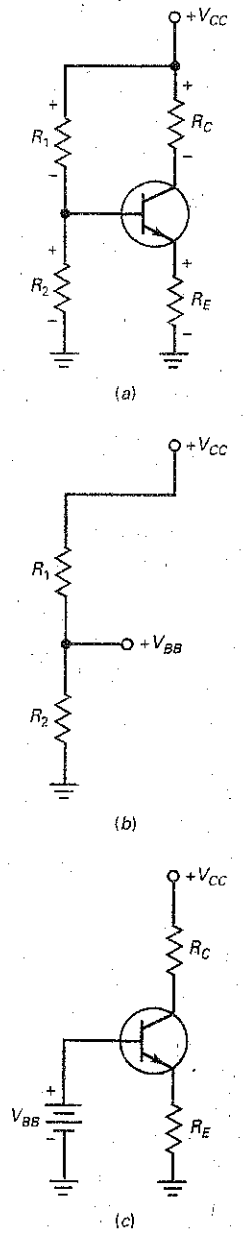
8-1 Voltage-Divider Bias

Figure 8-1*a* shows the most widely used biasing circuit. Notice that the base circuit contains a voltage divider (R_1 and R_2). Because of this, the circuit is called **voltage-divider bias (VDB).**

Figure 8-1 Voltage-divider bias. (*a*) Circuit; (*b*) voltage divider; (*c*) simplified circuit.



Simplified Analysis

For troubleshooting and preliminary analysis, use the following method. In any well-designed VDB circuit, the base current is much smaller than the current through the voltage divider. Since the base current has a negligible effect on the voltage divider, we can mentally open the connection between the voltage divider and the base to get the equivalent circuit of Fig. 8-1*b*. In this circuit, the output of the voltage divider is

$$V_{BB} = \frac{R_2}{R_1 + R_2} V_{CC}$$

Ideally, this is the base-supply voltage as shown in Fig. 8-1*c*.

As you can see, voltage-divider bias is really emitter bias in disguise. In other words, Fig. 8-1*c* is an equivalent circuit for Fig. 8-1*a*. This is why VDB sets up a fixed value of emitter current, resulting in a solid *Q* point that is independent of the current gain.

There is an error in this simplified approach, and we will discuss it in the next section. The crucial point is this: In any well-designed circuit, the error in using Fig. 8-1*c* is very small. In other words, a designer deliberately chooses circuit values so that Fig. 8-1*a* acts like Fig. 8-1*c*.

Conclusion

After you calculate V_{BB}, the rest of the analysis is the same as discussed earlier for emitter bias in Chap. 7. Here is a summary of the equations you can use to analyze VDB:

$$V_{BB} = \frac{R_2}{R_1 + R_2} V_{CC} \tag{8-1}$$

$$V_E = V_{BB} - V_{BE} \tag{8-2}$$

$$I_E = \frac{V_E}{R_E} \tag{8-3}$$

$$I_C \approx I_E \tag{8-4}$$

$$V_C = V_{CC} - I_C R_C \tag{8-5}$$

$$V_{CE} = V_C - V_E \tag{8-6}$$

These equations are based on Ohm's and Kirchhoff's laws. Here are the steps in the analysis:

1. Calculate the base voltage V_{BB} out of the voltage divider.
2. Subtract 0.7 V to get the emitter voltage (use 0.3 V for germanium).
3. Divide by the emitter resistance to get the emitter current.
4. Assume that the collector current is approximately equal to the emitter current.

5. Calculate the collector-to-ground voltage by subtracting the voltage across the collector resistor from the collector supply voltage.
6. Calculate the collector-emitter voltage by subtracting the emitter voltage from the collector voltage.

Since these six steps are logical, they should be easy to remember. After you analyze a few VDB circuits, the process becomes automatic.

GOOD TO KNOW

Since $V_E \cong I_C R_E$, Eq. (8-6) can also be shown as

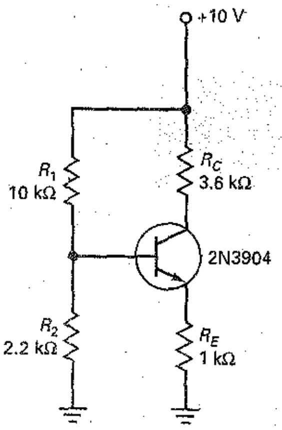
$$V_{CE} = V_{CC} - I_C R_C - I_C R_E$$

or

$$V_{CE} = V_{CC} - I_C(R_C + R_E).$$

Example 8-1

Figure 8-2 Example.



What is the collector-emitter voltage in Fig. 8-2?

SOLUTION The voltage divider produces an unloaded output voltage of:

$$V_{BB} = \frac{2.2\ \text{k}\Omega}{10\ \text{k}\Omega + 2.2\ \text{k}\Omega}\,10\ \text{V} = 1.8\ \text{V}$$

Subtract 0.7 V from this to get:

$$V_E = 1.8\ \text{V} - 0.7\ \text{V} = 1.1\ \text{V}$$

The emitter current is:

$$I_E = \frac{1.1\ \text{V}}{1\ \text{k}\Omega} = 1.1\ \text{mA}$$

Since the collector current almost equals the emitter current, we can calculate the collector-to-ground voltage like this:

$$V_C = 10\ \text{V} - (1.1\ \text{mA})(3.6\ \text{k}\Omega) = 6.04\ \text{V}$$

The collector-emitter voltage is:

$$V_{CE} = 6.04 - 1.1\ \text{V} = 4.94\ \text{V}$$

Here is an important point: The calculations in this preliminary analysis do not depend on changes in the transistor, the collector current, or the temperature. This is why the *Q* point of this circuit is stable, almost rock-solid.

PRACTICE PROBLEM 8-1 Change the power supply voltage of Fig. 8-2 from 10 V to 15 V and solve for V_{CE}.

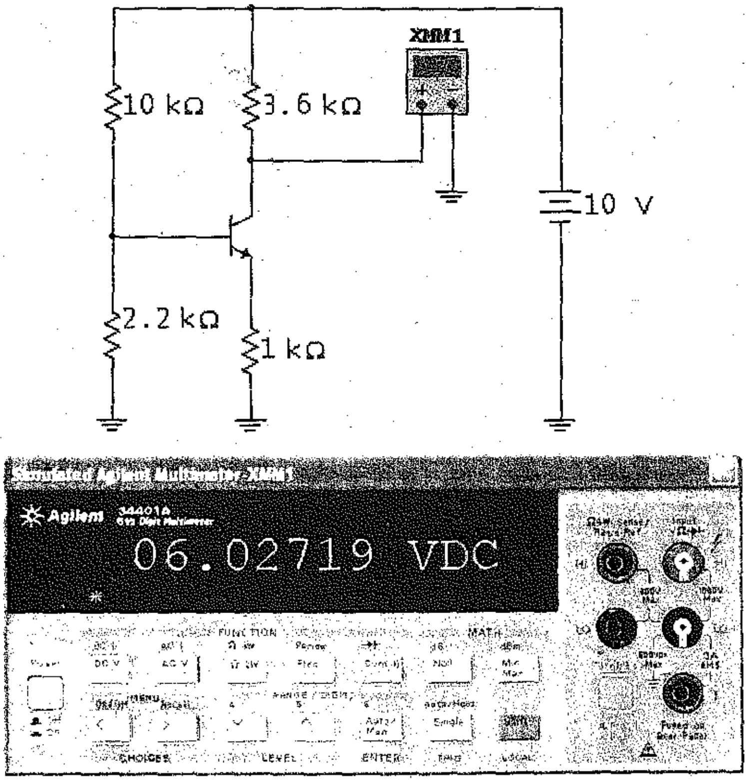
Example 8-2

Discuss the significance of Fig. 8-3, which shows a MultiSim analysis of the same circuit analyzed in the preceding example.

SOLUTION This really drives the point home. Here we have an almost identical answer using a computer to analyze the circuit. As you can see, the voltmeter reads 6.03 V (rounded to 2 places). Compare this to 6.04 V in the preceding example, and you can see the point. A simplified analysis has produced essentially the same result as a computer analysis.

You can expect this kind of close agreement whenever a VDB circuit has been well designed. After all, the whole point of VDB is to act like emitter bias to virtually eliminate the effects of changing the transistor, collector current, or temperature.

MultiSim **Figure 8-3** MultiSim example.



PRACTICE PROBLEM 8-2 Using MultiSim, change the supply voltage of Fig. 8-3 to 15 V and measure V_{CE}. Compare your measured value to the answer of Practice Problem 8-1.

8-2 Accurate VDB Analysis

What is a well-designed VDB circuit? It is one in which *the voltage divider appears stiff to the input resistance of the base.* The meaning of the last sentence needs to be discussed.

Source Resistance

Chapter 1 introduced the idea of a stiff voltage source:

Stiff voltage source: $R_S < 0.01R_L$

When this condition is satisfied, the load voltage is within 1 percent of the ideal voltage. Now, let us extend this idea to the voltage divider.