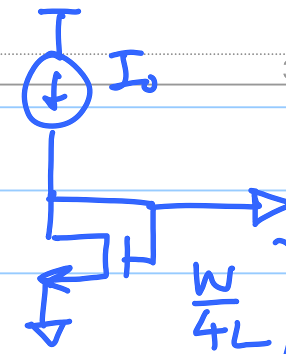
ECE 511 – Lecture 15

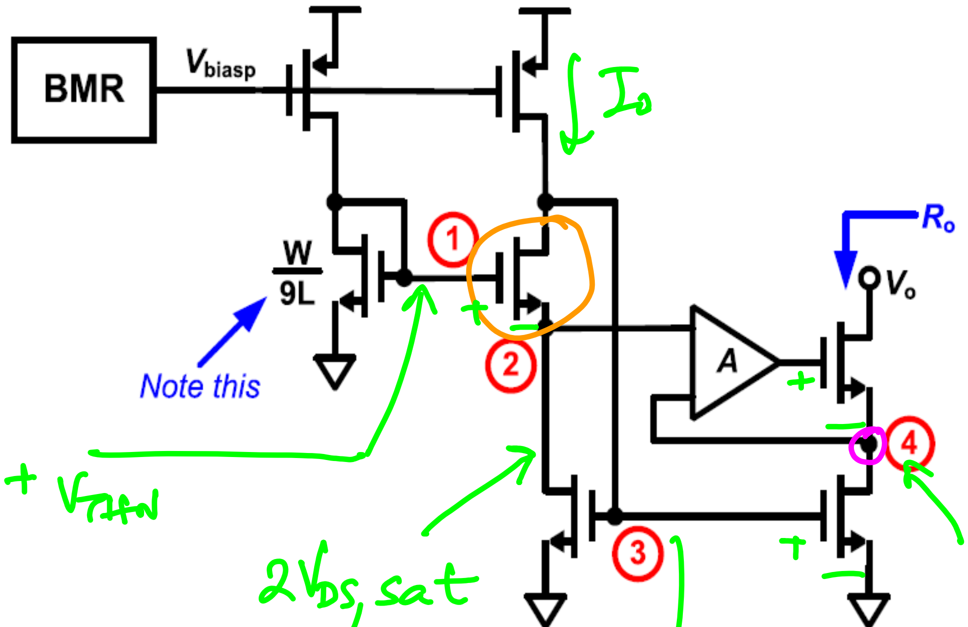
Note Title 3/10/2015



$2V_{DS,sat} + V_{THN}$

for $\frac{W}{9L}$

$\hookrightarrow 3V_{DS,sat} + V_{THN}$



I_o

$3V_{DS,sat} + V_{THN}$

$2V_{DS,sat}$

$2V_{DS,sat}$

$V_{DS,sat} + V_{THN}$

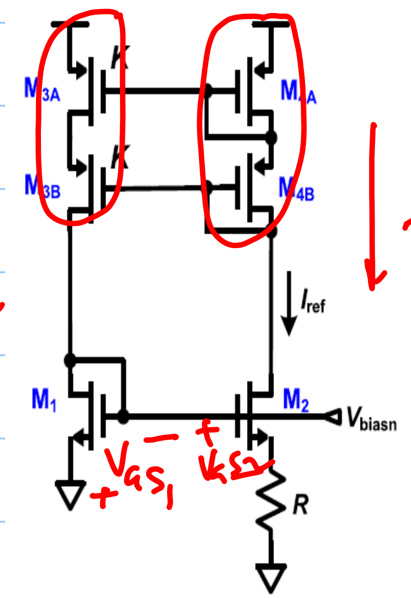
$$V_{DS} = V_{DS,sat} + V_{THN} - 2V_{DS,sat}$$

$$= V_{THN} - V_{DS,sat} > V_{DS,sat} \text{ for Saturation}$$

$V_{THN} > 2 V_{DS,sat}$

$40\,mV > 160\,mV$

KIref



Iref

$$I_{ref} = \frac{2}{\beta R^2}\left(\sqrt{K} - 1\right)^2$$

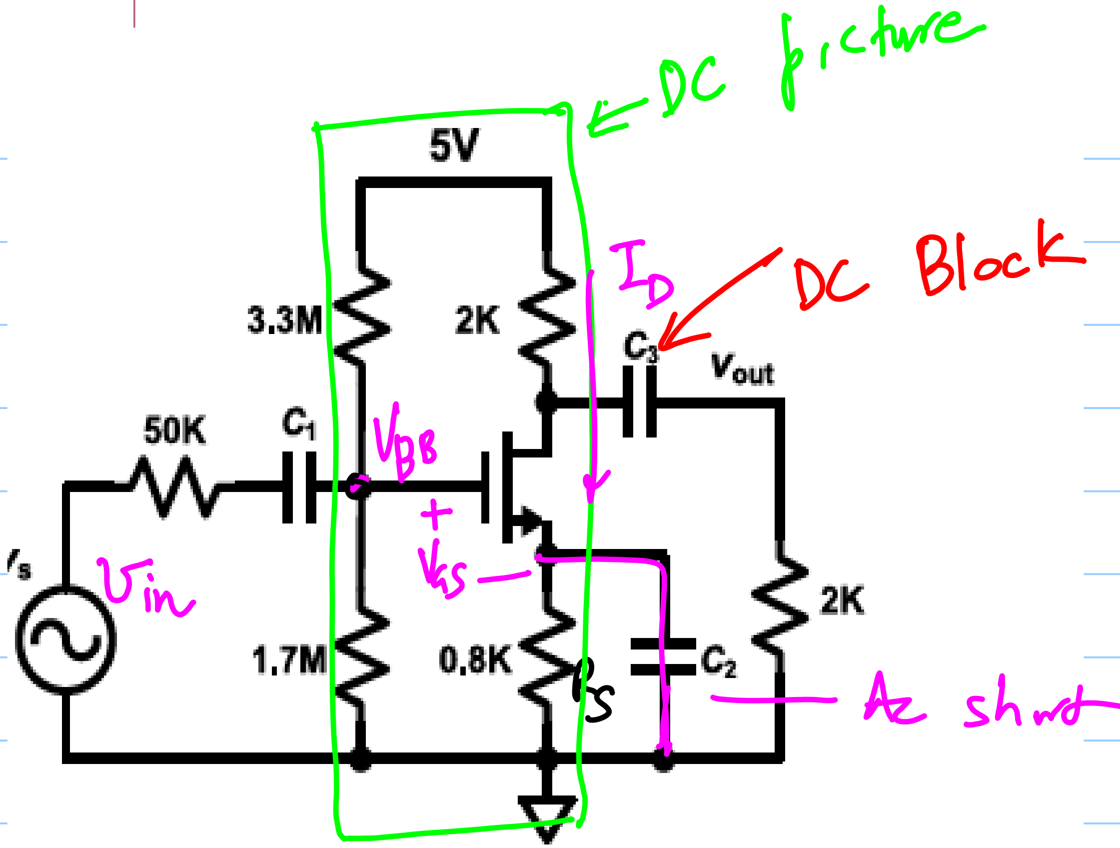
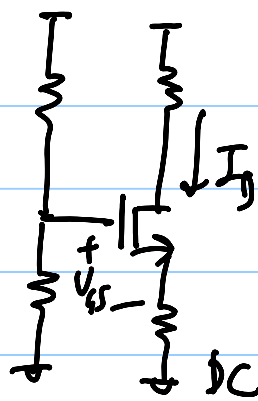


Figure 2

$$V_{BB} = 1.7V$$

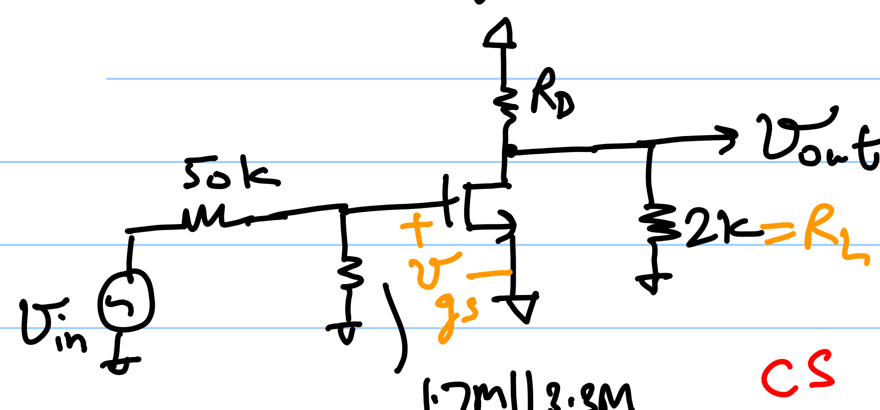
$$V_{GS} = V_{BB} - I_D R_S \rightarrow (1)$$

$$I_D = \frac{KP_n}{2}\frac{W}{L}\left(V_{GS} - V_{THN}\right)^2 \rightarrow (2)$$

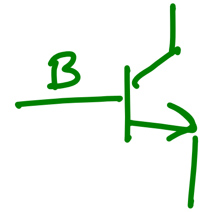


DC picture

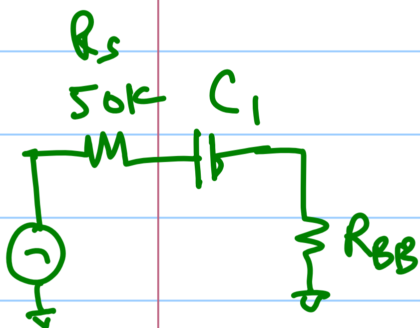
Ac picture



CS Amplifier



$R_{BB} = 3.3M \| 1.7M$



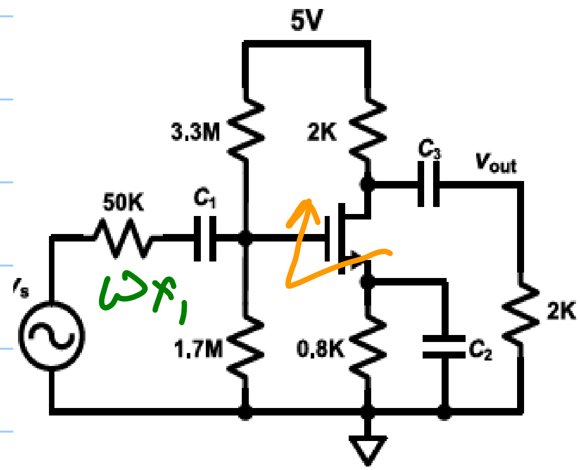
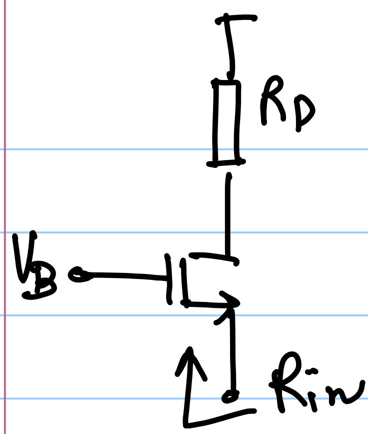


Figure 2

$$\tau = (R_{BB}+R_s)C_1$$

$$\omega_{x_1} = \frac{1}{(R_{BB}+R_s)C_1} < \frac{\omega_{in}}{10}$$



$$R_{in} \simeq \frac{R_D + r_o}{\cancel{1+}\,(g_m + g_{mb})\, r_o}$$

(a) $R_D = 0$, (SF case)

$$R_{in} \simeq \frac{1}{g_m + g_{mb}} \simeq 1/g_m$$

(b) $R_D = r_o$

$$R_{in} \simeq \frac{2\cancel{r_o}}{(g_m + g_{mb})\cancel{r_o}} = \frac{2}{g_m + g_{mb}} \simeq 1/g_m$$

(c) $R_D = g_m r_o^2$ (Cascode CM load)

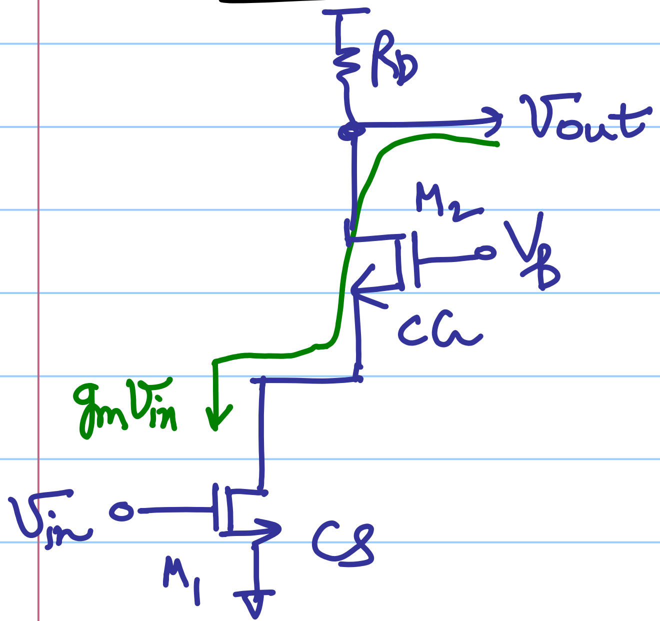
$$R_{in} \simeq \frac{g_m r_o^2 \cancel{+ r_o}}{(g_m + g_{mb})\, r_o} = \frac{g_m r_o}{g_m + g_{mb}}$$

$$= \frac{r_o}{(1+\eta)} \sim \text{of the order of } r_o$$

Amplifier	gain	Z_{in}	Z_{out}
CS	Large	∞	Moderate $\rightarrow$ "gain" Amplifier
CS + SD	Moderate	∞	High $\rightarrow$ linear amp
CD / SF	<1	∞	low $\approx \frac{1}{g_m}$ $\rightarrow$ Voltage Buffer
CG	Moderate	low $\approx 1/g_m$	Moderate/high $\rightarrow$ Current Buffer

Small-signal, low-frequency gain

Cascode Stage



$$V_{out} = -g_m V_{in} \left(R_D \| g_m r_o^2 \right)$$

$$A_v = -g_m \left(R_D \| g_m r_o^2 \right)$$

$g_m r_o^2$

Lemma:

In a linear circuit voltage gain $= -G_m R_{out}$

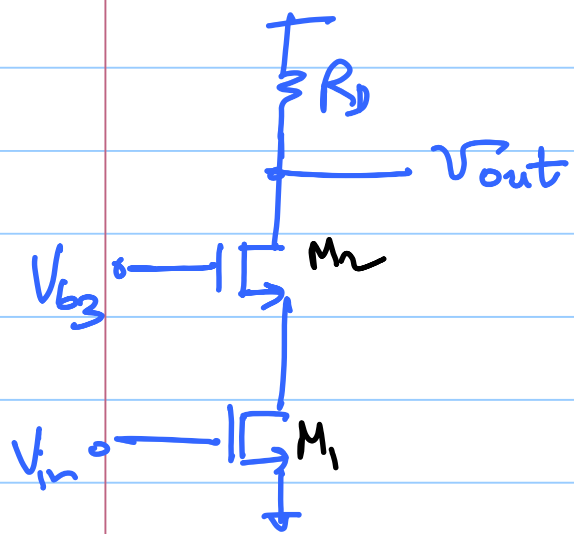
where,

$G_m \rightarrow$ transconductance of the circuit when the output is shorted to ground

&

$R_{out} \rightarrow$ output resistance of the circuit when the input is at zero.

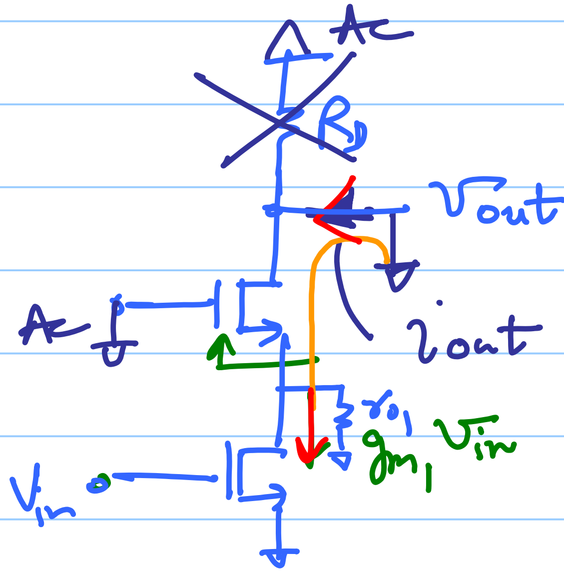
Cascode Amplifier.



$$R_{out} = R_D \,||\, (g_{m_2} r_{o_2} r_{o_1})$$

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

G_m



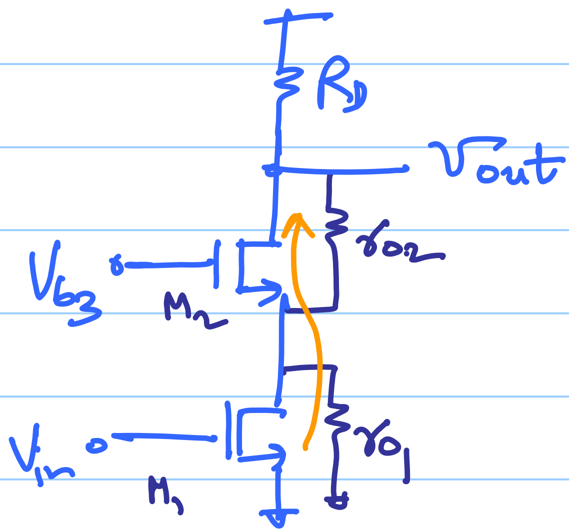
$$G_m \triangleq \frac{i_{out}}{v_{in}}$$

assume most of the current is relayed by M_2

$$i_{out} = g_{m_1} v_{in}$$

$$\Rightarrow \boxed{G_m = g_{m_1}}$$

* See Textbook for more accurate analysis

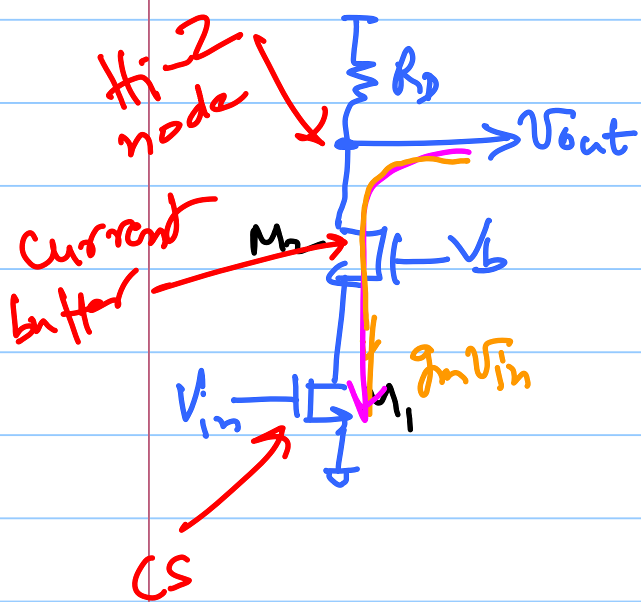


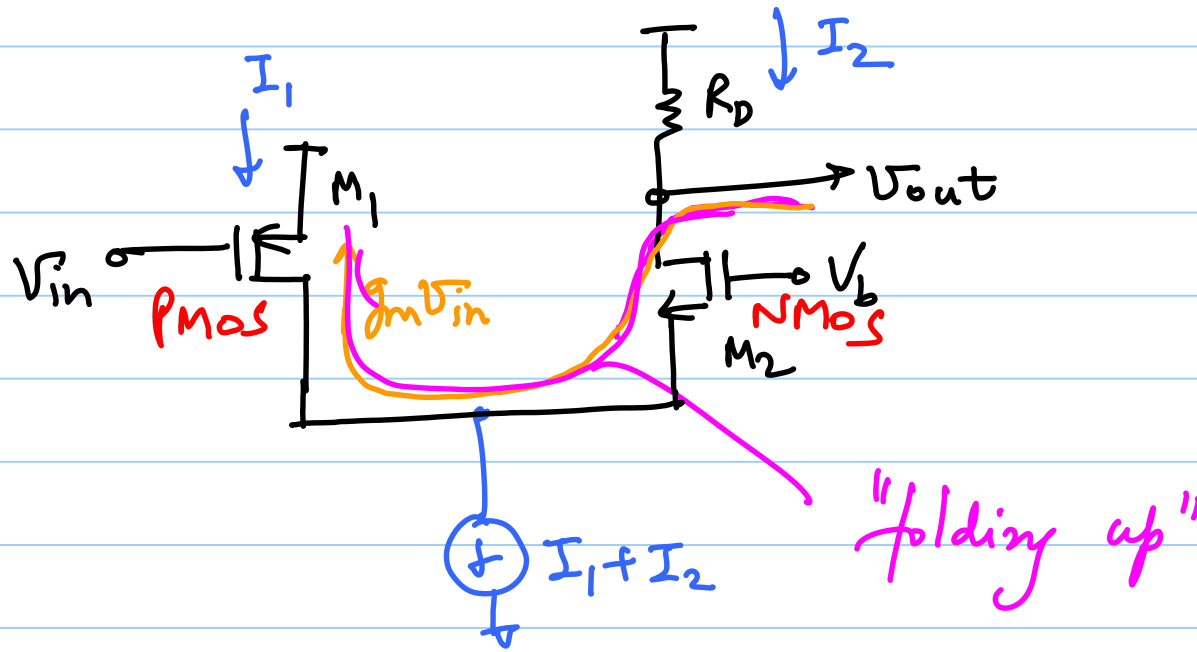
$$G_m = \frac{g_{m1} r_{o1} \left[r_{o2}(g_{m2} + g_{mb2}) + 1 \right]}{r_{o1} r_{o2} (g_{m2} + g_{mb2}) + r_{o1} + r_{o2}}$$

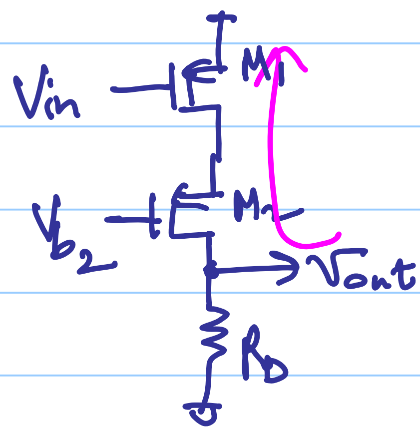
$$g_{m2} r_{o2} \gg 1$$

$$\simeq g_{m1}$$

Cascode



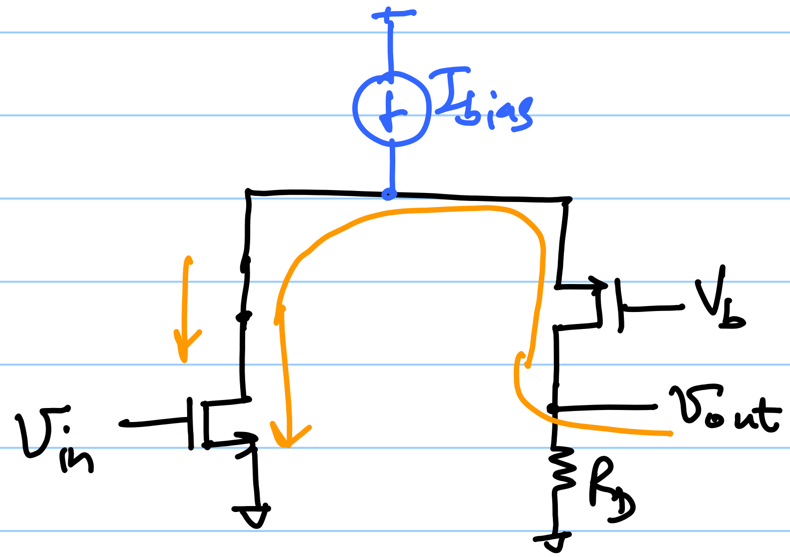




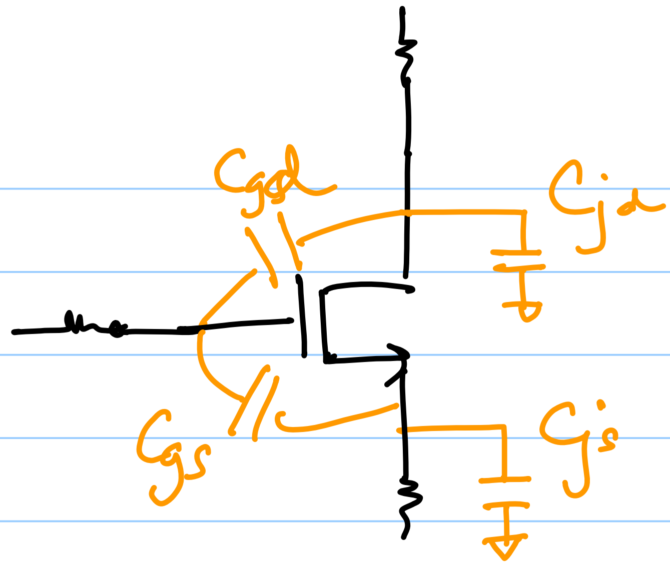
"folded cascode"

(+) leads to better headroom

(−) 2X bias current

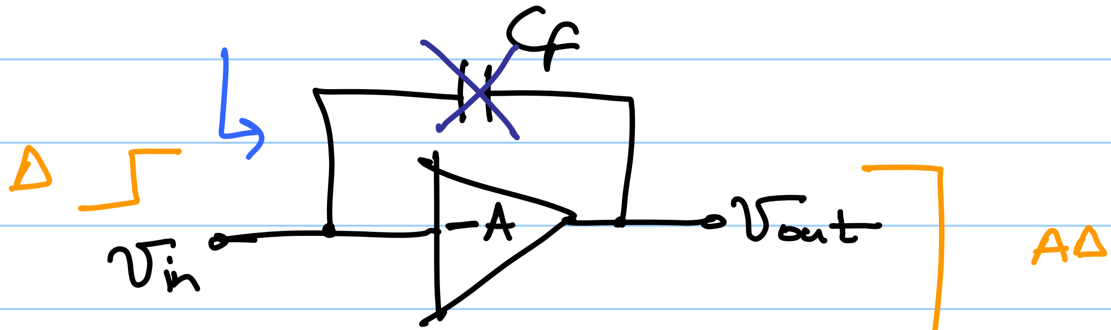


I_{bias}
V_b
V_{in}
v_{out}
R_D

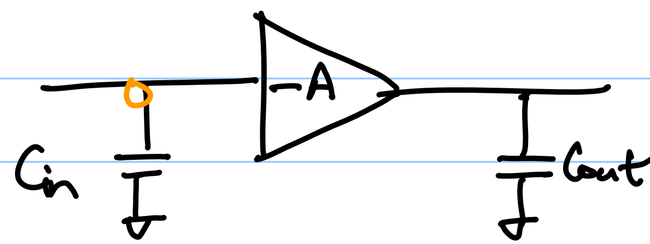


Cgd
Cjd
Cgs
Cjs

Miller Effect:

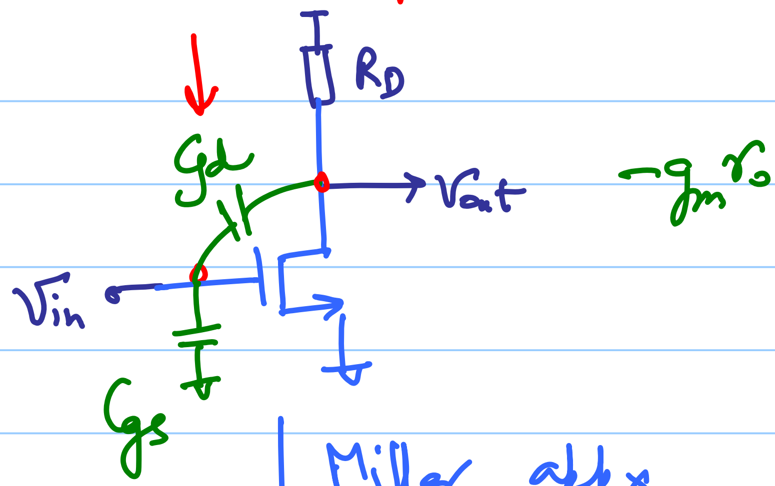


Capacitance multiplying effect



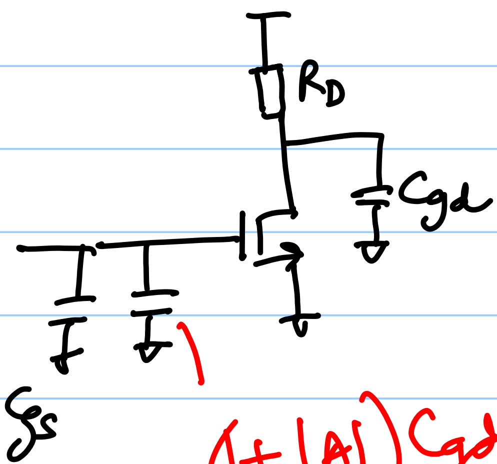
$$C_{in} = C_f(1+|A|) \qquad C_{out} = C_f\left(1+\frac{1}{|A|}\right)$$

Miller Cap



Miller appx omits a zero

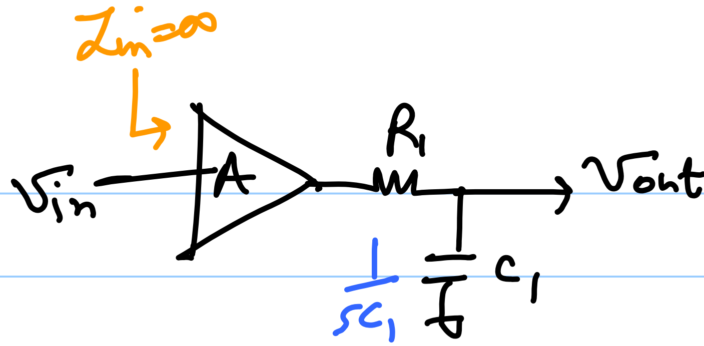
Miller appx



$(1+|A|)C_{gd}$

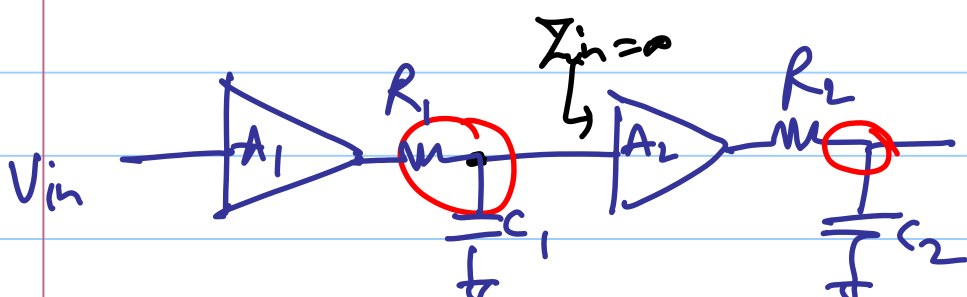
$g_m(r_o \| R_D)$

1st order

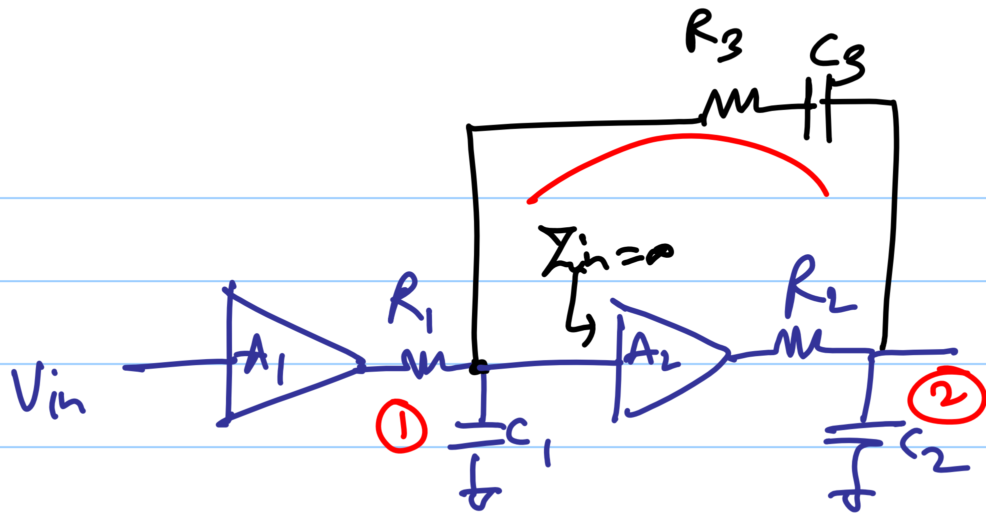


$$\frac{V_{out}}{V_{in}}(s) = \frac{A}{1+sR_1C_1} = \frac{A}{1+(s/\omega_p)}$$

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



$$\frac{V_{out}}{V_{in}}(s) = \frac{A_1}{\left(1+\frac{s}{\omega_p}\right)} \cdot \frac{A_2}{\left(1+\frac{s}{\omega_{p2}}\right)}$$


R3
C3
Zin = ∞
R1
R2
A1
A2
Vin
1
2
C1
C2