7-6 Emitter Bias

Digital circuits are the type of circuits used in computers. In this area, base bias and circuits derived from base bias are useful. But when it comes to amplifiers, we need circuits whose Q points are immune to changes in current gain.

Figure 7-9 shows **emitter bias.** As you can see, the resistor has been moved from the base circuit to the emitter circuit. That one change makes all the difference in the world. The Q point of this new circuit is now rock-solid. When the current gain changes from 50 to 150, the Q point shows almost no movement along the load line.

Basic Idea

The base supply voltage is now applied directly to the base. Therefore, a troubleshooter will read V_{BB} between the base and ground. The emitter is no longer grounded. Now the emitter is above the ground and has a voltage given by:

$$V_E = V_{BB} - V_{BE} \tag{7-7}$$

If V_{BB} is more than 20 times V_{BE}, the ideal approximation will be accurate. If V_{BB} is less than 20 times V_{BE}, you may want to use the second approximation. Otherwise your error will be more than 5 percent.

Finding the Q Point

Let us analyze the emitter-biased circuit of Fig. 7-10. The base supply voltage is only 5 V, so we use the second approximation. The voltage between the base and ground is 5 V. From now on, we refer to this base-to-ground voltage as the *base voltage*, or V_B. The voltage across the base-emitter terminals is 0.7 V. We refer to this voltage as the *base-emitter voltage*, or V_{BE}.

Figure 7-9 Emitter bias.

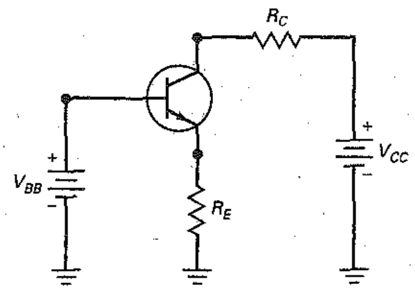
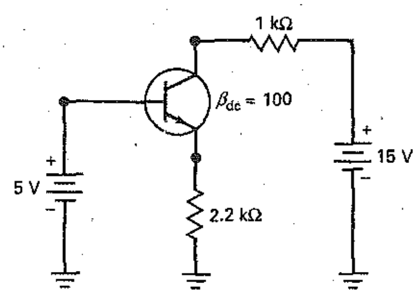


Figure 7-10 Finding the Q point.



The voltage between the emitter and ground is called the *emitter voltage.* It equals:

$$V_E = 5\text{ V} - 0.7\text{ V} = 4.3\text{ V}$$

This voltage is across the emitter resistance, so we can use Ohm's law to find the emitter current:

$$I_E = \frac{4.3\text{ V}}{2.2\text{ k}\Omega} = 1.95\text{ mA}$$

This means that the collector current is 1.95 mA to a close approximation. When this collector current flows through the collector resistor, it produces a voltage drop of 1.95 V. Subtracting this from the collector supply voltage gives the voltage between the collector and ground:

$$V_C = 15\text{ V} - (1.95\text{ mA})(1\text{ k}\Omega) = 13.1\text{ V}$$

From now on, we will refer to this collector-to-ground voltage as the *collector voltage.*

This is the voltage a troubleshooter would measure when testing a transistor circuit. One lead of the voltmeter would be connected to the collector, and the other lead would be connected to ground. If you want the collector-emitter voltage, you have to subtract the emitter voltage from the collector voltage as follows:

$$V_{CE} = 13.1\text{ V} - 4.3\text{ V} = 8.8\text{ V}$$

So, the emitter-biased circuit of Fig. 7-10 has a Q point with these coordinates: $I_C = 1.95$ mA and $V_{CE} = 8.8$ V.

The collector-emitter voltage is the voltage used for drawing load lines and for reading transistor data sheets. As a formula:

$$V_{CE} = V_C - V_E \qquad (7\text{-}8)$$

Circuit Is Immune to Changes in Current Gain

Here is why emitter bias excels. The Q point of an emitter-biased circuit is immune to changes in current gain. The proof lies in the process used to analyze the circuit. Here are the steps we used earlier:

1. Get the emitter voltage.
2. Calculate the emitter current.
3. Find the collector voltage.
4. Subtract the emitter from the collector voltage to get V_{CE}.

At no time do we need to use the current gain in the foregoing process. Since we don't use it to find the emitter current, collector current, and so on, the exact value of current gain no longer matters.

By moving the resistor from the base to the emitter circuit, we force the base-to-ground voltage to equal the base supply voltage. Before, almost all this supply voltage was across the base resistor, setting up a *fixed base current.* Now, all this supply voltage minus 0.7 V is across the emitter resistor, setting up a *fixed emitter current.*

GOOD TO KNOW

Because the values of I_C and V_{CE} are not affected by the value of beta in an emitter-biased circuit, this type of circuit is said to be *beta-independent.*

Minor Effect of Current Gain

The current gain has a minor effect on the collector current. Under all operating conditions, the three currents are related by:

$$I_E = I_C + I_B$$

which can be rearranged as:

$$I_E = I_C + \frac{I_C}{\beta_{dc}}$$

Solve this for the collector current, and you get:

$$I_C = \frac{\beta_{dc}}{\beta_{dc} + 1} I_E \tag{7-9}$$

The quantity that multiplies I_E is called a **correction factor.** It tells you how I_C differs from I_E. When the current gain is 100, the correction factor is:

$$\frac{\beta_{dc}}{\beta_{dc} + 1} = \frac{100}{100 + 1} = 0.99$$

This means that the collector current is equal to 99 percent of the emitter current. Therefore, we get only a 1 percent error when we ignore the correction factor and say that the collector current equals the emitter current.

Example 7-9

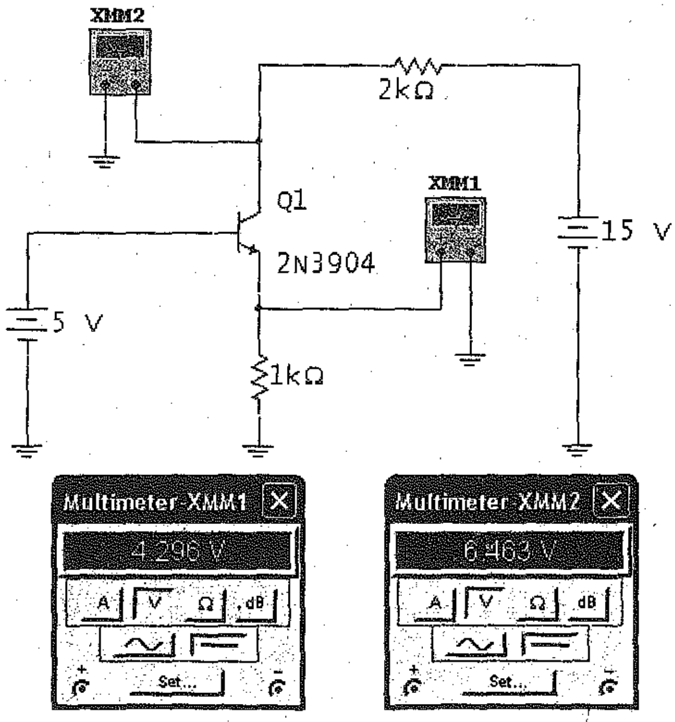
MultiSim

What is the voltage between the collector and ground in the MultiSim Fig. 7-11? Between the collector and the emitter?

SOLUTION The base voltage is 5 V. The emitter voltage is 0.7 V less than this, or:

$$V_E = 5\text{ V} - 0.7\text{ V} = 4.3\text{ V}$$

MultiSim Figure 7-11 Meter Values.



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.