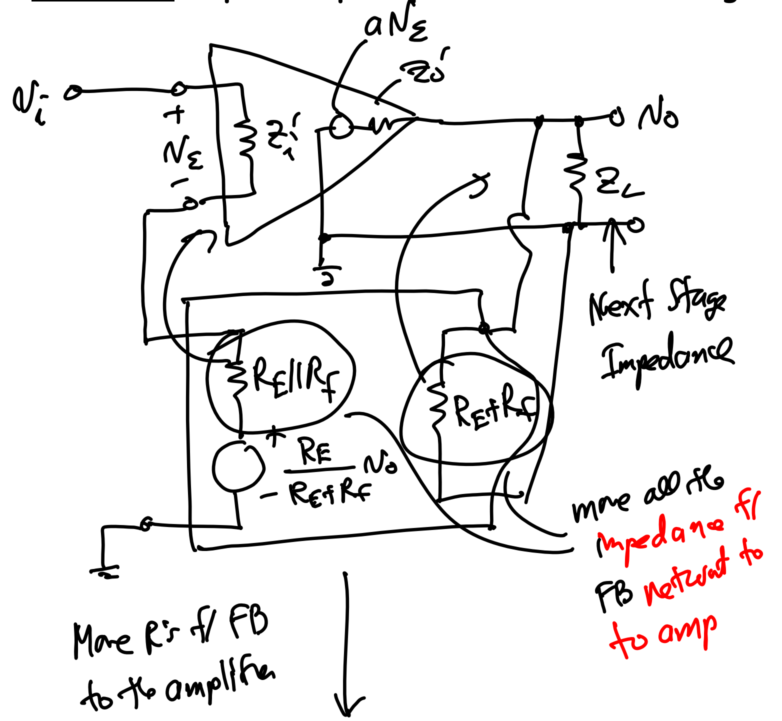
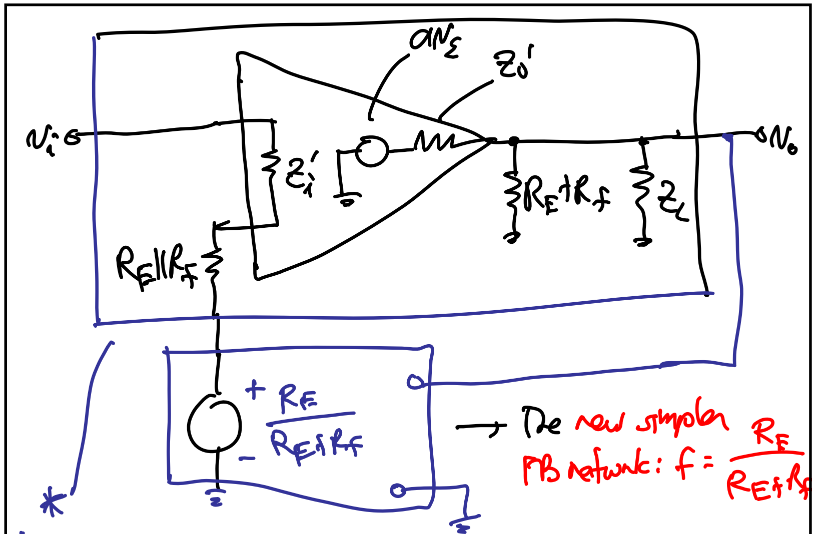
Lecture 27: Feedback Inspection

- **Announcements**:
  - Lab#3 (your project) due on Friday, May 6, at 5 p.m.
  - Passed out Feedback Inspection Handout
  - Passed out Final Information Sheet and sample Final Exam (from 2009)
- **Lecture Topics**:
  - Feedback Loading
  - Open-Loop Amp w/ Feedback Loading
  - Feedback By Inspection
  - Final Exam Info & Course Wrap Up
- ---------------------------------------
- **Last Time**: Open-Loop Amp w/ Feedback Loading

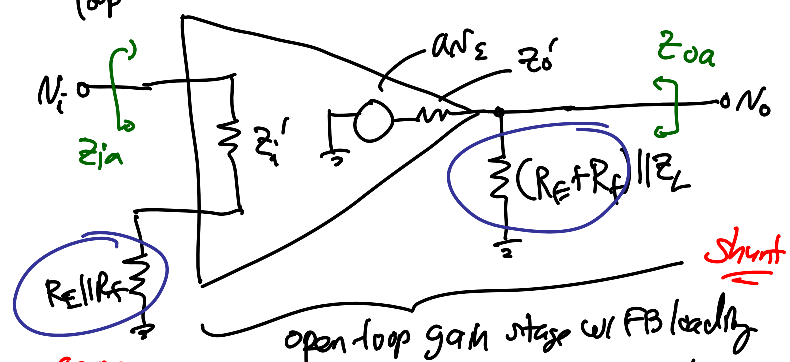




* The new a_v-network → use this to determine a_v, z_{ia}, & z_{oa}

The amplifier w/ FB loading (open loop)

$A_o = \frac{a_v}{1 + a_v f}$



$$v_o = aV_\varepsilon \left\{ \frac{(R_E+R_F) \| Z_L}{(R_E+R_F) \| Z_L + z_o'} \right\} ; \quad V_\varepsilon = v_i \left(\frac{z_i'}{z_i' + R_E \| R_F} \right)$$

$$\left.\frac{v_o}{v_i}\right|_{FB\,loading} = \left(\frac{z_i'}{z_i' + R_E \| R_F}\right) a \left(\frac{(R_E + R_F) \| z_L}{(R_E + R_F) \| z_L + z_o'}\right) = a_N$$

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

Get closed loop gain: A_o

$$A_o = \frac{v_o}{v_i} = \frac{a_N}{1 + a_N f} \cong \frac{1}{f} = 1 + \frac{R_F}{R_E}$$

What about R_i & R_o?

→ for the open-loop amplifier w/ FB loading:

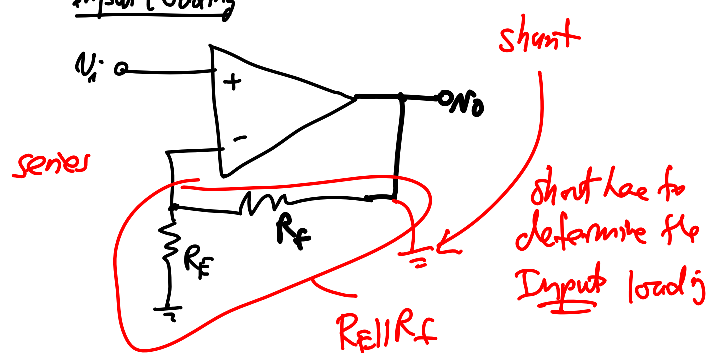
$z_{ia} = z_i' + R_E \| R_F$ —closed loop→ $z_i = (z_i' + R_E \| R_F)(1 + a_N f)$

$z_{oa} = z_o' \| (R_E + R_F) \| z_L$ —close loop→ $z_o = \frac{z_o' \| (R_E + R_F) \| z_L}{1 + a_N f}$

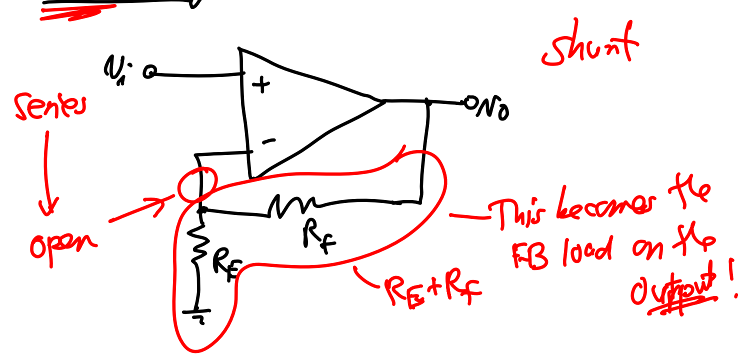
$$\omega_{-3dB}\Big|_{closed\ loop} = \left[\omega_{-3dB}\Big|_{\substack{open\text{-}loop\ amp \\ w/\ FB\ loading}}\right] \times (1 + a_N f)$$

To determine loading by FB:

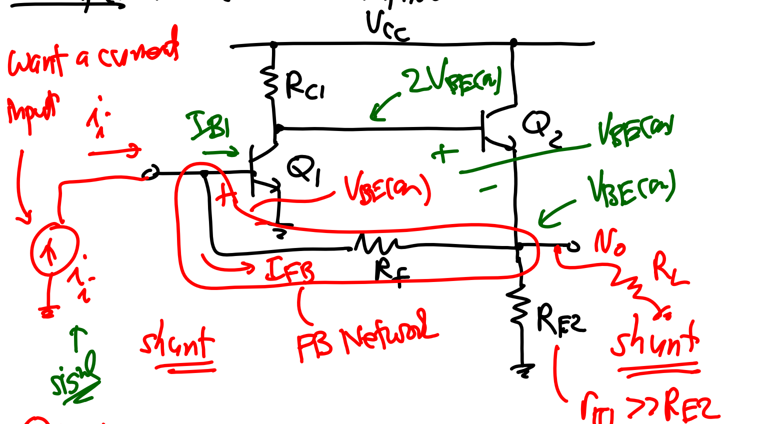
Input Loading



Output Loading:



Example: Transresistance Amplifier



① Determine the type of FB: ⟶ then determine the input & output variables

② Biasing:

$I_{FB} = I_{B1} \leftarrow$ tiny ≈ 0 ← Note: Shouldn't do this if R_f is very big...

$I_{C2} \approx I_{E2} = \frac{V_{BE(on)}}{R_{E2}}$ $I_{C1} = \frac{V_{CC} - 2V_{BE(on)}}{R_{C1}}$

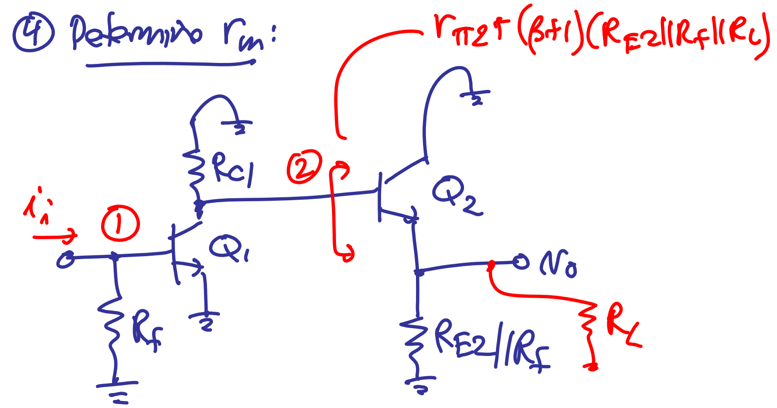
③ What kind of gain?

shunt-shunt FB ⟶ i→v gain

∴ we're looking for $R_m = \frac{v_o}{i_i} = \frac{r_m}{1 + r_m f}$ ← feedback factor

R_m: closed-loop gain; $\frac{v_o}{i_i}$: Ω; r_m: open-loop gain w/ FB loading

④ Determine r_m:



Get Gain: $\frac{v_o}{i_i} = \frac{v_①}{i_i} \cdot \frac{v_②}{v_①} \cdot \frac{v_o}{v_②} = \frac{v_o}{i_i}\Big|_{\text{OL w/ FB loading}} = r_m$

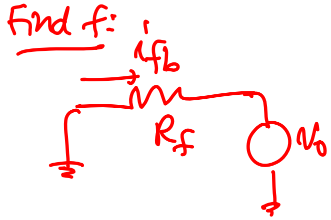
$v_① = i_i(r_{\pi 1} \| R_f) \rightarrow \frac{v_①}{i_i} = r_\pi \| R_f$

$\frac{v_②}{v_①} = -g_{m1}\left(R_{C1} \| \left(r_{\pi 2} + (\beta+1)(R_{E2} \| R_f \| R_L)\right)\right)$

$\frac{v_o}{v_②} \approx 1$

$r_m = \frac{v_o}{i_i}\Big|_{\text{OL w/ FB loading}} = -g_{m1}(r_{\pi 1} \| R_f)\left[R_{C1} \| (\quad)\right] = r_m$

Find f:



$$f = \frac{i_{fb}}{v_o} = -\frac{1}{R_f}$$

Thus: $T = r_m f = \left(-g_{m1}(r_\pi || R_f)\right)\left[R_a || (\ \ )\right]\left(-\frac{1}{R_f}\right)$ (large)

$$T \simeq g_{m1} R_{C1}\left(\frac{r_\pi || R_f}{R_f}\right)$$

⑤ Finally, get all parameters:

$$R_m = \frac{r_m}{1 + r_m f} \simeq \frac{1}{f} = -R_f \Rightarrow R_m = -R_f$$

↑ if r_m = large

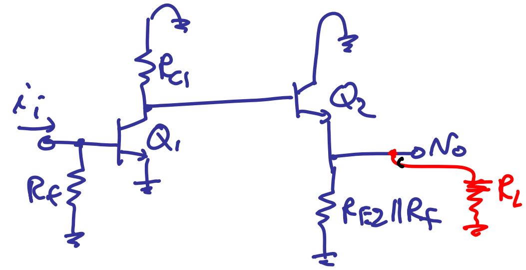
$$R_i = \frac{R_{ia}|_{w/\ FB\ loading}}{1 + r_m f} = \frac{r_\pi || R_f}{1 + g_{m1} R_{C1} \frac{(r_\pi || R_f)}{R_f}} = R_i$$

(denominator) large ∴ this = tiny

$$R_o = \frac{R_{oa}|_{w/\ FB\ loading}}{1 + r_m f} = \frac{\frac{r_{\pi 2} + R_{C1}}{\beta + 1} || R_{E2} || R_f || R_L}{1 + g_{m1} R_{C1} \frac{(r_\pi || R_f)}{R_f}} = R_o$$

Find ω_{-3dB}:

① Find the ω_{-3dB} of the open-loop amplifier w/ FB loading, i.e., of this: → use OCTC analysis



② Multiply by (1+T):

$$\omega_{-3dB}|_{closed\text{-}loop} = (1+T) \times \omega_{-3dB}|_{OL\ w/\ FB\ loading}$$

- What's next?
- EE 240: Advanced Analog Integrated Circuits
- Analysis and optimized design of integrated analog systems and building blocks. Specific topics include operational and wide-band amplifiers, gain-bandwidth and power considerations, analysis of noise in integrated circuits, low noise design, feedback, precision passive elements, analog switches, comparators, CMOS voltage references, non-idealities such as matching and supply/IO/substrate coupling. The course will include a significant design project applying the techniques taught in class to implement the analog front-end of a high-speed serial link.
- EE 142: Integrated Circuits for Communication
- Analysis and design of electronic circuits for communication systems, with an emphasis on integrated circuits for wireless communication systems. Analysis of noise and distortion in amplifiers with application to radio receiver design. Power amplifier design with application to wireless radio transmitters. Radio-frequency mixers, oscillators, phase-locked loops, modulators, and demodulators.
- EE C245: Introduction to MEMS
- Physics, fabrication, and design of micro-electromechanical systems (MEMS). Micro and nanofabrication processes, including silicon surface and bulk micromachining and non-silicon micromachining. Integration strategies and assembly processes. Transduction strategies and mechanical circuits. Electronic position-sensing circuits and electrical and mechanical noise. CAD for MEMS. Design project is required.