CHAPTER 6

Bipolar Junction Transistors (BJTs)

Disclaimer: Most of the slides are skeletons that will be filled/modified in the lecture. Please do not assume that you can know the material just by reading the slides.

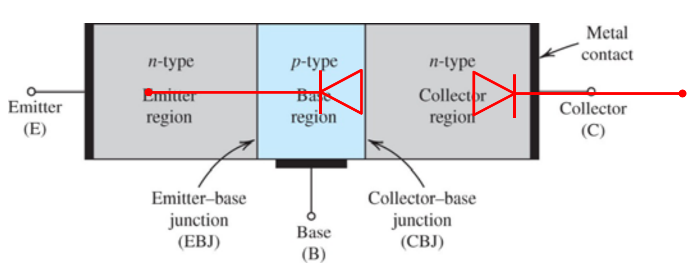
Chapter Objectives

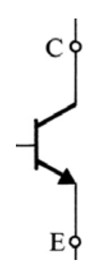
- Learn the physical structure of bipolar transistors and how it works.
- Learn how to analyze and design circuits that contain BJT.
- How the voltage between two terminals control the current that flows through the third terminal.
- How to use BJT to make amplifiers.
- How to obtain linear amplification from nonlinear BJT's

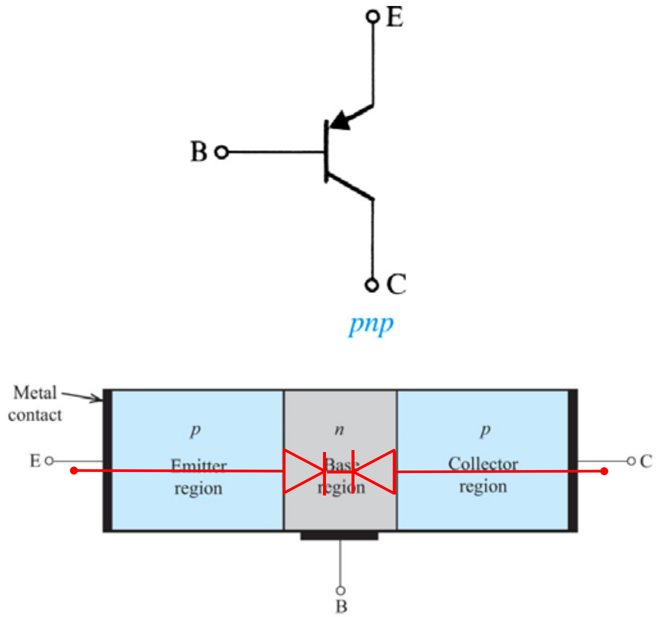
Bipolar Junction Transistors BJT

- Developed at Bell Labs in 1948. The vast majority of IC's now are MOSFET.
- BJT's are more reliable (Automotive applications) and have wider frequency response (RF systems).
- BJT are current driven (input current controls output current). For MOSFET (gate voltage controls drain current).
- BJT depends on the flow of both electrons and holes (only one carrier in MOSFET).
- BiCMOS

- 3 terminals (Emitter, Base, Collector)
- Two coupled p-n junctions
- The base is shared between the 2 junctions







Mode	EBJ	CBJ
Cutoff	Reverse	Reverse
Active	Forward	Reverse
Saturation	Forward	Forward

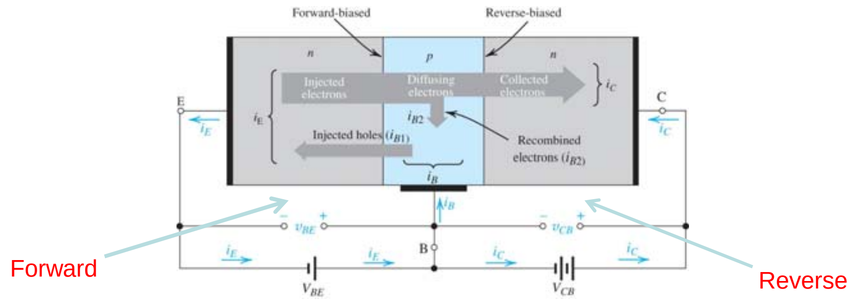
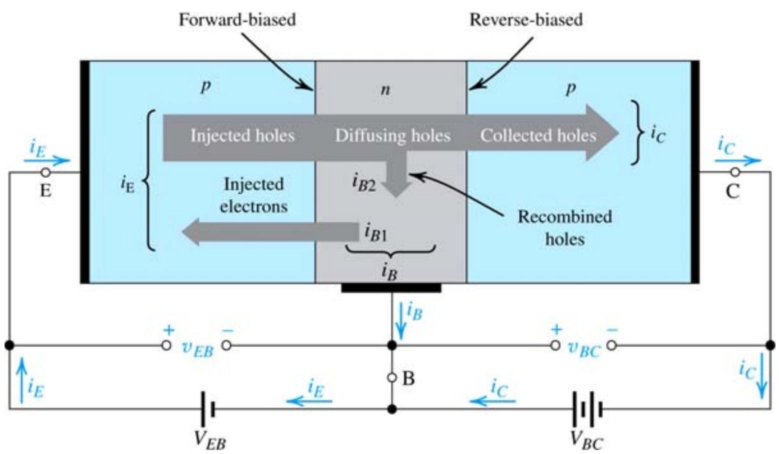
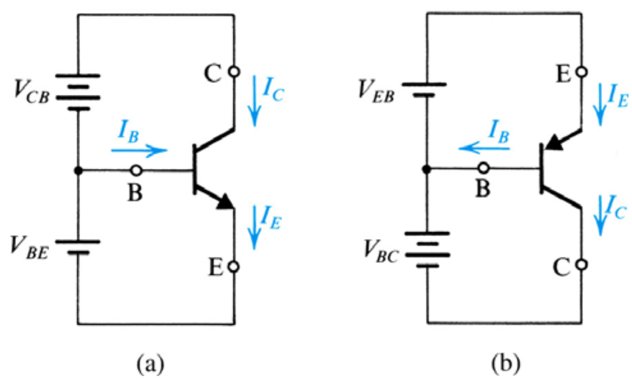


Figure 6.3 Current flow in an *npn* transistor biased to operate in the active mode. (Reverse current components due to drift of thermally generated minority carriers are not shown.)

pnp BJT





Microelectronic Circuits, Seventh Edition Sedra/Smith

Currents in BJT

- $i_E = i_C + i_B$
- In BJT, base current controls collector current
- $i_c = I_s e^{V_{BE}/V_T}$

$i_C = \beta_F i_B$ Common emitter current gain

$i_C = \alpha_F i_E$ Common base current gain

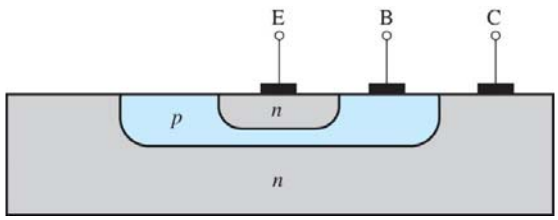


Figure 6.7 Cross section of an *npn* BJT.

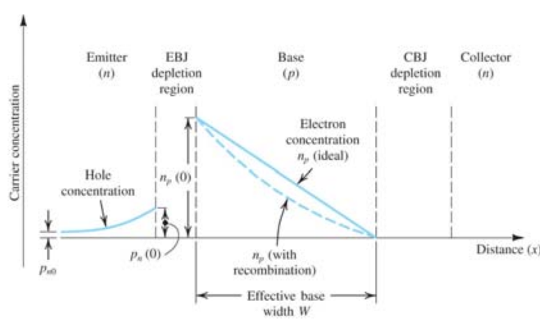
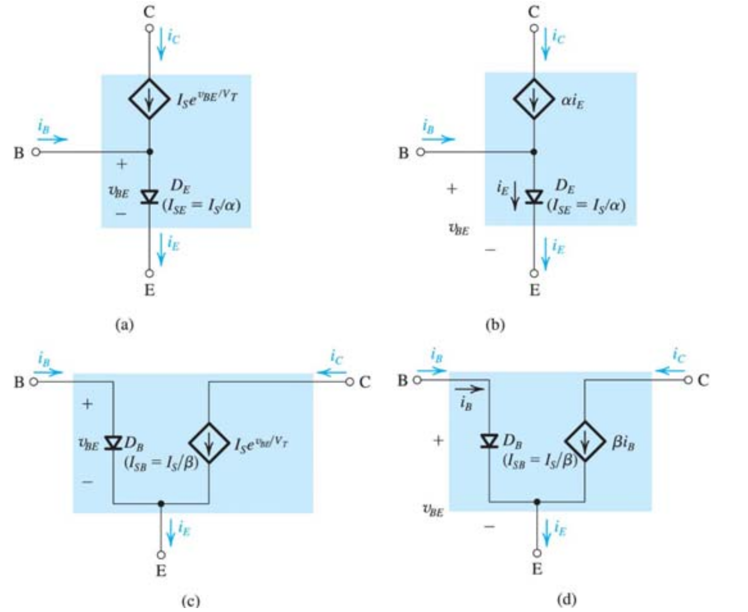


Figure 6.4 Profiles of minority-carrier concentrations in the base and in the emitter of an *npn* transistor operating in the active mode: $v_{BE} > 0$ and $v_{CB} \geq 0$.



$I_S = 10^{-15}$ A, $\beta = 100$

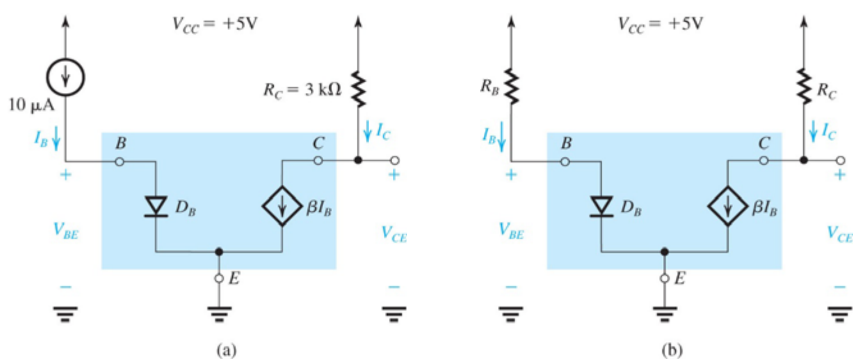


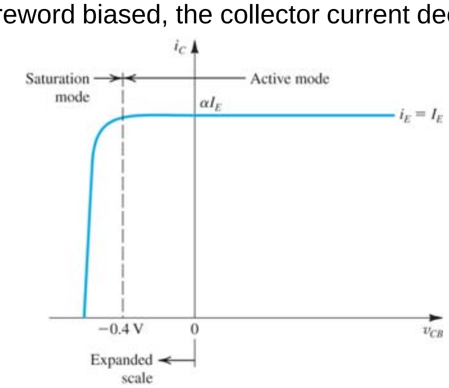
Figure 6.6 Circuits for Example 6.1.

Exercise

6.5 -- A transistor with $I_S=10^{-16}$A, β=100 with I_C=1mA find v_{BE}, I_{SE}, and I_{SB}

Operation in Saturation Mode

- For Forward active region, the CB junction must be reverse biased.
- THE CB junction will not be ON till at least 0.4V forward biased
- Before that, the collector current is constant
- After CB junction is foreword biased, the collector current decreases, why?



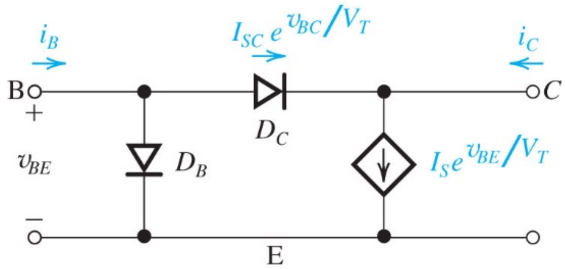


Figure 6.9 Modeling the operation of an *npn* transistor in saturation by augmenting the model of Fig. 6.5(c) with a forward-conducting diode D_C. Note that the current through D_C increases i_B and reduces i_C.

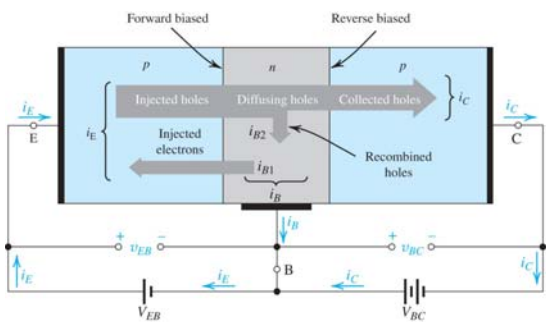


Figure 6.10 Current flow in a *pnp* transistor biased to operate in the active mode.

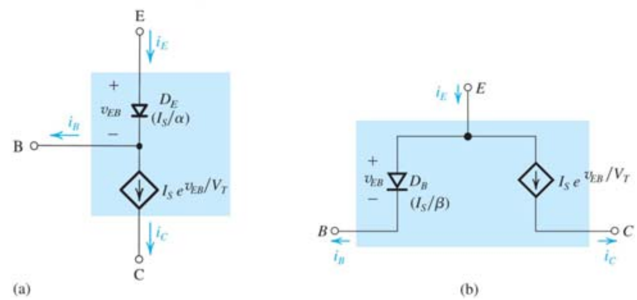


Figure 6.11 Two large-signal models for the *pnp* transistor operating in the active mode.

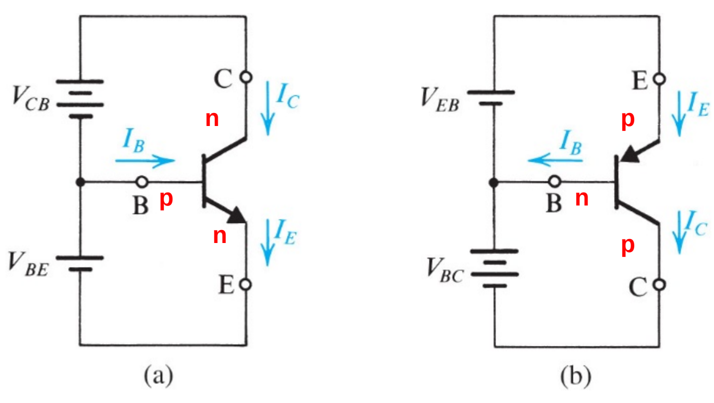


Figure 6.13 Voltage polarities and current flow in transistors operating in the active mode.

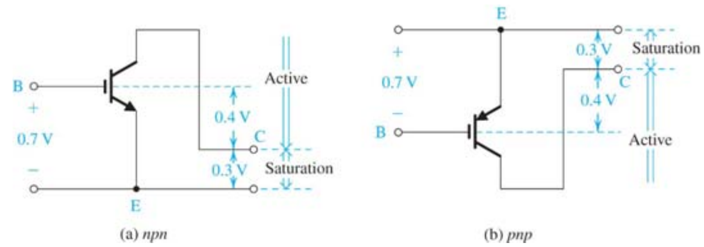


Figure 6.14 Graphical representation of the conditions for operating the BJT in the active mode and in the saturation mode.

Table 6.2 Summary of the BJT Current–Voltage Relationships in the Active Mode

$$i_C = I_S e^{v_{BE}/V_T}$$

$$i_B = \frac{i_C}{\beta} = \left(\frac{I_S}{\beta}\right) e^{v_{BE}/V_T}$$

$$i_E = \frac{i_C}{\alpha} = \left(\frac{I_S}{\alpha}\right) e^{v_{BE}/V_T}$$

Note: For the *pnp* transistor, replace v_{BE} with v_{EB}.

$i_C = \alpha i_E$ $\qquad$ $i_B = (1-\alpha) i_E = \dfrac{i_E}{\beta+1}$

$i_C = \beta i_B$ $\qquad$ $i_E = (\beta+1) i_B$

$\beta = \dfrac{\alpha}{1-\alpha}$ $\qquad$ $\alpha = \dfrac{\beta}{\beta+1}$

$V_T = \text{thermal voltage} = \dfrac{kT}{q} \simeq 25\text{ mV}$ at room temperature

