

E151 Lecture 6 – Small Signal BJT Models and Regions of Operations in Circuits

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Disclaimer

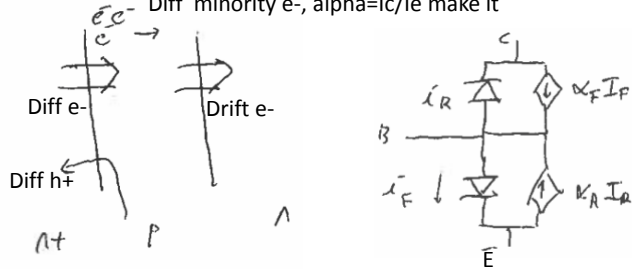
These are note for Prof. Spencer to give the lecture, they were not intended as a reference for students. Students asked for them anyway, so I'm putting them up as a courtesy. Remember that they are not intended as a substitute for lecture.

Introduced BJTs Last Time

More e- diff than h+ diff at n+/p b/c of doping imbalance

Diff minority e-, alpha=Ic/Ie make it

- Like two diodes, but short base region steals current sometimes.
- Started with device picture → Ebers-Moll (computer) model
- Now, go from Ebers-Moll to useful models:
 - Equivalent (large signal) circuits
 - Picture
 - Small signal models



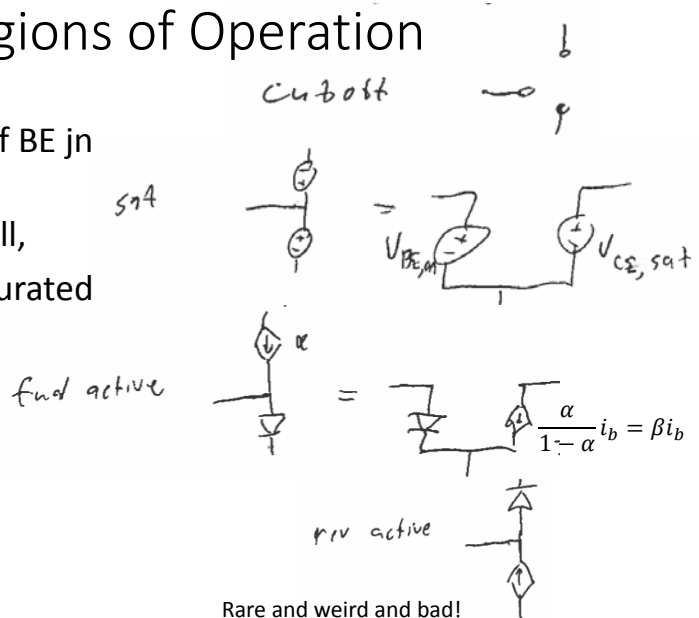
$$I_C = I_S (e^{V_{BC}/\phi_{TH}} - 1) - \frac{I_S}{\alpha_R} (e^{V_{BC}/\phi_{TH}} - 1)$$

$$I_E = I_S (e^{V_{BE}/\phi_{TH}} - 1) - \frac{I_S}{\alpha_F} (e^{V_{BE}/\phi_{TH}} - 1)$$

Notes: $I_{ES} = \alpha * I_{CS}$, simplify to one I_S , $1/\alpha$ terms represent carrier injection in model

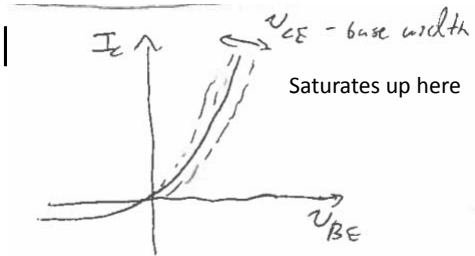
Circuit Models in Regions of Operation

- Specify each region in terms of BE jn on/off and BC jn on/off
- Link to what is on in Ebers-Moll,
- Clarify hitting $V_{CE,SAT}$ → saturated
- Point to U shape conversions
- Ignoring small I elements



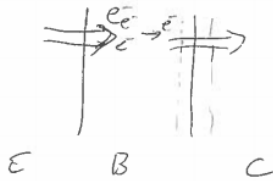
Two Ways to Draw Ebers-Moll → i_C - v_{BE} , i_C - v_{CE}

- i_B - v_{BE} is identical to i_C - v_{BE}
- Omitting breakdown
- Important Detail: Base Width Modulation

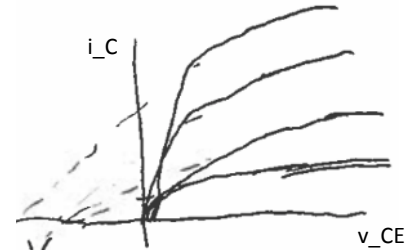


Base width modulation

- changing pn bias changes depletion region width



- affects base distribution
is BC width changes
- small change in I_C w/ V_{CE}



- don't forget base modulation - V_A

Small Signal in FAR Derivation

- Graphical, Ebers-Moll Equation Based, Diode argument, i_C linear i_B !

) small signal model review in FAR

Don't forget to show $g_m \cdot r_p = \beta$

$$i_c = \beta i_b$$

$$i_e = i_c + i_b$$

$$i_b = I_{ES} (e^{v_{BE}/\phi_{th}} - 1) \leftarrow \text{only a function of } v_{BE}$$

$$i_c = \beta I_{ES} (e^{v_{BE}/\phi_{th}} - 1) \left(1 + \frac{v_{CE}}{V_A} \right)$$

\rightarrow conductance, $r_p = \frac{\phi_{th}}{I_B} \approx \frac{\phi_{th}}{\beta I_E} \approx \frac{\phi_{th}}{\beta g_m}$
 $\frac{\partial i_b}{\partial v_{BE}} = \frac{I_B}{\phi_{th}}$
 $\frac{\partial i_c}{\partial v_{BE}} = \frac{I_C}{\phi_{th}} \approx g_m$
 $\frac{\partial i_c}{\partial v_{CE}} = \frac{I_C}{V_A} \leftarrow$ conductance
 $\rightarrow r_o = \frac{V_A}{I_C}$

we've been ignoring in class, but showing on large signal plots

