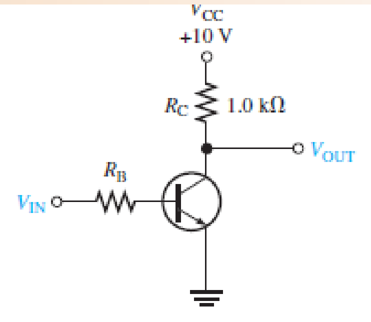
EXAMPLE 4–10

(a) For the transistor circuit in Figure 4–24, what is V_{CE} when $V_{IN} = 0$ V?

(b) What minimum value of I_B is required to saturate this transistor if β_{DC} is 200? Neglect $V_{CE(sat)}$.

(c) Calculate the maximum value of R_B when $V_{IN} = 5$ V.



Solution

(a) When $V_{IN} = 0$ V, the transistor is in cutoff (acts like an open switch) and

$$V_{CE} = V_{CC} = \mathbf{10\ V}$$

(b) Since $V_{CE(sat)}$ is neglected (assumed to be 0 V),

$$I_{C(sat)} = \frac{V_{CC}}{R_C} = \frac{10\text{ V}}{1.0\text{ k}\Omega} = 10\text{ mA}$$

$$I_{B(min)} = \frac{I_{C(sat)}}{\beta_{DC}} = \frac{10\text{ mA}}{200} = \mathbf{50\ \mu A}$$

This is the value of I_B necessary to drive the transistor to the point of saturation. Any further increase in I_B will ensure the transistor remains in saturation but there cannot be any further increase in I_C.

(c) When the transistor is on, $V_{BE} \cong 0.7$ V. The voltage across R_B is

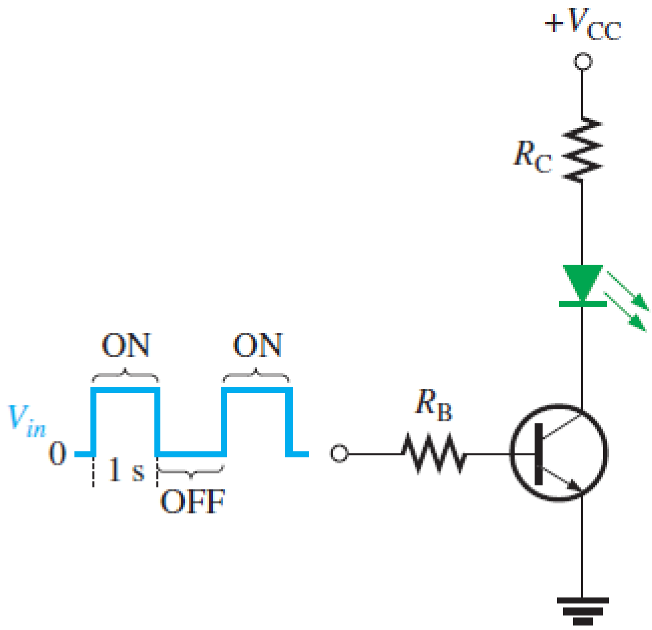
$$V_{R_B} = V_{IN} - V_{BE} \cong 5\text{ V} - 0.7\text{ V} = 4.3\text{ V}$$

Calculate the maximum value of R_B needed to allow a minimum I_B of 50 μA using Ohm's law as follows:

$$R_{B(max)} = \frac{V_{R_B}}{I_{B(min)}} = \frac{4.3\text{ V}}{50\ \mu\text{A}} = \mathbf{86\ k\Omega}$$

A Simple Application of a Transistor Switch

- When the square wave is at 0 V, the transistor is in cutoff→LED doesn't emit light.
- When the square wave goes to its high level, the transistor saturates. This forward-biases the LED.



▶ FIGURE 4–25

A transistor used to switch an LED on and off.

EXAMPLE 4–11

The LED in Figure 4–25 requires 30 mA to emit a sufficient level of light. Therefore, the collector current should be approximately 30 mA. For the following circuit values, determine the amplitude of the square wave input voltage necessary to make sure that the transistor saturates. Use double the minimum value of base current as a safety margin to ensure saturation. $V_{CC} = 9\text{ V}$, $V_{CE(sat)} = 0.3\text{ V}$, $R_C = 220\ \Omega$, $R_B = 3.3\text{ k}\Omega$, $\beta_{DC} = 50$, and $V_{LED} = 1.6\text{ V}$.

Solution

$$I_{C(sat)} = \frac{V_{CC} - V_{LED} - V_{CE(sat)}}{R_C} = \frac{9\text{ V} - 1.6\text{ V} - 0.3\text{ V}}{220\ \Omega} = 32.3\text{ mA}$$

$$I_{B(min)} = \frac{I_{C(sat)}}{\beta_{DC}} = \frac{32.3\text{ mA}}{50} = 646\ \mu\text{A}$$

To ensure saturation, use twice the value of $I_{B(min)}$, which is 1.29 mA. Use Ohm's law to solve for V_{in}.

$$I_B = \frac{V_{R_B}}{R_B} = \frac{V_{in} - V_{BE}}{R_B} = \frac{V_{in} - 0.7\text{ V}}{3.3\text{ k}\Omega}$$

$$V_{in} - 0.7\text{ V} = 2I_{B(min)}R_B = (1.29\text{ mA})(3.3\text{ k}\Omega)$$

$$V_{in} = (1.29\text{ mA})(3.3\text{ k}\Omega) + 0.7\text{ V} = \mathbf{4.96\text{ V}}$$

***Note**: several BJT applications when used as a switch is given in P.196 – P.198.*