BJTs: Bipolar Junction Transistors

Three terminal device:

- Emitter "emits" electrons
- Collector "collects" electrons

Is it back-to-back diodes?

BJT has very narrow base region

Collector voltage can influence current flow through base
Common-case Configuration

\[ I_E \quad I_C \]

\[ I_B \]

\[ \text{Minority carrier concentration} \]

\[ E \quad B \quad C \]

\[ N_{E0} \quad N_{B0} \quad N_{C0} \]

- \( E \) doping is high \( 10^{19} / \text{cm}^3 \)
- \( B \) moderate \( 10^{17} / \text{cm}^3 \)
- \( C \) lower \( 10^{15} / \text{cm}^3 \)
Forward Active Operation

BE = Forward Biased
BC = Reverse Biased

0) Electrons injected from E→B

2) Narrow base - electrons can diffuse through base

3) Some electrons "recombine" with holes in base. Holes are supplied with IB

4) BC junction R.B. ⇒ large electric field @ junction

5) Electrons get swept across BC junction and "collected"
Currents & Gains

\[ I_E = I_s \frac{V_{BE}}{V_T} \]

Essentially a diode

\[ I_c = \alpha I_E \]

Base transport factor
How much current goes through base
\(\alpha\): Common-base current gain

\[ I_B \propto I_s e^{V_{BE}/V_T} \]

\[ I_c = \beta I_B \]

\(\beta\): Common-Emitter current gain
\[ I_E = I_C + I_B \]
\[ = (\beta + 1)I_B \]
\[ I_C = \frac{\beta}{\beta + 1} I_E = \alpha I_E \]

\[ I_E = I_C + I_B \]
\[ I_B = (1 - \alpha)I_E \]
\[ I_C = \frac{\alpha}{1 - \alpha} I_B = \beta I_B \]

Graph:
- \( I_C, mA \) almost flat
- \( I_E = 3mA \)
- \( I_E = 2mA \)
- \( I_E = 1mA \)
- \( V_{CB} \) from 0.2-0.3V to 10V
Diagram of transistor bias conditions:

- **Reverse-Active**
  - $I_B > 0$
  - $I_C \sim I_E$
  - $I_E \gg 0$

- **Saturation**
  - $I_B > 0$
  - $I_C > 0$
  - $I_E \sim I_C$

- **Cut-off**
  - $I_B \ll 0$
  - $I_C \ll 0$
  - $I_E \ll 0$

- **Forward-Active**
  - $I_B > 0$
  - $I_C \gg 0$
  - $I_E \sim I_C$
Common-Emitter Configuration

\[ V_{CE} = 0.2 \text{ V} \]
identify the Regions

B
+ 0.7V

0.6V

E

C
+ 4V

0.7V

+ 0.2V

4.6V

5.4V