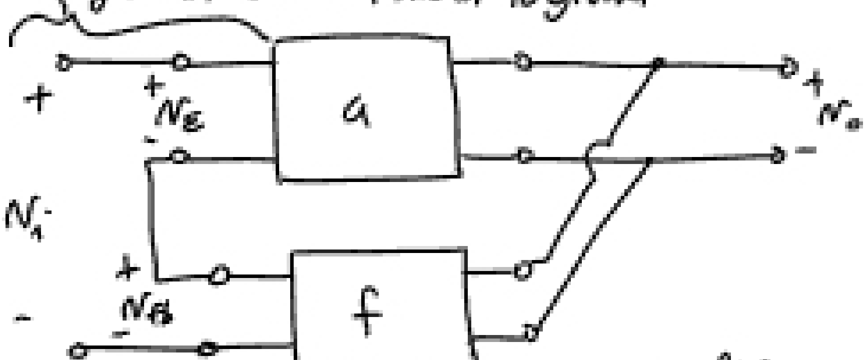
- **Announcements:**
  - ↳ Project is due this Friday, 5/1, at 8 p.m.
- **Today:**
  - ↳ Effect of Feedback on Z_i and Z_o
  - ↳ Feedback loading
  - ↳ Procedure for inspection analysis of FB

Last Time -

Identification of FB Connection Types

Series Connection - FB network port in series w/ amplifier port

↳ must go thru both the FB port & the amplifier port to get from the node of interest to ground



Shunt Connection - FB network port in shunt (parallel) w/ amplifier port

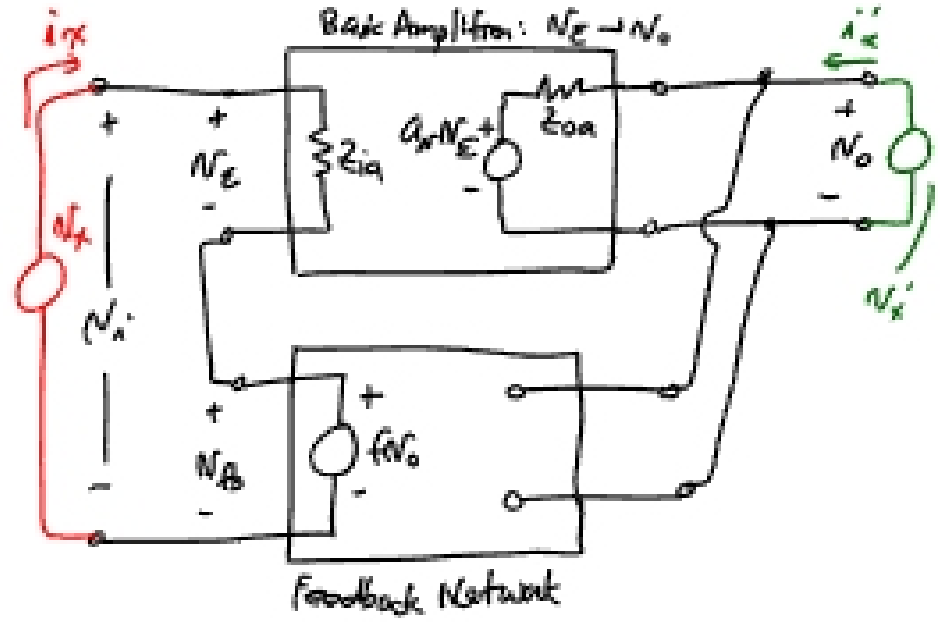
↳ Can get from the node of interest to ground via either FB network port or the amplifier port

Effect of FB on Z_i & Z_o

Ex. Series-Shunt FB

Assumption: FB network has ideal impedances

↳ i.e., it does not load the basic amplifier



Find the T.F. -

$$\left.\begin{aligned} v_\varepsilon &= v_i - v_{fb} \\ v_o &= a_v v_\varepsilon \\ v_{fb} &= f v_o \end{aligned}\right\} \quad v_o = a_v(v_i - f v_o) \Rightarrow \boxed{\frac{v_o}{v_i} = \frac{a_v}{1 + a_v f}}$$

✓ (as expected)

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Find $Z_i = \frac{v_x}{i_x}$:

$v_x = v_\varepsilon + v_{fb}$

$= v_\varepsilon + f v_o = v_\varepsilon + a_v f v_\varepsilon = v_\varepsilon (1 + a_v f)$

$i_x = \frac{v_\varepsilon}{Z_{ia}}$

$Z_i = \frac{v_x}{i_x} = \frac{v_\varepsilon (1 + a_v f)}{\frac{v_\varepsilon}{Z_{ia}}} = \boxed{Z_{ia}(1 + a_v f) = Z_i}$ ← loop gain!

When use series connection @ input! } Input impedance raised! by $(1 + a_v f)$!
↳ makes for a better voltage amplifier!

Find $Z_o = \frac{v_x'}{i_x'}$: (w/ input shorted)

$v_\varepsilon + v_{fb} = v_\varepsilon + f v_x' = 0 \rightarrow v_\varepsilon = -f v_x'$

$i_x' = \frac{v_x' - a_v v_\varepsilon}{Z_{oa}} = \frac{v_x' + a_v f v_x'}{Z_{oa}}$

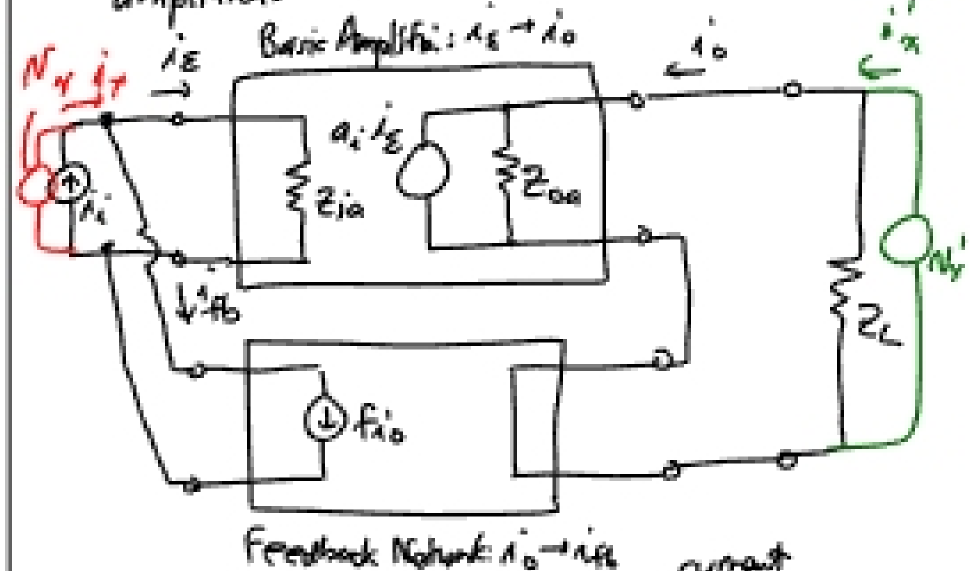
$\frac{v_x'}{i_x'} = \boxed{\frac{Z_{oa}}{1 + a_v f} = Z_o}$ ← Output impedance lowered by a factor of $(1+af)$

⇒ Again, makes for a better voltage amplifier!

Overall, series-shunt FB improves the impedance characteristics of a $v \rightarrow v$ amplifier: $Z_i \uparrow$, $Z_o \downarrow$ due to FB

Ex. Shunt-Series FB

⇒ Again, assume FB network does not load the amplifier.



Find the T.F.:

$i_o = a_i i_\varepsilon$

$i_\varepsilon = i_i - i_{fb} = i_i - f i_o$

} $\boxed{\frac{i_o}{i_i} = \frac{a_i}{1 + a_i f}}$ (current gain; current gain)

↓ Same as with $v \rightarrow v$.

↓ It's a universal form!

Find $Z_i = \frac{v_x}{i_x}$:

$\boxed{\frac{v_x}{i_x} = \frac{Z_{ia}}{1 + a_i f} = Z_i}$ → Again, a shunt connection reduces the impedance by $(1 + a_i f)$!

(loop gain)

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Find $z_o = \frac{v_x'}{i_x}$:

$$\frac{v_x'}{i_x} = z_{oa}(1+a_v f) = z_o$$

↳ series connection raises the impedance by $(1+a_v f)$

everything together makes for a better $i \to i$ amplifier when using shunt-series FB!

Summary:

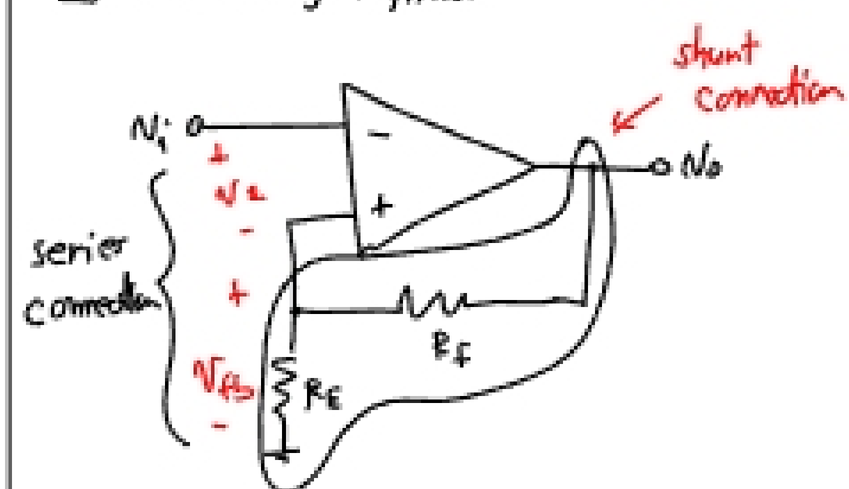
① series connection: $Z \to Z(1+T)$ ← T = loop gain

② shunt connection: $Z \to \frac{Z}{1+T}$

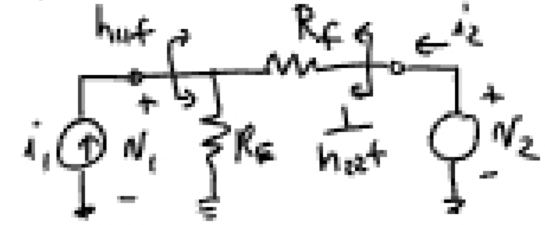
⇒ looked @ the handout & the prepared notes on "FB Loading".

Determine the FB Loading of an Amplifier

Ex. Non-Inverting Amplifier



The FB Network (in terms of h-parameters)

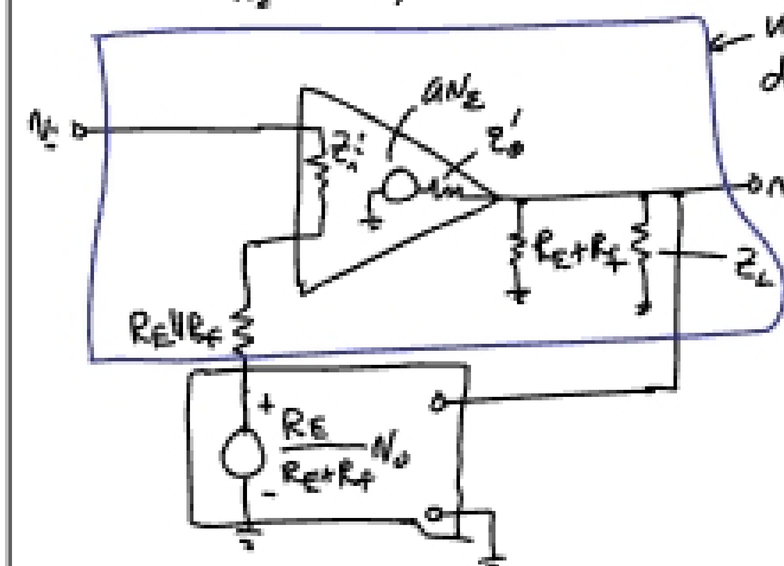


$$h_{22f} = \frac{i_2}{v_2}\Big|_{i_1=0} = \frac{1}{R_E+R_F} \quad \text{(this is loading)}$$

↑ This is a conductance.

$$h_{12f} = \frac{v_1}{v_2}\Big|_{i_1=0} = \frac{R_E}{R_E+R_F} = f \quad \text{(feedback gain factor)}$$

$$h_{11f} = \frac{v_1}{i_1}\Big|_{v_2=0} = R_E \| R_F \quad \text{(this is loading)}$$



← use this to determine a_v!

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