Lecture 11

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- npn Bipolar Junction Transistors
  - The collector "collects" electrons, and causes current to flow through the emitter
- npn Structure without Bias
  - At zero bias ($V_{be} = V_{bc} = 0$), neither electrons nor holes can overcome this built-in voltage barrier of $\approx .7$[V] (for Si)
    * $I_B = I_C = 0$ (cutoff)
- npn Structure with Forward-Biased EBJ
  - When ($V_{be} = .65$[V], $V_c > V_b$), electrons and holes can overcome the built-in voltage barrier between the base and emitter
    * $I_b > 0$ and $I_e > I_b$ (due to n^+ emitter doping)
  - If the base region is very thin, the electrons injected by the emitter are collected by the positive voltage applied at V_c
    * $I_c \approx I_E >> I_B$ (active region)
  - If the base region is too thick, many electrons injected at the emitter are lost by recombining with holes in the base before the voltage applied at V_c can collect them
    * $I_c < I_E$ (active region with low α and $\beta \to$ low gain)
- Achievement of high β during Fabrication
  - Thin base region
    * Increases the collection efficiency for injected electrons
    * Reduces the chance of electron recombination in the base
  - Heavily-doped emitter

    * $I_E/I_B \propto n(\text{emitter})/p(\text{base}) \propto \beta$
  - Doping concentrations are difficult to control precisely
    * Current gain is not uniform among BJTs (exception: when the BJTs are all fabricated on the same integrated circuit $\rightarrow$ small variations)

- The Early Effect
  - As V_c increases, the depletion width of the B-C junction widens
    * Base width becomes more narrow
    * Increased collection efficiency
    * Finally, I_c/I_b increases (higher β)