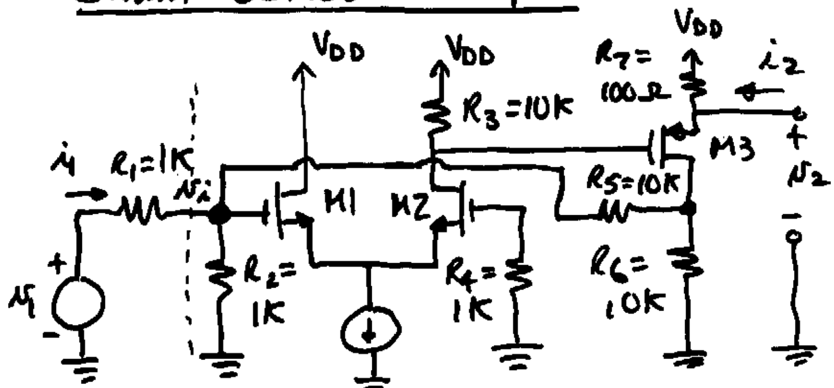
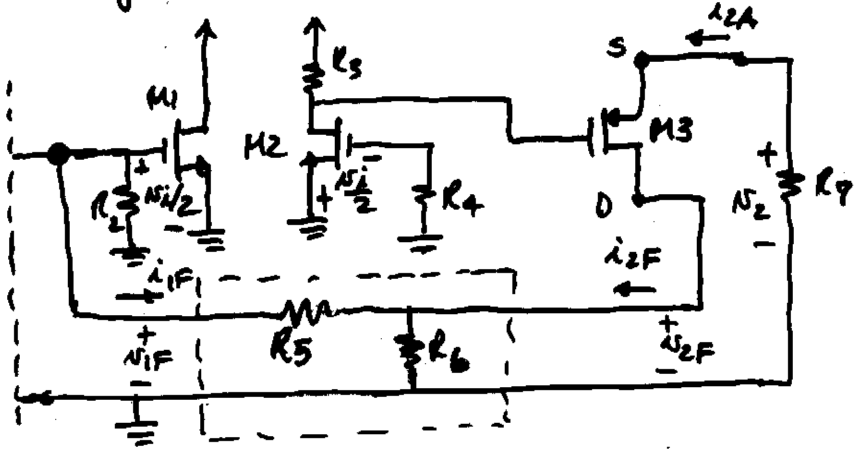
Shunt-Series Example



If $g_{m1} = g_{m2} = g_{m3} = 1\,mS$ and $r_{ds} = \infty$, find $\frac{v_2}{v_1}$, $\frac{v_1}{i_1}$, and $\frac{v_2}{i_2}$ using feedback analysis methods.

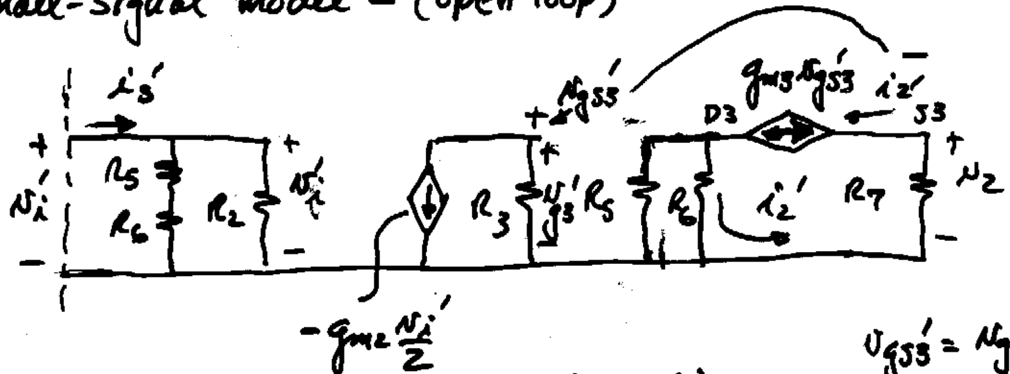
Rewriting in two-port form - (Closed loop)



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

$$\beta = -\frac{R_6}{R_5+R_6} = -\frac{1}{2}$$

Small-signal model - (open loop)



$$v_{gs3}' = v_{g3}' - v_{s3}'$$

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

$$\frac{i_2'}{i_s'} = \left(\frac{i_2'}{v_{gs3}'}\right)\left(\frac{v_{gs3}'}{v_{g3}'}\right)\left(\frac{v_{g3}'}{v_i'}\right)\left(\frac{v_i'}{i_s'}\right)$$

$$= (-g_{m3})\left(\frac{1}{1+g_{m3}R_7}\right)\left(\frac{g_{m2}R_3}{2}\right)\left[R_2 \| (R_5+R_6)\right] \qquad \frac{v_{gs3}'}{v_{g3}'} = \frac{1}{1+g_{m3}R_7}$$

$$\therefore A = \frac{i_2'}{i_s'} = (-1\,mS)\left(\frac{1}{1+0.1}\right)\left(\frac{10}{2}\right)(1k \| 20k) = -4.33\ A/A$$

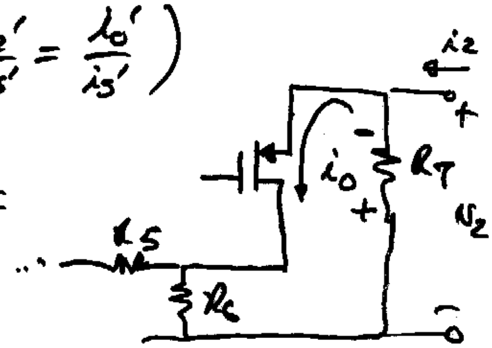
$$A_F = \frac{i_2}{i_s} = \frac{A}{1+A\beta} = \frac{-4.33}{1+(\frac{1}{2})(4.33)} = -1.368\ A/A \approx \frac{1}{\beta} = -2$$

$$R_{INF} = \frac{1}{(g_{11T}+G_s)(1+AB)} = \frac{R_2 \| (R_5+R_6)}{1+AB} \quad — \quad \frac{1}{\frac{1}{R_2}+\frac{1}{R_5+R_6}}$$

$$= \frac{952\,\Omega}{3.164} = 301\,\Omega$$

$$\therefore \frac{v_1}{i_1} = R_1 + R_{INF} = \underline{\underline{1.301\,k\Omega}} = R_{in}$$

$$\frac{v_2}{v_1} = \frac{-i_o R_7}{i_1 R_{in}} \qquad \left(i_o = i_2 \text{ of } A = \frac{i_2'}{i_s'} = \frac{i_o'}{i_s'} \right)$$



$$= A_F \frac{R_7}{R_{in}} = \left(-1.368\,\frac{A}{A}\right) \frac{-100\,\Omega}{1301\,\Omega} =$$

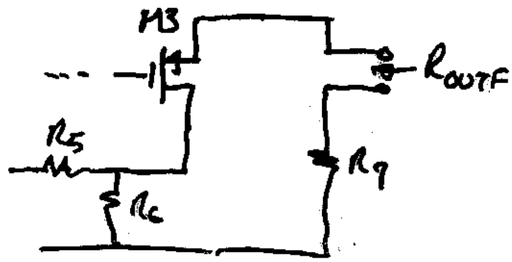
$$\frac{v_2}{v_1} = \underline{\underline{0.105\ V/V}}$$

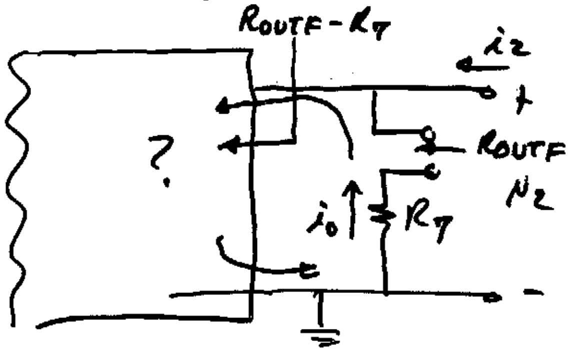
$$R_{out} = \frac{v_2}{i_2} = ?$$

$$\underline{R_{OUTF}} = (g_{22T} + R_7)(1+AB)$$

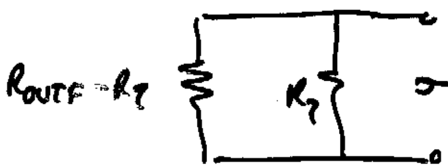
$$R_{OUTF} = \left(\frac{1}{g_{m3}} + R_7\right)(1+AB)$$

$$= (1K + 0.1K)(3.164) = 3.48K\,\Omega$$





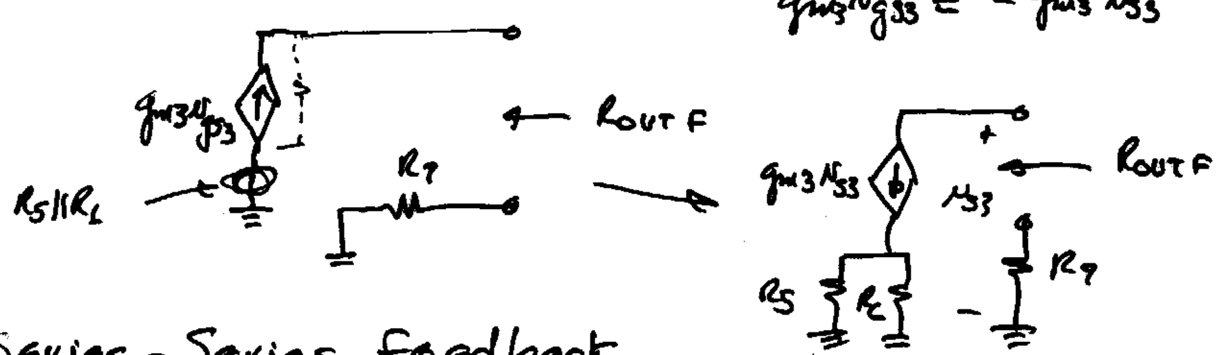
$$R_{out} = \frac{v_2}{i_2} = \left[(R_{OUTF} - R_7) \| R_7 \right]$$



$$R_{out} = (3.48K - 100) \| 100 = \underline{\underline{97.12\,\Omega}}$$

Question? Why not include R_5 & R_6 in g_{22T}?

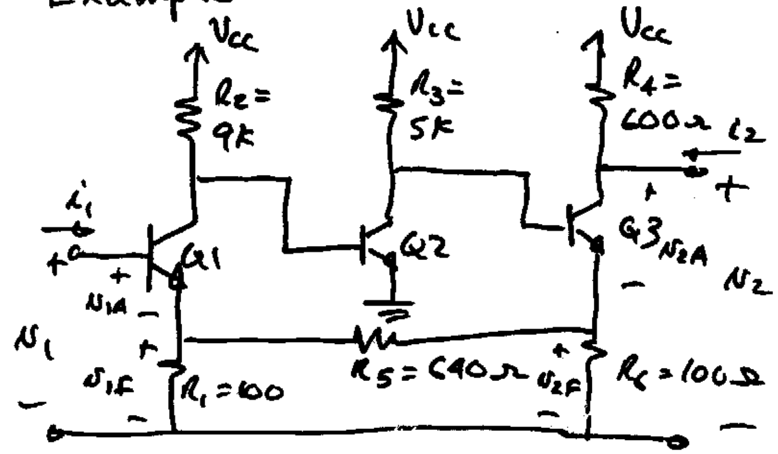
$g_{m3} v_{gs3} = -g_{m3} v_{s3}$



Series-Series Feedback

z parameters $\quad z_{12F} = \left.\dfrac{v_{1F}}{i_{2F}}\right|_{i_{1F}=0} = \beta$

Example -



Find $\frac{v_2}{v_1}$, $\frac{v_1}{i_1}$, & $\frac{v_2}{i_2}$

when $h_{fe1} = h_{fe2} = h_{fe3} = 100$

$I_{C1} = 0.6\,mA$

$I_{C2} = 1\,mA$

$I_{C3} = 4\,mA$

$V_A = \infty$