EE112 - Fall 2016
Analog Integrated Circuits I

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Bipolar Junction Transistors (BJT, 双极型晶体管)

npn BJT

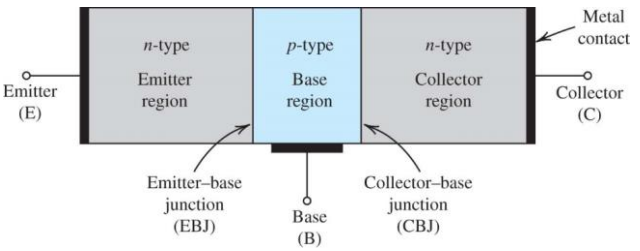
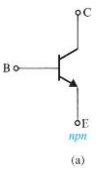


Figure 4.1 A simplified structure of the *npn* transistor.



pnp BJT

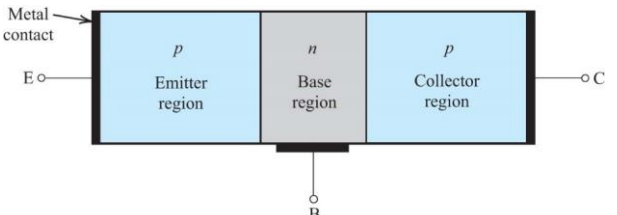


Figure 4.2 A simplified structure of the *pnp* transistor.

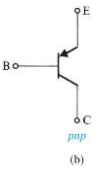


Figure 4.12 Circuit symbols for BJTs.

npn BJT in “Active” Mode

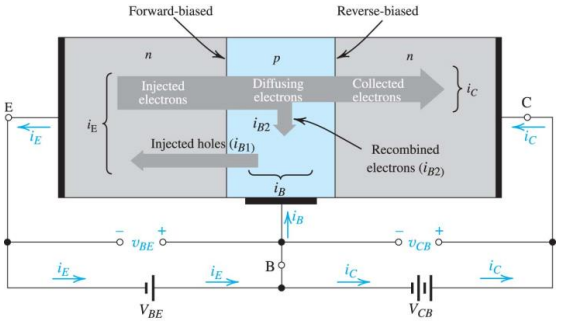


Figure 4.3 Current flow in an *npn* transistor biased to operate in the active mode. (Reverse current components due to drift of thermally generated minority carriers are not shown.)

- Question:

What’s the difference between an npn BJT and a serially connected np and pn diodes?

- BJT’s are biased in “active mode” for linear amplifiers (and most analog circuits”
- Base-Emitter junction is forward biased
- Base-Collector junction is reverse biased
- Electrons are injected from emitter, diffuse through base, and then swept by collector

In retrospect…

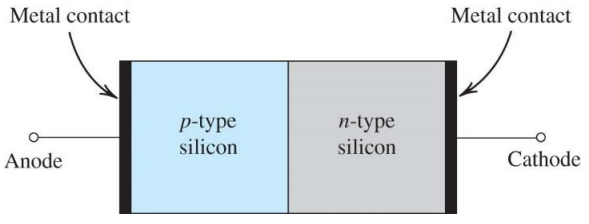


Figure 1.35 Simplified physical structure of the *pn* junction. (Actual geometries are given in Appendix A.) As the *pn* junction implements the junction diode, its terminals are labeled anode and cathode.

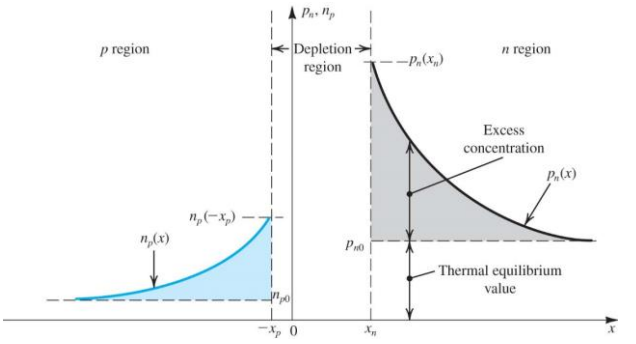


Figure 1.39 Minority-carrier distribution in a forward-biased pn junction. It is assumed that the p region is more heavily doped than the n region; $N_A >> N_D$

Minority Carrier Distribution and Collector Current

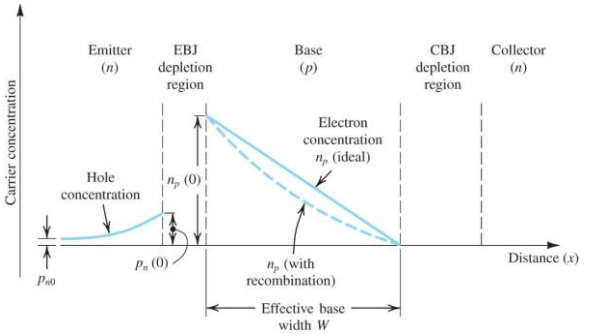
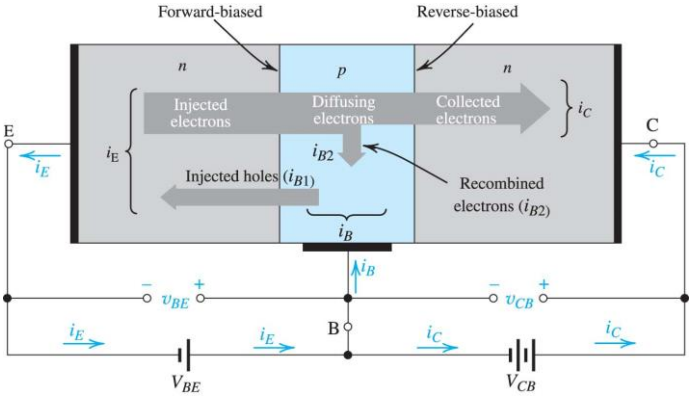


Figure 4.4 Profiles of minority-carrier concentrations in the base and in the emitter of an npn transistor operating in the active mode: $v_{BE} > 0$ and $v_{CB} > 0$.

Base Current and Emitter Current



Cross Section of npn BJT

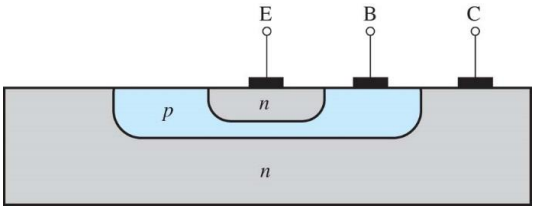


Figure 4.7 Cross section of an *npn* BJT.

Voltage Polarities and Current Flow in Transistors Operating in Active Mode

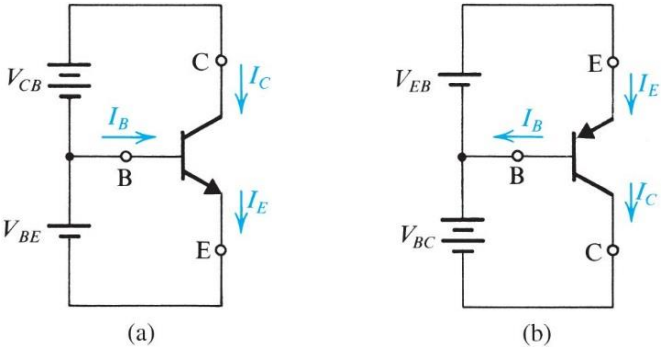


Figure 4.13 Voltage polarities and current flow in transistors operating in the active mode.

- Base-Emitter junction **forward-biased**
- Base-Collector junction **reverse-biased**

Saturation Mode vs. Active Mode

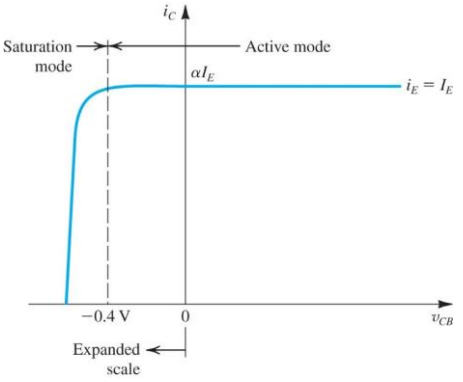


Figure 4.8 The i_C - v_{CB} characteristic of an npn transistor fed with a constant emitter current I_E. The transistor enters the saturation mode of operation for v_{CB} < -0.4 V, and the collector current diminishes.

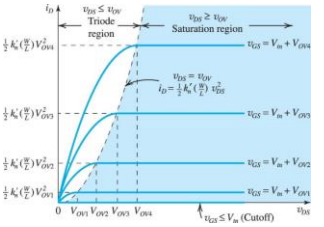


Figure 5.13 The i_D - v_{DS} characteristic for an enhancement-type NMOS transistor.

Operation Modes for BJT: Active and Saturation

Figure 4.14 Graphical representation of the conditions for operating the BJT in the active mode and in the saturation mode.

- **Active mode:**
  - » BE forward biased, BC reverse biased
  - » BJT's in linear amplifiers and most analog circuits are biased in active mode
- **Saturation mode:**
  - » Both junctions are forward biased, BE is biased more (larger voltage) than BC
  - » Used in digital circuits
- **Note**: Saturation modes in BJT and MOSFET (unfortunately) refer to different (**opposite**) regions of operation

BJT Bias Example

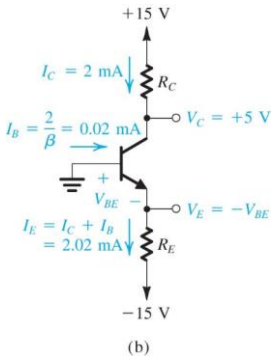


Figure 4.15 Circuit for Example 4.2.

- The BJT in the circuit has a current gain of β = 100, and i_C = 1mA when v_{BE} = 0.7V. Design a bias circuit (i.e., find R_C and R_E) such that I_C=2mA and V_C=5V .