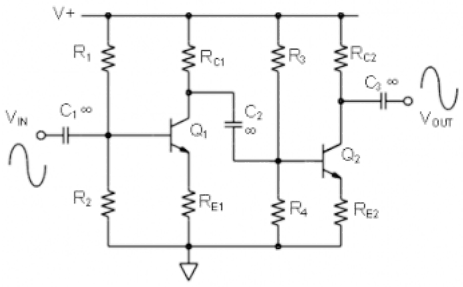
EE105 – Fall 2014
Microelectronic Devices and Circuits

Prof. Ming C. Wu

wu@eecs.berkeley.edu

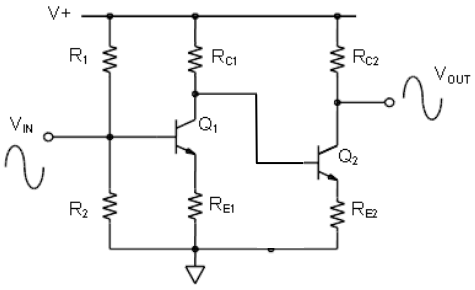
511 Sutardja Dai Hall (SDH)

AC-Coupled CE Amplifiers



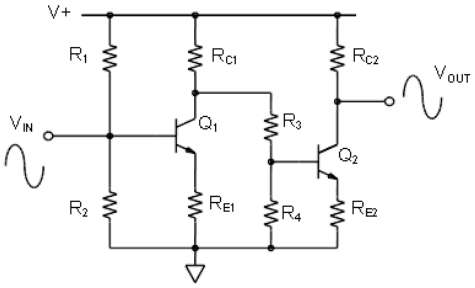
- **Discussed in Lecture 21**
- **Each stage has independent DC bias**
- **Cannot achieve very low frequency response**
  - **e.g., Lab 5 and 6 use DC coupling**

DC-Coupled Cascaded Common-Emitter Amplifiers



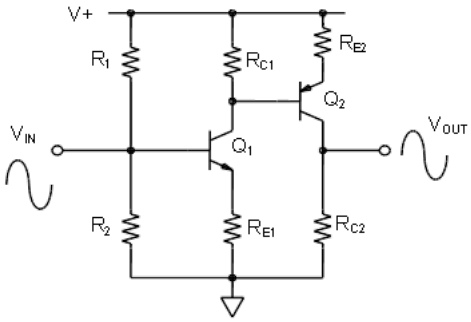
- In DC coupled multistage cascaded CE amplifiers, the output bias level of each stage increases to maintain the collector more positive than the base
  - If this voltage "stacking" is severe, little head room is left in the final stages of the cascade.

DC-Coupled Cascaded Common-Emitter Amplifiers



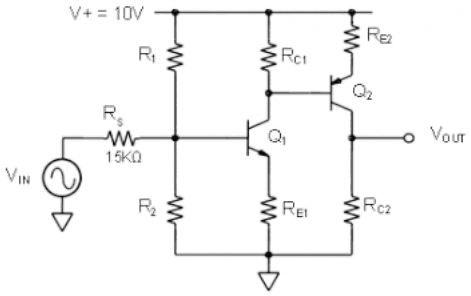
- The R_3, R_4 resistor divider not only reduces the signal amplitude seen at the base of Q_2, it also reduces the DC bias level from the collector of Q_1 to a more manageable DC level at the base of Q_2.
- This happens at the cost of overall signal gain in the combined amplifier.

Complementary Pair Amplifier



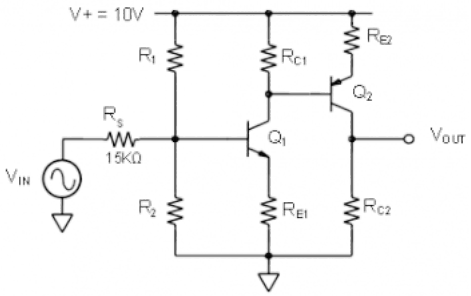
- Having both polarities of transistors allows for more flexibility in how amplifier sages can be combined and can make biasing easier as well.
- First stage: NPN CE
  Second stage: PNP CE
- By using complementary devices, active level shifting can be combined with amplification
  - The p-stage collector DC operating point tends to cancel the bias level "stacking" issue we encountered in the all NPN CE amplifier

Complementary Pair Amplifier – Design Example



- Design a Complementary Pair amplifier stage using 2N3904 and 2N3906 transistors
  - $\beta \sim 120$, $V_{BE} \sim 0.7V$
  - $V_{CC} = 10V$
  - $R_S = 15\ K\Omega$
- Question:
  - Estimate the DC bias voltages
  - Determine the small signal gain at1 KHz

Complementary Pair Amplifier – Design Example



DC bias:

$$V_{EQ} = V_{CC}\frac{R_2}{R_1+R_2} \qquad R_B = R_1 \| R_2$$

$$I_{C1} \approx \frac{V_{EQ}-0.7V}{R_B/\beta + R_{E1}} \qquad V_{C1} \approx V_{CC} - I_{C1}R_{C1}$$

$$I_{C2} \approx \frac{V_{CC}-V_{C1}-0.7V}{R_{E2}}$$

Small-signal gain:

Both Q_1 and Q_2 are CE with degeneration:

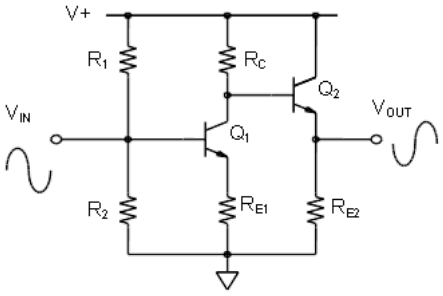
$$A_{V1} = -\frac{g_{m1}R_{C1}}{1+g_{m1}R_{E1}} \approx -\frac{R_{C1}}{R_{E1}}$$

$$A_{V2} \approx -\frac{R_{C2}}{R_{E2}}$$

$$A_V = \frac{R_B}{R_S+R_B}\left(\frac{R_{C1}}{R_{E1}}\right)\left(\frac{R_{C2}}{R_{E2}}\right)$$

$$R_B = R_1 \| R_2 \| (r_\pi + (1+\beta)R_{E1}) \approx R_1 \| R_2$$

DC-Coupled CE-CC Amplifier



$$I_{C1} = \frac{V_{EQ}-0.7V}{R_B/\beta + R_{E1}}$$

$$V_{C1} = V_{CC} - I_{C1}R_C$$

$$I_{C2} = \frac{V_{C1}-0.7V}{R_{E2}}$$

- **Input stage: CE**
  - **High R_{in}**
  - **Moderate to high gain**
- **Output stage: CC**
  - **Low R_{out}**
- **Overall gain is nearly independent of load resistance and source resistance**
- **Multiple CE stages can be cascaded with CC stages inserted between them to reduce the attenuation due to inter-stage loading**
- **Direct coupling is commonly used in IC because this saves biasing resistors**