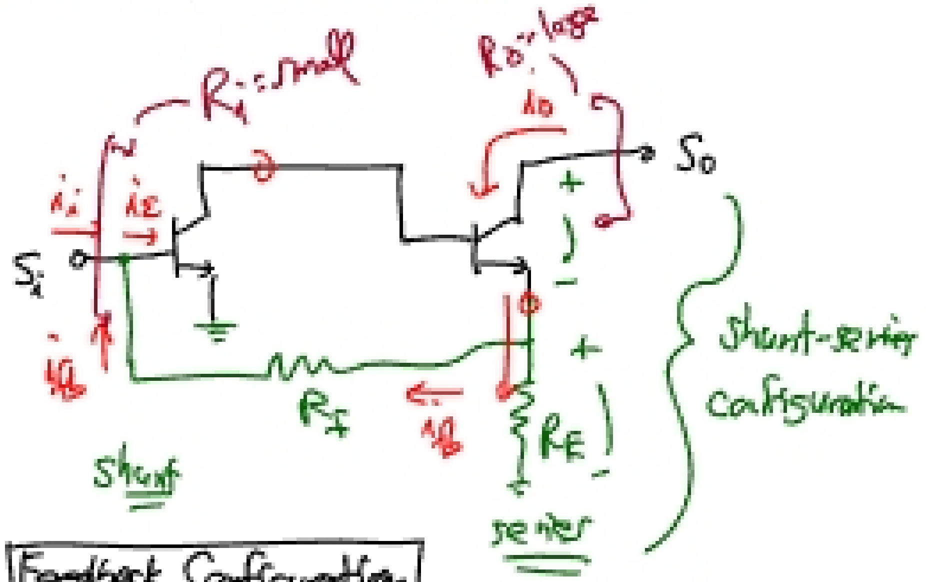
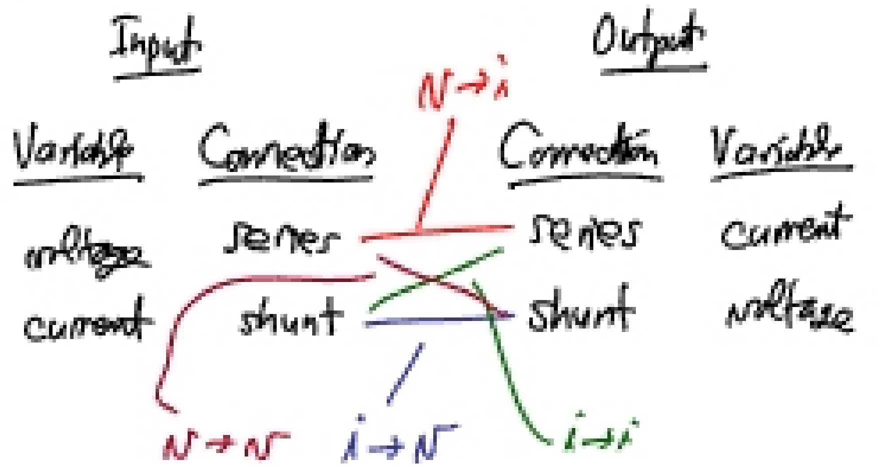
Lecture 26: Feedback Impedance

- Announcements:
  - Last HW#12 online (due during RRR week)
  - Yes, I know, but it'll help you on the Final
- Lecture Topics:
  - Effect of FB on Z_i and Z_o
  - Feedback Loading
- ---------------------------------------
- Last Time: Feedback Configurations



Feedback Configurations

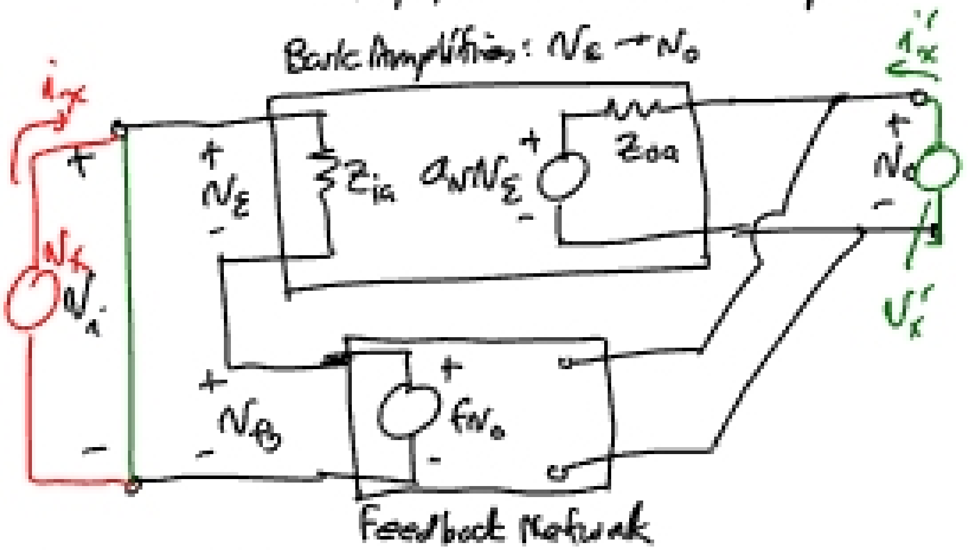


Effect of FB on Z_i & Z_o

Ex: series-shunt FB

Assumption: FB network has ideal impedances
↳ i.e., it does not load the amplifier

Basic Amplifier: $v_\varepsilon \to v_o$



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)

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

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

$= v_\varepsilon + f v_o = v_\varepsilon + a_{vr} f v_\varepsilon = v_\varepsilon(1+a_{vr}f)$

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

$Z_i = \frac{v_x}{i_x} = \frac{\cancel{v_\varepsilon}(1+a_{vr}f)}{\frac{\cancel{v_\varepsilon}}{Z_{ia}}} = \boxed{Z_{ia}(1+a_{vr}f) = Z_i}$

amplifier alone input impedance

loop gain!

when use series connection @ input! } Input impedance raised by $(1+a_{vr}f)$! → makes for a better voltage amplifier!

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

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

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

$\frac{v_x'}{i_x'} = \boxed{\frac{Z_{oa}}{1+a_{vr}f} = Z_o}$

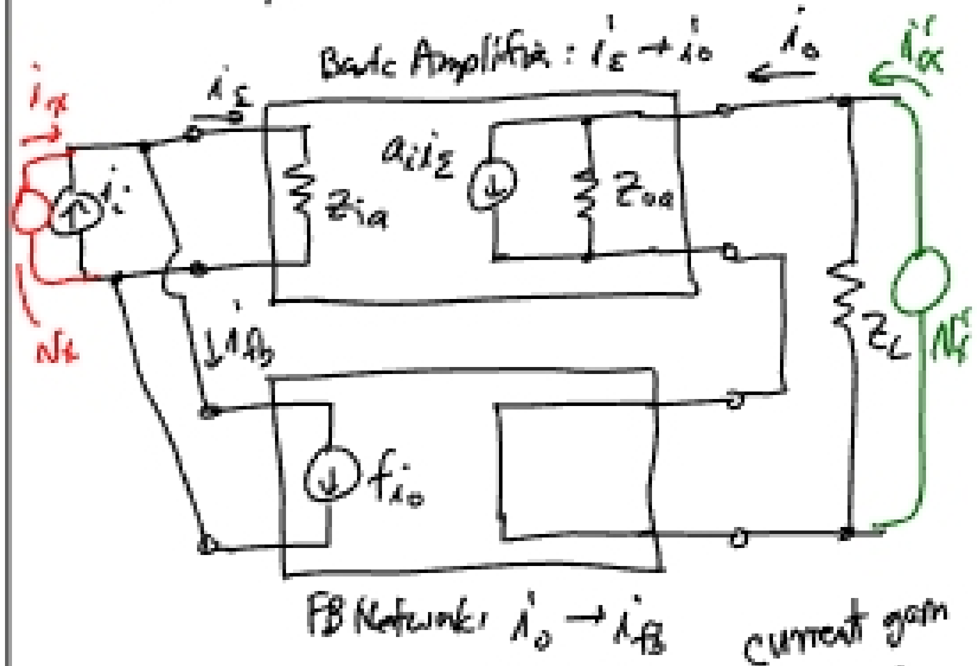
Output impedance lowered by a factor of $(1+a_{vr}f)$

Again, makes for a better voltage amplifier!

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

Ex. Shunt-Series FB

→ Again, assume FB network does not load the amplifier



Find 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 of amp alone

loop gain

Same form as for v→v amp. This is a universal form!

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

$$\boxed{\frac{v_x}{i_x} = \frac{Z_{ia}}{1+\underbrace{a_i f}_{\text{loop gain}}}}$$

⇒ again, a shunt connection reduces the impedance by $(1+a_i f)$!

Find Z_o: $\frac{v_x'}{i_x'}$:

$$\frac{v_x'}{i_x'} = \boxed{Z_{oa}(1+a_i f) = Z_o}$$

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

All together → makes for a better i→i amp (when using shunt-series FB)

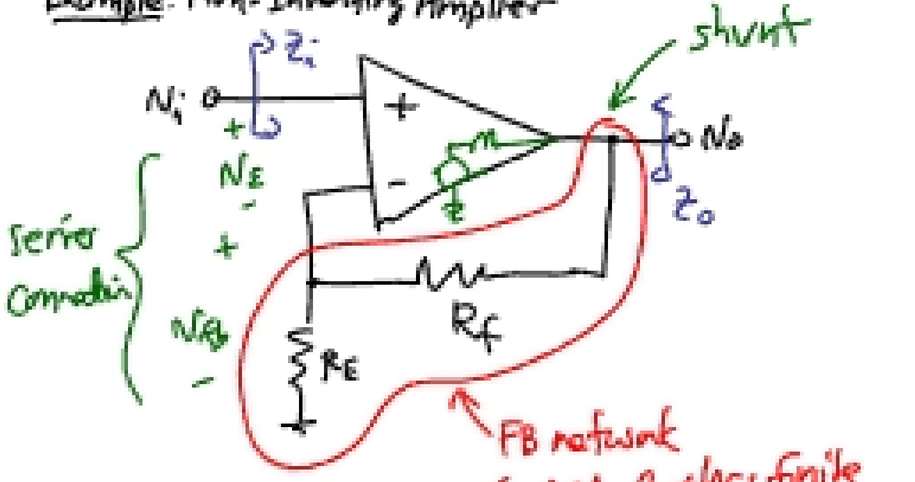
Summary:

① series connection: $Z \rightarrow Z(\underset{\text{T - loop gain}}{1+T})$

② shunt connection: $Z \rightarrow \frac{Z}{(1+T)}$

Determine the FB loading of an Amplifier

Example: Non-Inverting Amplifier



FB network (not ideal → has finite (Z_i & Z_o) → we need to convert it to ideal

Series-shunt: $v \rightarrow v$

Objective: Use $\underbrace{A_v = \frac{a_v}{1+a_v f}}$ to get A_v.

In order to use this equation, we must know

(i) $a_v \triangleq$ gain of the amplifier

(ii) $f \triangleq$ gain of the feedback (also, called the feedback factor)

In general: