Lee's review: NPN BJT large signal models

1. Collector - BE junction off & CE junction on
   - $i_e \rightarrow \frac{N}{P} \rightarrow \frac{N}{P}$
   - CE junction

2. Saturation
   - BE junction on & CE junction on
   - i.e.: $V_{BE}$ high
   - $i_c = V_{BE} > V_{BE,ON} \rightarrow V_{BE} - V_{CE} > V_{CE,ON}$
   - Naïve diode model

3. Active region (FAR)
   - BE junction on & CE junction on
   - i.e.: $V_{BE} > V_{BE,ON} \Rightarrow V_{BE} - V_{CE} > V_{CE,ON}$
   - Naïve diode model fails
   - BE narrow region

Common way to draw

- $i_c = \beta i_b$
- $V_{CE} > V_{CE,ON}$
- $i_c = I_C (e^{V_{BE}/V_T} - 1)$

This slope is new to our model
- $V_{BE}$ affects size of base
- Quantity w/ $V_A$
- Need to introduce PNP

- Sign all flipped around, makes even

- Makes sense when you see emitter linked to supply

- I focus on junctions to keep my head straight

\[ V_{BE} = V_{BE,ON} \text{ or } V_{BE} - V_{CE} > V_{CO,ON} \]

\[ I_e = I_c + I_B \text{ always } \]

You guys write voltage boundaries for cut-offs & saturation

- Need \( V_{BE} \) to be on or \( V_{BC} \) to be off

Recall, I find signs confusing

- Can be plotted too

Recall that I find this all confusing. Just think of PNP

in a circuit (or as junctions)

You guys

1. Find \( I_c \)

- For PNP, if we lack emitter to supply & recall stuff turns on below supply it makes sense

\[ B = 50 \]

\[ V_{BE,ON} = 0.7V \]

\[ V_R = 1.8V \quad \Rightarrow \quad I_B = 1.8mA \quad \Rightarrow \quad I_C = 90mA \quad (R_C = 0.5V) \]

2. What is \( R_1 \) before we enter saturation \( V_{CE, SAT} = 0.1V \)

\[ V_{CE} = 5V - 90mA \cdot R_1 \quad \Rightarrow \quad R_1 \text{ must be } < 0.99\Omega \]

\[ R_1 \approx 55k\Omega \]
Just saw an example of biasing a BJT

- depends on a precision voltage source, not practical
- But the basic idea - control I_b to set I_C - is good

NPN equivalent

\[ I_C = \frac{5V - V_C}{R_1} \]

- don't forget \( I_b \) changes bias point
- large signal can pull either \( R_C \) or \( R_b \)

\[ R_b = R_2 \]
\[ I_b = \frac{5V - 2.7V}{R_2} + 10mA \]

- big \( b_n \) makes easy design, \( R_2 \sim 1k \) ok, \( R_2 \sim 10k \) is a big deal.

How do we get signals in? (e.g., for small signal measurements)

- pick \( C \) so invisible
- at moderate freq.

- Amplifier works in "mid-band"

DC is for long-term

Other stuff causes high freq.

[Diagrams and annotations]
Let's review NPN & PNP small signal

- diode is function of 1 variable
- apply need to linearize i_d by u_d

- I_c varies if both V_be & V_ce
- need to linearize to both values

\[
\frac{\partial I_c}{\partial V_{ac}} = \frac{I_c}{V_{ac}} = \frac{1}{r_{ac}}
\]

\[
\frac{\partial I_c}{\partial V_{bc}} = \frac{I_c}{V_{bc}} = \frac{1}{r_{bc}}
\]

\[
\frac{I_c}{\Phi_{th}} = g_m
\]

→ called Hybrid-π

For PNP we have an identical model

\[
\frac{I_c}{I_b} = \frac{\Phi_{th}}{R_b} = \frac{R}{I_c} = g_m
\]

For PNP we have an identical model

\[
I_c = \beta I_b (e^{\frac{V_{be}}{\Phi_{th}}} - 1)
\]

\[
I_c = \frac{I_b e^{\frac{V_{be}}{\Phi_{th}}} - I_b e^{\frac{V_{be}}{\Phi_{th}}}}{I_b - I_b e^{\frac{V_{be}}{\Phi_{th}}}}
\]

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