CHAPTER 4

Wiring and Circuit Diagrams

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

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

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 4-1). 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.

Primary wiring refers to smaller wire with light insulation.

Secondary wiring refers to larger wire or cable with heavier insulation.

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

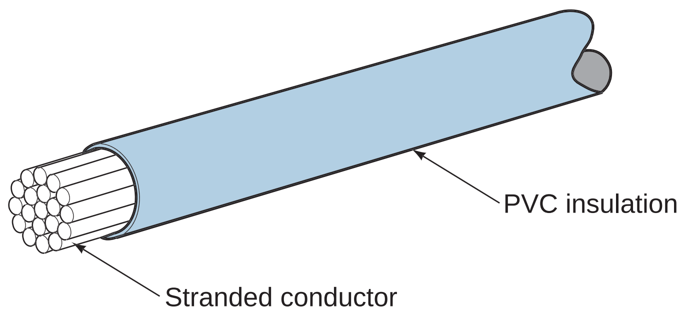

Figure 4-1 Stranded primary wire.

Stranded wire means the conductor is made of several individual wires that are wrapped together.

A **ballast resistor** reduces the current flow through the ignition coil to increase the life of the coil. The resistance value of the ballast resistor is usually between 0.8 and 1.2 ohms.

Resistance wire is designed with a certain amount of resistance per foot.

Spark plug wires are often referred to as television-radio-suppression (TVRS) cables.

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 4-2). 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.

A **ballast resistor** is used by some manufacturers to protect the ignition primary circuit from excessive voltage. It reduces the current flow through the coil's primary windings and provides a stable voltage to the coil. Some automobiles use a **resistance wire** in the ignition system instead of a ballast resistor. This wire is called the ballast resistor wire and is located between the ignition switch and the ignition coil (Figure 4-3) in the ignition "RUN" circuit.

Spark plug wires are also resistance wires. The resistance lowers the current flow through the wires. By keeping current flow low, the magnetic field created around the wires is kept to

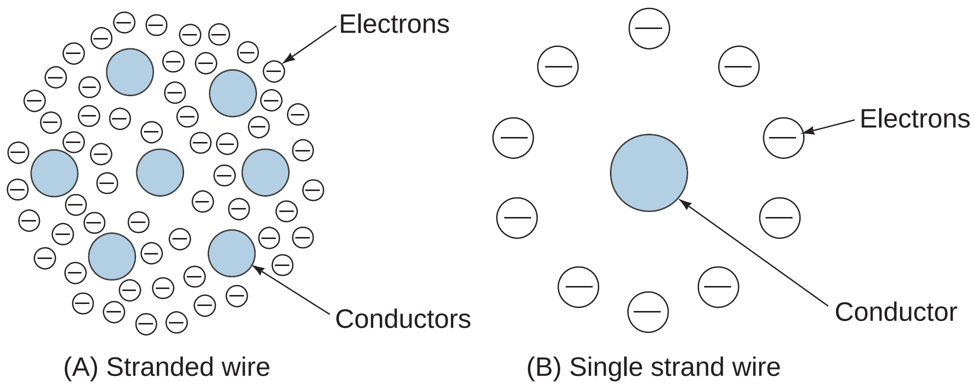

Figure 4-2 Stranded wire provides flexibility and more surface area for electron flow than a single-strand solid wire.

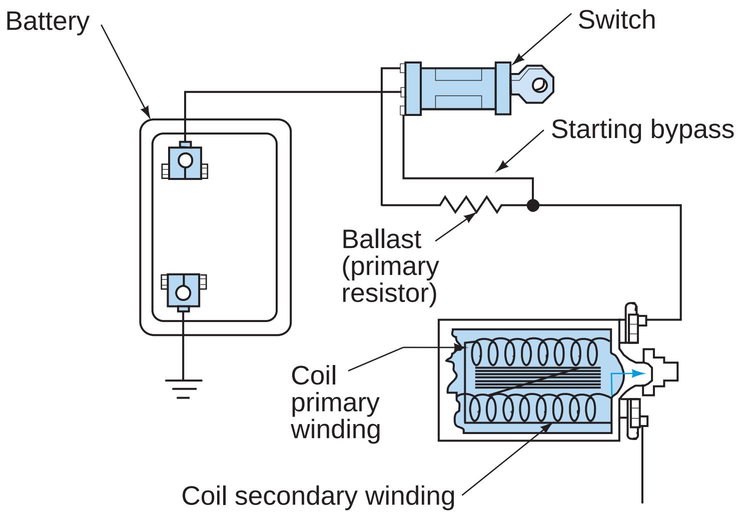

Figure 4-3 Ballast resistor used in some ignition primary wiring circuits.

a minimum. The magnetic field needs to be controlled because it causes radio interference. The result of this interference is noise on the vehicle's radio and all nearby radios and televisions. The noise can interfere with emergency broadcasts and the radios of emergency vehicles. Because of this concern, all ignition systems are designed to minimize radio interference; most do so with resistance-type spark plug wires. Spark plug wires are targeted because they carry high voltage pulses. The lower current flow has no adverse effect on the firing of the spark plug.

Most spark plug wire conductors are made of nylon, rayon, fiberglass, or aramid thread impregnated with carbon. This core is surrounded by rubber (Figure 4-4). The carbon-impregnated core provides sufficient resistance to reduce RFI, yet does not affect engine operation. As the spark plug wires wear because of age and temperature changes, the resistance in the wire will change. Most plug wires have a resistance value of 3,000 Ω to 6,000 Ω per foot. However, some have between 6,000 Ω and 12,000 Ω. The accepted value when testing is 10,000 Ω per foot as a general specification.

Because the high voltage within the plug wires can create electromagnetic induction, proper wire routing is important to eliminate the possibility of **cross-fire**. To prevent cross-fire, the plug wires must be installed in the proper separator. Any two parallel wires next to each other in the firing order should be positioned as far away from each other as possible (Figure 4-5). When induction cross-fire occurs, no spark is jumped from one wire to the other. The spark is the result of induction from another field. Cross-fire induction is most common in two parallel wires that fire one after the other in the firing order.

Cross-fire is the electromagnetic induction spark that can be transmitted in another wire close to the wire carrying the current.

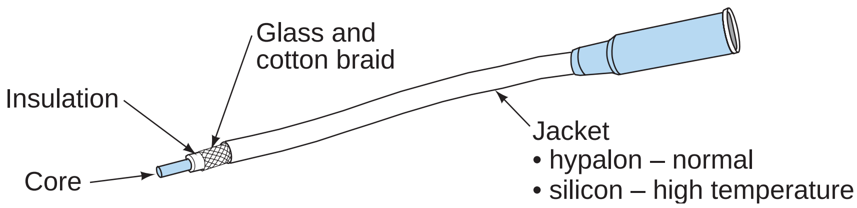

Figure 4-4 Typical spark plug wire.

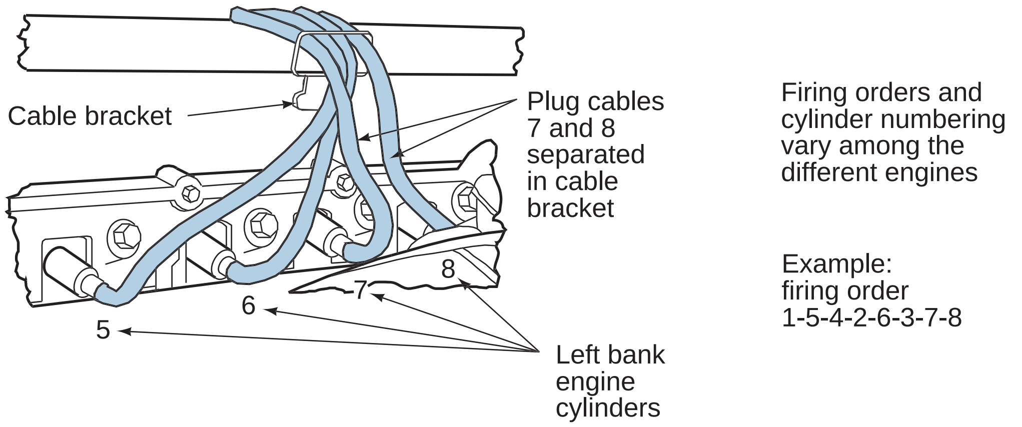

Figure 4-5 Proper spark plug wire routing to prevent cross-fire. (Reprinted with the permission of Ford Motor Company)

Wire Sizes

An additional amount of 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:

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 number assigned to a wire to indicate its size is referred to as **gauge.**

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. 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 (Figure 4-6) lists the wire size required to carry a given amount of current for different lengths.

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 (Figure 4-7).

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

Note: 18 AWG as indicated above this line could be 20 AWG electrically.
18 AWG is recommended for mechanical strength.

Figure 4-6 The distance the current must be carried is a factor in determining the correct wire gauge to use.

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 4-7 Approximate AWG to metric equivalents.

Terminals and Connectors

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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 (1.2V) may result in a 30% loss of lighting efficiency.

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 4-8) 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 4-9). Although the connector halves separate, the connector itself cannot be taken apart.

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2. **Multiple-wire hard-shell connector:** These connectors usually have a hard plastic shell that holds the connecting terminals of separate wires (Figure 4-10). 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 4-11).

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4. **Weather-Pack Connectors:** These connectors have rubber seals on the terminal ends and on the covers of the connector half (Figure 4-12). They are used on computer circuits to protect the circuit from corrosion, which may result in a voltage drop.

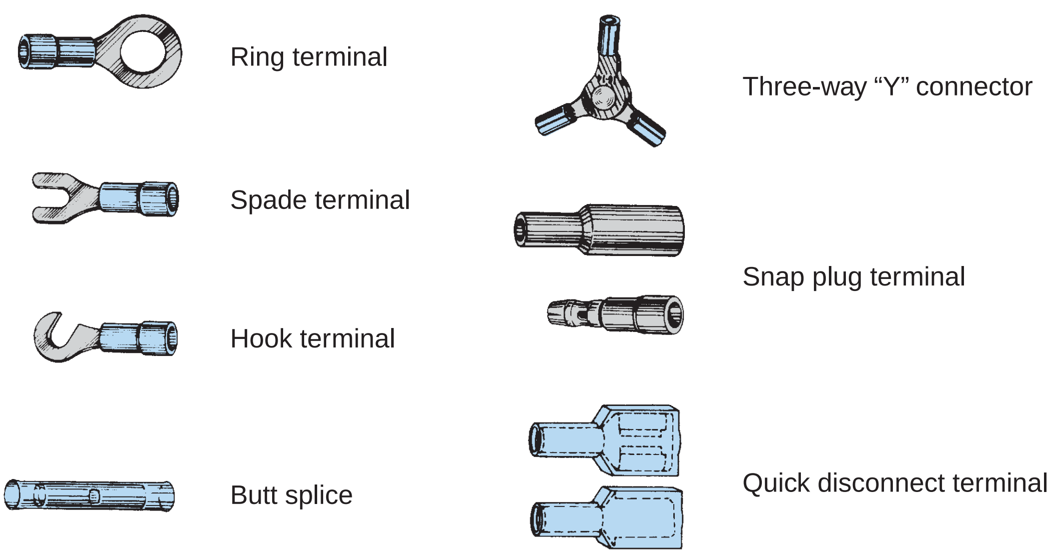

Figure 4-8 Primary wire terminals used in automotive applications.

Figure 4-9 Molded connectors cannot be disassembled to replace damaged terminals.

5. **Metri-Pack Connectors:** These are like the weather-pack connectors but do not have the seal on the cover half (Figure 4-13).

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 4-14). 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.

Common connections are used to share a source of power or a common ground and are often called a splice.

Printed Circuits

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 4-15). 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.

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.

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.

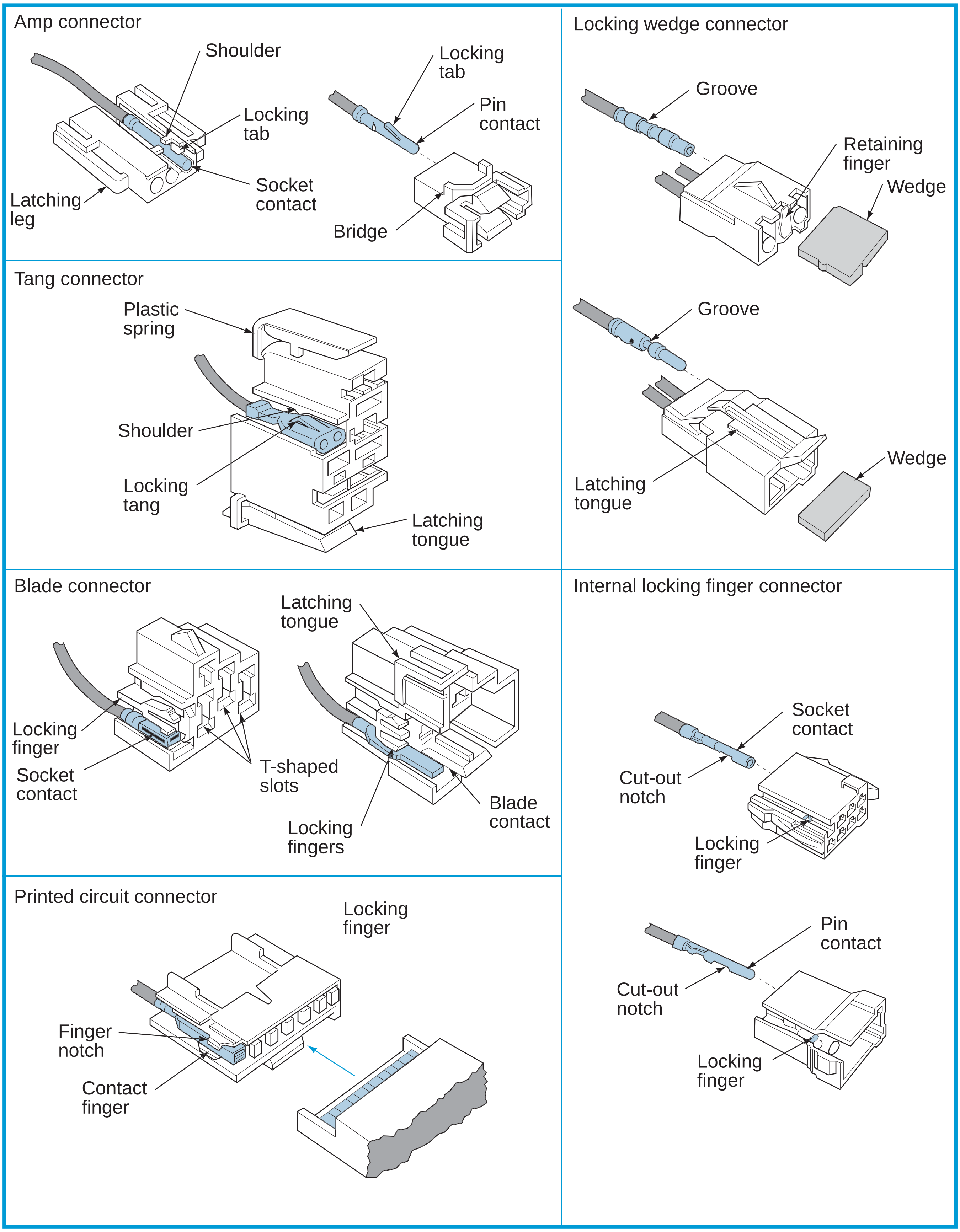

Figure 4-10 Multiple-wire hard shell connectors.

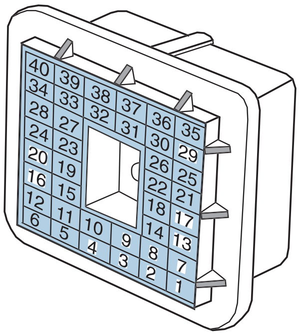

Figure 4-11 Bulkhead connector. (Courtesy of DaimlerChrysler Corporation)

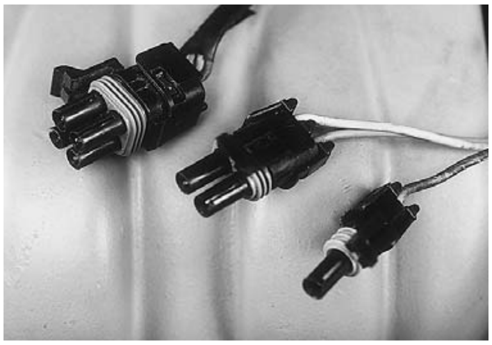

Figure 4-12 Weather-pack connector is used to prevent connector corrosion.

Figure 4-13 Metri-pack connector.

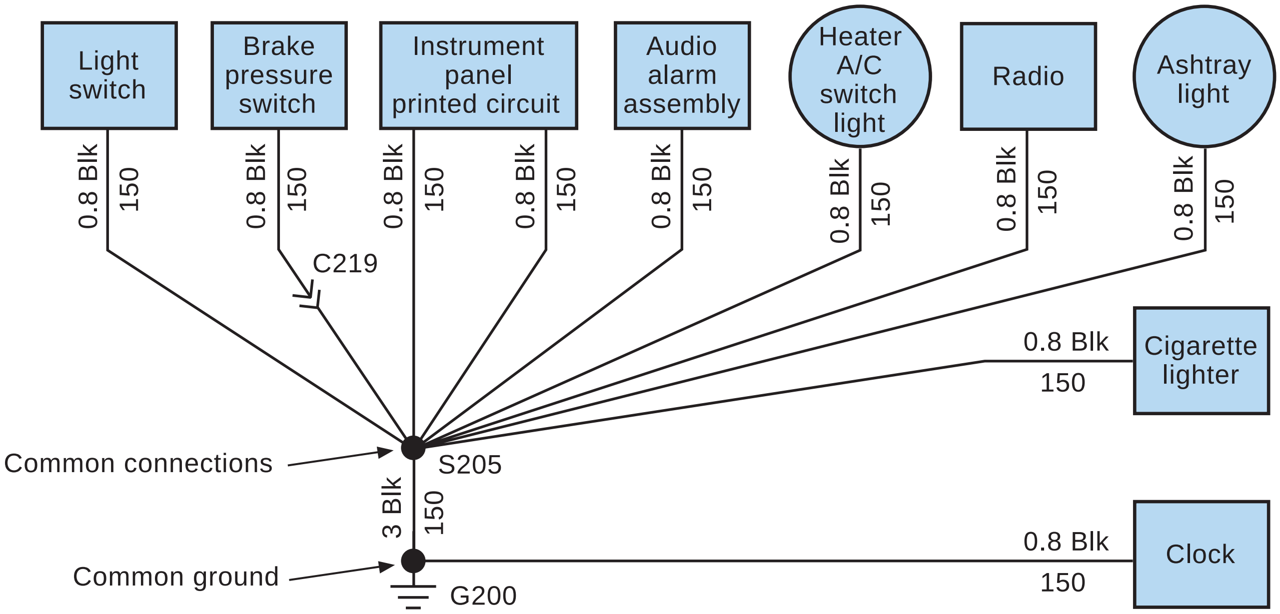

Figure 4-14 Common connections (splices) are used to reduce the amount of wire and connectors.

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.

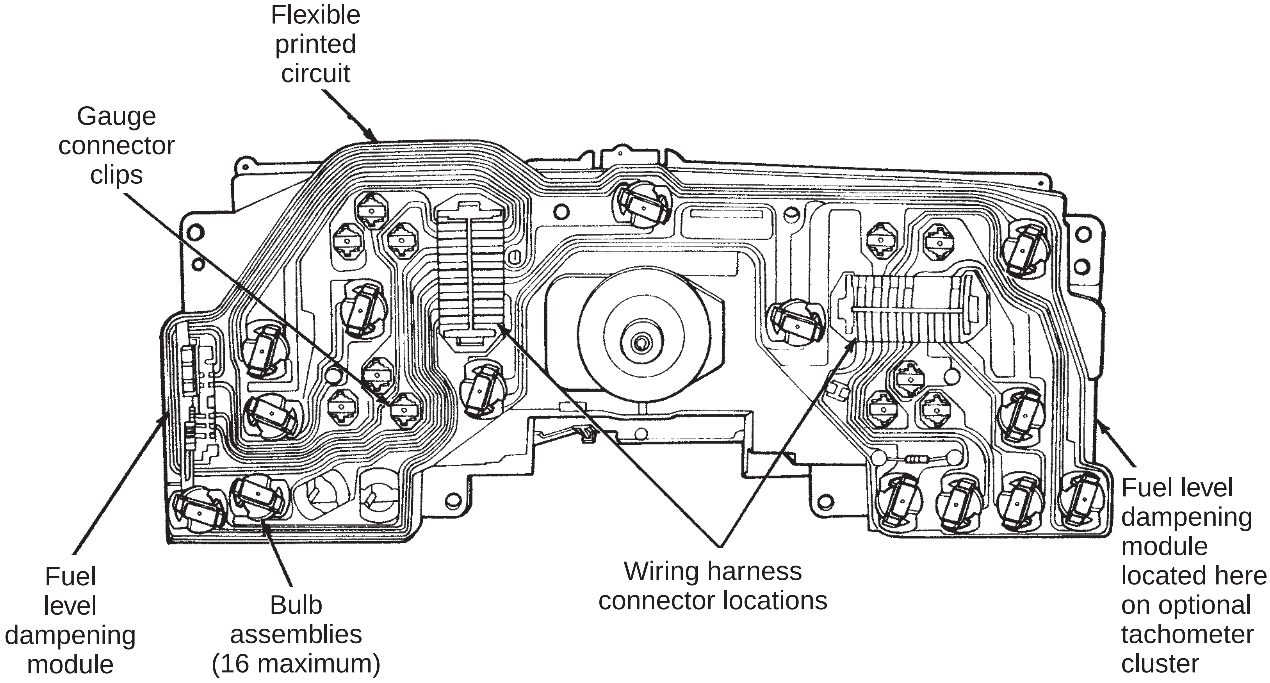

Figure 4-15 Printed circuits eliminate bulky wires behind the instrument panel.

A **wire harness** is an assembled group of wires that branch out to the various electrical components.

Wiring Harness

Most manufacturers use wiring harnesses to reduce the amount of loose wires hanging under the hood or dash of an automobile. The **wire 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 4-16). Lighting circuits usually use a more simple harness (Figure 4-17). 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.

Most wiring harnesses now use a flexible conduit to provide for quick wire installation (Figure 4-18). 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.

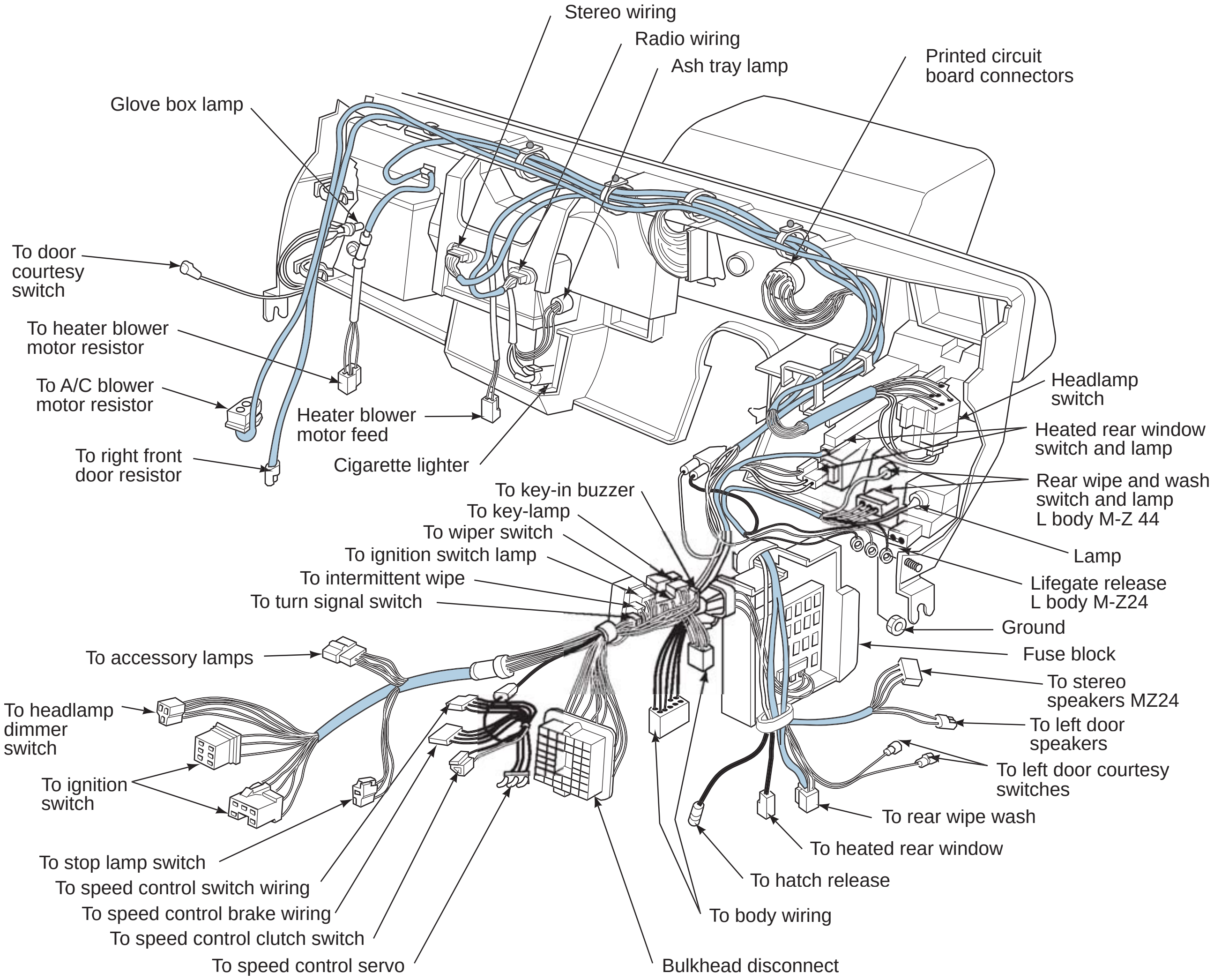

Figure 4-16 Complex wiring harness. (Courtesy of DaimlerChrysler Corporation)

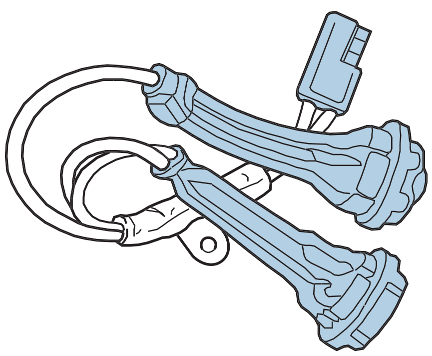

Figure 4-17 Simple wiring harness. (Courtesy of DaimlerChrysler Corporation)

Figure 4-18 Flexible conduit used to make wiring harnesses.

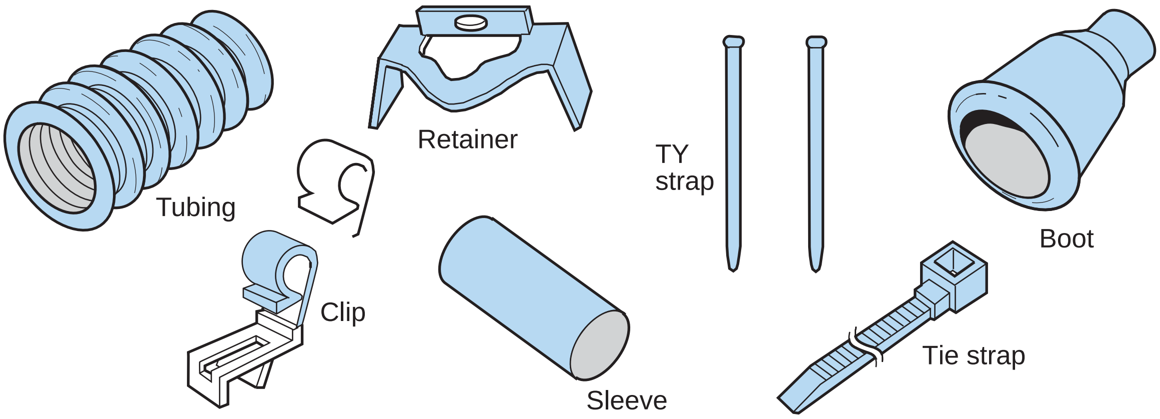

Figure 4-19 Typical wire protection devices. (Courtesy of DaimlerChrysler Corporation)

Wiring Protective Devices

Often overlooked, but very important to the electrical system, are proper wire protection devices (Figure 4-19). 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.

Wiring Diagrams

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One of the most important tools for diagnosing and repairing electrical problems is a **wiring diagram**. 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 4-20). Wiring diagrams do not explain how the circuit works; this is where your knowledge of electricity comes in handy.

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.

A wiring diagram can show the wiring of the entire vehicle (Figure 4 -21) or a single circuit (Figure 4-22). 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 manual. 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.

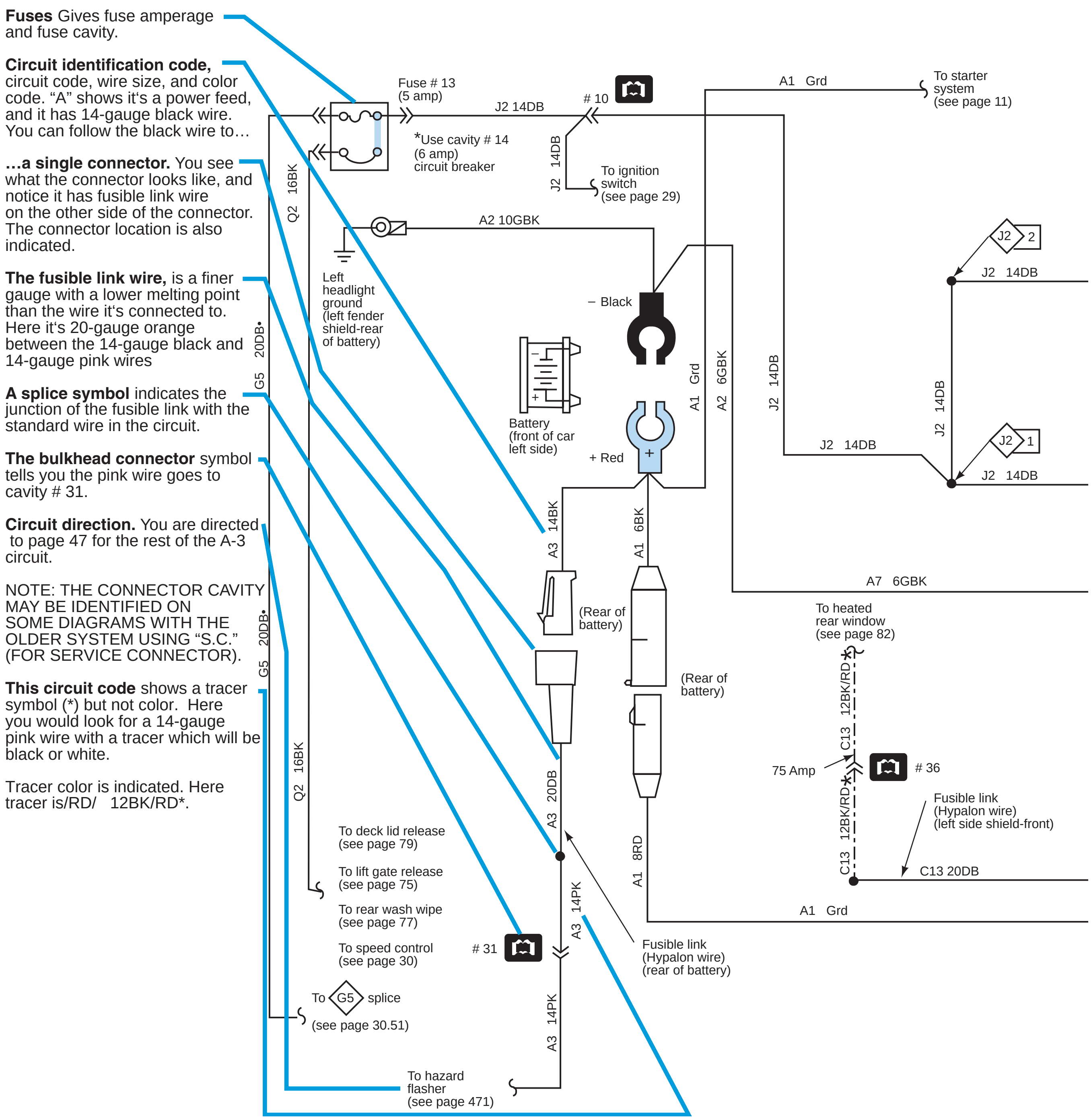
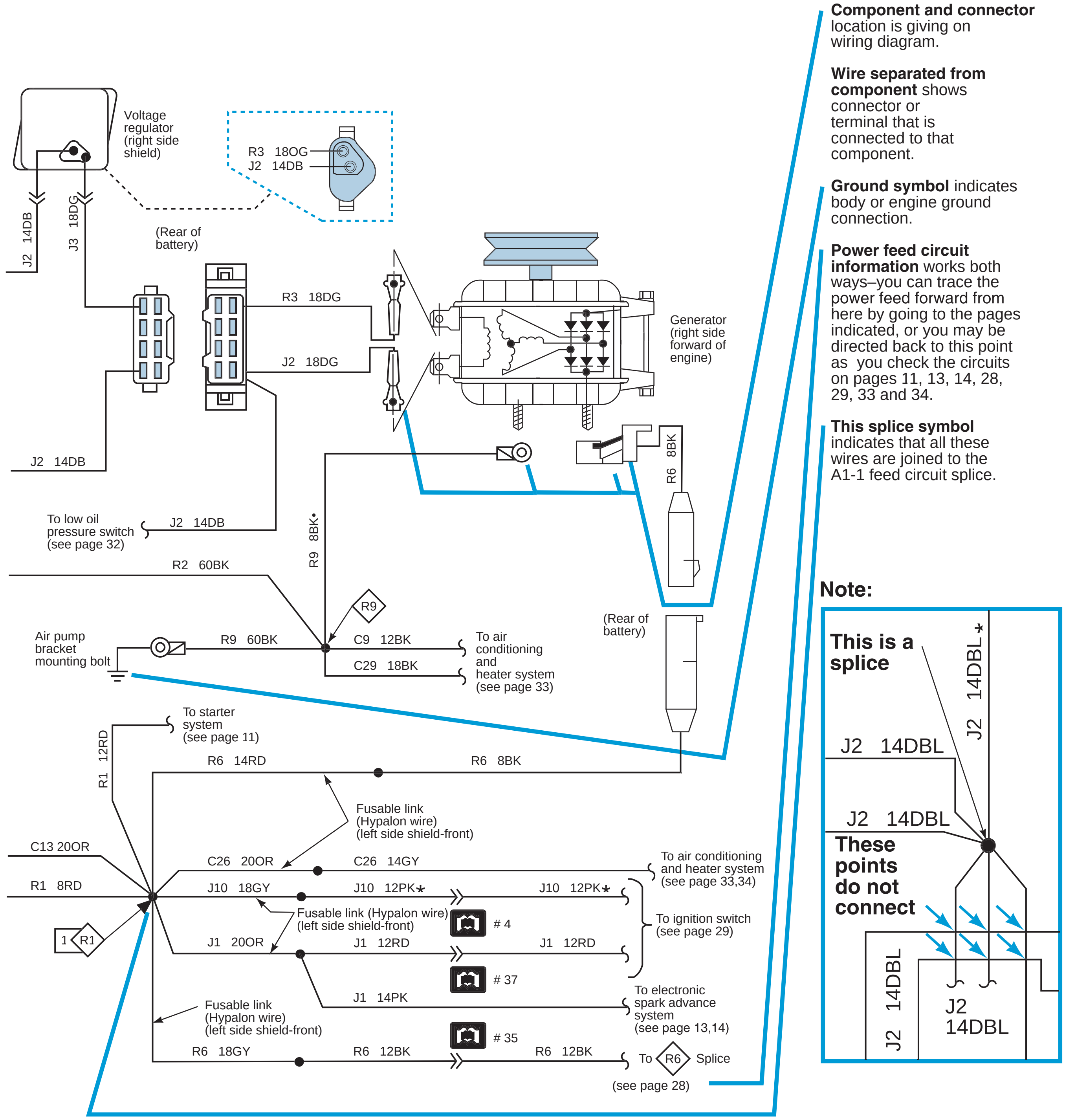


Figure 4-20 Wiring diagrams provide the technician with necessary information to accurately diagnose the electrical systems. (Courtesy of DaimlerChrysler Corporation)

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



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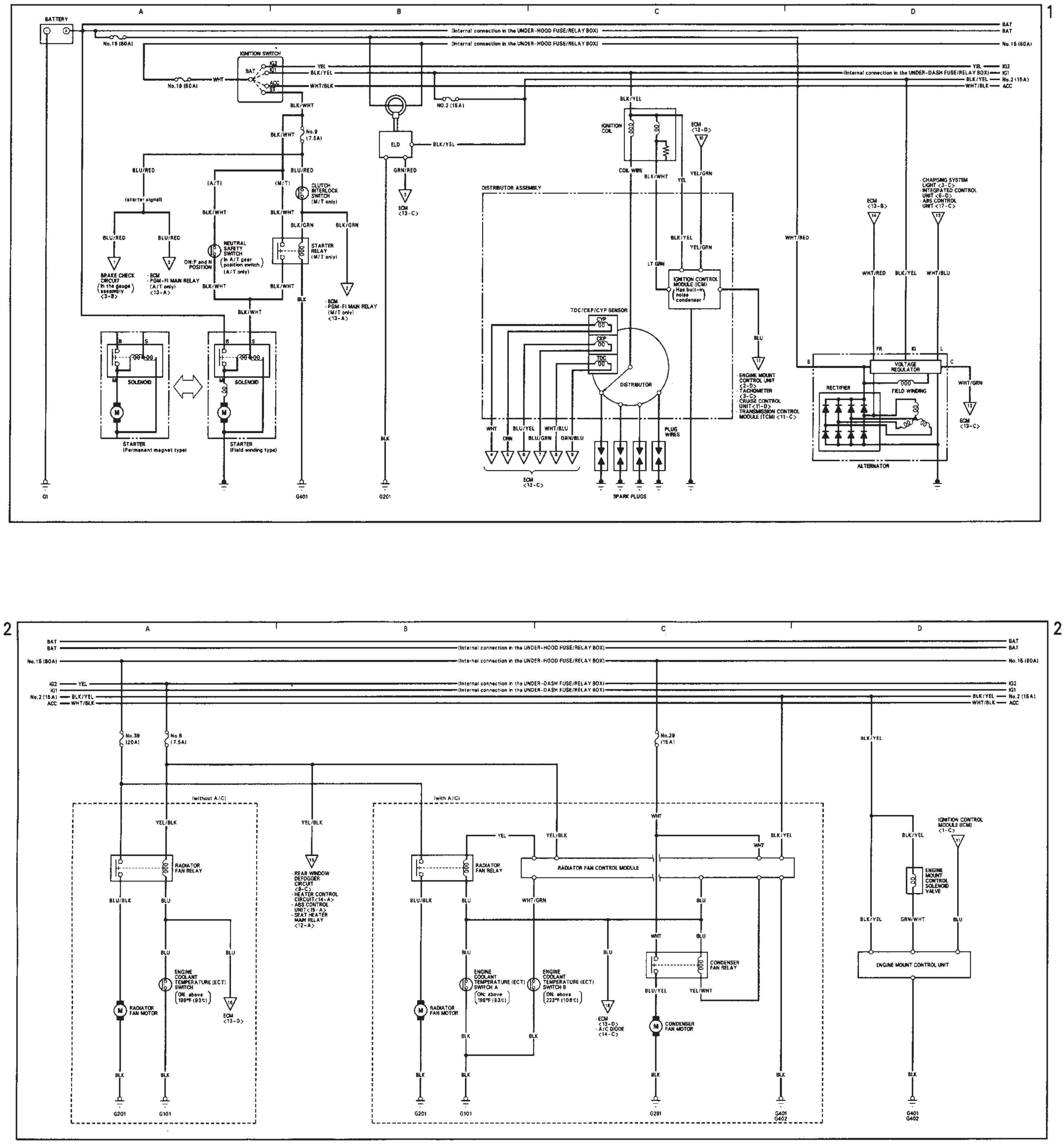
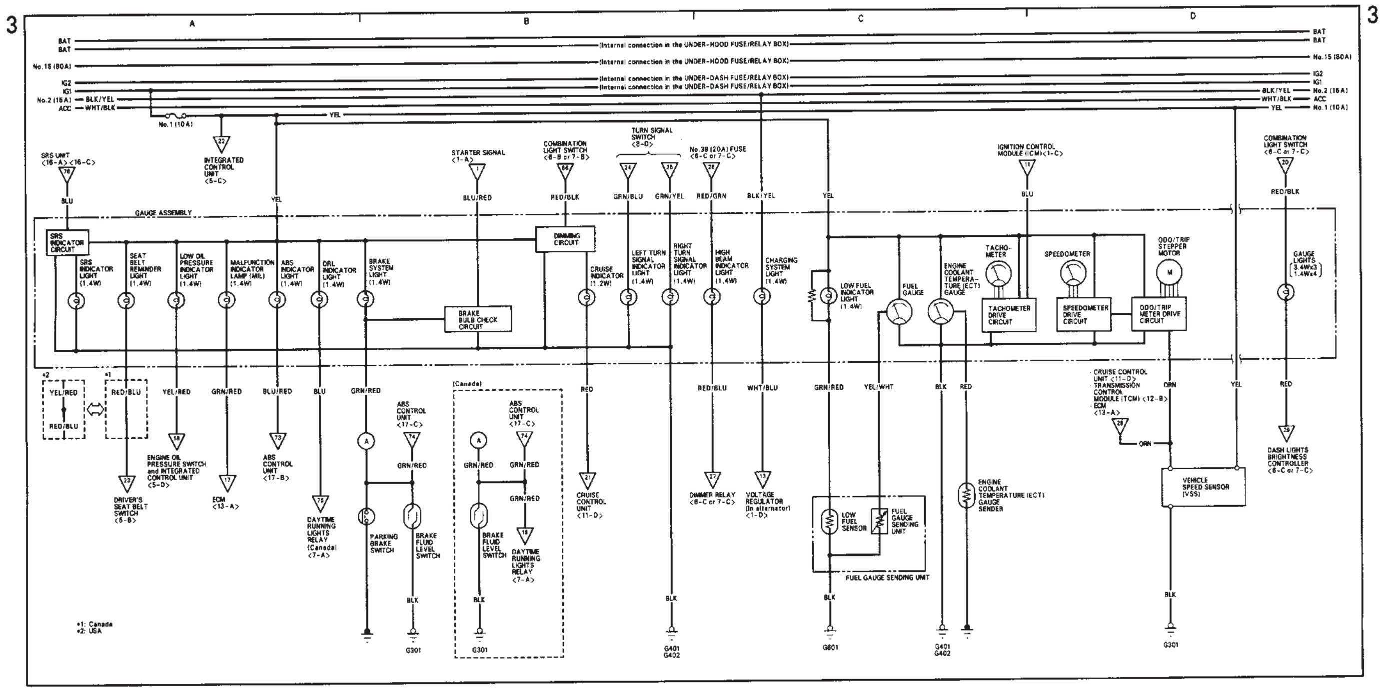
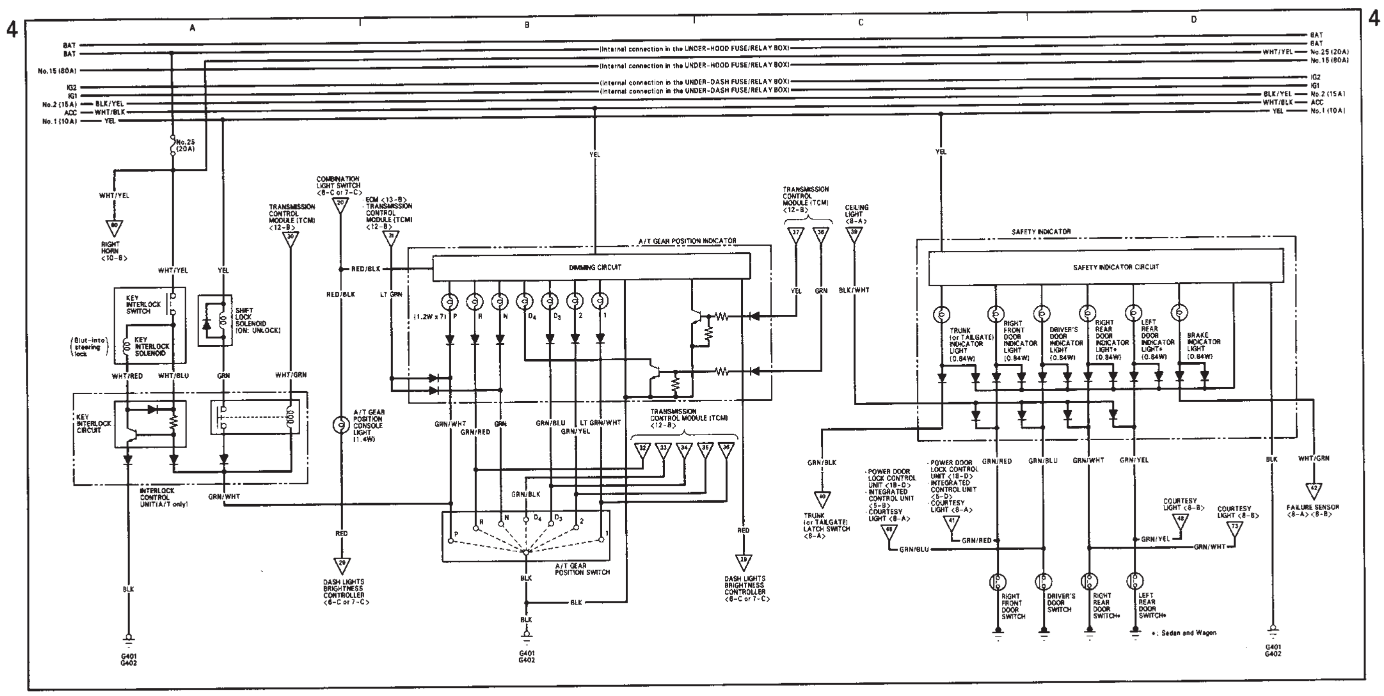


Figure 4-21 A wiring diagram that covers the complete electrical systems of a vehicle. (Courtesy of American Honda Motor Co., Inc.)





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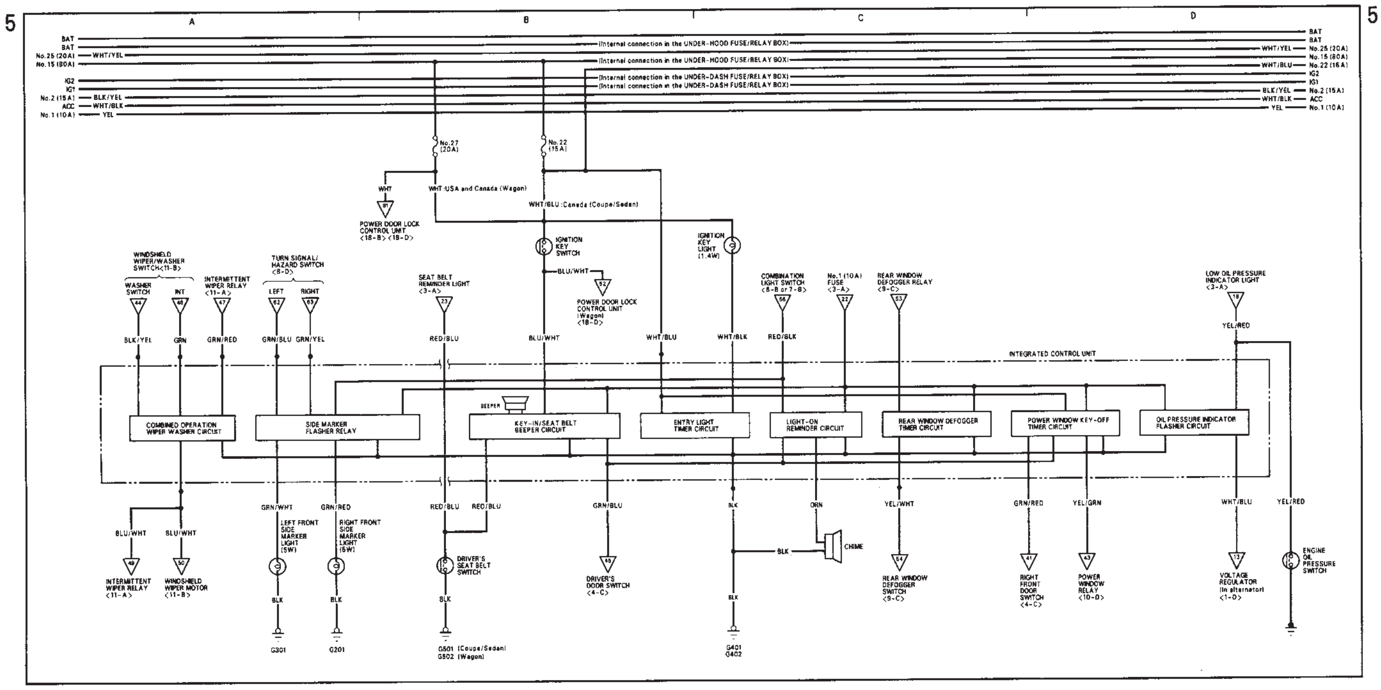

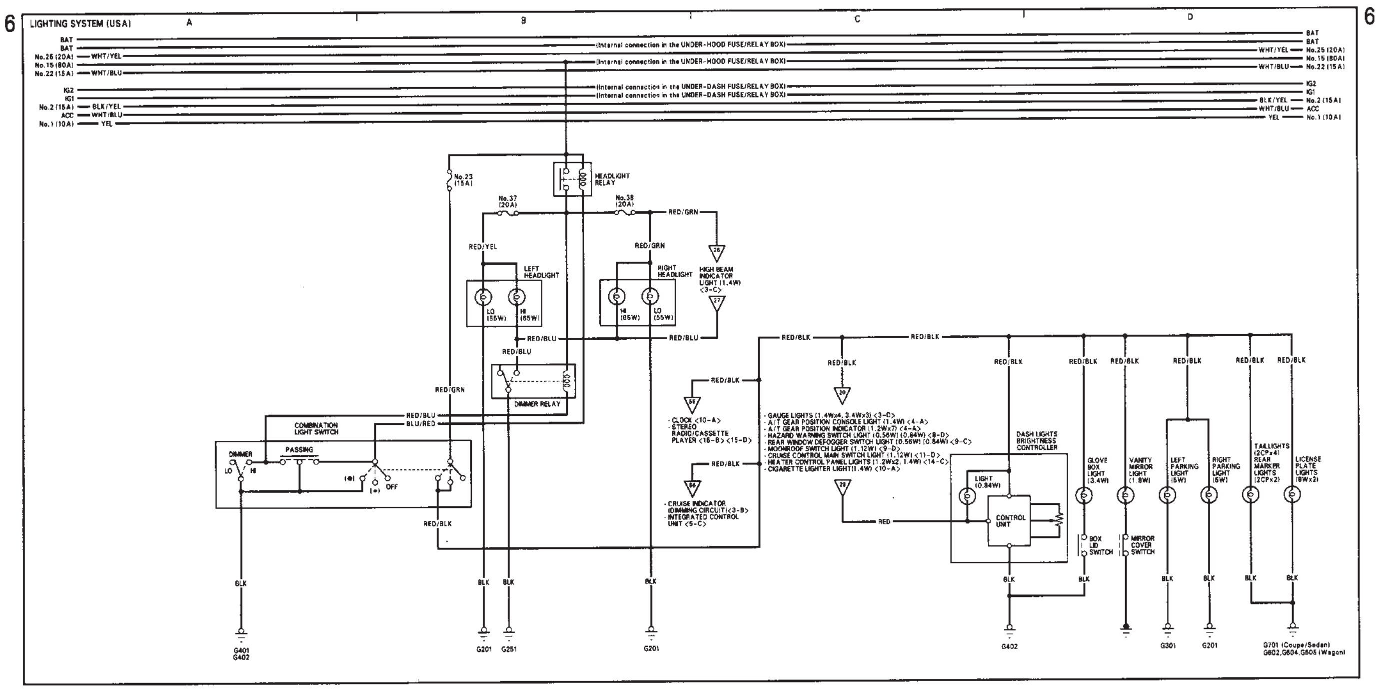

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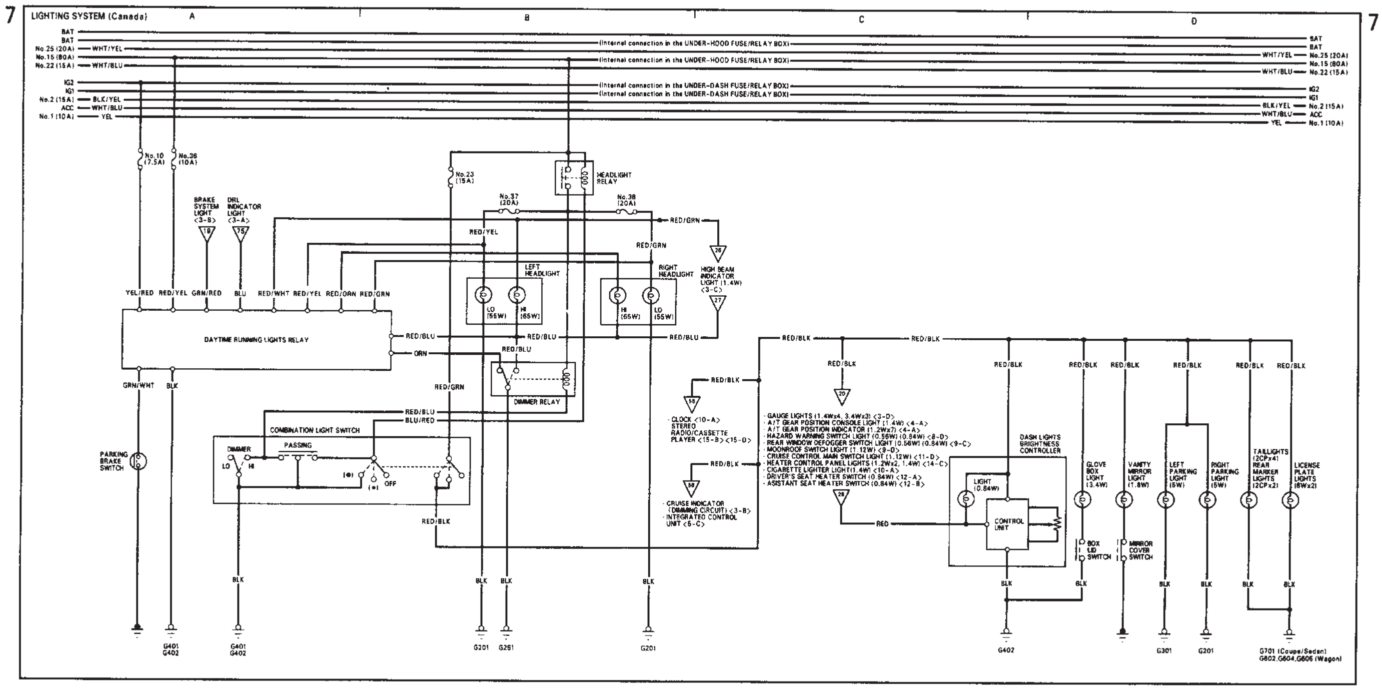

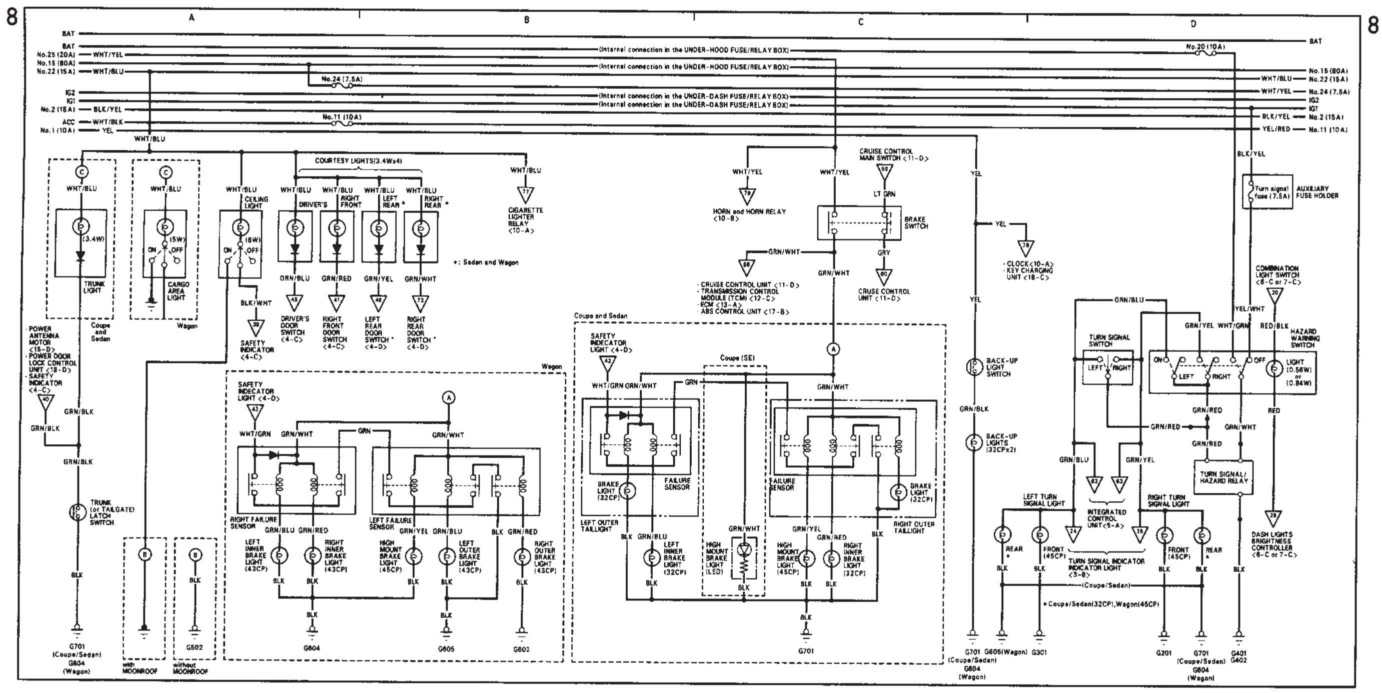

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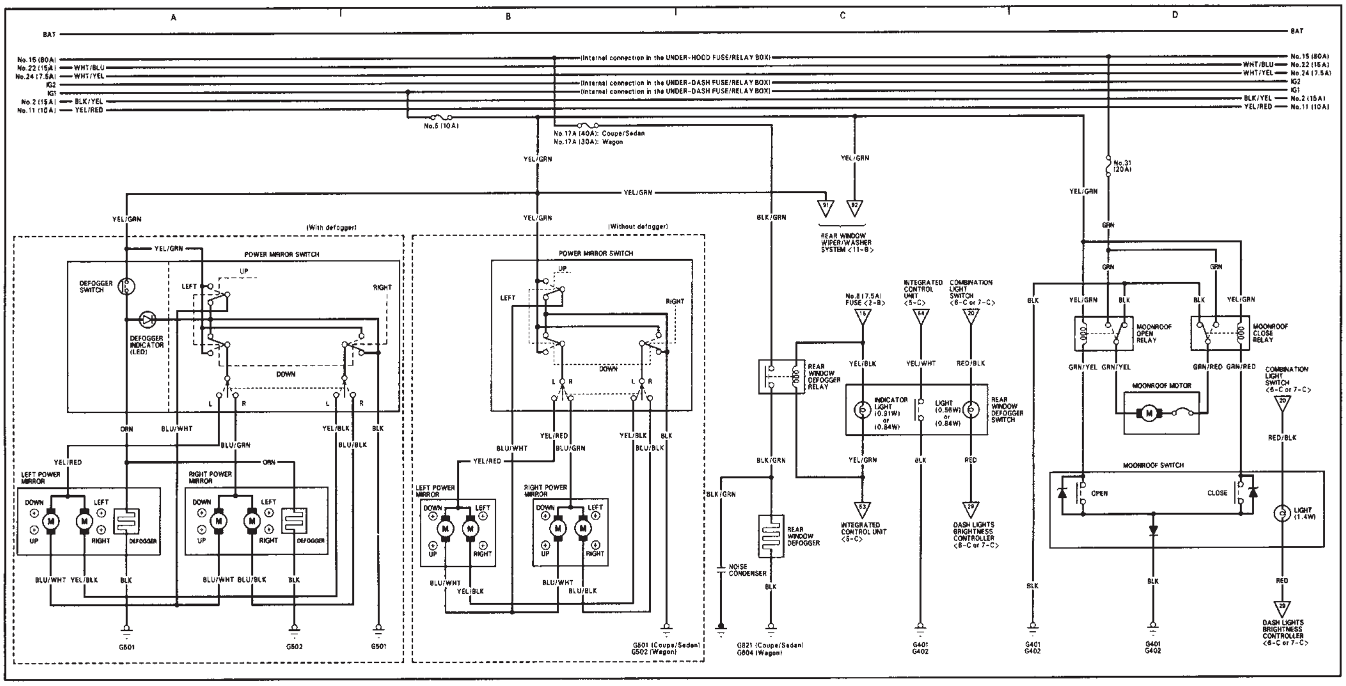

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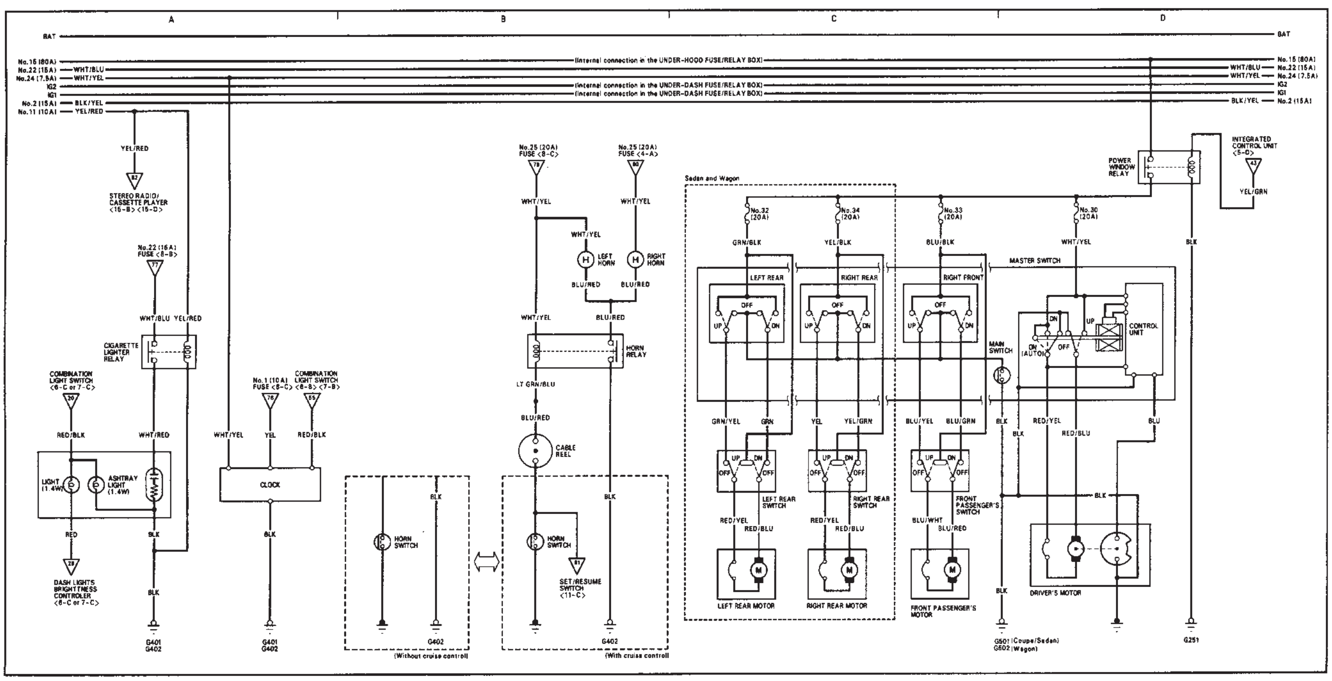

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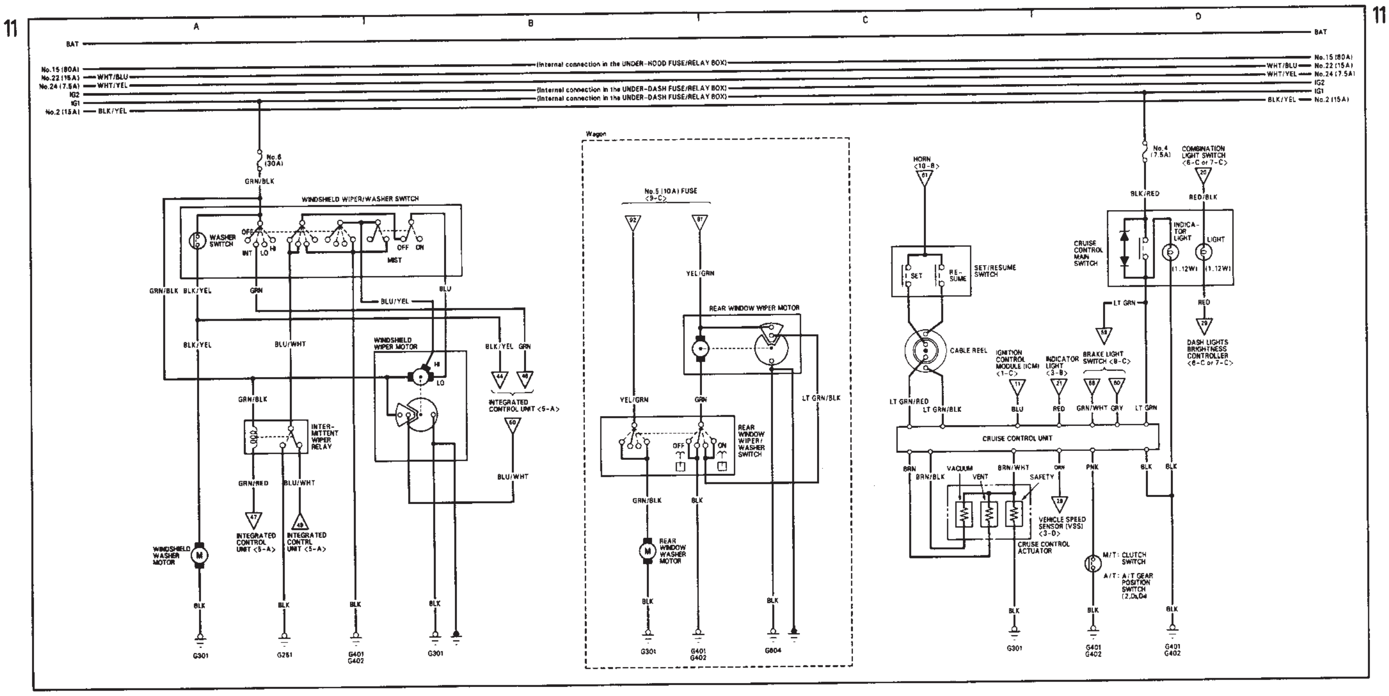

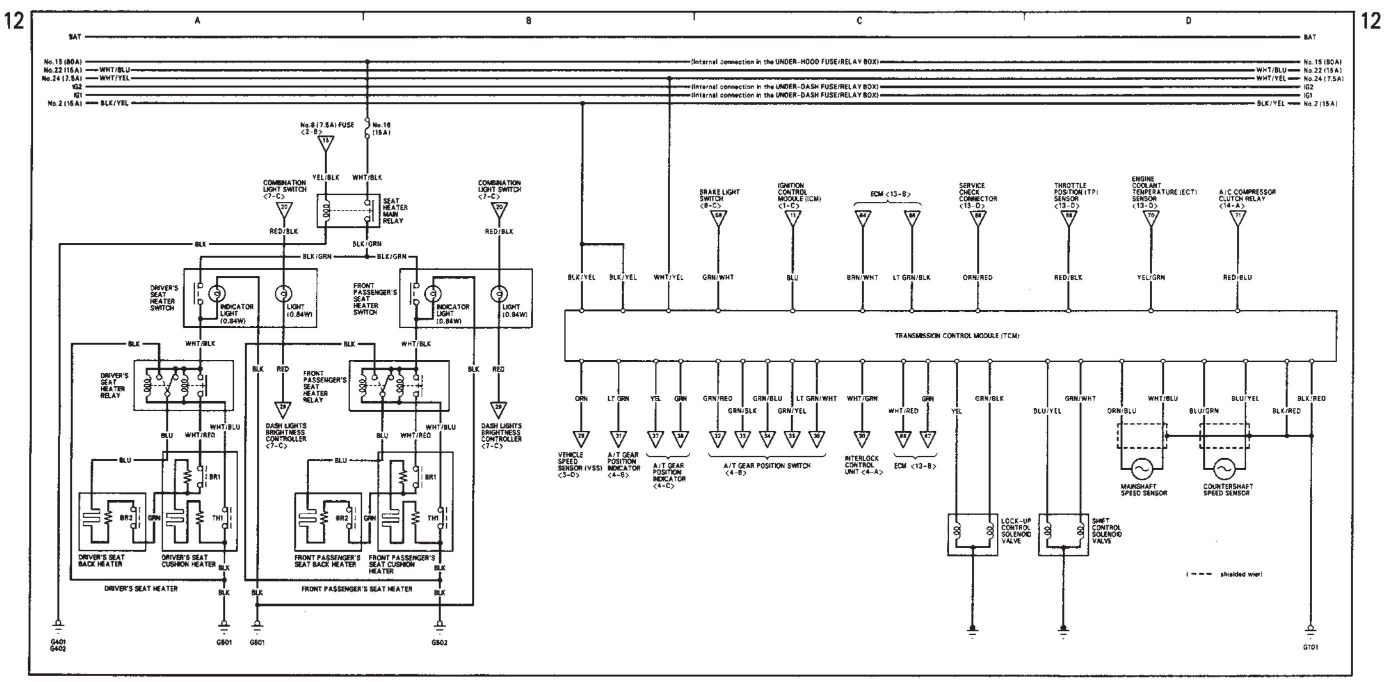

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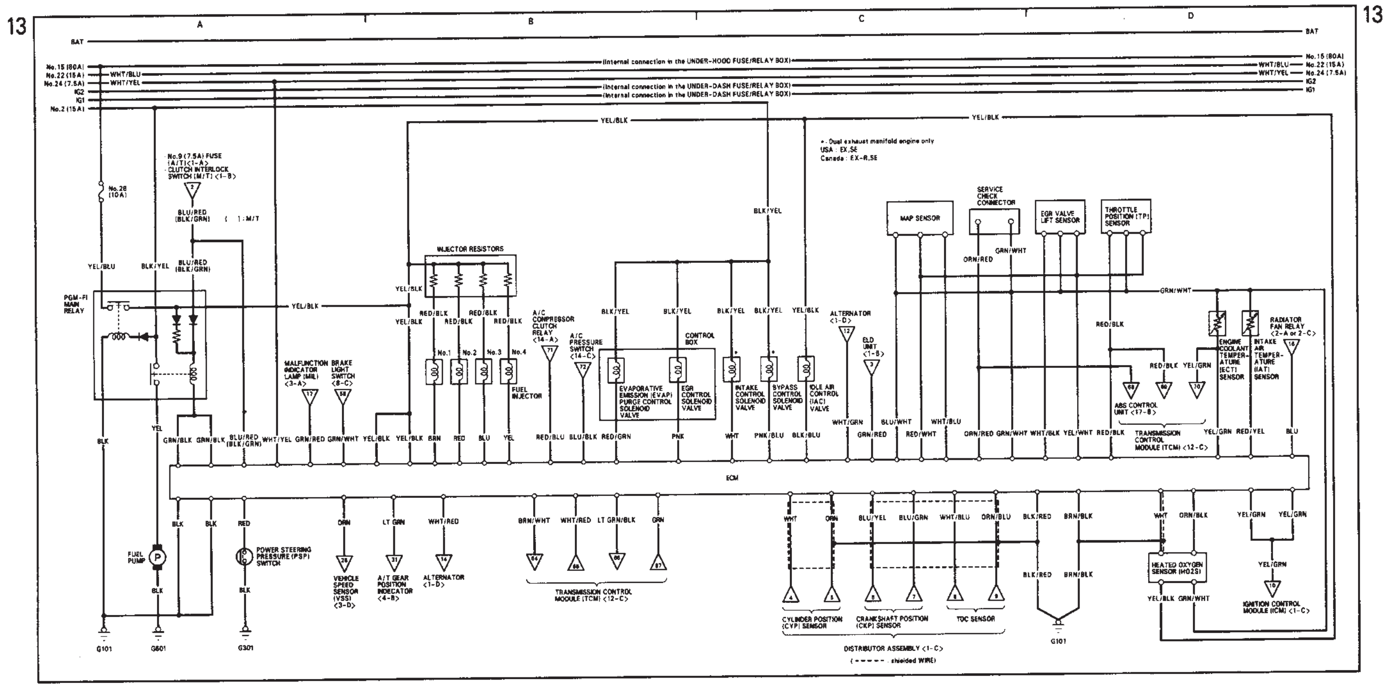


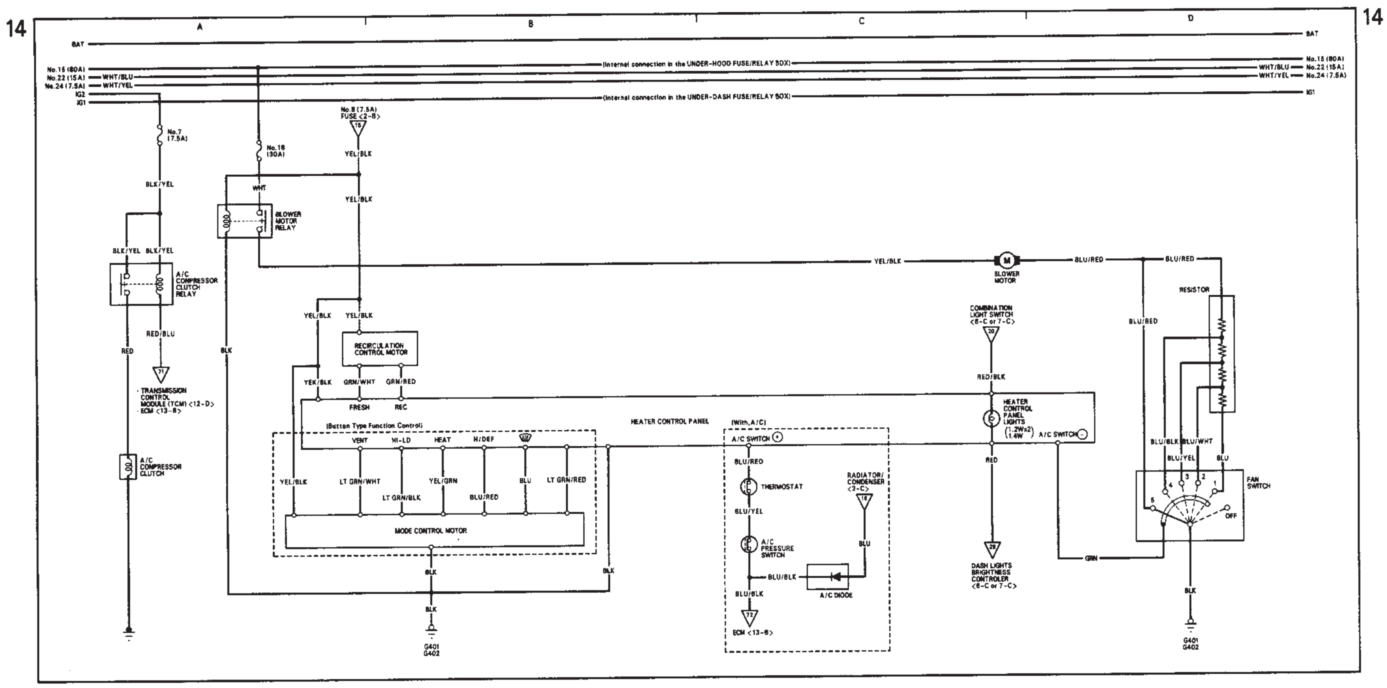
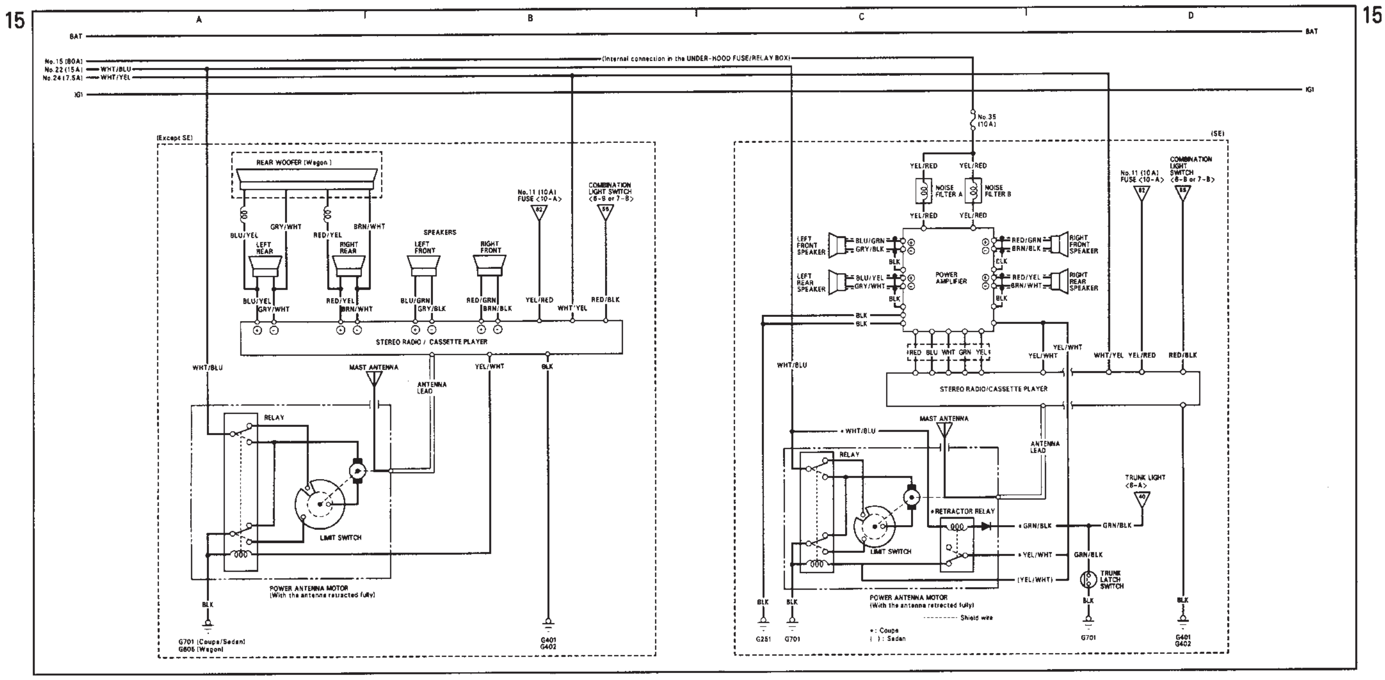


Figure 4-21 (continued)



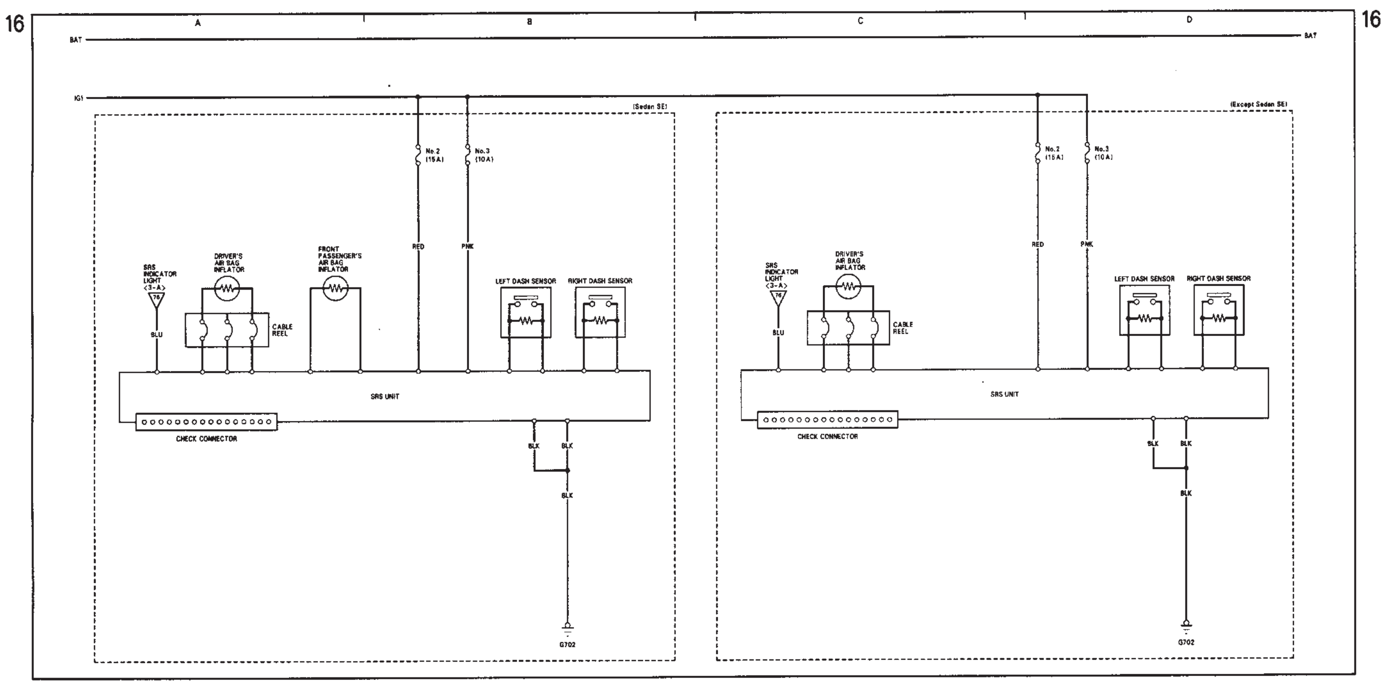
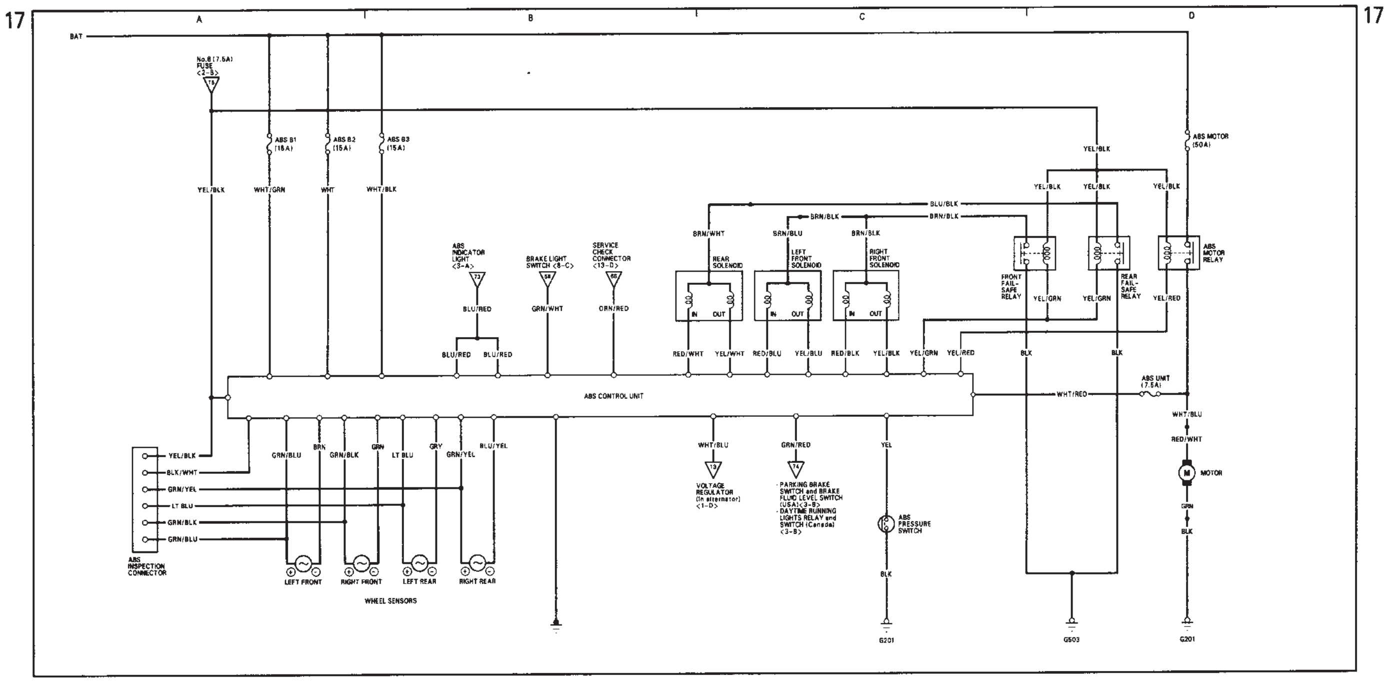


Figure 4-21 (continued)



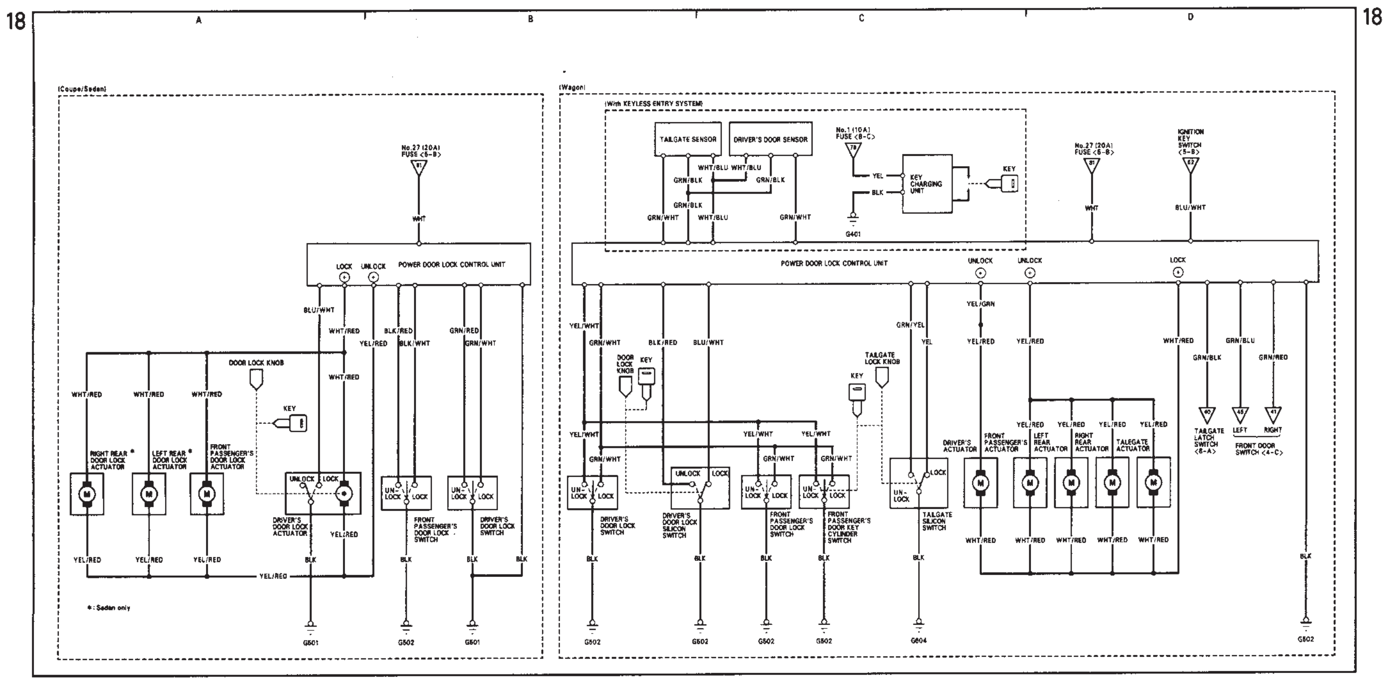


Figure 4-21 (continued)

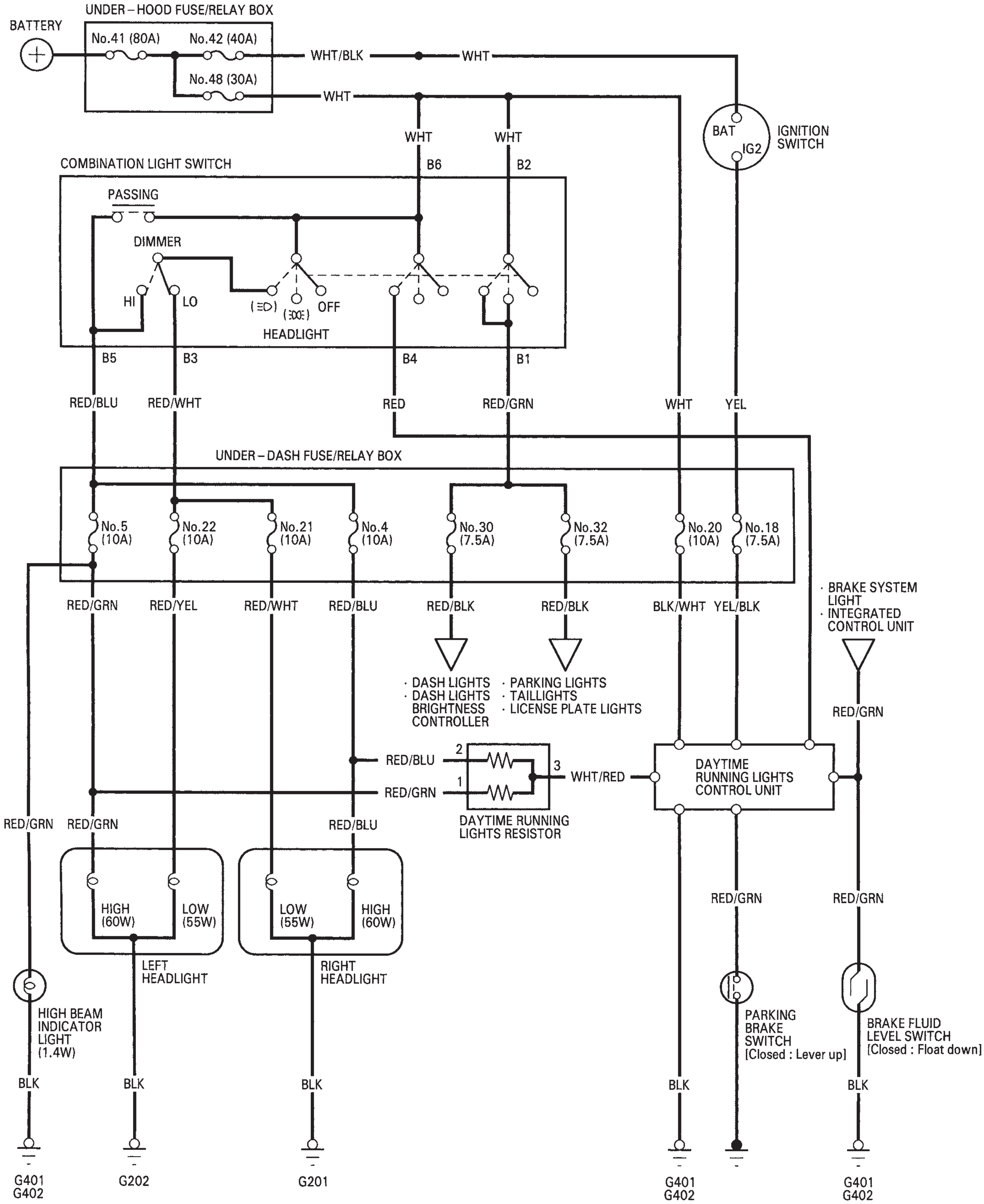


Figure 4-22 Wiring diagram illustrating only one specific circuit for easier reference. This is also known as a block diagram. (Courtesy of American Honda Motor Co., Inc.)

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 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.

Installation diagrams show where and how electrical components and wiring harnesses are installed in the vehicle. These are helpful when trying to locate where a particular wire or component may be in the car. These diagrams also may show how the component or wiring harness is attached to the vehicle (Figure 4-23).

Installation diagrams provide a more accurate duplication of where the wire harness, connectors, and components are found on the vehicle.

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 oper-

In place of actual pictures, a variety of **electrical symbols** are used to represent the components in the wiring diagram.

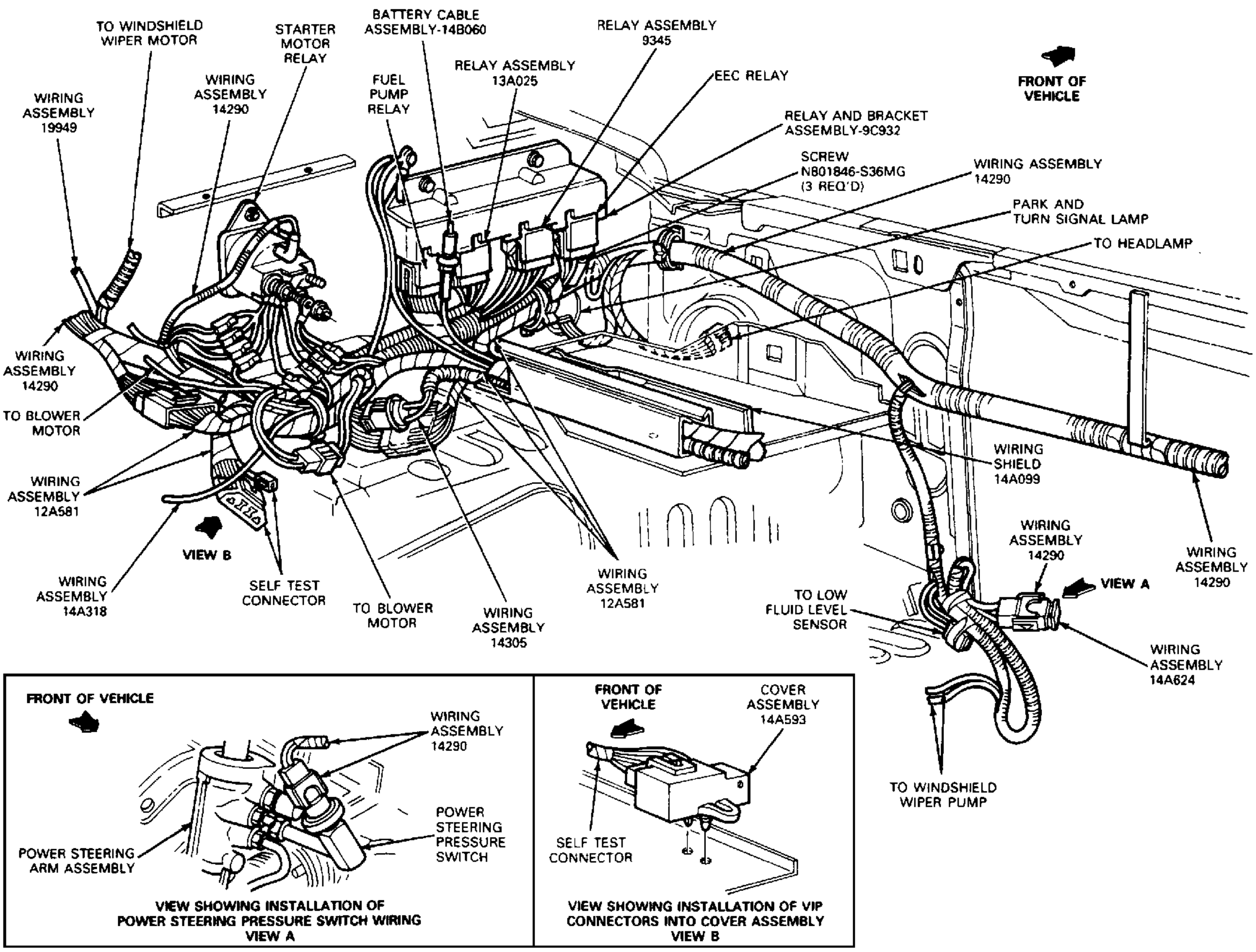


Figure 4-23 A typical installation diagram. (Reprinted with the permission of Ford Motor Company)

ation of the component. Many different symbols have been used in wiring diagrams through the years. Figure 4-24 shows some of the commonly used symbols. Recently, most manufacturers have begun to use some new style symbols (Figure 4-25). The reason for the change is because most manufacturers are going to electronic media instead of paper forms of service manuals. Some of the older symbols are not distinguishable when viewed on a monitor. 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.

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.

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 makes it easier to diagnose electrical problems. Unfortunately, not all manufacturers use the same method of wire identification. Figure 4-26 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.

A **tracer** is a thin or dashed line of a different color than the base color of the insulation.

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.

Ford uses four methods of color coding its wires (Figure 4-27):

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

DaimlerChrysler uses a numbering method to designate the circuits on the wiring diagram (Figure 4-28). The circuit identification, wire gauge, and color of the wire are included in the wire number. DaimlerChrysler identifies the main circuits by using a main circuit identification code that corresponds to the first letter in the wire number (Figure 4-29).

General Motors uses numbers that include the wire gauge in metric millimeters, the wire color, the circuit number, splice number, and ground identification (Figure 4-30). In this example, the circuit is designated as 100, the wire size is 0.8 mm^2, the insulation color is black, the splice is numbered S114, and the ground is designated as G117.

Most manufacturers also number connectors and terminals for identification.

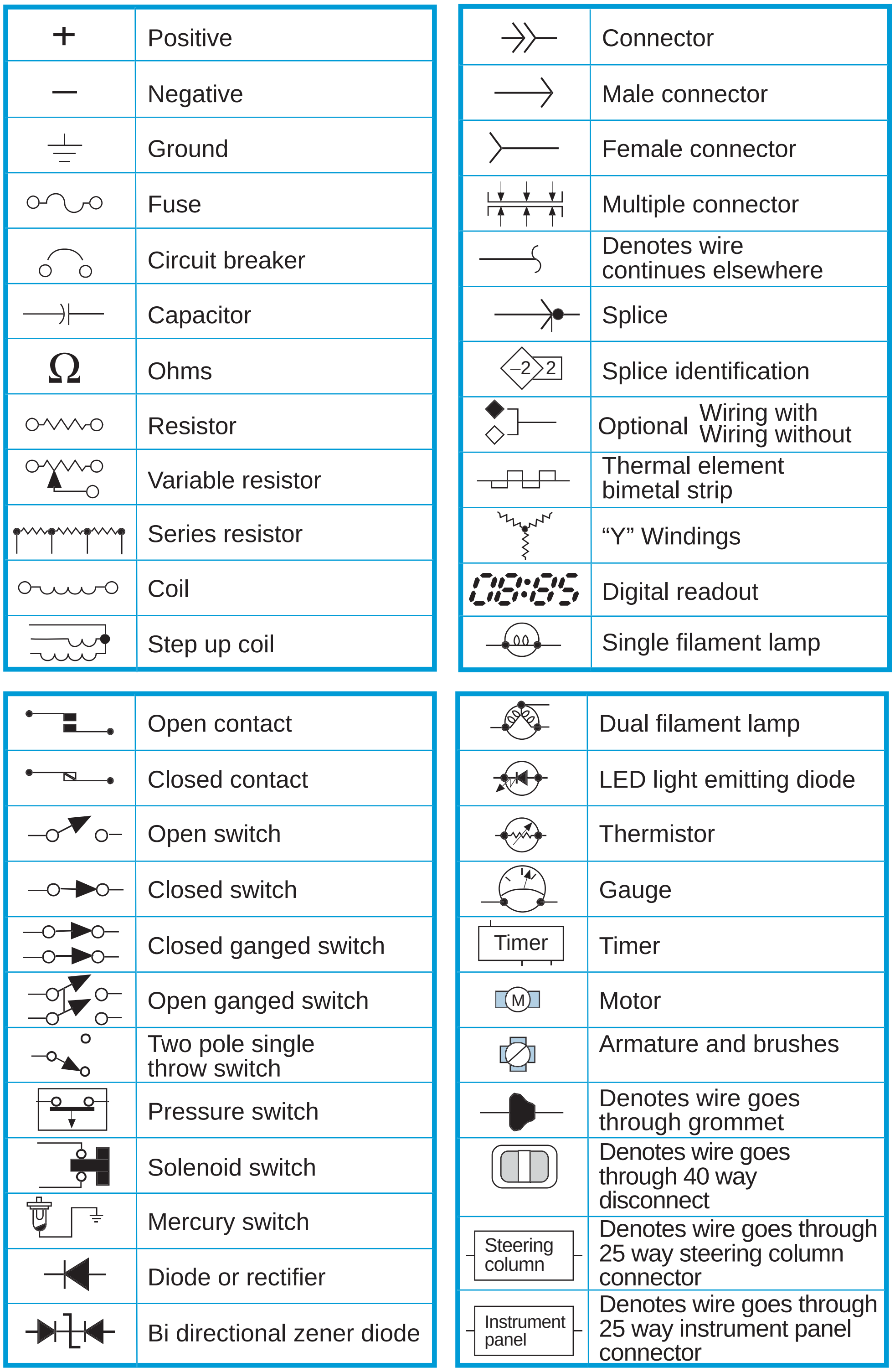


Figure 4-24 Common electrical symbols used in wiring diagrams. (Courtesy of DaimlerChrysler Corporation)

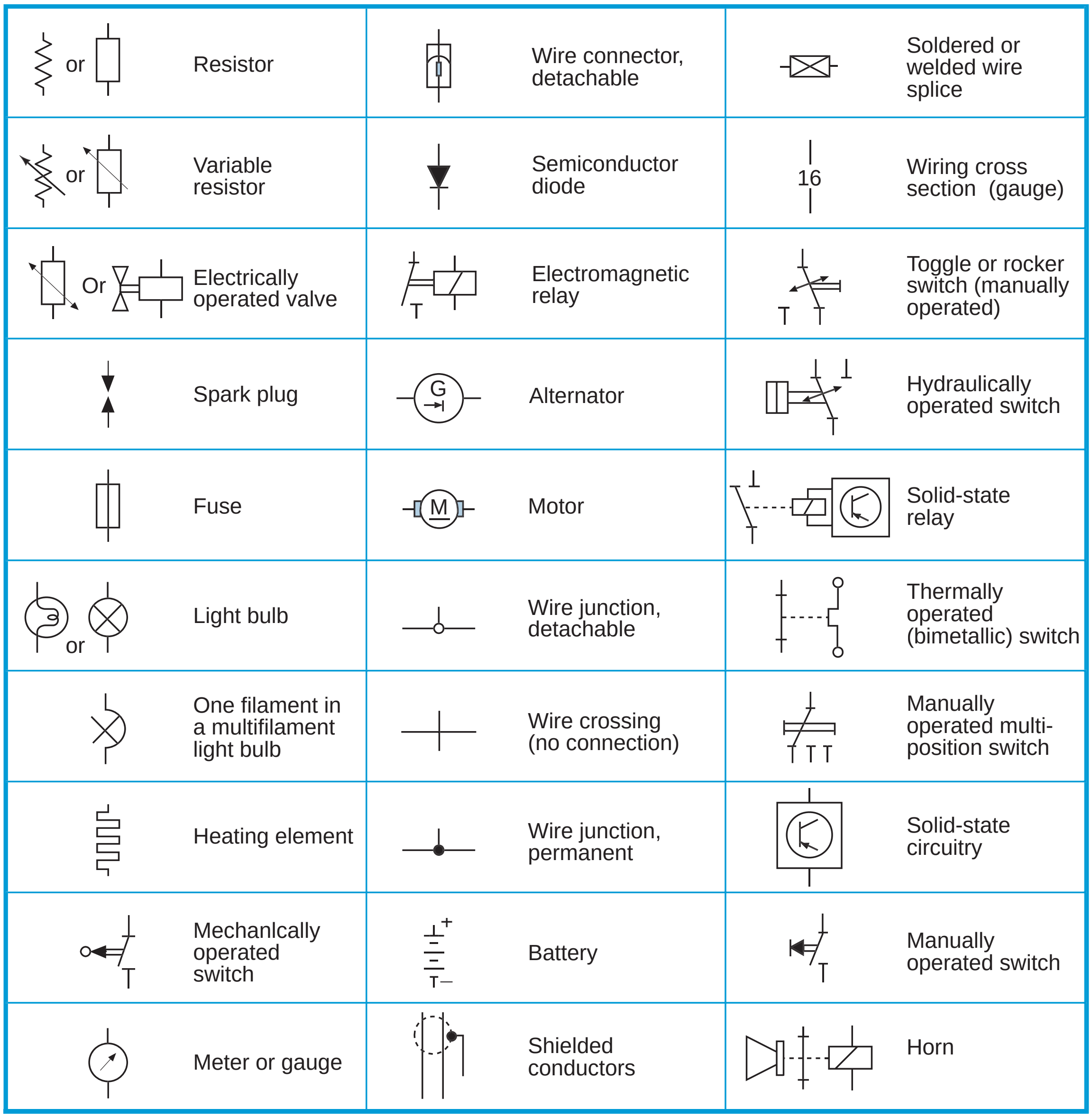


Figure 4-25 Electrical symbols used in more recent manuals.

Color	Abbreviations		
Aluminum	AL		
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	GRA	GR	G
Green (Green)	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

Figure 4-26 Common color codes used in automotive applications.

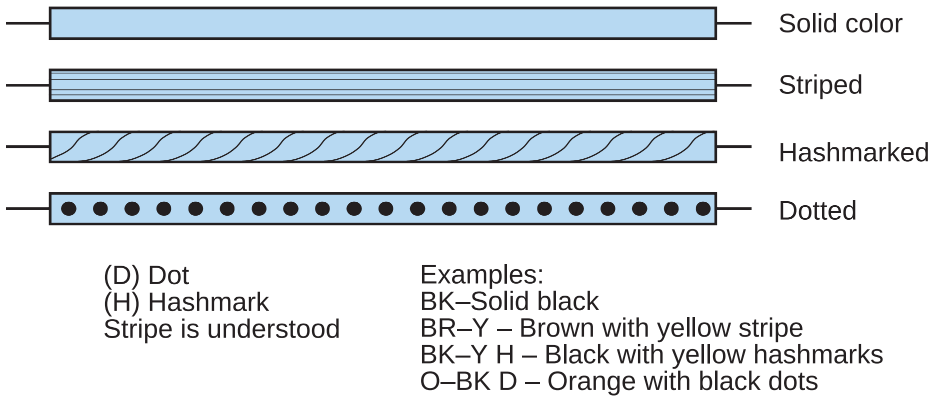


Figure 4-27 Four methods that Ford uses to color code their wires. (Reprinted with the permission of Ford Motor Company)

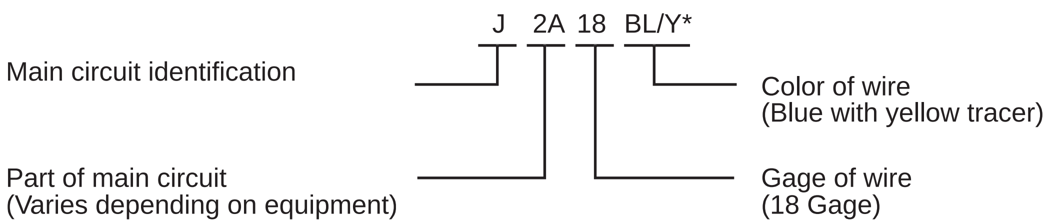


Figure 4-28 DaimlerChrysler's wiring code identification. (Courtesy of DaimlerChrysler Corporation)

Main Circuit Identification Codes

A	BATTERY FEED (i.e. Fuselink Feeds, Starter Feeds, Starter Relay)
B	Brakes
C	Climate Control (A/C, Heater, E.B.L. and Heated Mirror Related Circuits)
D	Diagnostic Circuits
E	Dimming Illumination Circuits
F	Fused Circuits (Non-Dedicated Multi-System Feeds)
G	Monitoring Circuits (Gages, Clocks, Warning Devices)
H	**OPEN**
I	Not used as a circuit designator
J	**OPEN**
K	Engine Logic Module Control Circuits
L	Exterior Lighting Circuits
M	Interior Lighting Circuits (Dome, Courtesy Lamps, Cargo Lamps)
N	ESA Module Electronic Circuits
O	Not used as a circuit designator
P	Power Options (Battery Feed) (i.e. Seats, Door Locks, Mirrors, Deck Lid Release, etc.)
Q	Power Options (Ignition Feed) (i.e. Windows, Power Top, Power Sun Roof, etc.)
R	Passive Restraint
S	Suspension and Steering Circuits
T	Transmission/Transaxle, Differential, Transfer Case and Starter System Circuits
U	**OPEN**
V	Speed Control and Wash Wipe Circuit
W	**OPEN**
X	Sound Systems (i.e. Radio and Horn)
Y	**OPEN**
Z	Grounds (B−)

Figure 4-29 DaimlerChrysler's circuit identification codes. (Courtesy of DaimlerChrysler Corporation)

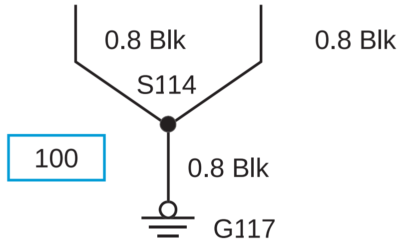


Figure 4-30 GM's method of circuit and wire identification.

DIN is the abbreviation for Deutsche Institut füer Normung (German Institute for Standardization) and is the recommended standard for European manufacturers to follow.

Standardized Wiring Designations. The Society of Automotive Engineers (SAE) is attempting to standardize the circuit diagrams used by the various manufacturers. The system that is developed may be similar to the **DIN** used by import manufacturers. DIN assigns certain color codes to a particular circuit as follows:

- ❑ Red wires are used for direct battery-powered circuits and also ignition-powered circuits.
- ❑ Black wires are also powered circuits controlled by switches or relays.
- ❑ Brown wires are usually the grounds.
- ❑ Green wires are used for ignition primary circuits.

A combination of wire colors is used to identify subcircuits. The base color still identifies the circuit's basic purpose. In addition to standardized color coding, DIN attempts to standardize terminal identification and circuit numbering.

Component Locators

A **component locator** is used to determine the exact location of several of the electrical components.

The wiring diagrams in most service manuals may not indicate the exact physical location of the components of the circuit. In another section of the service manual, 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 4-31).

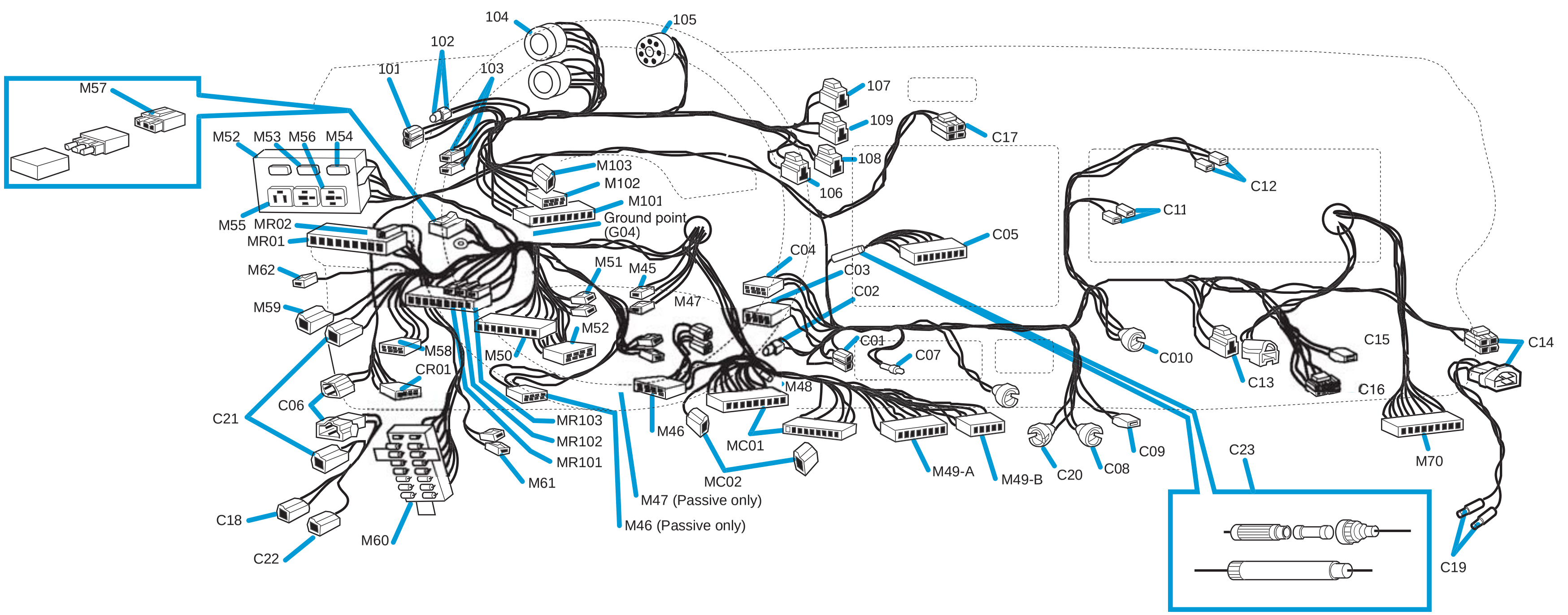
Many electrical components may be hidden behind kick panels, dash boards, fender wells, and under seats. The use of a component locator will save the technician time in finding the suspected defective unit.

Summary

Terms to Know

Ballast resistor
Bulkhead connectors
Common connections
Component locator
Cross-fire
DIN

- ❑ 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 withstand the anticipated vibration, and (3) The wire must be able to withstand the anticipated amount of heat exposure.



M45	Stop lamp switch
M46	Seat belt timer
M47	Chime bell
M48	Diode connector
M49	F.B.C. unit
M50	Multifunction switch
M51	Door opening switch
M52	Ignition switch
	Relay box (M53 HTD, M54 Idle up, M55 Flasher, M56 5-T M)
M57	Diode connector
M58	Heated timer
M59	Courtesy lamp extension wire
M60	Fuse box
M61	Tailgate opener switch
M62	Sun roof extension wire
M70	Lock up control unit
101	Defogger switch
102	Cluster illumination lamp

103, 104, 105	Instrument cluster
106	Cluster illumination lamp
107	Air conditioner switch
108	Rear wiper switch (except 4 door)
109	Rear washer switch (except 4 door)
M101, M102, M103	Instrument extension wire connector
C01	Rheostat switch
C02	Rheostat and intermittent wiper illumination lamp
C03	Intermittent wiper relay
C04	Blower switch
C05	Audio
C06	Front door speaker extension wire (LH)
C07	Ash tray illumination lamp
C08	Cigar lighter
C09	Cigar lighter
C10	Heater control illumination switch

C11	Glove box switch
C12	Glove box lamp
C13	Air conditioner extension wire
C14	Front door speaker extension wire (RH)
C15	Blower motor
C16	Heater resister
C17	Digital clock
C18	Front door speaker (LH)
C19	Front door speaker (RH)
C20	Tailgate opener switch (passive seat belt only)
C21	Seat belt extension wire (passive seat belt only)
C22	Seat belt switch (passive seat belt only)
C23	Radio fuse
CR01	Rear speaker extension wire
MR01, MR02	Rear wiring connector

Figure 4-31 The component locator is used to find the actual location of a component. (Courtesy of Hyundai Motor America)

I-MARK

Component & Location	Page NO. 11–	Fig. No.
A/C Relay (1987 Turbo): Behind LH Side Of I/P	53	25
A/C Relay (1987 Turbo): RH Side Of Cowl	36	6
A/C Relay (1987): Behind LH Side Of I/P	36	7
A/C Relay (1988 Turbo): Behind LH Side Of I/P	56	33
A/C Relay (1988 Turbo): RH Side Of Cowl	55	31
A/C Relay (1988): Behind LH Side Of I/P	55	32
AIR Vacuum Switching Valve (1987 Turbo):RH Side Of Cowl	38	12
AIR Vacuum Switching Valve (1988 Turbo): RH Side Of Cowl	62	42
Alternator (1987 Exc. Turbo): RH Side Of Engine	39	14
Alternator (1987 Turbo): RH Side Of Engine	41	16
Alternator (1988 Exc. Turbo): RH Side Of Engine	57	37
Alternator (1988 Turbo): RH Side Of Engine	59	39
Auto Choke Relay (1987 Exc. Turbo): RH Side Of Cowl	36	5
Auto Choke Relay (1988 Exc. Turbo): RH Side Of Cowl	55	30
Canister Vacuum Switching Valve (1988 Turbo): RH Side Of Cowl	38	12
Canister Vacuum Switching Valve (1988 Turbo): RH Side Of Cowl	62	42
Car Speed Sensor (1987 Turbo): Inside Speedometer	38	11
Car Speed Sensor (1987 Turbo): Inside Speedometer	38	12
Car Speed Sensor (1988 Turbo): Inside Speedometer	61	41
Car Speed Sensor (1988 Turbo): Inside Speedometer	62	42
Carburetor (1987 Exc. Turbo): On Intake Manifold	37	10
Carburetor (1988 Exc. Turbo): On Intake Manifold	60	40
Condenser Fan Relay (1987 Turbo): RH Render Apron	36	6
Condenser Fan Relay (1988 Turbo): RH Fender Apron	55	31
Connector A1 (1987 Exc. Turbo): Behind Center Of I/P	49	23
Connector A1 (1987 Turbo): Behind Center Of I/P	51	24
Connector A1 (1988 Exc. Turbo): Behind Center Of I/P	70	49
Connector A1 (1988 Turbo): Behind Center Of I/P	72	50
Connector A2 (1987 Exc. Turbo): Behind Center Of I/P	49	23
Connector A2 (1987 Turbo): Behind Center Of I/P	51	24
Connector A2 (1988 Exc. Turbo): Behind Center Of I/P	70	49
Connector A2 (1988 Turbo): Behind Center Of I/P	72	50
Connector A3 (1987 Exc. Turbo): Behind Center Of I/P	49	23
Connector A3 (1987 Turbo): Behind Center Of I/P	51	24

I-MARK—Continued

Component & Location	Page NO. 11–	Fig. No.
Connector A3 (1988 Exc. Turbo): Behind Center Of I/P	70	49
Connector A3 (1988 Turbo): Behind Center Of I/P	72	50
Connector A4 (1987 Exc. Turbo): Behind Center Of I/P	49	23
Connector A4 (1987 Turbo): Behind Center Of I/P	51	24
Connector A4 (1988 Exc. Turbo): Behind Center Of I/P	70	49
Connector A4 (1988 Turbo): Behind Center Of I/P	72	50
Connector A5 (1987 Exc. Turbo): Behind Center Of I/P	49	23
Connector A5 (1988 Exc. Turbo): Behind Center Of I/P	70	49
Connector C1 (1987 Exc. Turbo): LH Side Of Cowl	46	21
Connector C1 (1987 Turbo): LH Side Of Cowl	47	22
Connector C1 (1988 Exc. Turbo): LH Side Of Cowl	67	47
Connector C1 (1988 Turbo): LH Side Of Cowl	68	48
Connector C2 (1987 Exc. Turbo): LH Side Of Cowl	46	21
Connector C2 (1987 Turbo): LH Side Of Cowl	47	22
Connector C2 (1988 Exc. Turbo): LH Side Of Cowl	67	47
Connector C2 (1988 Turbo): LH Side Of Cowl	68	48
Connector C3 (1987 Exc. Turbo): LH Side Of Cowl	46	21
Connector C3 (1987 Turbo): LH Fender Apron	47	22
Connector C3 (1988 Exc. Turbo): LH Side Of Cowl	67	47
Connector C3 (1988 Turbo): LH Fender Apron	68	48
Connector C4 (1987 Exc. Turbo): LH Side Of Cowl	46	21
Connector C4 (1987 Turbo): LH Side Of Cowl	47	22
Connector C4 (1988 Exc. Turbo): LH Side Of Cowl	67	47
Connector C4 (1988 Turbo): LH Side Of Cowl	68	48
Connector C5 (1987 Exc. Turbo): LH Side Of Cowl	46	21
Connector C5 (1987 Turbo): LH Side Of Cowl	47	22
Connector C5 (1988 Exc. Turbo): LH Side Of Cowl	67	47
Connector C5 (1988 Turbo): LH Side Of Cowl	68	48
Connector C6 (1987 Exc. Turbo): LH Side Of Cowl	46	21
Connector C6 (1987 Turbo): LH Side Of Cowl	47	22
Connector C6 (1988 Exc. Turbo): LH Side Of Cowl	67	47
Connector C6 (1988 Turbo): LH Side Of Cowl	68	48
Connector C7 (1987 Exc. Turbo): LH Fender Apron	46	21
Connector C7 (1987 Turbo): LH Fender Apron	47	22
Connector C7 (1988 Exc. Turbo): LH Fender Apron	67	47
Connector C7 (1988 Turbo): LH Fender Apron	68	48

Figure 4-31 (continued)

- ❑ Wire size is based on the diameter of the conductor.
- ❑ Factors that affect the resistance of the wire include the conductor material, wire diameter, wire length, and temperature.
- ❑ 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 amount 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 (Continued)

Electrical symbols
Gauge
Installation diagrams
Primary wiring
Printed circuit boards
Resistance wire
Schematic
Secondary wiring
Stranded wire
Tracer
Wire 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. ________________ ________________ is the electromagnetic induction spark that can be transmitted in another wire that is close to the wire carrying the current.
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 ________________ ________________ 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. Spark plug wires are being discussed.
Technician A says RFI is controlled by using resistances in the conductor of the spark plug wire.
Technician B says all late model ignition systems use resistance wires to control RFI.
Who is correct?
A. A only **C.** Both A and B
B. B only **D.** Neither A nor B

4. Spark plug wire installation is being discussed.
Technician A says there is little that can be done to prevent cross-fire.
Technician B says the spark plug wires must be installed in the proper separator and any two parallel wires next to each other in the firing order should be positioned as far away from each other as possible.
Who is correct?
A. A only **C.** Both A and B
B. B only **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 **C.** Both A and B
B. B only **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 underhood harnesses are simple harnesses.
Who is correct?
A. A only **C.** Both A and B
B. B only **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 **C.** Both A and B
B. B only **D.** Neither A nor B