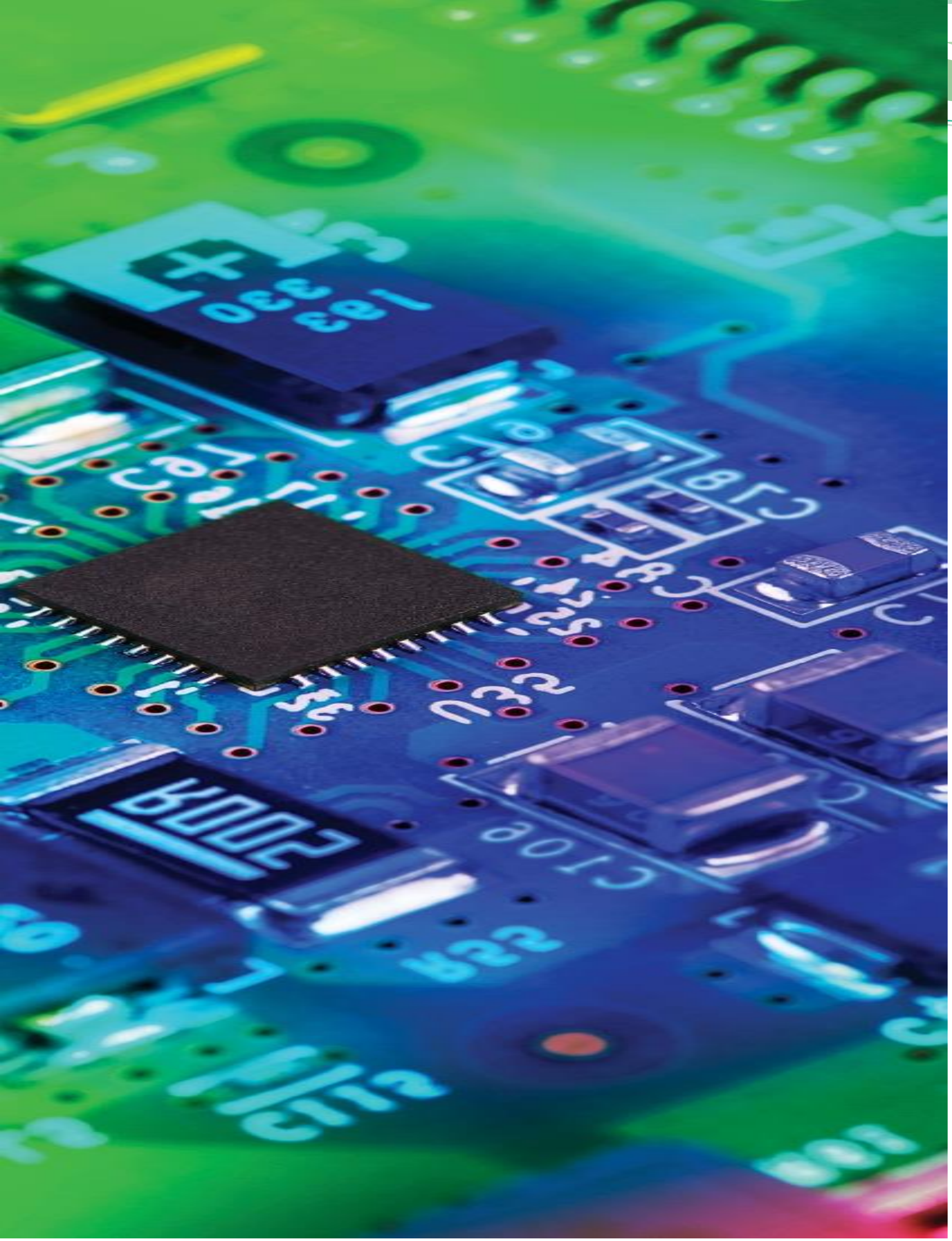
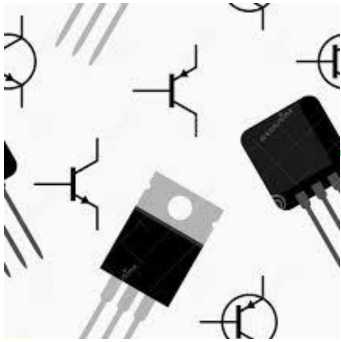
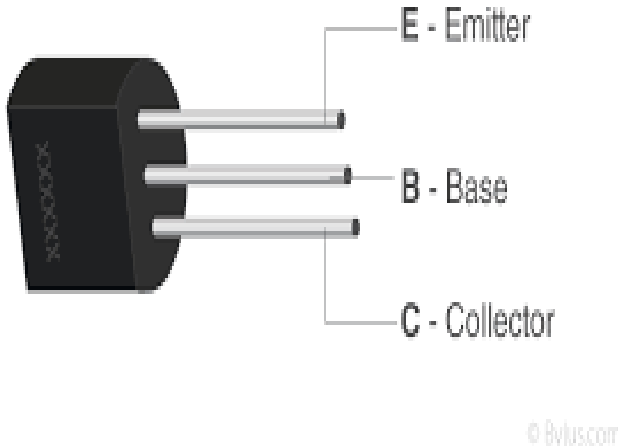


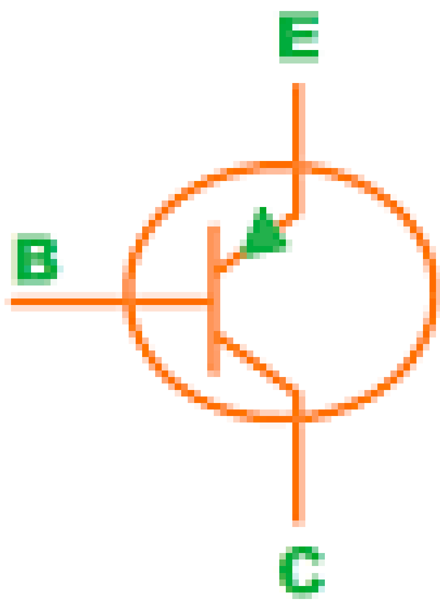
Bipolar Junction Transistors

Bipolar Junction Transistor

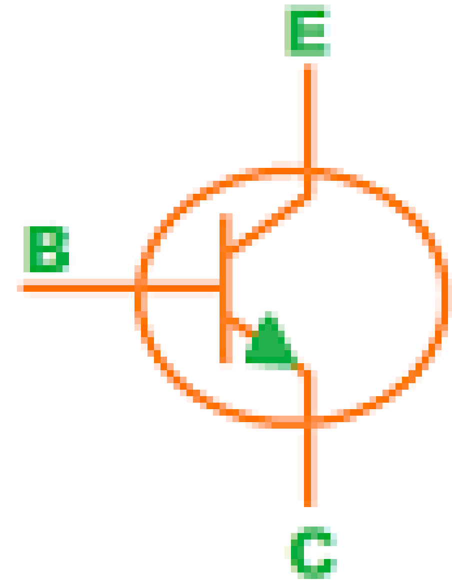




Typical Bipolar Junction Transistor



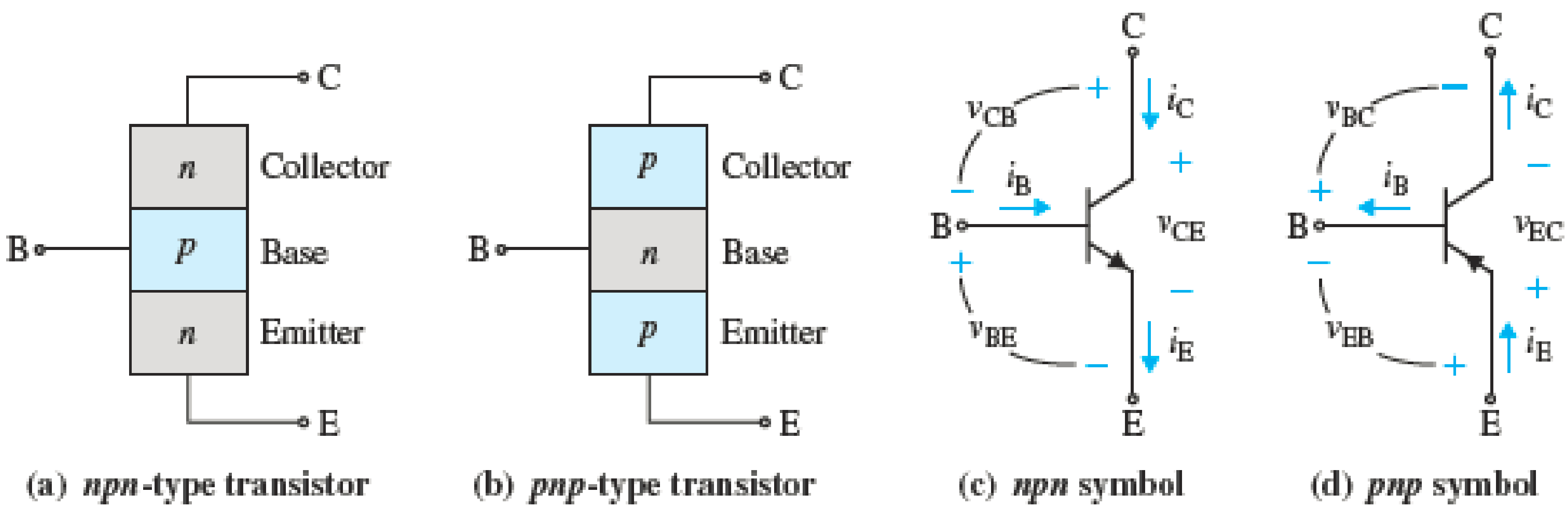
PNP BJT



NPN BJT

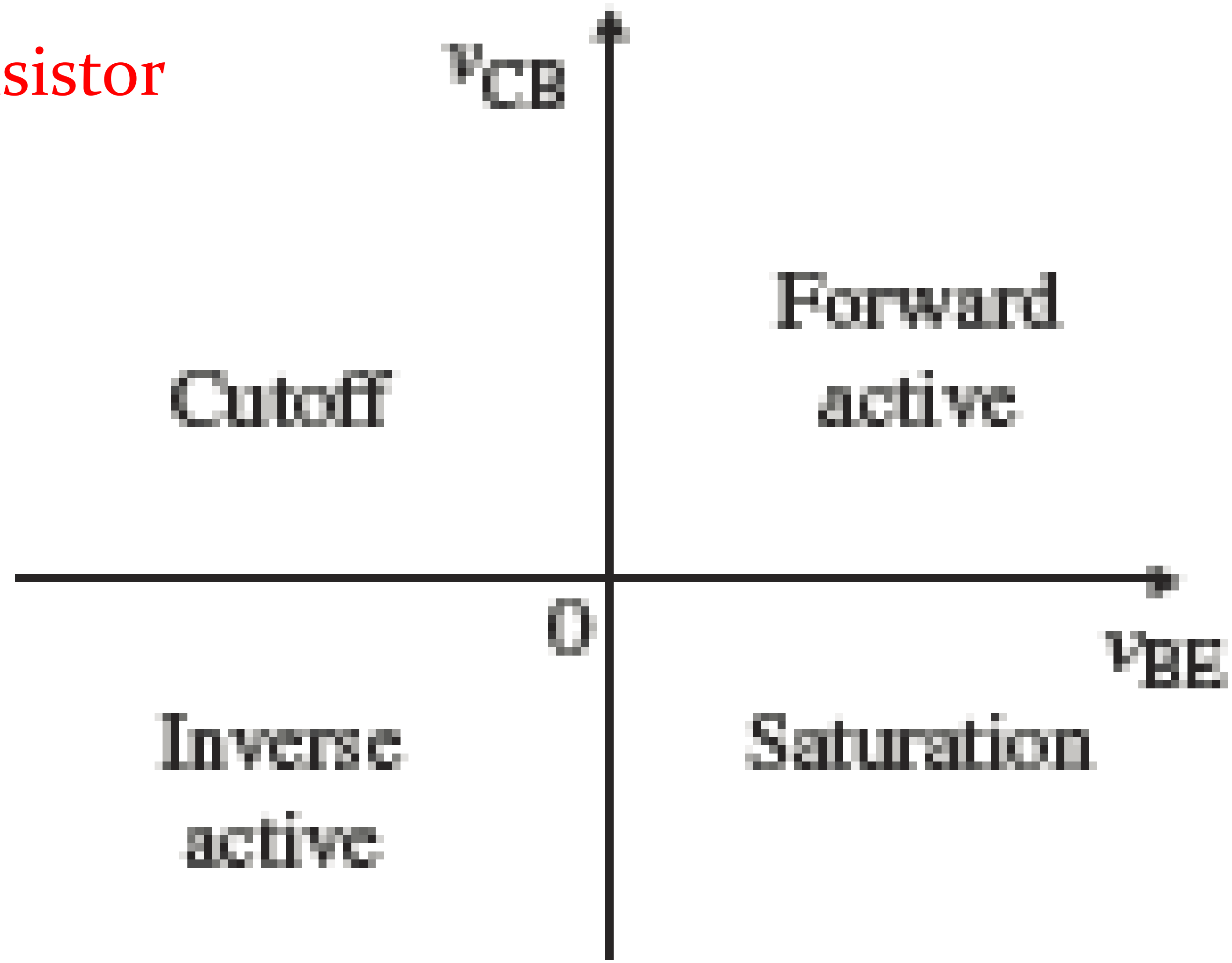
Performance Parameters

- A BJT is often referred to simply as a *transistor*.
- It has three terminals known as the *emitter* (E), the *base* (B), and the *collector* (C).
- The direction of the arrowhead by the emitter determines whether the transistor is an *npn* or a *pnp* transistor.



Modes of BJT Operation

npn transistor



Forward-Current Ratio

- The forward-current ratio (or the transport factor) is defined as the ratio of the collector to the emitter current.

$$\frac{\dot{i}_C}{\dot{i}_E} = \alpha_F$$

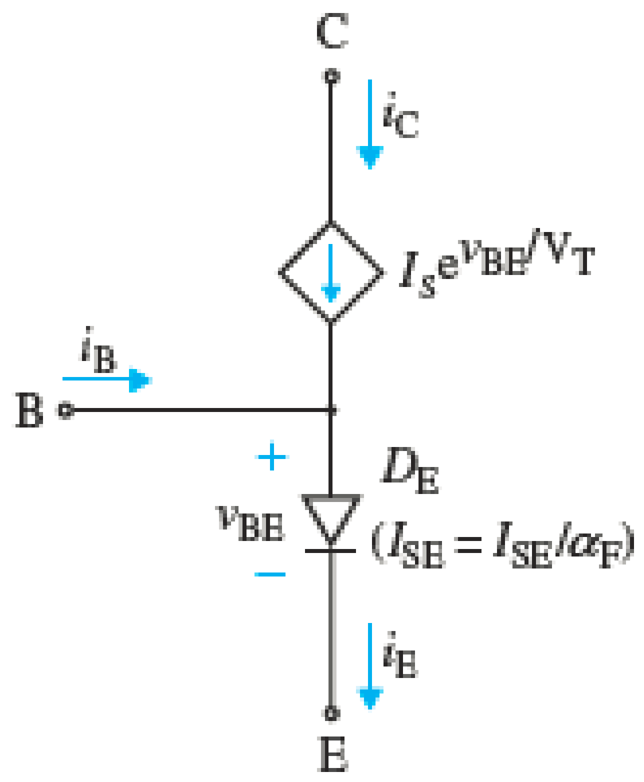
where α_F is the common-base forward-current ratio, $\alpha_F < 1$, but it should be as close to unity as possible.

Forward-Current Gain

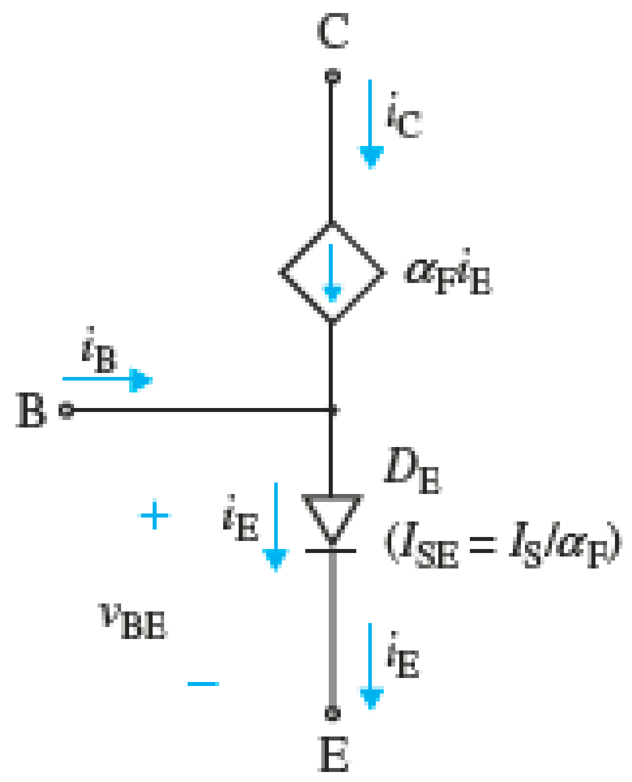
- The forward-current gain β_F is defined as the ratio of the collector to the base current.

$$\beta_F = \frac{i_C}{i_B} = \frac{\alpha_F}{1-\alpha_F} \Leftrightarrow \alpha_F = \frac{\beta_F}{\beta_F + 1}$$

T-type diode models of bipolar transistors

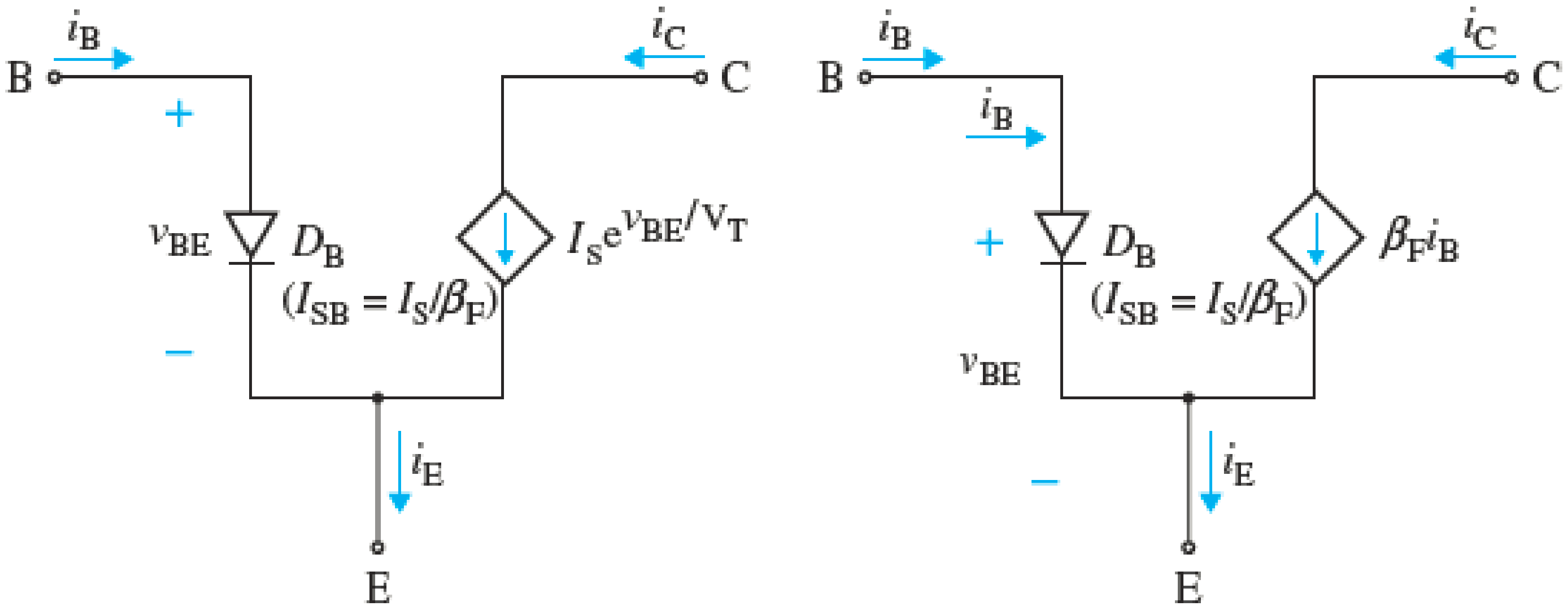


(a) Voltage-dependent current source



(b) Current-dependent current source

π-type diode models of bipolar transistors



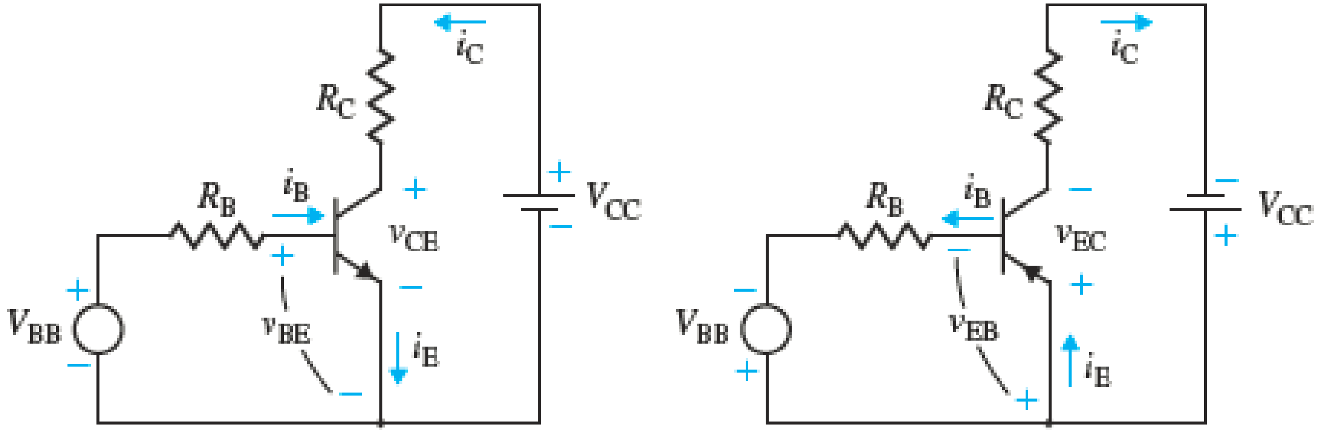
(a) Voltage-dependent current source (b) Current-dependent current source

Cutoff, Saturation, and Inverse-Active Modes of Operation

- In the cutoff mode:
  - the B-E junction is either reverse biased or zero biased.
  - the B-C junction is also reverse biased. That is, V_{BE} has negative voltage or zero, and V_{CB} has a positive voltage.
- In the saturation mode, both junctions are forward biased.
  - the B-E potential barrier is smaller than the potential barrier of the B-C junction.
- In the inverse-active mode, the B-E junction is reverse biased.
  - the B-C junction is forward biased.
  - It is a mirror image of the forward-active mode.

Input and Output Characteristics

- Three possible configurations:
- (1) common emitter (CE): the emitter is the common terminal;
- (2) common collector (CC) or emitter follower: the collector is the common terminal;
- (3) common base (CB): the base is the common terminal.



(a) *npn* biasing (b) *pnp* biasing

$$\boxed{V_{BB} = R_B i_B + v_{BE}}$$

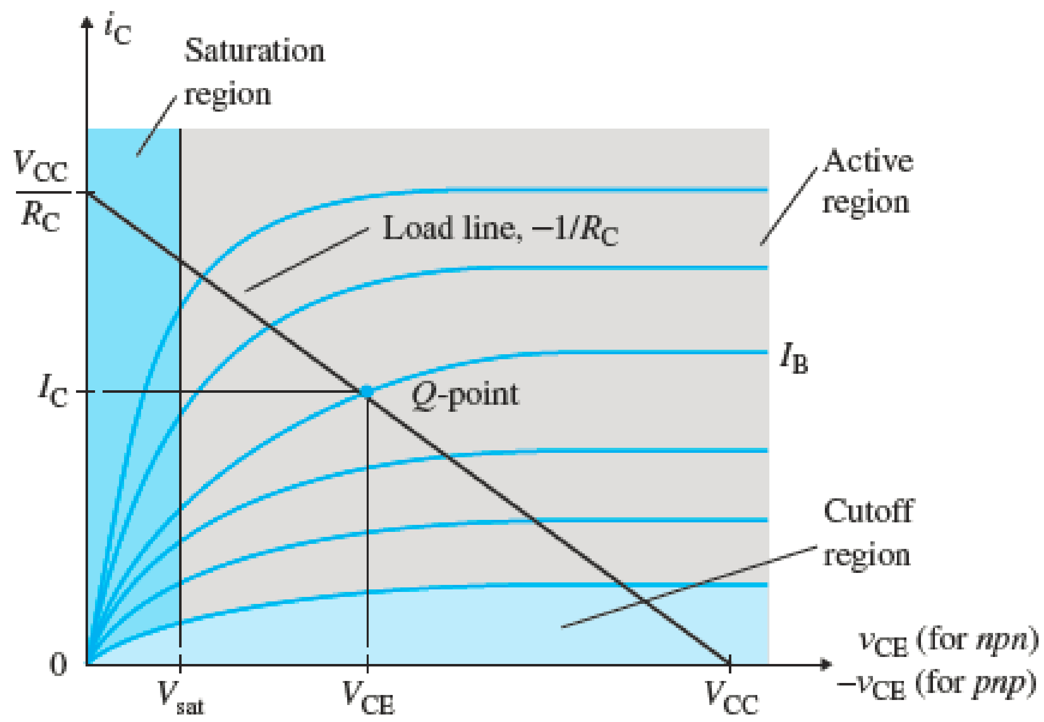
$$\boxed{v_{CC} = v_{CE} + i_C R_C}$$

Output Characteristics

- The collector current i_C is related to the base current by a forward-current amplification factor

$$\beta_F = \frac{i_C}{i_B}\bigg|_{v_{CE=\text{constant}}}$$

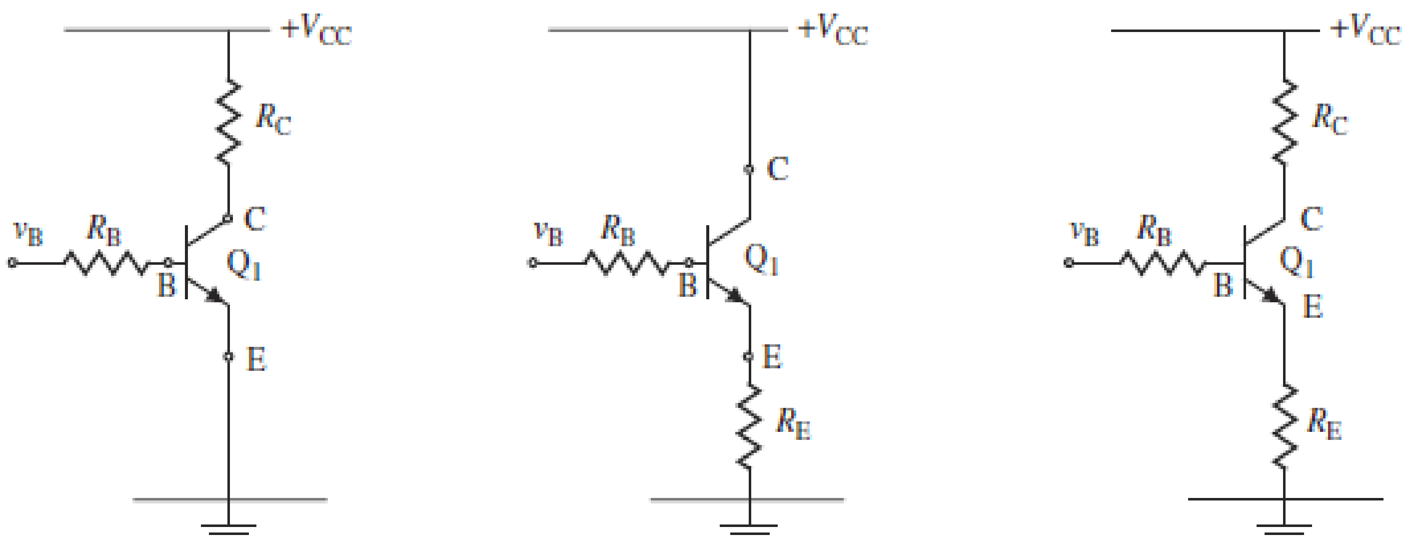
$$v_{CC} = v_{CE} + i_C R_C$$



(b) Output characteristic

DC Biasing of Bipolar Junction Transistors

- If a transistor is used for the amplification of voltage (or current), it is necessary to bias the device.
- The main reasons for biasing are to turn the device on and to place the operating point in the region of its characteristic where the device operates most linearly so that any change in the input signal causes a proportional change in the output signal.



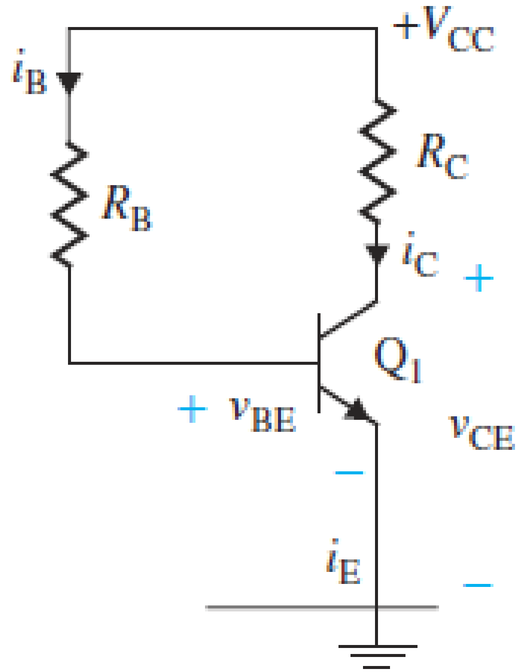
(a) Base and collector resistors R_B and R_C (b) Emitter resistor R_E (c) Collector and emitter resistors R_C and R_B

Single–Base Resistor Biasing

$$i_B = \frac{V_{CC} - v_{BE}}{R_B}$$

$$i_C = \beta_F i_B$$

$$v_{CE} = V_{CC} - R_C i_C$$

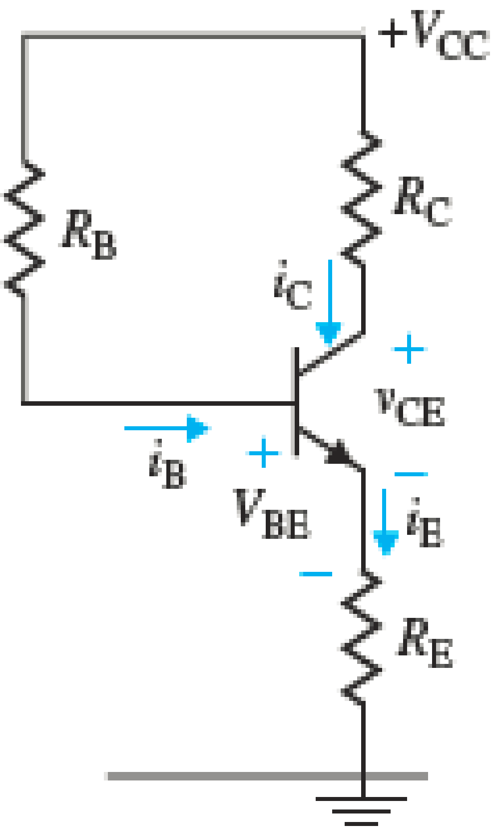


Emitter Resistance–Feedback Biasing

$$i_B = \frac{V_{CC} - v_{BE}}{R_B + R_E(1+\beta_F)}$$

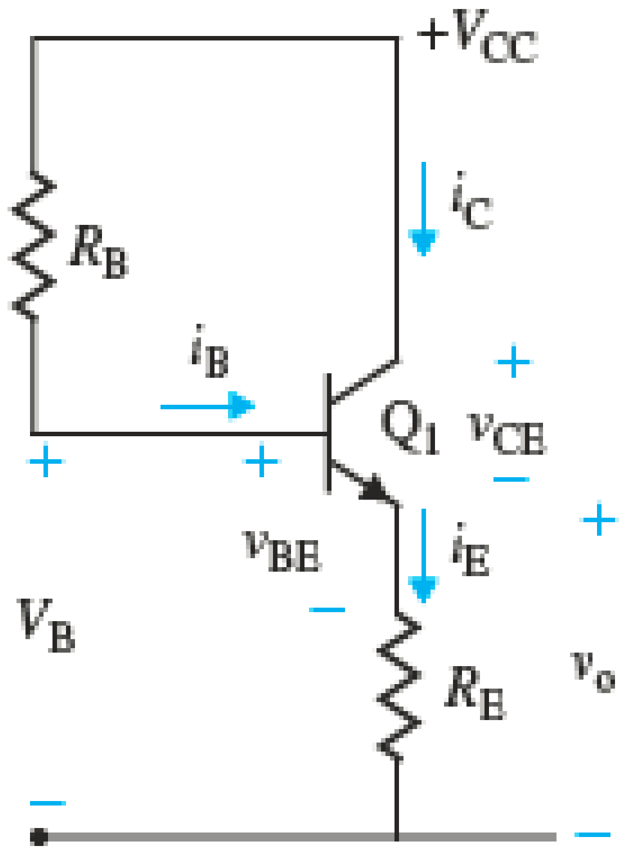
$$i_C = \beta_F i_B$$

$$v_{CE} = V_{CC} - R_C\beta_F i_B - (1+\beta_F)R_E i_B$$



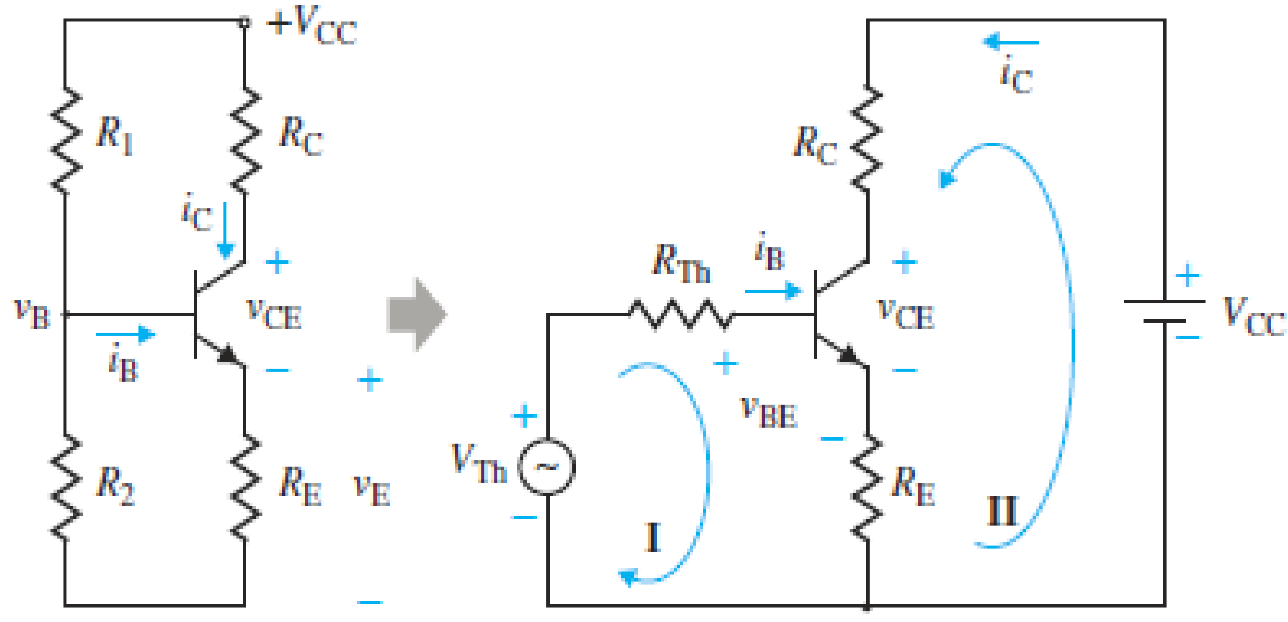
Emitter-Follower Biasing

$$i_B = \frac{V_{CC} - v_{BE}}{R_B + R_E(1 + \beta_F)}$$
$$i_C = \beta_F i_B$$
$$v_{CE} = V_{CC} - (1 + \beta_F)R_E i_B$$



Two–Base Resistor Biasing

$$V_{Th} = V_B = V_{CC} \times \frac{R_2}{R_1 + R_2} \qquad R_{Th} = \frac{R_1 R_2}{R_1 + R_2}$$



(a) Biasing circuit (b) Thevenin's equivalent

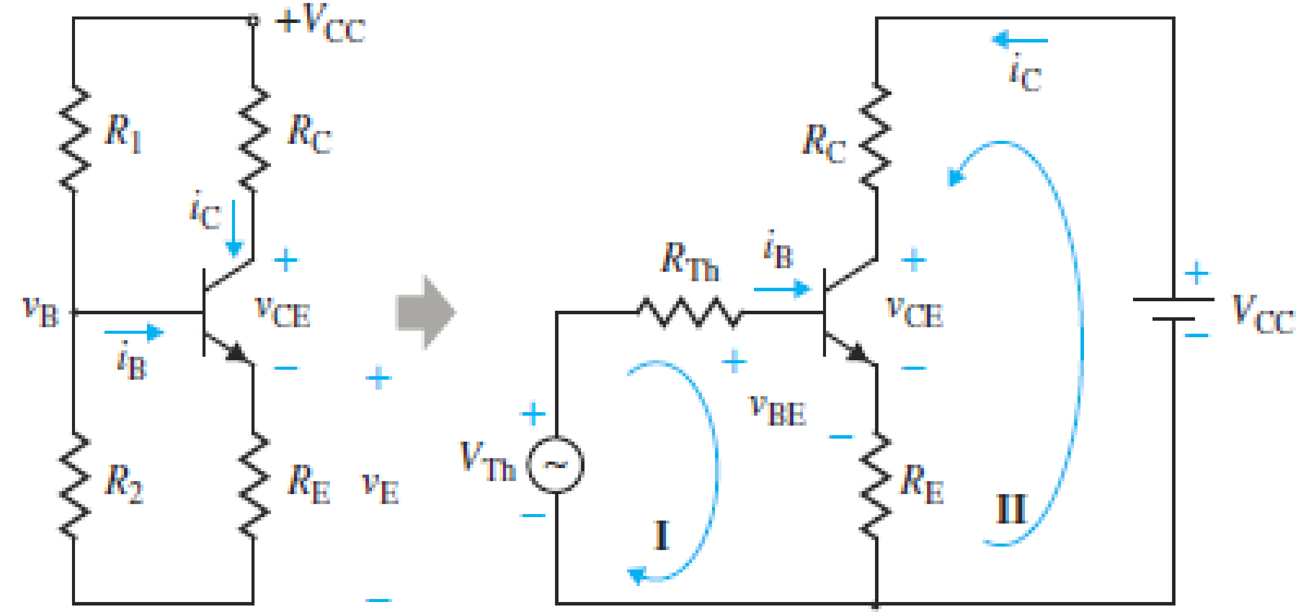
Two–Base Resistor Biasing

$$i_B = \frac{V_B - v_{BE}}{R_{Th} + R_E(1+\beta_F)} \qquad i_C = \beta_F i_B$$

$$v_{CE} = V_{CC} - R_C \beta_F i_B - (1 + \beta_F) R_F i_B$$

$$\boldsymbol{V_B = V_{CC} \times \frac{R_2}{R_1 + R_2}}$$

$$\boldsymbol{R_{Th} = \frac{R_1 R_2}{R_1 + R_2}}$$



(a) Biasing circuit (b) Thevenin's equivalent

The Darlington Pair Transistor

- A compound transistor configuration, known as a *Darlington pair*, is often used to give a much higher input resistance and a much lower input bias current than a single transistor provides.