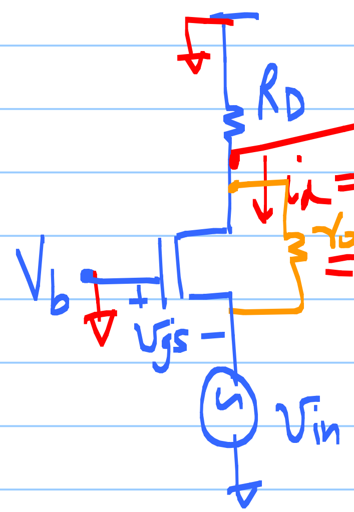
ECE 511 - Lecture 13

Note Title 3/7/2012



$i_d = g_m v_{gs}$ $\quad v_{gs} = -v_{in}$

$= -g_m v_{in}$

$v_{out} = \boxed{g_m R_D}\, v_{in}$

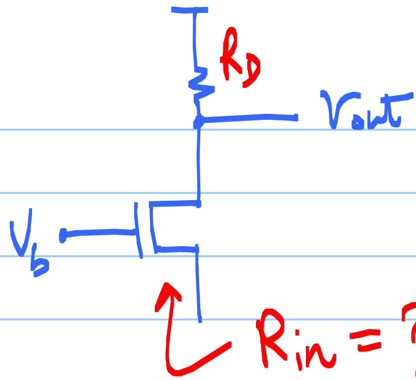
A_v

exact expression

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

for $r_o \gg R_D$

$$\cong \underline{(\eta + 1)\, g_m R_D}$$



$R_D \le r_o \Rightarrow R_{in} = \dfrac{1}{g_m + g_{mb}} \simeq \dfrac{1}{g_m}$

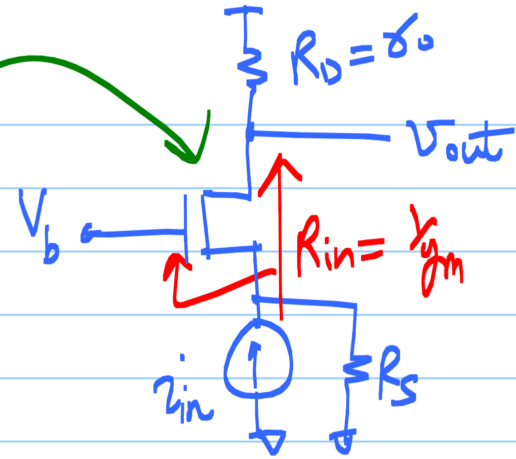
$1/g_m$

$R_D \gg r_o \Rightarrow R_{in} = \dfrac{R_D}{(g_m + g_{mb}) r_o} \simeq \dfrac{R_D}{g_m r_o}$

$R_D = g_m r_o^2$

$\hookrightarrow R_{in} \simeq r_o$

$R_{in} \ll \infty$



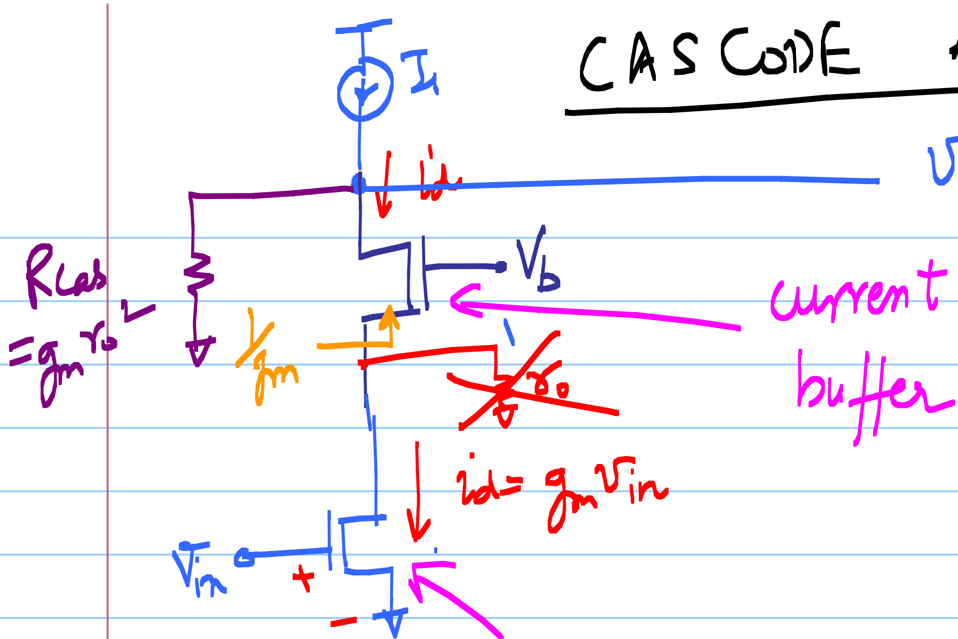
CG can make a good current buffer

$\frac{1}{g_m} \ll R_S$

Application → Transimpedance amplifier

	gain	Z_{in} @ Low-f	Z_{out} @ Low-f	
CS	Large	∞	Moderate (r_o)	→ Amplifier
CS-SD	Medium	∞	High	→ Linear amplifier
SF	(<1) Low	∞	* Low $(\simeq 1/g_m)$	→ Voltage Buffer
CG	Medium/high	Low *	Moderate/high	→ Current Buffer

CASCODE Amplifier



$$v_{out} = -i_d (R_D \| R_{cas})$$

$$= -g_m (R_D \| R_{cas})\, V_{in}$$

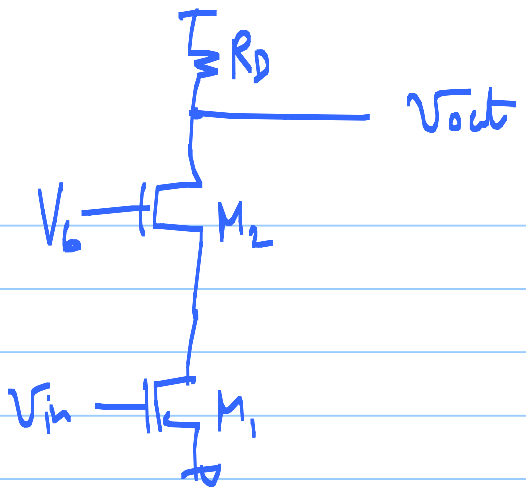
$$A_v = -g_m (R_D \| R_{cas})$$

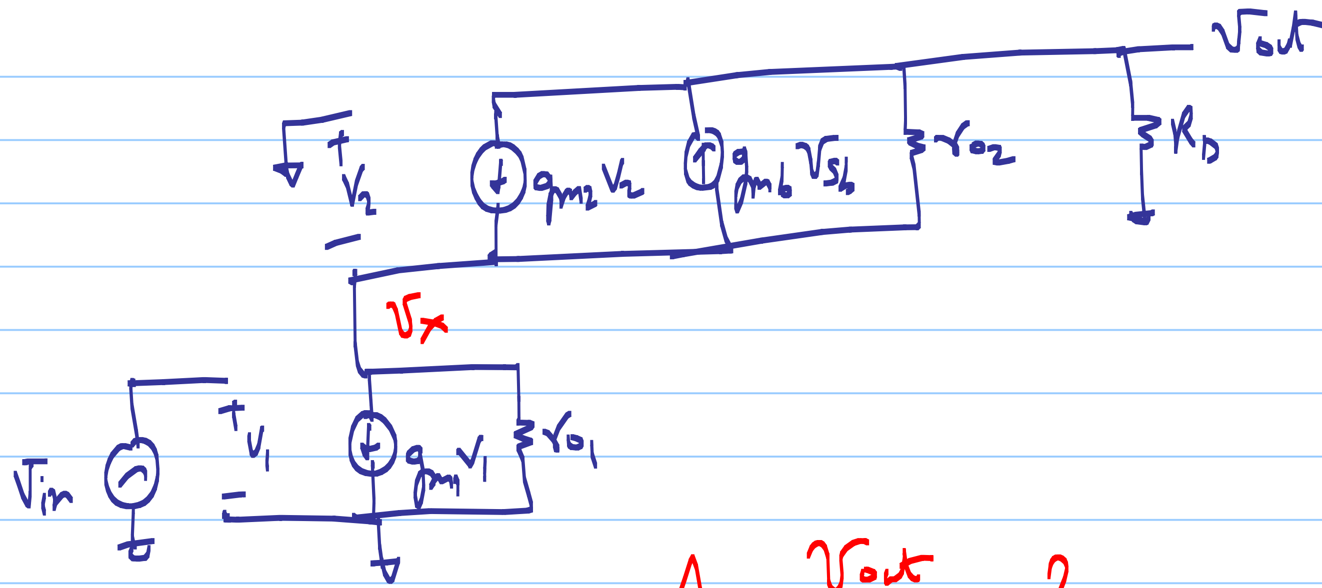
$$A_v = -g_m R_{cas}$$

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

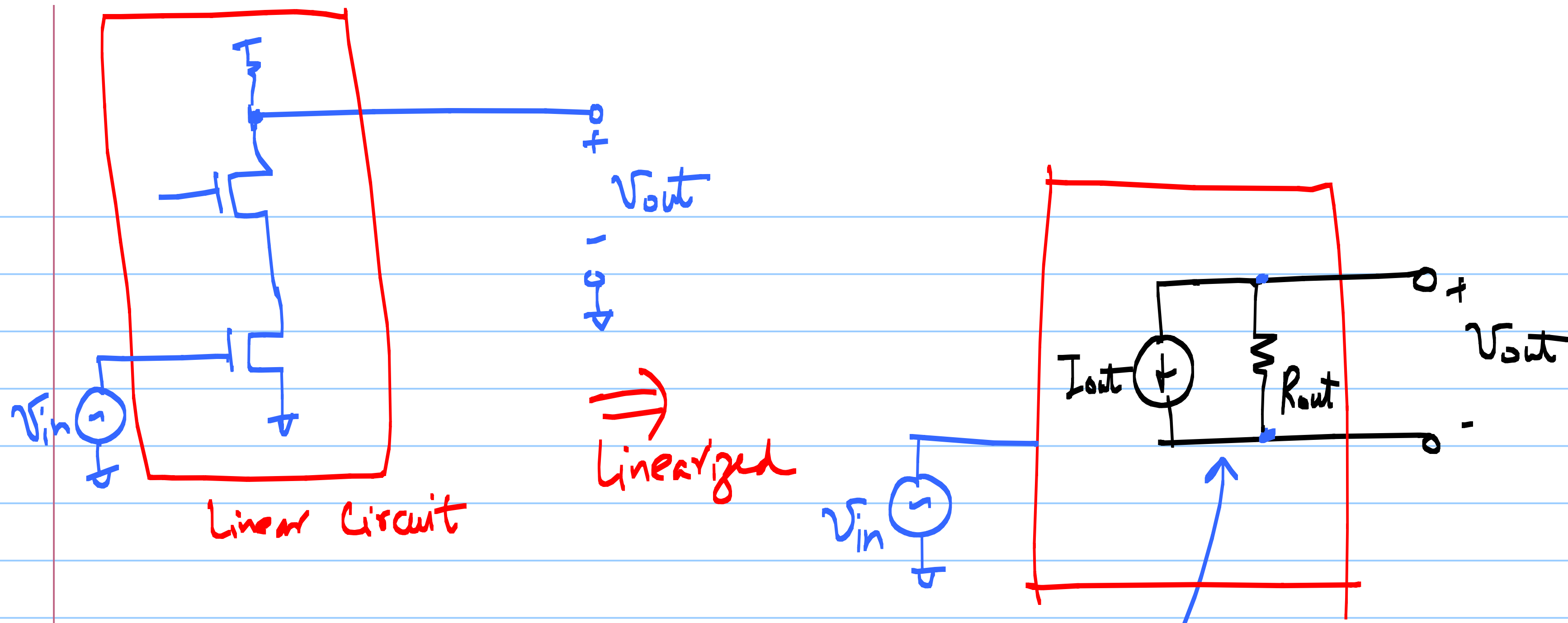
$$A_v = -g_m r_o$$

$$R_{out} = r_o$$

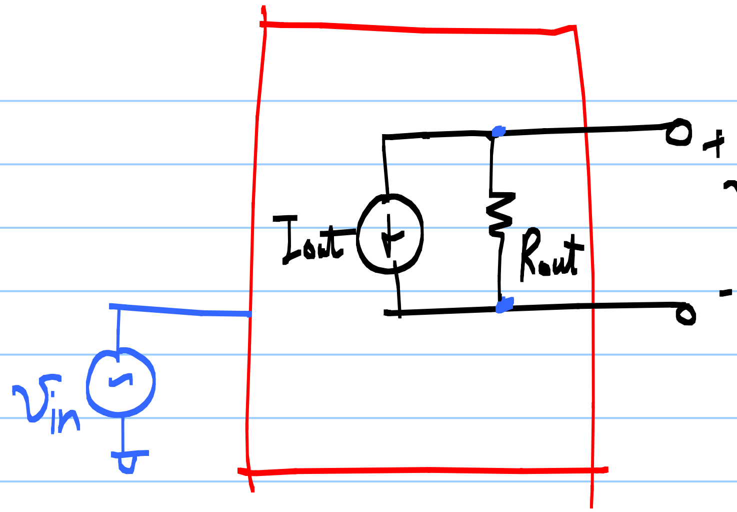




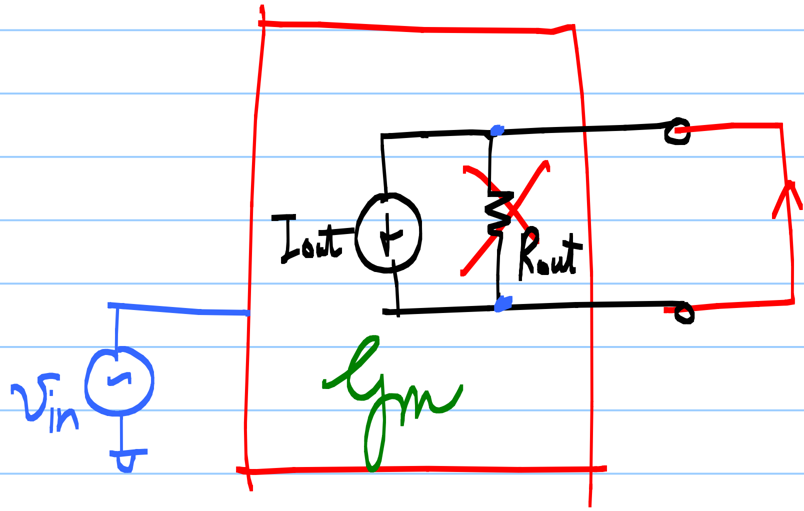
$$A_v = \frac{v_{out}}{v_{in}} = ?$$



Norton equivalent of the output port of the linear circuit open circuit output ?



$v_{out} = -I_{out} \cdot R_{out} \longrightarrow (1)$

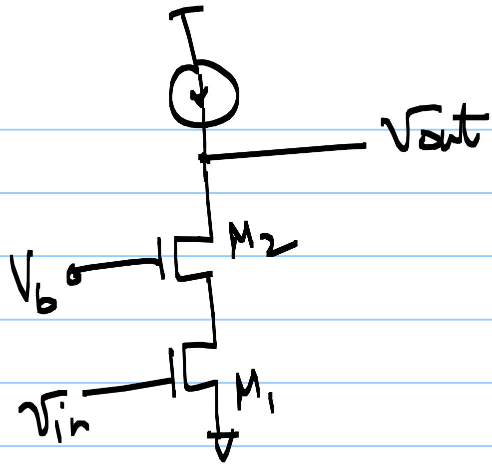


$$i_{out} = I_{out}$$

$$\text{If } \quad G_m \triangleq \frac{I_{out}}{v_{in}} \longrightarrow (2)$$

$$V_{out} = -I_{out}R_{out} = -(G_m R_{out})\, v_{in}$$

$$\Rightarrow \boxed{A_v = \frac{v_{out}}{v_{in}} = -G_m R_{out}}$$

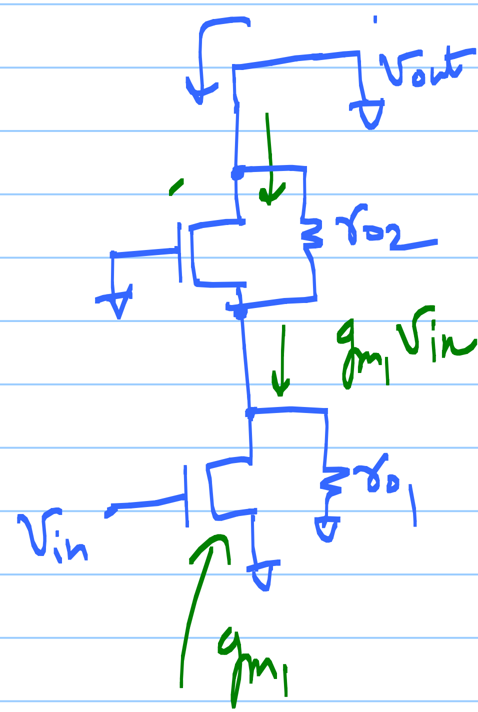


$$A_v = -G_m R_{out}$$

$i_{out} = g_{m1} v_{in}$??

$\approx (g_{m2}+g_{mb2}) r_{o2} r_{o1}$

$\triangleq g_m r_o^2$



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

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

$$\eta = \gamma = 0$$

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

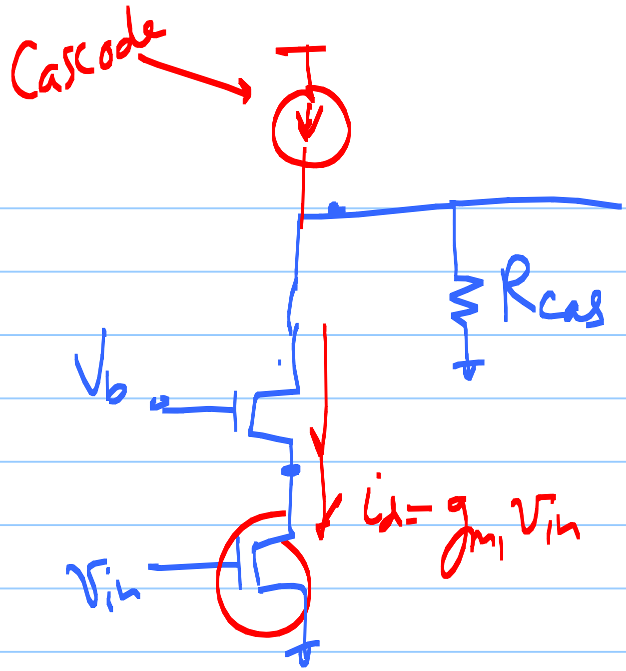
$$= \frac{g_{m1} r_{o1}\left[\cancelto{1}{\frac{g_{m2} r_{o2} + 1}{g_{m2} r_{o2}}}\right]}{r_{o1} + \frac{(r_{o1} + r_{o2})}{g_{m2} r_{o2}}} \qquad r_{o1} \gg \frac{(r_{o1} + r_{o2})}{g_{m2} r_{o2}}$$

$$= \frac{g_{m1} \cancel{r_{o1}}}{\cancel{r_{o1}} \cancel{+ g_{m2}}} = \underline{\underline{g_{m1}}} \Leftarrow \text{Approximation}$$

$$A_v \simeq -g_m R_{out}$$

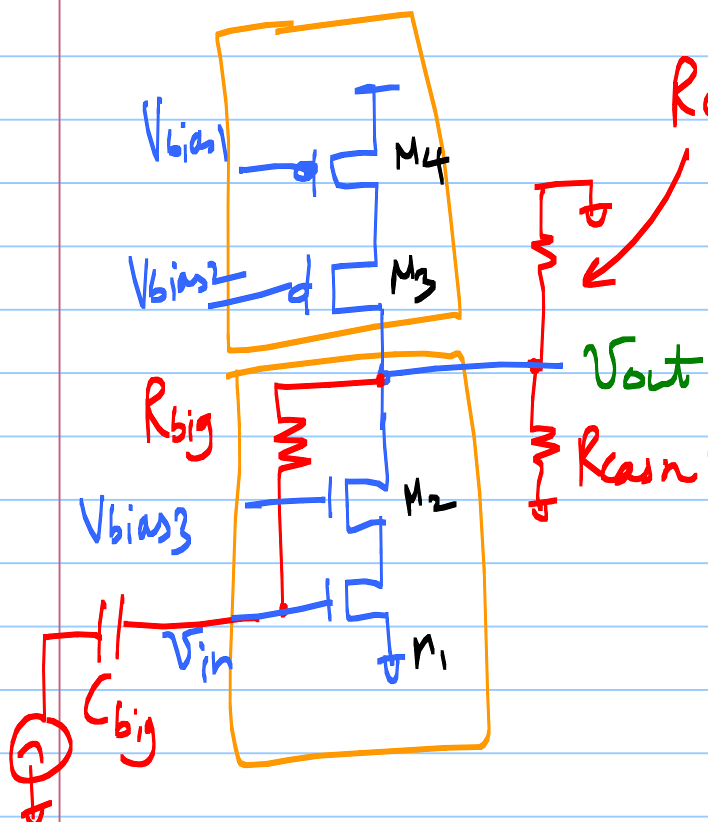
$$= -g_{m1} \cdot (g_{m2} + \cancel{g_{mb2}}) r_{o1} r_{o2}$$

$$= -g_{m1} \cdot (g_{m2} r_{o1} r_{o2}) \overset{\Delta}{=} -g_m^2 r_o^2$$



$$v_{out} = -\underbrace{g_{m1} R_{cas}} \cdot v_{in}$$

$\boxed{\text{Fig } 21.35}$



$$R_{casp} = g_{mp} r_{op}^2 = g_{m3} r_{o3} r_{o4}$$

$$R_{casn} = g_{mn} r_{on}^2 = g_{m1} r_{o1} r_{o2}$$

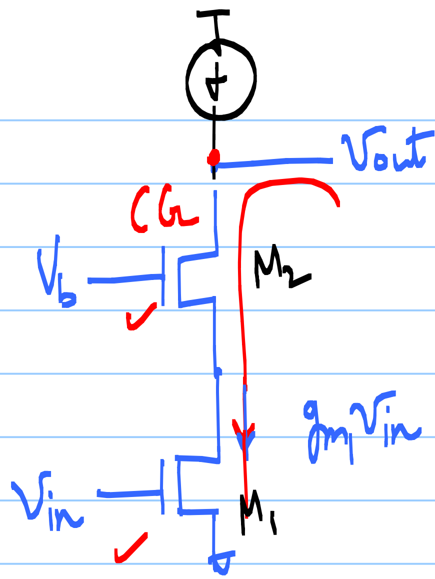
$$A_v = -\boxed{g_m \cdot R_{out}}$$

$$= -g_{m1} \cdot \left(g_{m1} r_{o1} r_{o2} \,\|\, g_{m3} r_{o3} r_{o4} \right)$$

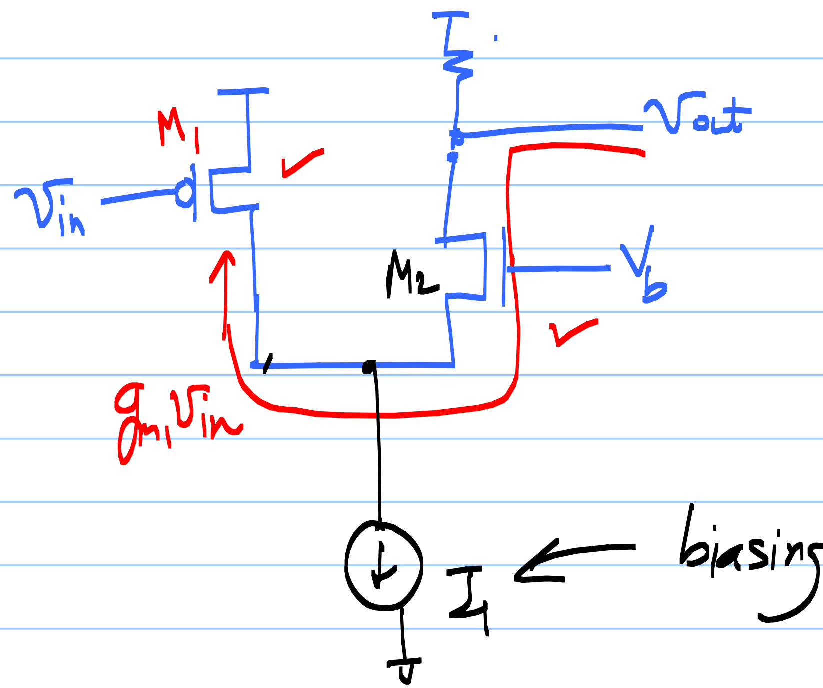
$$\overset{\Delta}{=} -g_m \left(g_m r_o^2 \,\|\, g_m r_o^2 \right)$$

$$= -\frac{g_m^2 r_o^2}{2}$$

Cascode



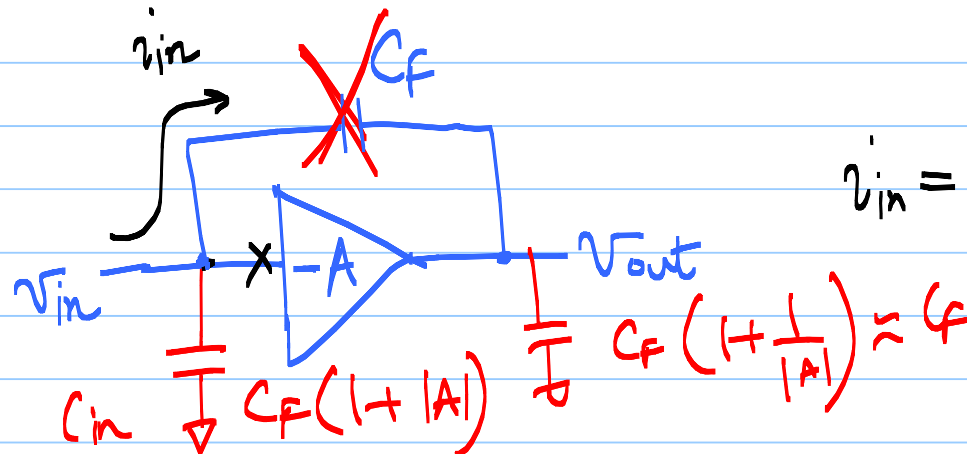
Folded - Cascode



Small-signal current is folded up

$\Rightarrow$ 2x bias current

Miller Effect :

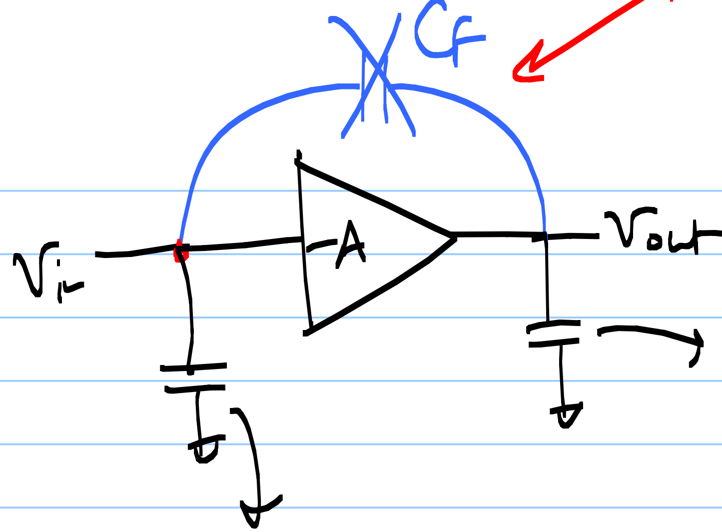


$$i_{in} = \frac{v_{in} - v_{out}}{1/sC_f} = sC_f(v_{in} - v_{out})$$

$$i_{in} = sC_f[v_{in} - (-|A| v_{in})] = s\boxed{C_f(1+|A|)}\, v_{in}$$

$$i_{out} = -i_{in} = -sC_f(v_{in} - v_{out})$$

$$= -sC_f\left(-\frac{v_{out}}{|A|} - v_{out}\right) = +s\boxed{C_f\left(1+\frac{1}{|A|}\right)} v_{out}$$



Miller Cap

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

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

$$|X_c| = \left|\frac{1}{j\omega C}\right| = \frac{1}{2\pi f C}$$

$$f \to \infty \quad |X_c| \to 0$$