11.5.4: Parallel Circuits

Photograph of a circuit board

Figure 17.4.1

Electrical circuits are everywhere: skyscrapers, jumbo jets, arcade games, lights, heating, security... Very few complex things work without electrical circuits. Since the late 1970's, electrical circuits have primarily looked like this. The circuits are formed by a thin layer of conducting material deposited on the surface of an insulating board. Individual components are soldered to the interconnecting circuits. Circuit boards are vastly more complicated than the series circuits previously discussed, but operate on many similar principles.

Parallel Circuits

Parallel circuits are circuits in which the charges leaving the potential source have different paths they can follow to get back to the source. In the sketch below, the current leaves the battery, passes through the orange switch, and then has three different paths available to complete the circuit. Each individual electron in this circuit passes through only one of the light bulbs. After the current passes through the switch, it divides into three pieces and each piece passes through one of the bulbs. The three pieces of current rejoin after the light bulbs and continue in the circuit to the potential source.

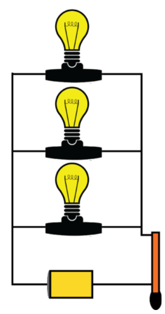

Figure 17.4.2

In the design of this parallel circuit, each resistor (light bulb) is connected across the battery as if the other two resistors were not present. Remember that the current going through each resistor goes through only the one resistor. Therefore, the voltage drop across each resistor must be equal to the total voltage drop though the circuit.

$$V_T=V_1=V_2=V_3$$

The total current passing through the circuit will be the sum of the individual currents passing through each resistor.

$$I_T=I_1+I_2+I_3$$

If we return to the analogy of a river, a parallel circuit is the same as the river breaking into three streams, which later rejoin to one river again. The amount of water flowing in the river is equal to the sum of the amounts of water flowing in the individual streams.

Ohm's Law applies to resistors in parallel, just as it did to resistors in a series. The current flowing through each resistor is equal to the total voltage drop divided by the resistance in that resistor.

$$I_1=V_T/R_1 \text{ and } I_2=V_T/R_2 \text{ and } I_3=V_T/R_3$$

$$\text{Since } I_T=I_1+I_2+I_3,$$

$$\text{then } I_T=V_T/R_1+V_T/R_2+V_T/R_3,$$

$$\text{and } V_T/R_T=V_T/R_1+V_T/R_2+V_T/R_3.$$

If we divide both sides of the final equation by V_T, we get the relationship between the total resistance of the circuit and the individual parallel resistances in the circuit. The total resistance is sometimes called the **equivalent resistance.**

$$1/R_T=1/R_1+1/R_2+1/R_3$$

Consider the parallel circuit sketched below.

The voltage drop for the entire circuit is 90. V. Therefore, the voltage drop in each of the resistors is also 90. V.

Three resistors in parallel

Figure 17.4.3

The current through each resistor can be found using the voltage drop and the resistance of that resistor:

$$I_1=V_T/R_1=90.\ V/60.\ \Omega=1.5\ A\ I_2=V_T/R_2=90.\ V/30.\ \Omega=3.0\ A\ I_3=V_T/R_3=90.\ V/30.\ \Omega=3.0\ A$$

The total current through the circuit would be the sum of the three currents in the individual resistors.

$$I_T=I_1+I_2+I_3=1.5\ A+3.0\ A+3.0\ A=7.5\ A$$

The equivalent resistance for this circuit is found using the equation above.

$$1/R_T=1/R_1+1/R_2+1/R_3=1/60.\ \Omega+1/30.\ \Omega+1/30.\ \Omega=160.\ \Omega+260.\ \Omega+260.\ \Omega=560.\ \Omega$$

$$R_T=60.\ \Omega/5=12\ \Omega$$

The equivalent resistance for the circuit could also be found by using the total voltage drop and the total current.

$$R_T=V_T/I_T=90.\ \Omega/7.5\ A=12\ \Omega$$

Use the PLIX below to observe the relationship between the individual voltage drops and the total voltage in a parallel circuit:

Use the PLIX Interactive below to observe the differences between parallel and series circuits. Adjust the number of resistors in the circuit and observe the difference in total resistance between a parallel and series circuit. Then, try to explain the different levels of bulb brightness observed in each circuit configuration:

Summary

- Parallel electrical circuits have multiple paths the current may take.
- $V_T=V_1=V_2=V_3$
- $I_T=I_1+I_2+I_3$
- $1/R_T=1/R_1+1/R_2+1/R_3$

Review

1. Three 15.0 Ω resistors are connected in parallel and placed across a 30.0 V potential difference.
    1. What is the equivalent resistance of the parallel circuit?
    2. What is the total current through the circuit?
    3. What is the current through a single branch of the circuit?
2. A 12.0 Ω and a 15.0 Ω resistor are connected in parallel and placed across a 30.0 V potential.
    1. What is the equivalent resistance of the parallel circuit?
    2. What is the total current through the circuit?
    3. What is the current through each branch of the circuit?
3. A 120.0 Ω resistor, a 60.0 Ω resistor, and a 40.0 Ω resistor are connected in parallel and placed across a potential difference of 12.0 V.
    1. What is the equivalent resistance of the parallel circuit?
    2. What is the total current through the circuit?
    3. What is the current through each branch of the circuit?

Explore More

Use this resource to answer the questions that follow.

1. Why do the light bulbs glow less brightly when connected across a 120 V source in a series circuit than when connected across the same 120 V source in a parallel circuit?
2. Why do the other bulbs go dark when one bulb is removed in the series circuit but the other bulbs do not go dark when one bulb is removed in the parallel circuit?

Additional Resources

Study Guide: Electrical Systems Study Guide

Real World Application: Lights in Parallel

Interactives: Dollhouse, Marquee Lights

Video: