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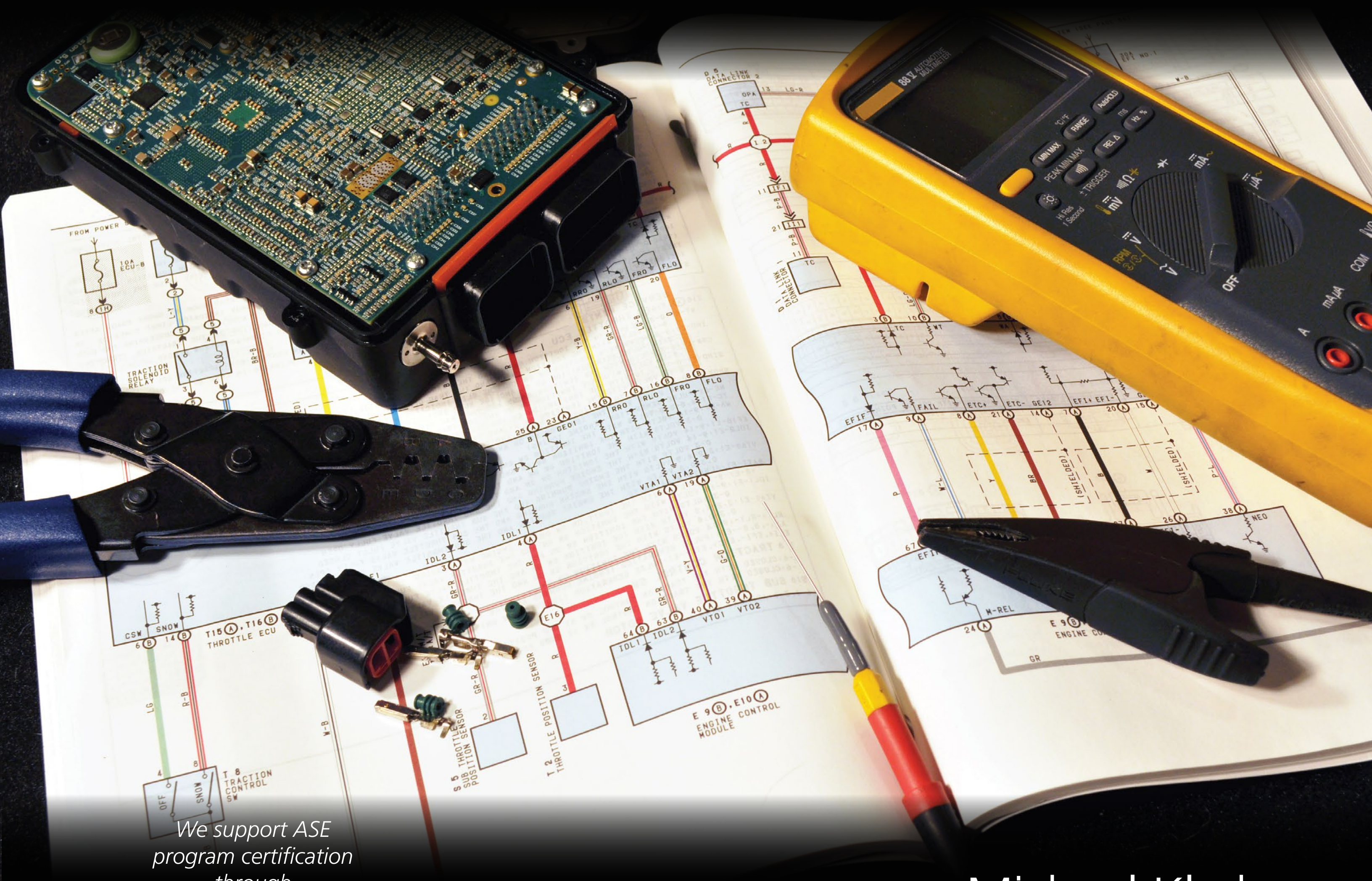
SAMPLE CHAPTER 6

Advanced Automotive Electricity and Electronics



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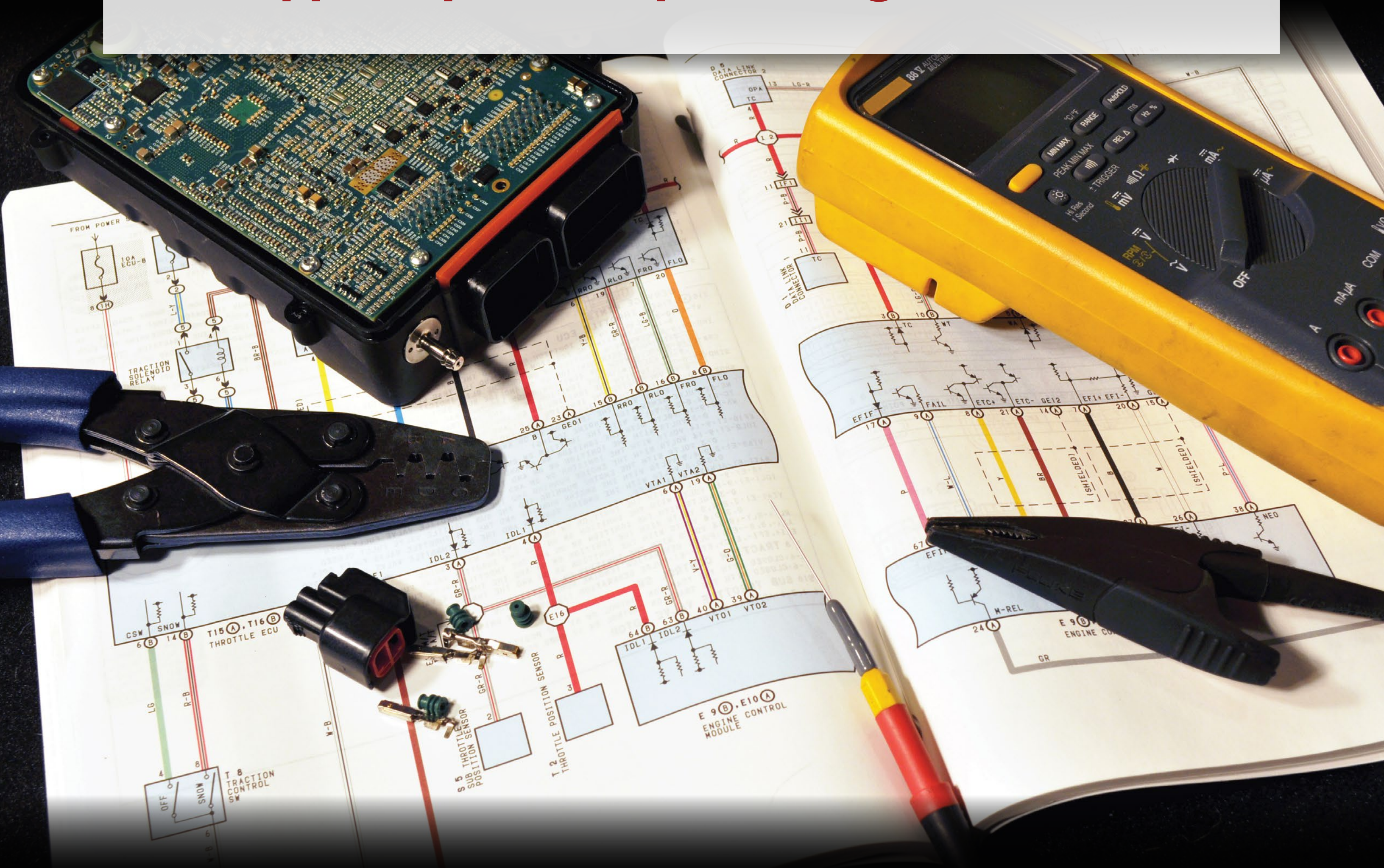

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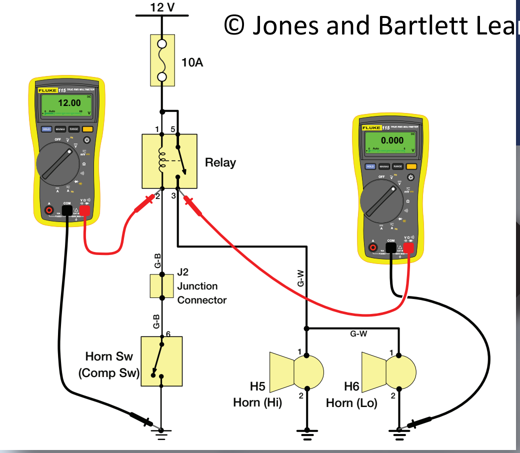


CHAPTER 6

Circuit Diagnosis

NATEF Tasks

- **N06001** Demonstrate proper use of a digital multimeter (DMM) when measuring source voltage, voltage drop (including grounds), current flow and resistance. (MLR/AST/MAST)
- **N06002** Use fused jumper wires to check operation of electrical circuits. (MLR/AST/MAST)
- **N06003** Demonstrate knowledge of the causes and effects from shorts, grounds, opens, and resistance problems in electrical/electronic circuits. (MLR/AST/MAST)
- **N06004** Measure key-off battery drain (parasitic draw). (MLR) Diagnose the cause(s) of excessive key-off battery drain (parasitic draw); determine needed action. (AST/MAST)
- **N06005** Inspect and test switches, connectors, and wires of starter control circuits; determine needed action. (MLR/AST/MAST)

Knowledge Objectives

After reading this chapter, you will be able to:

- **K06001** Describe how to measure voltage.
- **K06002** Outline the process of measuring amperage.
- **K06003** Describe the various types of circuit faults that you will diagnose as a technician.
- **K06004** Explain the diagnostic importance of testing switches, connectors, and wiring.

Skills Objectives

After reading this chapter, you will be able to:

- **S06001** Apply the diagnostic process to isolate the cause of an electrical concern beginning with the repair order and detailing your process and recommended repairs.
- **S06002** Create a repair order for your assigned vehicle(s) to document your diagnosis of automotive circuits that have one of the following faults:
  - **a.** Open circuit
  - **b.** High resistance
  - **c.** Short circuit
  - **d.** Shared voltage fault
  - **e.** Parasitic draw fault

You Are the Automotive Technician

The customer states the driver's door window operates slower than it used to and sometimes gets stuck in the down position. The technician verifies the driver's window is much slower going down or up than the other windows, which operate at normal speed. From the verification of the concern answer the following:

1. Can any circuit components be eliminated as the cause of the fault?
2. What components may be causing this fault?
3. What type of circuit tests would you use to isolate the cause of this fault?

▶ Introduction

A source, protection device, control device, load (component that does the work) and ground path are found in every automotive circuit. Customers do not bring in their vehicles for circuit checkups or maintenance; they come to the shop or, even worse, are towed in when an electrical system fault has occurred. The technician must be up for the task. Unlike a fluid leak or an abnormal noise, electrons flowing in a circuit cannot be seen or heard. Technicians must be proficient at using service information, circuit wiring diagrams, and the digital multimeter (DMM) for electrical system diagnosis. Like any task, repetition and practice allow technicians to identify the cause of electrical faults—just like a good baseball pitcher can, with practice, place the ball where desired over home plate.

K06001 Describe how to measure voltage.

N06001 Demonstrate proper use of a digital multimeter (DMM) when measuring source voltage, voltage drop (including grounds), current flow and resistance. (MLR/AST/MAST)

▶ TECHNICIAN TIP

A source voltage reading of 12.8 volts or more indicates the battery has a surface charge (**FIGURE 6-2**). Turn the headlights on for approximately one minute with the engine off, and then turn the lights off. Wait approximately two minutes and then measure source voltage again. A source voltage of 12.4 volts or less indicates the battery is discharged as follows: 12.4V = 75% charged, 12.2V = 50% charged, 12.0V = 25% charged, and 11.9V or less the battery is discharged. Modern batteries should be charged using a "**smart charger**" that monitors battery voltage and current, controlling how fast the battery is charged to prevent damage. Be sure to select the correct battery construction type on the smart charger control panel to prevent battery damage.

▶ Measuring Voltage

Measuring voltage is the most frequently performed electrical system diagnostic test. Measuring source voltage should be one of the first inspection points of any electrical system concern (**FIGURE 6-1**). Measure source voltage at the battery with the vehicle off and all electrical loads off. A fully charged battery should indicate very close to 12.6 volts on the **digital multimeter (DMM)**. Perform a battery test if source voltage is 12.4 volts or less before continuing diagnosis. The concern may be due to a faulty battery or a problem with the charging system.

The DMM on the volt setting is measuring the difference in voltage (potential or pressure) between the positive test lead and the negative test lead. Using the battery as an example, the positive post of the battery has a potential of 12.6 volts and the negative post of the battery has a potential of 0 volts when fully charged. In simple terms, the DMM takes the voltage measured on the positive lead and subtracts it from the negative lead: 12.6V – 0.0V = 12.6V. Looking at the voltage predicted in the circuit in **FIGURE 6-3**, the technician has predicted source voltage before the load and after the load when the circuit is off: 12.6V – 12.6V = 0.0V. There is no potential difference between these two test points when the circuit is off so the DMM displays 0.00V.

Measuring available voltage and voltage drop in the circuit is part of the diagnostic process. Perform these tests once you have reviewed the service information, traced circuit current paths, and predicted circuit voltages at applicable test points. It is usually best to start with available voltage tests as the results are shown on the DMM display even if no current is present in the circuit. Available voltage tests are made by placing the DMM negative test lead on a known good ground location. Place the DMM positive test lead at the desired test point in the circuit. Compare the test result to your predicted voltage on

FIGURE 6-1 Source voltage is measured at the battery and should be very close to 12.6 volts.

FIGURE 6-2 A battery with 12.4V or less should be tested and, if OK, charged to 100% using a "Smart" charging system.

the wiring diagram. A circuit fault is noted when the voltage is not close to what should be present. The available voltage test can quickly narrow your search for the cause of a circuit fault, like an open circuit concern (**FIGURE 6-4**).

Voltage drop tests require that current is present in the circuit. Remember, voltage only drops in the presence of current. The voltage drop test is the best test for isolating high resistance faults in a circuit (**FIGURE 6-5**). A voltage drop test is performed by placing the positive lead of the DMM on the most positive portion of the circuit and the negative lead on the most negative portion of the circuit with the test circuit energized (on). A voltage drop can be performed on any portion of the circuit—across the load where most of the voltage should be used to perform work, a connector, a switch, a section of wiring, or the ground (**TABLE 6-1**). You can apply one of Kirchhoff's laws to verify your voltage drop testing was done correctly. Kirchhoff stated that the sum of the voltage drops in a circuit must equal source voltage. After you note your voltage drops, add them up to verify they equal source voltage. This ensures that you did not misinterpret a voltage reading or have one or both of the test leads in the wrong location.

Resistance Testing

A resistance test is best used when testing a circuit component as part of the service information's diagnostic procedure. You may need to measure a relay coil, thermistor, solenoid, or a fuel injector for resistance and then compare your DMM reading with the service information specification (**FIGURE 6-6**).

Resistance tests are made with the circuit off and isolating the component or portion of the circuit you will be testing. Isolate the component by disconnecting the

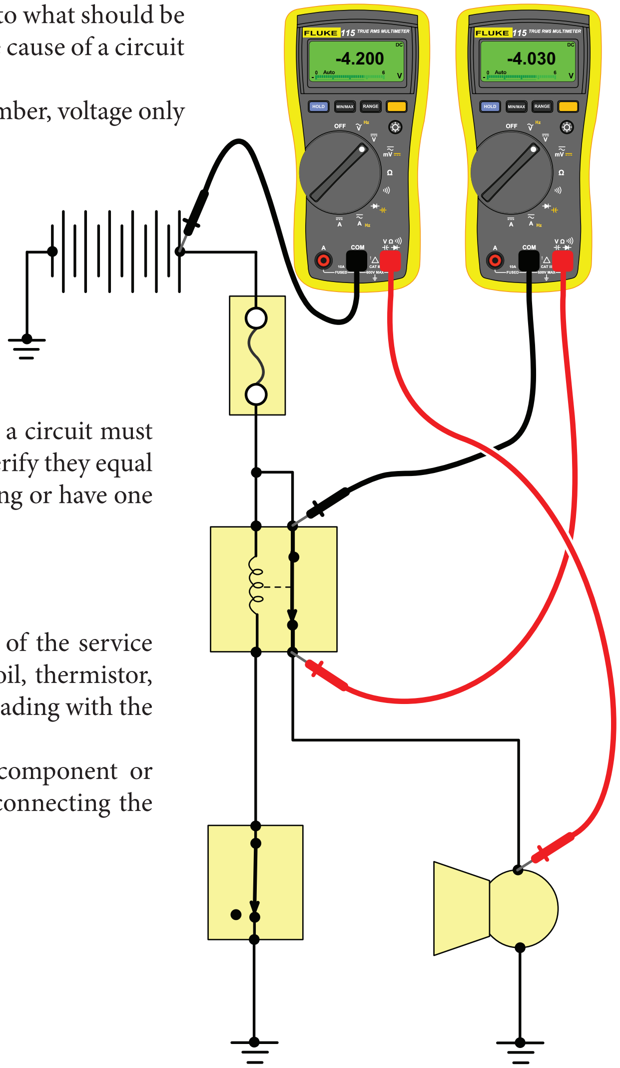


FIGURE 6-3 The DMM test leads are measuring the voltage before and after the relay coil with the circuit off. Source voltage is present at the positive and negative test lead so the DMM displays a difference between the two test points as 0.00V.

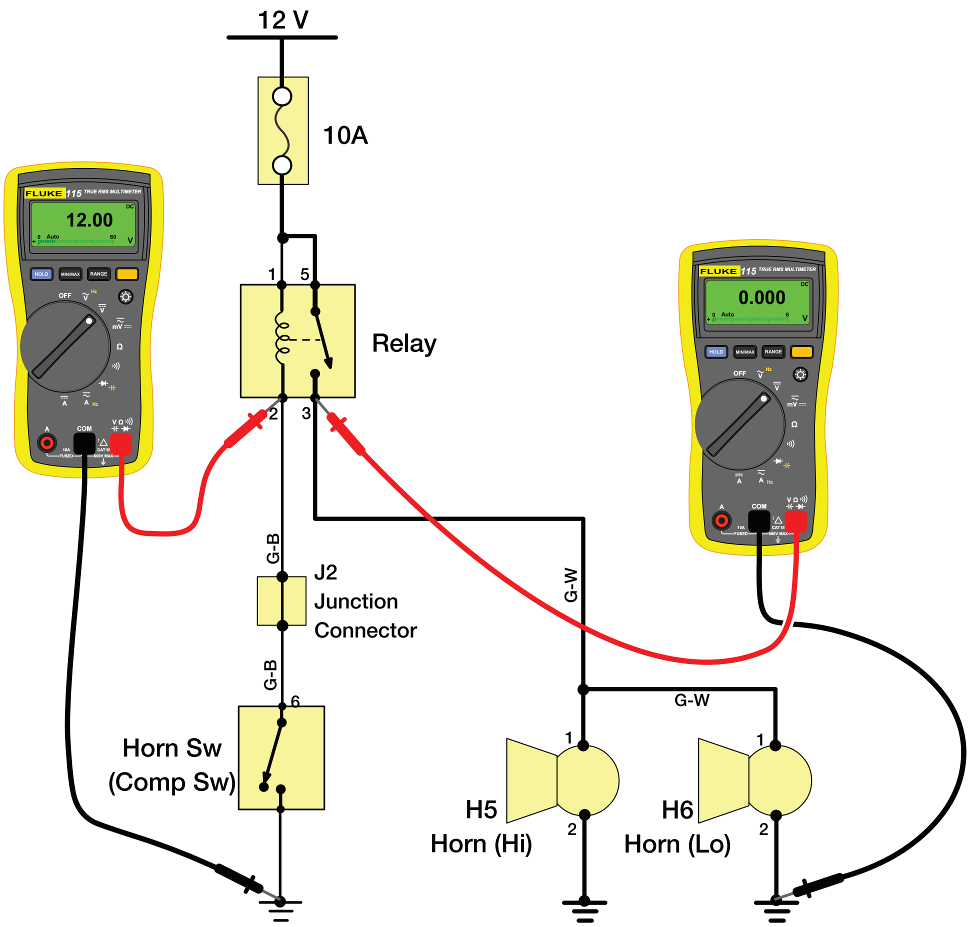


FIGURE 6-4 Available voltage tests do not require current to be present in the circuit and can quickly pinpoint that there is an open circuit fault.

▶ TECHNICIAN TIP

Why not use the resistance function of the DMM test to find an unwanted circuit resistance? DMM resistance tests require the circuit is off and the portion of the circuit or component you are testing is isolated from other parts of the circuit by disconnecting them. The DMM places a low voltage at each lead and monitors current to then calculate and display the resistance. The problem with this method is that the current is so low that it is very easy for faulty components to show normal resistance during the test. An example is a damaged wire where only one or two strands of copper are connected through the whole section of the wire. The resistance test will show the wire is OK; however, when the circuit is turned on, the normal current levels cause a high voltage drop at the point where the wire is damaged since only a small amount of current can pass through the remaining strands of wiring. The voltage drop test is able to detect the damaged wire because the circuit is on when being tested.

▶ TECHNICIAN TIP

It is important to note that the resistance of a component can change when it is energized (turned on). The resistance may increase or decrease and cause erratic operation. A component that is turned on by an electronic control unit (ECU), like a fuel injector, can damage the internal ECU circuits if the resistance drops to near zero or completely shorts to 0 ohms. This increases current to levels that damage electronic circuits. Many manufacturers require that both the component, like a fuel injector in this example, be replaced if it is also determined that the ECU is not functioning to operate it.

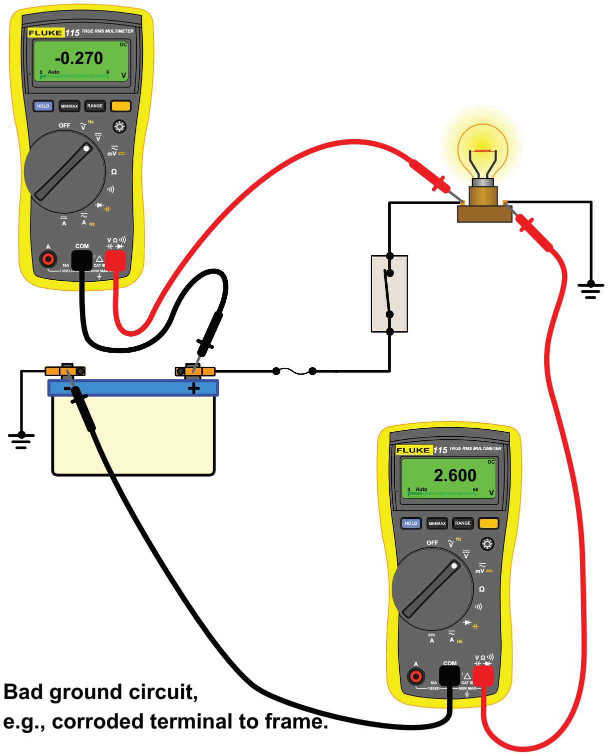


FIGURE 6-5 Voltage drops in the presence of current and can be measured with the DMM when the circuit is on.

TABLE 6-1

Component	Maximum voltage drop
Circuit load	Very close to source voltage
Connector	0.0 – 0.1 volt (<100 mV)
Section of wire	0.0 – 0.1 volt (<100 mV)
Current carrying switch	0.0 – 0.1 volt (<100 mV)
Relay contacts	0.0 – 0.1 volt (<100 mV)
Ground	0.0 – 0.05 volt (<50 mV)

harness connector. You may need to use a pin test toolkit to connect the DMM leads to the component (**FIGURE 6-7**). Compare your reading to the specification in the service information and note that if the temperature is warmer or colder than noted, your reading will vary. Warmer conditions increase resistance; cooler temperatures will lower the resistance. To measure resistance in a portion of the wiring harness, isolate it by disconnecting it at two locations (see Figure 6-7); you can then connect the DMM to the related pin in each connector and note the resistance reading. Wiring should have almost no resistance so the reading should be very close to 0 ohms.

▶ TECHNICIAN TIP

Most DMMs offer a "**zero**" feature when measuring resistance. This feature compensates for any resistance in the DMM test leads. Use the feature by touching the test leads together with the DMM set to the resistance function and then press the "zero" button. The DMM will reset the display to "zero." If your DMM does not have this feature, you can touch the test leads together and note the resistance, for example 1.3 ohms. Subtract 1.3 ohms from your resistance measurement to obtain the correct reading.

1. Inspect Fuel Injector Assembly

(a) Measure the resistance according to the value(s) in the table below.

Standard resistance:

TESTER CONNECTION	CONDITION	SPECIFICATION
1-2	20°C (68°F)	11.6 Ω to 12.4 Ω

If the result is not as specified replace the fuel injector assembly.

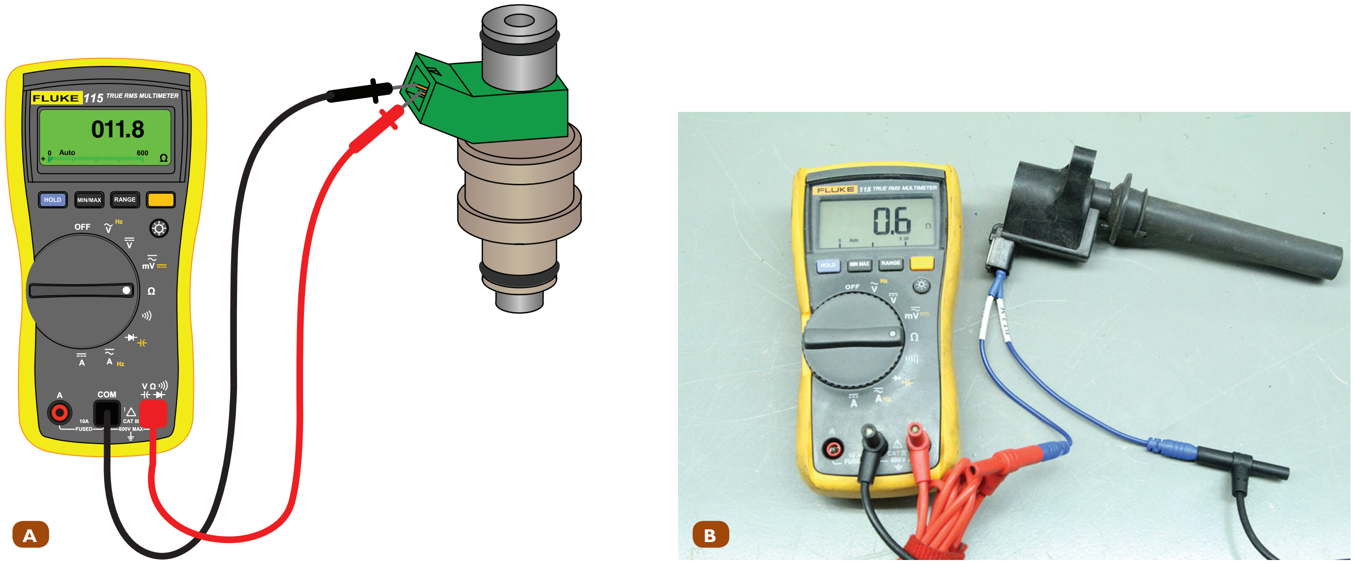


FIGURE 6-6 A resistance test can determine if a component is within service information specifications.

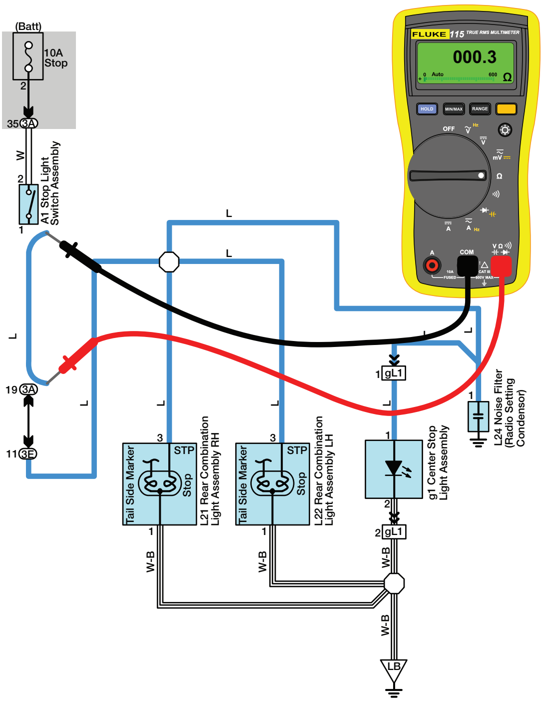


FIGURE 6-7 Measure resistance of the harness by disconnecting the wiring and then measuring with the DMM. Wiring resistance should be very close to 0 ohms. Disconnect the section of the circuit that you are testing. Connect the DMM leads and note the resistance reading on the display.

▶ Measuring Amperage

K06002 Outline the process of measuring amperage.

N06002 Use fused jumper wires to check operation of electrical circuits. (MLR/AST/MAST)

Using the DMM to measure circuit amperage is not often performed in automotive circuits. Most DMMs can only measure up to 10 amps of current, and most automotive body electrical circuits require more amperage than this to operate (note the fuse rating for the circuit you are diagnosing). The most common use for the ammeter function of the DMM

▶ TECHNICIAN TIP

It can be tempting to remove the circuit fuse and use this location to obtain the amperage reading. Only do this using fused jumper leads. Failure to do so can result in damage to the vehicle and to the DMM.

▶ TECHNICIAN TIP

An **inductive amperage pickup** is often used for circuit diagnosis where the amperage reading is required. The inductive pickup measures the magnetic field created in the wiring when the circuit is on and converts it into a voltage that is displayed on the DMM or a digital storage oscilloscope (DSO). The reading is usually in millivolts, and most low amperage inductive pickups use a conversion setting of 10mV or 100mV = 1 amp. A reading of 45mV when set to the 10mV scale would calculate to 4.5 amps (45 ÷ 10 = 4.5). Using the 100mV setting, the same measurement would display as 450mV on the DMM but the result would be the same, 4.5 amps (450 ÷ 100 = 4.5). High amperage inductive pickups are used for high current circuits like the charging or starting system and can display readings that convert to between 100 and 1000 amps.

FIGURE 6-8 An inductive clamp can be used to measure amperage values that exceed the limit of the DMM or if you want to view the signal on a DSO.

is measuring parasitic draw, which if excessive can cause the battery to discharge. Also the service information rarely provides current specifications.

It is recommended that you use **fused jumper leads** to prevent a short circuit that damages the DMM, the test leads, or vehicle circuits for amperage testing. The negative lead remains in the common jack of the DMM. Move the positive lead to the appropriate amperage jack, usually to measure either up to 200 milliamps or more than 200 milliamps to the DMM's limit (usually 10 amps). The DMM test leads become part of the circuit to measure amperage, as the current must go through the DMM so it can be measured. Open the circuit at a connector if possible and connect the positive lead to the most positive side of the circuit and the negative lead to the most negative side of the circuit. Turn the circuit on and note the reading on the DMM.

Warning: The DMM becomes part of the circuit when the amperage function is selected. Incorrect procedures or forgetting to place the positive lead back into the volt-ohm jack of the DMM can result in a short circuit if you then use the DMM to measure voltage. Some DMMs produce a warning beep when the positive lead is in the amperage jack with the function selector set to measure voltage. Failure to follow these procedures can blow circuit fuses, main body fusible links, or, if testing source voltage at the battery, create a spark that can cause the battery to explode (**FIGURE 6-8**).

K06003 Describe the various types of circuit faults that you will diagnose as a technician.

N06003 Demonstrate knowledge of the causes and effects from shorts, grounds, opens, and resistance problems in electrical/electronic circuits. (MLR/AST/MAST)

▶ Circuit Faults

Circuit faults result in a customer concern. These faults can be categorized as an open circuit, high resistance in a circuit, a short circuit, a shared voltage fault, or parasitic draw. It is important to determine the type of circuit fault you are dealing with during your diagnosis as it will affect the strategy and test methods used to isolate the cause of the fault.

Open Circuit

An open circuit no longer has a continuous path for current in the circuit and is the most common electrical system fault. Causes of an open circuit include disconnected connectors, a bad switch, damaged terminal connectors, cut wires, or a defective or blown fuse. When there is no observable sign of circuit operation, there may be an open circuit (**FIGURE 6-9**).

Begin by testing the available voltage in the circuit that is the easiest to reach of those that are the most likely cause of the concern. For the stop light circuit shown, you can test at left stop light connector pin 3. If source voltage is present, then the circuit open is after this point. If no voltage is present, the open is before this point in the circuit. With continued circuit testing, you find that there is source voltage at left stop light connector pin 1. This indicates the bulb should be OK. The next test location is the circuit ground point, L3—the DMM indicates 0 volts. Since there is source voltage at the ground side of the stop light bulb connector (L31 pin 1) and no voltage at the circuit ground point, the open is between these two points. Further testing should be performed by visually inspecting this section of the harness to determine the where the open is located.

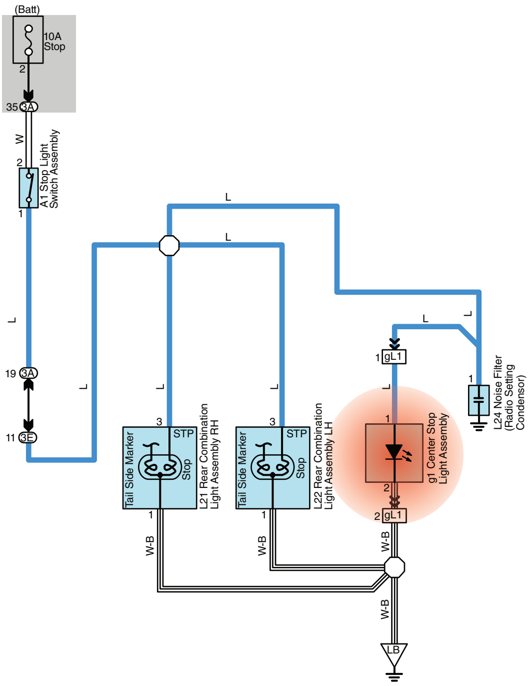


FIGURE 6-9 An open circuit may be indicated when there is no observable operation of the stop lights.

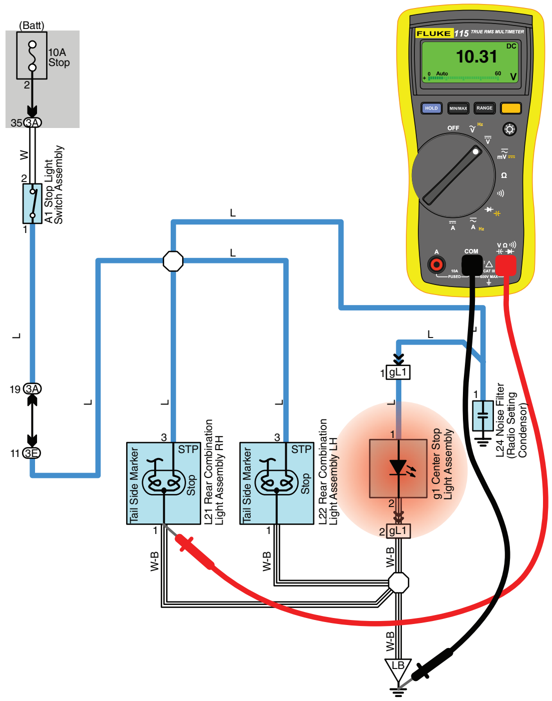


FIGURE 6-10

High Resistance in a Circuit

In some cases high resistance faults may appear to be open circuit faults. The difference is that current is present in the circuit with a high resistance fault. Additionally, instead of infinite resistance like an open circuit, there is a resistance that is causing an excessive voltage drop at some point before or after the circuit load (FIGURE 6-10).

The strategy for isolating the location of the high resistance fault is very similar to open circuit voltage testing. If the circuit load functions, but does not function correctly, you know that current is present. Therefore you can perform available voltage tests and voltage drop tests throughout the circuit to isolate the high resistance. If you are unable to determine whether current is present because the load does not appear to operate, begin with available voltage testing at the load at both the positive and ground pins of the connector. Source voltage at the load indicates the resistance is after the load, which should be confirmed when you obtain a reading that exceeds 100mV or greater on the ground side of the load (with the circuit on) (FIGURE 6-11).

Voltage that is much less than source voltage indicates the high resistance is before the load. Once you have isolated which part of the circuit has excess resistance, you can continue to use available voltage tests or voltage drop tests to isolate where the high resistance is.

Short Circuit

A short circuit occurs when current bypasses the load and goes directly to ground or when there is some fault in a circuit component (usually the load) that reduces resistance and increases current beyond normal levels. A relay coil that has failing wire insulation increases current, for example. Fuses, fusible links, and circuit breakers serve as circuit protection devices in case of a short circuit. Fuses and fusible links are designed to have their conductor melt from the excess current of a short circuit. When the conductor melts away, it opens the circuit and prevents overheating wiring, switches, and the load device which could lead to a vehicle fire.

Diagnosing a short circuit can seem like a daunting task since you cannot power the circuit on and then use your DMM to find the cause. There are a couple of methods that you can use to locate the fault. The first method involves using an incandescent light as a short-finding tool. Create the short-finding tool by using a 12-volt 1156 light socket, a fuse

> **▶ TECHNICIAN TIP**
>
> Never replace a blown fuse or fusible link with one of a higher amperage rating. Doing this can lead to a great deal of damage, an accident, injury, or death. The owner of a vehicle became frustrated by a fuse that kept blowing so one of a higher rating was installed. The circuit worked for two days and all seemed OK until he and his family came back to the vehicle in a large shopping center parking lot to find it surrounded by fire trucks. It had caught fire and was destroyed. The most likely cause was replacing the blown fuse with one of a higher amperage rating.

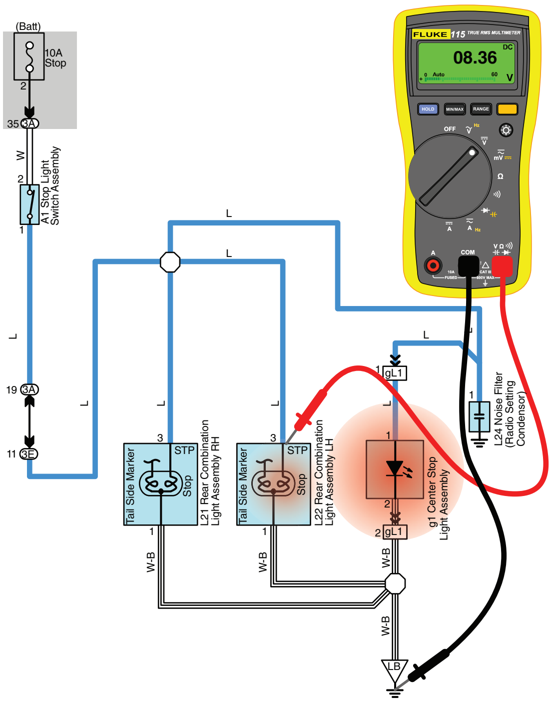


FIGURE 6-11 Measure voltage at the load. Less than source voltage on the source side indicates resistance before the load. Voltage that is greater than 100–300mV after the load indicates excess resistance after the load.

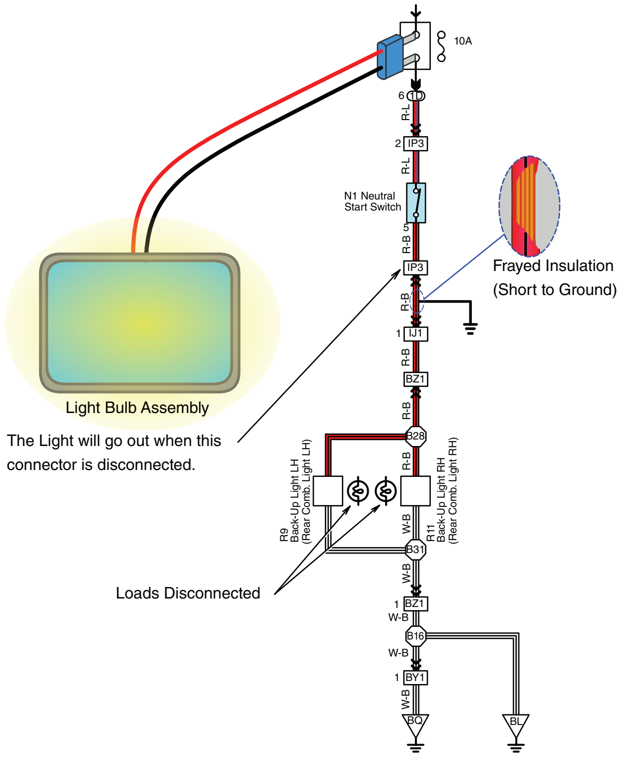


FIGURE 6-12 Locate the short using an 1156 lamp and socket with a fuse. Disconnect connectors in the circuit before the load until the light turns off to isolate the short location. Using an incandescent lamp with fused leads connected to the fuse holder is one method for locating a short circuit.

holder, and 16 gauge wire. Assemble as shown in **FIGURE 6-12**. Remove the circuit fuse and install the short-finding tool. Turn the affected circuit on and the 1156 bulb will illuminate. Begin disconnecting circuit connectors in the affected circuit one at a time. When the 1156 bulb goes out, you know the short is in that section of the circuit. You can then inspect the harness or component further to determine what repair is required.

Another option is to use a short-detecting tool. There are two basic types. The first uses a circuit breaker to power up the circuit for very short intervals. While it is energized, you use a hand-held tool that detects the magnetic field in the wiring harness. If the needle on the tool moves, there is current present. When the needle stops moving, you have found where the short to ground is. The second type of short detector uses a signal generating device connected to the affected circuit. Once it is connected, you leave the circuit off and then use the signal detector along the harness. As long as there is a signal, the wiring is OK. The signal stops where the short is. The difficulty with both of these methods is in the amount of the harness you must expose to find the short location, especially where the harness is difficult to reach behind the instrument panel.

Whichever method you use to find the cause of the short circuit, once found, perform the recommended repair and then thoroughly retest the circuit to ensure all is OK.

▶ TECHNICIAN TIP

Many vehicle manufacturers no longer allow wiring harness repairs under warranty. Instead, the whole harness must be replaced to repair an open, high resistance, short to ground, or other fault in the harness and related connectors. Customer pay repairs will often require repairing the harness due the potentially high cost of harness replacement.

Shared Voltage

A shared voltage fault is one of the most confusing faults to diagnose. A shared voltage fault occurs when one circuit shares its voltage with another causing it to operate at the same time. A shared voltage fault can occur when one circuit joins with another circuit causing the two circuits to operate when one or the other is energized. This may be caused when two wires chafe through the insulation and the bare wire touches, when damage to a connector causes adjacent pins to touch, when a fault or damage inside a junction block allows two distinct circuit paths to intersect and connect, or when a damaged dual filament light bulb allows voltage in one filament to touch the other filament and turn that part of the circuit on. An open ground in one circuit can also allow current to seek a path to ground through another related component like a light bulb or shared fuse (**FIGURE 6-13**).

Isolate the cause of a shared voltage fault by first checking for a blown fuse. The blown fuse may cause the lack of voltage in one circuit to seek a path through another circuit where they intersect in a junction block or junction connector. Shared voltage concerns in incandescent lighting circuits can be diagnosed by removing each bulb one at a time. Inspect the bulb to be sure it is the correct type and there is no damage to the bulb base or socket in the vehicle harness. If the other circuit turns off when you remove the bulb, you have isolated the cause to either the bulb or that part of the harness and bulb socket. Do this for each bulb in the circuit until you locate the cause of the fault. It is possible that a damaged harness or connector is allowing one circuit to power another due to exposed wires touching each other or two or more connector pins touching. Isolating where the short to voltage is should begin with where the two (or more) circuits have wiring in the same connector(s). Check for continuity between the two suspected wires. It should be an open circuit, but a resistance reading near 0 ohms indicates the two wires have made contact. Carefully inspect connectors for damage. If OK, move on to the harness sections and carefully inspect the individual wires for damage to insulation that would allow the circuits to share voltage from one to the other. Lastly, some circuits use diodes to isolate one part of the circuit from another. Refer to the wiring diagram; if there is an isolation diode present, locate the diode and check its operation with your DMM. Replace the diode if it fails the forward or reverse bias tests.

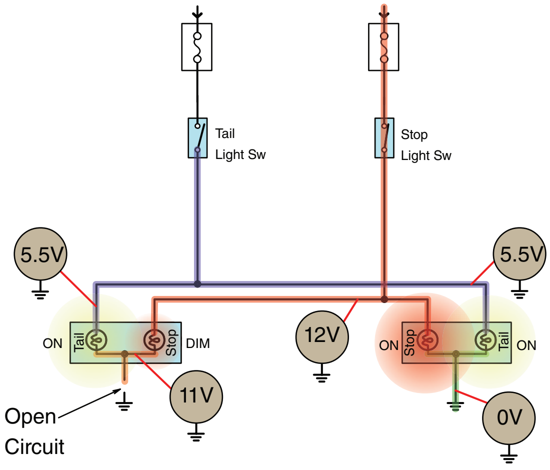


FIGURE 6-13 Shared voltage faults can be caused by two wires or two filaments in an incandescent bulb shorting together or by an open ground as shown.

Parasitic Draw

N06004 Measure key-off battery drain (parasitic draw). (MLR) Diagnose the cause(s) of excessive key-off battery drain (parasitic draw); determine needed action. (AST/MAST)

A parasitic draw is always present in the modern vehicle. ECUs have keep alive memory functions, and ECUs related to alarm and keyless entry systems remain active while the vehicle is locked and off. The typical vehicle should have less than 50mA (milliamps) of parasitic or ignition-off draw and should have little effect on battery voltage over a vehicle storage period of two to four weeks. Excessive parasitic draw usually presents as a customer concern that the battery has low or no charge to start the vehicle after it has been parked for a period of a few hours to a day or so.

Your diagnosis should begin with a thorough battery and charging system test. A failing battery or charging system that does not fully charge the battery can cause symptoms that may seem like a parasitic draw concern but are not. If the battery and charging system are OK, check for parasitic draw (**FIGURE 6-14**).

Parasitic current draw can be measured in several ways, the most common being the process of using an ammeter capable of measuring milliamps and inserting it in series

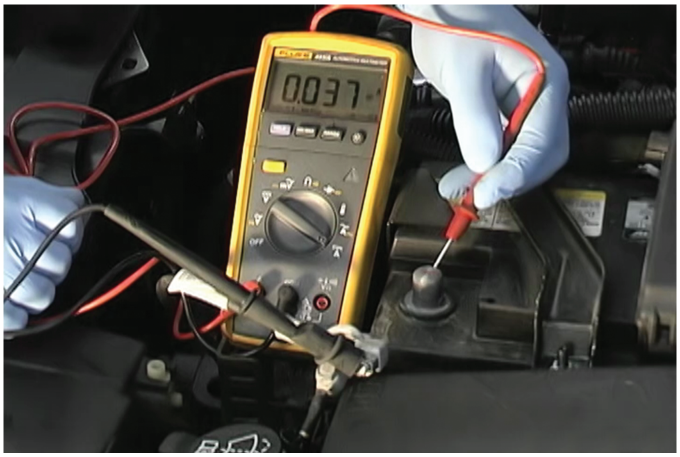


FIGURE 6-14 The parasitic draw test determines the amount of current used by systems when the vehicle is off.

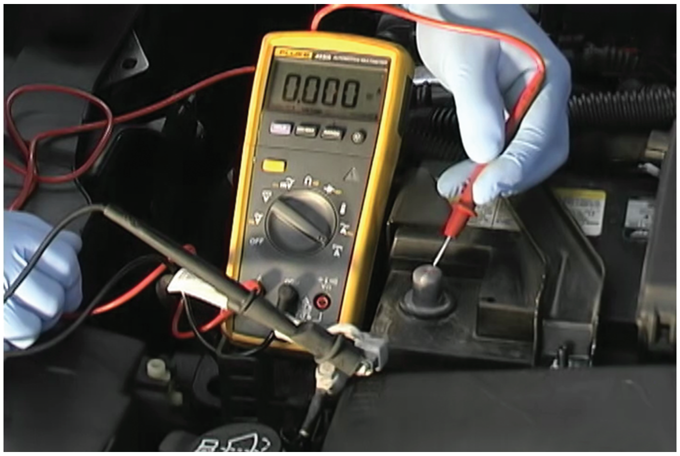


FIGURE 6-15 DMM hooked up to measure parasitic draw.

FIGURE 6-16 Low-amps probe hooked up to battery cable.

between the battery post and the battery terminal. The ammeter is usually put in series with the negative battery lead (**FIGURE 6-15**). If the vehicle is equipped with systems or modules that require electronic memory to be maintained, follow the procedure listed in previous paragraphs for identifying modules that lose their initialization during battery removal and maintain or restore electronic memory functions. Note that the timers may reset during the process of disconnecting the battery terminal and connecting the ammeter in series, so you may have to wait for the timers to go back to sleep. If excessive parasitic draw is measured, disconnect fuses or systems one at a time while monitoring parasitic current draw to determine the systems causing excessive draw. Also, in most cases, opening a door or trunk will cause the timers to reset.

Disconnecting the battery can be avoided if a sensitive, low-current (i.e., milliamps) clamp is available (**FIGURE 6-16**). The low-amps **current clamp** measures the magnetic field generated by a very small current flow through a wire or cable. Placing the low-amp current clamp around the negative battery cable will allow you to measure the parasitic draw. If excessive parasitic draw is measured, disconnect fuses or systems one at a time while monitoring parasitic current draw to determine the systems causing the excessive draw.

The last way to measure a parasitic draw is a bit controversial, but it is well worth trying out since it can save a lot of time and requires no special tools other than a DMM. It is named the Chesney parasitic load test after its creator, Sean Chesney. Instead of using an ammeter to measure the draw, an ohmmeter is used. Before doing anything, set the ohmmeter to ohms (the lowest scale), touch the meter leads together, and read the screen. The reading is the resistance of the meter leads and is called the "delta" value, which is the meter's true zero when used with those leads. Typically an ohmmeter will read about 0.1 ohms when the leads are touched together. Remember this number for later. Some meters have a delta feature that recalibrates the ohmmeter to zero when the leads are placed together and the delta button is pushed. If your meter has this delta feature, you can use it so that you will not have to remember the delta reading.

Next, with the battery terminals still connected to the battery, place the black lead on the negative post of the battery and the red lead on an unpainted surface of the alternator housing. Read the ohmmeter and subtract the delta value from the reading. This reading corresponds to the relative parasitic draw on the system.

Through testing, Chesney found that a draw of about 35 milliamps equaled an ohm reading of about 0.3 ohms delta (above the delta value) on a DMM with 10 megohms of impedance, and about 0.6 ohms delta on a DMM with 20 megohms of impedance (**FIGURE 6-17**). Anything above those readings

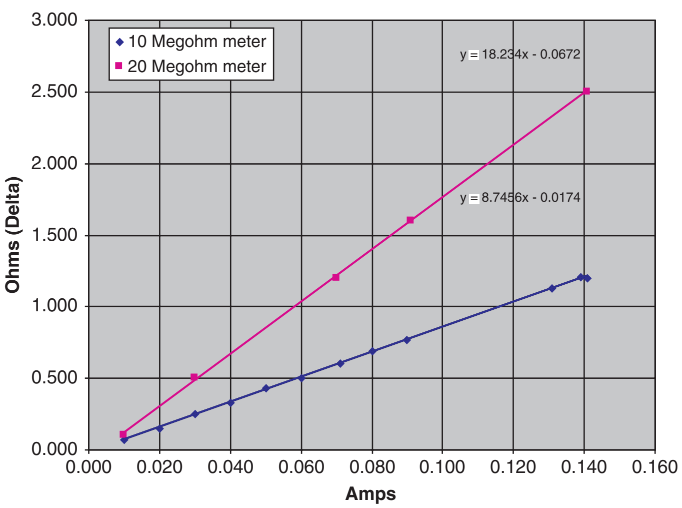


FIGURE 6-17 Chesney parasitic load test-ratio graph.

indicates an excessive parasitic draw. You may be skeptical of this method, so go out and try it on any vehicle. Simulate a parasitic draw by opening the driver's door, which illuminates the dome light, and watch the ohmmeter. It went up, right? Close the door. As soon as the light went off, the ohmmeter reading went back down, right? If you use this test and find an excessive draw, you can pull fuses one at a time, watching for the ohmmeter reading to decrease. If it does not decrease after removing all of the fuses, suspect an unfused circuit such as the alternator diodes or the ignition circuit on some vehicles.

▶ Testing Switches, Connectors, and Wiring

K06004 Explain the diagnostic importance of testing switches, connectors, and wiring.

N06005 Inspect and test switches, connectors, and wires of starter control circuits; determine needed action. (MLR/AST/MAST).

Switches, connector pins, and wiring from one part of a circuit to the next are often tested as part of the electrical system diagnosis. Service information often provides resistance specifications to check these components; however, the best test for component resistance is the voltage drop test, as discussed earlier in this chapter. Switch contacts should have infinite resistance when off and very close to 0 ohms when in the on position. Wiring and connector pins should have very close to 0 ohms of resistance. Also, wiring that delivers voltage to the load should have no continuity to ground (OL on the DMM).

Voltage drop testing is a dynamic test. The component is tested when current is present in the circuit. A switch, wire, or harness connector pins may have very little resistance when tested by the DMM and its very small current present during the resistance test. Applying full circuit current will cause resistance to show in the form of a voltage drop. Perform a voltage drop across a switch by measuring at the connector pins. The voltage drop should be less than 100mV for most circuits. Circuits with high current may have a higher voltage drop. For example, an incandescent stop light circuit may have 200–300mV drop across the brake light switch. Switch contacts can corrode or be damaged from repeated on to off cycling. A voltage drop of more than 500mV usually indicates the switch is faulty and should be replaced.

Connectors join sections of the harness together and allow for easier assembly or disassembly of the vehicle and related repairs that may be required. Connector pins are really only designed to be connected and disconnected three or four times in their vehicle life. Every time a connector is disconnected and reconnected, its pins may be damaged or there may be wear and damage to the housing and the retaining lock mechanism. Use caution when disconnecting the connectors and avoid repeated removing and installing. Tools are available to test for connector pin fit (**FIGURE 6-18**). An excessive voltage drop across a connector may be caused by a damaged pin. The use of this tool can help identify whether pin fit is the cause. A damaged connector or damaged pin usually requires a harness replacement if the vehicle is under warranty. Customer pay may require you repair or replace the connector pin or entire connector if the components are available. Some vehicle manufacturers provide terminal repair kits and a catalog of replacement connectors that are a direct replacement or can be adapted to fit, like using a 6 pin connector in place of a 4 pin.

Wiring can be damaged due many factors including high heat environments, flexing as the powertrain moves, chafing from road vibration and heat expansion and contraction, rubbing and flexing when doors and the deck lid or hatch open/close, and physical damage due to an accident or improperly installed accessories. The service information usually provides harness testing specifications in the related circuit diagnosis where required. Usually the information relates to resistance tests from connector to connector and to chassis ground. Unfortunately, a resistance test can miss diagnosing a damaged wire that can handle the full circuit current. For this reason a voltage drop test is recommended. The wiring should have very little resistance and a voltage drop that is less than 100mV for most body electrical circuits. Wiring that exceeds voltage drop limits or has a short to ground must be repaired by harness replacement or repair.

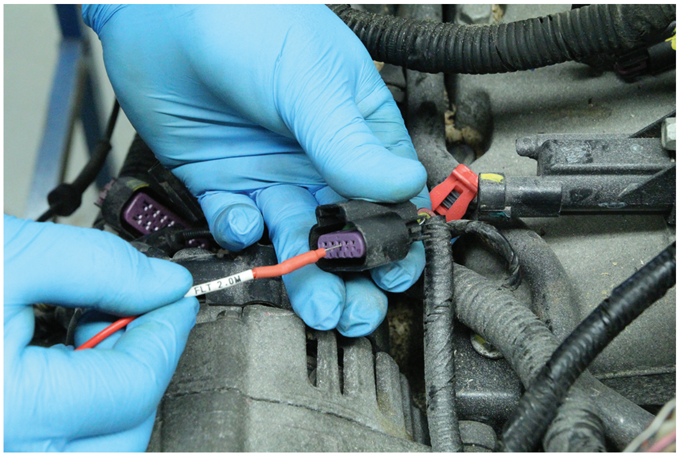


FIGURE 6-18 Terminal pin test tools can be used to verify the correct pin fit tension is present.

Wrap-Up

Ready for Review

- Circuit tests are most often made using a DMM to measure voltage, amperage, or resistance.
- Voltage tests include the following: source voltage measured at the battery, available voltage at circuit test points measured by placing the negative lead on a known "good" ground and then testing at various circuit test points with the positive lead, and measuring voltage drop by placing the positive and negative lead across the load or any other portion of the circuit to measure how much voltage is used in that portion.
- Amperage testing requires that the circuit be opened at some point so the DMM can become part of the circuit. The most common amperage test made with a DMM is for measuring parasitic draw.
- Resistance tests are most often made for the following: to measure the resistance of a component when specifications are provided in the service information, to determine if a circuit is open or if a section of wiring is shorted to chassis ground. Resistance testing requires that the circuit is off (deenergized) and that sections of the circuit are isolated for accurate test results.
- Open circuit faults occur when there is an incomplete path for current in the circuit. Causes include damaged wiring, a disconnected or damaged connector, or a faulty circuit component. Testing is usually done with available voltage testing and can be verified using a continuity test in the circuit section where the fault is suspected.
- High resistance faults occur when the path for current is restricted. This may be caused by a faulty load, damaged wiring, poor harness connections, and a poor ground. Available voltage and voltage drop testing are the best test methods to isolate a high resistance fault.
- A short circuit occurs when a path to ground exists that bypasses the circuit load. Current increases to very high levels and the fuse or related circuit protection opens the circuit to prevent major damage to the vehicle. Circuit diagnosis can be made using a load inserted into the circuit at the fuse and disconnecting sections of the circuit until the load turns off. This indicates the area where the short is located. It is also possible to isolate a short using a short detector provided there is adequate access to the vehicle harness so you can isolate where the short is located.
- A short to voltage concern is one of the most difficult electrical issues to diagnose. Diagnose by determining the possible locations the two (or more) circuits could intersect and then isolate those sections and use continuity testing to determine where the circuits have connected to each other.
- Parasitic draw faults are often indicated by repeated need to jump start a good battery and the charging system is operating to specification. Parasitic, or dark current as it is sometimes called, is excess current present when the vehicle is off. This drains the battery over several hours to a day or so. Isolate the circuit where the excess current is being used by monitoring parasitic draw with your DMM ammeter connected to the negative battery post and battery cable. Remove each circuit fuse, one at a time. When the draw returns to normal you have isolated which circuit(s) are at fault. Continue diagnosis to isolate which component is using excess current in the off condition and repair as required.
- Component tests may be made using voltage drop or resistance tests. Voltage tests are preferred as this is a dynamic test made with the circuit energized and is best for isolating faults that might appear OK when performing a resistance test.

Key Terms

DMM Digital multimeter, used to measure voltage amperage and resistance along with several other electrical measurement functions.

DMM "zero" function Used during resistance testing. Touch the DMM test leads together and select the zero function. The meter will "learn" the resistance of the test leads and then display 0 ohms on the display. This provides a more accurate test result when measuring resistance of a component or isolated sections in the circuit.

fused jumper leads Incorporate a replaceable fuse. This allows for safe circuit testing in case the test lead creates an excessive current condition during a circuit test.

inductive amperage pickup Used to measure amperage in a circuit. Most DMMs are limited to direct amperage measurements of less than 10 amps max. Many automotive circuits operate at higher amperage levels and an inductive pickup can be used to do this. The tool is placed around the circuit conductor anywhere in the applicable circuit. The DMM will display a reading in mV and this is multiplied by the factor selected on the tool. The result indicates the amount of amperage present in the circuit.

smart charger A battery charger with microprocessor control that manages voltage and amperage during charging that is matched to the type of battery being charged. This prevents over charging and any resulting damage that it could cause.

Review Questions

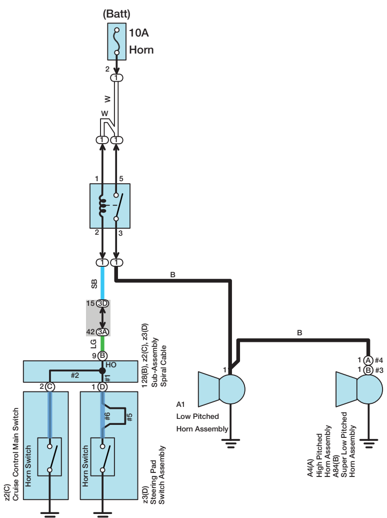
1. When there is a resistance that is causing an excessive voltage drop at some point before or after the circuit load, what type of circuit fault is it?
   a. High resistance circuit fault
   b. Shared voltage fault
   c. Parasitic draw
   d. Short circuit
2. What is a short circuit?
   a. A circuit that no longer has a continuous path for current.
   b. A circuit that shares its voltage with another, causing it to operate at the same time.

c. Current bypasses the load and goes directly to ground.
d. The battery has low or no charge to start the vehicle.

3. All of the following statements with respect to the use of DMM in circuit diagnosis are true *except*:
   a. Measuring source voltage is the first inspection point of any electrical system concern.
   b. The DMM on the volt setting is measuring the difference in voltage between the positive test lead and the negative test lead.
   c. Measuring available voltage and voltage drop in the circuit are performed as part of the diagnostic process.
   d. The DMM voltage circuit in simple terms takes the voltage measured on the negative lead and subtracts it from the positive lead.
4. The voltage drop test is the best test for isolating:
   a. high resistance faults.
   b. open circuit.
   c. short circuit.
   d. parasitic draw.
5. Choose the correct statement with respect to performing the resistance test.
   a. It is performed by placing the positive lead of the DMM on the most positive portion of the circuit and the negative lead on the most negative portion of the circuit, with the circuit that you are testing energized (on).
   b. It is performed with the circuit off and by isolating the component or portion of the circuit you will be testing.
   c. It is performed by measuring source voltage at the battery with the vehicle off and all electrical loads off.
   d. It is performed with the circuit on and by isolating the component or portion of the circuit you will be testing.
6. The most common use for the ammeter function of the DMM is measuring:
   a. parasitic draw.
   b. open circuit.
   c. short circuit.
   d. shared voltage fault.
7. All of the following statements with respect to diagnosing parasite draw are true *except*:
   a. The typical vehicle should have less than 50mA (milliamps) of parasitic or ignition off draw.
   b. Diagnosis should begin with a thorough battery and charging system test.
   c. The parasitic draw test determines the amount of current used by systems when the vehicle is on.
   d. ECUs related to alarm and keyless entry systems remain active while the vehicle is locked and off.
8. All of the following statements with respect to wiring and connector repairs are true *except*:
   a. Use caution when disconnecting the connectors and avoid repeated removing and installing.
   b. Every time a connector is disconnected, its pins get damaged so the connector has to be replaced.
   c. An excessive voltage drop across a connector may be caused by a damaged pin.
   d. If direct replacement is not available, a 6-pin connector can be used in place of a 4 pin.
9. Choose the correct statement.
   a. The best test for component resistance is the DMM resistance test.
   b. Switch contacts should have very close to 0 ohms when off.
   c. Switch contacts should have infinite resistance when on.
   d. Wiring and connector pins should have very close to 0 ohms of resistance.
10. A resistance test can miss diagnosing a damaged wire that can handle the full circuit current. For this reason, it is recommended that:
   a. voltage drop test is performed.
   b. source voltage test is performed.
   c. an inductive amperage pickup is used.
   d. the parasitic draw is measured first.

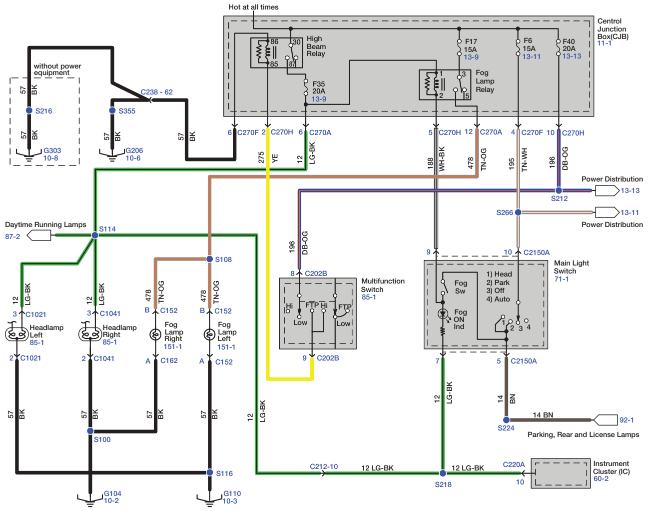
ASE Technician A/Technician B Style Questions

1. Tech A says a short circuit may be indicated by a blown fuse. Tech B says a short to power fault may cause a blown fuse. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
2. Tech A says an open circuit may be indicated when the circuit load does not operate. Tech B says an open circuit may be similar to a high resistance fault. Who is correct?
   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B
3. Refer to the horn circuit shown. The horns do not operate and the 10A fuse is blown. Tech A says a short to ground at the horn switch could be the cause. Tech B says an open circuit on the black wire from pin 1 of the low pitched horn to the high pitched horn could be the cause. Who is correct?



   a. Tech A
   b. Tech B
   c. Both A and B
   d. Neither A nor B

4. Refer to the fog light circuit shown where the left fog light does not work and 8.3V is present at C270H pin 5. Tech A says the fog light switch may be at fault. Tech B says the fog lamp relay may be at fault. Who is correct?



- **a.** Tech A
- **b.** Tech B
- **c.** Both A and B
- **d.** Neither A nor B

5. Refer to the fog light circuit shown. Tech A says the path to ground for the left fog light connects to ground point S116. Tech B says one of the components inside the fog lamp relay is a resistor. Who is correct?

- **a.** Tech A
- **b.** Tech B
- **c.** Both A and B
- **d.** Neither A nor B

6. Tech A says the cause of a short circuit may be isolated by using a short detection tool. Tech B says the cause of a short to voltage fault may be located in or near a connector that is shared between both affected circuits. Who is correct?

- **a.** Tech A
- **b.** Tech B
- **c.** Both A and B
- **d.** Neither A nor B

7. Tech A says excessive resistance in a circuit can be isolated with an available voltage test at various circuit test points. Tech B says the cause of an open circuit can be isolated by measuring voltage drop throughout the circuit. Who is correct?

- **a.** Tech A
- **b.** Tech B
- **c.** Both A and B
- **d.** Neither A nor B

8. Tech A says when diagnosing a high resistance fault, you can measure available voltage at the load to determine if the fault is on the source or ground side of the circuit. Tech B says voltage drop tests can isolate the location of a high resistance fault in a circuit. Who is correct?

- **a.** Tech A
- **b.** Tech B
- **c.** Both A and B
- **d.** Neither A nor B

9. Tech A says parasitic draw diagnosis uses the DMM amperage function. Tech B says removing fuses one at a time and monitoring parasitic amperage usually isolates the circuit that is causing the concern. Who is correct?

- **a.** Tech A
- **b.** Tech B
- **c.** Both A and B
- **d.** Neither A nor B

10. Tech A says isolating the cause of high resistance in a circuit is most accurate when using the voltage drop test. Tech B says a switch that has 0.8 ohms of resistance when OFF will function normally when current is present. Who is correct?

- **a.** Tech A
- **b.** Tech B
- **c.** Both A and B
- **d.** Neither A nor B