Microelectronics
Circuit Analysis and Design

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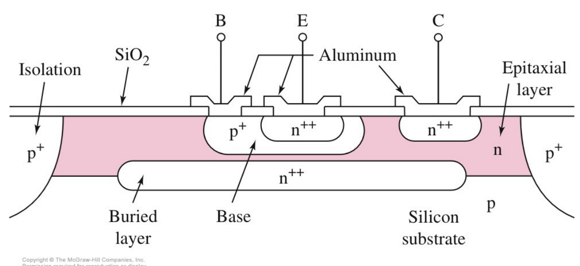
Chapter 5

The Bipolar Junction Transistor

In this chapter, we will:

- Discuss the physical structure and operation of the bipolar junction transistor.
- Understand the dc analysis and design techniques of bipolar transistor circuits.
- Examine three basic applications of bipolar transistor circuits.
- Investigate various dc biasing schemes of bipolar transistor circuits, including integrated circuit biasing.

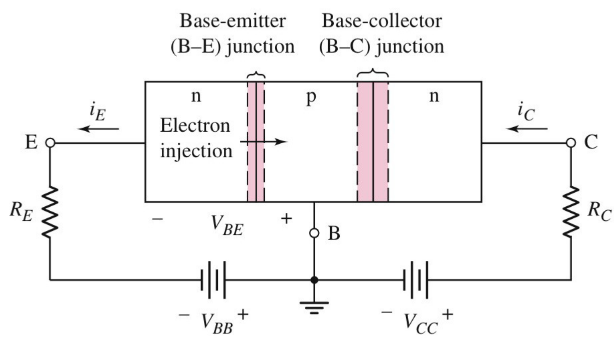
Cross Section of Integrated Circuit npn Transistor



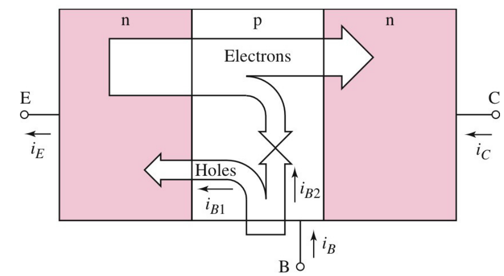
Modes of Operation

- Forward-Active
  - B-E junction is forward biased
  - B-C junction is reverse biased
- Saturation
  - B-E and B-C junctions are forward biased
- Cut-Off
  - B-E and B-C junctions are reverse biased
- Inverse-Active (or Reverse-Active)
  - B-E junction is reverse biased
  - B-C junction is forward biased

npn BJT in Forward-Active



Electrons and Holes in npn BJT

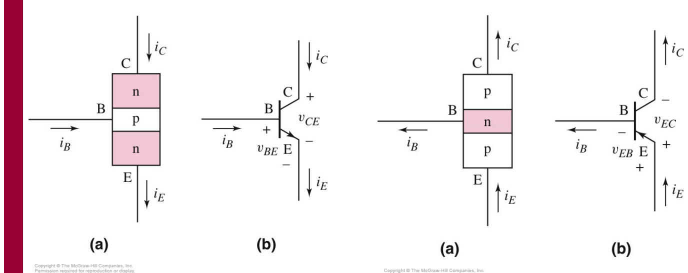


Electrons and Holes in npn BJT

With a + potential across the C-E terminals.
If a positive voltage is applied to the base (>0.6V), the B-E pn junction is forward biased.

The E side electrons cross the pn junction and many electrons are swept to the positive C side voltage (since the p base material is thin). This results in electron flow from E to C. (Conventional current flow from C to E).

Circuit Symbols and Current Conventions



Current Relationships

$$i_E = i_C + i_B$$

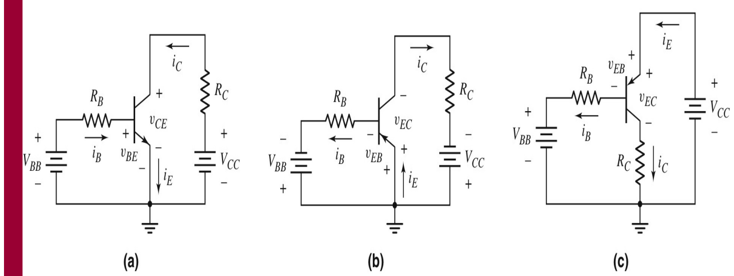
$$i_C = \beta i_B$$

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

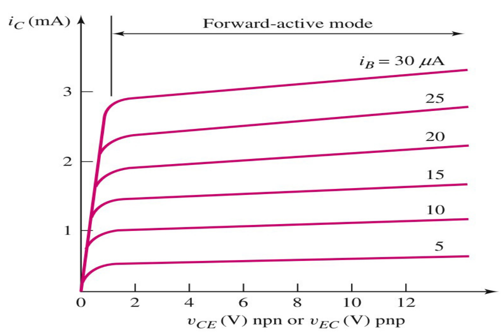
$$i_C = \alpha i_E$$

$$\beta = \frac{\alpha}{1-\alpha}$$

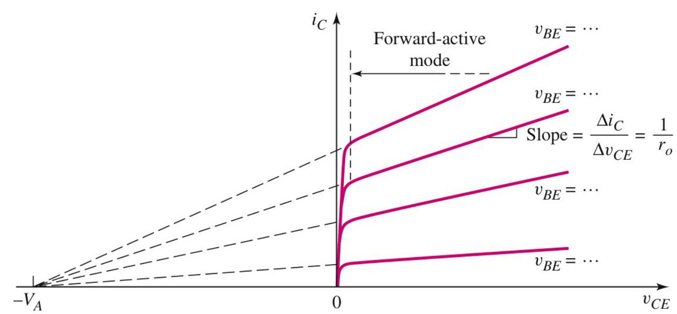
Common-Emitter Configurations



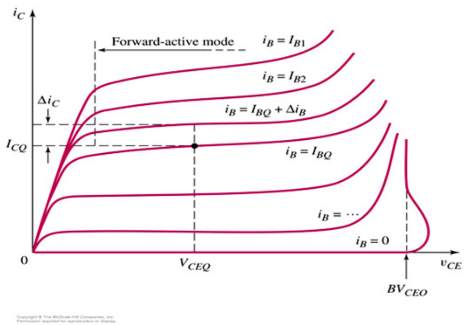
Current-Voltage Characteristics of a Common-Emitter Circuit



Early Voltage/Finite Output Resistance



Effect of Collector-Base **Breakdown** on Common Emitter I-V Characteristics



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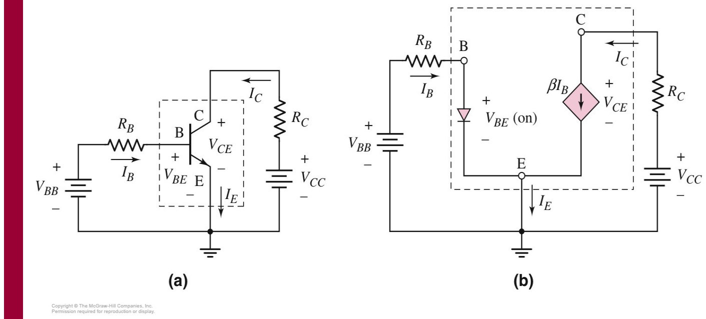
DC Equivalent Circuit for npn Common Emitter



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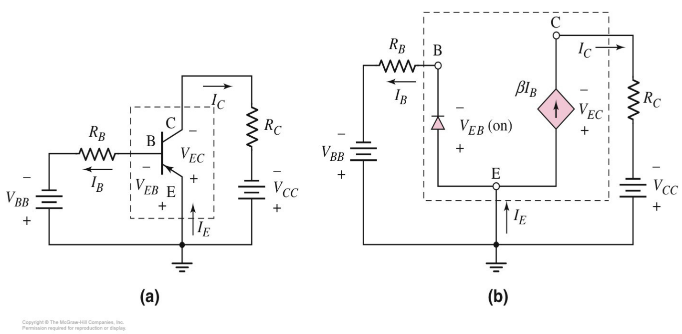
DC Equivalent Circuit for pnp Common Emitter



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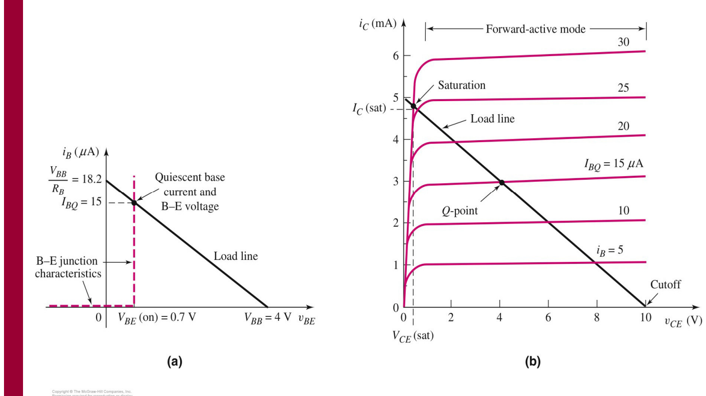
Load Line



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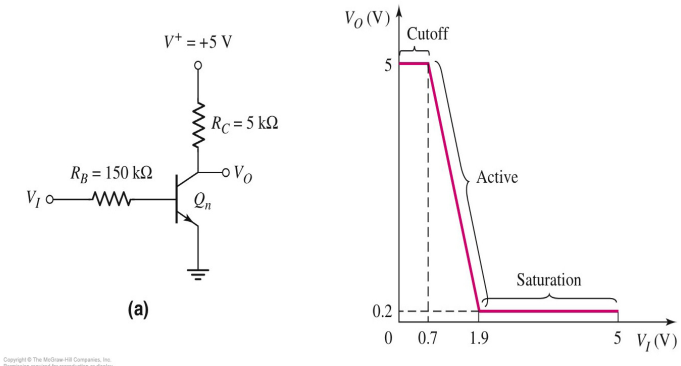
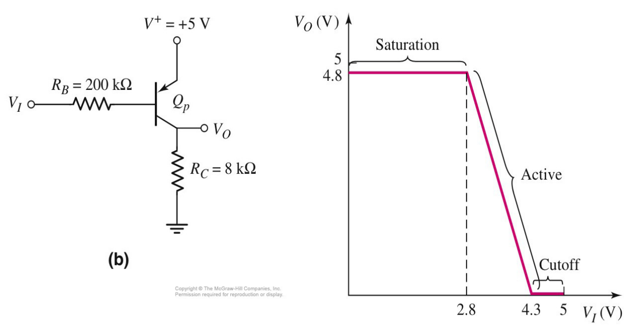
Problem-Solving Technique: Bipolar DC Analysis

1. Assume that the transistor is biased in forward active mode
   a. $V_{BE} = V_{BE}(on)$, $I_B > 0$, & $I_C = \beta I_B$
2. Analyze 'linear' circuit.
3. Evaluate the resulting state of transistor.
   a. If $V_{CE} > V_{CE}(sat)$, assumption is correct
   b. If $I_B < 0$, transistor likely in cutoff
   c. If $V_{CE} < 0$, transistor likely in saturation
4. If initial assumption is incorrect, make new assumption and return to Step 2.

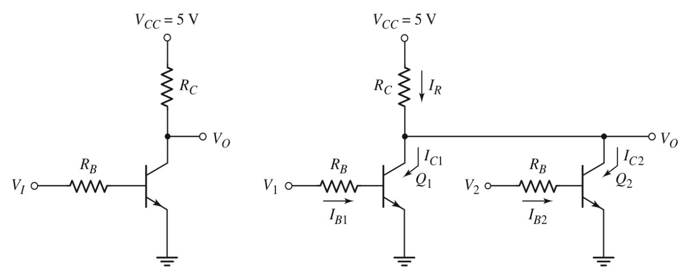
Voltage Transfer Characteristic for npn Circuit



Voltage Transfer Characteristic for pnp Circuit

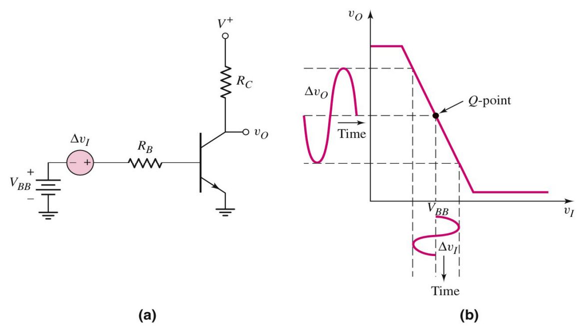


Digital Logic

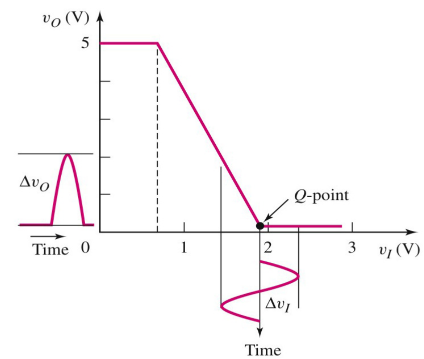


(a) Inverter (b) NOR gate

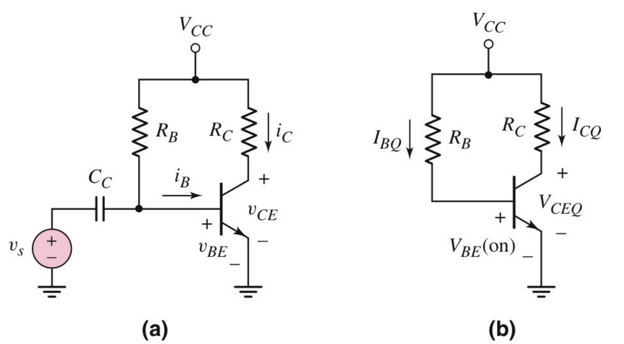
Bipolar Inverter as Amplifier



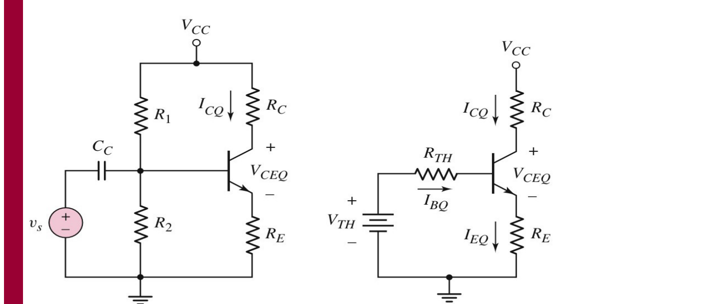
Effect of Improper Biasing on Amplified Signal Waveform



Single Base Resistor Biasing



Common Emitter with Voltage Divider Biasing and Emitter Resistor



(a) (b) $V_{TH} = [R_2/(R_1+R_2)]V_{CC}$