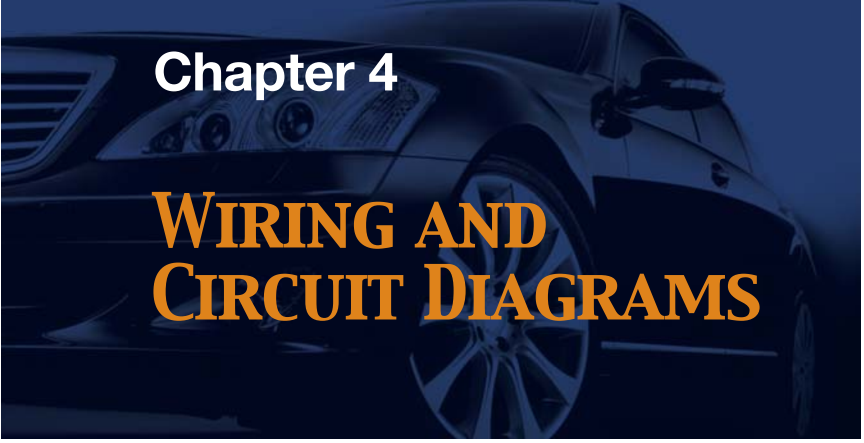

Chapter 4

Wiring and Circuit Diagrams

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

- When single-stranded or multistranded wire should be used.
- The use of resistive wires in a circuit.
- The construction of spark plug wires.
- How wire size is determined by the American Wire Gauge (AWG) and metric methods.
- How to determine the correct wire gauge to be used in a circuit.
- How temperature affects resistance and wire size selection.
- The purpose and use of printed circuits.
- Why wiring harnesses are used and how they are constructed.
- The purpose of wiring diagrams.
- The common electrical symbols that are used.
- The purpose of the component locator.

Introduction

Today's vehicles have a vast amount of electrical wiring that, if laid end to end, could stretch for half a mile or more. Today's technician must be proficient at reading wiring diagrams in order to sort through this great maze of wires. Trying to locate the cause of an electrical problem can be quite difficult if you do not have a good understanding of wiring systems and diagrams.

In this chapter, you will learn how wiring harnesses are made (Figure 4-1), how to read the wiring diagram, how to interpret the symbols used, and how terminals are used. This will reduce the amount of confusion you may experience when repairing an electrical circuit. It is also important to understand how to determine the correct type and size of wire to carry the anticipated amount of current. It is possible to cause an electrical problem by simply using the wrong gauge size of wire. A technician must understand the three factors that cause resistance in a wire—length, diameter, and temperature—to perform repairs correctly.

Automotive Wiring

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Primary wiring is the term used for conductors that carry low voltage. The insulation of primary wires is usually thin. **Secondary wiring** refers to wires used to carry high voltage, such as ignition spark plug wires. Secondary wires have extra-thick insulation.

Most of the primary wiring conductors used in the automobile are made of several strands of copper wire wound together and covered with a polyvinyl chloride (PVC) insulation (Figure 4-2). Copper has low resistance and can be connected to easily by using crimping connectors or soldered connections. Other types of conductor materials used in automobiles include silver, gold, aluminum, and tin-plated brass.

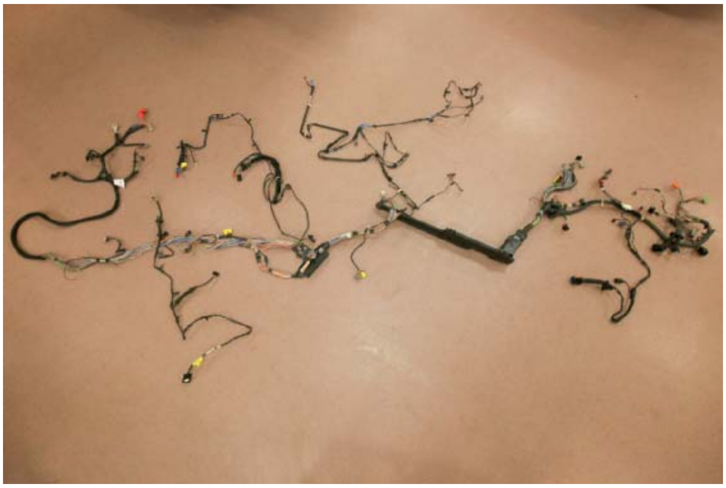

FIGURE 4-1 **Vehicle wiring harness.**

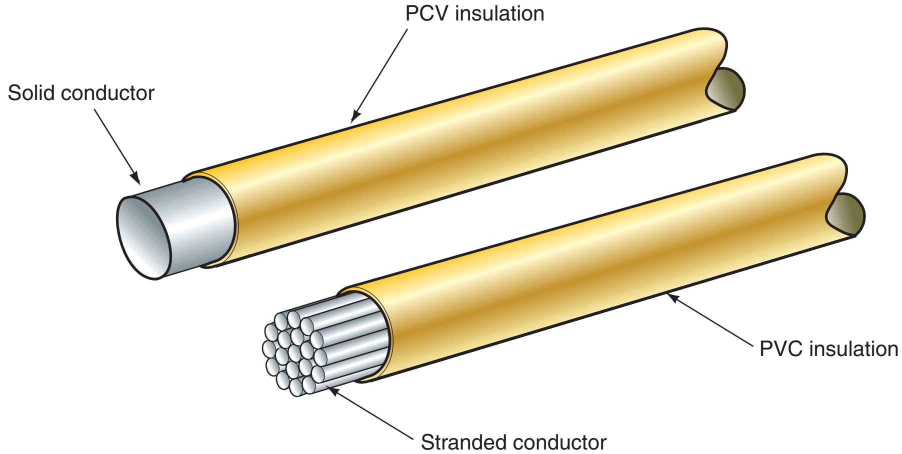

FIGURE 4-2 **Comparison between solid and stranded primary wire.**

AUTHOR'S NOTE: Copper is used mainly because of its low cost and availability.

Stranded wire means the conductor is made of several individual wires that are wrapped together. Stranded wire is used because it is very flexible and has less resistance than solid wire. This is because electrons tend to flow on the outside surface of conductors. Since there is more surface area exposed in a stranded wire (each strand has its own surface), there is less resistance in the stranded wire than in the solid wire (Figure 4-3). The PVC insulation is used because it can withstand temperature extremes and corrosion. PVC insulation is also capable of withstanding battery acid, antifreeze, and gasoline. The insulation protects the wire from shorting to ground and from corrosion.

AUTHOR'S NOTE: General Motors has used single-stranded aluminum wire in limited applications where no flexing of the wire is expected. For example, it is used in the taillight circuits.

Wire Sizes

Consideration must be given for some margin of safety when selecting wire size. There are three major factors that determine the proper size of wire to be used:

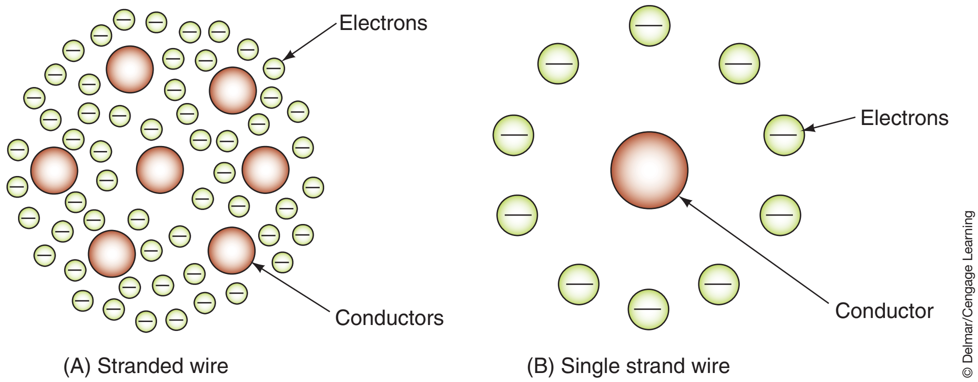

FIGURE 4-3 **Stranded wire provides flexibility and more surface area for electron flow than a single-strand solid wire.**

1. The wire must have a large enough diameter, for the length required, to carry the necessary current for the load components in the circuit to operate properly.
2. The wire must be able to withstand the anticipated vibration.
3. The wire must be able to withstand the anticipated amount of heat exposure.

Wire size is based on the diameter of the conductor. The larger the diameter, the less the resistance. There are two common size standards used to designate wire size: American Wire Gauge (AWG) and metric.

The AWG standard assigns a **gauge** number to the wire based on its diameter. The higher the number, the smaller the wire diameter. For example, 20-gauge wire is smaller in diameter than 10-gauge wire (Table 4-1). Most electrical systems in the automobile use 14-, 16-, or 18-gauge wire. Some high-current circuits will also use 10- or 12-gauge wire. Most battery cables are 2-, 4-, or 6-gauge cable.

Both wire diameter and wire length affect resistance. Sixteen-gauge wire is capable of conducting 20 amperes for 10 feet with minimal voltage drop. However, if the current is to be carried for 15 feet, 14-gauge wire would be required. If 20 amperes were required to be carried for 20 feet, then 12-gauge wire would be required. The additional wire size is needed to prevent voltage drops in the wire. The illustration (Table 4-2) lists the wire size required to carry a given amount of current for different lengths.

TABLE 4-1 **GAUGE AND WIRE SIZE CHART**

American Wire Gauge Sizes	
Gauge size	Conductor diameter (inches)
20	0.032
18	0.040
16	0.051
14	0.064
12	0.081
10	0.102
8	0.128
6	0.162
4	0.204
2	0.258
1	0.289
0	0.325
2/0	0.365
4/0	0.460

TABLE 4-2 **THE DISTANCE THE CURRENT MUST BE CARRIED IS A FACTOR IN DETERMINING THE CORRECT WIRE GAUGE TO USE**

Total Approximate Circuit Amperes	**Wire Gauge (for Length in Feet)**								
12 V	**3**	**5**	**7**	**10**	**15**	**20**	**25**	**30**	**40**
1.0	18	18	18	18	18	18	18	18	18
1.5	18	18	18	18	18	18	18	18	18
2	18	18	18	18	18	18	18	18	18
3	18	18	18	18	18	18	18	18	18
4	18	18	18	18	18	18	18	16	16
5	18	18	18	18	18	18	18	16	16
6	18	18	18	18	18	18	16	16	16
7	18	18	18	18	18	18	16	16	14
8	18	18	18	18	18	16	16	16	14
10	18	18	18	18	16	16	16	14	12
11	18	18	18	18	16	16	14	14	12
12	18	18	18	18	16	16	14	14	12
15	18	18	18	18	14	14	12	12	12
18	18	18	16	16	14	14	12	12	10
20	18	18	16	16	14	12	10	10	10
22	18	18	16	16	12	12	10	10	10
24	18	18	16	16	12	12	10	10	10
30	18	16	16	14	10	10	10	10	10
40	18	16	14	12	10	10	8	8	6
50	16	14	12	12	10	10	8	8	6
100	12	12	10	10	6	6	4	4	4
150	10	10	8	8	4	4	2	2	2
200	10	8	8	6	4	4	2	2	1

Another factor to wire resistance is temperature. An increase in temperature creates a similar increase in resistance. A wire may have a known resistance of 0.03 ohms per 10 feet at 70°F. When exposed to temperatures of 170°F, the resistance may increase to 0.04 ohms per 10 feet. Wires that are to be installed in areas that experience high temperatures, as in the engine compartment, must be of a size such that the increased resistance will not affect the operation of the load component. Also, the insulation of the wire must be capable of withstanding the high temperatures.

In the metric system, wire size is determined by the cross-sectional area of the wire. Metric wire size is expressed in square millimeters (mm^2). In this system the smaller the number, the smaller the wire conductor. The approximate equivalent wire size of metric to AWG is shown in Table 4-3.

Ground Straps

Usually there is not a direct metal to metal connection between the powertrain components and the vehicle chassis. The engine, transmission, and axle assemblies are supported by rubber mounts or bushings. The rubber acts as an insulator so any electrical components such as actuators or sensors that are mounted to the powertrain components will not have a completed circuit back to the vehicle's battery. This is especially true if the negative battery cable is attached to the vehicle's chassis instead of the engine block. **Ground straps** between the powertrain components and the vehicle's chassis are used to complete the return path to the

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TABLE 4-3 **APPROXIMATE AWG TO METRIC EQUIVALENTS**

Metric Size (mm^2)	AWG (Gauge) Size	Ampere Capacity
0.5	20	4
0.8	18	6
1.0	16	8
2.0	14	15
3.0	12	20
5.0	10	30
8.0	8	40
13.0	6	50
19.0	4	60

FIGURE 4-4 **Ground straps are used to provide a return part for components that are insulated from the chassis.**

battery (Figure 4-4). In addition, ground straps suppress electromagnetic induction (EMI) and radiation by providing a low-resistance circuit ground path.

AUTHOR'S NOTE: Ground straps are also referred to as bonding straps.

Ground straps can be installed in various locations. Some of the most common locations are:

- Engine to bulkhead or fender.
- Across the engine mounts.
- Radio chassis to instrument panel frame.
- Air-conditioning evaporator valve to the bulkhead.

The ground strap can be a large gauge insulated-type cable or a braided strap. Even on vehicles with the battery negative cable attached to the engine block, ground straps are used to connect between the engine block and the vehicle chassis. The additional ground cable ensures a good, low-resistance ground path between the engine and the chassis.

Ground straps are also used to connect sheet metal parts such as the hood, fender panels, and the exhaust system even though there is no electrical circuit involved. In these cases, the strap is used to suppress EMI since the sheet metal could behave as a large capacitor. The air space between the sheet metal forms an electrostatic field and can interfere with any computer-controlled circuits that are routed near the sheet metal.

Terminals and Connectors

To perform the function of connecting the wires from the voltage source to the load component reliably, terminal connections are used. Today's vehicles can have as many as 500 separate circuit connections. The terminals used to make these connections must be able to perform with very low voltage drop. Terminals are constructed of either brass or steel. Steel terminals usually have a tin or lead coating. A loose or corroded connection can cause an unwanted voltage drop that results in poor operation of the load component. For example, a connector used in a light circuit that has as little as 10% voltage drop (1.2 V) may result in a 30% loss of lighting efficiency.

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Terminals can be either crimped or soldered to the conductor. The terminal makes the electrical connection, and it must be capable of withstanding the stress of normal vibration. The illustration (Figure 4-5) shows several different types of terminals used in the automotive electrical system. In addition, the following connectors are used on the automobile:

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1. **Molded connector:** These connectors usually have one to four wires that are molded into a one-piece component (Figure 4-6). Although the connector halves separate, the connector itself cannot be taken apart.

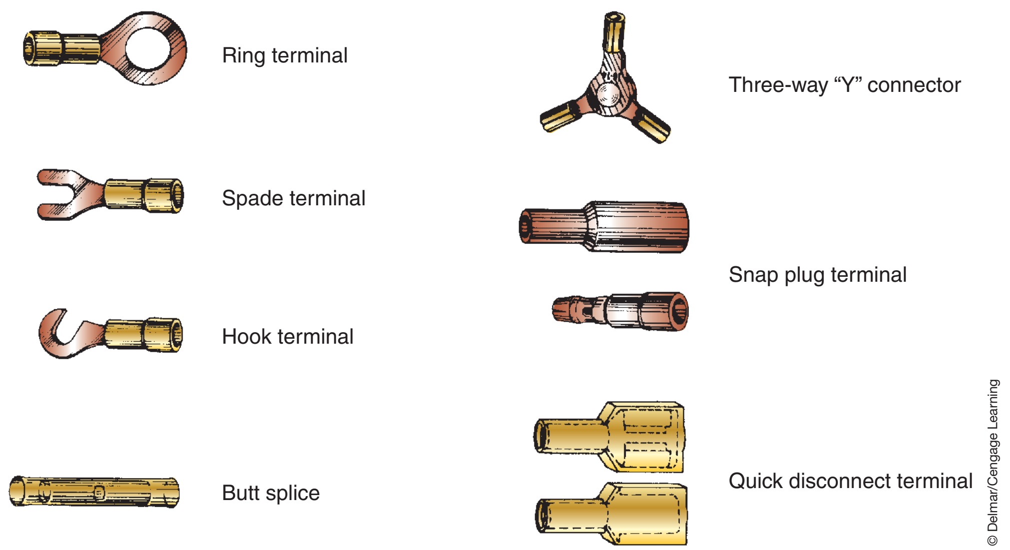

FIGURE 4-5 **Examples of primary wire terminals and connectors used in automotive applications.**

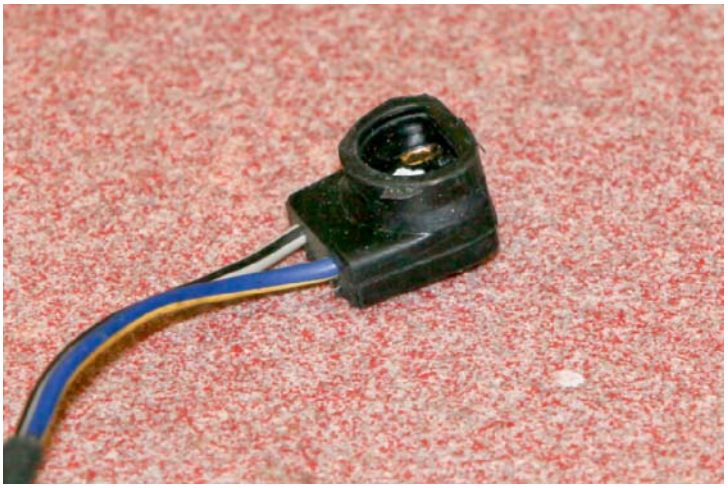

FIGURE 4-6 **Molded connectors cannot be disassembled to replace damaged terminals or to test.**

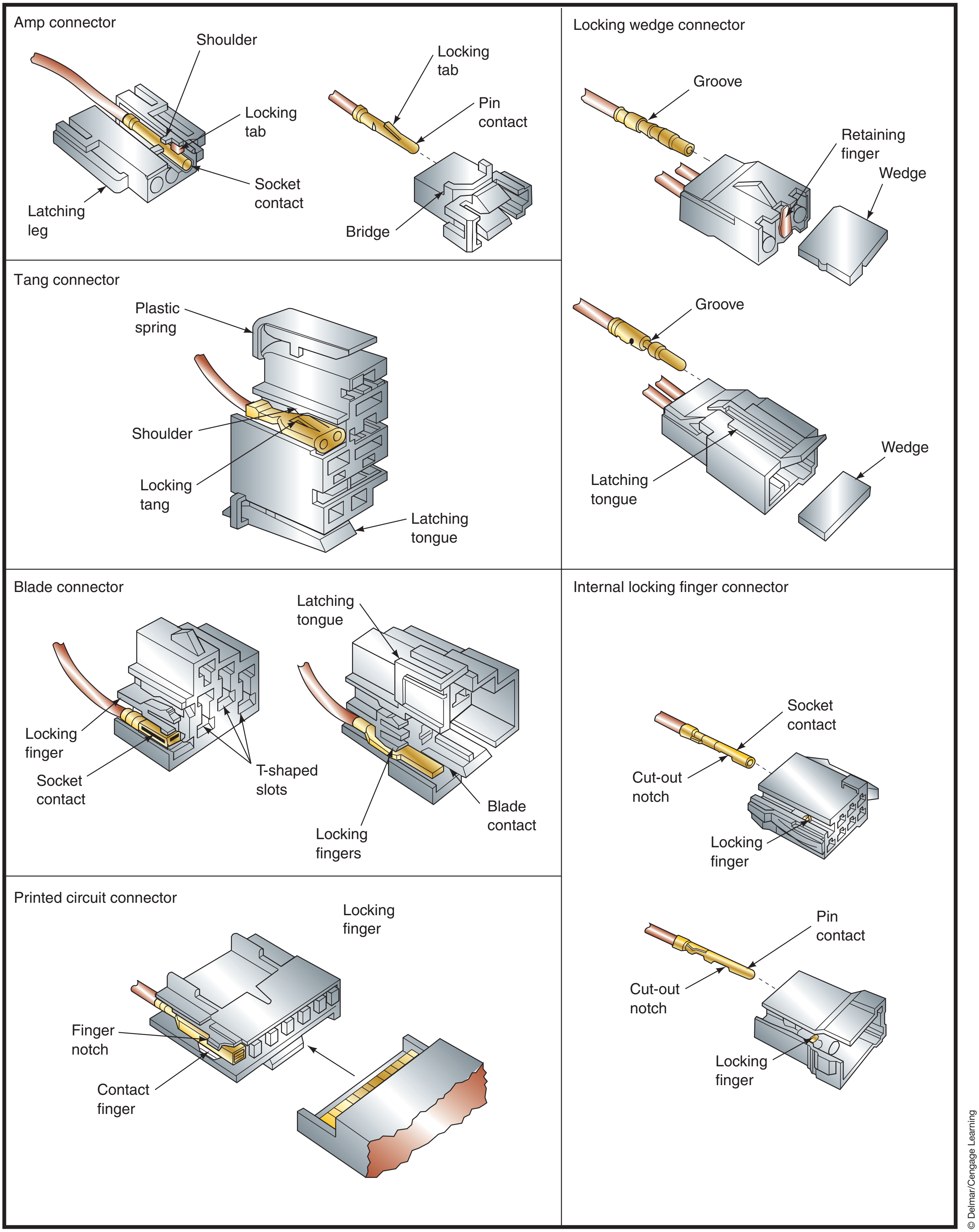

FIGURE 4-7 **Multiple-wire hard-shell connectors.**

2. **Multiple-wire, hard-shell connector:** These connectors usually have a hard, plastic shell that holds the connecting terminals of separate wires (Figure 4-7). The wire terminals can be removed from the shell to be repaired.
3. **Bulkhead connectors:** These connectors are used when several wires must pass through the bulkhead (Figure 4-8).
4. **Weather-Pack Connectors:** These connectors have rubber seals on the terminal ends and on the covers of the connector half (Figure 4-9). They are used on computer circuits to protect the circuit from corrosion, which may result in a voltage drop.
5. **Metri-Pack Connectors:** These are like the weather-pack connectors but do not have the seal on the cover half (Figure 4-10).
6. **Heat Shrink Covered Butt Connectors:** Recommended for air bag applications by some manufacturers. Other manufacturers allow NO repairs to the circuitry, while still others require silver-soldered connections.

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To reduce the number of connectors in the electrical system, a **common connection** can be used (Figure 4-11). Common connections are used to share a source of power or a common ground and are often called a splice. If there are several electrical components that are physically close to each other, a single common connection (splice) eliminates using a separate connector for each wire.

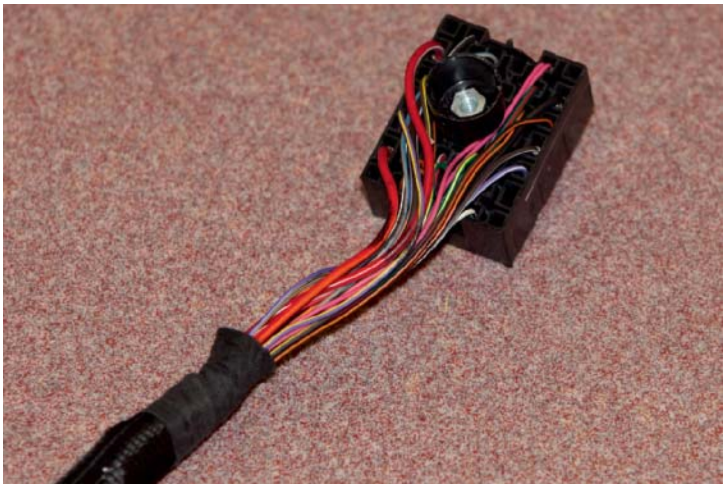

FIGURE 4-8 **Bulkhead connector.**

FIGURE 4-9 **Weather-pack connector is used to prevent connector corrosion.**

FIGURE 4-10 **Metri-pack connector.**

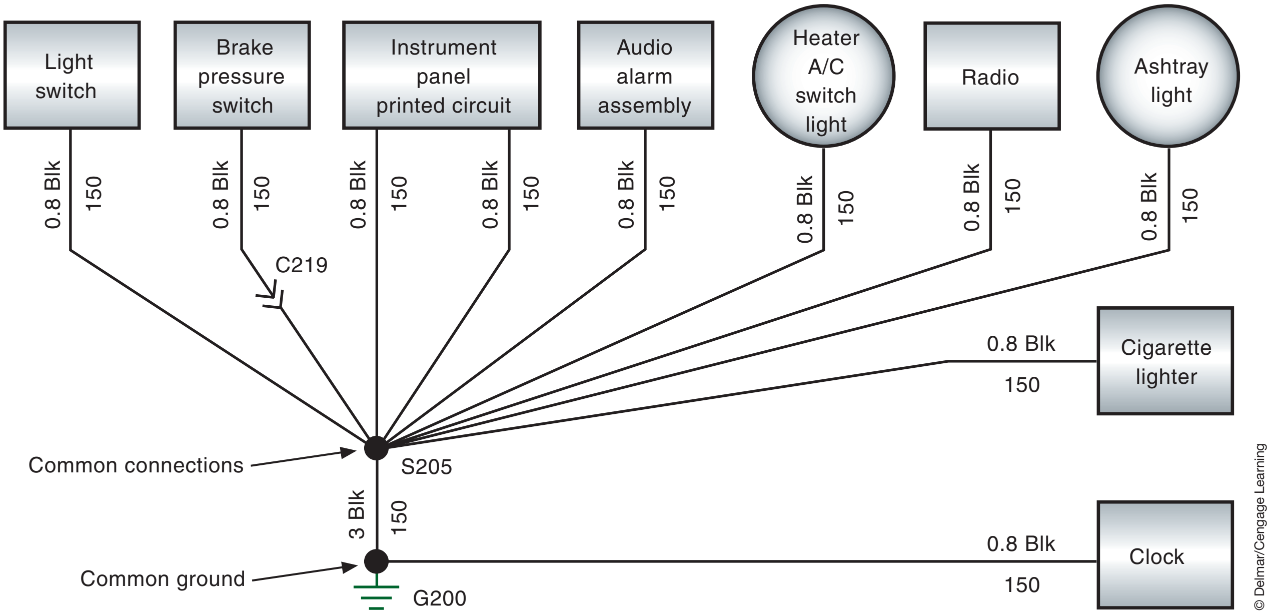

FIGURE 4-11 **Common connections (splices) are used to reduce the amount of wire and connectors.**

Printed Circuits

Printed circuit boards are used to simplify the wiring of the circuits they operate. Other uses of printed circuit boards include the inside of radios, computers, and some voltage regulators. Most instrument panels use printed circuit boards as circuit conductors. A printed circuit is made of a thin phenolic or fiberglass board that copper (or some other conductive material) has been deposited on. Portions of the conductive metal are then etched or eaten away by acid. The remaining strips of conductors provide the circuit path for the instrument panel illumination lights, warning lights, indicator lights, and gauges of the instrument panel (Figure 4-12). The printed circuit board is attached to the back of the instrument panel housing. An edge connector joins the printed circuit board to the vehicle wiring harness.

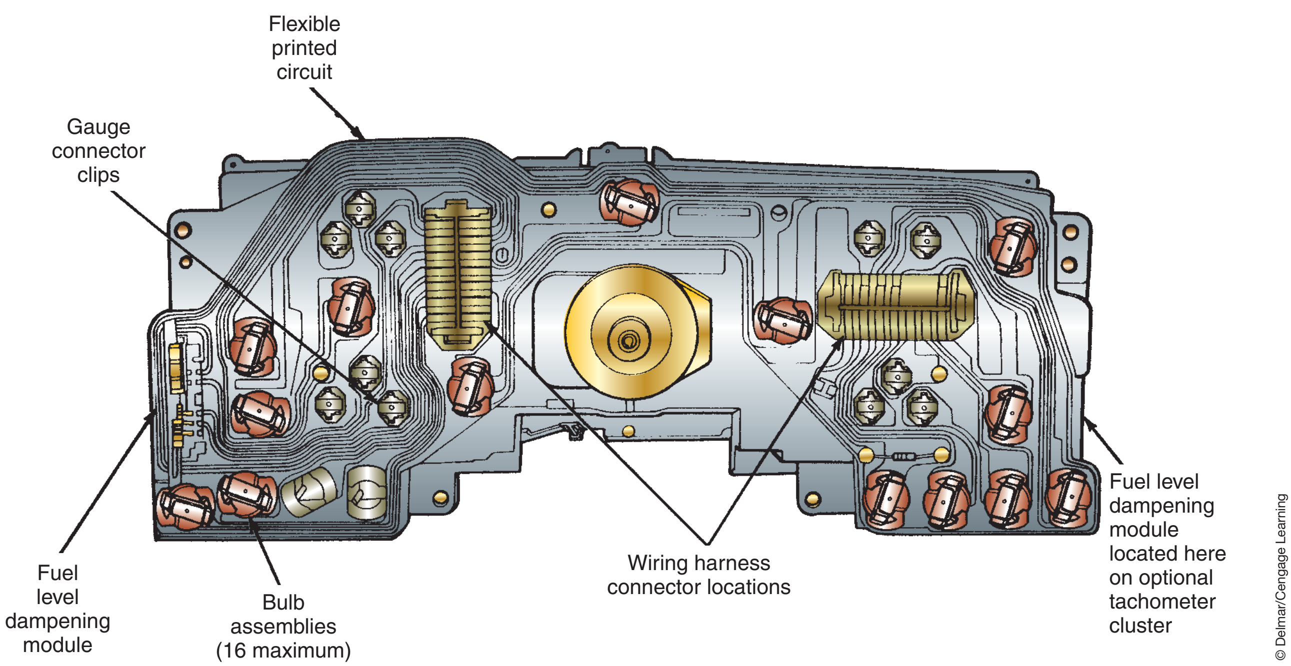

FIGURE 4-12 **Printed circuits eliminate bulky wires behind the instrument panel.**

Whenever it is necessary to perform repairs on or around the printed circuit board, it is important to follow these precautions:

1. When replacing light bulbs, be careful not to cut or tear the surface of the printed circuit board.
2. Do not touch the surface of the printed circuit with your fingers. The acid present in normal body oils can damage the surface.
3. If the printed circuit board needs to be cleaned, use a commercial cleaning solution designed for electrical use. If this solution is not available, it is possible to clean the board by *lightly* rubbing the surface with an eraser.

A Bit of History

The printed circuit board was developed in 1947 by the British scientist J. A. Sargrove to simplify the production of radios.

Wiring Harness

Most manufacturers use **wiring harnesses** to reduce the number of loose wires hanging under the hood or dash of an automobile. The wiring harness provides for a safe path for the wires of the vehicle's lighting, engine, and accessory components. The wiring harness is made by grouping insulated wires and wrapping them together. The wires are bundled into separate harness assemblies that are joined together by connector plugs. The multiple-pin connector plug may have more than 60 individual wire terminals.

There are several complex wiring harnesses in a vehicle, in addition to the simple harnesses. The engine compartment harness and the under-dash harness are examples of complex harnesses (Figure 4-13). Lighting circuits usually use a more simple harness

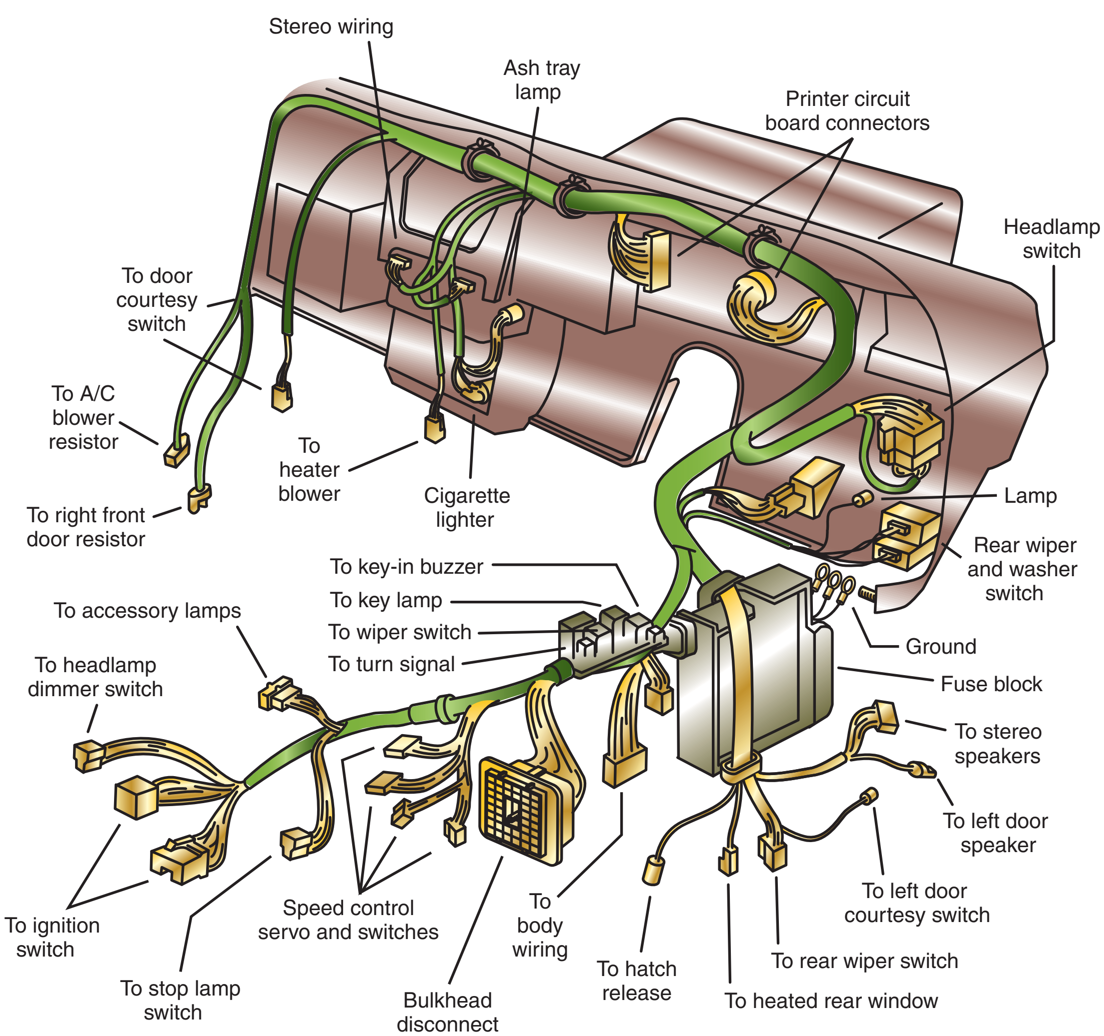

FIGURE 4-13 **Complex wiring harness.**

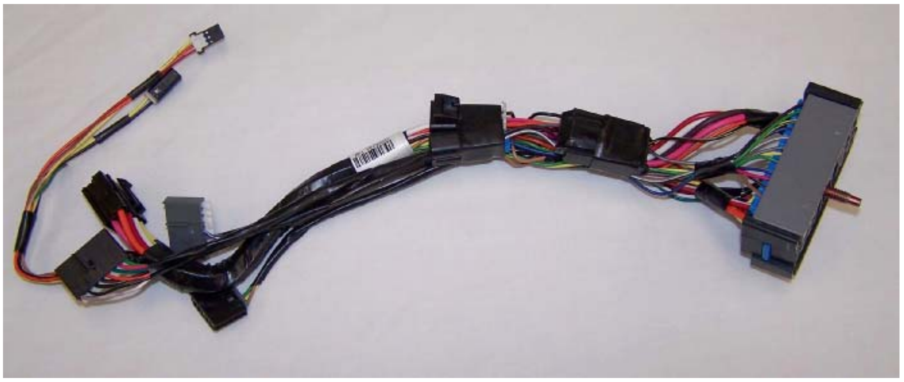

FIGURE 4-14 **Simple wiring harness.**

FIGURE 4-15 **Flexible conduit used to make wiring harnesses.**

(Figure 4-14). A complex harness serves many circuits. The simple harness services only a few circuits. Some individual circuit wires may branch out of a complex harness to other areas of the vehicle.

The conduit is commonly referred to as the *wire loom* or *corrugated loom*.

Most wiring harnesses now use a flexible conduit to provide for quick wire installation (Figure 4-15). The conduit has a seam that can be opened to accommodate the installation or removal of wires from the harness. The seam will close once the wires are installed, and will remain closed even if the conduit is bent.

Wiring Protective Devices

Often overlooked, but very important to the electrical system, are proper wire protection devices (Figure 4-16). These devices prevent damage to the wiring by maintaining proper wire routing and retention. Special clips, retainers, straps, and supplementary insulators provide additional protection to the conductor over what the insulation itself is capable of providing. Whenever the technician must remove one of these devices to perform a repair, it is important that the device be reinstalled to prevent additional electrical problems.

Whenever it is necessary to install additional electrical accessories, try to support the primary wire in at least 1-foot intervals. If the wire must be routed through the frame or body, use rubber grommets to protect the wire.

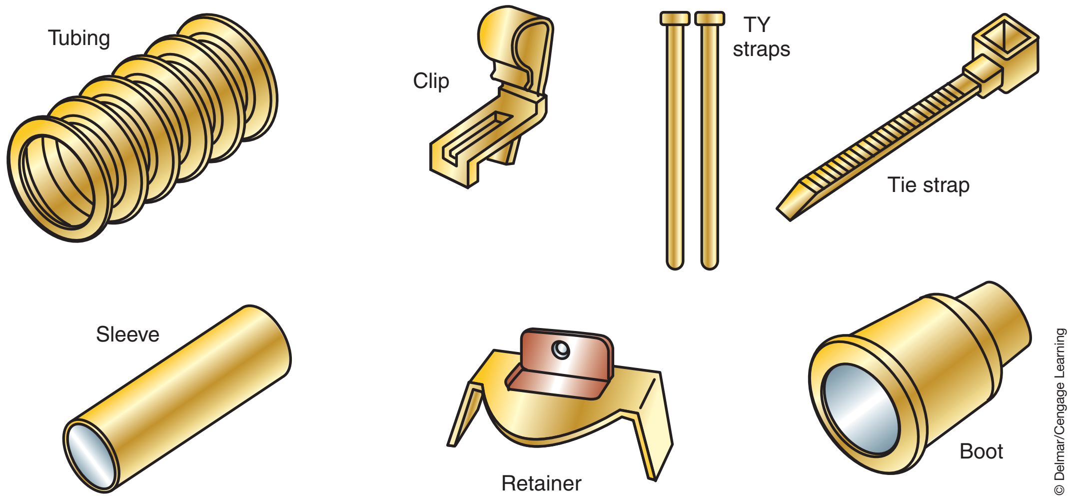

FIGURE 4-16 **Typical wire protection devices.**

Wiring Diagrams

One of the most important tools for diagnosing and repairing electrical problems is a **wiring diagram**. A wiring diagram is an electrical schematic that shows a representation of actual electrical or electronic components (by use of symbols) and the wiring of the vehicle's electrical systems. These diagrams identify the wires and connectors from each circuit on a vehicle. They also show where different circuits are interconnected, where they receive their power, where the ground is located, and the colors of the different wires. All of this information is critical to proper diagnosis of electrical problems. Some wiring diagrams also give additional information that helps you understand how a circuit operates and how to identify certain components (Figure 4-17). Wiring diagrams do not explain how the circuit works; this is where your knowledge of electricity comes in handy.

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A wiring diagram can show the wiring of the entire vehicle or a single circuit (Figure 4-18). These single-circuit diagrams are also called block diagrams. Wiring diagrams of the entire vehicle tend to look more complex and threatening than block diagrams. However, once you simplify the diagram to only those wires, connectors, and components that belong to an individual circuit, they become less complex and more valuable.

Wiring diagrams show the wires, connections to switches and other components, and the type of connector used throughout the circuit. Total vehicle wiring diagrams are normally spread out over many pages of a service information. Some are displayed on a single large sheet of paper that folds out of the manual. A system wiring diagram is actually a portion of the total vehicle diagram. The system and all related circuitry are shown on a single page. System diagrams are often easier to use than vehicle diagrams simply because there is less information to sort through.

Remember that electrical circuits need a complete path in order to work. A wiring diagram shows the insulated side of the circuit and the point of ground. Also, when lines (or wires) cross on a wiring diagram, this does not mean they connect. If wires are connected, there will be a connector or a dot at the point where they cross. Most wiring diagrams do not show the location of the wires, connectors, or components in the vehicle. Some have location reference numbers displayed by the wires. After studying the wiring diagram, you will know what you are looking for. Then you move to the car to find it.

In addition to entire vehicle and system-specific wiring diagrams, there are other diagrams that may be used to diagnose electricity problems. An electrical **schematic** shows how

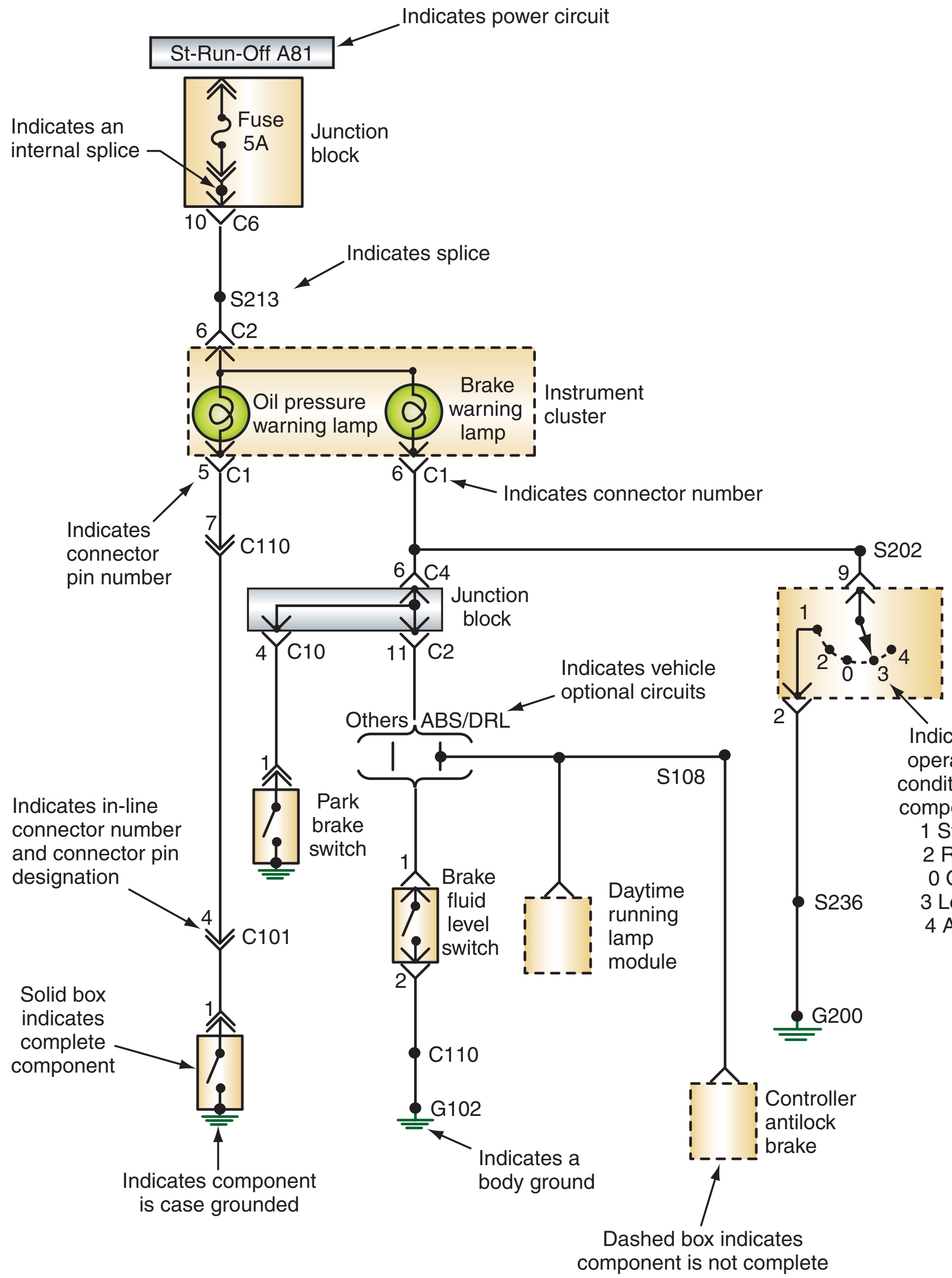


FIGURE 4-17 **Wiring diagrams provide the technician with necessary information to accurately diagnose the electrical systems.**

the circuit is connected. It does not show the colors of the wires or their routing. Schematics are what have been used so far in this book. They display a working model of the circuit. These are especially handy when trying to understand how a circuit works. Schematics are typically used to show the internal circuitry of a component or to simplify a wiring diagram. One of the troubleshooting techniques used by good electrical technicians is to simplify a wiring diagram into a schematic.

Electrical Symbols

Most wiring diagrams do not show an actual drawing of the components. Rather, they use **electrical symbols** to represent the components. Often the symbol displays the basic operation of the component. Many different symbols have been used in wiring diagrams

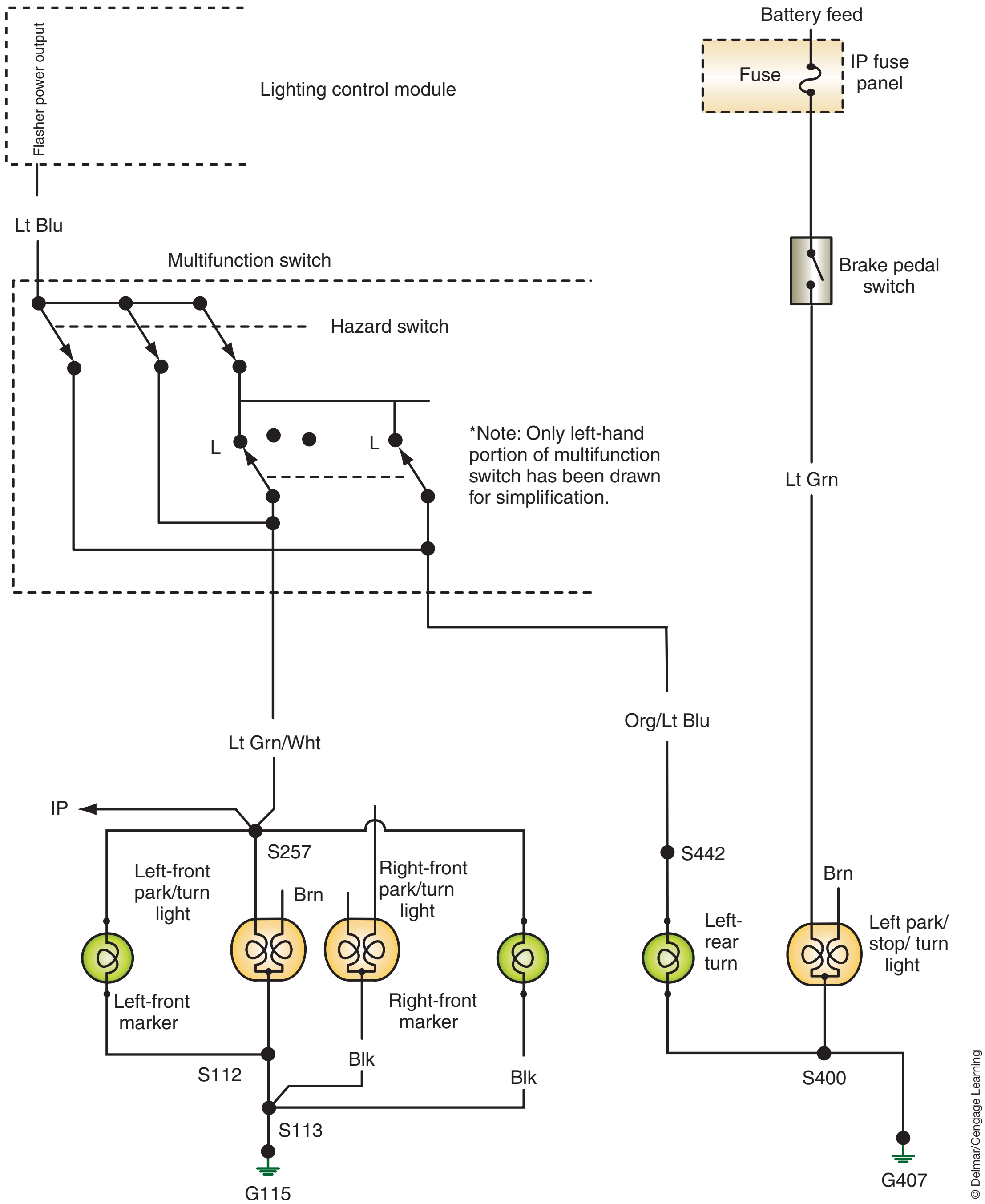


FIGURE 4-18 **Wiring diagram illustrating only one specific circuit for easier reference. This is also known as a block diagram.**

through the years. Table 4-4 shows some of the commonly used symbols. You need to be familiar with all of the symbols; however, you don't need to memorize all of the variations. Wiring diagram manuals include a "legend" that helps you interpret the symbols.

Color Codes and Circuit Numbering

Nearly all of the wires in an automobile are covered with colored insulation. These colors are used to identify wires and electrical circuits. The color of the wires is indicated on a wiring diagram. Some wiring diagrams also include circuit numbers. These numbers, or letters and numbers, help identify a specific circuit. Both types of coding make it easier to diagnose electrical problems. Unfortunately, not all manufacturers use the same method of wire

A Bit of History

The service manuals for early automobiles were hand drawn and labeled. They also had drawings of the actual components. As more and more electrical components were added to cars, this became impractical. Soon schematic symbols replaced the component drawings.

TABLE 4-4 **COMMON ELECTRICAL AND ELECTRONIC SYMBOLS USED IN WIRING DIAGRAMS**

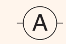
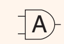
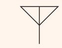
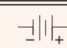
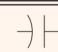
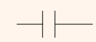
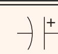
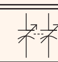
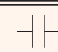
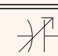
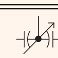
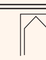
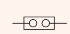
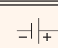
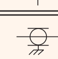
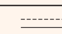
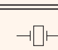
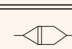
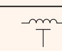
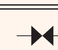
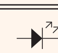
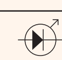
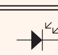
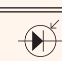
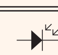
COMPONENT	SYMBOL	ALTERNATE
Ammeter		
And Gate		
Antenna		
Attenuator, Fixed		
Attenuator, Variable		
Battery		
Capacitor, Feedthrough		
Capacitor, Fixed, Nonpolarized		
Capacitor, Fixed, Polarized		
Capacitor, Ganged, Variable		
Capacitor, General		
Capacitor, Variable, Single		
Capacitor, Variable, Split-Stator		
Cathode, Cold		
Cathode, Directly Heated		
Cathode, Indirectly Heated		
Cavity Resonator		
Cell		
Choice Bracket		
Circuit Breaker or PTC device		
Clockspring		
Coaxial Cable		
Coil		
Crystal, Piezoelectric		
Delay Line		
Diode		
Diode, Gunn		
Diode, Light-Emitting		
Diode, Photosensitive		
Diode, Photovoltaic		

TABLE 4-4 *(continued)*

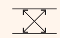
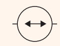
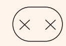
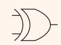
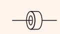
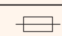
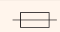
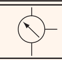
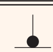
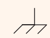
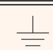
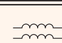
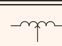
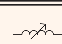
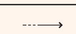
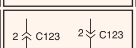
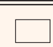
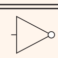
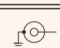
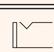
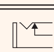
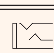
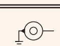
Diode, Pin		
Diode, Varactor		
Diode, Zener		
Directional Coupler		
Dual Filament Lamp		
Exclusive-Or Gate		
Female Contact		
Ferrite Bead		
Fuse		
Fusible link		
Gauge		
Ground, Chassis		
Ground, Earth		
Handset		
Headphone, Double		
Headphone, Single		
Heating element		
Hot Bar	BATT A0	
Inductor, Air-Core		
Inductor, Bifilar		
Inductor, Iron-Core		
Inductor, Tapped		
Inductor, Variable		
In-Line Connectors		
Integrated Circuit		
Inverter		
Jack, Coaxial		
Jack, Phone, 2-Conductor		
Jack, Phone, 2-Conductor Interrupting		
Jack, Phone, 3-Conductor		
Jack, Phono		

TABLE 4-4 (continued)

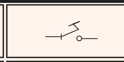
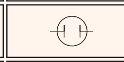
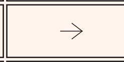
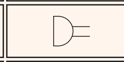
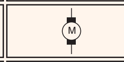
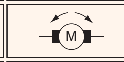
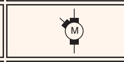
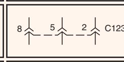
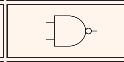
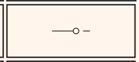
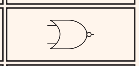
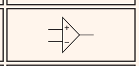
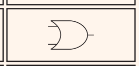
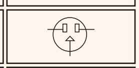
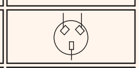
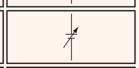
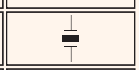
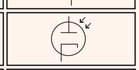
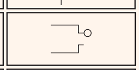
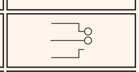
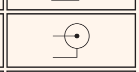
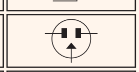
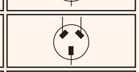
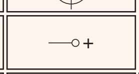
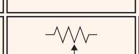
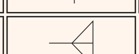
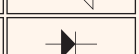
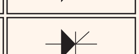
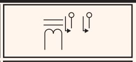
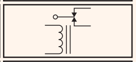
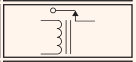
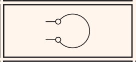
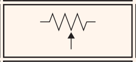
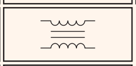
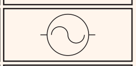
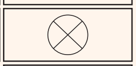
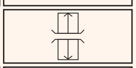
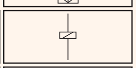
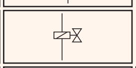
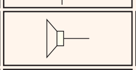
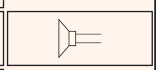
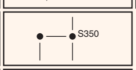
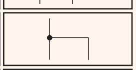
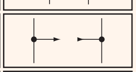
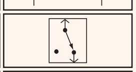
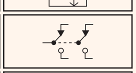
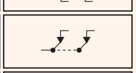
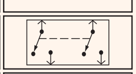
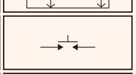
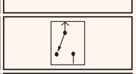
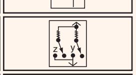
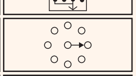
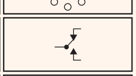
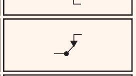
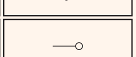
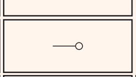
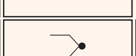
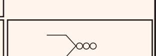
Key, Telegraph		
Lamp, Neon		
Male Contact		
Microphone		
Motor, One speed		
Motor, Reversible		
Motor, two Speed		
Multiple connectors		
Nand Gate		
Negative Voltage Connection		
Nor Gate		
Operational Amplifier		
Or Gate		
Outlet, Utility, 117-V		
Outlet, Utility, 234-V		
Oxygen Sensor		
Page Reference	(BW-30-10)	
Piezoelectric Cell		
Photocell, Tube		
Plug, Phone, 2-Conductor		
Plug, Phone, 3-Conductor		
Plug, Phono		
Plug, Utility, 117-V		
Plug, Utility, 234-V		
Positive Voltage Connection		
Potentiometer		
Probe, Radio-Frequency		
Rectifier, Semiconductor		
Rectifier, Silicon-Controlled		
Rectifier, Tube-Type		
Relay, DPDT		

TABLE 4-4 *(continued)*

Relay, DPST		
Relay, SPDT		
Relay, SPST		
Resistor		
Resonator		
Rheostat, Variable Resistor, Thermistor		
Saturable Reactor		
Shielding		
Signal Generator		
Single Filament Lamp		
Sliding Door Contact		
Solenoid		
Solenoid Valve		
Speaker		
Splice, External		
Splice, Internal		
Splice, Internal (Incompleted)		
Switch, Closed		
Switch, DPDT		
Switch, DPST		
Switch, Ganged		
Switch, Momentary-Contact		
Switch, Open		
Switch, Resistive Multiplex		
Switch, Rotary		
Switch, SPDT		
Switch, SPST		
Terminals		
Test Point		
Thermocouple		

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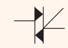
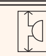
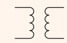
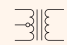
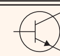
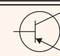
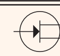
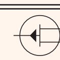
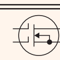
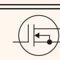
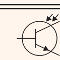
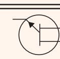
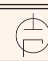
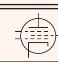
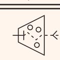
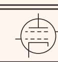
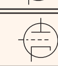
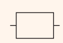
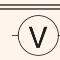
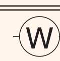
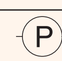
Thyristor		
Tone Generator		
Transformer, Air-Core		
Transformer, Iron-Core		
Transformer, Tapped Primary		
Transformer, Tapped Secondary		
Transistor, Bipolar, npn		
Transistor, Bipolar, pnp		
Transistor, Field-Effect, N-Channel		
Transistor, Field-Effect, P-Channel		
Transistor, Metal-Oxide, Dual-Gate		
Transistor, Metal-Oxide, Single-Gate		
Transistor, Photosensitive		
Transistor, Unijunction		
Tube, Diode		
Tube, Pentode		
Tube, Photomultiplier		
Tube, Tetrode		
Tube, Triode		
Unspecified Component		
Voltmeter		
Wattmeter		
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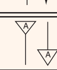
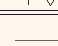
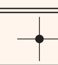
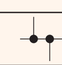
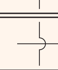
Wire Origin & Destination Within Cell		
Wires		
Wires, Connected, Crossing		
Wires, Not Connected, Crossing		

TABLE 4-5 COMMON COLOR CODES USED IN AUTOMOTIVE APPLICATIONS

Color	Abbreviations		
Black	BLK	BK	B
Blue (Dark)	BLU DK	DB	DK BLU
Blue	BLU	B	L
Blue (Light)	BLU LT	LB	LT BLU
Brown	BRN	BR	BN
Glazed	GLZ	GL	
Gray	GR A	GR	G
Green (Dark)	GRN DK	DG	DK GRN
Green (Light)	GRN LT	LG	LT GRN
Maroon	MAR	M	
Natural	NAT	N	
Orange	ORN	O	ORG
Pink	PNK	PK	P
Purple	PPL	PR	
Red	RED	R	RD
Tan	TAN	T	TN
Violet	VLT	V	
White	WHT	W	WH
Yellow	YEL	Y	YL

identification. Table 4-5 shows common color codes and their abbreviations. Most wiring diagrams list the appropriate color coding used by the manufacturer. Make sure you understand what color the code is referring to before looking for a wire.

In most color codes, the first group of letters designates the base color of the insulation. If a second group of letters is used, it indicates the color of the **tracer**. For example, a wire designated as WH/BLK would have a white base color with a black tracer. A tracer is a thin or dashed line of a different color than the base color of the insulation.

Ford uses four methods of color coding its wires (Figure 4-19):

1. Solid color.
2. Base color with a stripe (tracer).
3. Base color with hash marks.
4. Base color with dots.

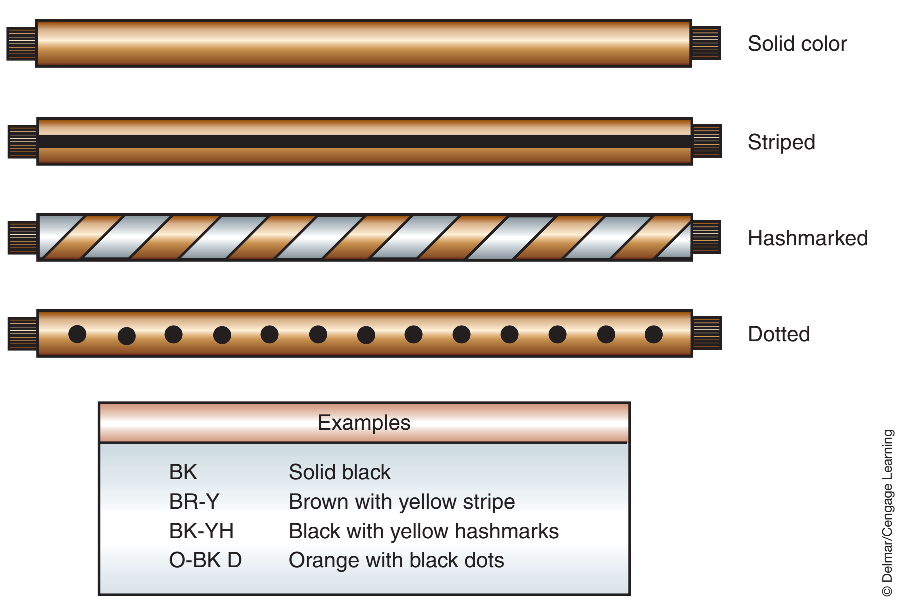


FIGURE 4-19 **Four methods that Ford uses to color code their wires.**

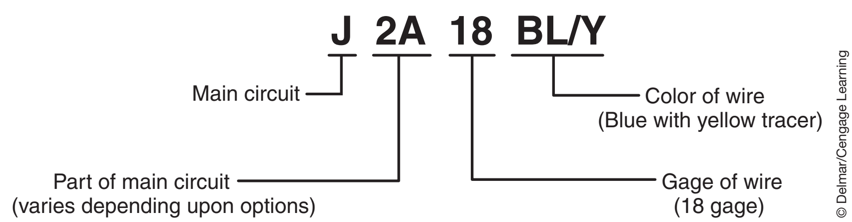


FIGURE 4-20 **Chrysler's wiring code identification.**

Chrysler uses a numbering method to designate the circuits on the wiring diagram (Figure 4-20). The circuit identification, wire gauge, and color of the wire are included in the wire number. Chrysler identifies the main circuits by using a main circuit identification code that corresponds to the first letter in the wire number (Table 4-6).

General Motors uses numbers that include the wire gauge in metric millimeters, the wire color, the circuit number, splice number, and ground identification (Figure 4-21). In this example, the circuit is designated as 100, the wire size is 0.8 mm2, the insulation color is black, the splice is numbered S114, and the ground is designated as G117.

Most manufacturers also number connectors, terminals, splices, and grounds for identification. The numbers correspond to their general location within the vehicle. The following is typical identification numbers:

100-199	Engine compartment forward of the dash panel
200-299	Instrument panel area
300-399	Passenger compartment
400-499	Deck area
500-599	Left front door
600-699	Right front door
700-799	Left rear door
800-899	Right rear door
900-999	Deck lid or hatch

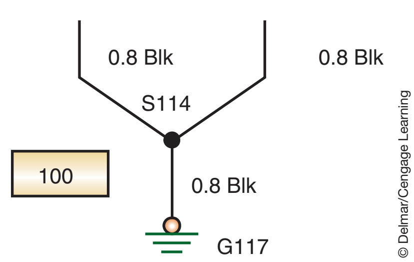


FIGURE 4-21 **GM's method of circuit and wire identification.**

TABLE 4-6 **CHRYSLER'S CIRCUIT IDENTIFICATION CODES**

CIRCUIT IDENTIFICATION CODE CHART	
CIRCUIT	**FUNCTION**
A	BATTERY FEED
B	BRAKE CONTROLS
C	CLIMATE CONTROLS
D	DIAGNOSTIC CIRCUITS
E	DIMMING ILLUMINATION CIRCUITS
F	FUSED CIRCUITS
G	MONITORING CIRCUITS (GAUGES)
H	MULTIPLE
I	NOT USED
J	OPEN
K	POWERTRAIN CONTROL MODULE
L	EXTERIOR LIGHTING
M	INTERIOR LIGHTING
N	MULTIPLE
O	NOT USED
P	POWER OPTION (BATTERY FEED)
Q	POWER OPTIONS (IGNITION FEED)
R	PASSIVE RESTRAINT
S	SUSPENSION/STEERING
T	TRANSMISSION/TRANSAXLE/TRANSFER CASE
U	OPEN
V	SPEED CONTROL, WIPER/WASHER
W	WIPERS
X	AUDIO SYSTEMS
Y	TEMPORARY
Z	GROUNDS

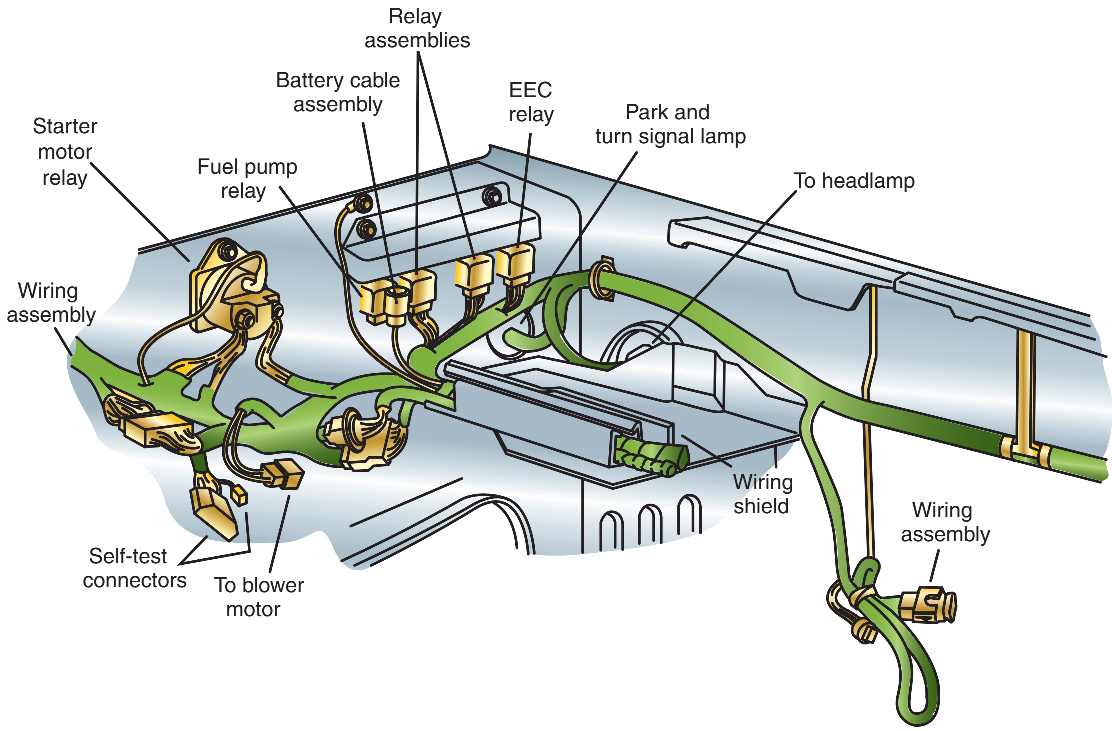


FIGURE 4-22 **A typical installation diagram.**

Component Locators

Component locators are also called installation diagrams

The wiring diagrams in most service informations may not indicate the exact physical location of the components of the circuit. In another section of the service information, or in a separate manual, a **component locator** is provided to help find where a component is installed in the vehicle. The component locator may use both drawings and text to lead the technician to the desired component (Figure 4-22).

Many electrical components may be hidden behind kick panels, dashboards, fender wells, and under seats. The use of a component locator will save the technician time in finding the suspected defective unit.

SUMMARY

- Most of the primary wiring conductors used in the automobile are made of several strands of copper wire wound together and covered with a polyvinyl chloride (PVC) insulation.
- Stranded wire is used because of its flexibility and current flows on the surface of the conductors. Because there is more surface area exposed in a stranded wire, there is less resistance in the stranded wire than in the solid wire.
- There are three major factors that determine the proper size of wire to be used: (1) The wire must be large enough diameter—for the length required—to carry the necessary current for the load components in the circuit to operate properly, (2) the wire must be able to with stand the anticipated vibration, and (3) the wire must be able to withstand the anticipated amount of heat exposure.
- Wire size is based on the diameter of the conductor.

SUMMARY

- Factors that affect the resistance of the wire include the conductor material, wire diameter, wire length, and temperature.
- Ground straps are used to complete the return path to the battery between components tht are insulated. They are also used to suppress electromagnetic induction (EMI) and radiation.
- Terminals can be either crimped or soldered to the conductor. The terminal makes the electrical connection and it must be capable of withstanding the stress of normal vibration.
- Printed circuit boards are used to simplify the wiring of the circuits they operate. A printed circuit is made of a thin phenolic or fiberglass board that copper (or some other conductive material) has been deposited on.
- A wire harness is an assembled group of wires that branch out to the various electrical components. It is used to reduce the number of loose wires hanging under the hood or dash. It provides for a safe path for the wires of the vehicle's lighting, engine, and accessory components.
- The wiring harness is made by grouping insulated wires and wrapping them together. The wires are bundled into separate harness assemblies that are joined together by connector plugs.
- A wiring diagram shows a representation of actual electrical or electronic components and the wiring of the vehicle's electrical systems.
- The technician's greatest helpmate in locating electrical problems is the wiring diagram. Correct use of the wiring diagram will reduce the amount of time a technician needs to spend tracing the wires in the vehicle.
- In place of actual pictures, a variety of electrical symbols are used to represent the components in the wiring diagram.
- Color codes and circuit numbers are used to make tracing wires easier.
- In most color codes, the first group of letters designates the base color of the insulation. If a second group of letters is used, it indicates the color of the tracer.
- A component locator is used to determine the exact location of several of the electrical components.

TERMS TO KNOW

Common connection
Component locator
DIN
Electrical symbols
Gauge
Ground straps
Installation diagrams
Primary wiring
Printed circuit boards
Schematic
Secondary wiring
Stranded wire
Tracer
Wiring harness
Wiring diagram

REVIEW QUESTIONS

Short-Answer Essays

1. Explain the purpose of wiring diagrams.
2. Explain how wire size is determined by the American Wire Gauge (AWG) and metric methods.
3. Explain the purpose and use of printed circuits.
4. Explain the purpose of the component locator.
5. Explain when single-stranded or multistranded wire should be used.
6. Explain how temperature affects resistance and wire size selection.
7. List the three major factors that determine the proper size of wire to be used.
8. List and describe the different types of terminal connectors used in the automotive electrical system.
9. What is the difference between a complex and a simple wiring harness?
10. Describe the methods the three domestic automobile manufacturers use for wiring code identification.

Fill in the Blanks

1. There is _______________ resistance in the stranded wire than in the solid wire.
2. ______________________________ complete the return path to the battery between components that are insulated.

3. Wire size is based on the _______________ of the conductor.
4. In the AWG standard, the _______________ the number, the smaller the wire _______________.
5. An increase in temperature creates a similar _______________ in resistance.
6. _______________ connectors are used when several wires must pass through the bulkhead.
7. _______________ _______________ _______________ are used to prevent damage to the wiring by maintaining proper wire routing and retention.
8. A wiring diagram is an electrical schematic that shows a _______________ of actual electrical or electronic components (by use of symbols) and the _______________ of the vehicle's electrical systems.
9. In most color codes, the first group of letters designates the _______________________________ of the insulation. The second group of letters indicates the color of the _______________.
10. A _______________ _______________ is used to determine the exact location of several of the electrical components.

Multiple Choice

1. Automotive wiring is being discussed.
   Technician A says most primary wiring is made of several strands of copper wire wound together and covered with an insulation.
   Technician B says the types of conductor materials used in automobiles include copper, silver, gold, aluminum, and tin-plated brass.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B
2. Stranded wire use is being discussed.
   Technician A says there is less exposed surface area for electron flow in a stranded wire.
   Technician B says there is more resistance in the stranded wire than in the same gauge solid wire.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B
3. A Chrysler wiring diagram designation of M2 14 BK/YL identifies the main circuit as being:
   A. Climate control
   B. Interior lighting
   C. Wipers
   D. None of the above
4. Ground straps are used to:
   A. Provide a return path to the battery between insulated components
   B. Suppress electromagnetic induction
   C. Both A and B
   D. Neither A nor B
5. The selection of the proper size of wire to be used is being discussed.
   Technician A says the wire must be large enough, for the length required, to carry the amount of current necessary for the load components in the circuit to operate properly.
   Technician B says temperature has little effect on resistance and it is not a factor in wire size selection.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B
6. Terminal connectors are being discussed.
   Technician A says good terminal connections will resist corrosion.
   Technician B says the terminals can be either crimped or soldered to the conductor.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B
7. Wire routing is being discussed.
   Technician A says to install additional electrical accessories it is necessary to support the primary wire in at least 10-foot intervals.
   Technician B says if the wire must be routed through the frame or body, use metal clips to protect the wire.
   Who is correct?
   A. A only C. Both A and B
   B. B only D. Neither A nor B

8. Printed circuit boards are being discussed.
   Technician A says printed circuit boards are used to simplify the wiring of the circuits they operate.
   Technician B says care must be taken not to touch the board with bare hands.
   Who is correct?
   A. A only
   B. B only
   C. Both A and B
   D. Neither A nor B

9. Wiring harnesses are being discussed.
   Technician A says a wire harness is an assembled group of wires that branches out to the various electrical components.
   Technician B says most under-hood harnesses are simple harnesses.
   Who is correct?
   A. A only
   B. B only
   C. Both A and B
   D. Neither A nor B

10. Wiring diagrams are being discussed.
    Technician A says wiring diagrams give the exact location of the electrical components.
    Technician B says a wiring diagram will indicate what circuits are interconnected, where circuits receive their voltage source, and what color of wires are used in the circuit.
    Who is correct?
    A. A only
    B. B only
    C. Both A and B
    D. Neither A nor B