to \infty$

* misses a zero in the T.F.

Poles $\longleftrightarrow$ Nodes

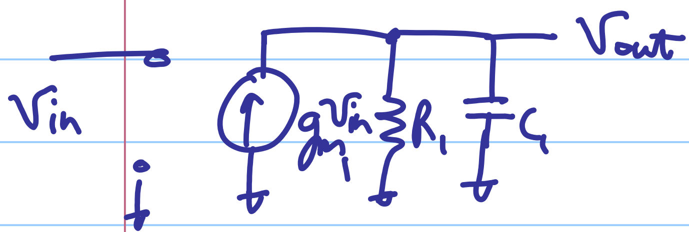


$$X_{C_1} = \frac{1}{sC_1}$$

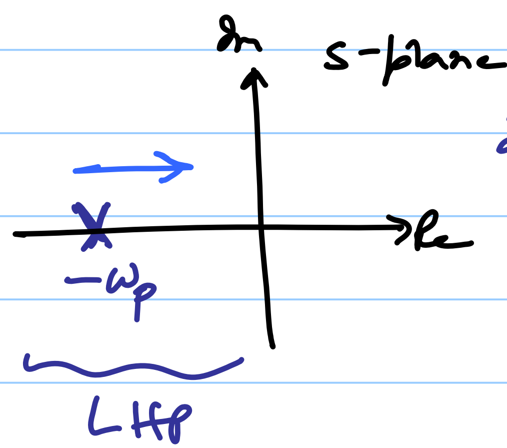
$$Z = R_1 C_1$$

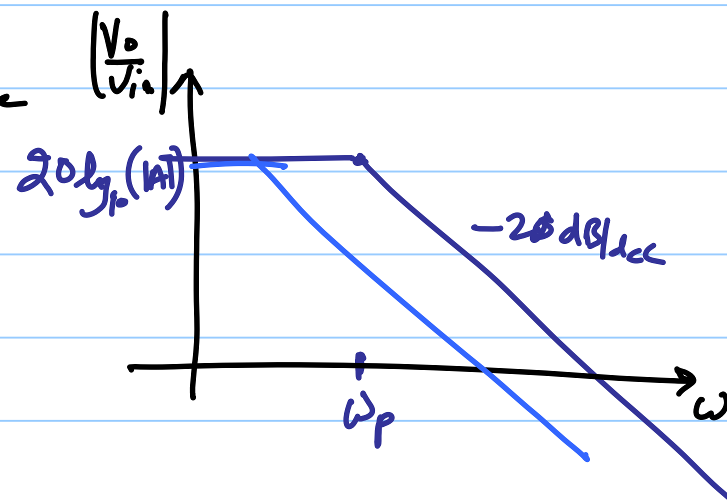
$$\frac{V_{out}}{V_{in}}(s) = \frac{A}{1 + sR_1C_1}$$

$$= \frac{A}{1 + \frac{s}{\omega_p}}$$ — pole



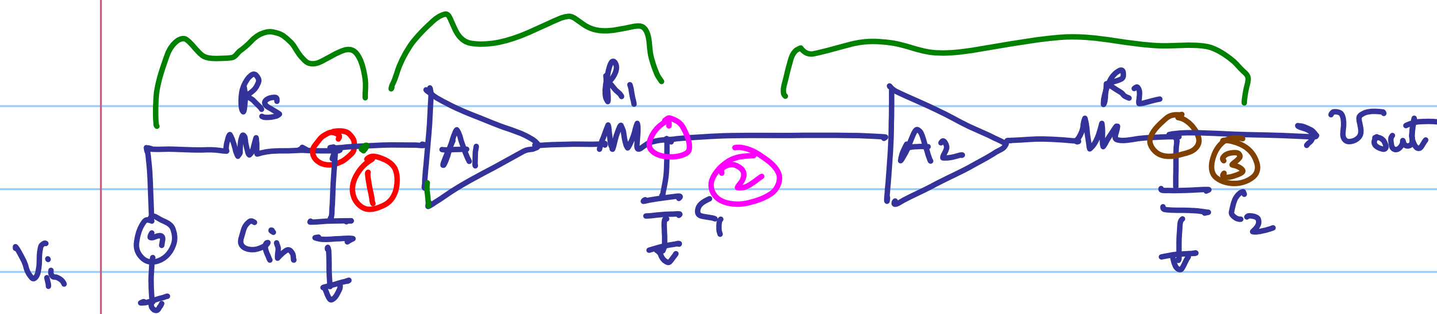
$$A = g_{m_1} R_1$$





$$\omega_p = \frac{1}{R_1 C_1}$$

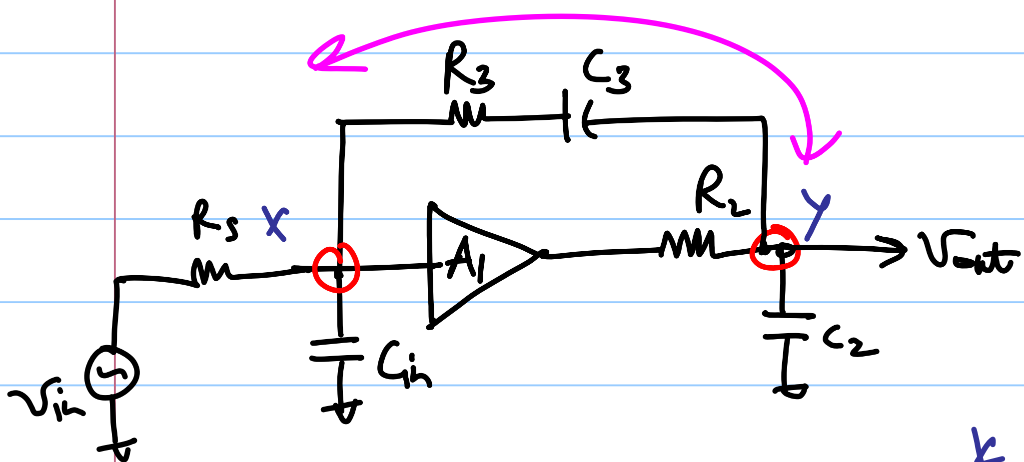
$$f_p = \frac{1}{2\pi R_1 C_1}$$



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

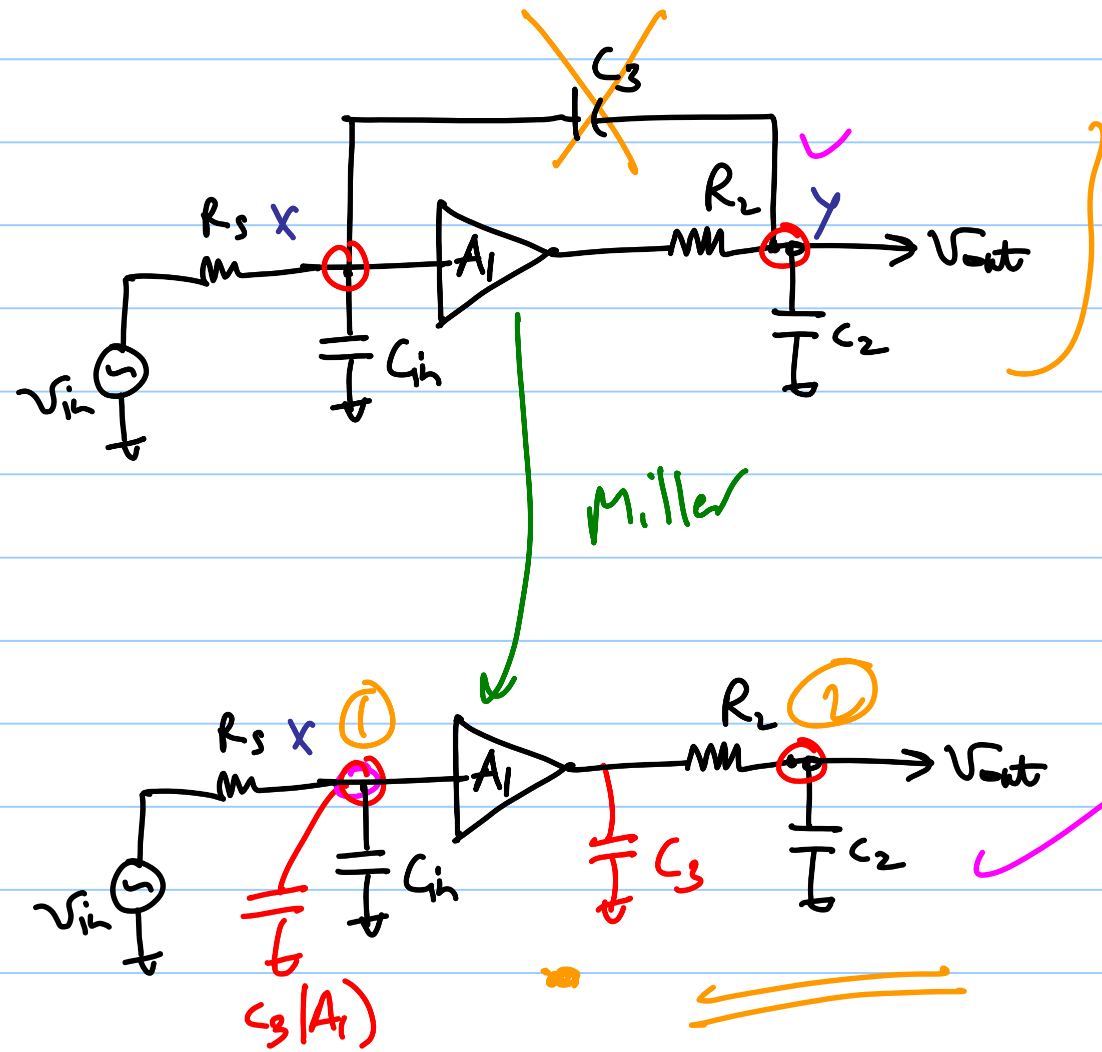
3 poles

each node contributes a pole to the transfer function

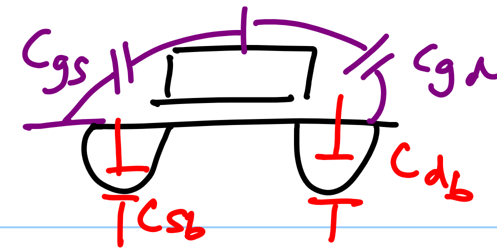


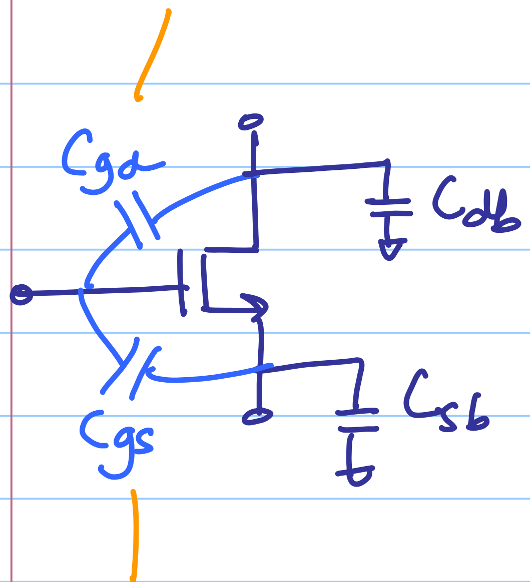
nodes X & Y are interacting through R_3 & C_3

* In general can't associate a pole to a node
* All poles are contributed by all interacting nodes in the circuit

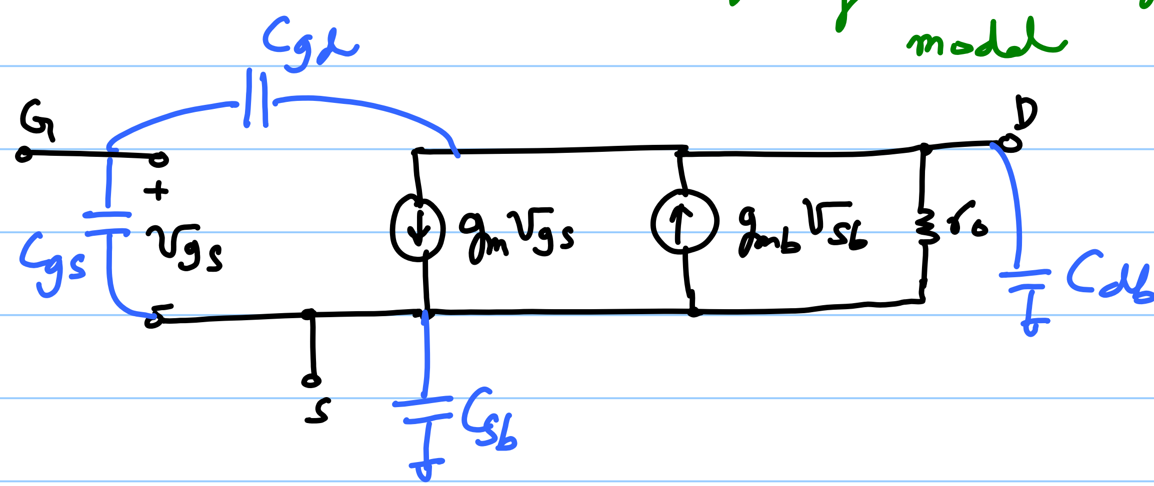


ok for intuition but may not always be accurate

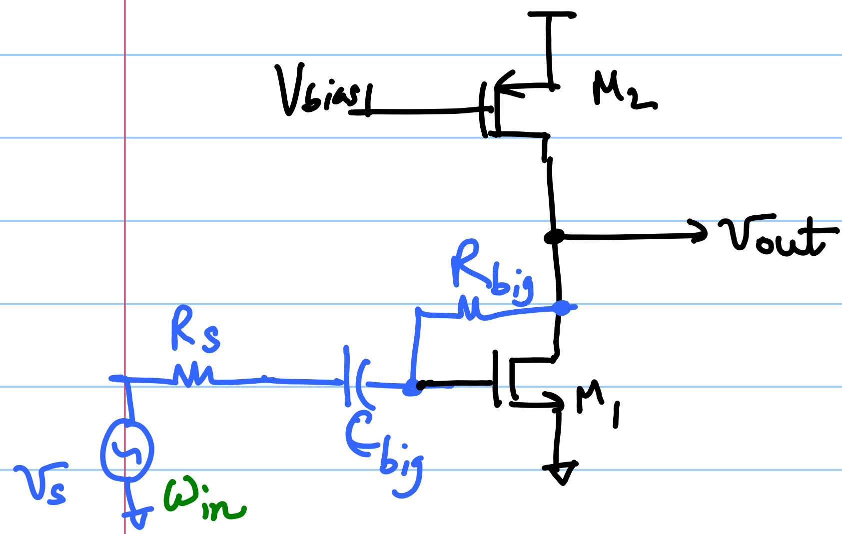




High-frequency small-signal model



CS Stage

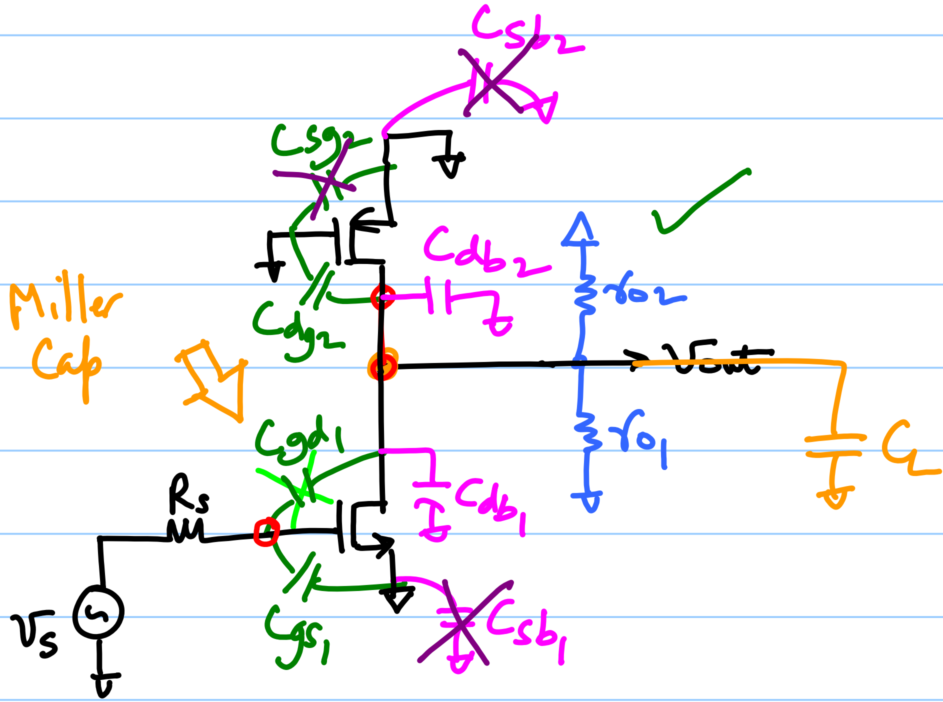


$$A_v = -g_{m1}(r_{o1} \| r_{o2})$$

low-freq gain

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

Ac picture with parasitic Caps

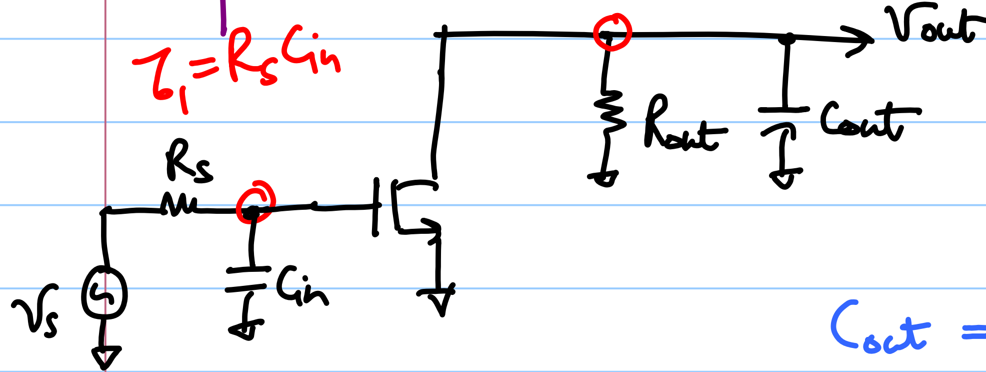


Let's use Miller appx. and derive quick results

ω_{in}

$\tau_1 = R_S C_{in}$

$\tau_2 = R_{out} C_{out} \rightarrow \omega_{out}$



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

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

$$C_{out} = C_{gd_1}\left(1 + \frac{1}{|A|}\right) + C_{db_1} + C_{db_2} + C_{dg_2}$$

$$\omega_{in} = \frac{1}{R_S C_{in}} = \frac{1}{\underbrace{R_S}\,[\underbrace{C_{gs_1} + (1+|A|)\,C_{gd_1}}]} \rightarrow \infty$$

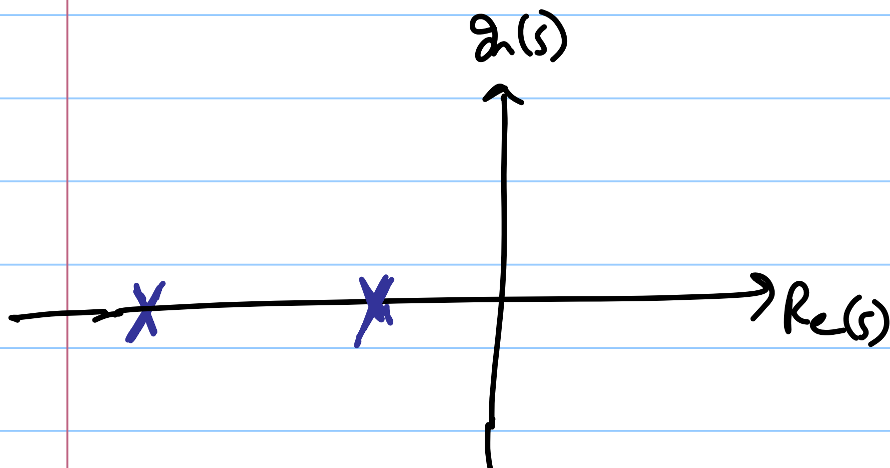
$R_S \simeq 0$

$$\omega_{out} = \frac{1}{R_{out} \cdot C_{out}} = \frac{1}{\underbrace{(r_{o1}||r_{o2})}\,[\underbrace{C_{gd_1} + C_{db} + C_{dg_2}}_{+\,C_L}]} \leftarrow \text{low-freq pole}$$

$$\simeq \frac{1}{(r_{o1}||r_{o2})\,C_L}$$

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

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

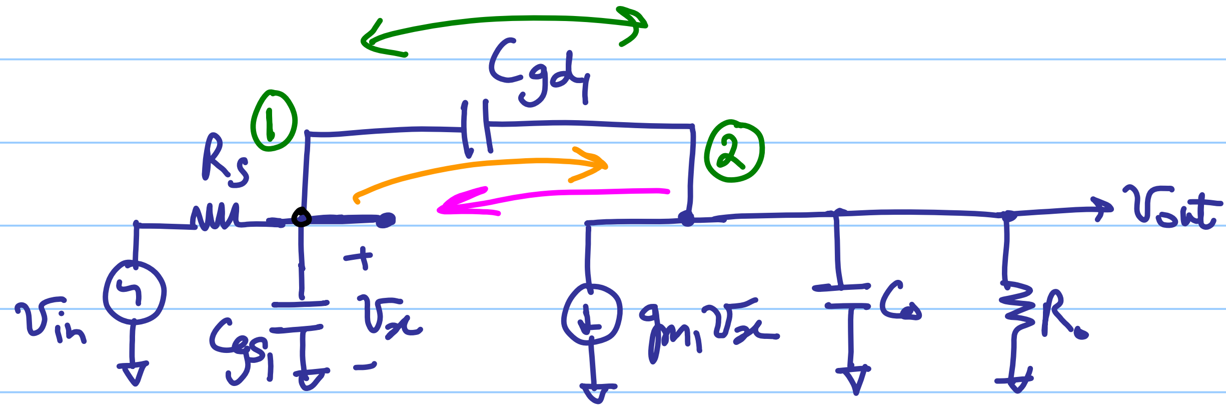


"Miller appx. doesn't capture the zero"

Draw Equivalent Circuit.

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

$C_o = C_{db} + C_{dj_2}$



Evaluate T.F.

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

Write Nodal equations @ 1 & 2

KCL

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

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