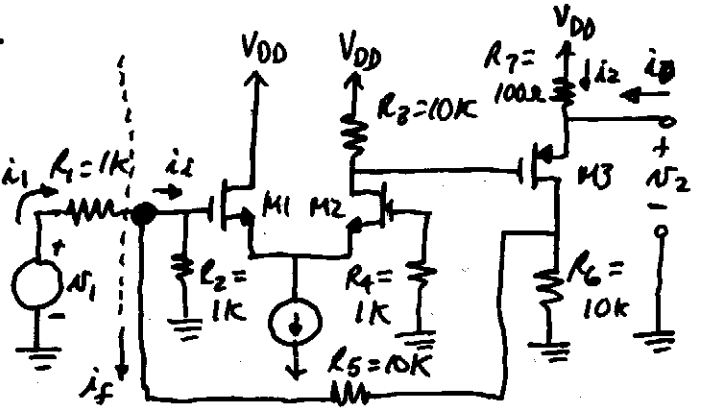
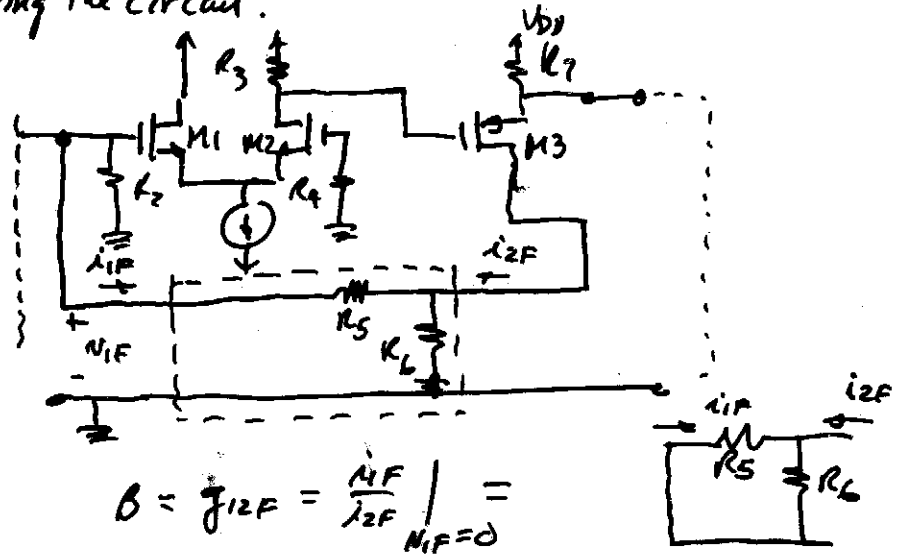
Shunt-Series Example

If $g_m = 1mS$ and $r_{ds} = \infty$ for all MOSFETs, find $\frac{v_2}{v_1}$, $\frac{v_1}{i_1}$, and $\frac{v_2}{i_0}$ using the methods of feedback analysis.



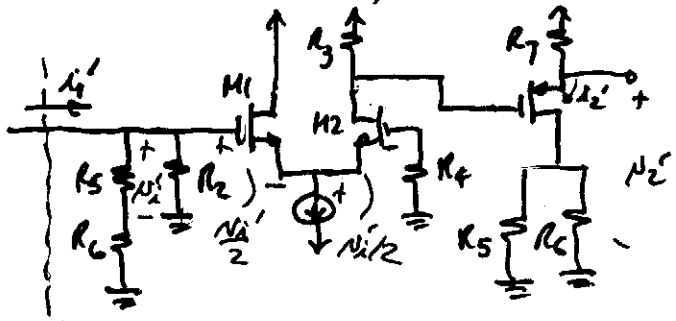
Simplifying the circuit:



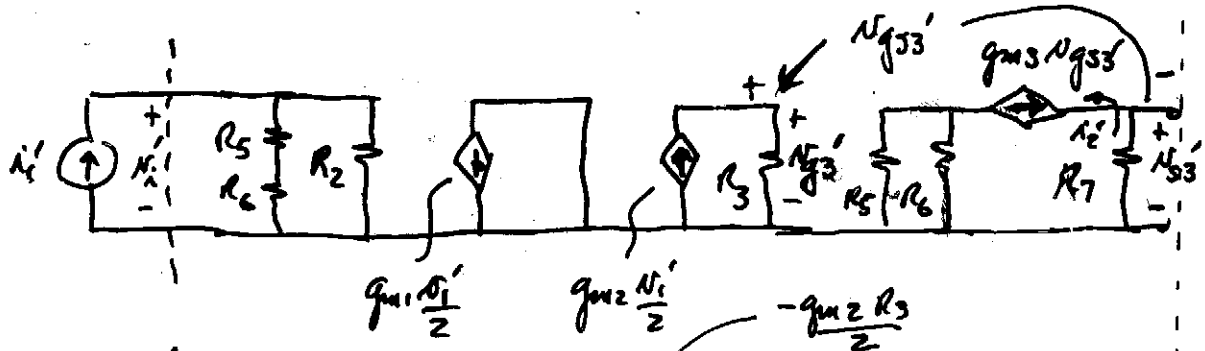
$$B = g_{12F} = \frac{i_{1F}}{i_{2F}}\bigg|_{v_{1F}=0} =$$

$$\therefore B = -\frac{R_L}{R_5+R_L} = \frac{-10k}{20k} = -\frac{1}{2}$$

Open-loop circuit ($B = 0$)



Small-signal Model of (B=0):



$$A = \frac{i_2'}{i_1'} = A_i = \left(\frac{i_2'}{v_{gs3}'}\right)\left(\frac{v_{gs3}'}{v_{g3}'}\right)\left(\frac{v_{g3}'}{v_1'}\right)\left(\frac{v_1'}{i_1'}\right)$$

$-g_{m3}$ ↑ ↑ $R_2 \| (R_5+R_6)$

$$v_{gs3}' = v_{g3}' - v_{s3}' = v_{g3}' - g_{m3}R_7 v_{gs3}'$$

$$v_{gs3}'(1+g_{m3}R_7) = v_{g3}' \rightarrow \frac{v_{gs3}'}{v_{g3}'} = \frac{1}{1+g_{m3}R_7}$$

$$\therefore A_i = \frac{i_2'}{i_1'} = (-g_{m3})\left(\frac{1}{1+g_{m3}R_7}\right)\left(+\frac{g_{m2}R_3}{2}\right)\left(R_2 \| (R_5+R_6)\right)$$

$$= (-1mS)\left(\frac{1}{1+0.1}\right)\left(\frac{10}{2}\right)(1k \| 20k) = -4.33\ A/A$$

$$\frac{i_2}{i_1} = \frac{A_i}{1+A_iB} = \frac{-4.33}{1+(-\frac{1}{2})(-4.33)} = \frac{-4.33}{3.164} = -1.365\ A/A$$

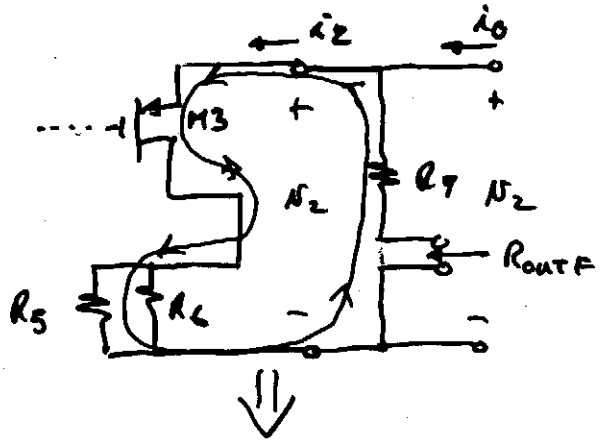
$$R_{inF} = \frac{R_{in}}{1+A_iB} = \frac{R_2 \| (R_5+R_6)}{3.164} = \frac{952\,\Omega}{3.164} = 301\,\Omega$$

$$\therefore \frac{v_1}{i_1} = R_1 + R_{inF} = 1000+301 = \underline{1301\,\Omega} = R^*$$

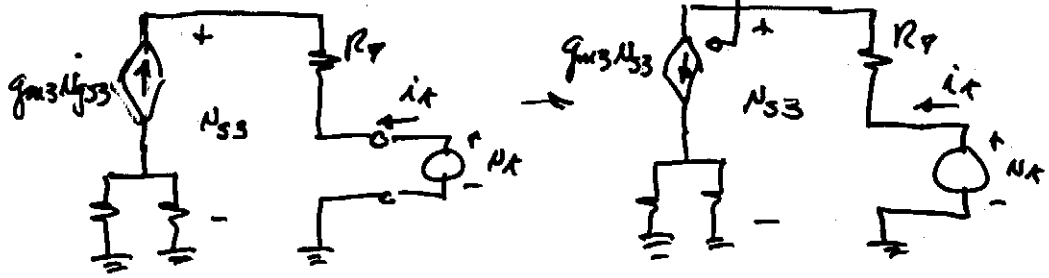
$$\frac{v_2}{v_1} = \frac{-i_2 R_7}{i_1 R^*} = \left(\frac{i_2}{i_1}\right)\left(-\frac{R_7}{R^*}\right) = (-1.365)\left(\frac{100\,\Omega}{1301\,\Omega}\right) = \underline{0.105\ V/V}$$

$R_{outF} = R_{out}(1+A_iB)$

What is R_{out} or R_{outF}?



R_{out} or R_{outF} is the resistance seen in series with the output loop

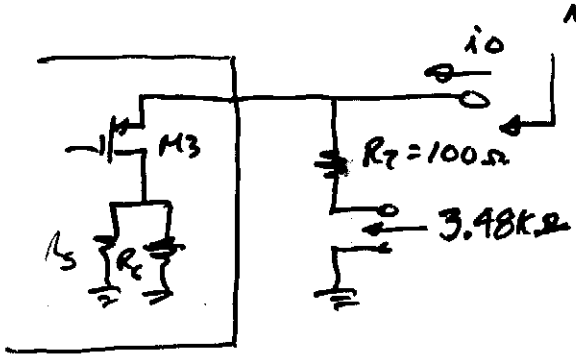


$$V_x = i_x R_7 + V_{S3} \qquad i_x = g_{m3} V_{S3}$$

$$V_x = i_x R_7 + \frac{1}{g_{m3}} i_x \Rightarrow \frac{V_x}{i_x} = 100 + 1000 = 1.1\,k$$

$$R_{out} = R_7 + \frac{1}{g_{m3}} \qquad R_{outF} = R_{out}(1 + A_i B)$$

$$R_{outF} = 1.1k(3.164) = 3.48\,k\Omega$$



$$\frac{V_2}{i_o} = (R_{outF} - R_7) \| R_7$$

$$= \underline{\underline{97.12\,\Omega}}$$