This voltage is across the emitter resistance, which is now 1 kΩ. Therefore, the emitter current is 4.3 V divided by 1 kΩ, or:

$$I_E = \frac{4.3\text{ V}}{1\text{ k}\Omega} = 4.3\text{ mA}$$

The collector current is approximately equal to 4.3 mA. When this current flows through the collector resistance (now 2 kΩ), it produces a voltage of:

$$I_C R_C = (4.3\text{ mA})(2\text{ k}\Omega) = 8.6\text{ V}$$

When you subtract this voltage from the collector supply voltage, you get:

$$V_C = 15\text{ V} - 8.6\text{ V} = 6.4\text{ V}$$

This voltage value is very close to the value measured by the MultiSim meter. Remember, this is the voltage between the collector and ground. This is what you would measure when troubleshooting.

Unless you have a voltmeter with a high input resistance and a floating ground lead, you should not attempt to connect a voltmeter directly between the collector and the emitter because this may short the emitter to ground. If you want to know the value of V_{CE}, you should measure the collector-to-ground voltage, then measure the emitter-to-ground voltage, and subtract the two. In this case:

$$V_{CE} = 6.4\text{ V} - 4.3\text{ V} = 2.1\text{ V}$$

PRACTICE PROBLEM 7-9 MultiSim Decrease the base supply voltage of Fig. 7-11 to 3 V. Predict and measure the new value of V_{CE}.

7-7 LED Drivers

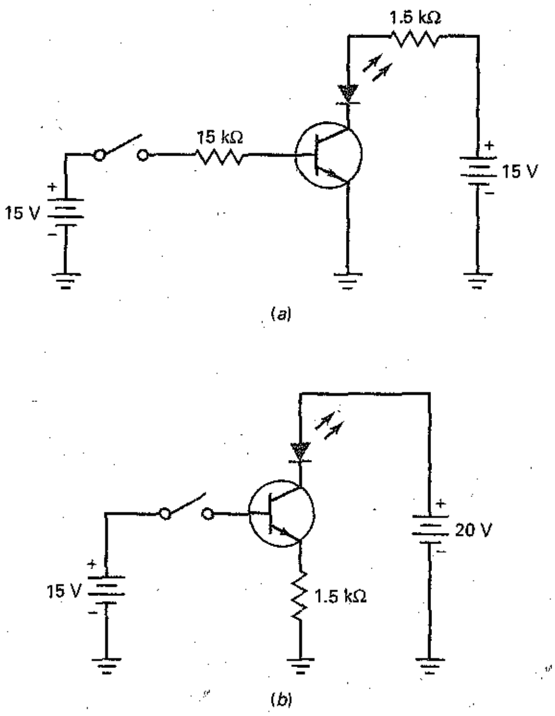
You have learned that base-biased circuits set up a fixed value of base current, and emitter-biased circuits set up a fixed value of emitter current. Because of the problem with current gain, base-biased circuits are normally designed to switch between saturation and cutoff, whereas emitter-biased circuits are usually designed to operate in the active region.

In this section, we discuss two circuits that can be used as LED drivers. The first circuit uses base bias, and the second circuit uses emitter bias. This will give you a chance to see how each circuit performs in the same application.

Base-Biased LED Driver

The base current is zero in Fig. 7-12*a*, which means that the transistor is at cutoff. When the switch of Fig. 7-12*a* closes, the transistor goes into hard saturation. Visualize a short between the collector-emitter terminals. Then the collector supply voltage (15 V) appears across the series connection of the 1.5 kΩ and the LED. If we ignore the voltage drop across the LED, the collector current is ideally 10 mA. But if we allow 2 V across the LED, then there is 13 V across the 1.5 kΩ, and the collector current is 13 V divided by 1.5 kΩ, or 8.67 mA.

Figure 7-12 (*a*) Base-biased; (*b*) emitter-biased.



There is nothing wrong with this circuit. It makes a fine LED driver because it is designed for hard saturation, where the current gain doesn't matter. If you want to change the LED current in this circuit, you can change either the collector resistance or the collector supply voltage. The base resistance is made 10 times larger than the collector resistance because we want hard saturation when the switch is closed.

Emitter-Biased LED Driver

The emitter current is zero in Fig. 7-12*b*, which means that the transistor is at cutoff. When the switch of Fig. 7-12*b* closes, the transistor goes into the active region. Ideally, the emitter voltage is 15 V. This means that we get an emitter current of 10 mA. This time, the LED voltage drop has no effect. It doesn't matter whether the exact LED voltage is 1.8, 2, or 2.5 V. This is an advantage of the emitter-biased design over the base-biased design. The LED current is independent of the LED voltage. Another advantage is that the circuit doesn't require a collector resistor.

The emitter-biased circuit of Fig. 7-12*b* operates in the active region when the switch is closed. To change the LED current, you can change the base supply voltage or the emitter resistance. For instance, if you vary the base supply voltage, the LED current varies in direct proportion.

Example 7-10

We want 25 mA of LED current when the switch is closed in Fig. 7-12*b*. How can we do it?

SOLUTION One solution is to increase the base supply. We want 25 mA to flow through the emitter resistance of 1.5 kΩ. Ohm's law tells us that the emitter voltage has to be:

$$V_E = (25\text{ mA})(1.5\text{ k}\Omega) = 37.5\text{ V}$$

Ideally, $V_{BB} = 37.5$ V. To a second approximation, $V_{BB} = 38.2$ V. This is a bit high for typical power supplies. But the solution is workable if the particular application allows this high a supply voltage.

A supply voltage of 15 V is common in electronics. Therefore, a better solution in most applications is to decrease the emitter resistance. Ideally, the emitter voltage will be 15 V, and we want 25 mA through the emitter resistor. Ohm's law gives:

$$R_E = \frac{15\text{ V}}{25\text{ mA}} = 600\ \Omega$$

The nearest standard value with a tolerance of 5 percent is 620 Ω. If we use the second approximation, the resistance is:

$$R_E = \frac{14.3\text{ V}}{25\text{ mA}} = 572\ \Omega$$

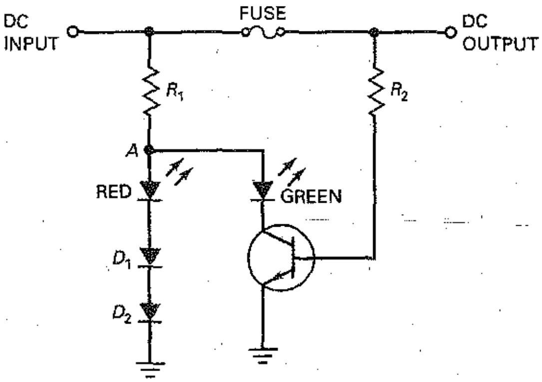
The nearest standard value is 560 Ω.

PRACTICE PROBLEM 7-10 In Fig. 7-12*b*, what value of R_E is needed to produce an LED current of 21 mA?

Example 7-11

What does the circuit of Fig. 7-13 do?

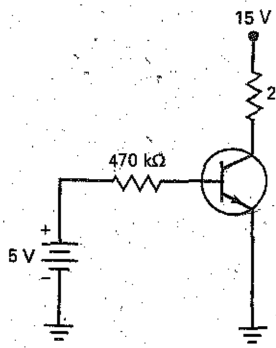
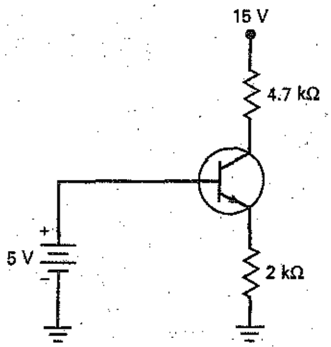
Figure 7-13 Base-biased LED driver.



SOLUTION This is a blown-fuse indicator for a dc power supply. When the fuse is intact, the transistor is base-biased into saturation. This turns on the green LED to indicate that all is OK. The voltage between point A and ground is approximately 2 V. This voltage is not enough to run on the red LED. The two series diodes (D_1 and D_2) prevent the red LED from turning on because they require a drop of 1.4 V to conduct.

When the fuse blows, the transistor goes into cutoff, turning off the green LED. Then, the voltage of point A is pulled up toward the supply voltage. Now there is enough voltage to turn on the two series diodes and the red LED to indicate a blown fuse. Summary Table 7-1 illustrates the differences between base bias and emitter bias.

Summary Table 7-1 | Base Bias Vs. Emitter Bias

Circuit		
Characteristic	**Fixed base current**	**Fixed emitter current**
$\beta_{dc} = 100$	$I_B = 9.5\ \mu A$ $I_C = 915\ \mu A$	$I_B = 21.5\ \mu A$ $I_E = 2.15$ mA
$\beta_{dc} = 300$	$I_B = 9.15\ \mu A$ $I_C = 2.74$ mA	$I_B = 7.17\ \mu A$ $I_E = 2.15$ mA
Modes used	Cutoff and saturation	Active or linear
Applications	Switching/digital circuits	Controlled I_C drivers and amplifiers

7-8 The Effect of Small Changes

Earlier chapters introduced up-down analysis, which is helpful to anyone trying to understand circuits. For the up-down analysis of Fig. 7-14, a small change means a change of approximately 10 percent (the tolerance of some resistors).

For instance, Fig. 7-14 shows an emitter-biased circuit with these circuit values:

$$V_{BB} = 2\text{ V} \qquad V_{CC} = 15\text{ V} \qquad R_E = 130\ \Omega \qquad R_C = 470\ \Omega$$