BASIC ELECTRICAL

CIRCUIT OPERATION

Understanding circuit basics and the construction of series and parallel circuits is fundamental to diagnosing electrical concerns successfully.

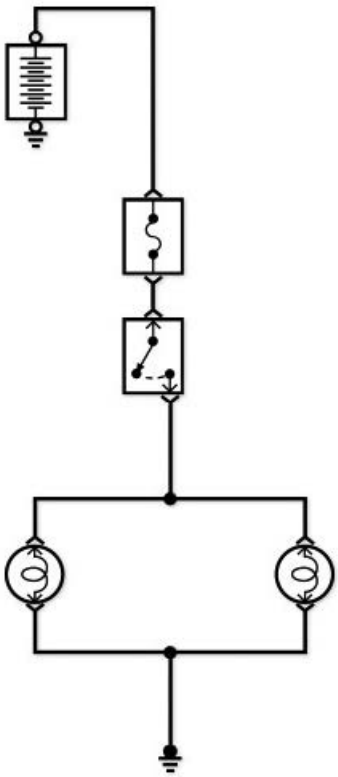
Circuits operate with all components working together as a system. A single malfunction can cause the entire circuit to become inoperative.

When a circuit or component fails, your DMM and the bus electrical schematics are tools you can use to diagnose the problem.

LEARNING OBJECTIVES

By the end of this section, you should be able to:

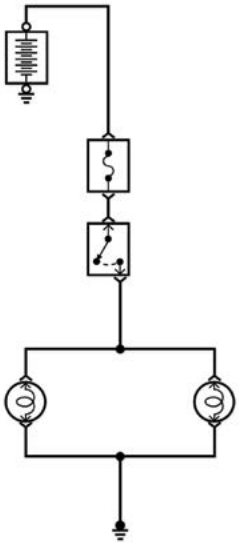
- Describe basic circuit operation
- Discuss circuit malfunctions
- Explain the process to test a circuit board



CIRCUITS REVIEW – POWER AND GROUND

Electrical components require a power source and ground path to operate. The conductors, connections, and control devices all come together to provide the necessary energy.

Without reliable power and ground sources, systems can malfunction and become inoperative.

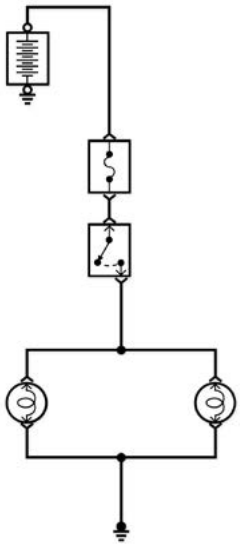


CIRCUITS REVIEW – VOLTAGE

Often, the first thing to check is the available voltage at a component, control device, or circuit protection device.

To check for voltage:

1. Place the DMM selector in Volts position.
2. Attach the black meter lead to ground.
3. Activate the circuit.
4. Touch the red meter lead to the circuit being tested.

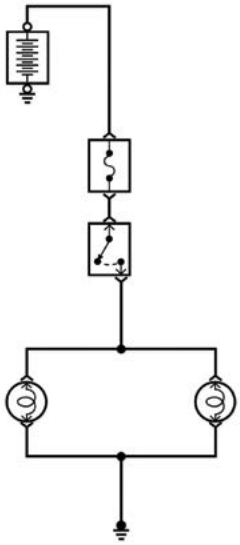


CIRCUITS REVIEW – RESISTANCE

Checking for resistance is crucial to understanding the general condition of a conductor or component.

To measure resistance:

1. Power OFF the circuit.
2. Electrically isolate the component you are testing.
3. Set the DMM to Ohms.
4. Touch one meter lead to each end of the conductor or component.

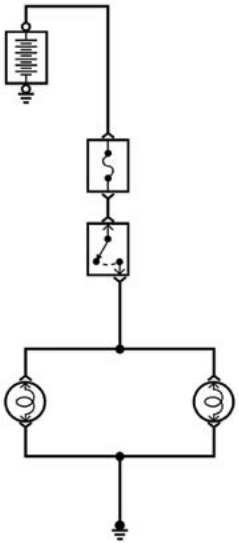


CIRCUITS REVIEW – AMPERAGE

Current flow is a good indicator of the overall health of a circuit and component.

To measure current of 10 amps or less:

1. Insert the red lead in the A jack on the meter.
2. Set the meter selector to mA~A.
3. Connect the meter leads in series with the load.
4. Activate the circuit.

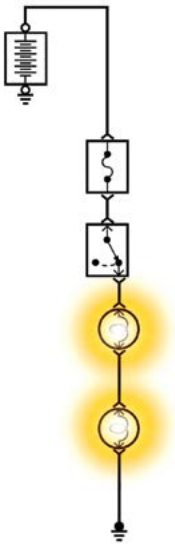


Measuring amperage higher than 10A requires specialized equipment, which we will discuss in a later section.

CIRCUITS EXPLAINED – SERIES CIRCUIT

A series circuit has specific characteristics:

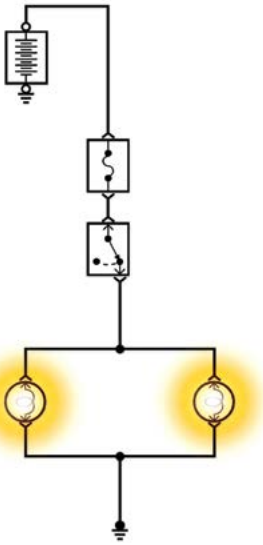
- One path to power
- One path to ground
- Electricity flows one way
- All components share the same current
- Total resistance is the sum of individual resistances
- Sum of voltage drops equals source voltage



CIRCUITS EXPLAINED – PARALLEL CIRCUIT

A parallel circuit has specific characteristics:

- More than one path to power
- More than one path to ground
- Electricity flows along multiple paths
- All components share the same voltage
- Total resistance is less than the lowest branch resistance
- Total current equals sum of branch currents

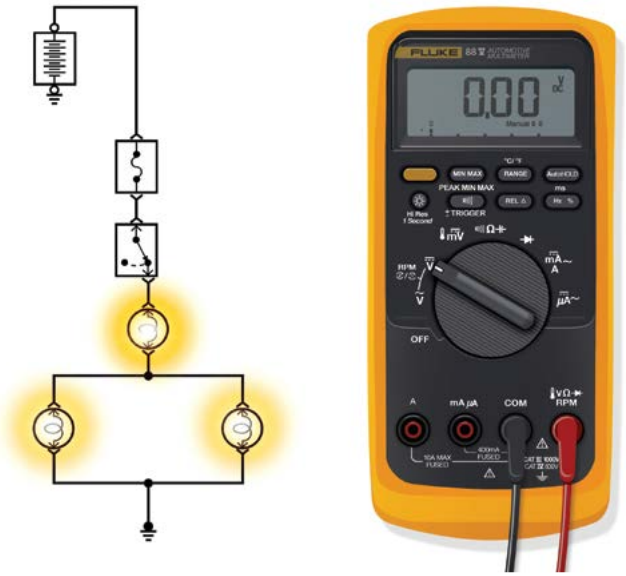


CIRCUITS EXPLAINED – SERIES-PARALLEL CIRCUIT

A series-parallel circuit consists of both series and parallel wiring.

This type of circuit uses a load to regulate the amperage in series to the rest of the circuit that is in parallel.

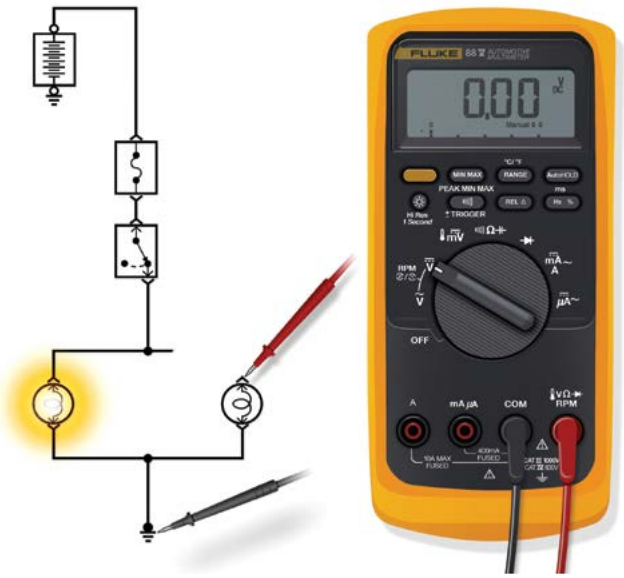
Always review diagrams to understand how the circuits are arranged.



CIRCUITS EXPLAINED – OPEN CIRCUIT

An open circuit is a loss of continuity within the circuit. When systems experience open circuit failures, components usually stop operating.

Sometimes an open in one circuit affects others. When diagnosing issues, make note of all circuits that are not operating correctly.



OPEN CIRCUIT – ACTIVITY

With the circuit activated, use your DMM in Volts mode to test for voltage at the load. If you find voltage potential at the load, test the ground path. A reading of source voltage on the ground side of the load indicates an open in the ground circuit.

If there is no voltage at the load, follow the circuit on the schematic and test for voltage at various connectors along the path.

The loss of continuity will be between the connector you are testing and the voltage source.

CIRCUITS EXPLAINED – SHORTED CIRCUIT

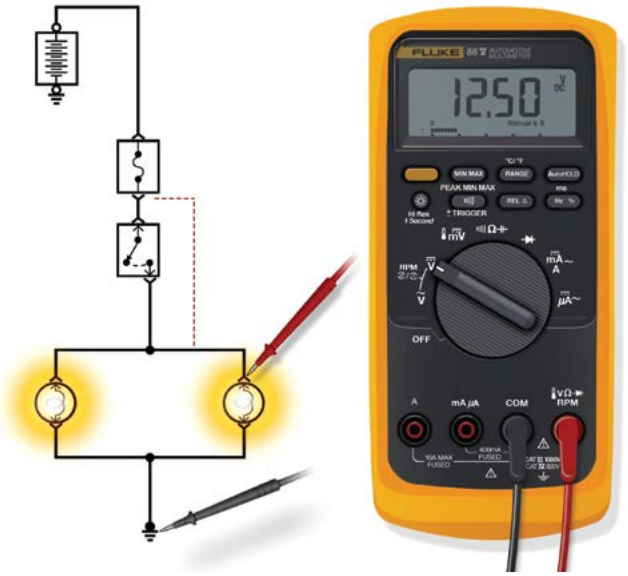
There are two types of short circuits:

- Short-to-power
- Short-to-ground

Short-to-Power

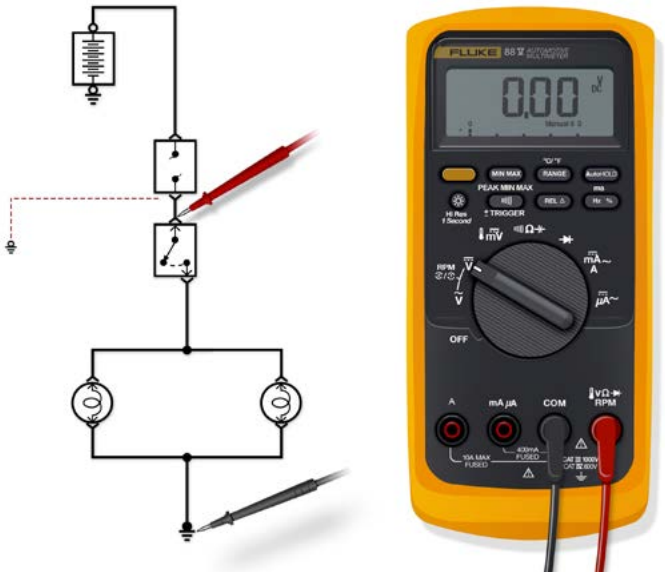
A circuit unintentionally shorted to a power source can cause a motor to run or lights to illuminate.

An activated circuit can cause a power drain, also referred to as a ‘parasitic load,’ even without a visual indication.



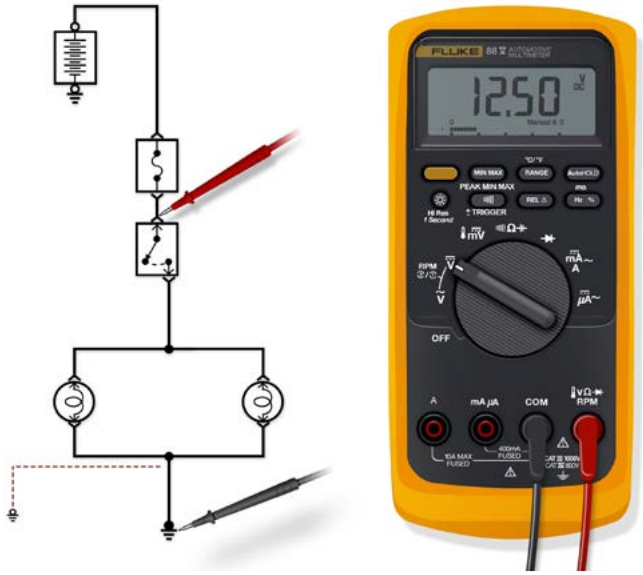
Short-to-Ground

A short-to-ground typically causes a fuse to blow or a circuit breaker to open. The increased amperage will overload the circuit protection device depending on the short's location.



CAUTION: Never replace a fuse or circuit breaker with one that has a higher amperage rating.

Other short-to-ground failures may not show any symptoms, depending on where the failure has occurred.



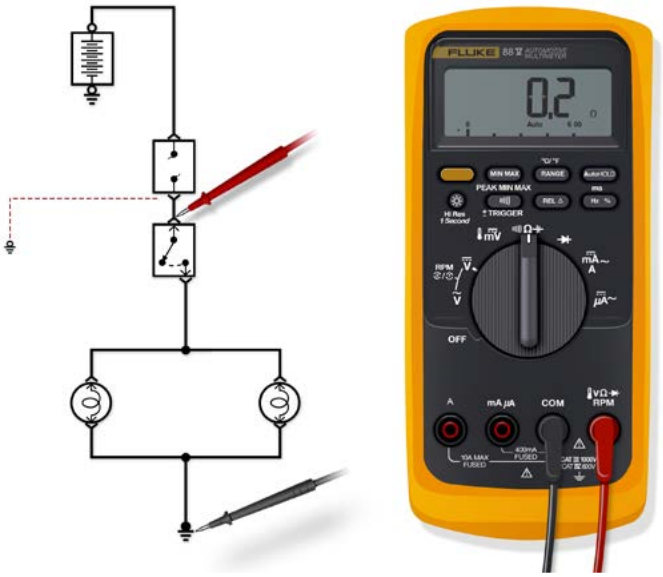
An example is when a short-to-ground occurs within a circuit after the load. The circuit could remain unaffected by that type of failure.

SHORTED CIRCUIT – ACTIVITY

When diagnosing issues, make note of all circuits that are not operating correctly.

With the circuit deactivated, use your DMM in Ohms mode. Disconnect the load and verify that its resistance reading is within specification. Leave the load disconnected to eliminate the ground circuit.

Follow the circuit on the schematic and test for low resistance to ground at various connectors along the path. The short will be between the connector you are testing and the voltage source.

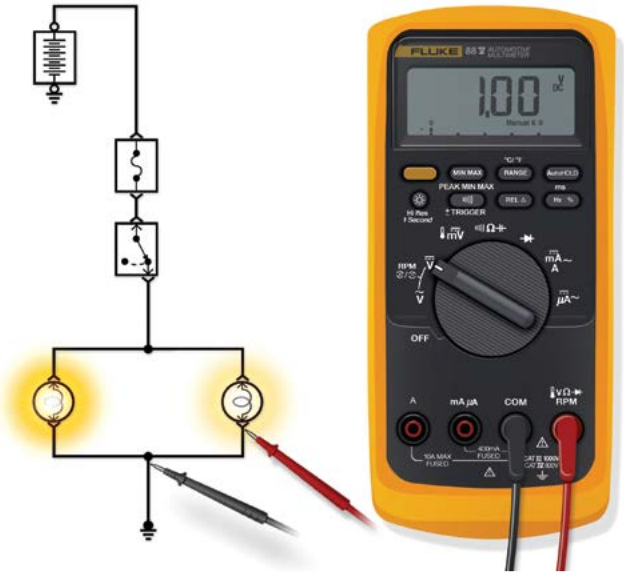


CIRCUITS EXPLAINED – EXCESSIVE RESISTANCE

Circuits with excessive resistance cause components to operate slowly or not at all.

Excessive resistance reduces current flow, leaving less current available to operate the load.

Often the excessive resistance is located at a connection within the circuit, at the load, or the chassis ground.



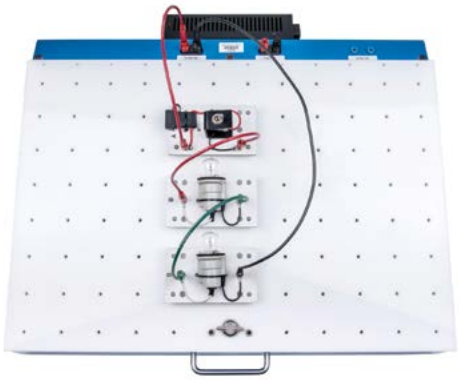
EXCESSIVE RESISTANCE – ACTIVITY

Using the schematic as a guide, perform a visual inspection of the circuit. Look for melted connectors or corrosion, common causes of high resistance.

With the circuit deactivated, use your DMM in Ohms mode. Disconnect the load and verify that its resistance reading is within specification. Follow the circuit on the schematic and test for high resistance between the voltage source and various connectors along the path.

The high resistance source will be between the connector you are testing and the voltage source.

With the circuit activated, use the voltage drop method and your DMM in Volts mode. Follow the circuit on the schematic and test for low voltage at each connection.



The following table lists the generally-accepted guidelines for allowed voltage drops.

SAE Recommended Maximum Voltage Drops	
Component	**Voltage Drop**
Small current connection	0.0 V
Large current connection (fuel pumps, headlights, etc.)	0.1 V
Ground connection	0.1 V
High current cables (battery/starter cables)	0.3 V
Switch or relay contacts	0.3 V

NOTE: Take all measurements at normal operating voltage and load.

Limits are for each connection. Individual voltage drops are cumulative in a circuit.

NOTE: Individual bus manufacturers have different circuit specifications. Always refer to the appropriate service manual for specific instructions and specifications.

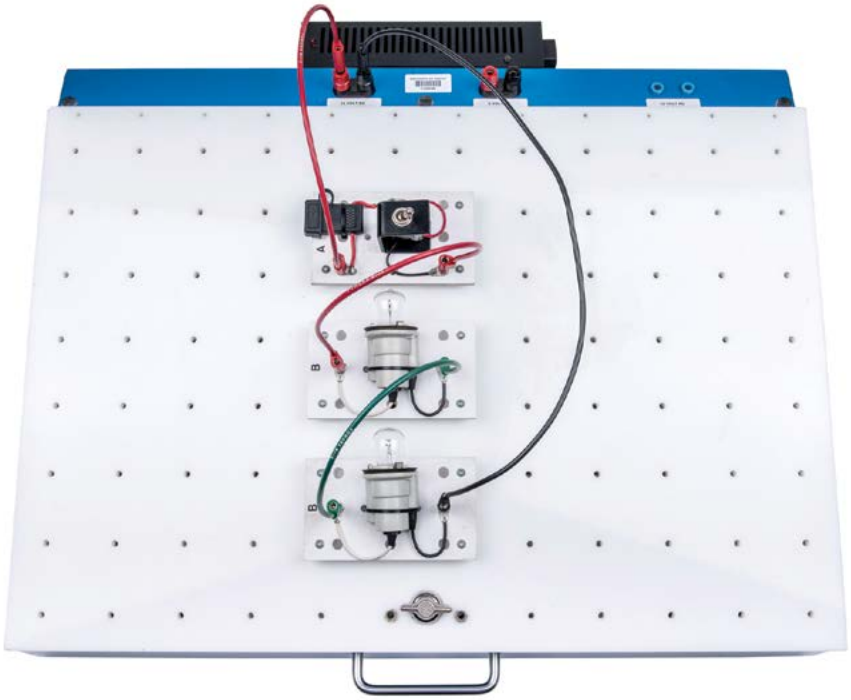
BUS CIRCUITS – EXPLORE THE WIRING DIAGRAM

Regardless of what you are diagnosing, be sure to reference the electrical schematics for the correct circuits to test.

Use the service information or wiring diagram to diagnose the circuit.

SUMMARY – CIRCUIT OPERATION

In this section, you have learned the characteristics of series, parallel, and series/parallel circuits. You have also learned how to use your DMM to identify common circuit faults and practice basic diagnostic techniques on simulations of real-world circuits.

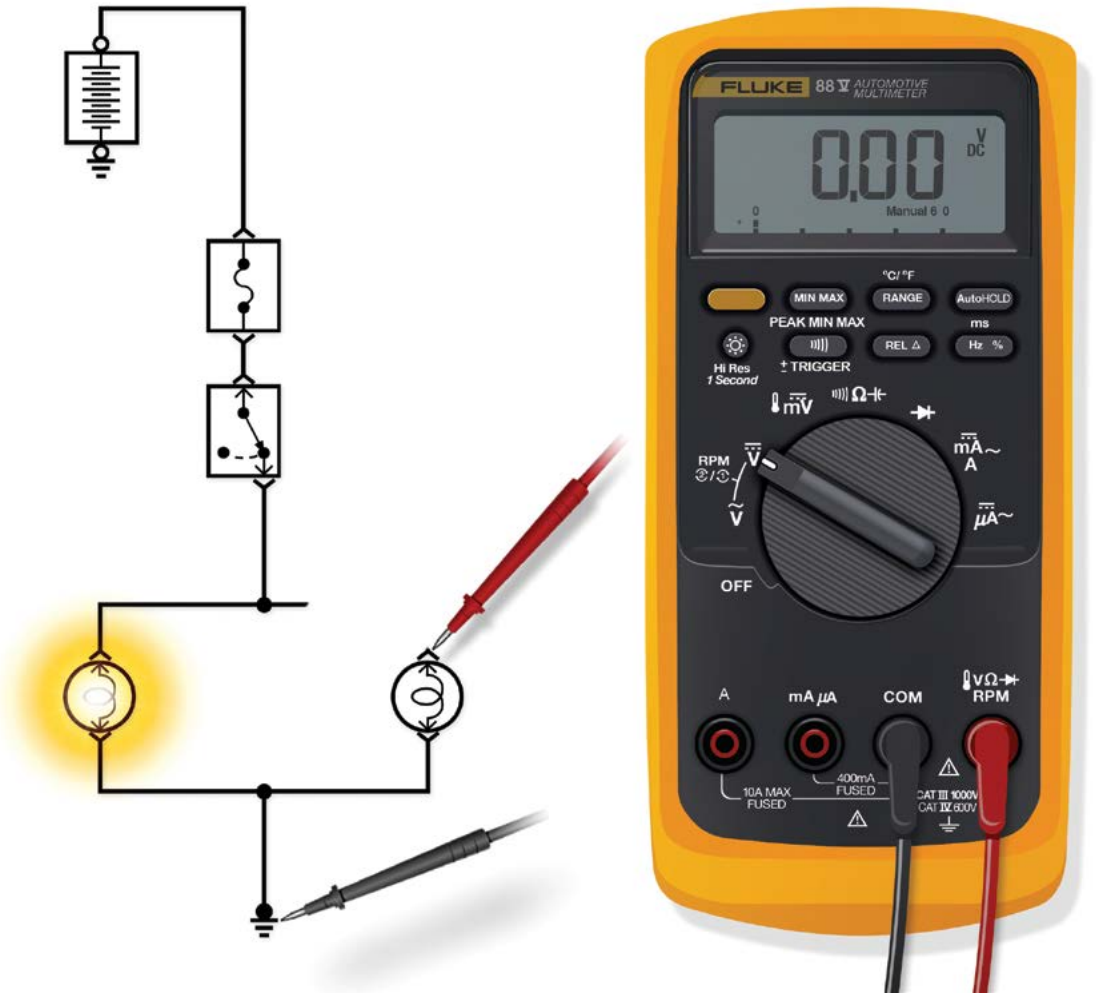


CIRCUITS EXPLAINED – OPEN CIRCUIT

An open circuit occurs when voltage cannot flow through the circuit.

You can test for an open using your DMM.

- To verify an open circuit, set your DMM to the Volts or the Ohms setting.
- When using the Ohms setting, the circuit must be powered OFF and the component isolated.



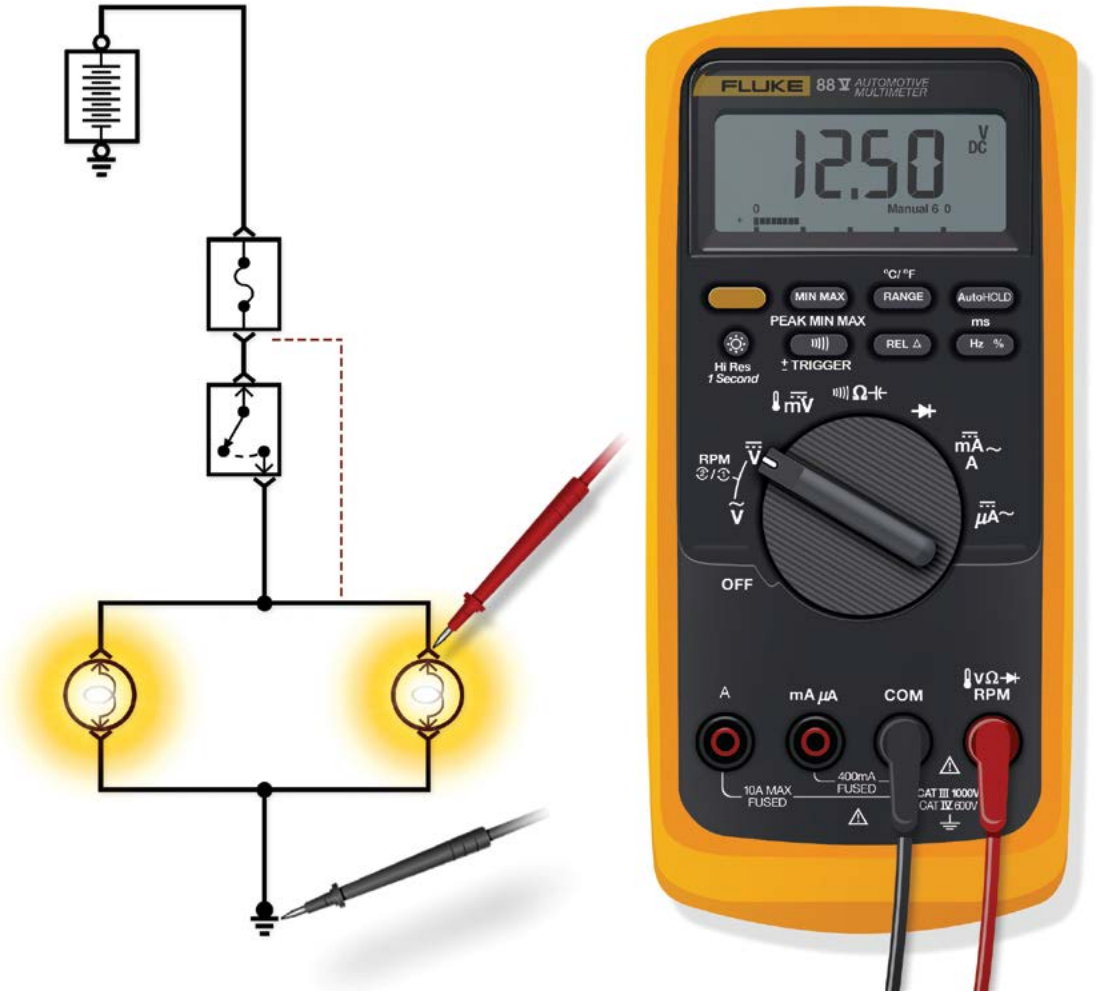
CIRCUITS EXPLAINED – SHORT-TO-POWER

Short-to-power occurs when wiring is unintentionally connected to the power source.

You can use your DMM to test for short-to-power.

- To test for short-to-power, set your DMM to the Volts setting.

Using the Volts setting, you can test for available voltage and voltage drop. The voltage drop measurement is the most accurate indication of what is occurring in the circuit.



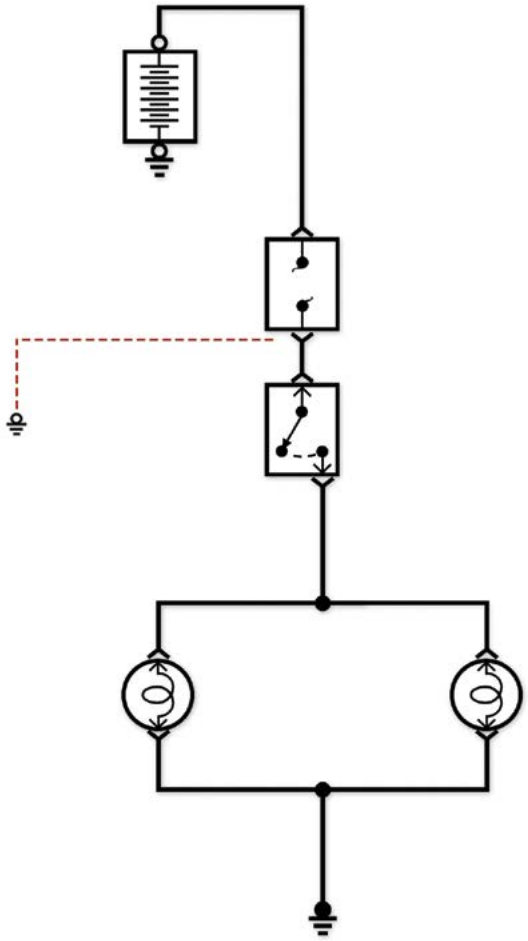
CIRCUITS EXPLAINED – SHORT-TO-GROUND

Short-to-ground occurs when the circuit is connected to an additional ground other than the one that already exists.

You can use your DMM to test for short-to-ground.

- To test for short-to-ground, set your DMM to the Volts setting.

Using the Volts setting, you can test for available voltage and voltage drop. The voltage drop measurement is the most accurate indication of what is occurring in the circuit.



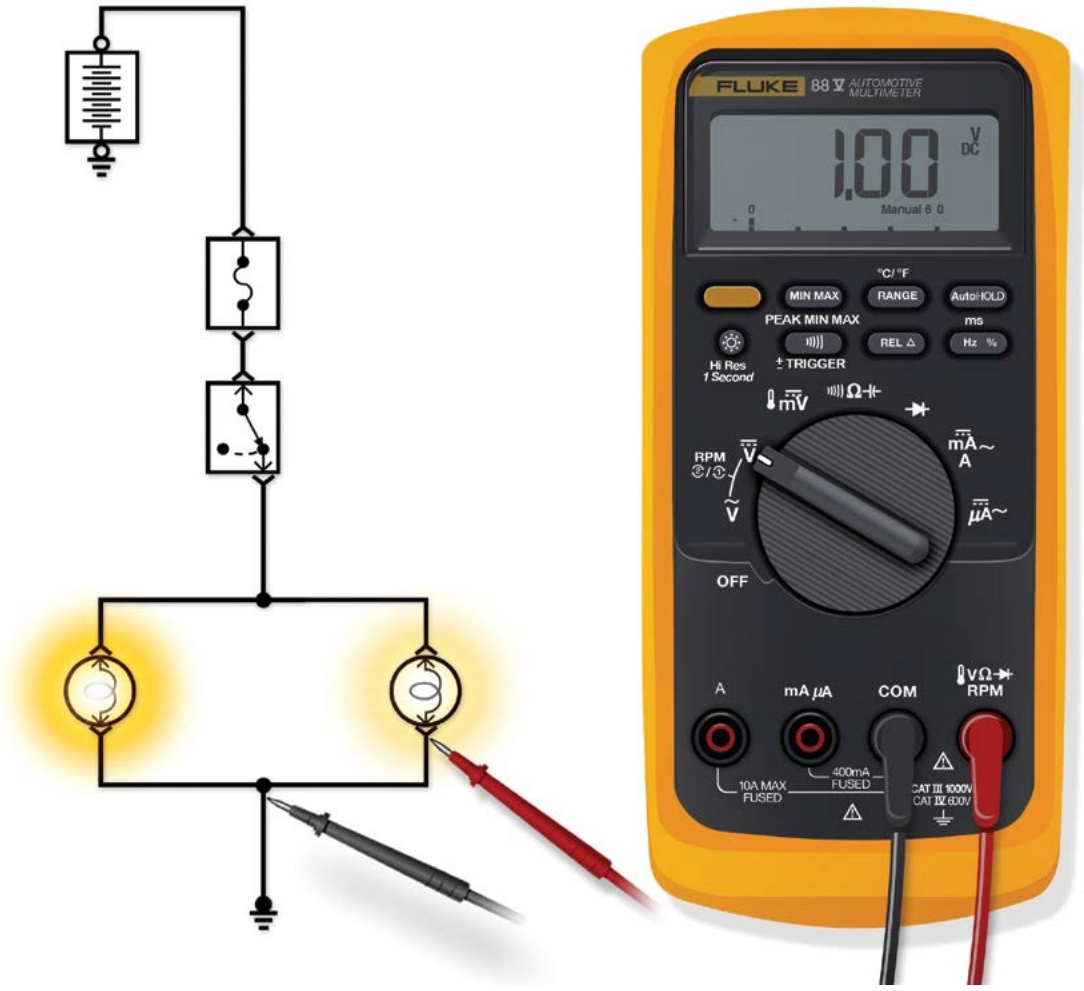
CIRCUITS EXPLAINED – HIGH RESISTANCE

High resistance occurs when resistance in a circuit exceeds its normal range, causing components to operate slowly or not at all.

You can use your DMM to test for resistance.

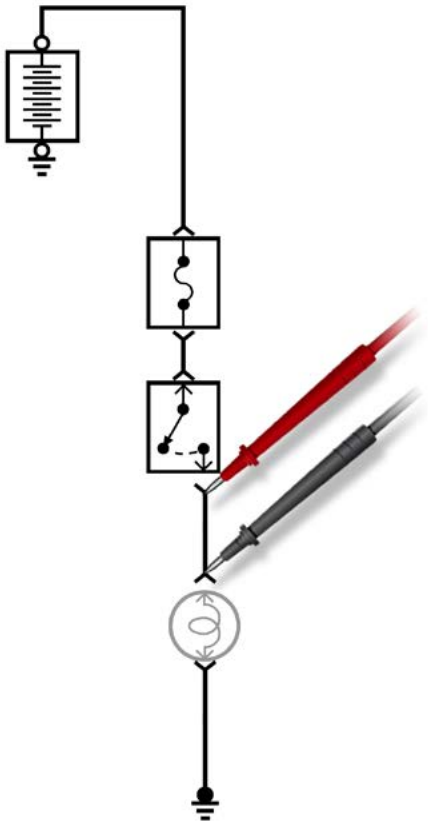
- To test for resistance, set your DMM to the Volts or the Ohms setting.
- When using the Ohms setting, the circuit must be powered OFF and the component isolated.

Since high resistance manifests as excessive voltage drop when the circuit is live, you can use voltage drop to test for this malfunction. The voltage drop measurement is the most accurate indication of what is occurring in the circuit.



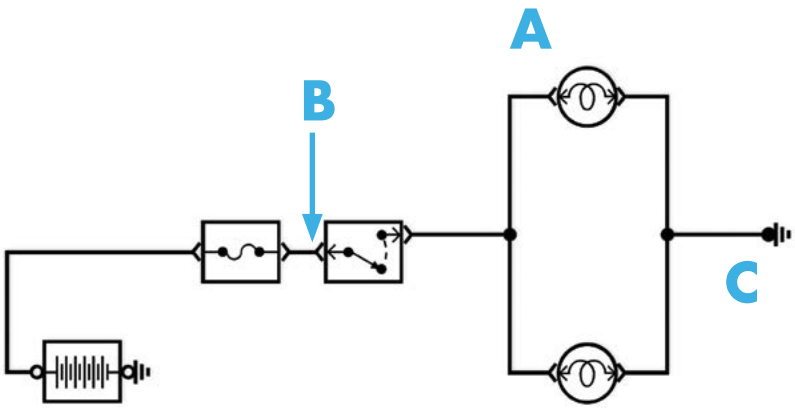
CIRCUITS EXPLAINED – CONTINUITY

- **Use the wiggle test whenever you are checking for continuity or intermittent faults in a harness.**
- **You can use your DMM to test for continuity and intermittent faults.**
  - To test for continuity and intermittent faults, set your DMM to the Ohms setting.
- **Meter leads must be connected to both ends of the harness for the same wire.**
- **Wiggle the harness while observing the DMM or scan tool diagnostic software for changes.**
- **Readings should remain constant and not fluctuate.**



CIRCUIT MALFUNCTIONS	NAME:	DATE:

Assemble the circuit below, perform the following tasks and answer questions about circuit malfunctions.



1. Disconnect the ground for light bulb A. What happened?

2. Describe the circuit malfunction. Reconnect the ground to light bulb A.

3. If there is a short-to-power from point B to point A, what happens to light bulb A in the circuit?

4. What is the reason behind your result?

5. Would the fuse still work?

In the circuit shown, there is a short-to-power from point B to point C resulting in excessive amperage. This causes major problems in the operation of the circuit.

6. Comparing this circuit malfunction with the malfunction described in question 3, what are the differences?

7. What happens to the fuse in the scenario described in the previous question?

8. If there is a short-to-ground immediately after light bulb A, what happens to the fuse?

9. Considering the circuit malfunctions presented in this worksheet, which one would cause a circuit overload?

10. Which circuit causes an incomplete circuit?

NOTES

NOTES