EE 140/240A: Analog Integrated Circuits

Lecture 26w: Feedback By Inspection

CTN 12/3/13

Lecture 26: Feedback By Inspection

- **Announcements**:
- HW#12 online soon, due 12/11 @ 8 a.m.
- Pre-Lecture Feedback Loading Handout online
- "Inspection Analysis of Feedback Circuits" Handout online
- Project (Lab#3) due Friday, 12/13, at 5 p.m. in the 140/240A homework box
  - Best to be finished with design by next Monday, so you have plenty of time to write the report
  - Make sure the report is good, since it is what is graded in the end
- Will talk about Final Exam next lecture
- **Lecture Topics**:
  - Effect of FB on Z_i and Z_o
  - Feedback Loading
  - Feedback By Inspection
- ------------------------------------
- **Last Time**:

Summary:

T = loop gain

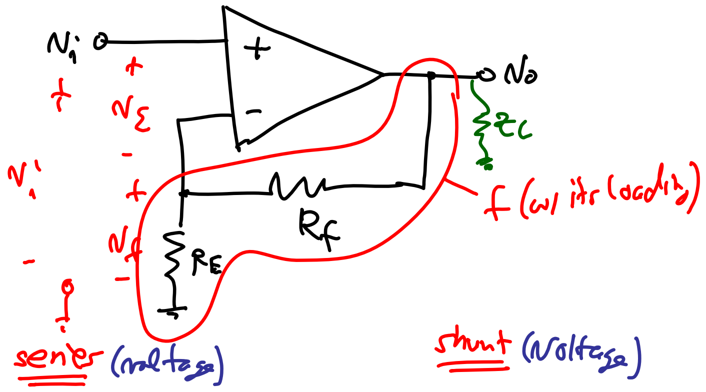
① series connection: $Z \to Z(1+T)$

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

- Going through the "Loading from the FB Network" Handout … continue doing this

Determine the FB loading of an Amplifier

Example. Non-Inverting Amplifier



closed loop gain

open loop gain w/ FB loading

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

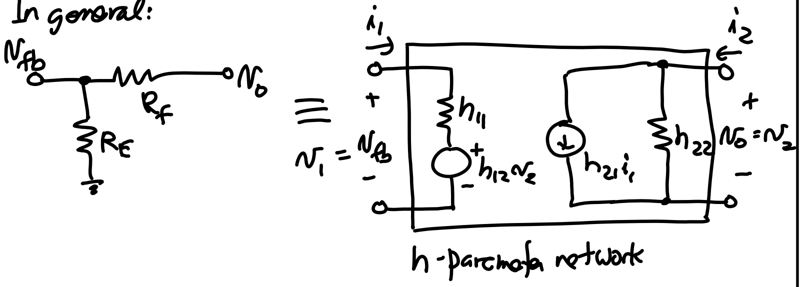
feedback factor w/o FB loading

In order to use this equation, we must know

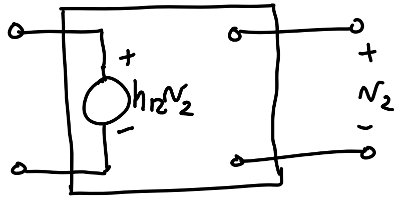
(i) $a_v \triangleq$ gain of the amplifier

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

In general:

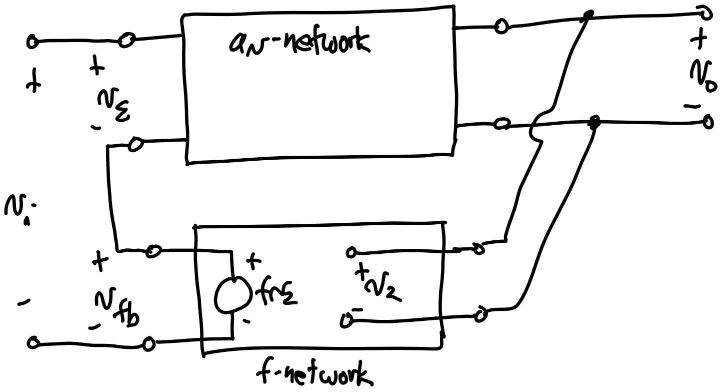


But to simplify things,
we would like to be able to represent the feedback network by just:

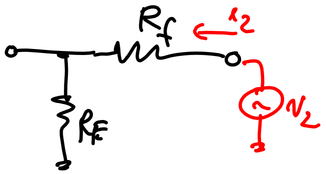


where: ① The small h_{21} is neglected.
② All impedances have been moved out of the f-network and moved to the a_v-network.

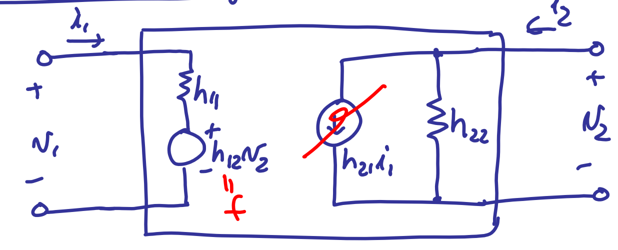
Pictorially:



The FB Network: (find the h-parameter representation)



h-parameter Network (just a reminder)



Port Equations:

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

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

Elements:

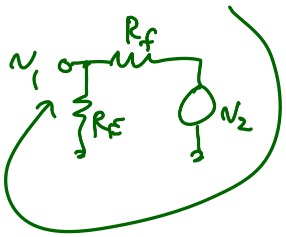
$h_{11} = \frac{v_1}{i_1}\Big|_{v_2=0}$ $h_{12} = \frac{v_1}{v_2}\Big|_{i_1=0}$

$h_{21} = \frac{i_2}{i_1}\Big|_{v_2=0}$ $h_{22} = \frac{i_2}{v_2}\Big|_{i_1=0}$

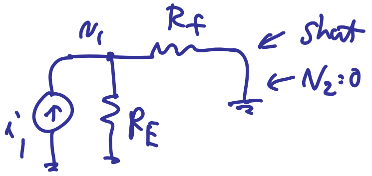
$$h_{22f} = \frac{i_2}{v_2}\Big|_{i_1=0} = \frac{1}{R_E+R_F}$$ ← This is the loading @ port 2, i.e., at the amplifier output port.

↑ This is a conductance

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



Open



$$h_{11f} = \frac{v_1}{i_1}\Big|_{v_2=0} = R_E \| R_F$$ ← This is the loading @ port 1, i.e., at the amplifier input.

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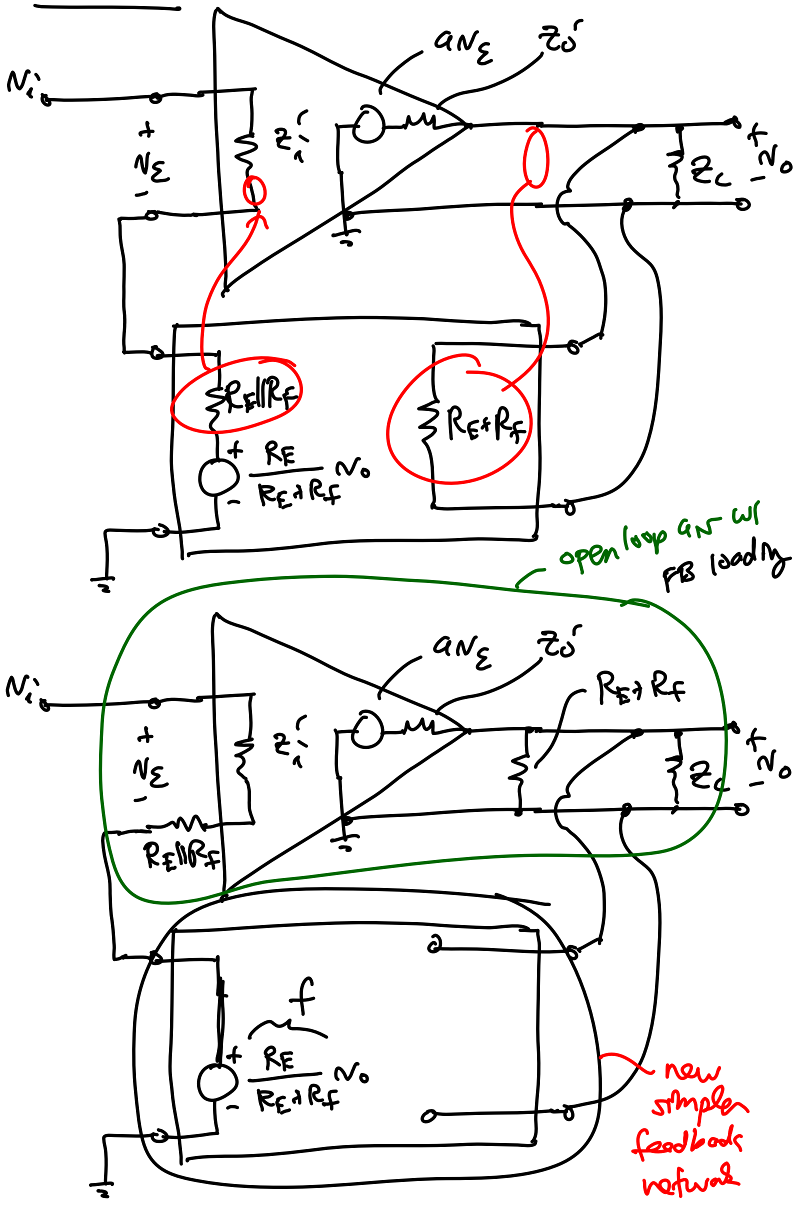
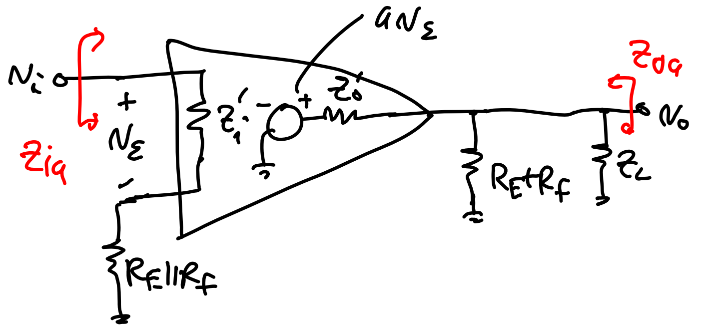
So we have:



Want $A_o = \frac{a_v|_{OL\ w/\ FB\ loading}}{1 + a_v|_{OL\ w/\ FB\ loading} \times f}$

Determine $a_v|_{OL\ w/\ FB\ loading}$:



$v_o = a v_\varepsilon \left\{ \frac{(R_E+R_F) \| Z_L}{(R_E+R_F) \| Z_L + Z_o'} \right\}$; $v_\varepsilon = v_i \left\{ \frac{z_i'}{z_i' + R_E \| R_F} \right\}$

$$\frac{v_o}{v_i}\Big|_{OL\ w/\ FB\ loading} = \left(\frac{z_i'}{z_i' + R_E \| R_F} \right) a \left(\frac{(R_E+R_F) \| Z_L}{(R_E+R_F) \| Z_L + Z_o'} \right) = a_v$$

We have: $\boxed{f = \frac{R_E}{R_E+R_F}}$

Get closed-loop gain A_o:

$$A_o = \frac{v_o}{v_i} = \frac{a_v}{1 + a_v f} \simeq \frac{1}{f} = 1 + \frac{R_F}{R_E}$$

Must use this if a_v not large.

What about Z_i & Z_o?

→ For the open-loop amp w/ FB loading:

$Z_{ia} = Z_i' + R_E \| R_F$

$Z_{oa} = Z_o' \| (R_E + R_F) \| Z_L$

} original open-loop w/ FB loading Z's

→ For closed-loop, just multiply or divide by $(1+a_v f)$ depending on the type of FB connection

Series: $\boxed{Z_i = Z_{ia}(1+a_v f) = (Z_i' + R_E \| R_F)(1+a_v f)}$

for closed-loop

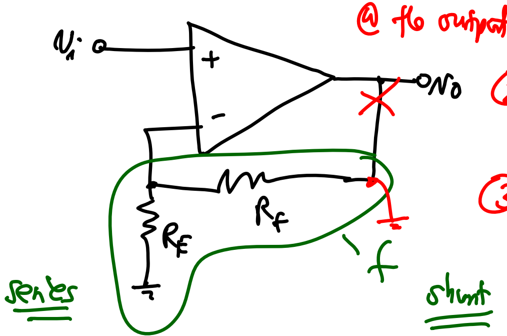
shunt: $\boxed{Z_o = \frac{Z_{oa}}{1+a_v f} = \frac{Z_o' \| (R_E+R_F) \| Z_L}{1+a_v f}}$

What about ω_{-3dB}?

$$\omega_{-3dB}\Big|_{\text{closed-loop}} = \Big[\omega_{-3dB}\Big|_{\substack{\text{open-loop amp}\\ \text{w/ FB loading}}}\Big] \times (1+a_v f)$$

To determine loading by FB:

Input loading



① Determine the feedback type @ the output (Here, it's shunt)

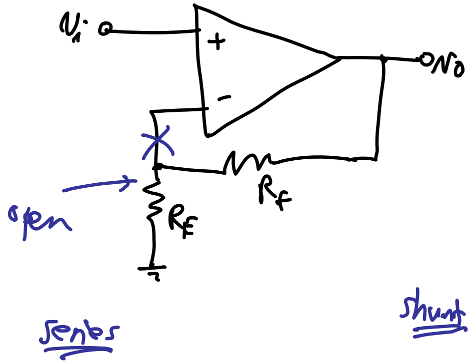
② Break the loop @ the output

③ For shunt, ground the loose end

↓

(if series, open it.)

Output loading:



① Determine the feedback type @ input. (Here, it's series)

② Break the loop @ input.

③ For series, open the loose end.

↘ (If shunt, short it.)

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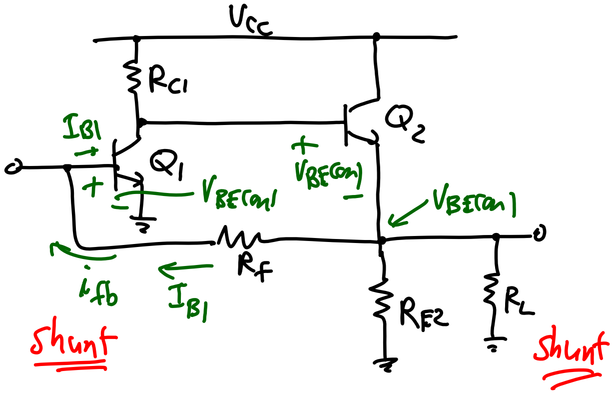
- Go through the "Inspection Analysis of Feedback Circuits" Handout
- In the end, if one can determine the open loop gain with FB loading and feedback factor, then the rest of the problem becomes simple
- Study the table in the handout
  - Be able to fluently go between different types of gain, from v → v, to i → v, etc.

Example. Transresistance Amplifier



① Determine type of FB → determine the type of gain

② Biasing

Note: Don't do this if R_f: large.

$I_{B1} \leftarrow$ tiny ≈ 0

$$I_{C2} \simeq I_{E2} = \frac{V_{BE(on)}}{R_{E2} \| R_L} \; ; \; I_{C1} \simeq \frac{V_{CC} - 2V_{BE(on)}}{R_{C1}}$$