Microelectronics
Circuit Analysis and Design

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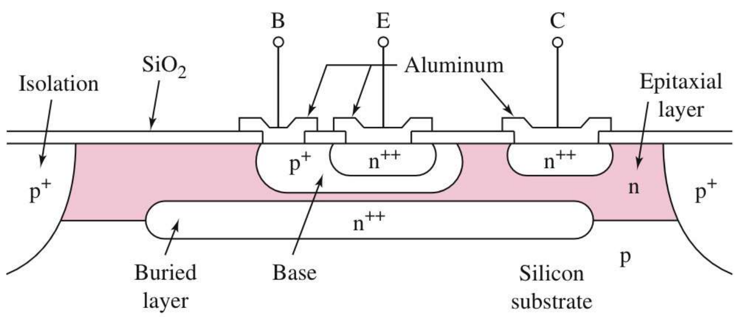
Chapter 5

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.
- Consider the dc biasing of multistage or multi-transistor circuits.

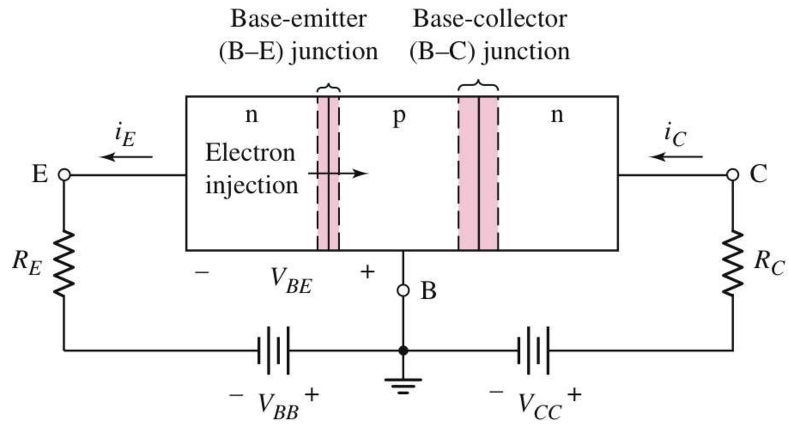
Cross Section of Integrated Circuit npn Transistor



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



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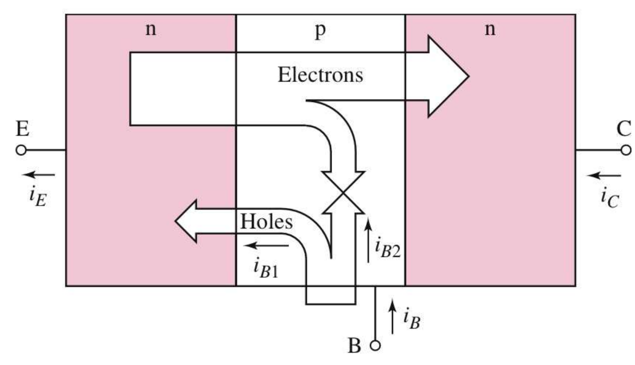
Electrons and Holes in npn BJT



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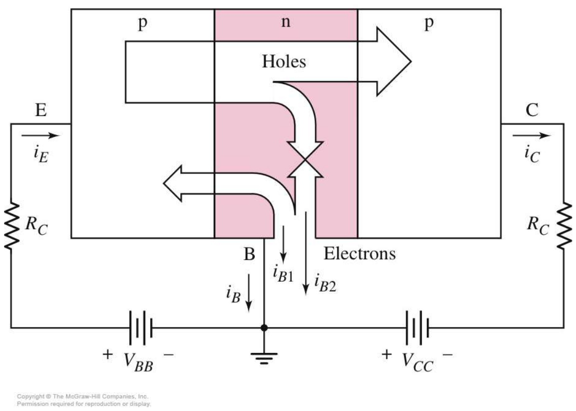
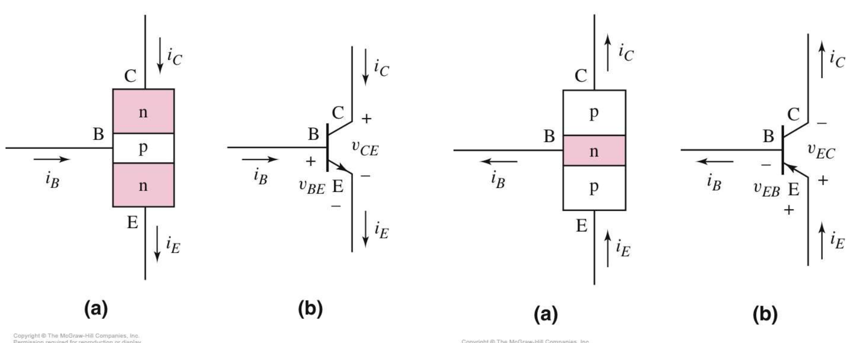
Electrons and Holes in pnp BJT



Circuit Symbols and Current Conventions



Current Relationships

$$i_E = i_C + i_B$$

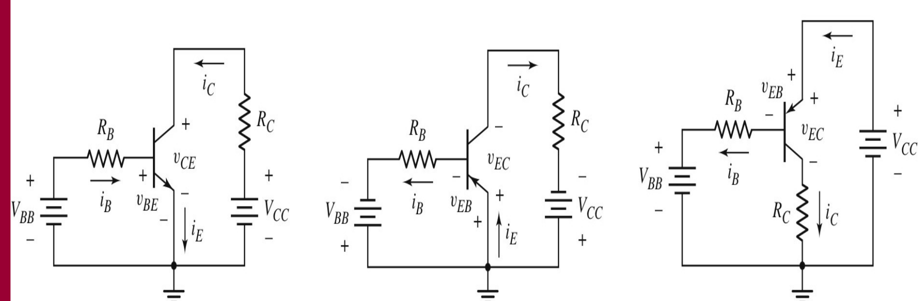
$$i_C = \beta i_B$$

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

$$i_C = \alpha i_E$$

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

Common-Emitter Configurations



(a) (b) (c)

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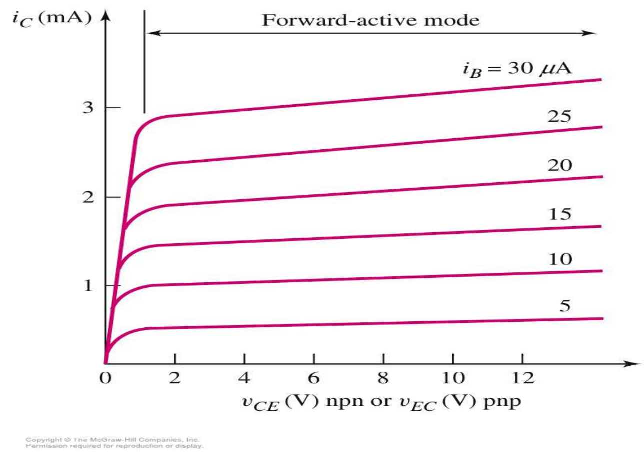
Current-Voltage Characteristics of a Common-Emitter Circuit



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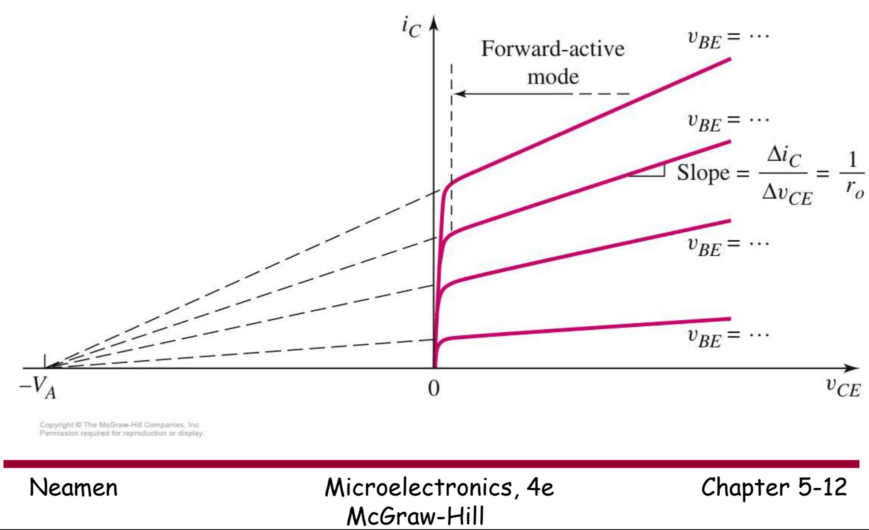
Early Voltage/Finite Output Resistance



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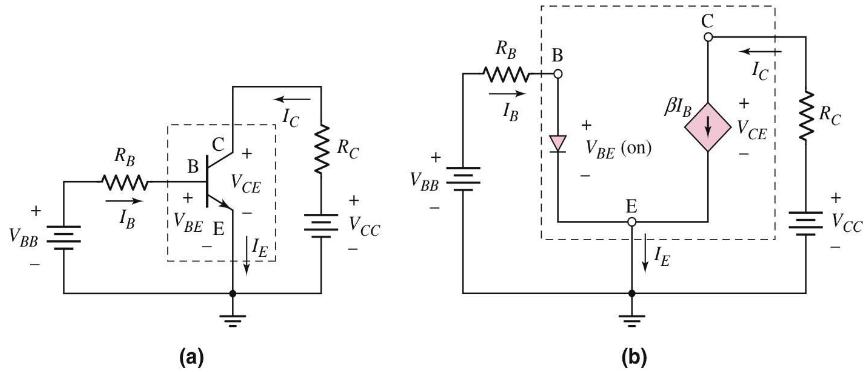
DC Equivalent Circuit for npn Common Emitter



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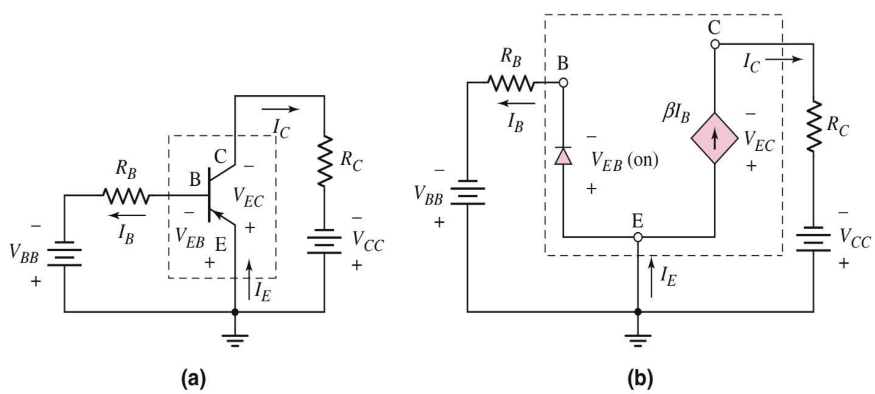
DC Equivalent Circuit for pnp Common Emitter



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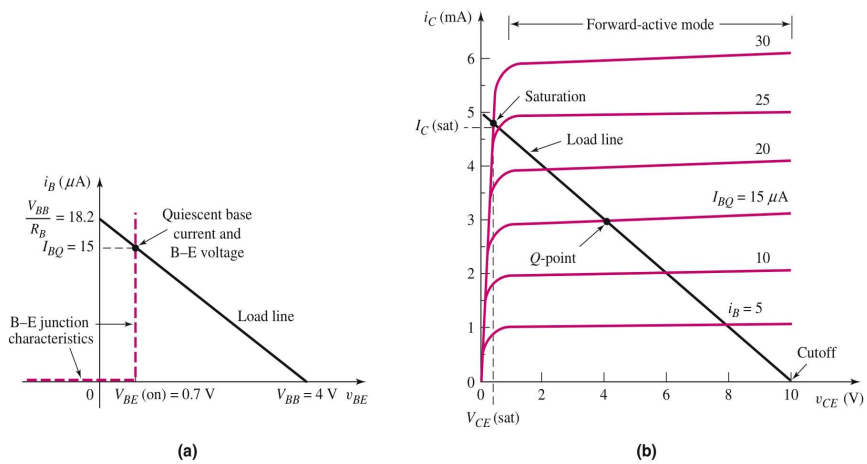
Load Line



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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.

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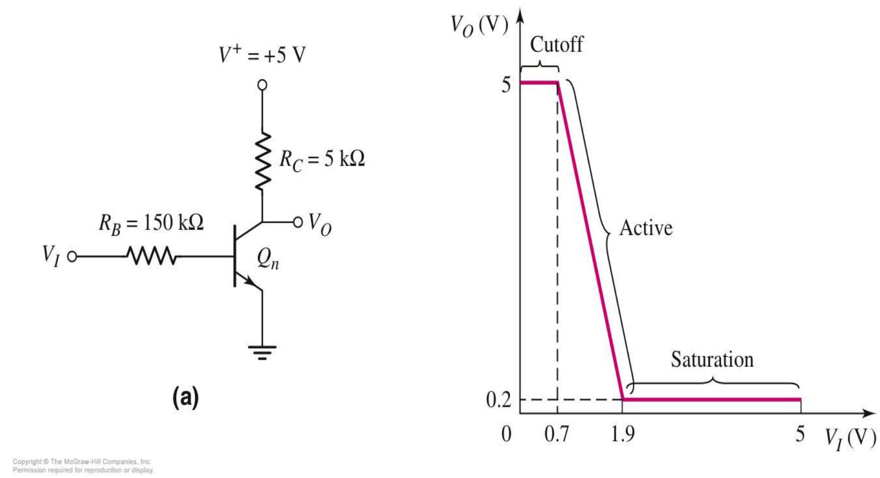
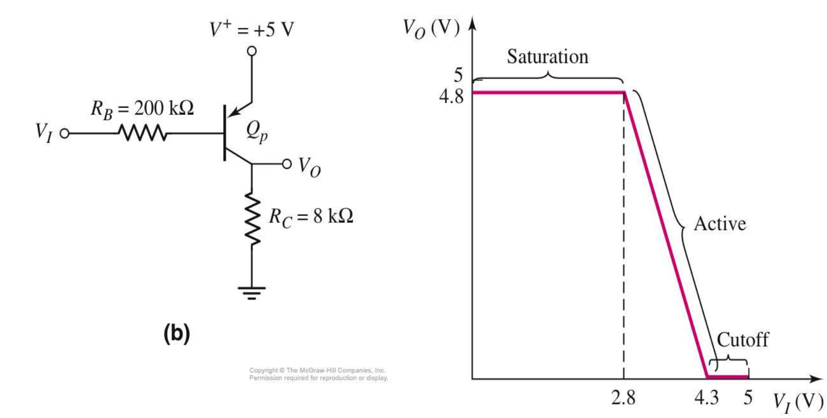
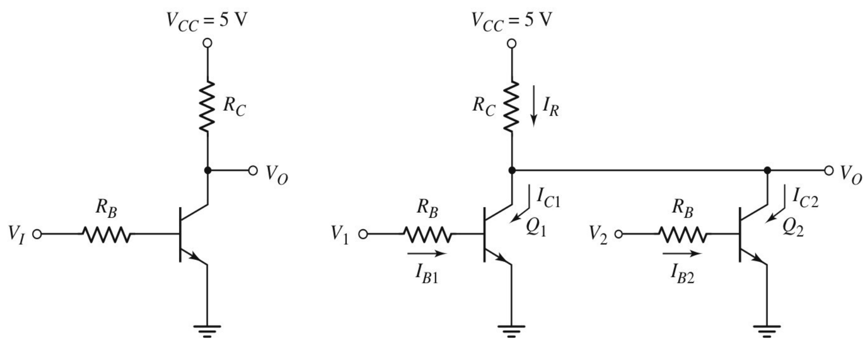
Voltage Transfer Characteristic for npn Circuit



Voltage Transfer Characteristic for pnp Circuit



Digital Logic



(a) Inverter

(b) NOR gate

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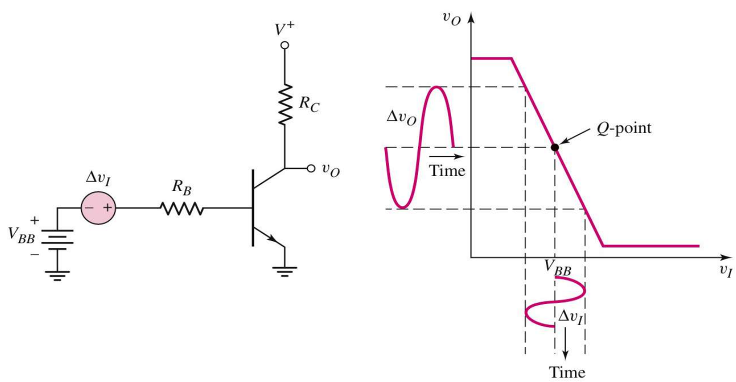
Bipolar Inverter as Amplifier



(a)

(b)

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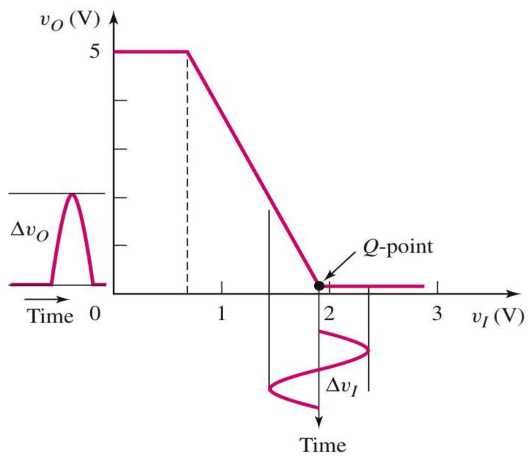
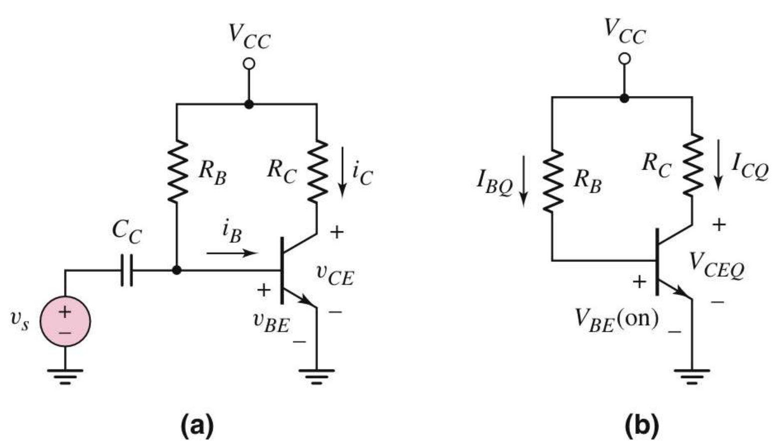
Effect of Improper Biasing on Amplified Signal Waveform



Single Base Resistor Biasing



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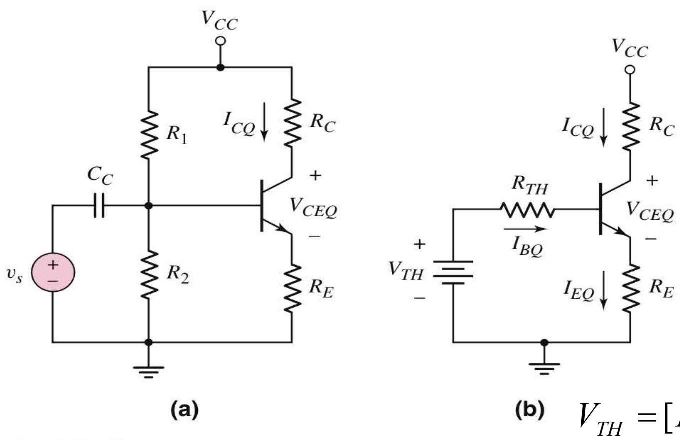
Common Emitter with Voltage Divider Biasing and Emitter Resistor



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

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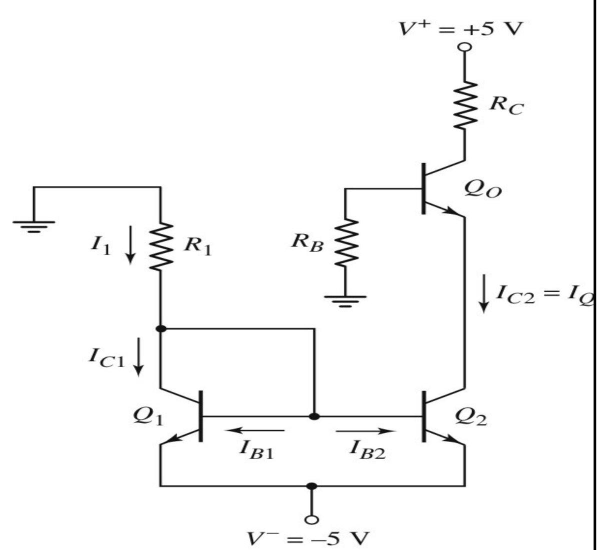
Integrated Circuit Biasing

$$I_C = I_Q = \frac{I_1}{1 + \frac{2}{\beta}}$$



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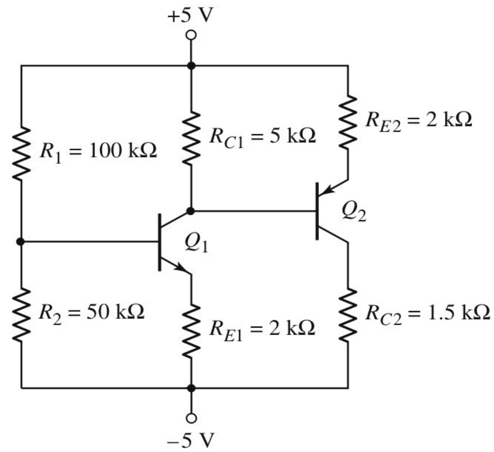
Multistage Cascade Transistor Circuit



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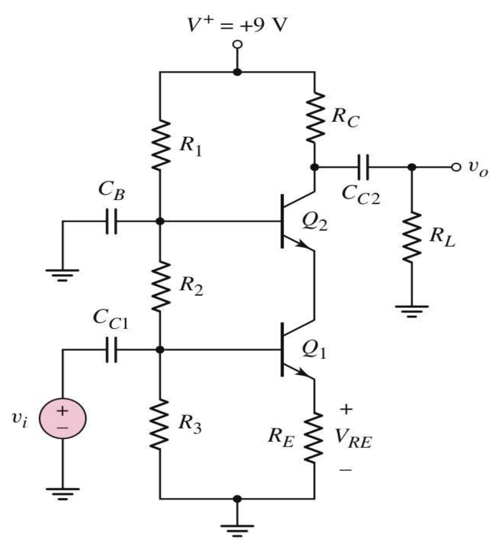
Multistage Cascode Transistor Circuit



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