5

Series, Parallel, and Series-Parallel Circuits

LEARNING OBJECTIVES

Upon completion and review of this chapter, you should be able to:

- Define a series circuit.
- Identify the series circuit laws and apply Ohm's Law for voltage, current, and resistance.
- Define a parallel circuit.
- Identify the parallel-circuit laws and apply Ohm's Law for voltage, current, and resistance.
- Define Kirchhoff's Voltage Drop Law and Current Law.
- Define a series-parallel circuit.
- Identify the series and parallel circuit loads of a series-parallel circuit.
- Using Ohm's Law, solve series-parallel circuits for voltage, current, and resistance.

KEY TERMS

Circuit
Kirchhoff's Law of Current
Kirchhoff's Law of Voltage Drops
Parallel Circuit
Series Circuit
Series-Parallel Circuits
Voltage Drop

INTRODUCTION

In this chapter you will apply the individual series and parallel circuit laws learned in previous chapters to a combination circuit consisting of some components connected in series and some in parallel. Series/parallel electrical circuits seem complicated, but are in fact fairly simple to understand if you remember which circuit laws apply to each circuit load component. Most vehicle electrical circuits used today contain several series-parallel circuits, or portions of a series-parallel circuit.

BASIC CIRCUITS

In Chapter 3, we explained that a **circuit** is a path for electric current (Figure 5-1). Current flows from one end of a circuit to the other when the ends are connected to opposite charges (positive

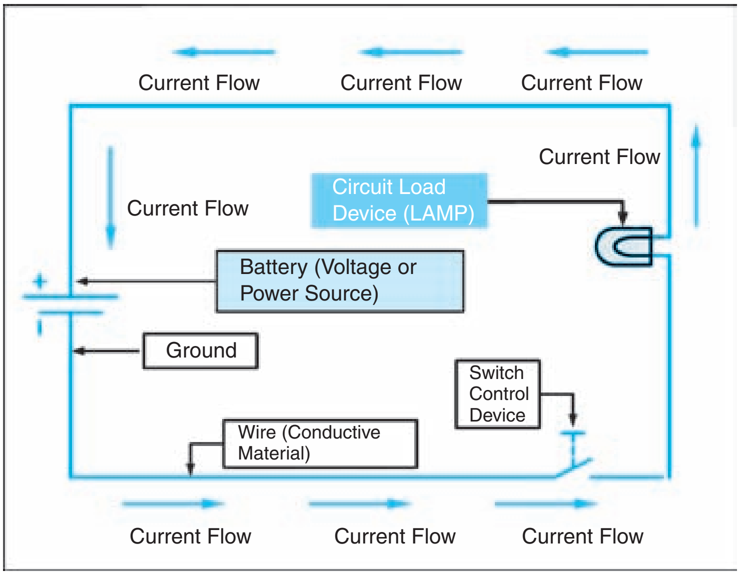


Figure 5-1. Basic circuit.

and negative). We usually call these ends *power* and *ground.* Current flows only in a closed or completed circuit. If there is a break somewhere in the circuit, current cannot flow. We usually call a break in a circuit an *open.* Every automotive circuit contains a source of power, protection, a load, controls, wires (conductive material) and a ground. These elements are connected to each other with conductors.

SERIES CIRCUIT

A **series circuit** (Figure 5-2) is the simplest kind of circuit. Automotive systems almost never include a pure series circuit. A series circuit is a complete circuit that has more than one electrical load through which the current has to flow. These are characteristics of all series circuits:

- Voltage drops add up to the source voltage.
- There is only one path for current flow.
- The same current flows through every component. In other words, you would get the same current measurement at any point along the circuit.
- Since there is only one path, an open anywhere in the circuit stops current flow.
- Individual resistances add up to the total resistance.

For more information about series circuits, see the section on “Circuit Devices” in Chapter 5 of the *Shop Manual.*

PARALLEL CIRCUIT

A parallel circuit is a complete circuit where the current flow has more than one electrical path for the current flow. These are characteristics of all parallel circuits (Figure 5-3):

- There is more than one path for current flow. Each current path is called a branch.
- All of the branches connect to the same positive terminal and the same negative terminal. This means the same voltage is applied to all of the branches.
- Each branch drops the same amount of voltage, regardless of resistance.
- The current flow in each branch can be different depending on the resistance. Total current in the circuit equals the sum of the branch currents.
- The total resistance is *always* less than the smallest resistance in any branch.

We call the top segment of this circuit the *main line* because it’s the lead connecting the voltage source to the other branches. For more information about

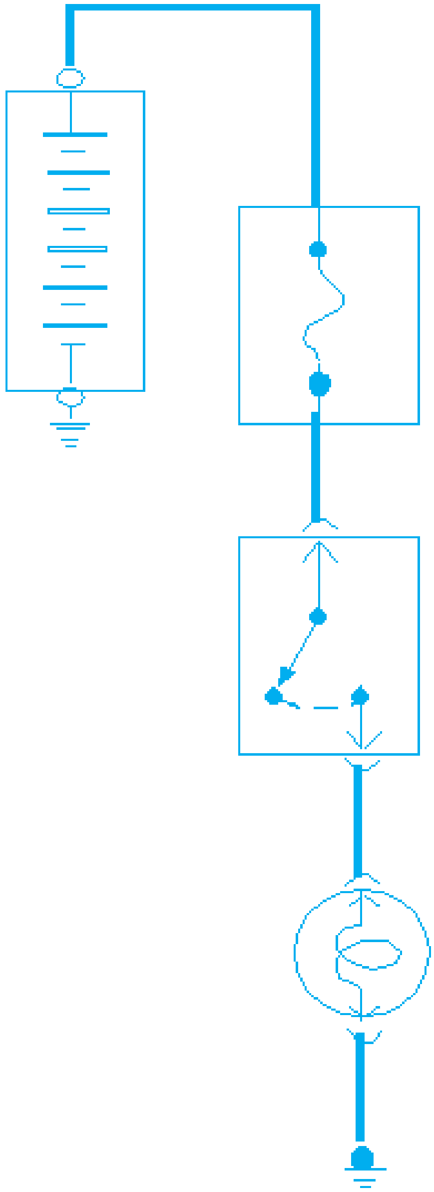


Figure 5-2. Series circuit. (GM Service and Parts Operations)

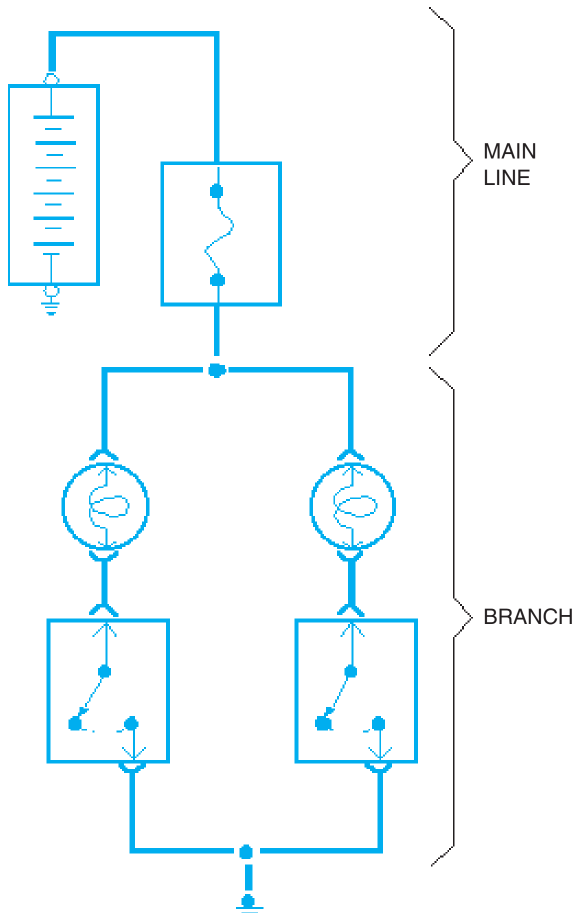


Figure 5-3. Parallel circuit. (GM Service and Parts Operations)

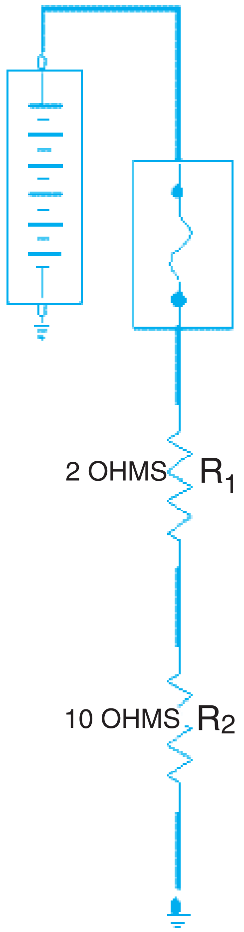
parallel circuits, see the section on "Circuit Protectors" in Chapter 5 of the *Shop Manual*.

SERIES CIRCUIT VOLTAGE DROPS

As current passes through resistance, energy is converted. It's tempting to say that energy is used up, but that's not strictly accurate. In truth, energy can't be used up; it can only be converted to some other form, such as heat, motion, or light. In any case, the effect of this change in energy is that the voltage before a resistance is greater than the voltage after the resistance. We call this a **voltage drop,** and we usually talk about a voltage drop across a resistance or load. As electricity moves through a resistance or load, there is a change in potential, but the current does not change.

Using a circuit schematic, along with Ohm's Law, we can calculate the voltage drop across a single resistance. The total of all voltage drops in a series circuit (as shown in Figure 5-4), is always equal to the source voltage (also called the applied voltage). This is known as **Kirchhoff's Law of Voltage Drops.**

Kirchhoff's second law, also called the voltage law, states that the sum of the voltage drops in any closed circuit is equal to the source voltage.



$$I = \frac{E_t}{R_t} = \frac{12volts}{2\Omega + 10\Omega} = \frac{12volts}{12\Omega} = 1amp$$

$$E_{R_1} = I \times R_1 = 1amp \times 2\Omega = 2volts$$

$$E_{R_2} = I \times R_2 = 1amp \times 10\Omega = 10volts$$

$$E_T = E_{R1} + E_{R2} = 2volts + 10volts = 12volts$$

Figure 5-4. Calculating series circuit voltage drops. (GM Service and Parts Operations)

Series Circuit Exercise

Exercise Objective: Demonstrate that the sum of the voltage drops for each load in a series circuit is equal to the source voltage.

When you measure any voltage, you measure the *difference* in potential between two points. Components in circuits cause voltage drops. Each voltage drop is a difference in potential between two points—one point before a load, the other point after the load. When you add together all of the voltage drops in a circuit, the total will equal the supply voltage. For more information about applying Kirchhoff's Law of Voltage Drops, see the "Circuit Faults" section in Chapter 5 of the *Shop Manual.*

Assemble a circuit as shown in Figure 5-5. Measure the voltage drop across each of the following circuit sections and record the readings in the spaces provided in the illustration.

Does the sum of the voltage drops equal the applied voltage?________

Why do the voltage drops in a series circuit add up to the source voltage?

Measure the values of the resistors:

R_1: ____

R_2: ____

R_3: ____

R_4: ____

PARALLEL CIRCUIT VOLTAGE DROPS

In a *parallel circuit,* each branch drops the same voltage, regardless of the resistance. If the resistance values are not the same, then different amounts of current will flow in each branch (Figure 5-6). According to Kirchhoff's Law of Current, the current that flows through a parallel circuit divides into each path in the circuit: When the current flow in each path is added, the total current will equal the current flow leaving the power source. When calculating the current flow in parallel circuits, each current flow path must be treated as a series circuit or the total resistance of the circuit must be calculated before calculating total current. When performing calculation on a parallel circuit, it should be remembered that more current will always flow through the path with the least resistance.

Kirchhoff's Law of Current (Kirchhoff's 1st Law) states that the current flowing into a junction or point in an electrical circuit must equal the current flowing out.

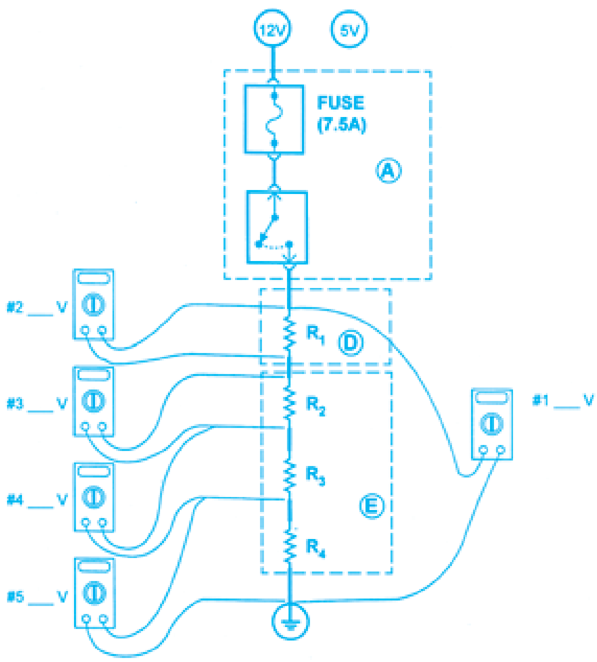


Figure 5-5. Series circuit voltage drop exercise. (GM Service and Parts Operations)

Parallel Circuit Voltage Drops Exercise

Exercise Objective: Demonstrate that all branches of a parallel circuit drop an equal amount of voltage.

In a parallel circuit, each branch drops the same voltage, regardless of the resistance. If the resistance values are not the same, then a different amount of current flows in each branch. Assemble the circuit shown in Figure 5-7. Measure voltage between each of the following pairs of points and record the readings.

Record Measurements:

1 to 2 ________________________________volts

3 to 4 ________________________________volts

5 to 6 ________________________________volts

7 to 8 ________________________________volts

Are the voltage drops in the three branches equal?________

Does the sum of the 3-4, 5-6, and 7-8 voltage drops equal the supply voltage?________ Should it?________

Why do you think all branches of a parallel circuit drop an equal amount of voltage?

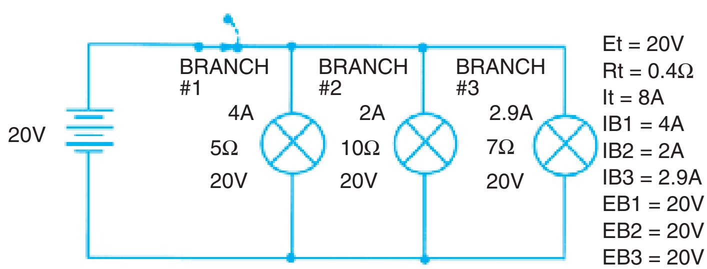


Figure 5-6. Parallel circuit voltage drops.

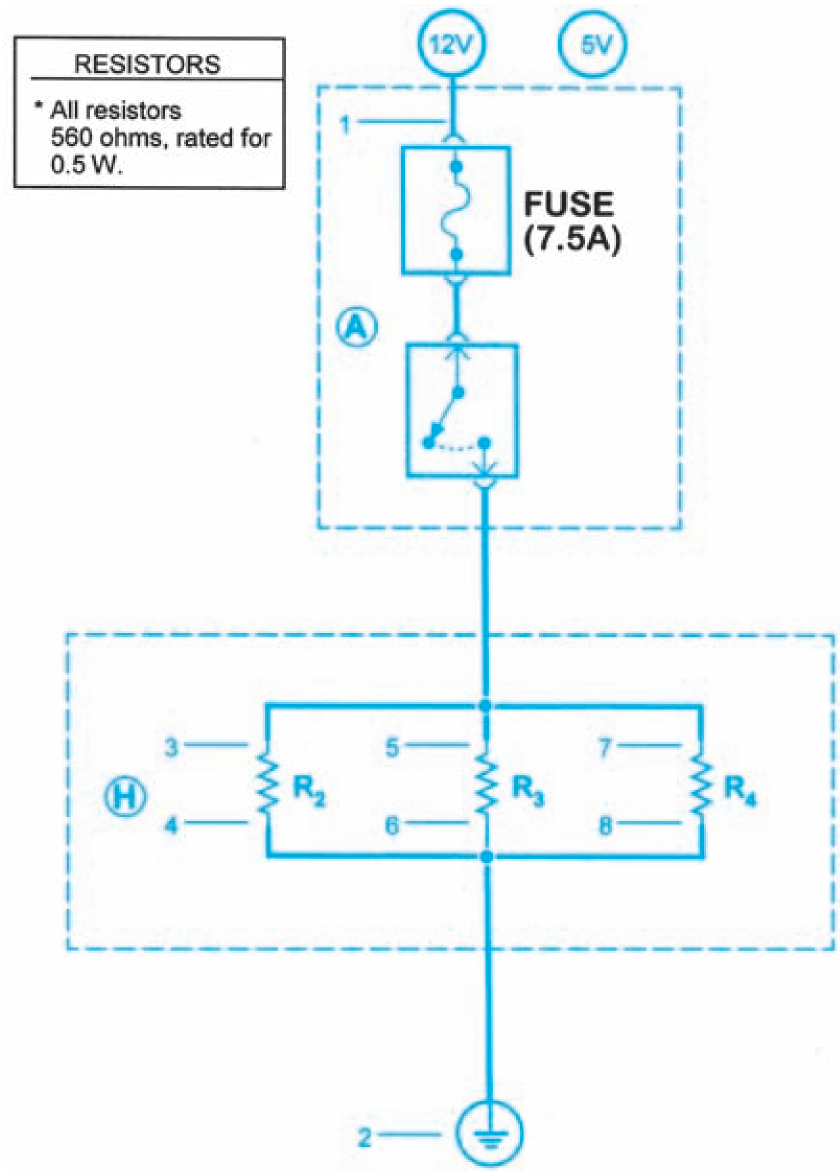


Figure 5-7. Parallel circuit voltage drop exercise. (GM Service and Parts Operations)

CALCULATING SERIES CIRCUIT TOTAL RESISTANCE

The way resistance behaves in a series circuit is easy to understand. Each resistance affects the entire circuit because there is only one current path. If a resistance is added or if an existing resistance increases, the current for the entire circuit decreases. To calculate the total resistance in a series circuit, add up the individual resistances. The total resistance of the series circuit in Figure 5-8 is 3 + 3 + 4 = 10 ohms. The total circuit resistance is usually called the equivalent resistance.

Open in Series Circuit

There is only one path for current flow in a series circuit. If that path is open, there is no current flow and the circuit loads cannot work. If there is an open in a series circuit, the voltage

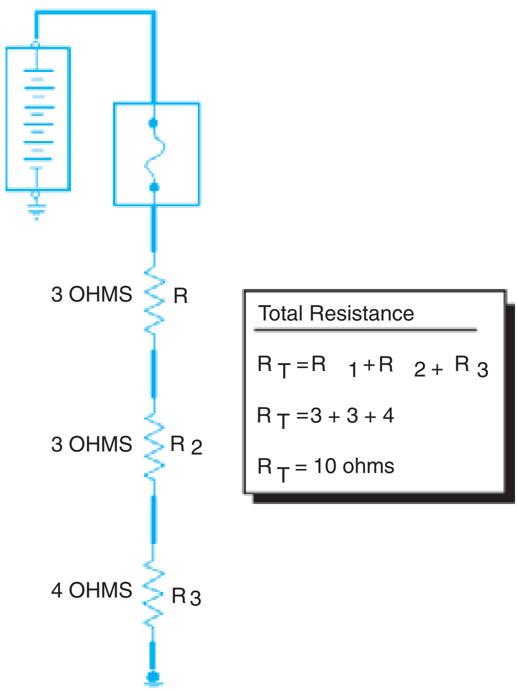


Figure 5-8. Series circuit total resistance. (GM Service and Parts Operations)

drop across the load in that circuit will be zero volts (Figure 5-9). At some point in that circuit, you will be able to measure applied voltage. If you measure the voltage across the open ends of the circuit (on either side of the break), you will measure the applied voltage. There will be no continuity (infinite resistance) between the source and ground. You will measure zero current flow at any point on the circuit. For more information about opens in a series circuit, see the "Circuit Faults" section in Chapter 5 of the *Shop Manual.*

Open in Series Circuit Exercise

Read each question carefully and fill in the blanks.

Turn to the "HVAC: Blower Controls, Manual C60" schematic in an OEM service manual and think about the following conditions.

Condition A

You suspect a problem in the blower resistor assembly and want to check the resistances across its various terminals.

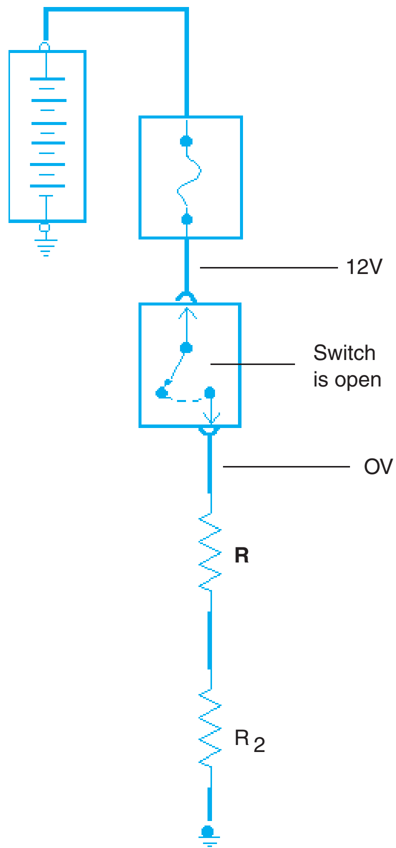


Figure 5-9. Open series circuit. (GM Service and Parts Operations)

1. Which DMM input terminal do you use?____
2. To which position do you turn the rotary switch?______
3. If you measure infinite resistance across terminals C and B of the blower resistor assembly, is it possible for the blower motor to work correctly in positions *LOW* and *M1*?
   a. Yes
   b. No

Condition B

The blower motor doesn't work with the blower switch in the *LOW* and *M1* positions. You know the blower switch is okay, and you suspect the problem is in the blower resistor assembly. You measure voltage between terminal 30 of the blower relay and ground while moving the blower switch through the various positions. The mode selector is turned to *MAX* and the engine is running.

4. Which DMM input terminal do you use?____
5. To which position do you turn the rotary switch?______

Current in a Series Circuit

You learned earlier that since there is a single current path in a series circuit, the current is the same in every part of the circuit. You can relate this back to the water pipe analogy. If water flows from a tank through a single pipe, the rate of flow will be the same in every part of the water circuit. It doesn't matter how many faucets or other parts are plumbed into the circuit, the flow of water has to be the same in every part. The same holds true for an electrical circuit.

CALCULATING PARALLEL CIRCUIT TOTAL RESISTANCE

Understanding the effect of resistance in a parallel circuit is more complicated than for a series circuit. The math for calculating the equivalent resistance for a parallel circuit is complex, and it's not likely you'll ever need to do such a calculation in your work. However, it is important for you to know that the total resistance of a parallel circuit is actually less than the resistance of its smallest resistor. For example, the circuit in Figure 5-10 contains 5-, 10-, and 30-ohm resistors. The smallest resistance is 5 ohms. The total resistance must be less than that. In fact, it's 3 ohms. If there are two loads in parallel of different resistance the following equation can be used to determine the total resistance:

$$R_t = \frac{R_1 \times R_2}{R_1 + R_2}$$

If you have more than two loads, because in a parallel circuit resistance is fractional, you use the following formula for total resistance:

$$R_t = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}} = \frac{1}{\frac{1}{6} + \frac{1}{3}} = \frac{1}{\frac{1}{6} + \frac{2}{6}}$$

$$= \frac{1}{\frac{3}{6}} = \frac{1}{\frac{1}{2}} = \frac{1}{0.5} = 2 \text{ ohms}$$

You can think of a parallel circuit in plumbing terms like water going through pipes. Consider a water tank with a pipe and two faucets (Figure 5-11). Assume the tank holds 10 gallons of water. Now assume that each faucet will allow water to flow out of the tank at about 1 gallon per minute: If you open one faucet, it flows 1 gallon per minute. It will take 10 minutes to empty 10 gallons from the tank. With both faucets open, the water flows at 1 gallon per minute through each faucet. With the faucets in parallel, a total

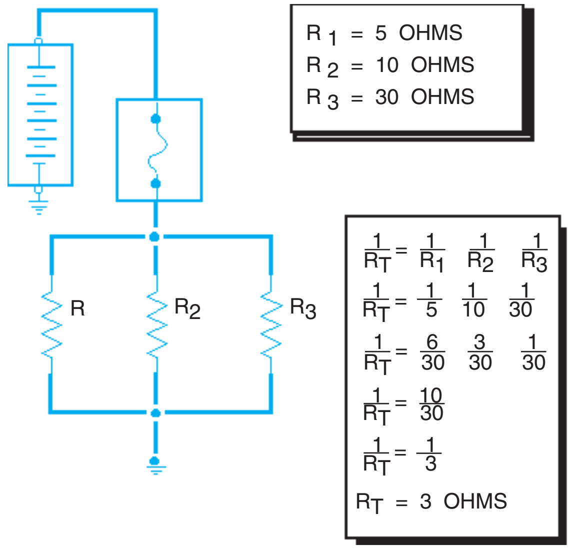


Figure 5-10. Parallel circuit total resistance. (GM Service and Parts Operations)

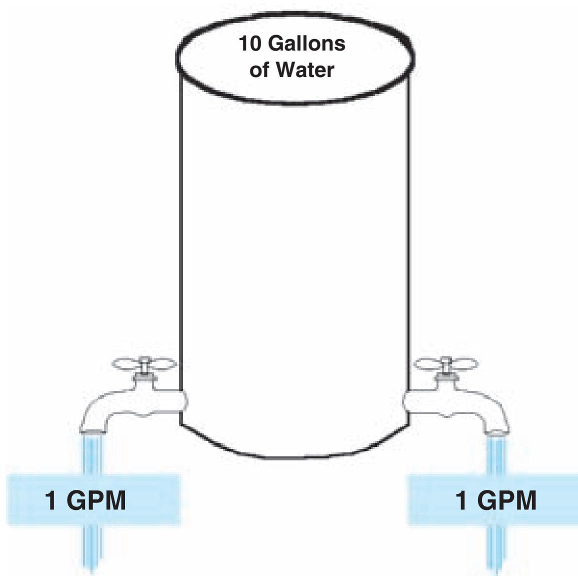


Figure 5-11. Water analogy for parallel circuits. (GM Service and Parts Operations)

of 2 gallons per minute flows out of the tank. It will take 5 minutes to empty 10 gallons from the tank.

Notice that the faucets are connected like resistors in a parallel circuit. Because each faucet offers a path for water to flow, two paths offer less resistance than one. In the same way, two parallel paths offer less resistance than a single path and allow more total current to flow.

Current in a Parallel Circuit

The current is not the same throughout a parallel or series-parallel circuit. It is true that the same voltage is applied to each branch. But, because the resistance in each branch can be different, the current for each branch can also be different. To find the total current in a parallel or series-parallel circuit, add up the currents in all of the circuit branches. For example, you will find the current to be $2\frac{1}{2}$ amps in the circuit shown in Figure 5-12. The current of the main line is always the same as the total current because it is the only path for that part of the circuit.

SERIES-PARALLEL CIRCUITS

A **series-parallel circuit** is a circuit that contains both series circuits and parallel circuits. This type of circuit is also known as a combination circuit as shown in a circuit in Figure 5-13. The simple circuit in Figure 5-13 has a 2-ohm resistor in series from the battery then splits into two parallel branches of first a 6-ohm resistor and then a 3-ohm resistor before recombining and returning to the battery. There is no specific law or formula that pertains to the whole series-parallel circuit for voltage, amperage, and resistance. Instead, it is a matter of determining

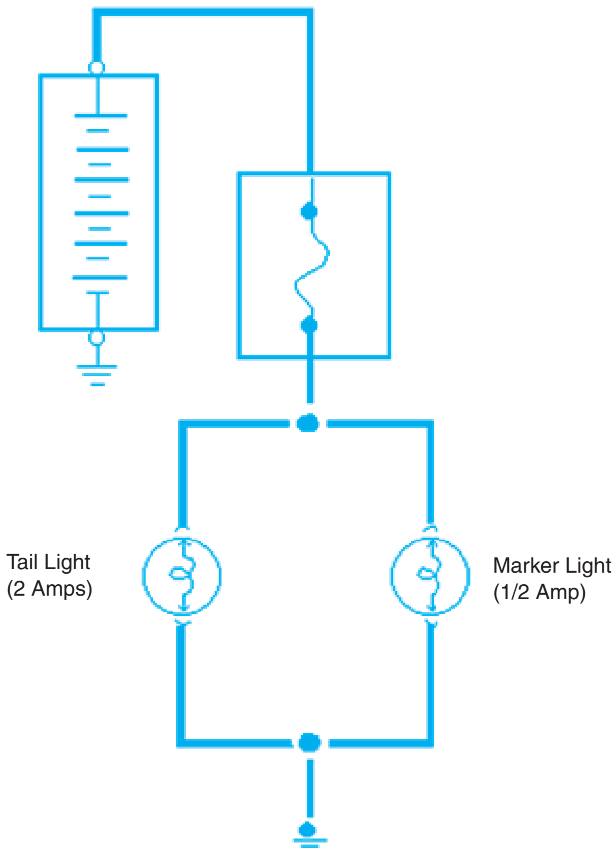


Figure 5-12. Current in a parallel circuit. (GM Service and Parts Operations)

which branch loads of the circuit are in series and which are in parallel, simplifying the circuit where possible, and using the circuit laws that apply to each of these branches to find the value totals. For more information about series-parallel circuits, see the "Circuit Faults" section in Chapter 5 of the *Shop Manual*.

Series-Parallel Circuits and Ohm's Law

Values in a series-parallel circuit are figured by reducing the parallel branches to equivalent values for single loads in series. Then the equivalent values and any actual series loads are combined. To calculate total resistance, first find the resistance of all loads wired in parallel. If the circuit is complex, it may be handy to group the parallel branches into pairs and treat each pair separately. Then add the values of all loads wired in series to the equivalent resistance of all the loads wired in parallel. In the circuit shown in Figure 5-13,

$$R_t = \frac{R_1 \times R_2}{R_1 + R_2} = \frac{6 \times 3}{6 + 3} + 2$$

$$= \frac{18}{9} + 2 = 4 \text{ ohms}$$

The equivalent resistance of the loads in parallel is

$$R_t = \frac{R_1 \times R_2}{R_1 + R_2} = \frac{6 \times 3}{6 + 3} = \frac{18}{9} = 2 \text{ ohms}$$

The total of the branch currents is $1 + 2 = 3$ amps, so the voltage drop is $E = IR = 3 \times 2 = 6$. The voltage drop across the load in series is $2 \times 3 = 6$ volts. Add these voltage drops to find the source voltage: $6 + 6 = 12$ volts.

To determine the source voltage in a series-parallel circuit, you must first find the equivalent resistance of the loads in parallel, and the total current through this equivalent resistance. Figure out the voltage drop across this equivalent resistance and add it to the voltage drops across all loads wired in series. To determine total current, find the currents in all parallel branches and add them together. This total is equal to the current at any point in the series circuit.

$$I = \frac{E}{R_1} + \frac{E}{R_2} = \frac{6}{6} + \frac{6}{3} = 1 + 2 = 3 \text{ amps}$$

In Figure 5-13, notice that there is only 6 volts across each of the branch circuits because another 6 volts has already been dropped across the 2-ohm resistor.

Figure 5-14 is a complete headlamp circuit with all bulbs and switches, which is an example of a series-parallel circuit.

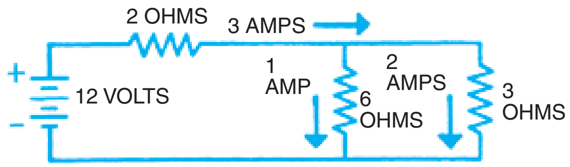


Figure 5-13. Series-parallel circuit.

Series-Parallel Circuit Exercise

Exercise Objective: Demonstrate that a series-parallel circuit has the characteristics of both a series circuit and a parallel circuit.

Assemble the circuit shown in Figure 5-15 and answer the following questions.

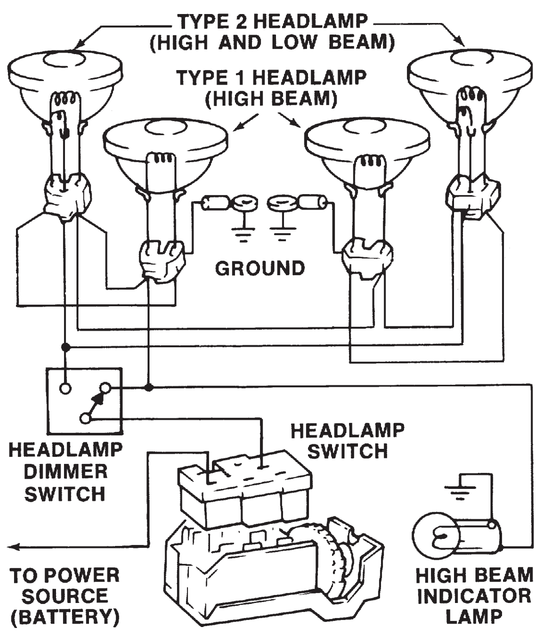


Figure 5-14. A complete headlamp circuit with all bulbs and switches, which is a series-parallel circuit.

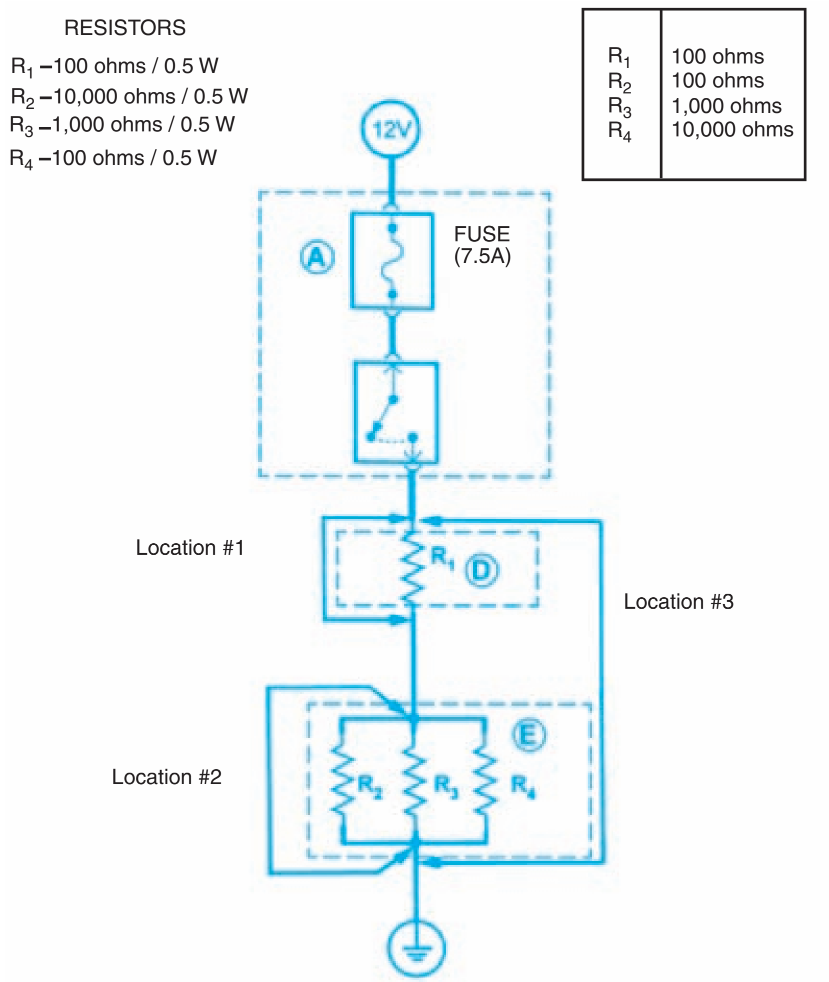


Figure 5-15. Series-parallel circuit exercise. (GM Service and Parts Operations)

1. Measure the voltage drop at location #1 and #2.
2. Measure the resistance at location #1.
3. Measure the resistance of each resistor in the parallel portion of the circuit.
4. Use Ohm's Law to figure out the total resistance for the parallel circuit.
5. Measure the resistance at location #2. Does it match your calculation?
6. Measure the resistance at location #3.
7. Does the resistance at location #1 and #2 add up to the resistance you measured at location #3?
8. Calculate the total circuit current using Ohm's Law.
9. Measure the total circuit current. Does it match your calculation?
10. Measure the current of each branch of the parallel portion of the circuit.

SERIES AND PARALLEL CIRCUIT FAULTS

Opens in a Parallel Circuit

The effect of an open on a parallel circuit (Figure 5-16) depends on where in the circuit the open is located and on the design of the circuit. If an open occurs in the main line, none of the loads on the circuit can work. In effect, all of the branches are open. If an open occurs on a branch below the main line, only the load on that branch is affected. All of the other branches still form closed circuits and still operate. For more information about opens in a parallel circuit, see the "Circuit Faults" section in Chapter 5 of the *Shop Manual*.

Opens in a Parallel Circuit Exercise

Using an OEM service manual, go to the "Exterior Lights" schematic to answer these questions. You should assume the following:

- The ignition is ON
- The turn signal switch is in LEFT
- The headlight switch is OFF

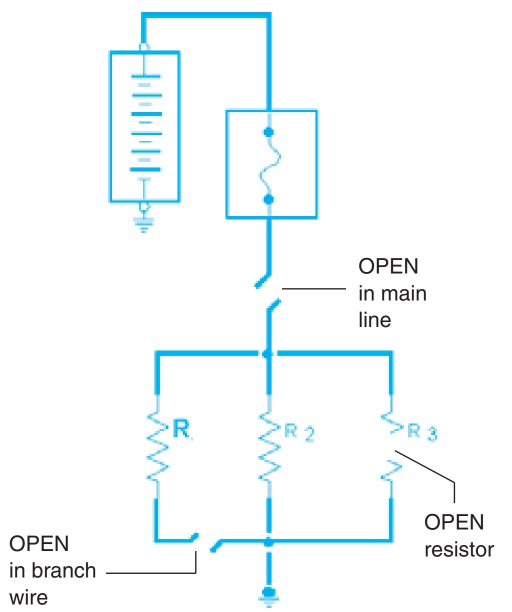


Figure 5-16. Open parallel circuits. (GM Service and Parts Operations)

1. Which loads would operate if the circuit was operating properly?

____
____
____
____

2. Which loads would operate if there was an open circuit between the turn flasher and the turn/hazard-headlight switch assembly in the circuit?

____

3. Which loads would operate if there was an open circuit between the turn/hazard-headlight switch assembly and the ground?

____

Which loads would not operate?

____

4. Which loads would operate if there was an open in the circuit between the turn/hazard-headlight switch assembly and the first connector?

____

Which loads would not operate?

____

Short to Voltage in a Parallel Circuit

A short to voltage happens when one circuit is shorted to the voltage of another circuit. Such a short can also occur between two separate branches of the same circuit. The cause is usually broken or damaged wire insulation. You can narrow down the location of a short to voltage by following the appropriate diagnostic steps, such as removing fuses and observing the results. We'll discuss these diagnostic steps in detail in Chapter 5 of the *Shop Manual*. You should also keep in mind that the OEM Service Manual often contains diagnostic procedures for specific symptoms.

The symptoms of a short to voltage depend on the location of the short in both circuits. One or both circuits may operate strangely. For example, in Figure 5-17A, the short is before the switches on both circuits. This means both switches control both loads. A different problem shows up if the

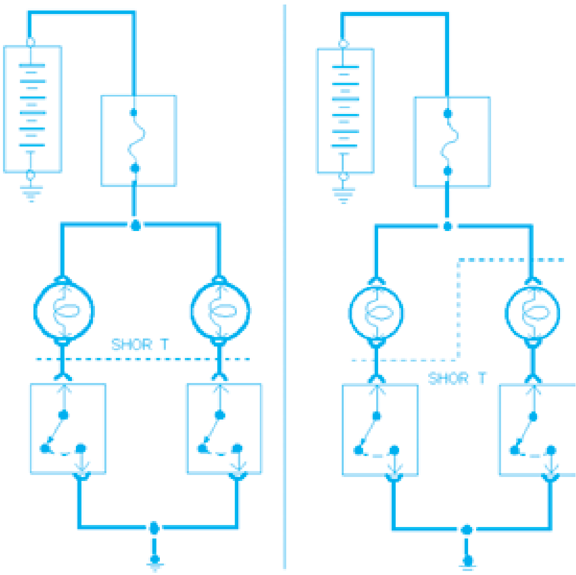


Figure 5-17. Short to voltage in a parallel circuit. (GM Service and Parts Operations)

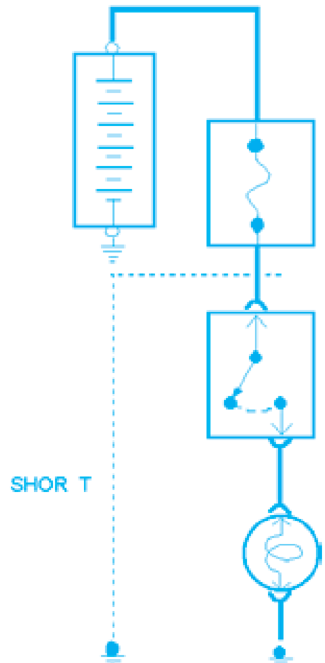


Figure 5-18. Short to ground before the switch. (GM Service and Parts Operations)

short is after the load on one branch and before the load on the second (Figure 5-17 B). The load in the second branch operates normally. The load in the first branch will not come on at all, or the current flow might be so high that the fuse blows. If there is no circuit protector, the wire could get so hot that it actually catches on fire.

Short to Ground

A short to ground (Figure 5-18) occurs when current flow is grounded before it was designed to be. This usually happens when wire insulation breaks and the wire touches a ground. The effect of a short to ground depends on the design of the circuit and on its location in relationship to the circuit control and load.

Figure 5-19 shows a short located between the switch and the load. The resistance is lower than it should be because the current is not passing through the loads. The fuse blows only after the switch is closed. Lower resistance means the current flow is higher than normal. The fuse or other circuit protector will open. An automatically resetting circuit breaker would repeatedly open and close. If there was no circuit protector at all, the wire might get hot enough to burn.

Figure 5-20 shows an example where a short to ground is after the load but before the control.

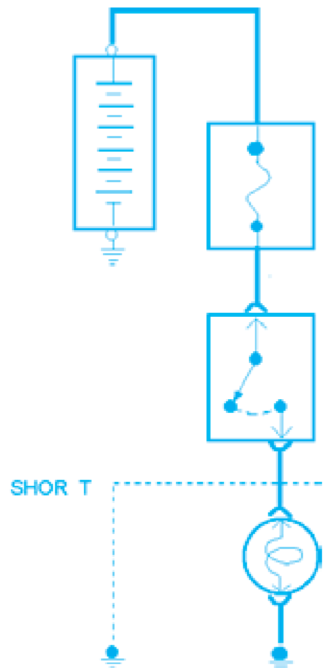


Figure 5-19. A short to ground before the load. (GM Service and Parts Operations)

This means the control switch is cut out of the circuit and the circuit is always closed. As a result, the bulb is lit all of the time. If a short to ground occurs close to the intended ground connection, you probably won't notice any effects.

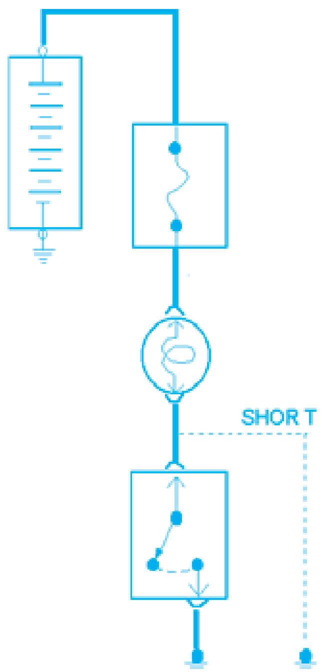


Figure 5-20. Short circuit before switch. (GM Service and Parts Operations)

SUMMARY OF SERIES CIRCUIT OPERATION

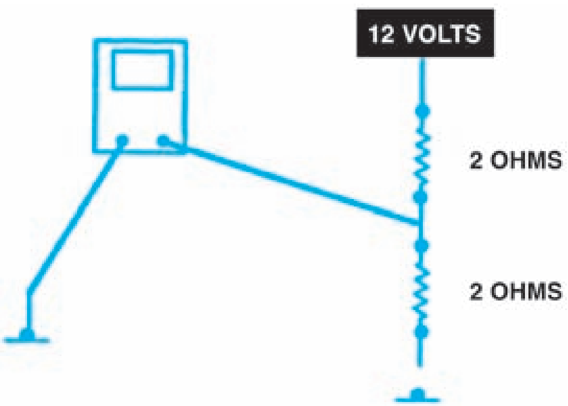
- The current flows through the circuit in only *one* path.
- The current flow is the same at any point in the circuit.
- The voltage drops in the circuit *always* add up to the source voltage.
- The total resistance is equal to the sum of the individual resistances.

SUMMARY OF PARALLEL CIRCUIT OPERATION

- The sum of the currents in each branch equals the total current in the circuit.
- The voltage drop will be the same across each branch in the circuit.
- The total resistance is always lower than the smallest branch resistance.

Review Questions

1. The total resistance is equal to the sum of all the resistance in:
   a. Series circuits
   b. Parallel circuits
   c. Series-parallel circuits
   d. Series and parallel circuits
2. What type of circuit does this figure illustrate?



   a. Series
   b. Parallel
   c. Series-parallel
   d. Broken
3. The amperage in a series circuit conforms to which of these statements:
   a. It is the same anywhere in the circuit.
   b. It is always the same at certain points.
   c. It is the same under some conditions.
   d. It is never the same any where in the circuit.
4. Where current can follow more than one path to complete the circuit, the circuit is called:
   a. Branch
   b. Series
   c. Complete
   d. Parallel
5. If resistance in a parallel circuit is unknown, dividing the voltage by the branch ________ equals branch resistance.
   a. Amperage
   b. Conductance
   c. Voltage drops
   d. Wattage
6. In most modern automobiles, the chassis can act as a ground because it is connected to the ______
   a. Negative battery terminal
   b. Generator output bolt
   c. Generator ground
   d. Positive battery terminal
7. The following are all examples of loads:
   a. Switch, motor, bulb
   b. Bulb, fuse, resistor
   c. Bulb, motor, solenoid
   d. Fuse, wire, circuit breaker
8. A circuit has only one path for current.
   a. Parallel
   b. Series
   c. Series-parallel
   d. Ground
9. In a circuit with more than one resistor, the total resistance of a series circuit is ______ the resistance of any single resistor.
   a. Greater than
   b. Less than
   c. The same
   d. Equal to
10. In a circuit with more than one resistor, the total resistance of a parallel circuit is ______ the resistance of any single resistor.
    a. Greater than
    b. Less than
    c. The same
    d. Equal to
11. Technician A says an open in one of the branches of a parallel circuit will not affect the operation of the other branches. Technician B says an open in one of the branches of a parallel circuit will not affect the operation of the other branches. Who is right?
    a. A only
    b. B only
    c. Both A and B
    d. Neither A nor B
12. Which of the following describes characteristics of two resistances connected in series?
    a. They must have different resistances.
    b. They must have the same resistance.

c. The voltage drop will be equal across each.
d. There will be only one path for current to flow.

13. What happens when one resistance in a series circuit is open?
 a. The current in the other resistance is at maximum.
 b. The current is zero at all resistances.
 c. The voltage drop increases.
 d. The current stays the same.

14. Which of the following is true regarding a series circuit with unequal resistances?
 a. The highest resistance has the most current.
 b. The lowest resistance has the most current.
 c. The lowest resistance has the highest voltage drop.
 d. The highest resistance has the highest voltage drop.

15. Which of the following is true regarding a parallel circuit with unequal branch resistance?
 a. The current is equal in all branches.
 b. The current is higher in the highest resistance branch.
 c. The voltage is higher in the lowest resistance branch.
 d. The current is higher in the lowest resistance branch.

16. The total resistance of a series circuit is:
 a. Equal to the current
 b. The sum of the individual resistances
 c. Always a high resistance
 d. Each resistance multiplied together

17. In a circuit with three parallel branches, if one branch opens, the total current will:
 a. Increase
 b. Decrease
 c. Stay the same
 d. Blow the fuse

18. Which of the following is true regarding series-parallel circuits?
 a. Voltages are always equal across each load.
 b. Current is equal throughout the circuit.
 c. Only one current path is possible.
 d. Voltage applied to the parallel branches is the source voltage minus any voltage drop across loads wired in series.

19. The amperage in a series circuit is:
 a. The same throughout the entire circuit
 b. Different, depending on the number of loads
 c. Sometimes the same, depending on the number of loads
 d. Never the same anywhere in the circuit

20. What does a short circuit to ground before the load cause?
 a. An increase in circuit resistance
 b. Voltage to increase
 c. Current flow to Increase
 d. Current flow to decrease

21. Three lamps are connected in parallel. What would happen if one lamp burns out?
 a. The other two lamps would go out.
 b. Current flow would increase through the "good" lamps.
 c. Total circuit resistance would go up.
 d. Voltage at the other two lamps would increase.

22. Total resistance in a series circuit is equal to the:
 a. Sum of the individual resistances
 b. Voltage drop across the resistor with the highest value
 c. Current in the circuit divided by the source voltage
 d. Percent of error in the voltmeter itself

23. Parallel circuits are being discussed. Technician A says that adding more branches to a parallel circuit reduces total circuit resistance. Technician B says that adding more branches to a parallel circuit increases the total current flowing in the circuit. Who is right?
 a. Technician A
 b. Technician B
 c. Both A and B
 d. Neither A nor B

24. The sum of all voltage drops in a series circuit equals the:
    a. Voltage across the largest load
    b. Voltage across the smallest load
    c. Source or applied voltage

25. What is the name for a circuit that allows two or more paths for current flow?
    a. Series circuit
    b. Parallel circuit
    c. Both A and B
    d. Neither A nor B

26. What is the name for a circuit that allows only one path for current to flow?
    a. Series circuit
    b. Parallel circuit
    c. Series-parallel circuit
    d. Integrated circuit