ENG2210
Electronic Circuits
Chapter 6
Bipolar Junction Transistor

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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

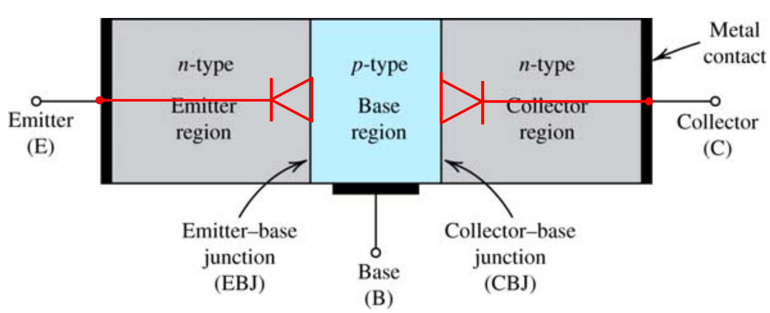
- Learn the physical structure of bipolar transistors and how it works.
- Learn how to analyze and design circuits that contain BJT.
- How the voltage between two terminals control the current that flows through the third terminal.
- How to use BJT to make amplifiers.
- How to obtain linear amplification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

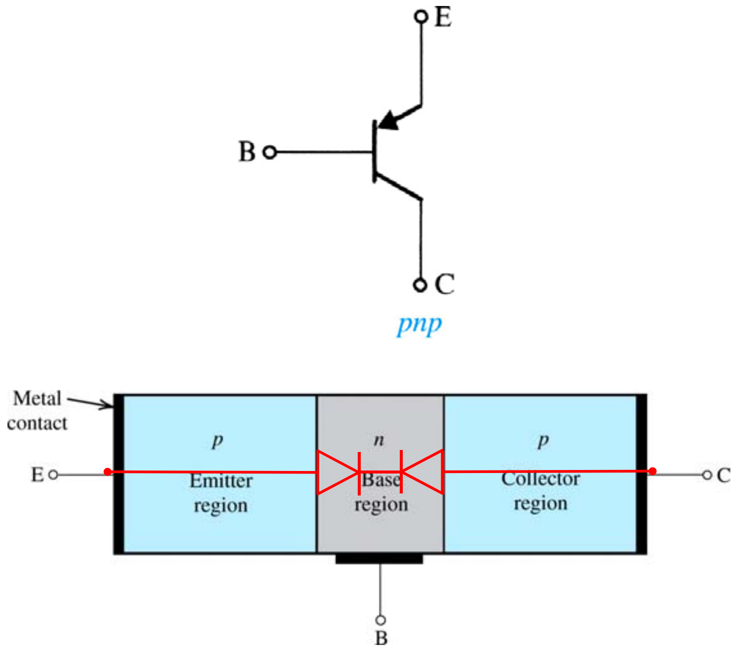
Bipolar Junction Transistors BJT

- 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

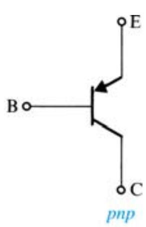
BJT

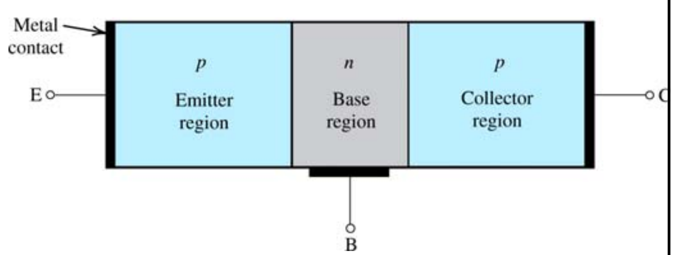
- 3 terminals (Emitter, Base, Collector)
- Two coupled p-n junctions
- The base is shared between the 2 junctions





Modes of Operation





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

npn in the Active Mode

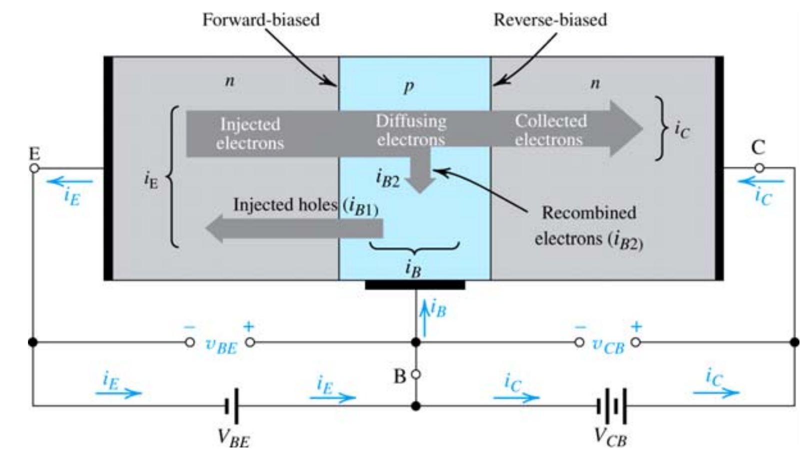
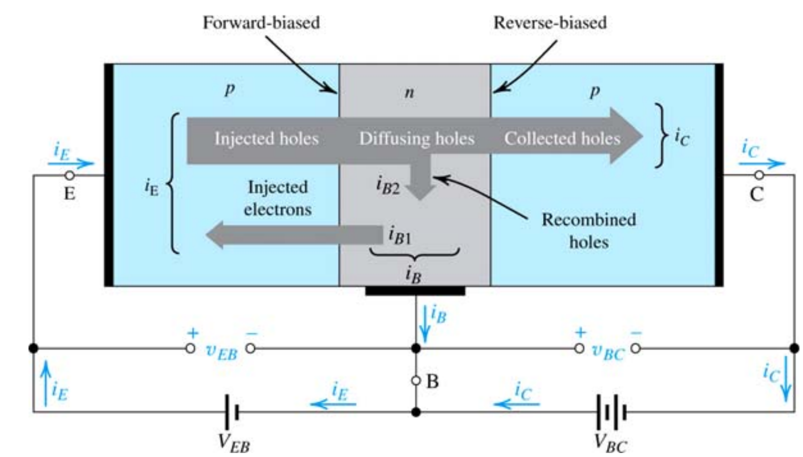


Figure 6.3 Current flow in an *npn* transistor biased to operate in the active mode. (Reverse current components due to drift of thermally generated minority carriers are not shown.)

pnp in Active Forward Mode



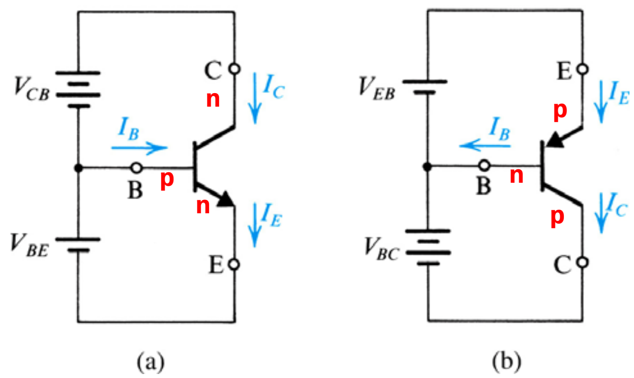


Figure 6.13 Voltage polarities and current flow in transistors biased in the active mode.

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

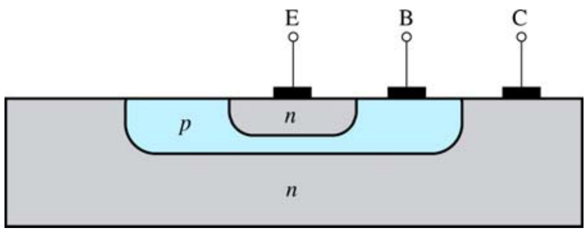
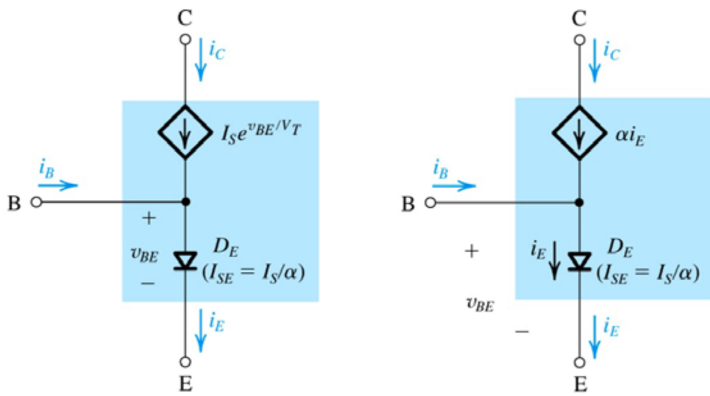
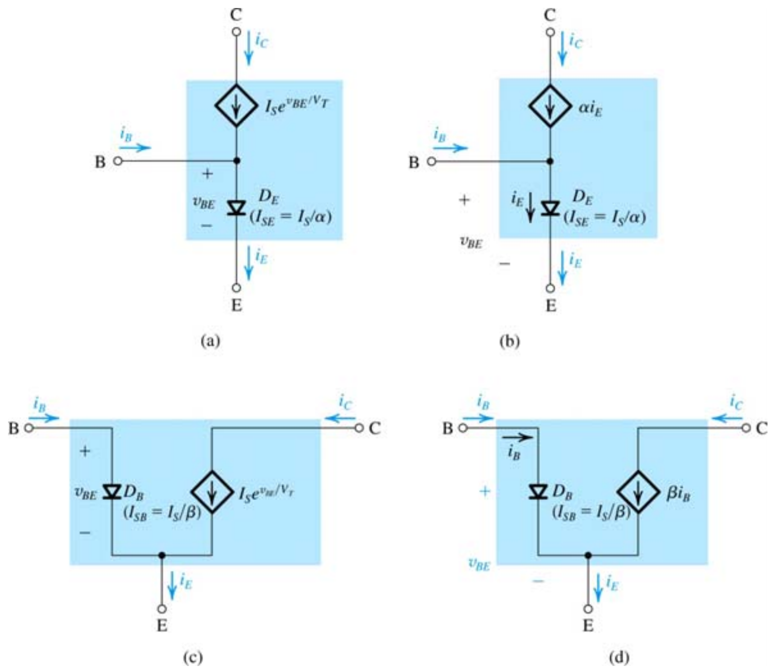


Figure 6.7 Cross-section of an *npn* BJT.

Equivalent Circuit (npn)

- The BE junction is forward biased
- V_{BE}





Example

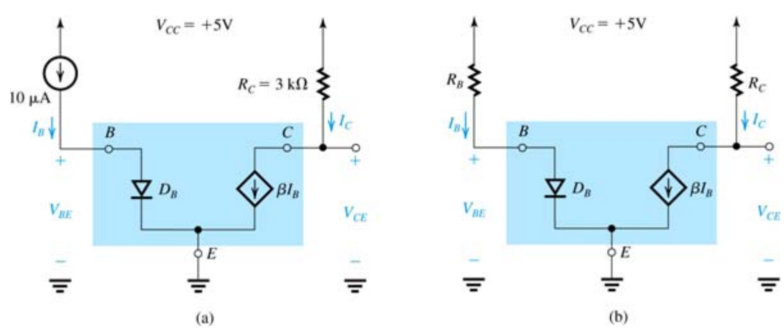
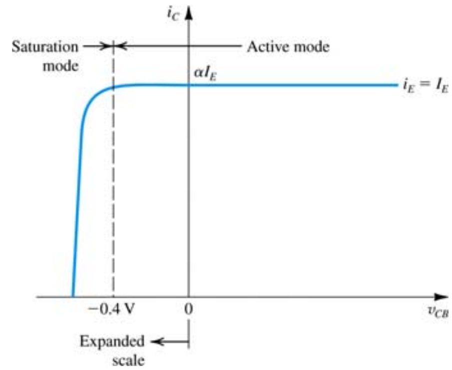


Figure 6.6 Circuits for Example 6.1.

Saturation Region

- 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?

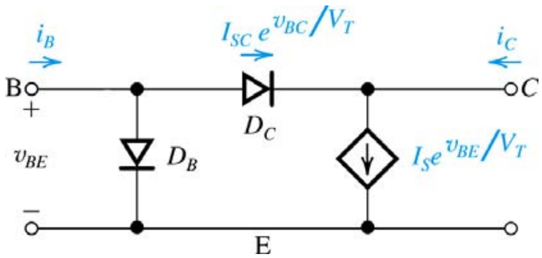


$$i_C = I_s e^{v_{BE}/V_T} - I_{sc} e^{v_{BC}/V_T}$$

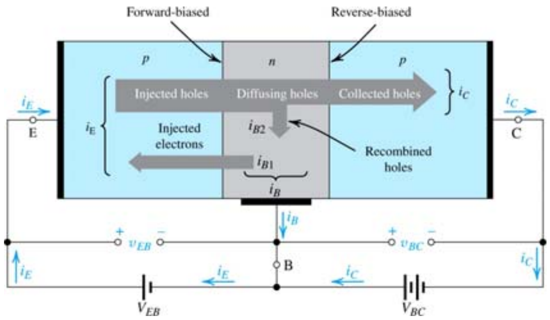
$$i_B = (I_s/\beta) e^{v_{BE}/V_T} + I_{sc} e^{v_{BC}/V_T}$$

$$\beta_{forced} = \left.\frac{i_C}{i_B}\right|_{saturation} \leq \beta$$

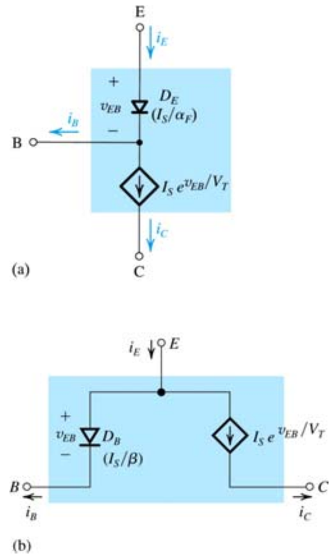
We can control β in the saturation region using v_{BC}



pnp



Forward-biased
Reverse-biased
Injected holes
Diffusing holes
Collected holes
Injected electrons
Recombined holes
E
C
B
V_EB
V_BC



E
B
C
D_E
(I_S/α_F)
(a)
D_B
(I_S/β)
(b)