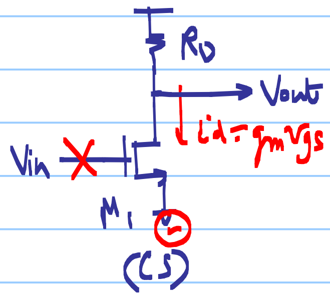
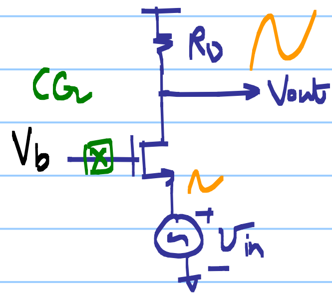
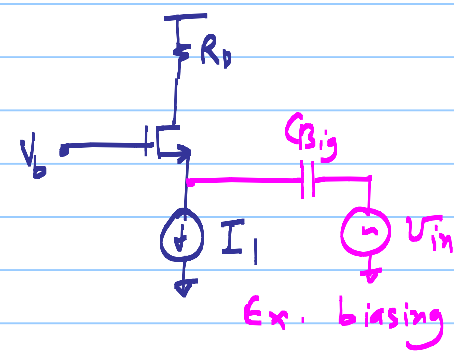
ECE 511 – Lecture 12

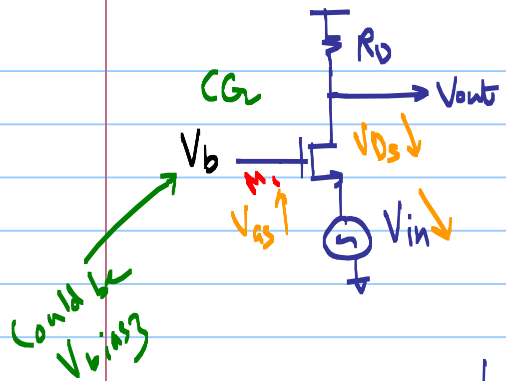
Note Title 2/28/2013

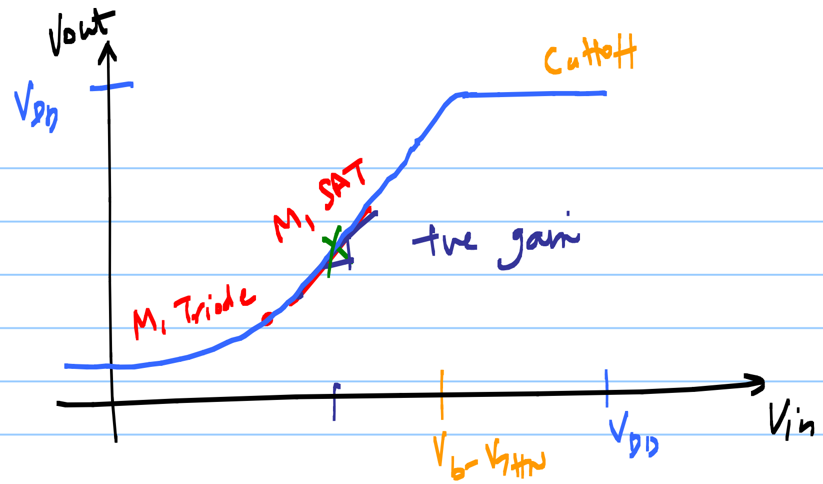
Common Gate Stage











$V_{out} = f(V_{in})$

$A_v = \frac{\partial V_{out}}{\partial V_{in}}$

$$V_{out} = V_{DD} - \frac{\beta}{2}\left(V_b - V_{in} - V_{THN}\right)^2 R_D$$

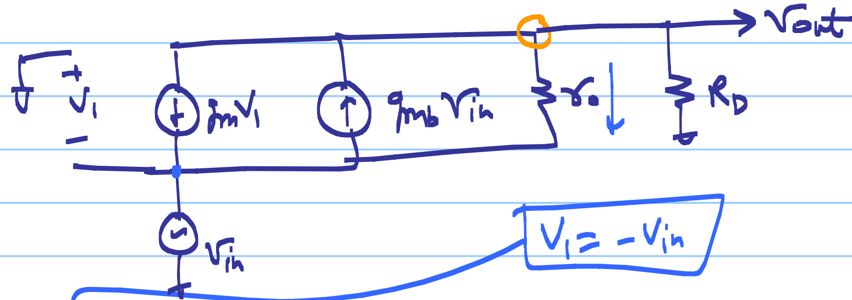
$$A_v = \frac{\partial V_{out}}{\partial V_{in}} = -\frac{\beta}{\cancel{2}} \times \cancel{2}\left(V_b - V_{in} - V_{THN}\right) \cdot R_D \cdot$$

$$- \frac{\beta}{\cancel{2}} \cancel{2}\left(V_b - V_{in} - V_{THN}\right) \cdot \frac{\partial V_{THN}}{\partial V_{in}} \cdot R_D$$

$$= \beta\left(V_b - V_{in} - V_{THN}\right)\left(1 + \underbrace{\frac{\partial V_{THN}}{\partial V_{SB}}}_{\eta}\right) R_D$$

$$= \beta\left(\underbrace{V_b - V_{in}}_{V_{GS}} - V_{THN}\right) \cdot R_D \cdot (1 + \eta)$$

$$\boxed{A_v = +\underbrace{g_m R_D}_{\text{CS gain}}(\eta+1)}$$



$\boxed{V_1 = -V_{in}}$

$$-g_m V_1 + g_{mb} V_{in} - \left(\frac{V_{out} - V_{in}}{r_o}\right) - \frac{V_{out}}{R_D} = 0$$

$$\Rightarrow V_{in}(g_m + g_{mb}) + \frac{V_{in}}{r_o} = \frac{V_{out}}{r_o \| R_D}$$

$$\frac{1}{r_o \| R_D} = \frac{1}{r_o} + \frac{1}{R_D}$$

$$(g_o + G_D) = g_o + G_D$$

ASIDE

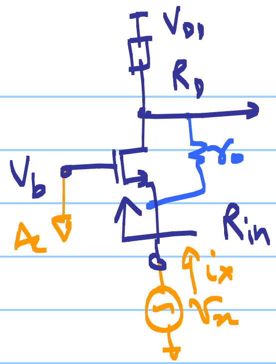
$$\Rightarrow A_v = \frac{(g_m + g_{mb})r_o + 1}{\cancel{r_o}} \times \frac{R_D \cancel{r_o}}{R_D + r_o}$$

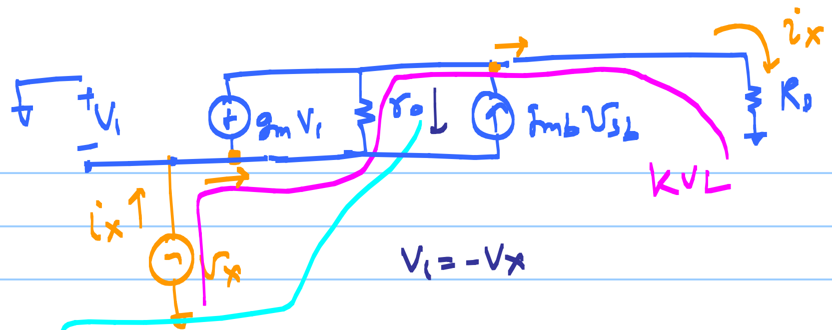
$$= \frac{(g_m + g_{mb})r_o + 1}{R_D + r_o} \cdot R_D$$

for $r_o \gg R_D$ & $g_m r_o \gg 1$

$$\Rightarrow A_v = (g_m + g_{mb}) R_D = \boxed{+(\eta + 1) g_m R_D}$$

Input impedance:





$V_1 = -V_x$

$$I_{r_o} = i_x + g_m V_1 + g_{mb} V_1$$
$$= i_x - (g_m + g_{mb}) V_x \longrightarrow (1)$$

* Adding up the voltages across r_o & R_D

$$R_D i_x + r_o \left[i_x - (g_m + g_{mb}) V_x \right] = V_x$$

$$R_{in} = \frac{V_x}{i_x} = \frac{R_D + r_o}{\cancel{1+}(g_m + g_{mb}) r_o}$$

$(g_m + g_{mb}) r_o >> 1$

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

Case I:

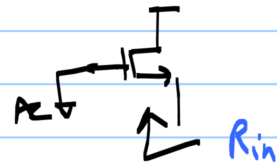
$R_D \ll (g_m + g_{mb}) r_o$ $\simeq r_o$ or smaller

* R_D can't be a cascoded CM load

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

Case II:

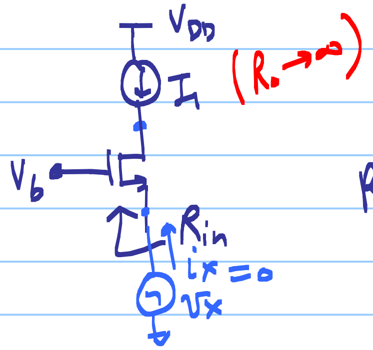
$R_D = 0$



Same case as a SF

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

Case III: $R_D \rightarrow$ ideal current source

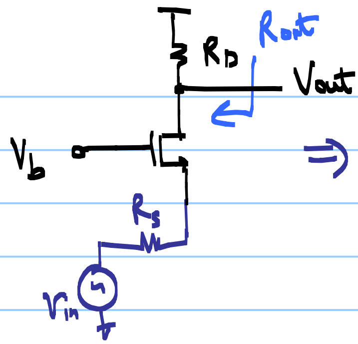


$$R_{in} \simeq \frac{R_o}{(g_m + g_{mb})\, r_o} \rightarrow \infty$$

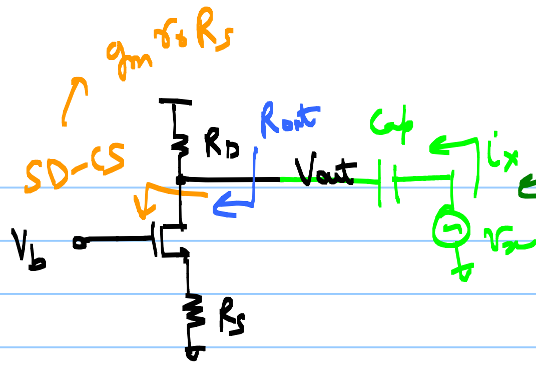
input impedance is large

Case IV $R_D = g_m r_o^2$

$R_{in} \simeq r_o \leftarrow$ large

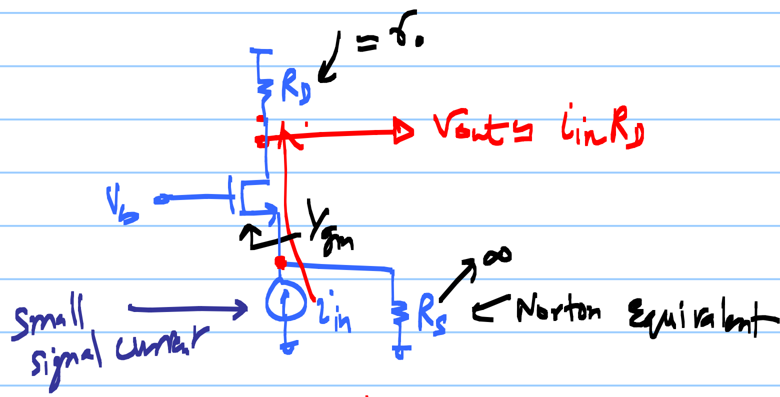


$\Rightarrow$



for sims
(Don't disturb the DC biasing)

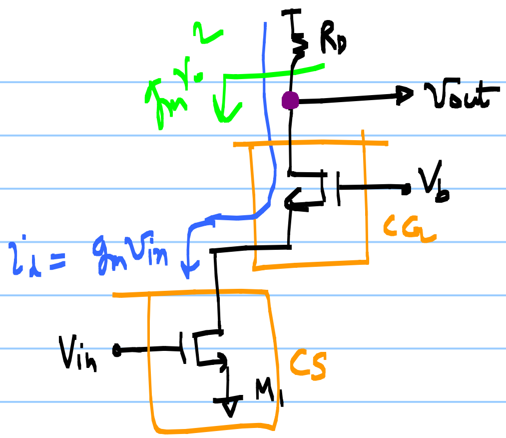
$$R_{out} = \{[1+(g_m+g_{mb})r_o]R_s + r_o\} \,\|\, R_D$$



"CG stage makes a good current buffer"

Type	Gain	Z_{in}	Z_{out}	Application
CS	Large	∞	Moderate $(\simeq r_o)$	(Voltage) Amplifier
CS + SD	Moderate	∞	High / Moderate	Linear amplifier
CD / SF	low (≤ 1)	∞	Low	Voltage Buffer
CG	Medium / High	Low	Moderate / High	Current Buffer

Cascode Stage



$$V_{out} \simeq -g_m V_{in} \left(R_D \,||\, R_{casn} \right)$$

$R_D \to \infty$, $R_{casn} \to g_m r_o^2$

$$= -g_m^2 r_o^2$$

$$= -(g_m r_o)^2$$

Lemma: In a linear circuit:

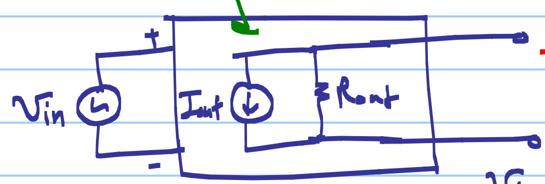
Voltage gain $= -G_m \cdot R_{out}$

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

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

Proof:

Norton Equiv. of the output stage

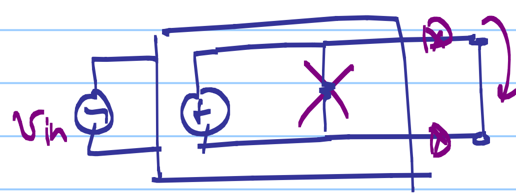


$+$ V_{out} $-$

Claim: $V_{out} = -G_m R_{out} \cdot V_{in}$

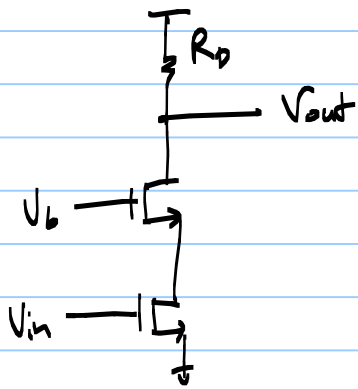
$V_{out} = -I_{out} \cdot R_{out}$

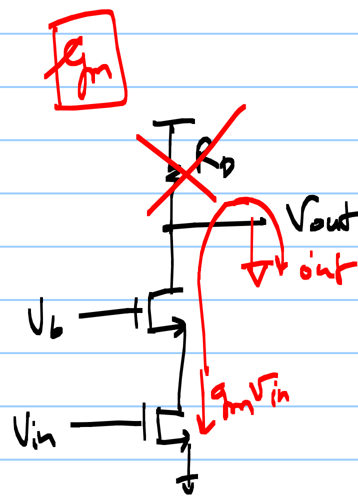
G_m:



$I_{sc} = -I_{out}$

$\Rightarrow G_m \triangleq \dfrac{I_{out}}{V_{in}}$

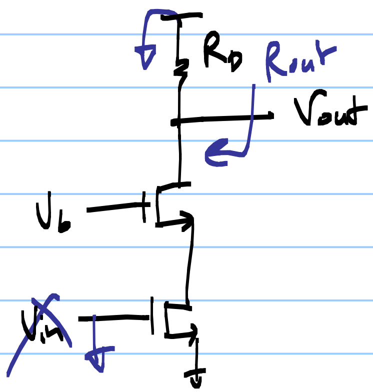




$$i_{out} = g_m v_{in}$$

G_m

$\boxed{R_{out}}$



$(R_D \| g_m r_o^2)$

$R_D \gg g_m r_o^2$

$$A_v = -g_{m1}(R_D \| g_m r_o^2)$$

$$\simeq -(g_m r_o)^2$$