**Lecture 31: Multi-Transistor Circuit**

- **Announcements:**
- HW#10 online and due Friday two weeks from now via Gradescope
- Lab#5 due Tuesday, Nov. 6, 5 p.m.
- Midterm coming up
  - Friday next week, Nov. 9, @ 5 p.m., in 277 Cory (just like last time)
  - Midterm Info Sheet online
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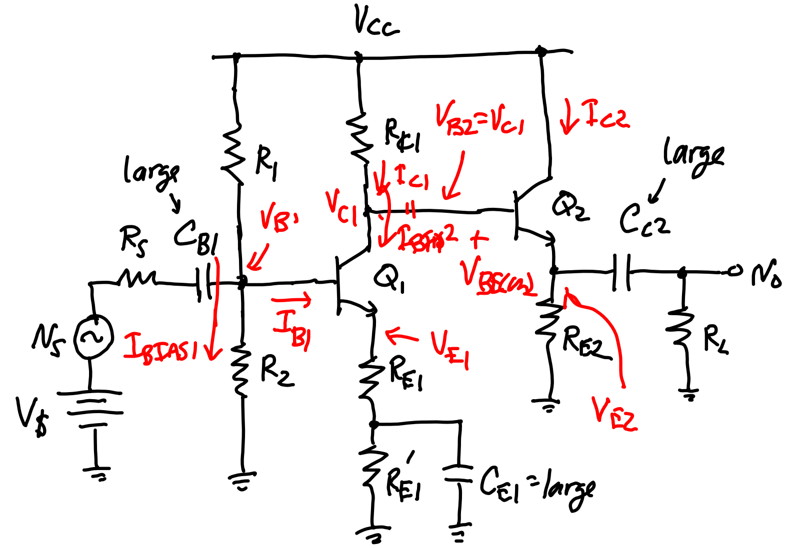
- Lecture Topics:
  - Midterm Info Sheet
  - Generally-Loaded Transistor
    - —Terminal Resistances
    - —Terminal-to-Terminal Gains
    - —Inspection Analysis Sheet
    - —Examples
- ------------------------------------
- **Last Time:**
- Presented the Inspection Analysis Sheet
- Now use it on a multi-transistor circuit …

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: $I_{BIAS1} > 10 I_{B1}$

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

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

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

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

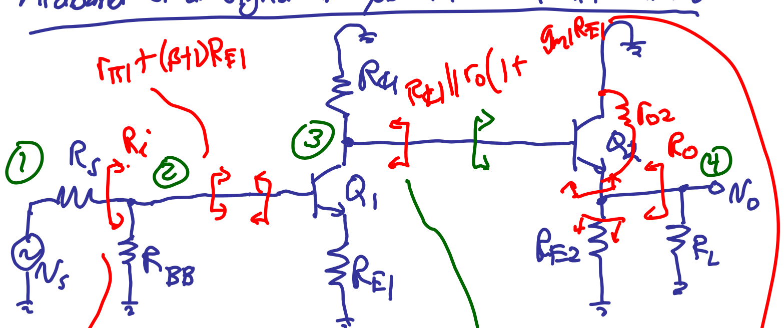
**Remarks.**

1. Look for the $V_{BE(on)}$'s. → well-defined voltages.
2. Current usually be determined by $\frac{V_E}{R_E}$'s.

For Bias Stability:

$I_{BIAS1} > 10 I_{B1}$ also $I_{C1} - I_{BIAS2} \geq 10 I_{B2}$

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




$R_i = R_{BB} \| (r_{\pi1} + (\beta_1+1)R_{E1})$

$R_o = R_{E2} \| r_{o2} \| \left\{ \dfrac{R_{C1} \| r_{o1}\left(1 + \dfrac{g_{m1}R_{E1}}{1 + \frac{R_s \| R_{BB}}{r_{\pi1}}}\right) + r_{\pi2}}{(\beta_2+1)} \right\}$

(bis)

$R_o = R_{E2} \| \left(\dfrac{r_{\pi2} + R_{C1}}{\beta+1}\right)$

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

$\dfrac{v_{②}}{v_{①}} = \dfrac{v_{②}}{v_s} = \dfrac{R_i}{R_s + R_i} = \dfrac{R_{BB} \| (r_{\pi1} + (\beta_1+1)R_{E1})}{R_s + R_{BB} \| (r_{\pi1} + (\beta+1)R_{E1})}$

(voltage divider)

$\dfrac{v_{③}}{v_{②}} = -G_{m1} R_{C1}$

$= -\dfrac{g_{m1}}{1 + g_{m1}R_{E1}} \left\{ R_{C1} \| r_{o1}\left(1 + \dfrac{g_{m1}R_{E1}}{1 + \frac{R_s \| R_{BB}}{r_{\pi1}}}\right) \| \left[ r_{\pi2} + (\beta_2+1)(R_{E2} \| R_L \| r_{o2}) \right] \right\}$

(large) (large)

$\dfrac{v_{③}}{v_{②}} = -\dfrac{g_{m1}R_{C1}}{1 + g_{m1}R_{E1}}$

$\dfrac{v_{④}}{v_{③}} = \dfrac{R_{E2} \| R_L \| r_{o2}}{r_{e2} + R_{E2} \| R_L \| r_{o2}} \simeq 1$

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

$$\therefore \frac{v_o}{v_s} = \frac{v_{②}}{v_{①}} \cdot \frac{v_{③}}{v_{②}} \cdot \frac{v_{④}}{v_{③}} = \frac{v_{④}}{v_{①}}$$

$$= -\frac{R_{BB} \| (r_{\pi 1} + (\beta_1 + 1) R_{E1})}{R_s + R_{BB} \| (r_{\pi 1} + (\beta_1 + 1) R_{E1})} \cdot \frac{g_{m1} R_{C1}}{1 + g_{m1} R_{E1}} = \frac{v_o}{v_s}$$