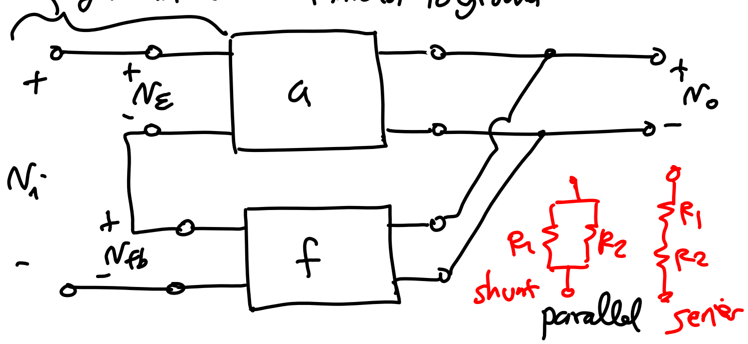
Lecture 25: Feedback Z

- Announcements:
- HW#11 due tomorrow @ 8 a.m.
- No homework over Thanksgiving
- Pre-Lecture Feedback Loading Handout online
- Lecture Topics:
  - Recognizing Feedback Configurations
  - Effect of FB on Z_i and Z_o
  - Feedback Loading
- ------------------------------------
- Last Time: started inspection analysis of FB

$\boxed{\text{Identification of FB Connection Types}}$

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

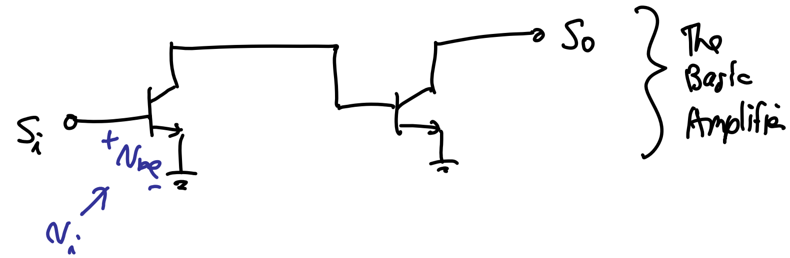
must go thru both the FB port & the amplifier port to get from the node of interest to ground

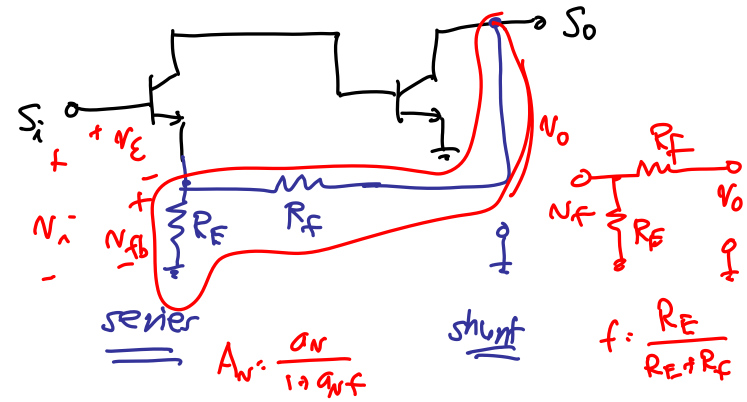


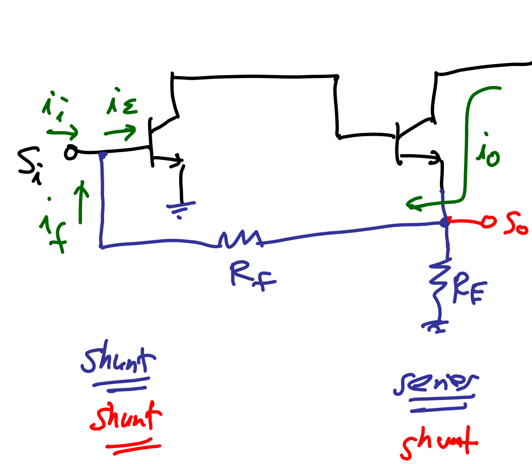
Shunt Connection – FB network port in shunt w/ amplifier port

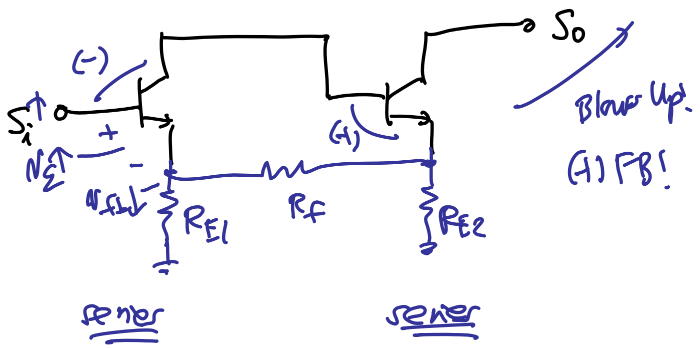
can get from the node of interest to ground via either FB network port or the amplifier port

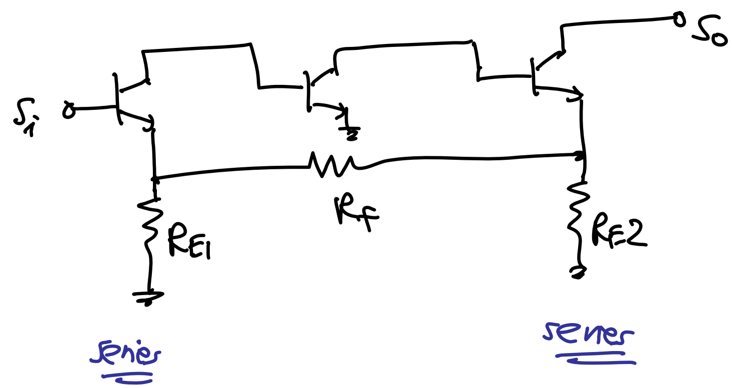
Example.

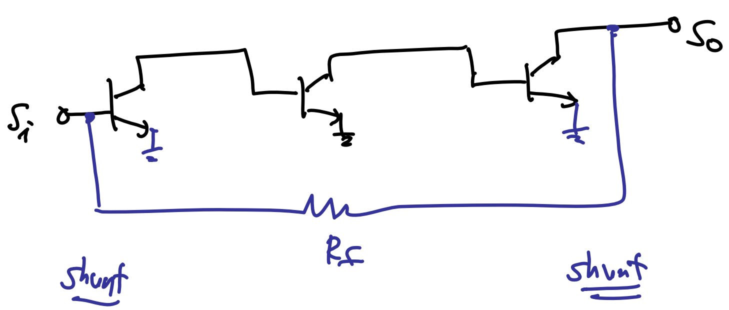


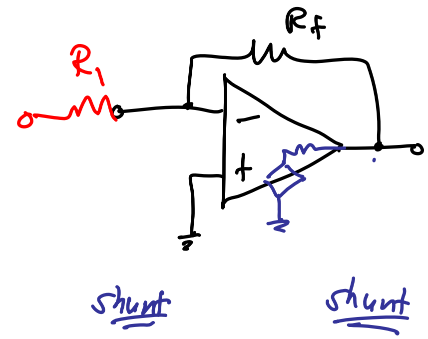












Feedback Configurations

Input			Output	
Variable	Connection		Connection	Variable
voltage	series		series	current
current	shunt		shunt	voltage

v→i

v→v

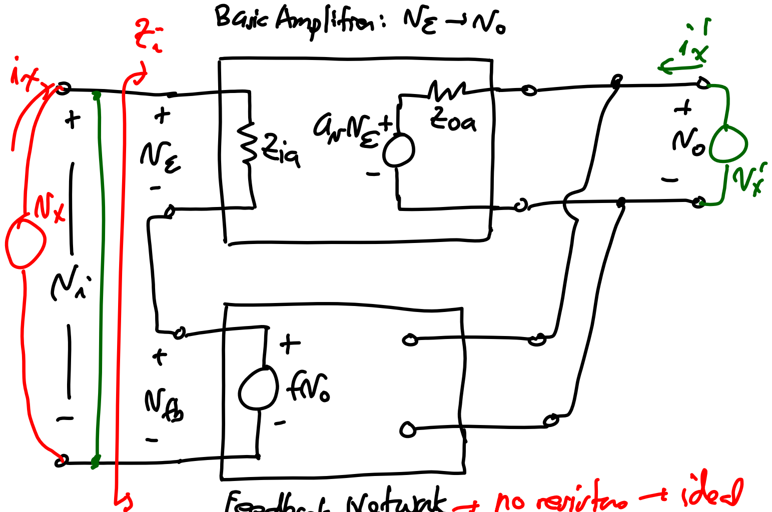
i→i

i→v

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.:

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

(as expected)

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

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

$$= v_\varepsilon + f v_o = v_\varepsilon + a_v f v_\varepsilon = v_\varepsilon(1 + \underbrace{a_v f}_{\text{loop gain}})$$

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

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

closed loop input impedance

loop gain!

original open-loop impedance of op amp

When use series connection @ input } Closed-loop input impedance raised by $(1 + a_v f)$!

↓

If $Z_i \uparrow$ → better voltage amplifier!

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

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

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

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

orig. amplifier open-loop output impedance

closed-loop output impedance z_o lowered by a factor $(1 + a_v f)$

loop gain

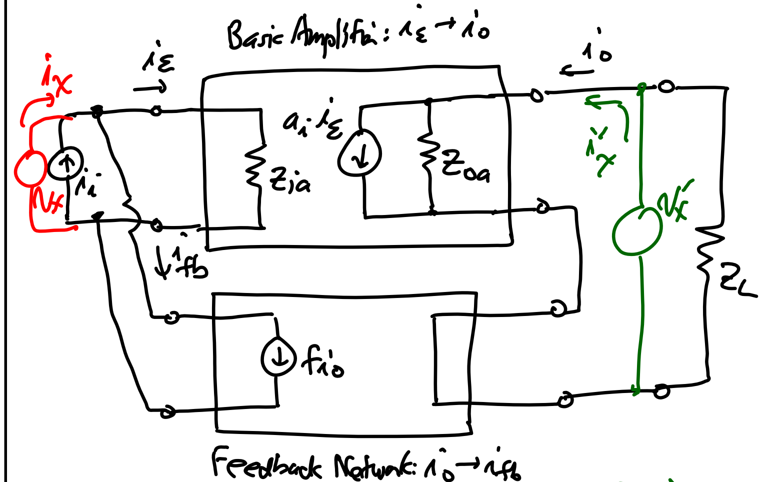
Again, makes for a better voltage amplifier!

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 the FB network does not load the amplifier



shunt

series

Find the T.F.:

$i_o = a_i i_\varepsilon$

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

$$\boxed{\frac{i_o}{i_i} = \frac{a_i}{1 + a_i f}}$$

open loop $i \rightarrow i$ gain

loop gain

Similar to the $v \rightarrow v$ case, except now $i \rightarrow i$

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

open-loop input impedance

$$\boxed{\frac{v_x}{i_x} = \frac{Z_{io}}{1+a_i f} = Z_i}$$

loop gain

$\Rightarrow$ Again, a shunt connection reduces impedance by a factor of $(1+a_i f)$!

expect a i input!

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

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

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

Summary: shunt-series makes for a better $i \to i$ amplifier!

Summary:

T = loop gain

① series connection: $Z \to Z(1+T)$

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

- Now go through the "Loading from the FB Network" Handout