**Figure 45-1** The center wire is a solid color wire, meaning that the wire has no other identifying tracer or stripe color. The two end wires could be labeled **BRN/WHT**, indicating a brown wire with a white tracer or stripe.

**Chart 45-1** Typical abbreviations used on schematics to show wire color. Some vehicle manufacturers use two letters to represent a wire color. Check service information for the color abbreviations used.
Figure 45-2. Typical section of a wiring diagram. Notice that the wire color changes at connection C-210. The .8” represents the metric wire size in square millimeters.

Figure 45-3. Typical electrical and electronic symbols used in automotive wiring and circuit diagrams.

TECH TIP: Read the Arrows
Wiring diagrams indicate connections by symbols that look like arrows. SEE FIGURE 45-4 on page 481. Do not read these “arrows” as pointers showing the direction of current flow. Also observe that the power side (positive side) of the circuit is usually the female end of the connector. If a connector becomes disconnected, it will be difficult for the circuit to become shorted to ground or to another circuit because the wire is recessed inside the connector.
In this typical connector, note that the positive terminal is usually a female connector.

The symbol for a battery. The positive plate of a battery is represented by the longer line and the negative plate by the shorter line. The voltage of the battery is usually stated next to the symbol.

The ground symbol on the left represents earth ground. The ground symbol on the right represents a chassis ground.
Figure 45-7: Starting at the top, the wire from the ignition switch is attached to terminal B of connector C2, the wire is 0.5 mm (20 gauge AWG), and it's yellow. The circuit number is 5. The wire enters connector C202 at terminal B3.

Figure 45-8: The electrical terminals are usually labeled with a letter or number.

Figure 45-9: Two wires that cross at the dot indicate that the two are electrically connected.
Figure 45-10  Wires that cross, but do not electrically contact each other, are shown with one wire bridging over the other.

**Wires Not Electronically Connected**

Figure 45-11  Connectors (C), grounds (G), and splices (S) are followed by a number, generally indicating the location in the vehicle. For example, G209 is a ground connection located under the dash.

Figure 45-12  The ground for the battery, labeled G305 indicating the ground connector is located in the passenger compartment of the vehicle. The ground wire is black (BLK), the circuit number is 50, and the wire is 32 mm² (2 gauge AWG).
**Figure 45-13** The symbol for light bulbs shows the filament inside a circle, which represents the glass envelope of the bulb.

**Figure 45-14** An electric motor symbol shows a circle with the letter M in the center and two black sections that represent the brushes of the motor. This symbol is used even though the motor is a brushless design.

**Figure 45-15** Resistor symbols vary depending on the type of resistor.
A rheostat uses only two wires—one is connected to a voltage source and the other is attached to the movable arm.

Symbols used to represent capacitors. If one of the lines is curved, this indicates the capacitor having polarity. On the other hand, the one without a curved line can be installed in the circuit without concern about polarity.

The grid-like symbol represents an electrically heated element. This symbol is used to represent a cigarette lighter or a heated rear window (rear window defogger).
Figure 45-19 A dashed outline represents a portion (part) of a component.

Figure 45-20 A solid box represents an entire component.

Figure 45-21 This symbol represents a component that is case grounded.
Figure 45-22  (a) A symbol for a single-pole, single-throw (SPST) switch. This type of switch is normally open (N.O.) because nothing is connected to the terminal that the switch is contacting in its normal position. (b) A single-pole, double-throw (SPDT) switch has three terminals. (c) A double-pole, single-throw (DPST) switch has two positions (off and on) and can control two separate circuits. (d) A double-pole, double-throw (DPDT) switch has six terminals—three for each pole. Note: The dotted line between the two arms indicates that they are mechanically connected, called a “ganged switch.”

Figure 45-23 (a) A symbol for a normally open (N.O.) momentary switch.

Figure 45-23 (b) A symbol for a normally closed (N.C.) momentary switch.
TECH TIP: Color-Coding Is Key to Understanding

Whenever diagnosing an electrical problem, it is common practice to print out the schematic of the circuit and then take it to the vehicle. A meter is then used to check for voltage at various parts of the circuit to help determine where there is a fault. The diagnosis can be made easier if the parts of the circuit are first color coded using markers or color pencils. A color-coding system that has been widely used is one developed by Jorge Menchu (www.aeswave.com). The colors represent voltage conditions in various parts of a circuit. Once the circuit has been color coded, then the circuit can be tested using the factory wire colors as a guide. SEE FIGURE 45-24.

Figure 45-24. Using a marker and color-coding the various parts of the circuit makes the circuit easier to understand and helps diagnosing electrical problems easier. (Courtesy of Jorge Menchu.)

Figure 45-25. A relay uses a movable arm to complete a circuit whenever there is a power at terminal 86 and a ground at terminal 85. A typical relay only requires about 1/10 ampere through the relay coil. The movable arm then makes the contacts (85 to 87) and relays 30 amperes or more.
Figure 45-26  A cross-sectional view of a typical four-terminal relay. Current flowing through the coil (terminals 86 and 85) causes the movable arm (called the armature) to be drawn toward the coil magnet. The contact points complete the electrical circuit connected to terminals 30 and 87.

Figure 45-27  A typical relay showing the schematic of the wiring in the relay.

Figure 45-28  All schematics are shown in their normal, nonenergized position.
A typical horn circuit. Note that the relay contacts supply the heavy current to operate the horn. When the horn switch simply completes a low-current circuit to ground, causing the relay contacts to close.

When the relay or solenoid coil current is turned off, the stored energy in the coil flows through the clamping diode and effectively reduces voltage spike.

A resistor used in parallel with the coil windings is a common spike reduction method used in many relays.
TECH TIP: Divide the Circuit in Half

When diagnosing any circuit that has a relay, start testing at the relay and divide the circuit in half.

- **High current portion:** Remove the relay and check that there are 12 volts at the terminal 30 socket. If there is, then the power side is okay. Use an ohmmeter and check between terminal 87 socket and ground. If the load circuit has continuity, there should be some resistance. If OL, the circuit is electrically open.
  - **Control circuit (low current):** With the relay removed from the socket, check that there is 12 volts to terminal 86 with the ignition on and the control switch on. If not, check service information to see if power should be applied to terminal 86, then continue troubleshooting the switch power and related circuit.

TECH TIP: Divide the Circuit in Half (cont.)

- **Check the relay itself:** Use an ohmmeter and measure for continuity and resistance.
  - Between terminals 85 and 86 (coil), there should be 60 to 100 ohms. If not, replace the relay.
  - Between terminals 30 and 87 (high-amperage switch controls), there should be continuity (low ohms) when there is power applied to terminal 85 and a ground applied to terminal 86 that operates the relay. If OL is displayed on the meter set to read ohms, the circuit is open which requires that the relay be replaced.
  - Between terminals 30 and 87a (if equipped), with the relay turned off, there should be low resistance (less than 5 ohms).

FREQUENTLY ASKED QUESTION: What Is the Difference Between a Relay and a Solenoid?

Often, these terms are used differently among vehicle manufacturers, which can lead to some confusion.

**Relay:** A relay is an electromagnetic switch that uses a movable arm. Because a relay uses a movable arm, it is generally limited to current flow not exceeding 30 amperes.

**Solenoid:** A solenoid is an electromagnetic switch that uses a movable core. Because of this type of design, a solenoid is capable of handling 200 amperes or more and is used in the starter motor circuit and other high-amperage applications, such as in the glow plug circuit of diesel engines.
REAL WORLD FIX: The Electric Mirror Fault Story

Often, a customer will notice just one fault even though other lights or systems may not be working correctly. For example, a car dealer mentioned that the electric mirrors were not working. The service technician checked all options and components of the vehicle and discovered that the interior lights were also not working.

The service technician did not mention to the customer that the interior lights were not working, but realized that the customer might have mentioned it if they had noticed that the interior lights were not working. The service technician found the interior light and power accessory fuse blown. Replacing the fuse restored the proper operation of the electric outside mirrors and the interior lights. However, what caused the fuse to blow? A visual inspection of the dome light, next to the electric sunroof, showed an area where a wire was bare. Evidence showed that the wire had touched the metal roof, which could cause the fuse to blow. The technician covered the bare wire with a section of vacuum hose and then taped the hose with electrical tape to complete the repair.

Figure 45-32 - A typical wiring diagram showing multiple switches and bulbs powered by one fuse.

Figure 45-33 - To add additional lighting, simply tap into an existing light wire and connect a relay. Whenever the existing light is turned on, the coil of the relay is energized. The arm of the relay then connects power from another circuit (powered by a different fuse) to the auxiliary lights without overloading the existing light circuit.
TECH TIP: Do It Right—Install a Relay

Often the owners of vehicles, especially owners of pickup trucks and sport utility vehicles (SUVs), want to add additional electrical accessories or lighting. It is tempting to simply spliced into an existing circuit. However, when another circuit or component is added, the current that flows through the newly added component is also added to the current for the original component. This additional current can easily overload the fuse and wiring. Do not simply install a larger amp fuse; the wire gauge size was not engineered for the additional current and could overheat.

The solution is to install a relay, which uses a small coil to create a magnetic field that causes a movable arm to switch on a higher current circuit. The typical relay coil has from 50 to 150 ohms (usually 60 to 100 ohms) of resistance and requires just 0.24 to 0.08 ampere when connected to a 12 volt source. This small additional current will not be enough to overload the existing circuit. See Figure 45–33 for an example of how to add additional lighting.

FREQUENTLY ASKED QUESTION: Where to Start?

The common question is, where does a technician start diagnosing when using a wiring diagram (schematic)?

HINT 1: If the circuit contains a relay, start your diagnosis at the relay. The entire circuit can be tested at the terminals of the relay.

HINT 2: The easiest first step is to locate the unit on the schematic that is not working at all or not working correctly.
   a. Trace where the unit gets its ground connection.
   b. Trace where the unit gets its power connection.

HINT 3: Divide the circuit in half by locating a connector or a part of the circuit that can be easily accessed. Then check for power and ground at this midpoint. This step could save you much time.

HINT 4: Use a fused jumper wire to substitute a ground or a power source to replace a suspected switch or section of wire.
Figure 45-35 (a) After removing the blown fuse, a pulsing circuit breaker is connected to the terminals of the fuse.

Figure 45-35 (b) The circuit breaker causes current to flow, then stop, then flow again, through the circuit up to the point of the short-to-ground. By observing the Gauss gauge, the location of the short is indicated near where the needle stops moving due to the magnetic field created by the flow of current through the wire.

Figure 45-36 A Gauss gauge can be used to determine the location of a short circuit even behind a metal panel.
TECH TIP

Heat or Movement
Electrical shorts are commonly caused either by movement, which causes the insulation around the wiring to be worn away, or by heat melting the insulation. When checking for a short circuit, first check the wiring that is susceptible to heat, movement, and damage.

1. Heat. Wiring near heat sources, such as the exhaust system, cigarette lighter, or alternator
2. Wire movement. Wiring that moves, such as in areas near the doors, trunk, or hood
3. Damage. Wiring subject to mechanical injury, such as in the trunk, where heavy objects can move around and smash or damage wiring, can also occur as a result of an accident or a previous repair

TECH TIP

Wiggle Test
Intermittent electrical problems are common and difficult to locate. To help locate these hard-to-find problems, try operating the circuit and then start wigging the wires and connections that control the circuit. If in doubt where the wiring goes, try moving all the wiring starting at the battery. Pay particular attention to wiring running near the battery or the windshield-washer container. Corrosion can cause wiring to fail, and battery acid and limes and alcohol-based windshield washer fluid can start or contribute to the problem. If you notice any change in the operation of the device being tested while wigging the wiring, look closer in the area you were wigging until you locate and correct the actual problem.

Figure 45-37
A tone generator type tester used to locate open circuits and circuits that are shorted-to-ground. Included with this tester is a transmitter (tone generator), receiver probe, and headphones for use in noisy shops.
To check for a short-to-ground using a tone generator, connect the black transmitter lead to a good chassis ground and the red lead to the load side of the fuse terminal. Turn the transmitter on and check for tone signal with the receiver. Using a wiring diagram, follow the strongest signal to the location of the short-to-ground. There will be no signal beyond the fault, either a short-to-ground or an open circuit.

**REAL WORLD FIX: Shocking Experience**

A customer complained that after driving for a while, he got a static shock whenever he grabbed the door handle when exiting the vehicle. The customer thought that there must be an electrical fault and that the shock was coming from the vehicle itself. In a way, the shock was caused by the vehicle, but it was not a fault. The service technician sprayed the cloth seats with an antistatic spray and the problem did not recur. Obviously, a static charge was being created by the movement of the driver’s clothing on the seats and then discharged when the driver touched the metal door handle. *See Figure 45–39.*

Figure 45–39 Antistatic spray can be used by customers to prevent being shocked when they touch a metal object like the door handle.