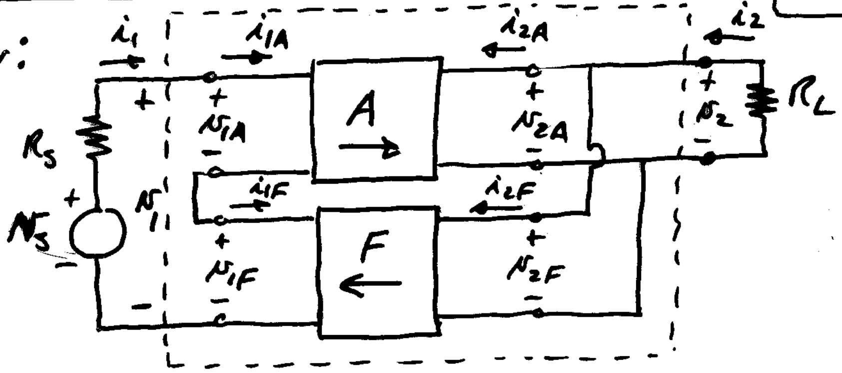
Hmwk 11 Due 3/31

Voltage Amplifiers – Series-Shunt Feedback

Topology:



$$v_1 = (h_{11A}+h_{11F})i_1 + (\overset{0}{\cancel{h_{12A}}}+h_{12F})v_2$$
$$i_2 = (h_{21A}+\overset{0}{\cancel{h_{21F}}})i_1 + (h_{22A}+h_{22F})v_2$$

$$v_1 = h_{11T}i_1 + h_{12F}v_2$$
$$i_2 = h_{21A}i_1 + h_{22T}v_2$$

where $h_{11T} = \left.\frac{v_1}{i_1}\right|_{v_2=0}$, $h_{12F} = \left.\frac{v_{1F}}{v_{2F}}\right|_{i_{1F}=0=i_1} \approx \cancel{\left.\frac{v_1}{v_2}\right|_{i_1=0}}$, $h_{21A} = \left.\frac{i_{2A}}{i_{1A}}\right|_{v_{2A}=0=v_2} \approx \cancel{\left.\frac{i_2}{i_1}\right|_{v_2=0}}$

and $h_{22T} = \left.\frac{i_2}{v_2}\right|_{i_1=0}$

What is the closed-loop transfer function including R_S & R_L?

(1) $v_S = i_1R_S + v_1 = i_1R_S + h_{11T}i_1 + h_{12F}v_2 = i_1(R_S+h_{11T}) + h_{12}v_2$

$v_2 = -i_2R_L \rightarrow -\frac{v_2}{R_L} = h_{21A}i_1 + h_{22T}v_2 \rightarrow 0 = h_{21A}i_1 + (h_{22T}+G_L)v_2$

2nd eq. $\rightarrow$ $i_1 = -\frac{(h_{22T}+G_L)}{h_{21A}}v_2$

Substitute into eq. (1) to get

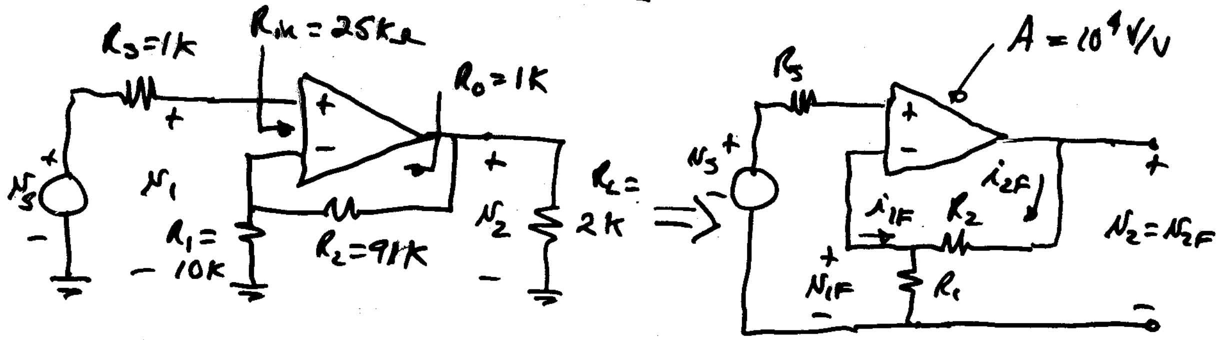
$$v_S = -(R_S+h_{11T})\left(\frac{h_{22T}+G_L}{h_{21A}}\right)v_2 + h_{12F}v_2$$

$$\frac{v_2}{v_S} = \text{Closed loop T.F.} = \frac{h_{21A}}{-(R_S+h_{11T})(h_{22T}+G_L)+h_{12F}h_{21A}}$$

$$\frac{v_2}{v_S} = A_{VF} = \frac{\dfrac{-h_{21A}}{(R_S+h_{11T})(h_{22T}+G_L)}}{1+\dfrac{-h_{21A}}{(R_S+h_{11T})(h_{22T}+G_L)}(h_{12F})} = \frac{A}{1+AB} = \frac{A}{1+AF}$$

$$\therefore \boxed{A = \frac{-h_{21A}}{(R_S + h_{11T})(G_L + h_{22T})}} \quad \text{and} \quad \boxed{\beta = F = h_{12F}}$$

Example of Series-Shunt Fb.



Find $\frac{v_2}{v_s}$.

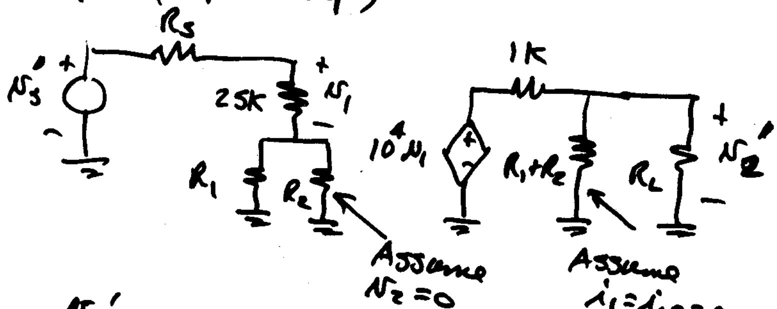
$$h_{11T} = h_{11A} + h_{11F} = 25k\Omega + \left.\frac{v_{1F}}{i_{1F}}\right|_{v_2=0} = 25k\Omega + R_1 \| R_2 = 25K + 9.01K$$

$$h_{11T} = 34.01\,k\Omega$$

$$h_{22T} = h_{21A} + h_{22F}, \rightarrow h_{22F} = \left.\frac{i_{2F}}{v_2}\right|_{i_{1F}=0} = \frac{1}{R_1+R_2} = \frac{1}{101K}$$

$$h_{12F} = \left.\frac{v_{1F}}{v_2}\right|_{i_{1F}=0} = \frac{R_1}{R_1+R_2} = 0.099 = F = \beta$$

$h_{21A} = ?$ (Open loop)



$$\frac{v_2'}{v_s'} = A = \left(\frac{25K}{1K + 25K + 9.01K}\right)\left(10^4\right)\left(\frac{(R_1+R_2)\|R_L}{1K + (R_1+R_2)\|R_L}\right)$$

$$= 4730\,\frac{V}{V}$$

$$\therefore A_{VF} = \frac{v_2}{v_s} = \frac{A}{1+A\beta} = \frac{4730}{1+(4730)(0.099)} = 10.08\,\frac{V}{V}$$

Input Resistance

For the voltage amplifier feedback network -

$$R_{inF} = \frac{v_s}{i_1} = (R_s + h_{11T})\left[1 + \frac{-h_{21A}\, h_{12F}}{(R_s + h_{11T})(G_L + h_{22T})}\right]$$

$$= (R_s + h_{11T})[1 + AB] = \text{Input } R \text{ w/o fb} \,(1 + \text{Loop gain})$$

Output Resistance ($v_s = 0$)

$$R_{outF} = \left.\frac{v_2}{i_2}\right|_{v_s=0} = \frac{1}{(h_{22} + G_L)\left[1 + \frac{-h_{21A}\, h_{12F}}{(R_s + h_{11T})(G_L + h_{22T})}\right]}$$

$$= \frac{1}{(h_{22} + G_L)(1 + AB)} = \frac{\text{Output Resistance w/o fb}}{1 + \text{Loop Gain}}$$

General Approach to Analyzing a fb. Amplifier is:

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

2.) Find h_{22F} (output conductance of the F network with the input O.C.)

3.) Find $h_{12F} = F = B$ (voltage gain of F ntwk from output to input with the input O.C.)

4.) Use the amplifier ckt. to find A (including h_{11F} and h_{22F})

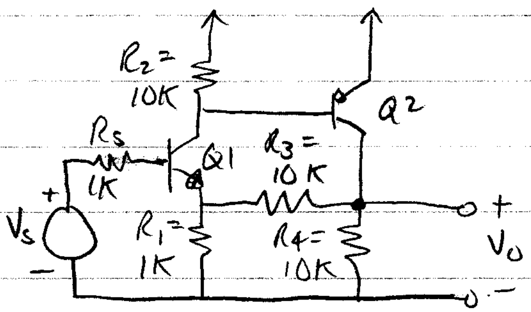
5.) $A_F = \frac{A}{1 + AB}$

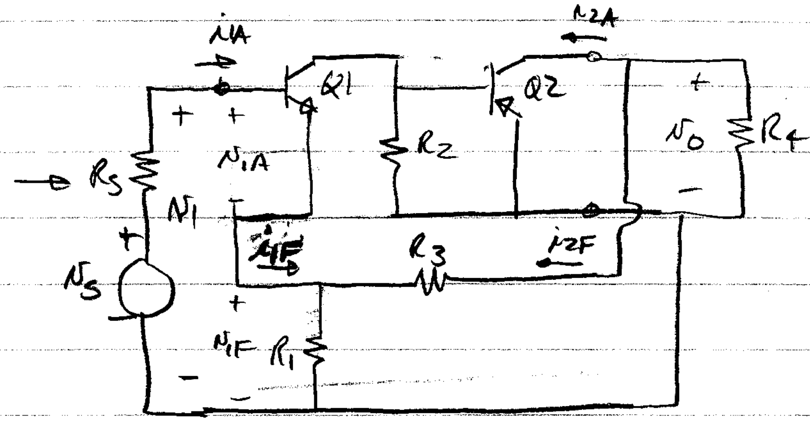
6.) $R_{inF} = (R_s + h_{11T})(1 + BA)$

7.) $R_{outF} = \frac{1}{(G_s + h_{22T})(1 + AB)}$

This the next lecture page (to be covered 3/31/04). It should help to work the homework.

Example





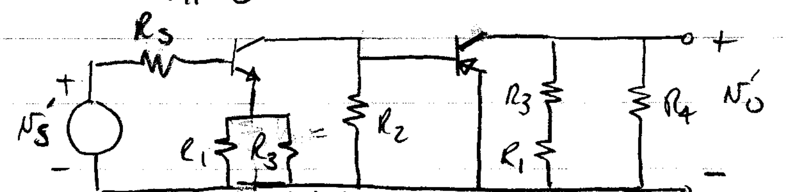
$\beta = 100 \quad r_\pi = 10K$

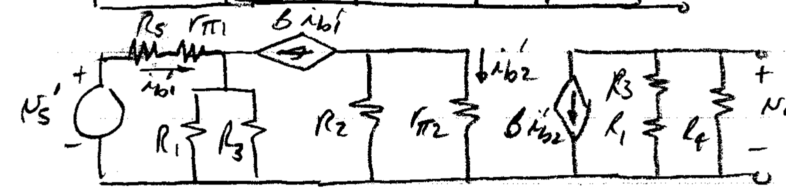
1.) $h_{11F} = \left.\dfrac{v_{1F}}{i_{1F}}\right|_{v_o=0} = R_1 \| R_3 = 0.91K$

2.) $h_{22F} = \left.\dfrac{i_{2F}}{v_o}\right|_{i_{1F}=0} = \dfrac{1}{R_1+R_3} = \dfrac{1}{11K}$

3.) $h_{12F} = \left.\dfrac{v_{1F}}{v_o}\right|_{i_{1F}=0} = \dfrac{1}{11}$

4.)





$$A = \frac{v_o'}{v_s'} = \left(\frac{v_o'}{i_{b2}'}\right)\left(\frac{i_{b2}'}{i_{b1}'}\right)\left(\frac{i_{b1}'}{v_s'}\right) = \left[-\beta R_4 \| (R_1+R_3)\right]\left[-\beta \frac{R_2}{R_2+r_{\pi 2}}\right]\left[\frac{1}{R_s + r_{\pi 1} + (1+\beta) R_1 \| R_3}\right]$$

$$A = \left[-100(5.24K)\right]\left[-100 \frac{10}{20}\right]\left[\frac{1}{102.8K}\right] = +255 \text{ V/V}$$

5.) $A_F = \dfrac{v_o}{v_s} = \dfrac{255}{1+\left(\frac{1}{11}\right)(255)} = \dfrac{255}{1+23.17} = \underline{\underline{10.54 \text{ V/V}}}$

6.) $R_s + h_{11T} = R_s + r_{\pi 1} + (1+\beta) R_1 \| R_3 = 102.8K$

$\therefore R_{INF} = 102.8K(1+A\beta) \cong 102.8K(24.17) = \underline{\underline{2.485M\Omega}}$

7.) $h_{22T} + G_L = h_{22A} + h_{22F} + G_L = \dfrac{1}{11K} + \dfrac{1}{\infty} + \dfrac{1}{10K} = \dfrac{1}{5.23K}$

$\therefore R_{OUTF} = \dfrac{5.23K}{1+A\beta} = \dfrac{5.23K}{24.17} = \underline{\underline{216\Omega}}$