8-2-12

Lec 15

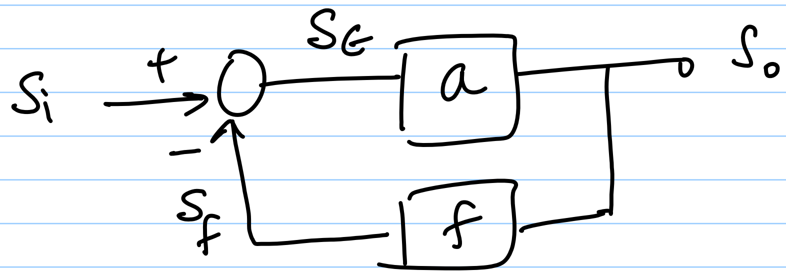
Feedback

Why?

* stabilise gain etc. against parameter changes due to PVT variations
  - process
  - voltage
  - temperature
* modify input & output impedances
* reduction in distortion
* Increase -3dB BW of ckts

disadvantages of FB:

* gain of ckt is reduced
  → extra stages = area, power
* stability issues



note the signs of the summer inputs

$$S_o = a\,S_\epsilon$$

$$S_f = f \cdot S_o$$

$$S_\epsilon = S_i - f S_o$$

$$\Rightarrow S_o = a S_i - af S_o$$

$$\Rightarrow \frac{S_o}{S_i} = A = \frac{a}{1+af}$$

Closed loop gain $= A$

Loop gain $= T = af$ $\left\{ = \text{total gain around f.b. loop} \right\}$

If $T \gg 1$, $A \approx \frac{1}{f}$

$f \rightarrow$ often based on stable, passive elements

$\rightarrow$ well-defined

$$S_\epsilon = S_i - f S_o = S_i - \frac{f a S_i}{1+af}$$

$$\frac{S_\epsilon}{S_i} = \frac{1}{1+af}$$

$$\frac{S_f}{S_i} = \frac{af}{1+af}$$ If $T \gg 1$, $S_f \approx S_i$

$$\Rightarrow S_o = \frac{1}{f} S_f = \frac{S_i}{f}$$

$|f| < 1 \Rightarrow S_o =$ amplified replica of S_i

<u>Gain sensitivity</u>

$$\frac{dA}{da} = \frac{(1+af) - af}{(1+af)^2} = \frac{1}{(1+af)^2}$$

$$\Rightarrow \quad \delta A = \frac{\delta a}{(1+af)^2}$$

$$\frac{\delta A}{A} = \frac{1+af}{a} \cdot \frac{\delta a}{(1+af)^2}$$

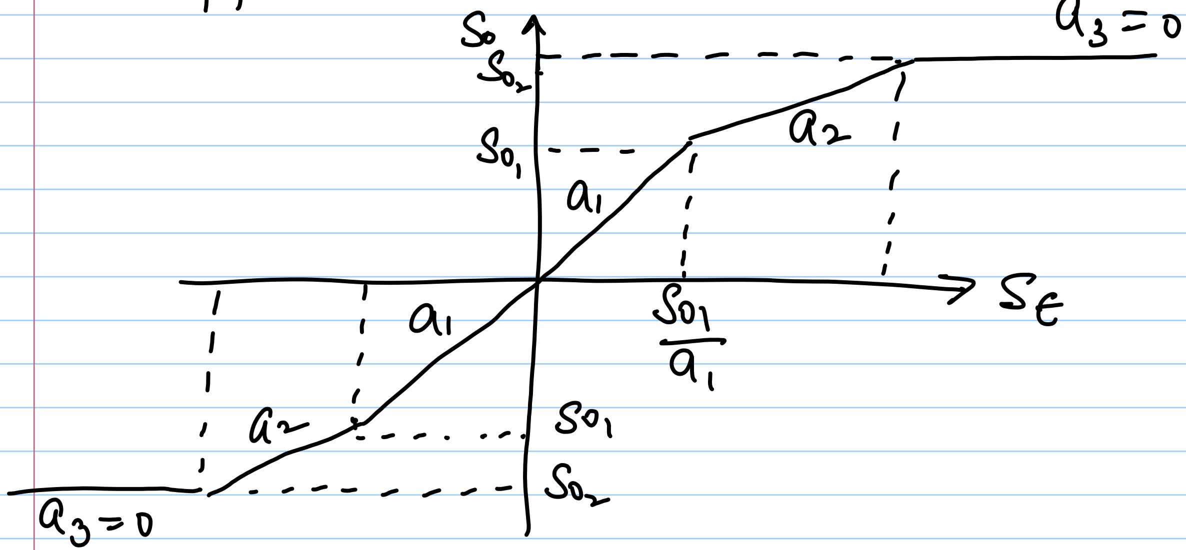
$$= \frac{(\delta a / a)}{(1+af)}$$

$\Rightarrow$ fractional change in A is reduced by $(1+T)$

e.g. $T = 100$, $\delta a / a = 10\%$

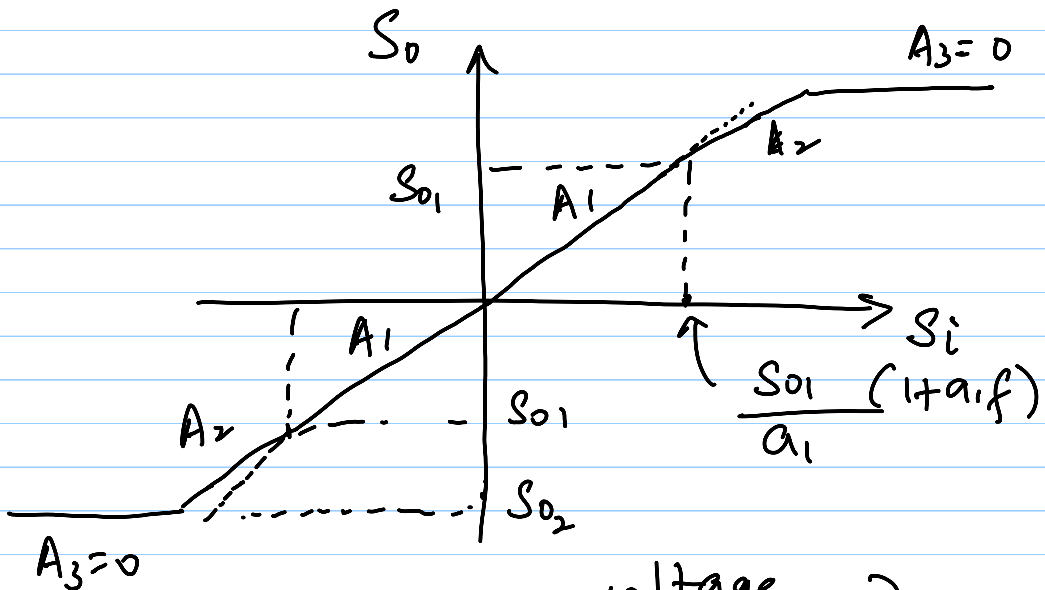
$$\Rightarrow \quad \frac{\delta A}{A} = 0.1\ \%$$

Effect on distortion



$$A_1 = \frac{a_1}{1 + a_1 f} \simeq \frac{1}{f}$$

$$A_2 = \frac{a_2}{1 + a_2 f} \simeq \frac{1}{f}$$



S_i < voltage, current

S_o < voltage, current

} four configs.

Effect on gain-BW

$$a(s) = \frac{a_0}{1 + s/\omega_{p1}} \quad \text{(1-pole)}$$

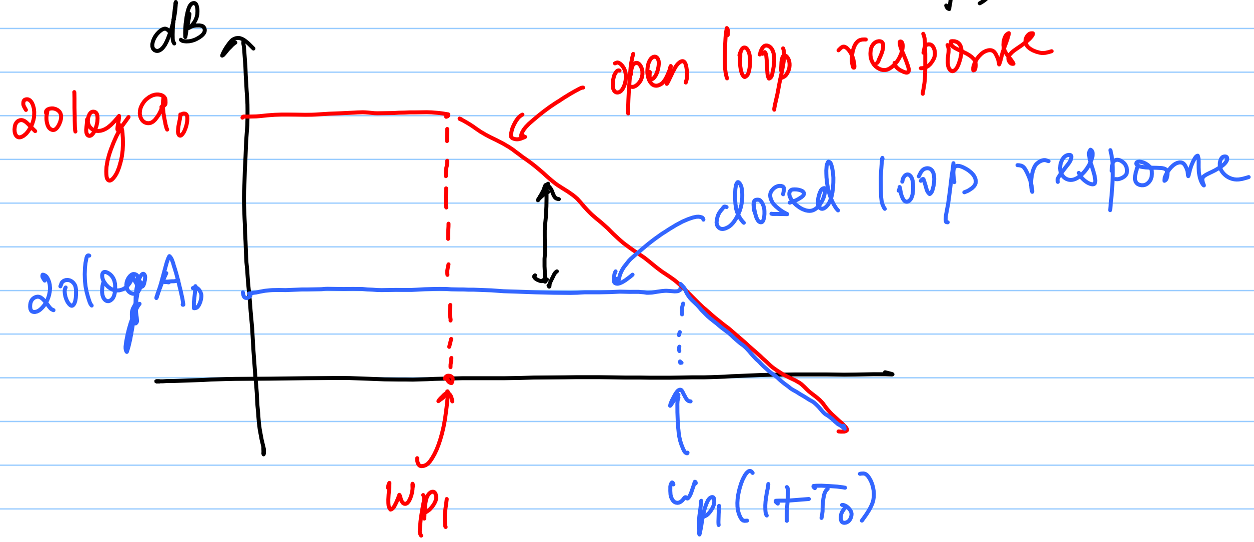
$f =$ constant & freq. independent

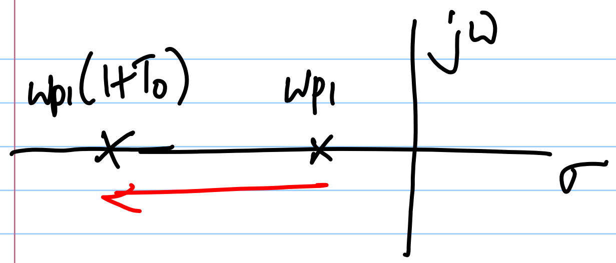
$$A(s) = \frac{a(s)}{1 + a(s)\cdot f}$$

$$= \frac{a_0}{1 + a_0 f} \cdot \frac{1}{1 + \frac{s}{\omega_{p1}(1 + a_0 f)}}$$

$$\Rightarrow A_0 = \frac{a_0}{1 + a_0 f}$$

$$\omega_{3\text{-}dB} = \omega_{p1}(1 + a_0 f)$$

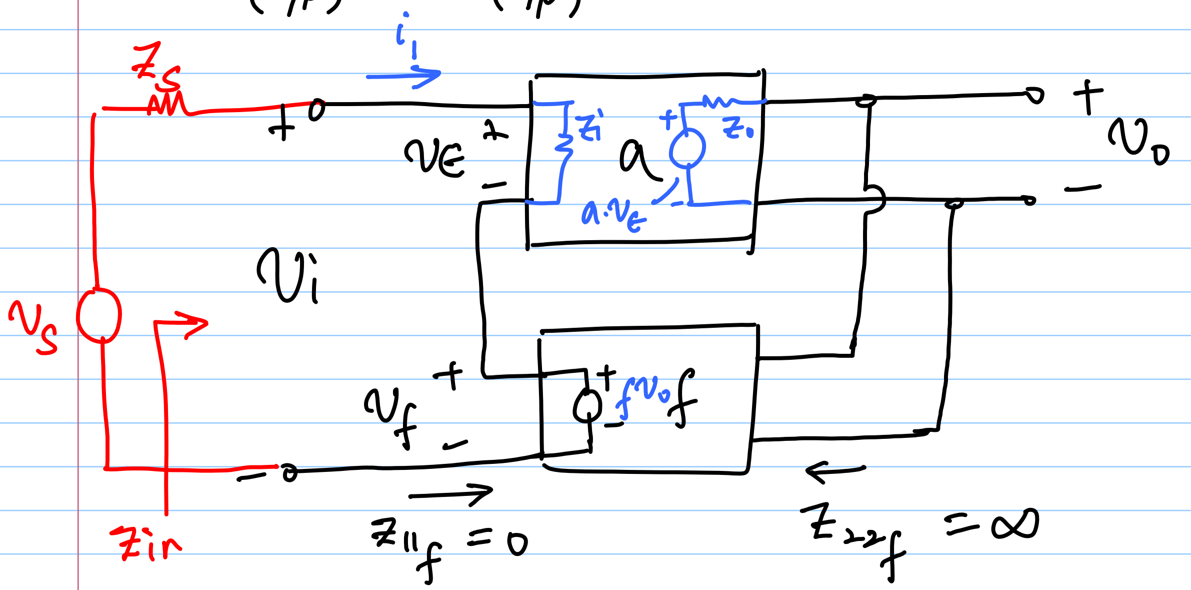




$$@\ \omega_0 = \omega_{p1}(1+A_0)$$

$$T(\omega) = 0\,dB = 1 \quad \text{(unity loop gain freq.)}$$

I Series - shunt f.b.
(i/p) (o/p)



$$\frac{v_o}{v_i} = \frac{a}{1+af} \; ; \quad v_i = \frac{Z_{in}}{Z_{in}+Z_s} \cdot v_s$$

$\Rightarrow$ If $Z_s \sim Z_{in}$,

$$v_i = f(Z_{in})$$

not very well-defined

$\Rightarrow$ $\frac{v_o}{v_i}$ will not be stabilised

$\therefore$ ideal driving source is a voltage source (low-impedance)

$$v_o = a v_E$$

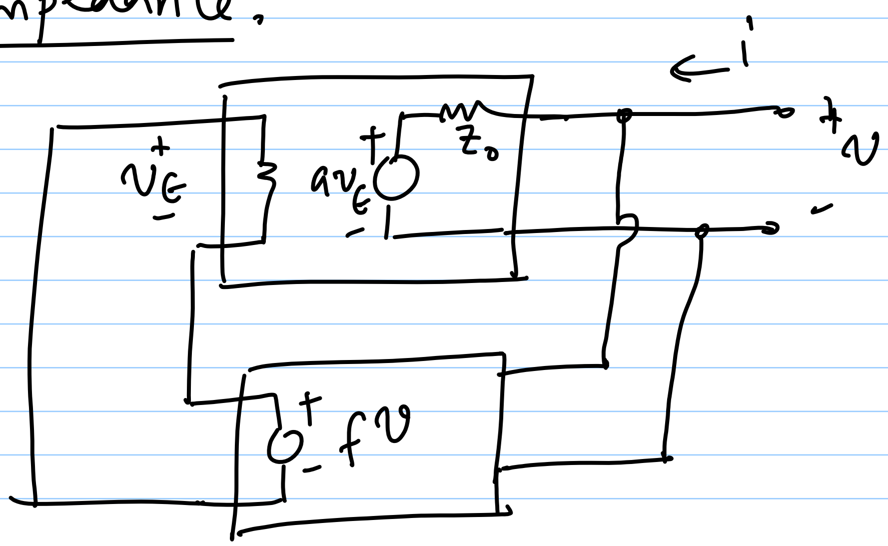
$$v_i = v_E + f v_o$$

$$i_i = \frac{v_E}{Z_i} = \frac{v_i}{Z_i} \frac{1}{(1+af)}$$

$$\Rightarrow Z_{in} = \frac{v_i}{i_i} = (1+T) Z_i$$

* Series f.b. @ input always raises the input impedance by $(1+T)$

o/p impedance:



$$v_\epsilon + f v = 0$$

$$i = \frac{v - a v_\epsilon}{Z_o}$$

$$= \frac{v + a f v}{Z_o}$$

$$Z_{out} = \frac{v}{i} = \frac{Z_o}{1+T}$$

* Shunt f.b. always <u>lowers</u> output impedance by $(1+T)$

series-shunt f.b. $\Rightarrow$ good voltage amp

<u>other types</u>

II Shunt-shunt $\begin{pmatrix} \text{sense} = V \\ \text{f.b.} = I \end{pmatrix}$

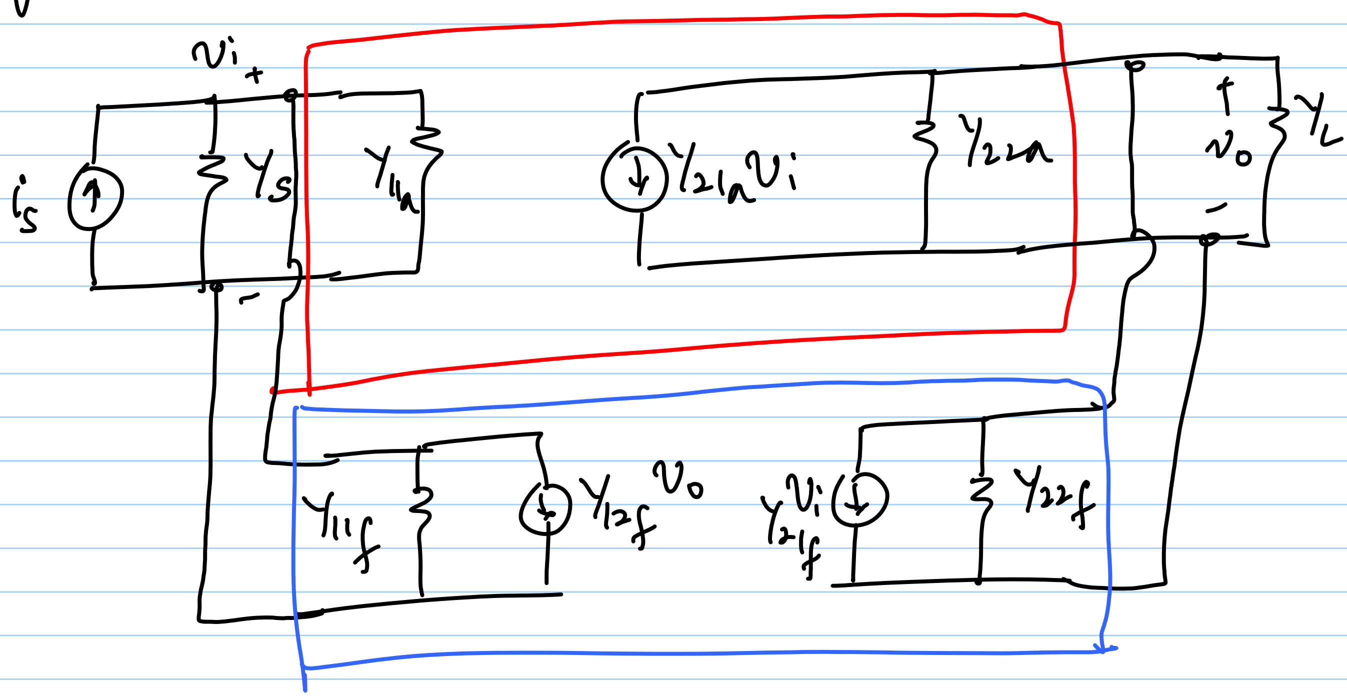
III Shunt-series $\begin{pmatrix} \text{sense} = I \\ \text{f.b.} = I \end{pmatrix}$

IV Series-series $\begin{pmatrix} \text{sense} = I \\ \text{f.b.} = V \end{pmatrix}$

Z_i, Z_o etc. get modified appropriately

Effect of loading

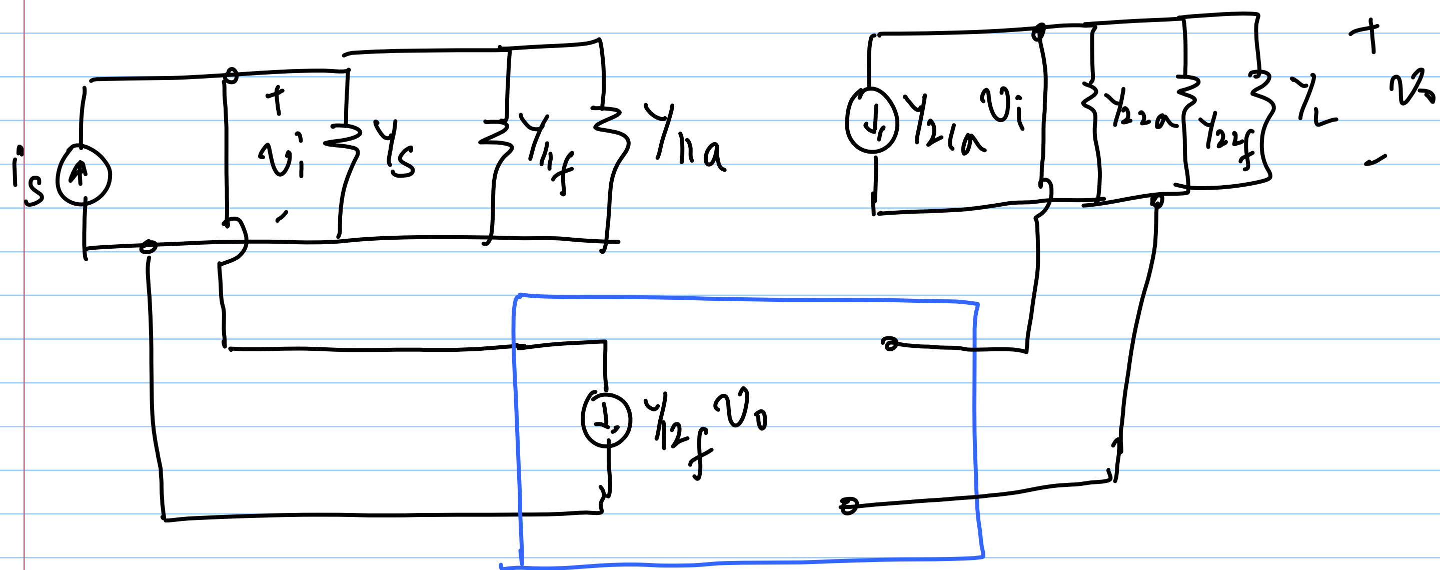
e.g. shunt - shunt



$$|Y_{21a}| \gg |Y_{21f}|$$

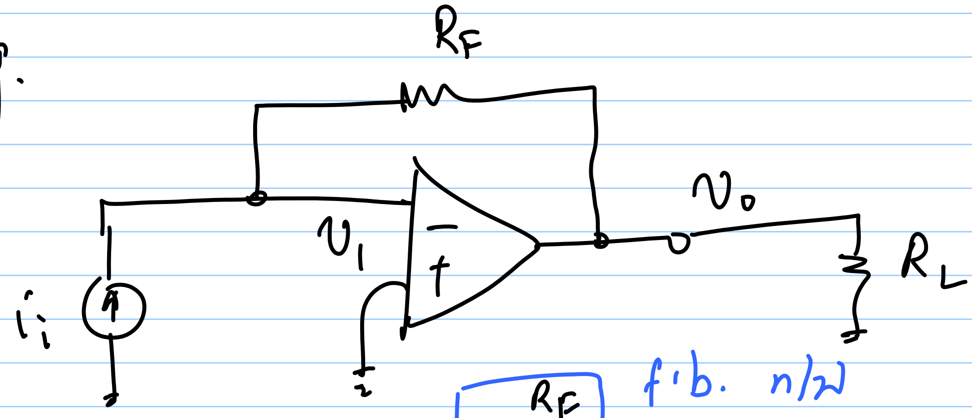
$$|Y_{12f}| \gg |Y_{12a}|$$

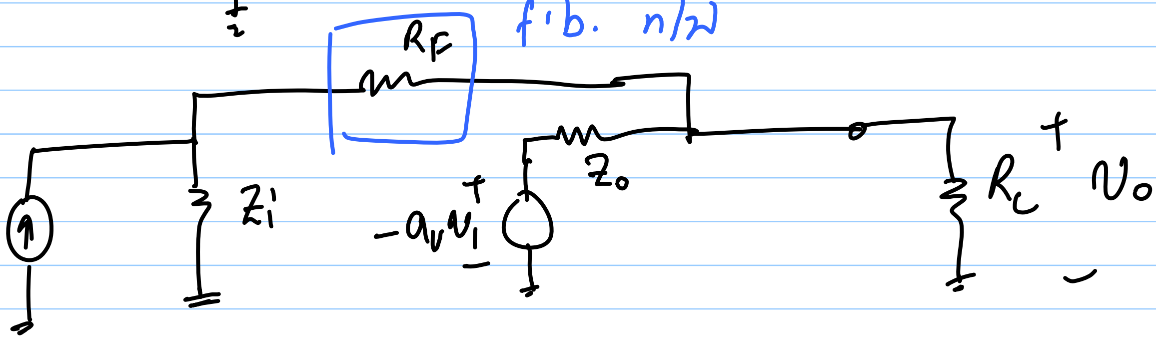
Redraw:

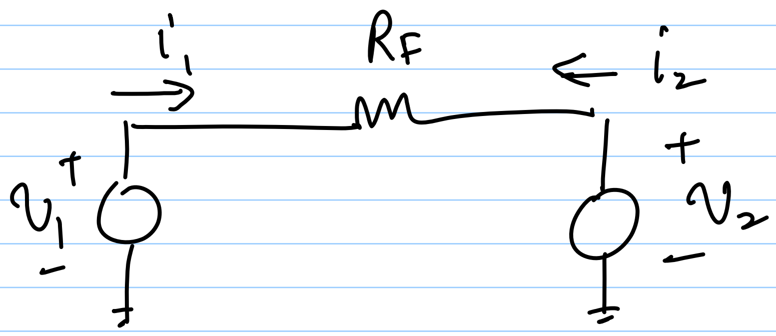


* Further analysis with y-param is <u>not</u> necessary

e.g.





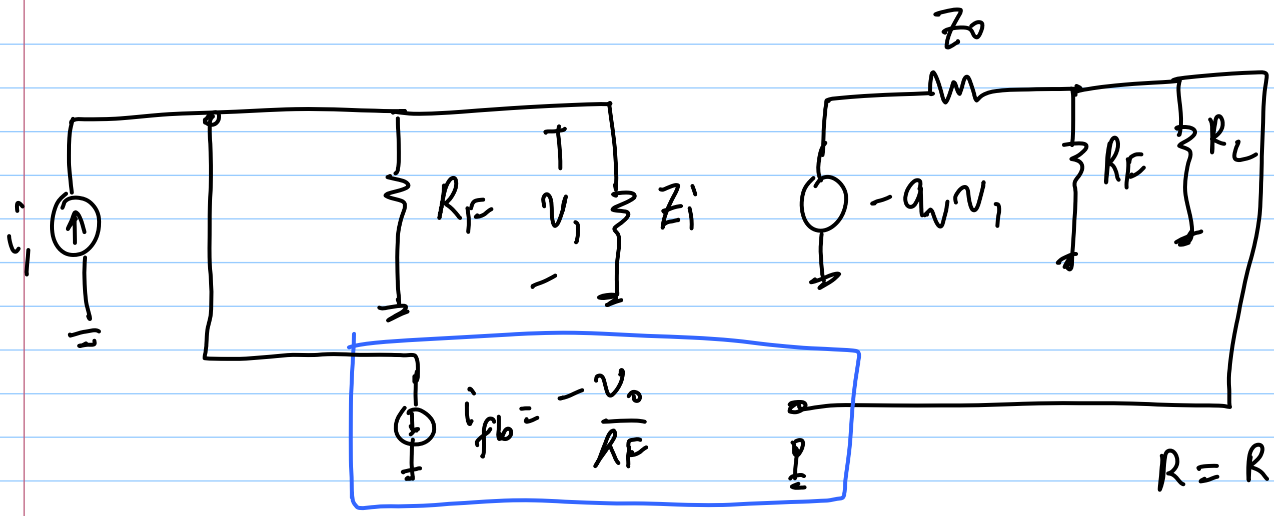


$$Y_{11f} = \frac{1}{R_F}$$

$$Y_{22f} = \frac{1}{R_F}$$

$$Y_{12f} = -\frac{1}{R_F} = f$$

neglect Y_{21f}



$R = R_F \| R_L$

$$v_1 = \frac{Z_i R_F}{Z_i + R_F} \cdot i_1$$

$$v_o = -\frac{R}{R + Z_o} \cdot a_o v_1$$

$$\frac{v_o}{i_1} = a = -\frac{R}{R + Z_o} \cdot a_v \cdot \frac{Z_i R_F}{Z_i + R_F}$$

impedances w/ Y_{12f} etc. are divided by $(1+T)$ based on orig. theory