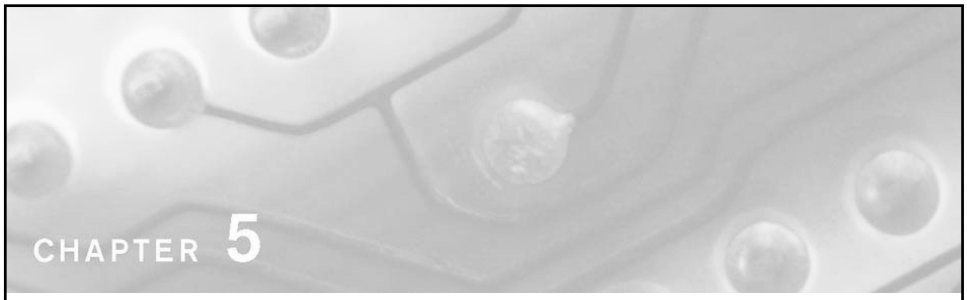
ECE321 Electronics I
Fall 2006

Professor James E. Morris

Lecture 11
31st October, 2006



Bipolar Junction Transistors (BJTs)

5.1 Device Structure & Physics
5.2 I-V Characteristics
Convert 5.1 information to circuit applications

2

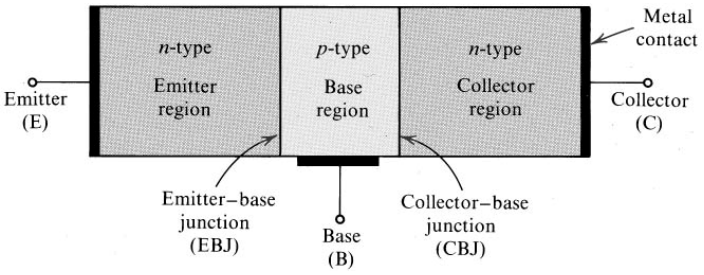


Figure 5.1 A simplified structure of the *npn* transistor.

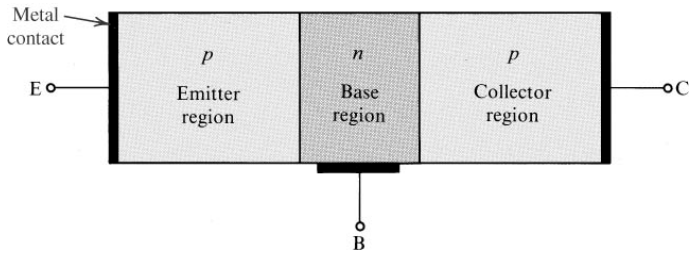


Figure 5.2 A simplified structure of the *pnp* transistor.

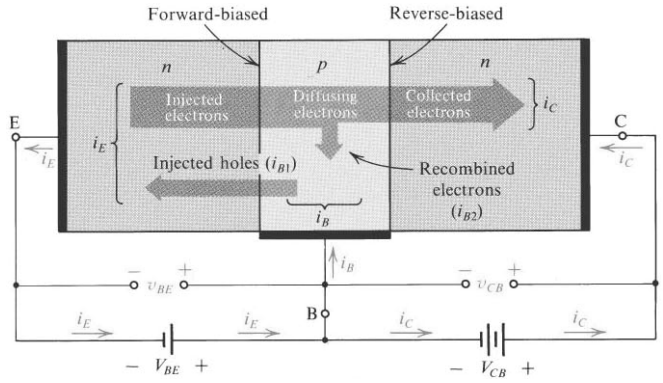


Figure 5.3 Current flow in an *npn* transistor biased to operate in the active mode. (Reverse current components due to drift of thermally generated minority carriers are not shown.)

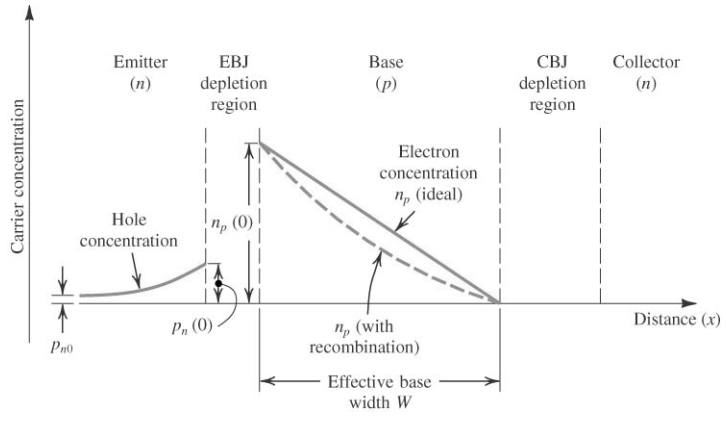


Figure 5.4 Profiles of minority-carrier concentrations in the base and in the emitter of an *npn* transistor operating in the active mode: $v_{BE} > 0$ and $v_{CB} \geq 0$.

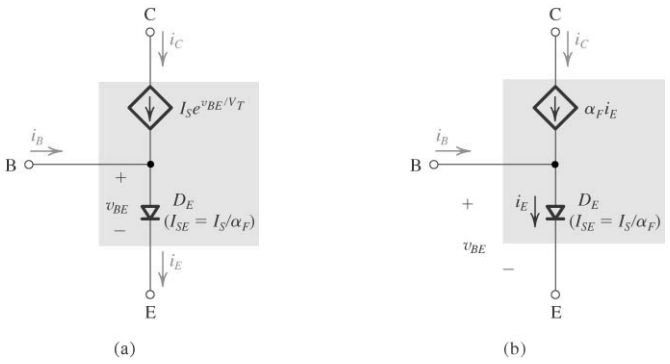


Figure 5.5 Large-signal equivalent-circuit models of the *npn* BJT operating in the forward active mode.

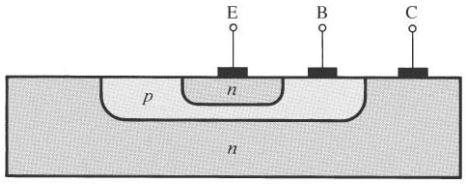


Figure 5.6 Cross-section of an *npn* BJT.

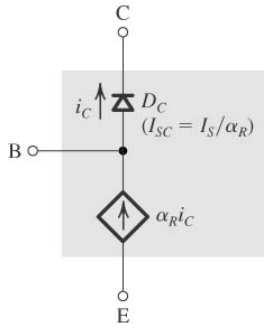


Figure 5.7 Model for the *npn* transistor when operated in the reverse active mode (i.e., with the CBJ forward biased and the EBJ reverse biased).

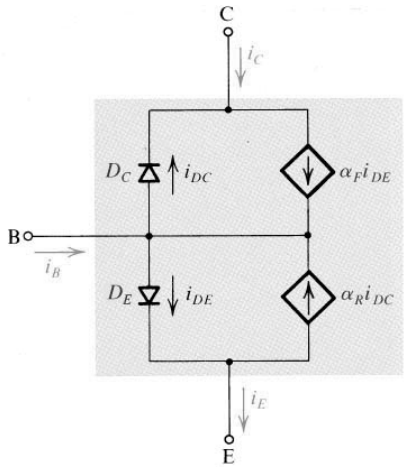


Figure 5.8 The Ebers-Moll (EM) model of the *npn* transistor.

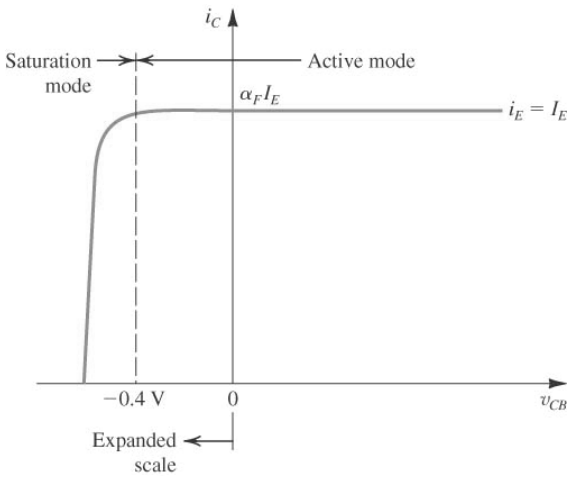


Figure 5.9 The i_C–v_{CB} characteristic of an *npn* transistor fed with a constant emitter current I_E. The transistor enters the saturation mode of operation for $v_{CB} < -0.4$ V, and the collector current diminishes.

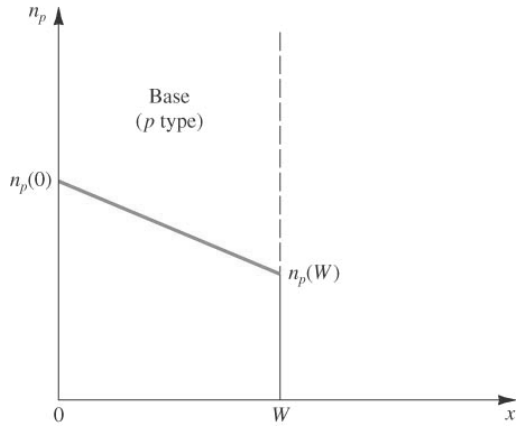


Figure 5.10 Concentration profile of the minority carriers (electrons) in the base of an *npn* transistor operating in the saturation mode.

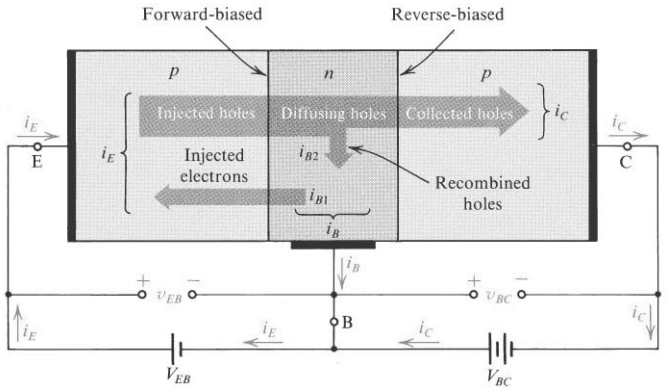


Figure 5.11 Current flow in a *pnp* transistor biased to operate in the active mode.

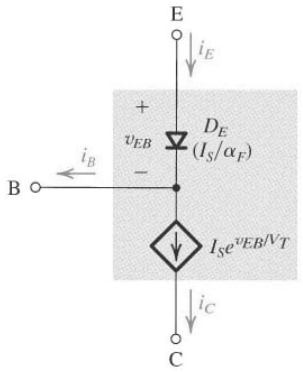


Figure 5.12 Large-signal model for the *pnp* transistor operating in the active mode.

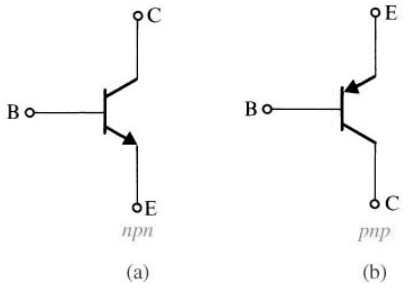


Figure 5.13 Circuit symbols for BJTs.

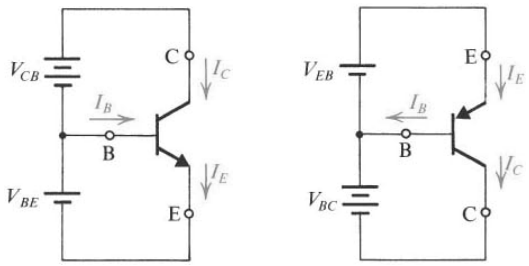


Figure 5.14 Voltage polarities and current flow in transistors biased in the active mode.

Circuit for Exercise 5.10, but ignore RHS values …..

V_{CC}= -V_{EE} =10v, R_C=5K, R_E=10K, β=50

Find I_E, I_B, I_C, V_C

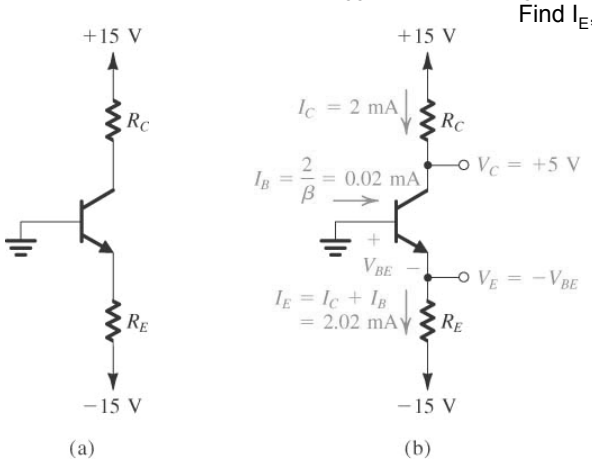


Figure 5.15 Circuit for Example 5.1.

Circuit for Exercise 5.11: V_B=1v, V_E=+1.7v …….. Find α, β, V_C

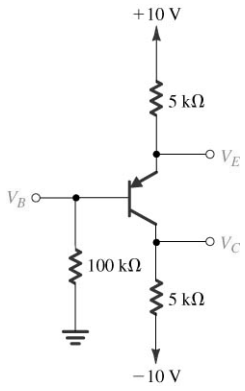


Figure E5.11

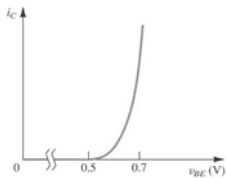


Figure 5.16 The i_C–v_{BE} characteristic for an *npn* transistor.

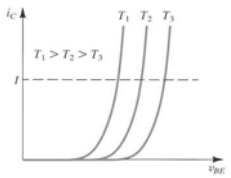


Figure 5.17 Effect of temperature on the i_C–v_{BE} characteristic. At a constant emitter current (broken line), v_{BE} changes by –2 mV/°C.

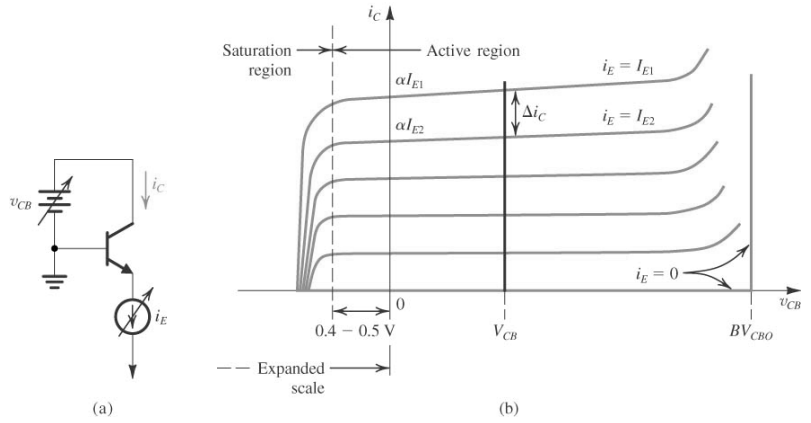


Figure 5.18 The i_C–v_{CB} characteristics of an *npn* transistor.

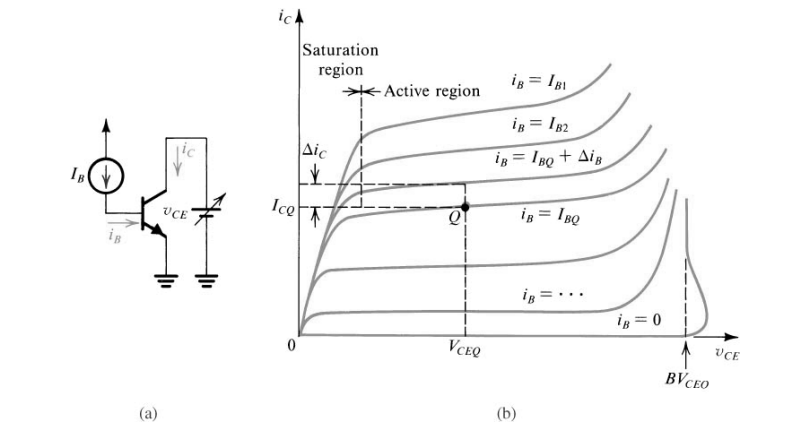


Figure 5.21 Common-emitter characteristics. Note that the horizontal scale is expanded around the origin to show the saturation region in some detail.

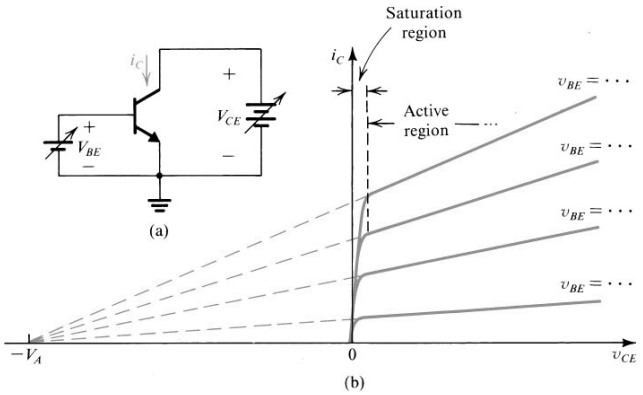


Figure 5.19 **(a)** Conceptual circuit for measuring the i_C–v_{CE} characteristics of the BJT. **(b)** The i_C–v_{CE} characteristics of a practical BJT.

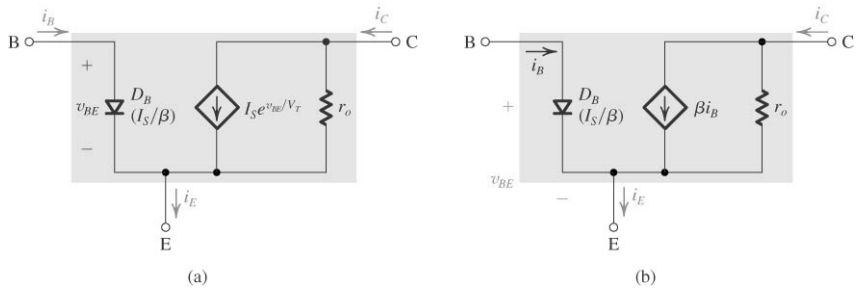


Figure 5.20 Large-signal equivalent-circuit models of an *npn* BJT operating in the active mode in the common-emitter configuration.

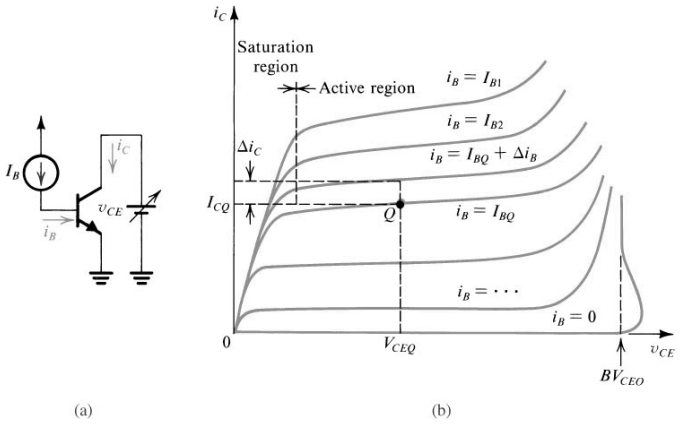


Figure 5.21 Common-emitter characteristics. Note that the horizontal scale is expanded around the origin to show the saturation region in some detail.

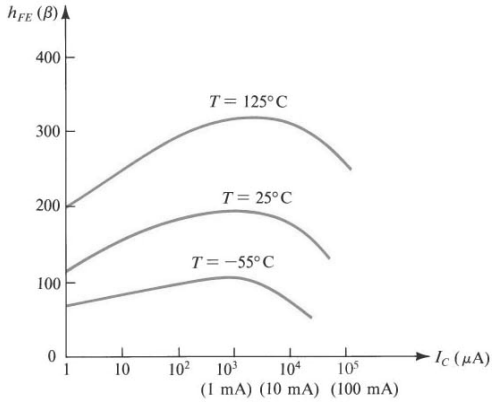


Figure 5.22 Typical dependence of β on I_c and on temperature in a modern integrated-circuit *npn* silicon transistor intended for operation around 1 mA.

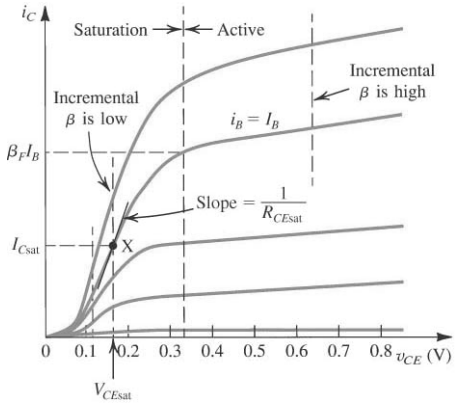


Figure 5.23 An expanded view of the common-emitter characteristics in the saturation region.

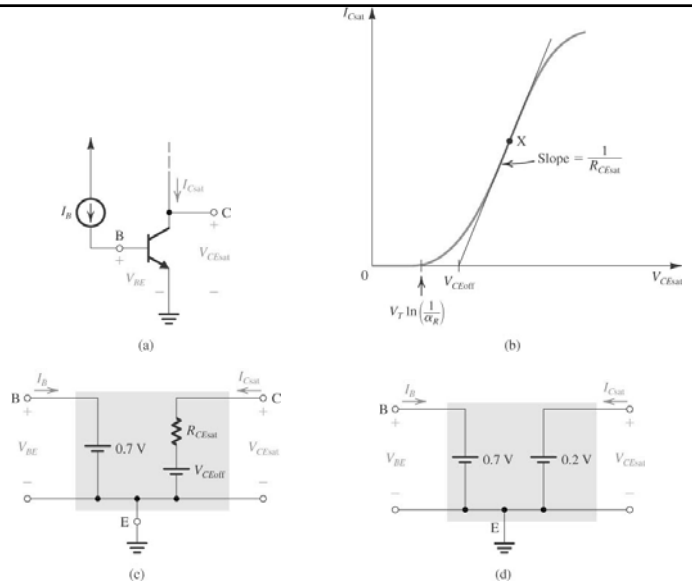


Figure 5.24 **(a)** An *npn* transistor operated in saturation mode with a constant base current I_B. **(b)** The i_C–v_{CE} characteristic curve corresponding to $i_B = I_B$. The curve can be approximated by a straight line of slope $1/R_{CEsat}$. **(c)** Equivalent-circuit representation of the saturated transistor. **(d)** A simplified equivalent-circuit model of the saturated transistor.

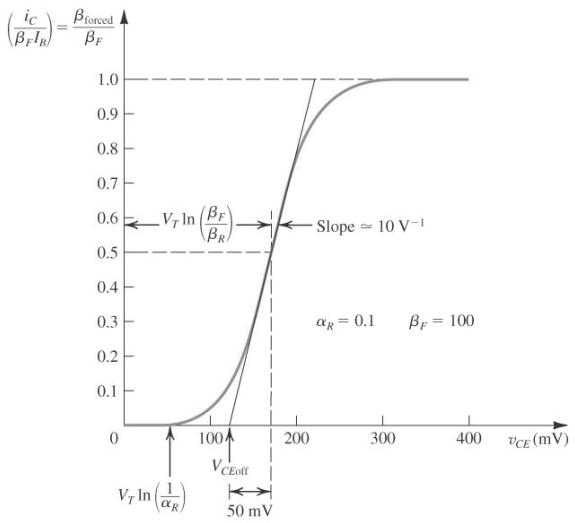


Figure 5.25 Plot of the normalized i_C versus v_{CE} for an *npn* transistor with $\beta_F = 100$ and $\alpha_R = 0.1$. This is a plot of Eq. (5.47), which is derived using the Ebers-Moll model.

Figure for Exercise 5.18: BV_{CBO}=70v. Find V_O

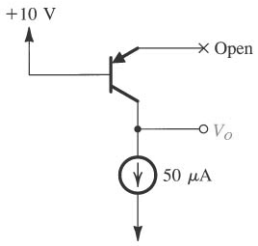


Figure E5.18

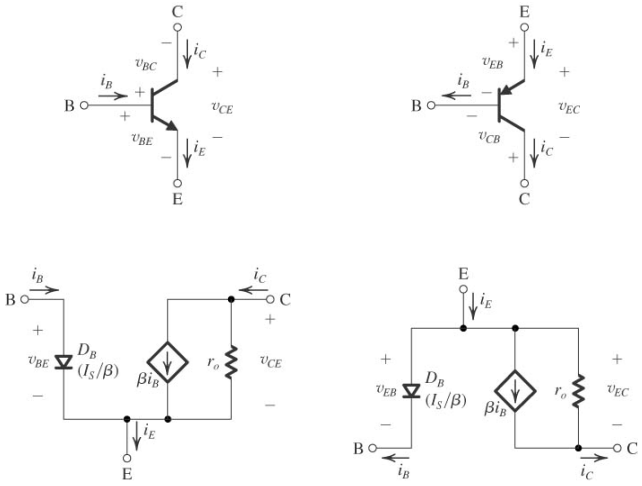


Table 5.3

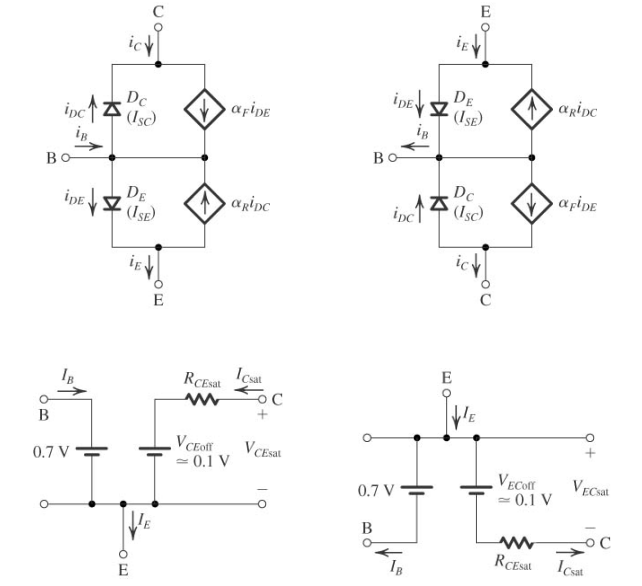


Table 5.3 *(Continued)*