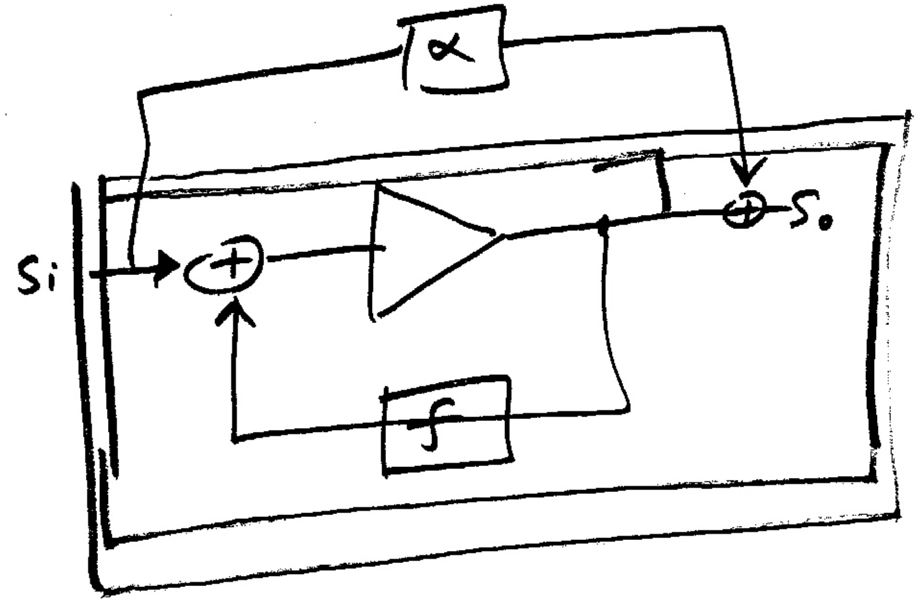
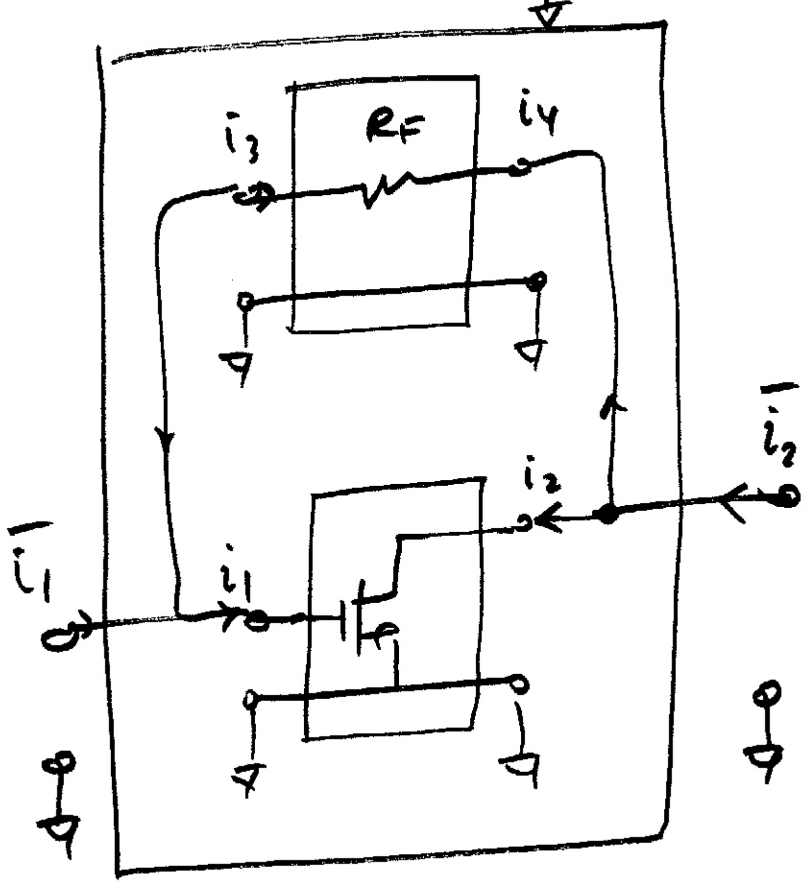
Lecture 13

FEEDBACK





$$\bar{i}_2 = i_2 + i_4$$

$$\bar{i}_1 = i_1 + i_3$$

$$\begin{pmatrix} i_1 \\ i_2 \end{pmatrix} = Y^a \begin{pmatrix} v_1 \\ v_2 \end{pmatrix}$$

$$\begin{pmatrix} i_3 \\ i_4 \end{pmatrix} = Y^{fb} \begin{pmatrix} v_1 \\ v_2 \end{pmatrix}$$

$$\begin{pmatrix} \bar{i}_1 \\ \bar{i}_2 \end{pmatrix} = \left(Y^a + Y^{fb}\right) \begin{pmatrix} \bar{v}_1 \\ v_2 \end{pmatrix}$$

Y-PARAM AMP

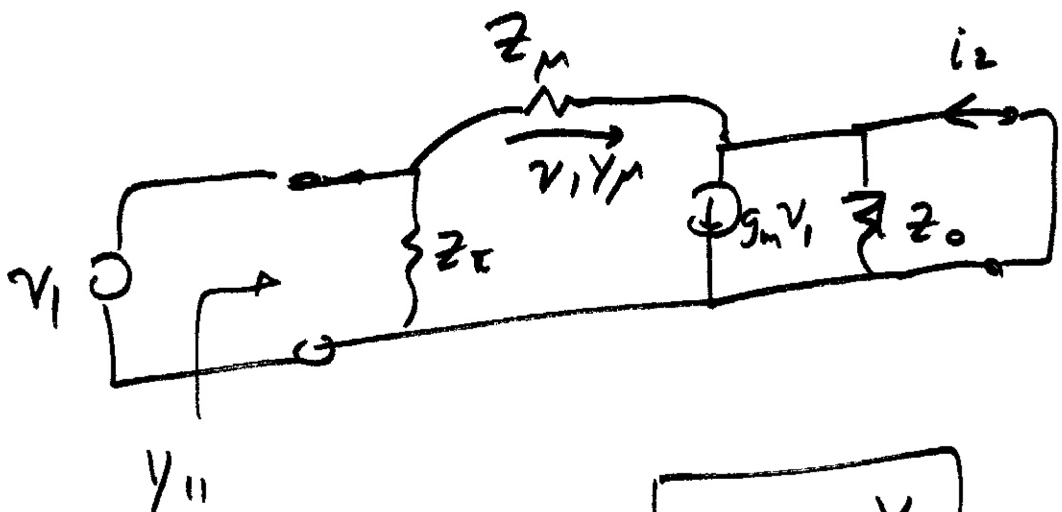
$$i_1 = y_{11} v_1 + y_{12} v_2$$

$$i_2 = y_{21} v_1 + y_{22} v_2$$

$$y_{11} = \left.\frac{i_1}{v_1}\right|_{v_2=0}$$

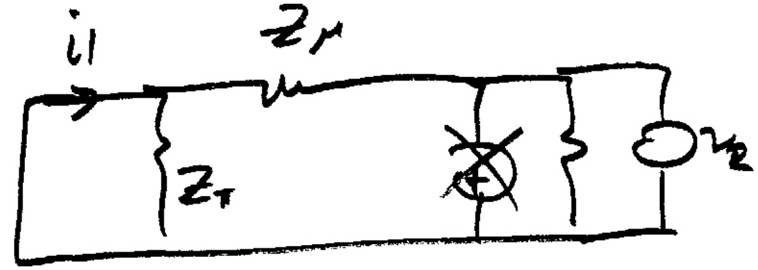
$$\boxed{y_{11} = Y_\pi + Y_\mu}$$

$$\boxed{Y_{22} = Y_o + Y_\mu}$$

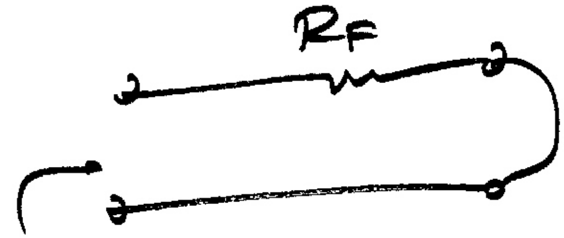


$$Y_{21} = \left.\frac{i_2}{v_1}\right|_{v_2=0} = \boxed{g_m - Y_\mu}$$

$$Y_{12} = \left.\frac{i_1}{v_2}\right|_{v_1=0} = \boxed{-Y_\mu}$$



FB NETWORK

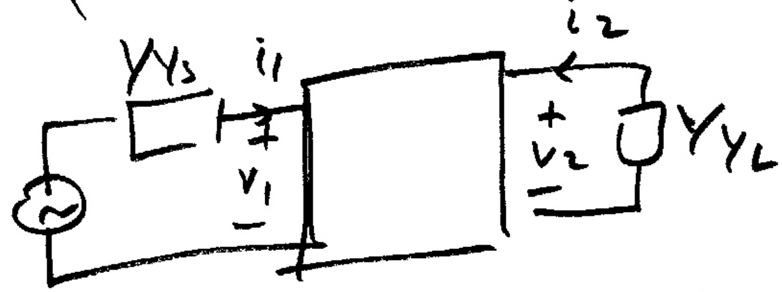


$$Y_{11} = Y_{22} = 1/R_F = G_F$$

$$Y_{12} = Y_{21} = -G_F$$

$$Y = Y^a + Y^{fb} = \begin{bmatrix} j\omega(C_{gs}+C_{gd}) + G_F & -j\omega C_{gd} - G_F \\ g_m - j\omega C_{gd} - G_F & G_o + j\omega(C_{db}+C_{gd}) + G_F \end{bmatrix}$$

$$Y^a + \begin{pmatrix} G_F & -G_F \\ -G_F & G_F \end{pmatrix} =$$



$$i_2 = -Y_L \cdot v_2$$

$$i_2 = Y_{21} v_1 + Y_{22} v_2 = -Y_L v_2$$

$$v_2 (Y_{22} + Y_L) = -Y_{21} v_1$$

$$A_{v,i} = \frac{v_2}{v_1} = \frac{-Y_{21}}{Y_{22}+Y_L}$$

$$A_v = \frac{V_2}{V_S} = \frac{V_2}{V_1} \cdot \frac{V_1}{V_S} = A_{v,i} \cdot \underbrace{\frac{Y_S}{Y_S + Y_{in}}}_{\text{VOLTAGE DIVIDER}}$$

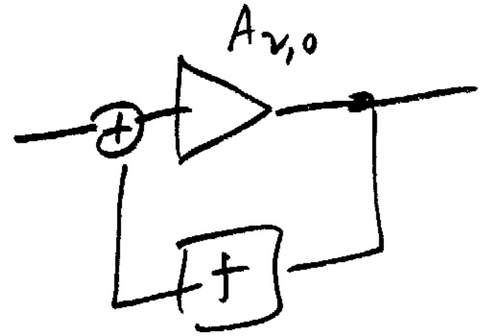
$$Y_{in} = Y_{11} - \frac{Y_{12}Y_{21}}{(Y_L + Y_{22})}$$

$$A_v = \frac{-Y_{21}}{\cancel{Y_{22}+Y_L}} \cdot \frac{Y_S(\cancel{Y_L+Y_{22}})}{Y_S(Y_L+Y_{22}) + Y_{11}(Y_L+Y_{22}) - Y_{12}Y_{21}}$$

$$\boxed{A_v = \frac{-Y_{21}Y_S}{(Y_S+Y_{11})(Y_L+Y_{22}) - Y_{12}Y_{21}}}$$

$$A_{v,0} = A_v\Big|_{Y_{12}=0} = \frac{-Y_{21} Y_S}{(Y_S+Y_{11})(Y_L+Y_{22})}$$

$$A_v = \frac{\dfrac{-Y_{21} Y_S}{(Y_S+Y_{11})(Y_L+Y_{22})}}{1 - \dfrac{Y_{12} Y_{21}}{(Y_S+Y_{11})(Y_L+Y_{22})}}$$



$$\frac{S_o}{S_i} = \frac{A_{v0}}{1 - \underbrace{A_{v,0} f}_{T}}$$

$$\boxed{A_v = \frac{A_{v0}}{1 - T}}$$

$$T = A_{v0} \cdot f = \frac{Y_{12} Y_{21}}{(Y_S+Y_{11})(Y_L+Y_{22})} = \frac{-Y_{21} Y_S}{(Y_S+Y_{11})(Y_L+Y_{22})} \cdot f$$

$$\boxed{f = -\frac{Y_{12}}{Y_S}}$$

$$A_{vo} = \frac{-Y_{21} Y_S}{(Y_S + Y_{11})(Y_L + Y_{22})} = \frac{-(g_m - j\omega C_{gd} - G_F)\, G_S}{(G_S + j\omega(C_{gs} + C_{gd}) + G_F) \times (G_L + j\omega(C_{db} + C_{gd}) + G_F)}$$

$$T = A_{v,o} \cdot f = -A_{v,o} \cdot \frac{-(j\omega C_{gd} + G_F)}{G_S}$$

$$T(\omega \simeq 0) = \frac{+ g_m G_S}{(G_S + G_F)(G_L + G_F)} \, \frac{G_F}{G_S}$$

$$\boxed{T = \frac{g_m G_F}{(G_S + G_F)(G_L + G_F)} = \frac{g_m R_F}{\left(1 + \frac{R_F}{R_S}\right)\left(1 + \frac{R_F}{R_L}\right)}}$$

<u>EX</u>: $g_m = 10\,mS$ $\quad R_F = 10\,k\Omega$

$\frac{R_F}{R_S} = \frac{R_F}{R_L} = 1$ $\qquad T = \frac{100}{4} = 25$

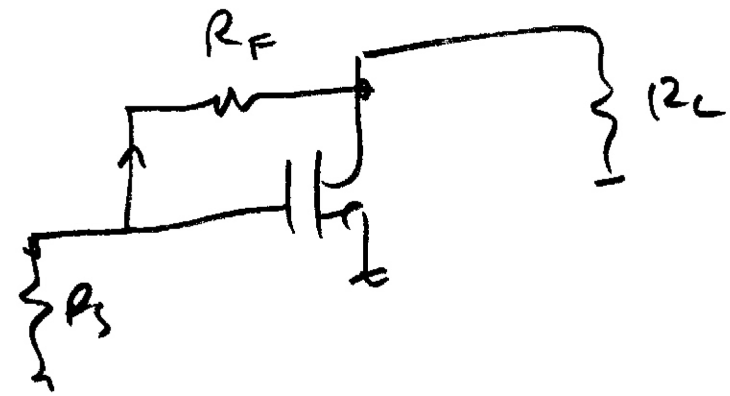
AS $R_S \to \infty$ $\quad T = \dfrac{g_m R_F}{\left(1 + \dfrac{R_F}{R_L}\right)}$

GOOD CURRENT AMPLIFIER

(TO VOLTAGE)

AS $R_S \to 0$ $\quad T = \dfrac{g_m R_F}{\left(1 + \dfrac{R_F}{R_S \to 0}\right)\left(\quad \right)} \Rightarrow 0$

LOADED FB CALC



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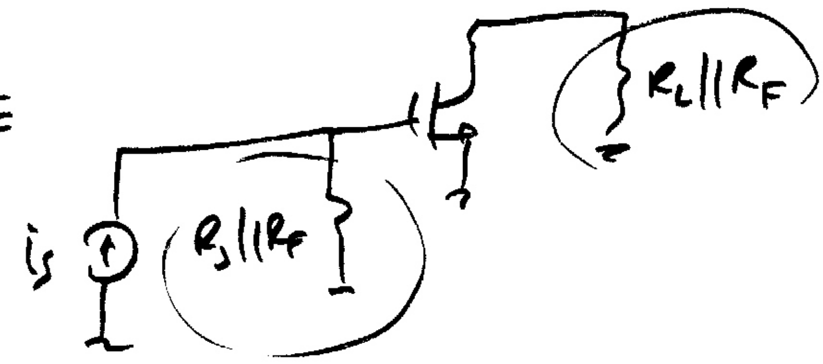
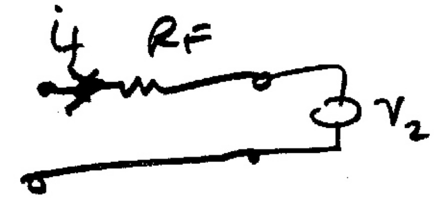




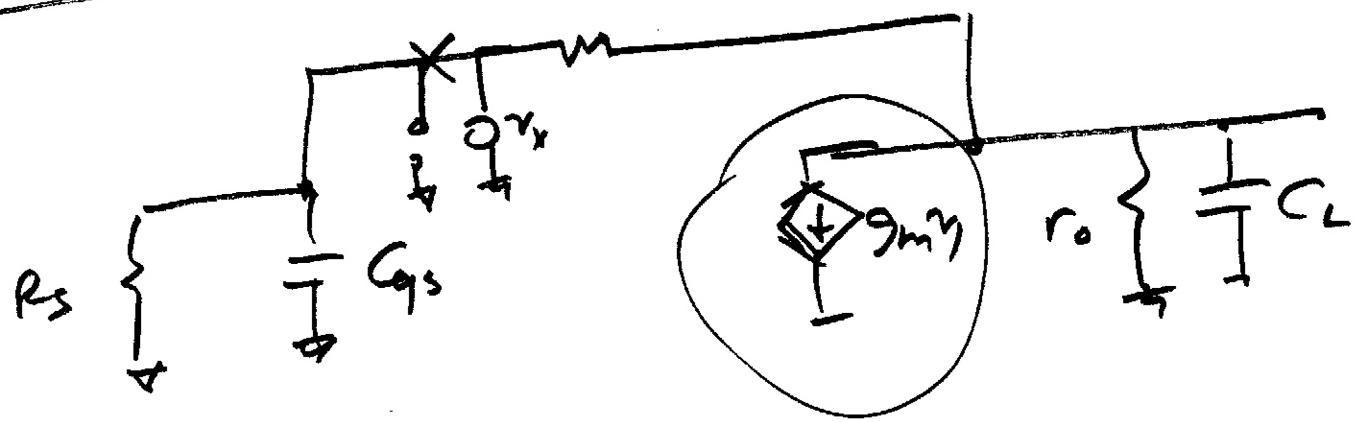
$$A_o = -g_m (R_S || R_F)(R_L || R_F)$$

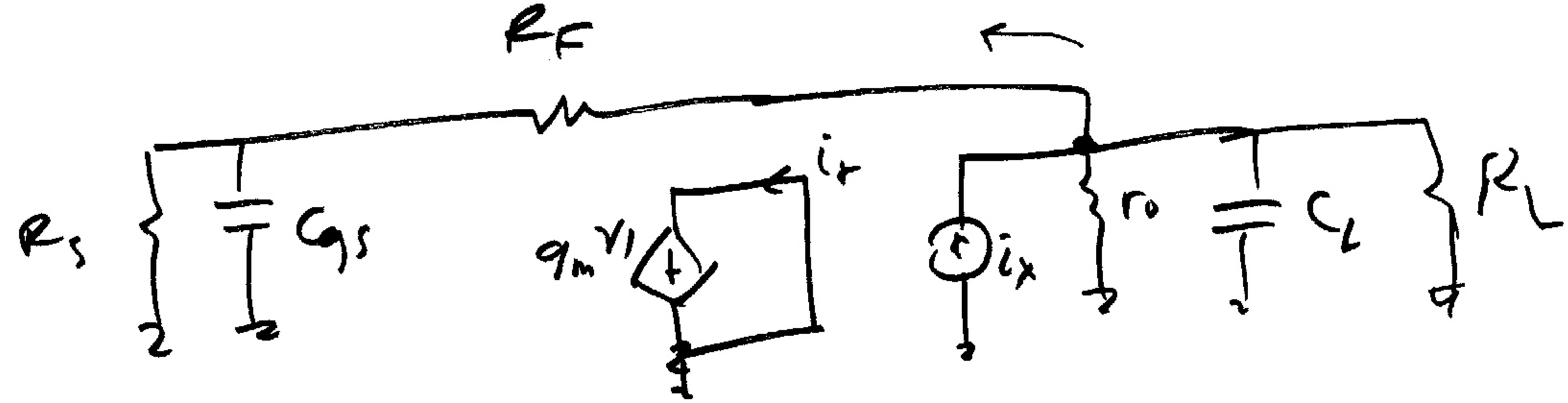
$$f = -1/R_F$$

$$T = A_o f = \frac{g_m \quad 1/R_F}{\left(\frac{1}{R_S} + \frac{1}{R_F}\right)\left(\frac{1}{R_L} + \frac{1}{R_F}\right)}$$

$$= \frac{g_m R_F}{\left(1 + \frac{R_F}{R_S}\right)\left(1 + \frac{R_F}{R_L}\right)}$$ ✓

"RETURN RATIO"





$$R = \frac{i_r}{i_x}$$

$$i_x \frac{(G_o + j\omega C_L)}{G_o + j\omega C_L + G}$$

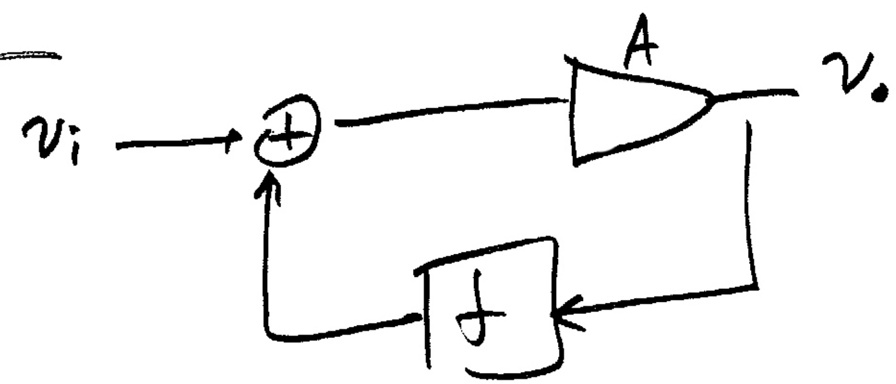
$$i_x \frac{R_L}{R_L + R_F + R_S} \cdot R_S \cdot g_m = i_r$$

$$T = \frac{i_r}{i_x} = \frac{g_m R_L R_S}{R_L + R_F + R_S}$$

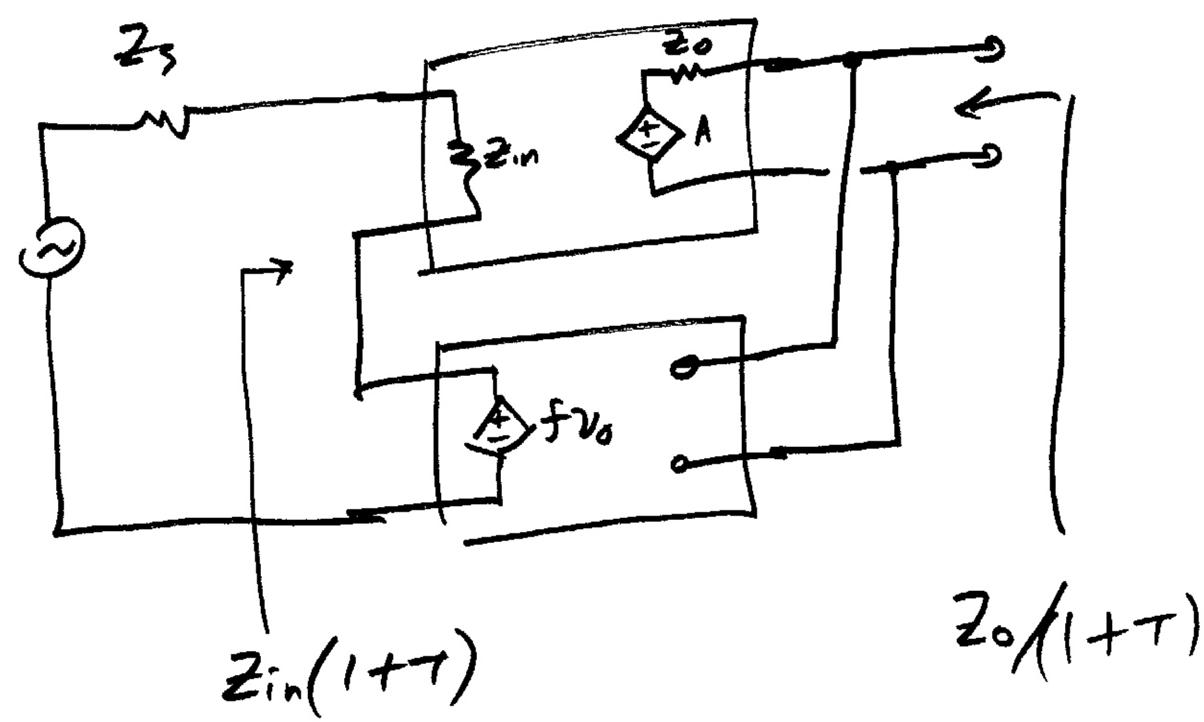
$$= \frac{g_m \cdot R_F}{\left(\frac{R_F}{R_S} + \frac{R_F}{R_L} + \frac{R_F^2}{R_L R_S}\right)}$$

$$= \frac{g_m R_F}{\left(1 + \frac{R_F}{R_S}\right)\left(1 + \frac{R_F}{R_L}\right) - 1}$$

"LOADED" FB

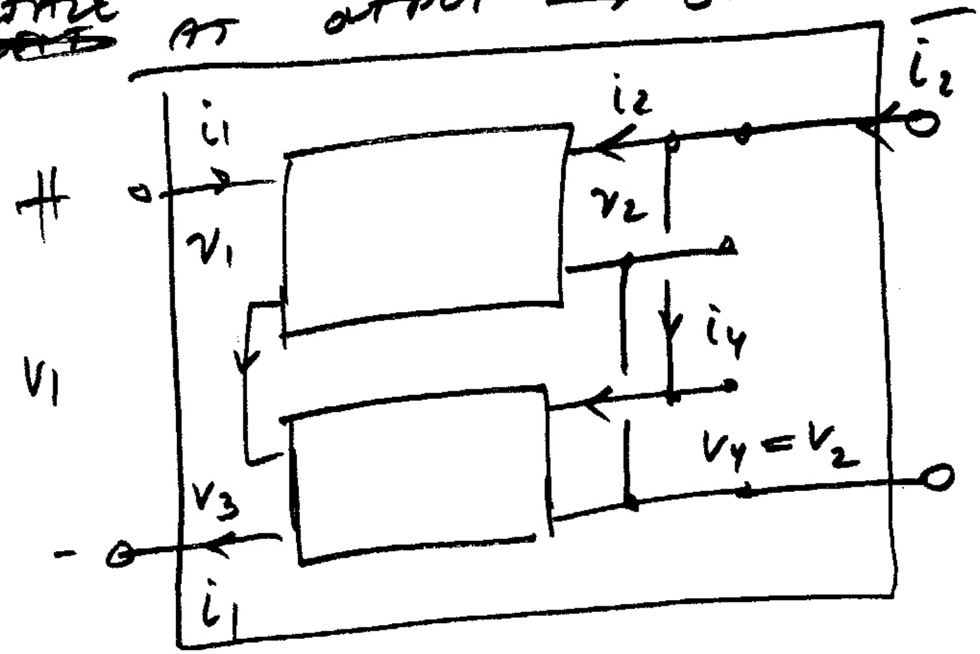


VOLTAGE AMP ⟹ SERIES – SHUNT FB



VOLTAGE AT INPUT ⇒ SERIES

VOLTAGE AT OUTPUT ⇒ SHUNT



$$i_1 = i_3 = \bar{i}_1 \qquad \bar{v}_2 = v_2 = v_4$$

$$\bar{v}_1 = v_1 + v_3 \qquad \bar{i}_2 = i_2 + i_4$$

$$\begin{pmatrix} v_1 \\ i_2 \end{pmatrix} = \underset{\substack{\parallel \\ H}}{A} \cdot \begin{pmatrix} i_1 \\ v_2 \end{pmatrix}$$

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

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

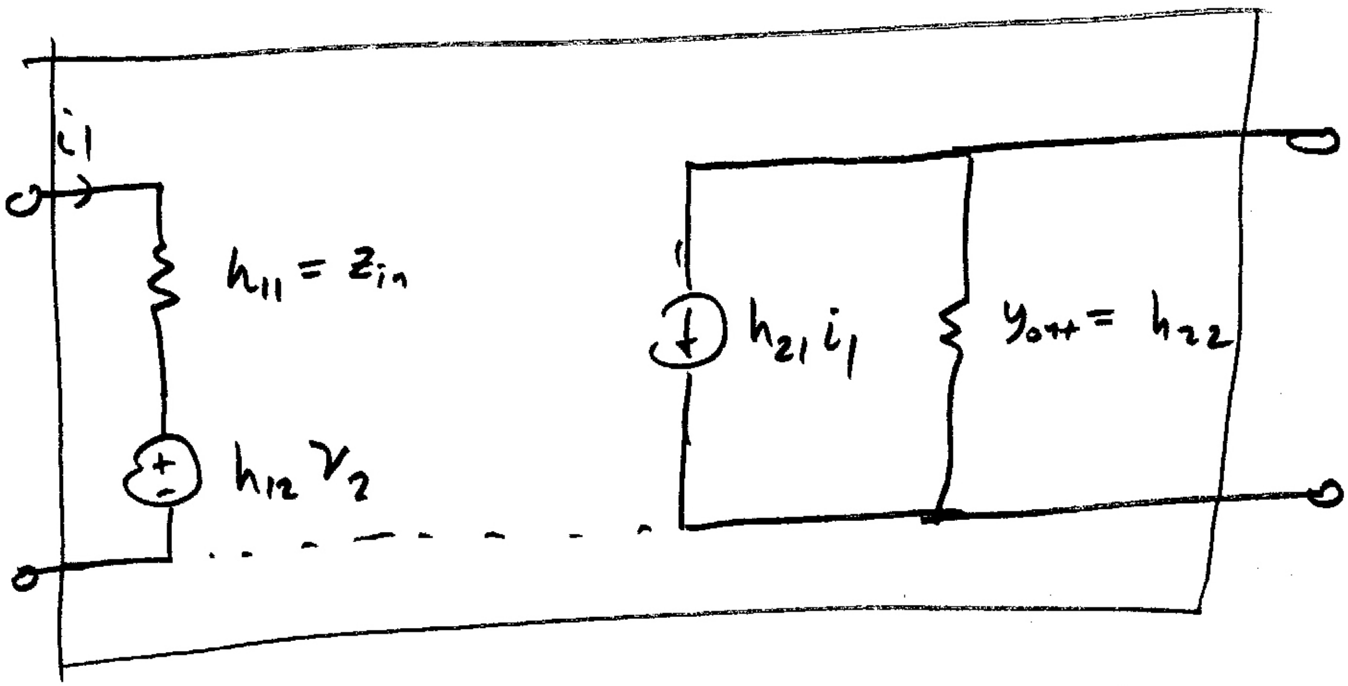
$$h_{11} = \left.\frac{v_1}{i_1}\right|_{v_2=0}$$ = SHORT CIRCUIT INPUT IMPEDANCE

$$h_{21} = \left.\frac{i_2}{i_1}\right|_{v_2=0}$$ = SHORT CIRCUIT CURRENT GAIN

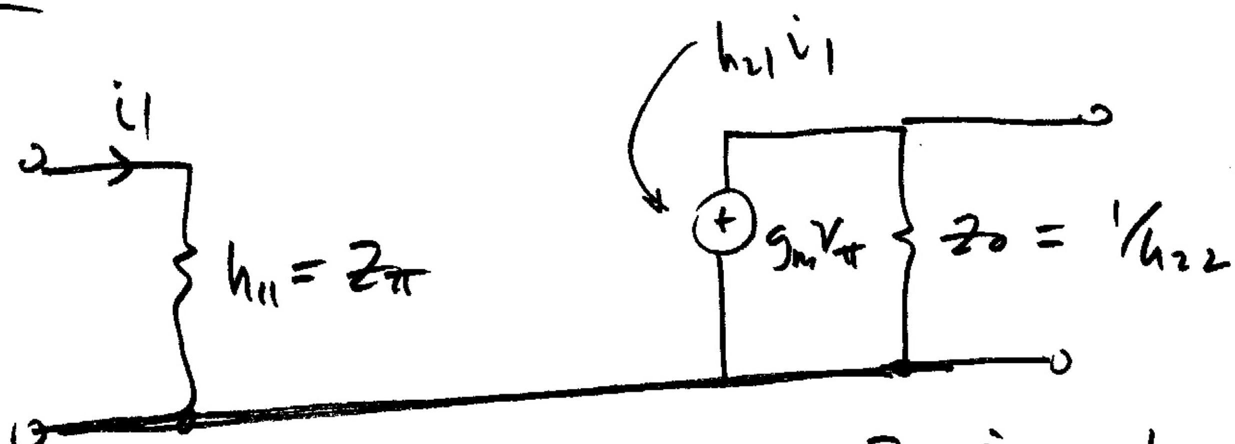
$$h_{12} = \left.\frac{v_1}{v_2}\right|_{i_1=0}$$ REVERSE VOLTAGE GAIN

OPEN CIRCUIT

$$h_{22} = \left.\frac{i_2}{v_2}\right|_{i_1=0}$$ OPEN CIRCUIT OUTPUT ADMITTANCE

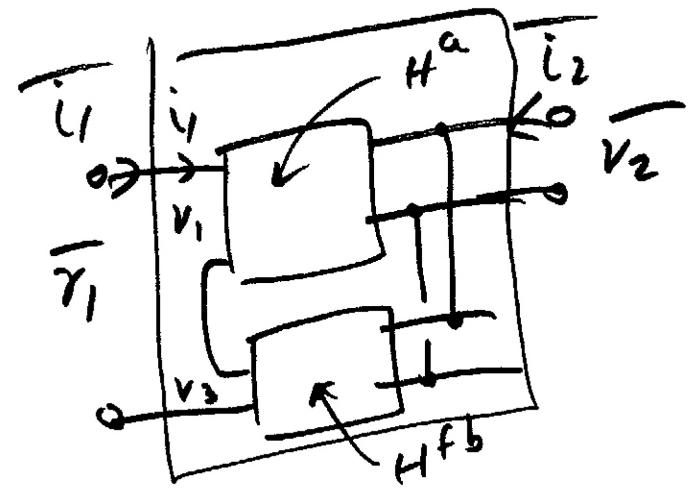


TRANSISTOR $h_{12} \simeq 0$ UNILATERAL AMP



$$g_m v_\pi = i_1 \cdot Z_\pi \cdot g_m = g_m Z_\pi \, i_1 = h_{21} \, i_1$$

$$\boxed{h_{21} = g_m Z_\pi = \beta}$$

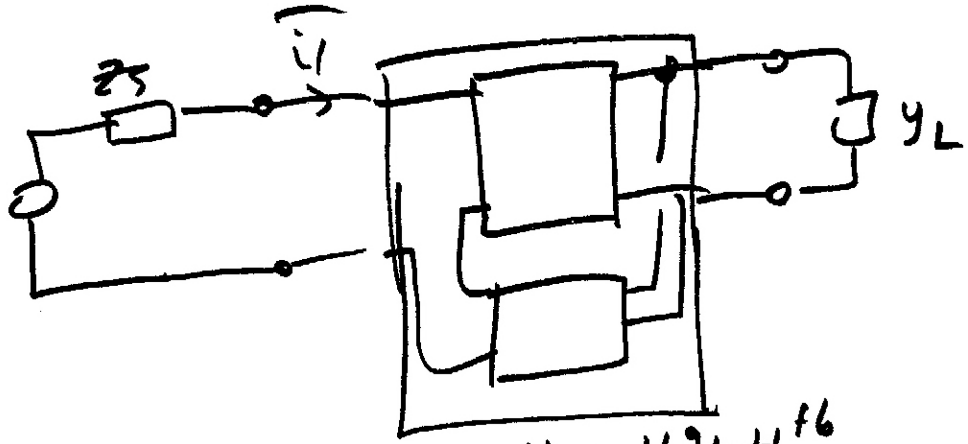


$$\begin{pmatrix} v_1 \\ i_2 \end{pmatrix} = H^{amp} \cdot \begin{pmatrix} i_1 \\ v_2 \end{pmatrix}$$

$$\begin{pmatrix} v_3 \\ i_4 \end{pmatrix} = H^{fb} \cdot \begin{pmatrix} i_3 = i_1 \\ v_4 = v_2 \end{pmatrix}$$

$$\begin{pmatrix} v_1 + v_3 \\ i_2 + i_4 \end{pmatrix} = \left(H^{amp} + H^{fb} \right) \begin{pmatrix} i_1 \\ v_2 \end{pmatrix}$$

$$\begin{pmatrix} \bar{v}_1 \\ \bar{i}_2 \end{pmatrix} = H \begin{pmatrix} \bar{i}_1 \\ \bar{v}_2 \end{pmatrix}$$



$$H = H^{a} + H^{fb}$$

$$v_s = \left(z_s + h_{11a} + h_{11f}\right)\bar{i}_1 + \left(h_{12a} + h_{12f}\right)\bar{v}_2$$

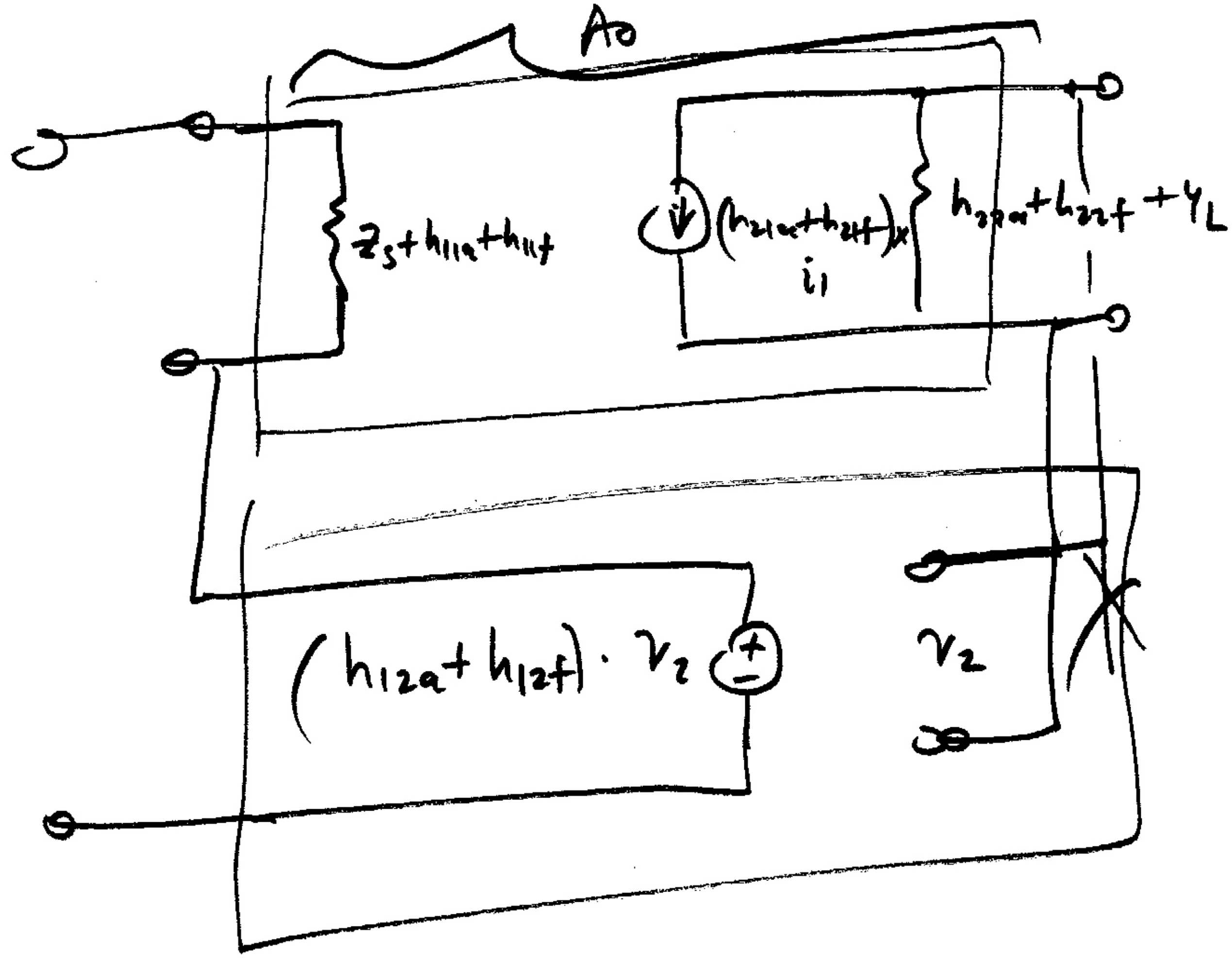
$$0 = \left(h_{21a} + h_{21f}\right)\bar{i}_1 + \left(y_L + h_{22a} + h_{22f}\right)\bar{v}_2$$

$$H = \underbrace{\begin{bmatrix} z_s + h_{11a} + h_{11f} & 0 \\ h_{21a} + h_{21f} & y_L + h_{22a} + h_{22f} \end{bmatrix}}_{\text{IDEAL AMP}} + \underbrace{\begin{bmatrix} 0 & h_{12a} + h_{12f} \\ 0 & 0 \end{bmatrix}}_{\text{IDEAL FB}}$$

I/P LOAD, FB, FWD, O/P LOAD

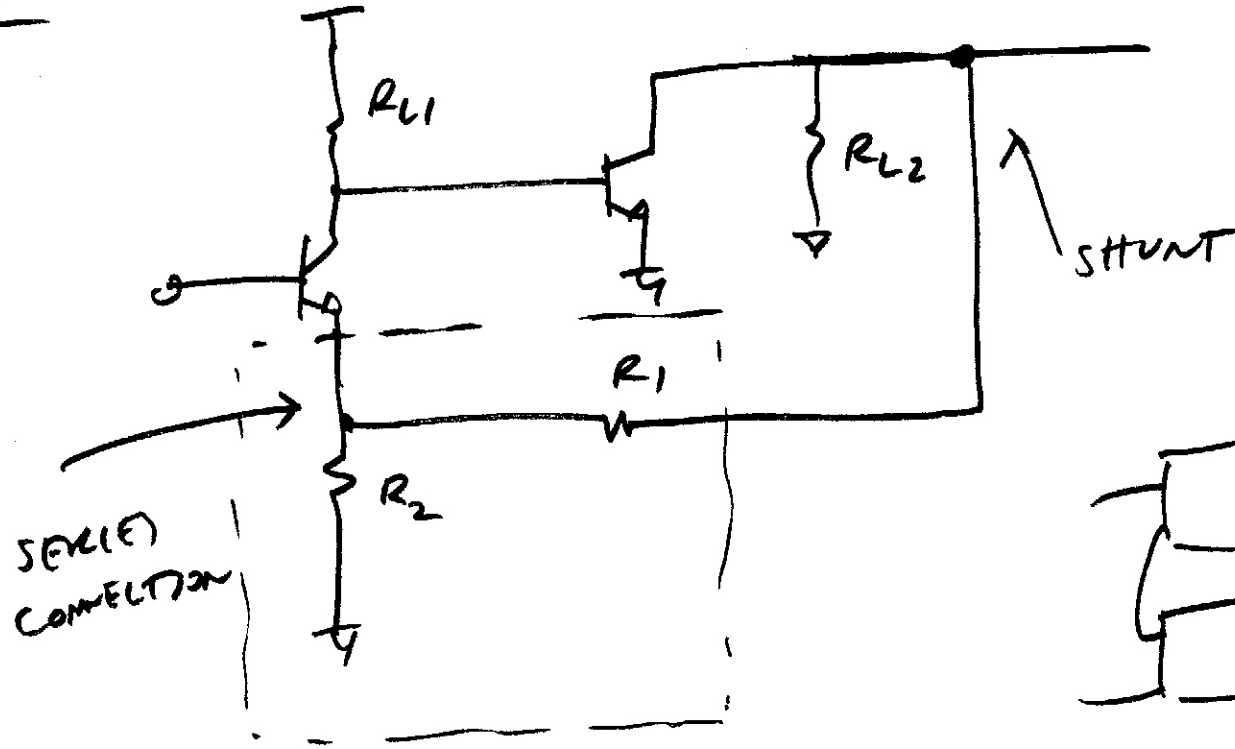
IDEAL <u>UNILATERAL</u> AMP

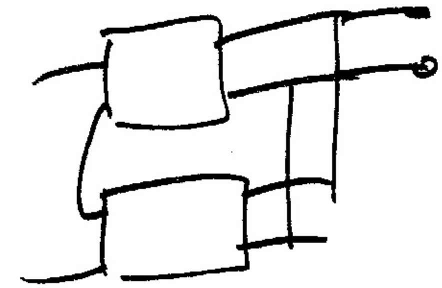
IDEAL FB



Ao
Zs+h11a+h11f
(h21a+h21f)x i1
h22a+h22f+YL
(h12a+h12f) · v2
v2

EX



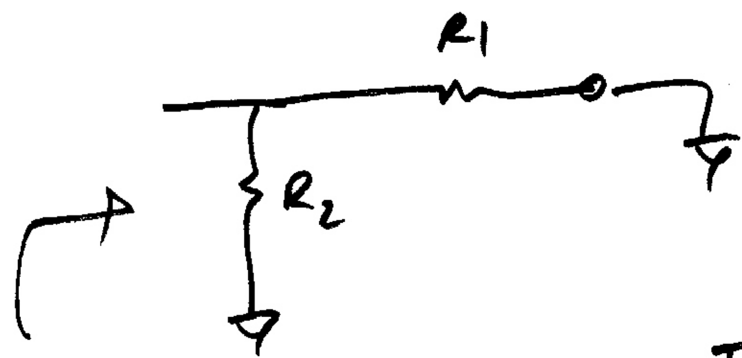


VOLTAGE – VOLTAGE

SERIES – SHUNT

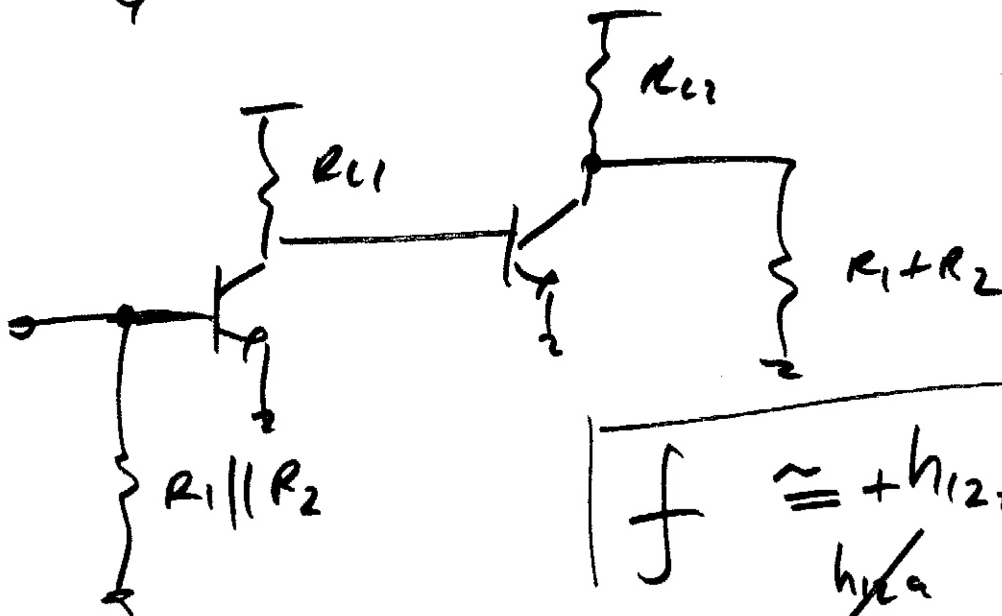
OPEN

SHORT



$$h_{11fb} = R_1 \| R_2$$

$$h_{22fb} = (R_1 + R_2)^{-1}$$



$$f \cong +h_{12fb} = \frac{R_2}{R_1 + R_2}$$

h_{12a} → 0