Lecture 30: Multi-Transistor Circuit

- **Announcements**:
- Lab#5 due Tuesday, Nov. 12, 5 p.m.
- Midterm 2 next Friday, Nov. 15, @ 7 p.m., in 160 Kroeber Hall
  - Review Session will be next Tuesday, 6-8 p.m., in 400 Cory
  - Midterm Info Sheet online today
  - Handing out sample Midterm 2 today
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- Lecture Topics:
  - Generally-Loaded Transistor
    - —Terminal Resistances
    - —Terminal-to-Terminal Gains
    - —Inspection Analysis Sheet
    - —Examples
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- **Last Time**:
- Went through inspection analysis sheet
- Now, use this to analyze a multi-transistor circuit

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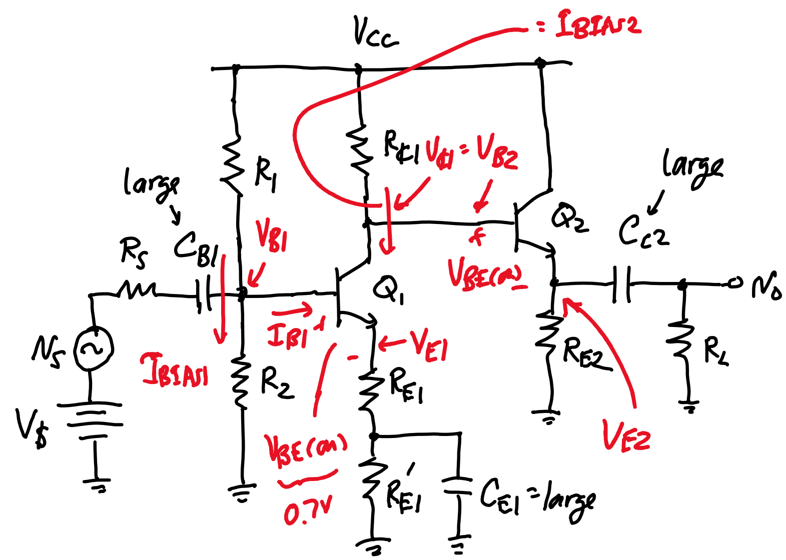
Example. Multi-Transistor Amplifier Inspection Analysis

(C.E. w/ Degeneration, C.C. Cascade)



Find R_i, R_o, $a_v = \frac{v_o}{v_s}$, and f_H.

First, find the DC operating pt:

Good Design: (stable bias pt.) $\Rightarrow$ $I_{BIAS1} > 10 I_{B1}$

$$V_{B1} = \frac{R_2}{R_1+R_2} V_{CC} \rightarrow V_{E1} = V_{B1} - \underbrace{V_{BE(on)}}_{0.7V}$$

$$I_{C1} \cong I_{E1} = \frac{V_{E1}}{R_{E1}+R_{E1}'} = \frac{V_{B1}-V_{BE(on)}}{R_{E1}+R_{E1}'}$$

$$V_{C1} = V_{CC} - I_{C1}R_{C1} = V_{B2} \rightarrow V_{E2} = V_{B2} - V_{BE(on)}$$

$I_{C2} \cong I_{E2} = \dfrac{V_{E2}}{R_{E2}}$

Remarks.

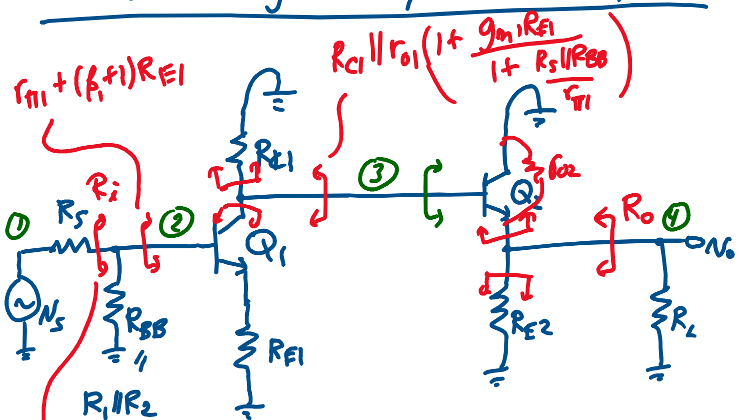
① Look for the $V_{BE(on)}$'s → well-defined voltages

② Current usually determined by $\dfrac{V_E}{R_E}$'s.

For bias stability:

$I_{BIAS1} > 10 I_{B1}$, also $I_{C1} = I_{BIAS2} > 10 I_{B2}$

Midband Small-Signal Analysis for Gain, R_i, and R_o:



$$\boxed{R_i = R_{BB} \| (r_{\pi 1} + (\beta_1+1)R_{E1})}$$

$$R_o = R_{E2} \| r_{o2} \| \left\{ \frac{r_{\pi 2} + R_{C1} \| r_{o1}\left(1 + \frac{g_{m1}R_{E1}}{1 + \frac{R_S \| R_{BB}}{r_\pi}}\right)}{\beta_2+1} \right\}$$

big!

big!

$$\boxed{R_o = R_{E2} \| \left(\frac{r_{\pi 2} + R_{C1}}{\beta_2+1}\right)}$$

Get gain $\dfrac{v_o}{v_s}$: (gain from ① to ④)

$$\frac{v_o}{v_s} = \frac{v_②}{v_s} \cdot \frac{v_③}{v_②} \cdot \frac{v_o}{v_③}$$

$$\frac{v_②}{v_s} = \frac{R_i}{R_s + R_i} = \frac{R_{BB} \| (r_{\pi 1} + (\beta_1+1)R_{E1})}{R_s + R_{BB} \| (r_{\pi 1} + (\beta_1+1)R_{E1})}$$

(voltage divider)

$$\frac{v_③}{v_②} = -G_{m1} R_{C1}$$

$$= -\frac{g_{m1}}{1 + g_{m1}R_{E1}} \left\{ R_{C1} \| r_{o1}\left(1 + \frac{g_{m1}R_{E1}}{1 + \frac{R_S \| R_{BB}}{r_{\pi 1}}}\right) \| \bigcirc \right\}$$

large   large

$r_{\pi 2} + (\beta_2+1)(R_{E2} \| R_L \| r_{o2})$

$$\frac{v_③}{v_②} = -\frac{g_{m1} R_{C1}}{1 + g_{m1} R_{E1}}$$

$$\frac{v_④}{v_③} = \frac{R_{E2} \| R_L \| r_{o2}}{r_{e2} + R_{E2} \| R_L \| r_{o2}} \approx 1$$

$r_{e2} = \dfrac{1}{g_{m2}}$

$$\therefore \frac{v_o}{v_s} = \frac{v_2}{v_s}\cdot\frac{v_3}{v_2}\cdot\frac{v_o}{v_3}$$

$$= \boxed{-\frac{R_{BB}\|(r_{\pi1}+(\beta_1+1)R_{E1})}{R_S+R_{BB}\|(r_{\pi1}+(\beta_1+1)R_{E1})}\;\frac{g_{m1}R_{E1}}{1+g_{m1}R_{E1}}\;:\;\frac{v_o}{v_s}}$$

Procedure for Midband Gain Inspection Analysis:

- Identify and label all signal path nodes
- Get stage gain from node to node
  - For each stage, be sure to account for loading by the next stage, specifically load resistance to ground
  - For transistor terminal-to-terminal gains, will likely need to determine output node resistance to ground
    - including loading by the next stage, and
    - even the influence of loading by the previous stage, e.g., when determining R_c
- Take the product of all node-to-node gains to get the total gain
- Can do all of this by inspection if
  - There is no feedback
  - You know all the terminal-to-terminal gain equations or can “see” or “derive” them quickly
  - You know all the equations for resistances looking into the transistor terminals (to ground) or can “see” or “derive” them quickly
  - “see” or “derive” quickly can often be done by following the currents