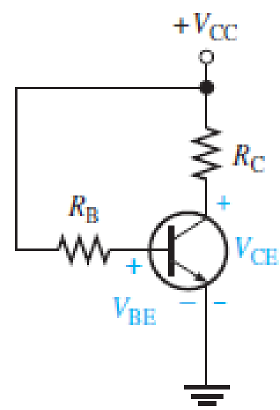
## 1. Base Bias

Base bias is common in switching circuits, and it has the advantage of simplicity because it uses only one resistor to obtain bias. Figure shows a base-biased transistor. The analysis of this circuit for the linear region shows that it is directly dependent on $\beta$DC. Starting with Kirchhoff's voltage law around the base circuit,




$$V_{CC} - V_{R_B} - V_{BE} = 0$$

Substituting $I_B R_B$ for $V_{R_B}$, you get

$$V_{CC} - I_B R_B - V_{BE} = 0$$

Then solving for $I_B$,

$$I_B = \frac{V_{CC} - V_{BE}}{R_B}$$

Kirchhoff's voltage law applied around the collector circuit in Figure 5–19 gives the following equation:

$$V_{CC} - I_C R_C - V_{CE} = 0$$

Solving for $V_{CE}$,

$$V_{CE} = V_{CC} - I_C R_C$$

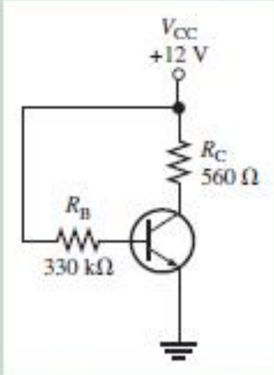
Substituting the expression for $I_B$ into the formula $I_C = \beta_{DC} I_B$ yields

$$I_C = \beta_{DC}\left(\frac{V_{CC} - V_{BE}}{R_B}\right)$$

**EXAMPLE 5–8**

Determine how much the Q-point ($I_C$, $V_{CE}$) for the circuit in Figure 5–20 will change over a temperature range where $\beta_{DC}$ increases from 100 to 200.

▶ FIGURE 5–20




*Solution* For $\beta_{DC} = 100$,

$$I_{C(1)} = \beta_{DC}\left(\frac{V_{CC} - V_{BE}}{R_B}\right) = 100\left(\frac{12\text{ V} - 0.7\text{ V}}{330\text{ k}\Omega}\right) = 3.42\text{ mA}$$

$$V_{CE(1)} = V_{CC} - I_{C(1)}R_C = 12\text{ V} - (3.42\text{ mA})(560\ \Omega) = 10.1\text{ V}$$

For $\beta_{DC} = 200$,

$$I_{C(2)} = \beta_{DC}\left(\frac{V_{CC} - V_{BE}}{R_B}\right) = 200\left(\frac{12\text{ V} - 0.7\text{ V}}{330\text{ k}\Omega}\right) = 6.84\text{ mA}$$

$$V_{CE(2)} = V_{CC} - I_{C(2)}R_C = 12\text{ V} - (6.84\text{ mA})(560\ \Omega) = 8.17\text{ V}$$

The percent change in $I_C$ as $\beta_{DC}$ changes from 100 to 200 is

$$\%\Delta I_C = \left(\frac{I_{C(2)} - I_{C(1)}}{I_{C(1)}}\right)100\%$$

$$= \left(\frac{6.84\text{ mA} - 3.42\text{ mA}}{3.42\text{ mA}}\right)100\% = \mathbf{100\%}\text{ (an increase)}$$

The percent change in $V_{CE}$ is

$$\%\Delta V_{CE} = \left(\frac{V_{CE(2)} - V_{CE(1)}}{V_{CE(1)}}\right)100\%$$

$$= \left(\frac{8.17\text{ V} - 10.1\text{ V}}{10.1\text{ V}}\right)100\% = \mathbf{-19.1\%}\text{ (a decrease)}$$

As you can see, the Q-point is very dependent on $\beta_{DC}$ in this circuit and therefore makes the base-bias arrangement very unreliable for linear circuits, but it can be used in switching applications.

*Related Problem* Determine $I_C$ if $\beta_{DC}$ increases to 300.

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## 2. Emitter-Feedback Bias

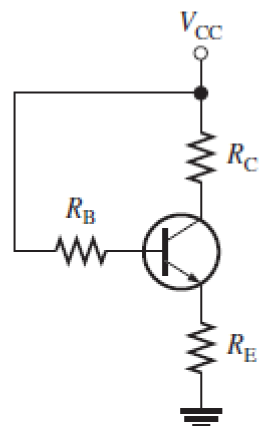
If an emitter resistor is added to the base-bias circuit, the result is emitter feedback bias, as shown in Figure. The idea is to help make base bias more predictable with negative feedback, which negates any attempted change in collector current with an opposing change in base voltage.

To calculate IE, you can write Kirchhoff's voltage law (KVL) around the base circuit.

$$-V_{CC} + I_B R_B + V_{BE} + I_E R_E = 0$$

Substituting $I_E/\beta_{DC}$ for $I_B$, you can see that $I_E$ is still dependent on $\beta_{DC}$.

$$I_E = \frac{V_{CC} - V_{BE}}{R_E + R_B/\beta_{DC}}$$




**EXAMPLE 5–9**

The base-bias circuit from Example 5–8 is converted to emitter-feedback bias by the addition of a 1 kΩ emitter resistor. All other values are the same, and a transistor with a $\beta_{DC} = 100$ is used. Determine how much the Q-point will change if the first transistor is replaced with one having a $\beta_{DC} = 200$. Compare the results to those of the base-bias circuit.

*Solution* For $\beta_{DC} = 100$,

$$I_{C(1)} = I_E = \frac{V_{CC} - V_{BE}}{R_E + R_B/\beta_{DC}} = \frac{12\text{ V} - 0.7\text{ V}}{1\text{ k}\Omega + 330\text{ k}\Omega/100} = 2.63\text{ mA}$$

$$V_{CE(1)} = V_{CC} - I_{C(1)}(R_C + R_E) = 12\text{ V} - (2.63\text{ mA})(560\ \Omega + 1\text{ k}\Omega) = 7.90\text{ V}$$

For $\beta_{DC} = 200$,

$$I_{C(2)} = I_E = \frac{V_{CC} - V_{BE}}{R_E + R_B/\beta_{DC}} = \frac{12\text{ V} - 0.7\text{ V}}{1\text{ k}\Omega + 330\text{ k}\Omega/200} = 4.26\text{ mA}$$

$$V_{CE(2)} = V_{CC} - I_{C(2)}(R_C + R_E) = 12\text{ V} - (4.26\text{ mA})(560\ \Omega + 1\text{ k}\Omega) = 5.35\text{ V}$$

The percent change in $I_C$ is

$$\%\Delta I_C = \left(\frac{I_{C(2)} - I_{C(1)}}{I_{C(1)}}\right)100\% = \left(\frac{4.26\text{ mA} - 2.63\text{ mA}}{2.63\text{ mA}}\right)100\% = \mathbf{62.0\%}$$

$$\%\Delta V_{CE} = \left(\frac{V_{CE(2)} - V_{CE(1)}}{V_{CE(1)}}\right)100\% = \left(\frac{5.35\text{ V} - 7.90\text{ V}}{7.90\text{ V}}\right)100\% = \mathbf{-32.3\%}$$

Although the emitter-feedback bias significantly improved the stability of the bias for a change in $\beta_{DC}$ compared to base bias, it still does not provide a reliable Q-point.

*Related Problem* Determine $I_C$ if a transistor with $\beta_{DC} = 300$ is used in the circuit.

## 3. Collector-Feedback Bias

In Figure , the base resistor RB is connected to the collector rather than to VCC, as it was in the base bias arrangement discussed earlier. The collector voltage provides the bias for the base-emitter junction.

***Analysis of a Collector-Feedback Bias Circuit*** By Ohm's law, the base current can be expressed as

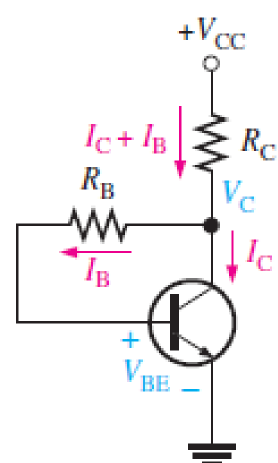
$$I_B = \frac{V_C - V_{BE}}{R_B}$$

Let's assume that $I_C \gg I_B$. The collector voltage is

$$V_C \cong V_{CC} - I_C R_C$$

Also,

$$I_B = \frac{I_C}{\beta_{DC}}$$




Substituting for $V_C$ in the equation $I_B = (V_C - V_{BE})/R_B$,

$$\frac{I_C}{\beta_{DC}} = \frac{V_{CC} - I_C R_C - V_{BE}}{R_B}$$

The terms can be arranged so that

$$\frac{I_C R_B}{\beta_{DC}} + I_C R_C = V_{CC} - V_{BE}$$

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Then you can solve for $I_C$ as follows:

$$I_C\left(R_C + \frac{R_B}{\beta_{DC}}\right) = V_{CC} - V_{BE}$$

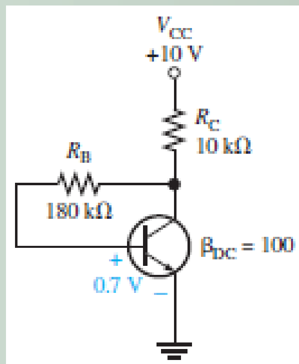
$$I_C = \frac{V_{CC} - V_{BE}}{R_C + R_B/\beta_{DC}}$$

Since the emitter is ground, $V_{CE} = V_C$.

$$V_{CE} = V_{CC} - I_C R_C$$

**EXAMPLE 5–10** Calculate the Q-point values ($I_C$ and $V_{CE}$) for the circuit in Figure 5–23.

▶ FIGURE 5–23




*Solution* Using Equation 5–13, the collector current is

$$I_C = \frac{V_{CC} - V_{BE}}{R_C + R_B/\beta_{DC}} = \frac{10\text{ V} - 0.7\text{ V}}{10\text{ k}\Omega + 180\text{ k}\Omega/100} = \mathbf{788\ \mu A}$$

Using Equation 5–14, the collector-to-emitter voltage is

$$V_{CE} = V_{CC} - I_C R_C = 10\text{ V} - (788\ \mu\text{A})(10\text{ k}\Omega) = \mathbf{2.12\ V}$$

*Related Problem* Calculate the Q-point values in Figure 5–23 for $\beta_{DC} = 200$ and determine the percent change in the Q-point from $\beta_{DC} = 100$ to $\beta_{DC} = 200$.

Open the Multisim file EXM05-10 or LT Spice file EXS05-10 in the Examples folder on the website. Measure $I_C$ and $V_{CE}$. Compare with the calculated values.