Unit 31 Transistor bias circuits

- The function of a transistor bias circuit is to maintain a forward bias on the emitter-base junction and a reverse bias on the base-collector junction.
- The currents and voltages in transistor bias circuits can usually be determined by using:

$$\begin{aligned} I_C &= \beta \times I_B \\ I_C &\approx I_E \\ V_{BE} &\approx 0.7\,\text{V} \end{aligned}$$

  to solve a basic equation which represents the sum of the voltage drops across the components along a path between the supply voltage rail and the ground rail.
- The basic equation for calculating the currents in transistor bias circuits is determined along a path such that:

  Voltage supply = Sum of voltage drops across individual components.

Before a transistor can be made to do anything useful it must be biased so that the emitter-base junction is forward biased and the base-collector junction is reverse biased. There are only a small number of circuits which are used to bias transistors and place the transistor in the middle of its operating range.

The first operation to be carried out in determining the currents and voltages is to identify a path through the circuit from the supply voltage rail to the ground rail for which the sum of the voltage drops across the individual components can be explicitly stated. We call this the basic equation. The main aim of this unit is to learn how to identify the basic equation for any problem rather than to try to remember all possible basic equations for all possible circuits.

In Examples 31.1 and 31.2, the path along which the basic equation is set up is identified in a separate sketch. In general, the basic equation will not be set up along a path which includes the base-collector junction because the current through this junction is nearly independent of the voltage across the junction and is not readily calculated.

31.1 Examples

31.1 Calculate the emitter, base and collector voltages and currents for the circuit shown in Figure 31.1 (a). Use $\beta = 250$.

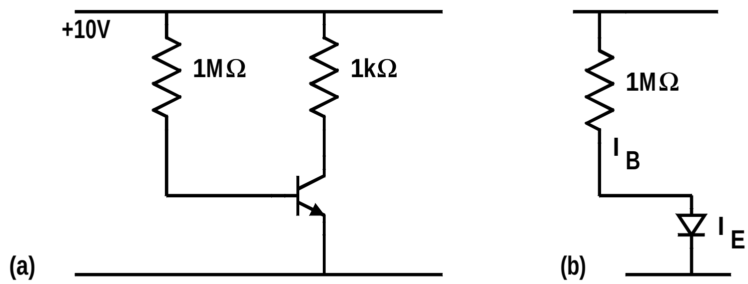

Figure 31.1: Example 31.1.

By inspection it can be seen that:

$$V_E = 0\,\text{V}$$
$$V_B = 0.7\,\text{V}$$

The path along which the basic equation is evaluated is shown in Figure 31.1 (b) and the basic equation is:

$$10\,\text{V} = I_B \times R_B + 0.7\,\text{V}$$

which gives
$$10\,\text{V} = I_B \times 10^6 + 0.7\,\text{V}$$

and then
$$I_B = \frac{10 - 0.7}{10^6} = 9.3\,\mu\text{A}$$
$$I_C = \beta \times I_B = 250 \times 9.3\,\mu\text{A} = 2.3\,\text{mA}$$

This gives
$$V_C = 10\,\text{V} - I_C \times R_C = 10\,\text{V} - 2.3\,\text{mA} \times 1\,\text{k}\Omega = 7.7\,\text{V}$$

Note that the collector voltage, V_C, is calculated as $I_C \times R_C$ down from the supply voltage of 10 V.

31.2 Calculate the emitter, base and collector voltages and currents for the circuit shown in Figure 31.2 (a). Use $\beta = 300$.

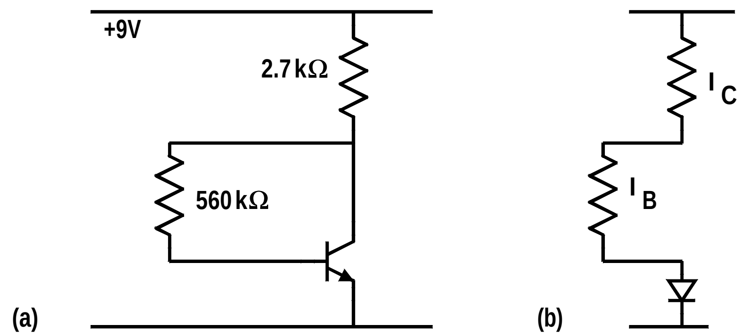

Figure 31.2: Example 31.2.

By inspection, we find that:

$$\begin{aligned} V_E &= 0\,\text{V} \\ V_B &= 0.7\,\text{V} \end{aligned}$$

From Figure 31.2 (b), the basic equation is:

$$\begin{aligned} 9\,\text{V} &= I_C \times R_C + I_B \times R_B + 0.7\,\text{V} \\ \text{Use} \quad I_C &= \beta \times I_B \\ \text{to get} \quad 9\,\text{V} &= \beta \times I_B \times R_C + I_B \times R_B + 0.7\,\text{V} \\ \text{Solve to get} \quad I_B &= \frac{9 - 0.7}{\beta \times R_C + R_B} \\ &= \frac{8.3}{300 \times 2.7 \times 10^3 + 560 \times 10^3} \\ &= 6.06\,\mu\text{A} \\ \text{Then} \quad I_C &= \beta \times I_B \\ &= 1.82\,\text{mA} \\ V_C &= 9\,\text{V} - 1.82\,\text{mA} \times 2.7\,\text{k}\Omega \\ &= 9\,\text{V} - 4.91\,\text{V} \\ &= 4.09\,\text{V} \end{aligned}$$

31.3 Calculate the emitter, base and collector voltages and currents for the circuit shown in Figure 31.3.

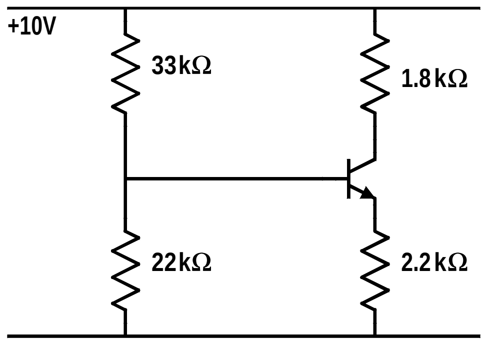

Figure 31.3: Example 31.3.

In this circuit, the basic equation can be set up along a path through the potential divider, subject to the condition that the current flowing into the base is less than 10% of the current in the resistors in the potential divider.

$$\begin{aligned} \text{Current in potential divider} &= \frac{10\,\text{V}}{33\,\text{k}\Omega + 22\,\text{k}\Omega} \\ &= 182\,\mu\text{A} \end{aligned}$$

which satisfies the 10% condition since the base current is usually $\approx 10\,\mu$A. The base voltage is then determined by the potential divider as:

$$V_B = \frac{22}{33+22} \times 10\,\text{V} = 182\,\mu\text{A} \times 22\,\text{k}\Omega = 4\,\text{V}$$

The emitter-base voltage is 0.7 V and therefore:

$$\begin{aligned} V_E &= V_B - 0.7\,\text{V} \\ &= 4.0\,\text{V} - 0.7\,\text{V} = 3.3\,\text{V} \\ \text{Then} \quad I_E &= \frac{3.3\,\text{V}}{2.2\,\text{k}\Omega} = 1.5\,\text{mA} \\ \text{and} \quad I_C &\approx 1.5\,\text{mA} \\ V_C &= 10\,\text{V} - 1.8\,\text{k}\Omega \times 1.5\,\text{mA} \\ &= 10\,\text{V} - 2.7\,\text{V} = 7.3\,\text{V} \end{aligned}$$

The interesting feature of this circuit is that the currents and voltages have been determined without having to use any specific value of the current gain, β, in the calculation. When transistors are manufactured, the value of the β has great variation from one batch to the next. From the catalogs it can be seen that the manufacturers only specify that the current gain, β, or h_{fe} for a BC109 transistor (a typical transistor) lies in the range from 200 to 800.

This type of bias circuit is usually chosen by designers and manufacturers of electronic circuits because it only requires that the value for β exceed some minimum value. The resistors then determine the operating values for the transistor. Compare this situation with Examples 31.1 and 31.2 where any variation in the value of β has a large effect on the operating point.

31.2 Problems

31.1 Calculate the emitter, base and collector voltages and currents for the circuit shown in Figure 31.4. Use $\beta = 150$.

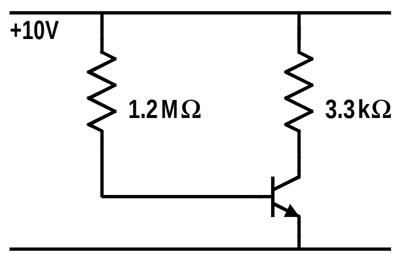

Figure 31.4: Problem 31.1.

31.2 Calculate the emitter, base and collector voltages and currents for the circuit shown in Figure 31.5. Use $\beta = 250$.

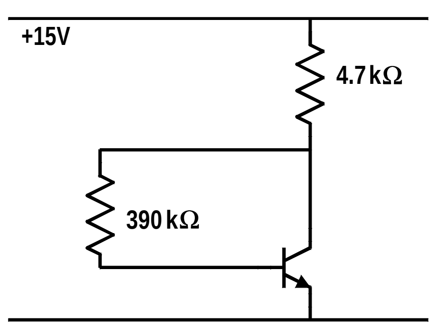

Figure 31.5: Problem 31.2.

31.3 The circuit shown in Figure 31.6 was constructed and the voltage at the collector was measured to be +6.2 V. Calculate the emitter, base and collector currents and calculate the current gain, β, for the transistor used in the circuit.

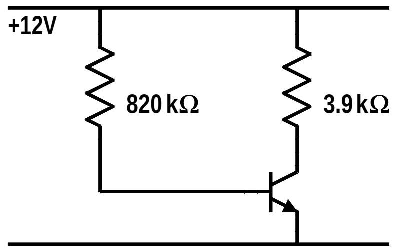

Figure 31.6: Problem 31.3.

31.4 Calculate the emitter, base and collector voltages and currents for the circuit shown in Figure 31. 7. Use $\beta = 300$.

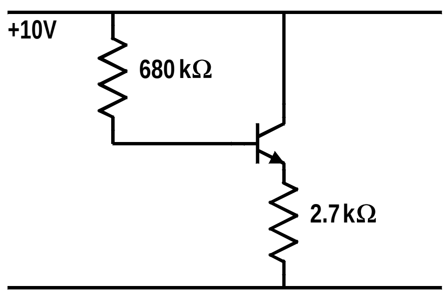

Figure 31. 7: Problem 31.4.

31.5 Calculate the emitter, base and collector voltages and currents for the circuit shown in Figure 31.8. Use $\beta = 200$.

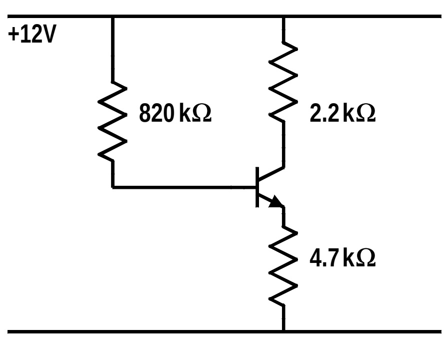

Figure 31.8: Problem 31.5.

31.6 Calculate the new values of the voltages and currents in the circuit of Problem 31.5 which result from replacing the transistor by another transistor having a $\beta = 300$.

31.7 Calculate the emitter, base and collector voltages and currents for the circuit shown in Figure 31.9. The current gain for the pnp transistor is $\beta = 185$.

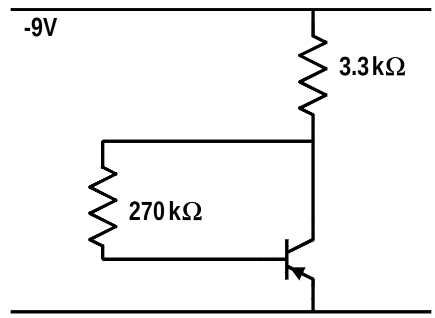

Figure 31.9: Problem 31. 7.

31.8 Calculate the emitter, base and collector voltages and currents for the circuit shown in Figure 31.1 0.

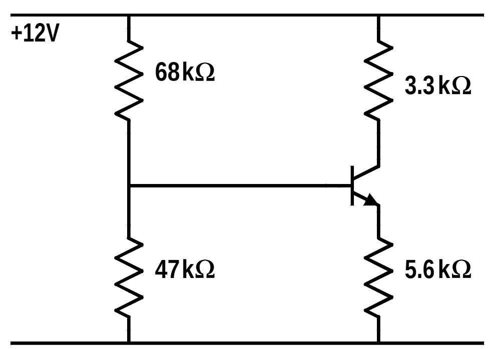

Figure 31.10: Problem 31.8.