Lecture 2: Device Models I (Bipolar Review)

Announcements:
- The course website was up and running last week
  - Just google ee140 to get to it
- HW#1 online last week ... due next week
  - Wednesday, at 8 a.m., in the 140/240A box on 1st floor (near the TI lab)
- My Monday Office Hours updated to 2-3 p.m.

Lecture Topics:
- Review (fast)
  - Bipolar Junction Transistor Modeling
    - Basic Structure & Physics
    - Large Signal Models
    - DC Operating Point
    - Small Signal Models
    - Frequency Shaping Elements
    - Layout
    - Unity Gain Frequency
- Last Time: Reviewed op amps and started into BJT modeling using the module handout
- Continue with the handout

Simple Biasing Example

\[ V_{cc} = 10V \]
\[ V_{BB} = V_{cc}(R_2/R_1+R_2) \]
\[ V_{BE} = 0.7V \]
\[ V_{BE(a)} \]
\[ V_{EB} = 0.7V \]
\[ R_B = \frac{V_{cc}}{I_E} \]
\[ R_P = \frac{V_{cc}}{I_E} \]
\[ KVL \]
\[ I_E = \frac{V_{BB}-V_{BE(a)}}{\beta} \]
\[ I_C = \frac{V_{BB}-V_{BE(a)}}{\alpha+\beta} \]

Example:
\[ V_{cc} = 10V, V_{BE(a)} = 0.7V, R_E = 5k\Omega, R_1 = R_2 = 20k\Omega \]
\[ B = 200 \rightarrow \alpha = \frac{200}{201} = 0.995 \]
\[ V_{BB} = 9.5V \]
\[ I_C = \frac{0.7}{5k\Omega + 20k\Omega} = 0.35mA \]
\[ I_E = \frac{4.3}{5k\Omega + 0.9k\Omega} = 0.86mA \]
Example: Find the DC operating pt.

- Want Ic's of all elements
- Simultaneous
- Elements

\[ V_{CC} = 10V \]
\[ R_{ref} = 10k\Omega \]
\[ Q_1 \]
\[ Q_2 \]
\[ Q_3 \]
\[ Q_4 \]
\[ Q_5 \]
\[ Q_6 \]

\[ I_{Ic} = \frac{V_{CC} - V_{BE}(n)}{R_{ref}} = \frac{10 - 0.7}{10K} = 0.93mA \]

\[ V_{CE} = V_{BE}(a) = 0.7V \]

For Q_5 to be FA, need: 
- \[ V_{CE}\text{sat} > 0.2V \]
- \[ V_0 < V_{CC} - V_{BE}(n) - V_{CE}\text{sat} \]

\[ V_0 = V_{BE}(n) + I_{ref}R_S = 0.7 + (0.93mA)(2k) = 2.56V \]

In biasing, \( V_{BE(n)} \) are well-defined

\[ V_{BE(n)} \]

\[ V_0 < V_{CC} - V_{BE}(n) - V_{CE}\text{sat} \]
\[ 10 - 0.7 - 0.2 = 9.1V \]

What if \( R_S = 20k\Omega \)?

\[ V_0 = 0.7V + (0.93mA)(20k) = 19.3V \rightarrow \]

\[ Q_5 \text{ is saturated!} \]

\[ V_0 = V_{CC} - V_{BE}(n) - V_{CE}(sat) = 9.1V \]

\[ I_{ES} = \frac{V_0 - V_{BE}(n)}{R_S} = \frac{9.1 - 0.7}{20K} = 0.42mA \]