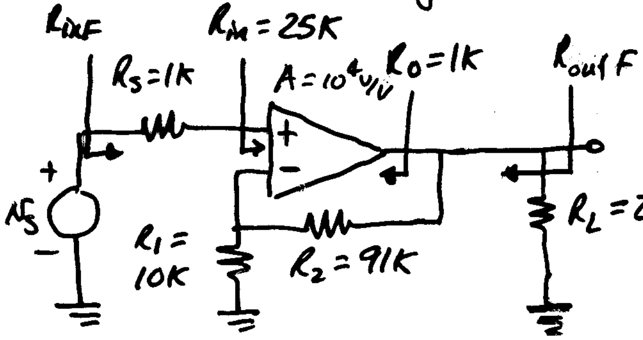
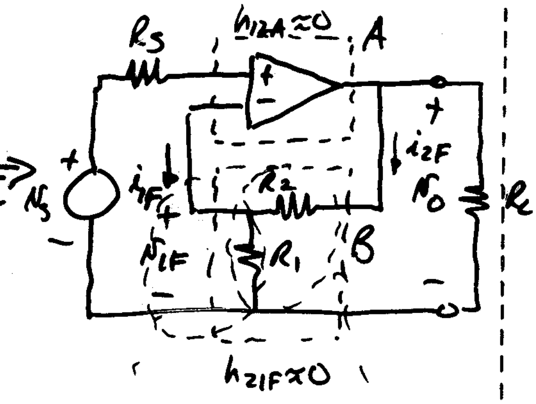
Example of Series-Shunt Feedback using an Op Amp

Consider the following series-shunt feedback circuit:





Find $\frac{v_o}{v_S}$, R_{INF} & $R_{OUT F}$

From previous work we know that,

$$\frac{v_o}{v_S} = \frac{h_{21A}}{h_{12F}h_{21A} - (R_S + h_{11T})(G_L + h_{22T})} = \frac{A}{1+AF}$$

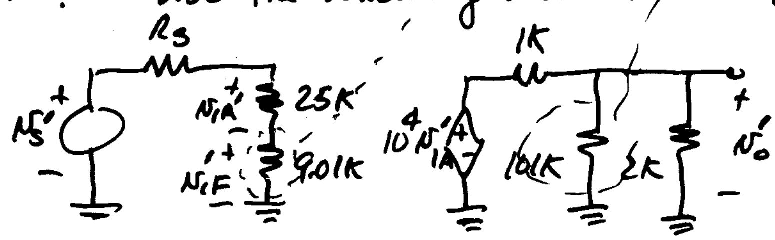
where $A = \frac{-h_{21A}}{(R_S + h_{11T})(G_L + h_{22T})}$ and $F = h_{21F}$

$$h_{11F} = \left.\frac{v_{1F}}{i_{1F}}\right|_{v_o=0} = R_1 \| R_2 = 9.01K \qquad h_{22F} = \left.\frac{i_{2F}}{v_o}\right|_{i_{1F}=0} = \frac{1}{R_1+R_2} = \frac{1}{101K}$$

$$h_{12F} = \left.\frac{v_{1F}}{v_o}\right|_{i_{1F}=0} = \frac{R_1}{R_1+R_2} = 0.099$$

$$\left\{\begin{aligned} v_1 &= h_{11}i_1 + h_{12}v_2 \\ i_2 &= h_{21}i_1 + h_{22}v_2 \end{aligned}\right.$$

$A = ?$ Use the following model for A



$h_{11T} = h_{11A} + h_{11F}$

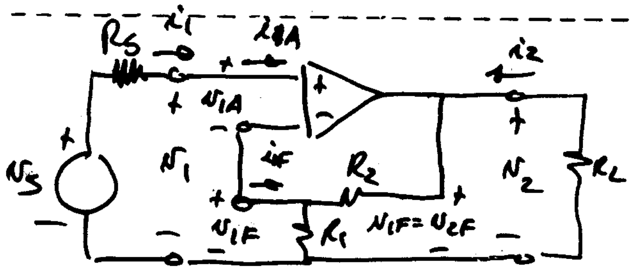
↑
25K

$h_{22T} = h_{22A} + h_{22F} = \frac{1}{1K} + \frac{1}{101K}$

$$A = \frac{v_o'}{v_S'} = \left(\frac{25K}{1K + 25K + 9.01K}\right)(10^4)\left(\frac{2K \| 101K}{1K + 2K \| 101K}\right) = 4730\ V/V$$

$$\beta = h_{12F} = 0.099 \qquad \therefore \frac{v_o}{v_S} = \frac{A}{1+A\beta} = \frac{4730}{1 + 4730(0.099)} = \underline{\underline{10.08\ V/V}}$$

$R_{inF} = ?$



$$v_S = v_1 = (R_S + h_{11T})\, i_1 + h_{12T}\, v_2 \qquad h_{12T} = \overset{0}{\cancel{h_{12A}}} + h_{12F} \qquad v_2 = -R_L\, i_2$$

$$\underbrace{i_2 = h_{21T}\, i_1 + h_{22T}\, v_2 \longleftarrow i_2 = -G_L v_2}$$

$$-G_L v_2 = h_{21T}\, i_1 + h_{22T}\, v_2$$

$$0 = (\overset{0}{\cancel{h_{21F}}} + h_{21A})\, i_1 + (h_{22} + G_L)\, v_2$$

$$v_1 = (R_S + h_{11T})\, i_1 + h_{12F}\, v_2 \leftarrow v_1$$

$$0 = h_{21A}\, i_1 + (h_{22} + G_L)\, v_2$$

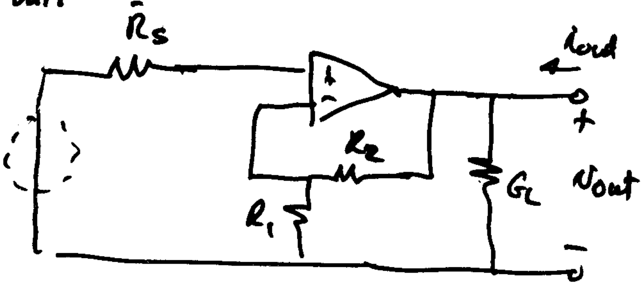
$$\therefore \left.\begin{aligned} v_S &= (R_S + h_{11T})\, i_1 + h_{12F}\, v_2 \\ 0 &= h_{21A}\, i_1 + (h_{22T} + G_L)\, v_2 \end{aligned}\right\} \quad \frac{v_S}{i_1} = ?$$

$$\frac{v_S}{i_1} = R_{inF} = R_S + h_{11T} + \frac{-h_{21A}\, h_{12F}}{(h_{22T} + G_L)}$$

$$= (R_S + h_{11T})\left[1 + \underbrace{\frac{-h_{21A}\, h_{12F}}{(R_S + h_{11T})(h_{22T} + G_L)}}_{AF = AB}\right] = R_{in}(1 + AF)$$

$$R_{inF} = \underline{\underline{16.47\, M\Omega}}$$

$R_{outF} = ?$



$$R_{outF} = \frac{1}{(h_{22} + G_L)\left[1 + \dfrac{-h_{21A}\, h_{12F}}{(R_S + h_{11T})(h_{22T} + G_L)}\right]}$$

$$= \frac{662\,\Omega}{1 + (4730)(0.099)} = \underline{\underline{1.41\,\Omega}}$$

∴ The general approach to analyzing series-shunt fb networks is:

1.) Find h_{11F} (input resistance of the F network with the output short-circuited)

$v_1 = h_{11} i_1 + h_{12} v_2$

$i_2 = h_{21} i_1 + h_{22} v_2$

2.) Find h_{22F} (output conductance of the F network with the input open-circuited)

3.) Find $h_{12F} = B = F$ (Voltage gain from output to input with input open-circuited)

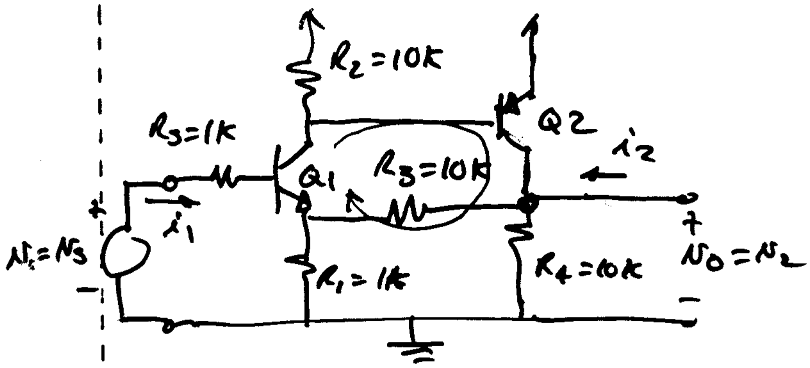
4.) Use the A circuit including the loading of the F circuit (h_{11F} & h_{22F}) to find A.

5.) $A_F = \dfrac{A}{1+AF} = \dfrac{A}{1+AB}$

6.) $r_{inF} = (R_S + h_{11T})(1+AF) = (R_S + h_{11T})(1+AF)$

7.) $r_{outF} = \dfrac{(h_{22T}+G_L)}{1+AF} = \dfrac{h_{22T}+G_L}{1+AB}$

Example



If $\beta_1 = \beta_2 = 100$ & $r_{\pi 1} = r_{\pi 2} = 10K$, find $\dfrac{v_2}{v_1}$, $\dfrac{v_1}{i_1}$ and $\dfrac{v_2}{i_2}$

To be continued ...