

Chapter 1

INTRODUCTION TO AUTOMOTIVE ELECTRICAL AND ELECTRONIC SYSTEMS

UPON COMPLETION AND REVIEW OF THIS CHAPTER, YOU SHOULD BE ABLE TO UNDERSTAND AND DESCRIBE:

- The importance of learning automotive electrical systems.
- The role of electrical systems in today's vehicles.
- The interaction of the electrical systems.
- The purpose of the starting system.
- The purpose of the charging system.
- The role of the computer in today's vehicles.
- The purpose of vehicle communication networks.
- The purpose of various electronic accessory systems.
- The purpose of passive restraint systems.
- The purpose of alternate propulsion systems.

INTRODUCTION

You are probably reading this book for one of two reasons. Either you are preparing yourself to enter into the field of automotive service or you are expanding your skills to include automotive electrical systems. In either case, congratulations on selecting one of the most fast-paced segments of the automotive industry. Working with the electrical systems can be challenging, yet very rewarding; however, it can also be very frustrating at times.

For many people, learning electrical systems can be a struggle. It is my hope that I am able to present the material to you in such a manner that you will not only understand electrical systems but will excel at it. There are many ways the theory of electricity can be explained, and many metaphors can be used. Some compare electricity to a water flow, while others explain it in a purely scientific fashion. Everyone learns differently. I am presenting electrical theory in a manner that I hope will be clear and concise. If you do not fully comprehend a concept, then it is important to discuss it with your instructor. Your instructor may be able to use a slightly different method of instruction to help you to completely understand the concept. Electricity is somewhat abstract; so if you do have questions, be sure to ask your instructor.

WHY BECOME AN ELECTRICAL SYSTEM TECHNICIAN?

In the past it was possible for technicians to work their entire careers and be able to almost completely avoid the vehicle's electrical systems. They would specialize in engines, steering/suspension, or brakes. Today there is not a system on the vehicle that is immune to the role

of electrical circuits. Engine controls, electronic suspension systems, and antilock brakes are common on today's vehicles. Even electrical systems that were once thought of as being simple have evolved to computer controls. Headlights are now pulse-width modulated using high-side drivers and will automatically brighten and dim based on the light intensity of oncoming traffic. Today's vehicles are equipped with twenty or more computers, laser-guided cruise control, sonar park assist, infrared climate control, fiber optics, and radio frequency transponders and decoders. Simple systems have become more computer reliant. For example, the horn circuit on the 2008 Chrysler 300C involves three separate control modules to function. Even the tires have computers involved, with the addition of tire pressure monitoring systems!

Today's technician must possess a full and complete electrical background to be able to succeed. The future will provide great opportunities for those technicians who have prepared themselves properly.



A BIT OF HISTORY

Karl Benz of Mannheim, Germany, patented the world's first automobile on January 29, 1886. The vehicle was a three-wheeled automobile called the Benz Motorwagen. That same year Gottlieb Daimler built a four-wheeled vehicle. It was powered by a 1.5-horsepower engine that produced 50% more power than that of the Benz Motorwagen. The first automobile to be produced for sale in the United States was the 1896 Duryea.

THE ROLE OF ELECTRICITY IN THE AUTOMOBILE

In the past, electrical systems were basically stand-alone. For example, the ignition system was only responsible for supplying the voltage needed to fire the spark plugs. Ignition timing was controlled by vacuum and mechanical advance systems. Today there are very few electrical systems that are still independent.

Today, most manufactures **network** their electrical systems together through computers. This means that information gathered by one system can be used by another. The result may be that a faulty component may cause several symptoms. Consider the following example. The wiper system can interact with the headlight system to turn on the headlights whenever the wipers are turned on. The wipers can interact with the vehicle speed sensor to provide for speed-sensitive wiper operation. The speed sensor may provide information to the antilock brake module. The antilock brake module can then share this information with the transmission control module, and the instrument cluster can receive vehicle speed information to operate the speedometer. If the vehicle speed sensor should fail, this could result in no antilock brake operation and a warning light turned on in the dash. But it could also result in the speedometer not functioning, the transmission not shifting, and the wipers not operating properly.

INTRODUCTION TO THE ELECTRICAL SYSTEMS

The purpose of this section is to acquaint you with the electrical systems that will be covered in this book. We will define the purpose of these systems.

AUTHOR'S NOTE: The discussion of the systems in this section of the chapter provides you with an understanding of their *main* purpose. Some systems have secondary functions. All of these will be discussed in detail in later chapters.

The Starting System

The **starting system** is a combination of mechanical and electrical parts that work together to start the engine. The starting system is designed to change the electrical energy, which is being supplied by the battery, into mechanical energy. For this conversion to be accomplished, a starter or cranking motor is used. The basic starting system includes the following components (Figure 1-1):

1. Battery.
2. Cable and wires.

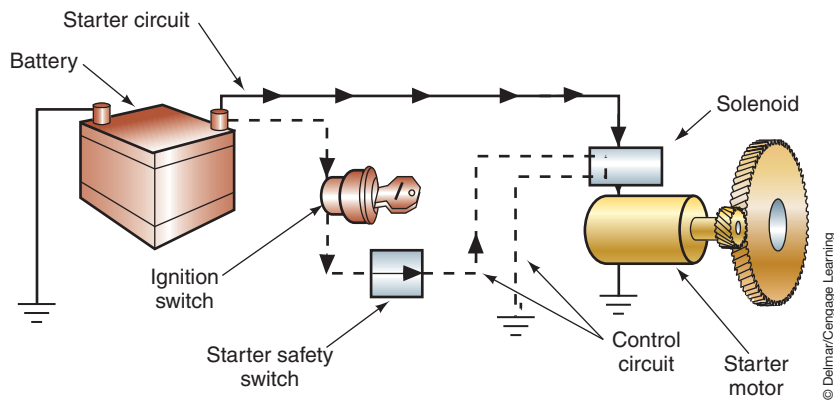


FIGURE 1-1 Major components of the starting system.

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3. Ignition switch.
4. Starter solenoid or relay.
5. Starter motor.
6. Starter drive and flywheel ring gear.
7. Starting safety switch.

The starter motor (Figure 1-2) requires large amounts of current (up to 400 amperes) to generate the torque needed to turn the engine. The conductors used to carry this amount of current (battery cables) must be large enough to handle the current with very little voltage drop. It would be impractical to place a conductor of this size into the wiring harness to the ignition switch. To provide control of the high current, all starting systems contain some type of magnetic switch. There are two basic types of magnetic switches used: the solenoid and the relay.

The **ignition switch** is the power distribution point for most of the vehicle's primary electrical systems. The ignition switch is spring loaded in the start position. This momentary contact automatically moves the contacts to the RUN position when the driver releases the key. All other ignition switch positions are detent positions.

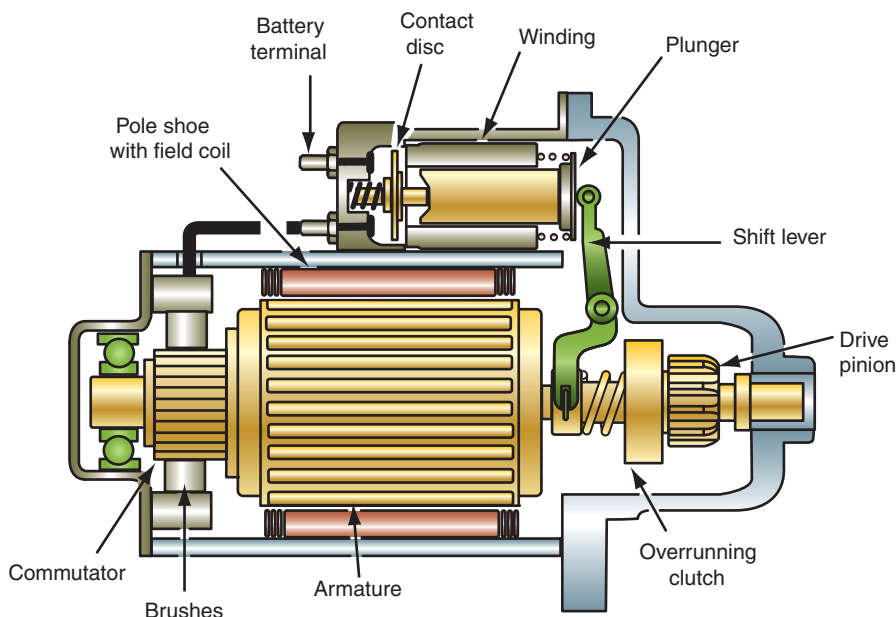


FIGURE 1-2 Starter motor.

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A BIT OF HISTORY

The Model T was called the first “people’s car.” Prior to its introduction by the Ford Motor Company in 1908, the automobile could only be purchased by the wealthy. It was Henry Ford’s desire to build a car for the masses. Although Henry Ford had no professional engineering education, he did possess a natural inclination toward mechanics. To keep production costs down, he used assembly-line production to manufacture the Model T. Henry Ford also introduced the moving conveyor belt into the assembly process, further accelerating production. The Model T was nicknamed Tin Lizzie because its body was made from lightweight sheet steel. The production of the Model T continued till 1927, with more than 16.5 million vehicles being produced. The electrical system was very simple and originally consisted of

The **neutral safety switch** is used on vehicles that are equipped with automatic transmissions. It opens the starter control circuit when the transmission shift selector is in any position except PARK or NEUTRAL. Vehicles that are equipped with automatic transmissions require a means of preventing the engine from starting while the transmission is in gear. Without this feature, the vehicle would lunge forward or backward once it was started, causing personal or property damage. The normally open neutral safety switch is connected in series into the starting system control circuit and is usually operated by the shift lever (Figure 1-3). When in the PARK or NEUTRAL position, the switch is closed, allowing current to flow to the starter circuit. If the transmission is in a gear position, the switch is opened and current cannot flow to the starter circuit.

Many vehicles that are equipped with manual transmissions use a similar type of safety switch. The start/clutch interlock switch is usually operated by movement of the clutch pedal (Figure 1-4).

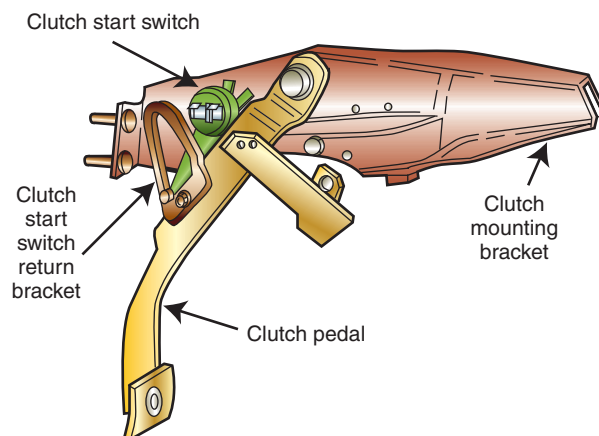
The Charging System

The automotive storage battery is not capable of supplying the demands of the electrical systems for an extended period of time. Every vehicle must be equipped with a means of replacing the energy that is being drawn from the battery. A **charging system** is used to restore to the battery the electrical power that was used during engine starting. In addition, the



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FIGURE 1-3 The neutral safety switch is usually attached to the transmission.



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FIGURE 1-4 Most vehicles with a manual transmission use a clutch start switch.

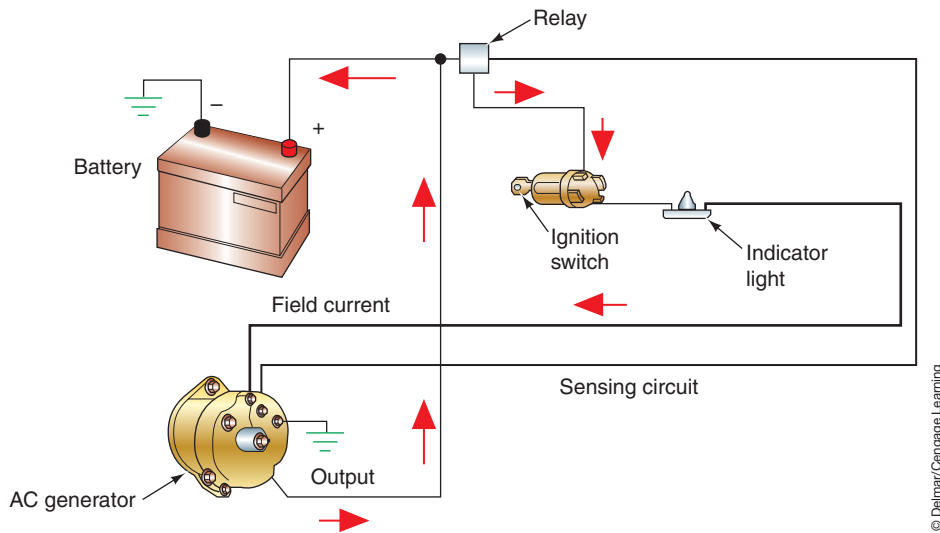


FIGURE 1-5 Components of the charging system.



A BIT OF HISTORY

(continued)

a flywheel magneto that produced low-voltage alternating current. This AC voltage was used to power a trembler coil that created a high-voltage current for use by the ignition system. The ignition pulse was passed to the timer (distributor) and directed to the proper cylinder. Ignition timing was adjusted manually via the spark advance lever that was mounted on the steering column. Moving the lever rotated the timer to advance or retard the ignition timing. Since the magneto may not produce sufficient current when starting the engine with the hand crank, a battery could be used to provide the required starting current. When electric headlights were introduced in 1915, the magneto was used to supply power for the lights and the horn.

charging system must be able to react quickly to high load demands required of the electrical system. It is the vehicle's charging system that generates the current to operate all of the electrical accessories while the engine is running.

The purpose of the charging system is to convert the mechanical energy of the engine into electrical energy to recharge the battery and run the electrical accessories. When the engine is first started, the battery supplies all the current required by the starting and ignition systems.

As illustrated in Figure 1-5, the entire charging system consists of the following components:

1. Battery.
2. AC generator or DC generator.
3. Drive belt.
4. Voltage regulator.
5. Charge indicator (lamp or gauge).
6. Ignition switch.
7. Cables and wiring harness.
8. Starter relay (some systems).
9. Fusible link (some systems).

All charging systems use the principle of electromagnetic induction to generate the electrical power. A **voltage regulator** controls the output voltage of the AC generator, based on charging system demands, by controlling field current. The battery, and the rest of the electrical system, must be protected from excessive voltages. To prevent early battery and electrical system failure, regulation of the charging system is very important. Also, the charging system must supply enough current to run the vehicle's electrical accessories when the engine is running.

The Lighting System

The **lighting system** consists of all of the lights used on the vehicle (Figure 1-6). This includes headlights, front and rear park lights, front and rear turn signals, side marker lights, daytime running lights, cornering lights, brake lights, back-up lights, instrument cluster backlighting, and interior lighting.

The lighting system of today's vehicles can consist of more than 50 light bulbs and hundreds of feet of wiring. Incorporated within these circuits are circuit protectors, relays,



FIGURE 1-6 Automotive lighting system.

switches, lamps, and connectors. In addition, more sophisticated lighting systems use computers and sensors. Since the lighting circuits are largely regulated by federal laws, the systems are similar among the various manufacturers. However, there are variations that exist in these circuits.

With the addition of solid-state circuitry in the automobile, manufacturers have been able to incorporate several different lighting circuits or modify the existing ones. Some of the refinements that were made to the lighting system include automatic headlight washers, automatic headlight dimming, automatic on/off with timed-delay headlights, and illuminated entry systems. Some of these systems use sophisticated body computer-controlled circuitry and fiber optics.

Some manufacturers have included such basic circuits as turn signals into their body computer to provide for pulse-width dimming in place of a flasher unit. The body computer can also be used to control instrument panel lighting based on inputs that include if the side marker lights are on or off. By using the body computer to control many of the lighting circuits, the amount of wiring has been reduced. In addition, the use of computer control of these systems has provided a means of self-diagnosis in some applications.

Today, high-density discharge (HID) headlamps are becoming an increasingly popular option on many vehicles. These headlights provide improved lighting over conventional headlamps.

Vehicle Instrumentation Systems

Vehicle instrumentation systems (Figure 1-7) monitor the various vehicle operating systems and provide information to the driver about their correct operation. Warning devices also provide information to the driver; however, they are usually associated with an audible signal. Some vehicles use a voice module to alert the driver to certain conditions.

Electrical Accessories

Electrical accessories provide for additional safety and comfort. There are many electrical accessories that can be installed into today's vehicles. These include safety accessories such as the horn, windshield wipers, and windshield washers. Comfort accessories include the blower motor, electric defoggers, power mirrors, power windows, power seats, and power door locks.

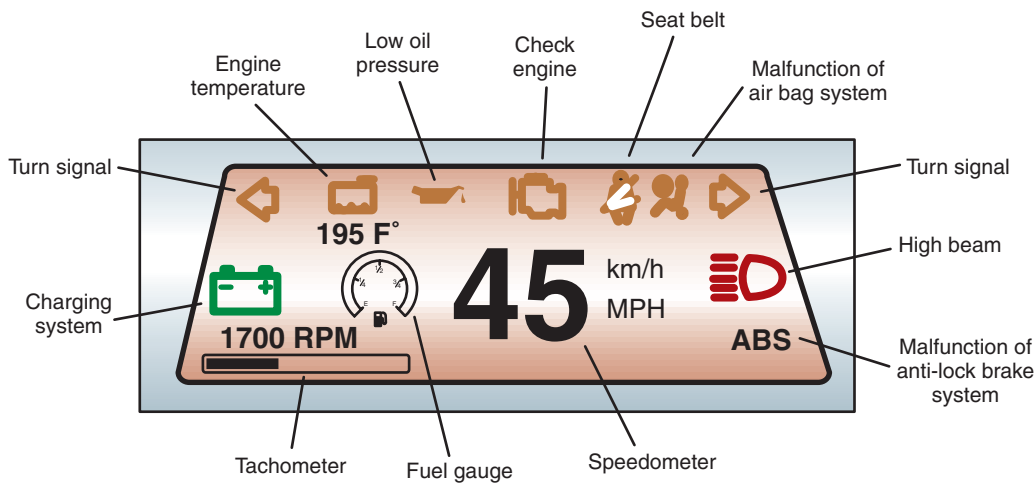


FIGURE 1-7 The instrument panel displays various operating conditions.



FIGURE 1-8 Automotive horn.

Horns. A **horn** is a device that produces an audible warning signal (Figure 1-8). Automotive electrical horns operate on an electromagnetic principle that vibrates a diaphragm to produce a warning signal. This vibration of the diaphragm is repeated several times per second. As the diaphragm vibrates it causes a column of air that is in the horn to vibrate. The vibration of the column of air produces the sound.

Windshield Wipers. **Windshield wipers** are mechanical arms that sweep back and forth across the windshield to remove water, snow, or dirt (Figure 1-9). The operation of the wiper arms is through the use of a wiper motor. Most windshield wiper motors use permanent magnet fields, or electromagnetic field motors.

Electric Defoggers. **Electric defoggers** heat the rear window to remove ice and/or condensation. Some vehicles use the same circuit to heat the outside driver-side mirror. When electrons are forced to flow through a resistance, heat is generated. Rear window defoggers use this principle of controlled resistance to heat the glass. The resistance is through a grid that is baked on the inside of the glass (Figure 1-10). The system may incorporate a timer circuit that controls the relay.

Power Mirrors. **Power mirrors** are outside mirrors that are electrically positioned from the inside of the driver compartment. The electrically controlled mirror allows the driver to



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FIGURE 1-9 Windshield wipers.



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FIGURE 1-10 Rear window defogger grid.

position the outside mirrors by use of a switch. The mirror assembly will use built-in, dual-drive, reversible permanent magnet (PM) motors.

Power Windows. **Power windows** are windows that are raised and lowered by use of electrical motors. Many vehicle manufacturers have replaced the conventional window crank with electric motors that operate the side windows. The motor used in the power window system is a reversible PM or two-field winding motor. The power window system usually consists of the following components:

1. Master control switch.
2. Individual control switches.
3. Individual window drive motors.

Power Door Locks. **Electric power door locks** use either a solenoid or a permanent magnet reversible motor to lock and unlock the door. Many vehicles are equipped with automatic door locks that are activated when the gear shift lever is placed in the DRIVE position. The doors unlock when the selector is returned to the PARK position.



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FIGURE 1-11 A control module is used to process data and operate different automotive systems.

Computers

A **computer** is an electronic device that stores and processes data and is capable of operating other devices (Figure 1-11). The use of computers on automobiles has expanded to include control and operation of several functions, including climate control, lighting circuits, cruise control, antilock braking, electronic suspension systems, and electronic shift transmissions. Some of these are functions of what is known as a body control module (BCM). Some body computer-controlled systems include direction lights, rear window defogger, illuminated entry, intermittent wipers, and other systems that were once thought of as basic.

A computer processes the physical conditions that represent information (data). The operation of the computer is divided into four basic functions:

1. Input.
2. Processing.
3. Storage.
4. Output.

Vehicle Communication Networks

Most manufacturers now use a system of vehicle communications called **multiplexing** (MUX) to allow control modules to share information (Figure 1-12). Multiplexing provides the ability to use a single circuit to distribute and share data between several control modules throughout the vehicle. Because the data is transmitted through a single circuit, bulky wiring harnesses are eliminated.

Vehicle manufacturers will use multiplexing systems to enable different control modules to share information. A MUX wiring system uses **bus** data links that connect each module. The term *bus* refers to the transporting of data from one module to another. Each module can transmit and receive digital codes over the bus data links. The signal sent from a sensor can go to any one of the modules and can be shared by the other modules.

Electronic Accessory Systems

With the growing use of computers, most systems can be controlled electronically. This provides for improved monitoring of the systems for proper operation and the ability to detect if a fault occurs. The systems that are covered in this book include the following:

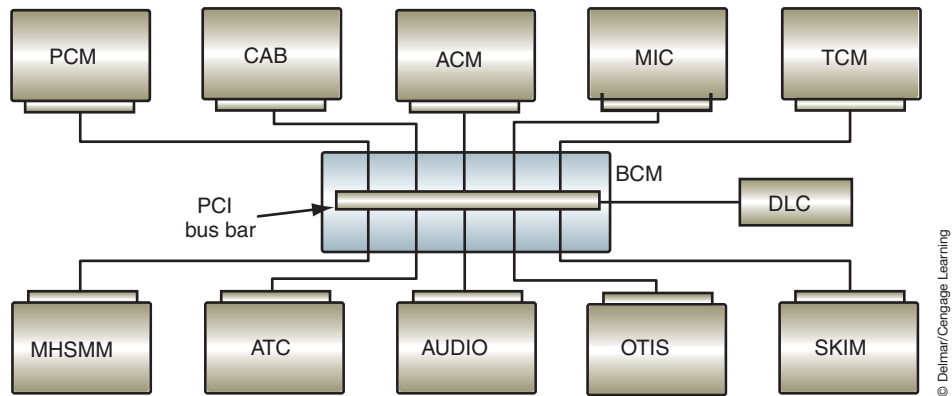


FIGURE 1-12 Automotive computers are networked together through multiplexing.

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Cruise control systems are also referred to as *speed control*.

Electronic Cruise Control Systems. **Cruise control** is a system that allows the vehicle to maintain a preset speed with the driver's foot off of the accelerator. Most cruise control systems are a combination of electrical and mechanical components.

Memory Seats. The **memory seat** feature allows the driver to program different seat positions that can be recalled at the push of a button. The memory seat feature is an addition to the basic power seat system. Most memory seat systems share the same basic operating principles, the difference being in programming methods and number of positions that can be programmed. Most systems provide for two seat positions to be stored in memory.

An **easy exit** feature may be an additional function of the memory seat that provides for easier entrance and exit of the vehicle by moving the seat all the way back and down. Some systems also move the steering wheel up and to full retract.

Electronic Sunroofs. Some manufacturers have introduced electronic control of their electric sunroofs. These systems incorporate a pair of relay circuits and a timer function into the control module. Motor rotation is controlled by relays that are activated according to signals received from the slide, tilt, and limit switches.

Antitheft Systems. The **antitheft system** is a deterrent system designed to scare off would-be thieves by sounding alarms and/or disabling the ignition system. Figure 1-13 illustrates many of the common components that are used in an antitheft system. These components include:

1. An electronic control module.
2. Door switches at all doors.
3. Trunk key cylinder switch.
4. Hood switch.
5. Starter inhibitor relay.
6. Horn relay.
7. Alarm.

In addition, many systems incorporate the exterior lights into the system. The lights are flashed if the system is activated.

Some systems use ultrasonic sensors that will signal the control module if someone attempts to enter the vehicle through the door or window. The sensors can be placed to sense the parameter of the vehicle and sound the alarm if someone enters within the protected parameter distance.

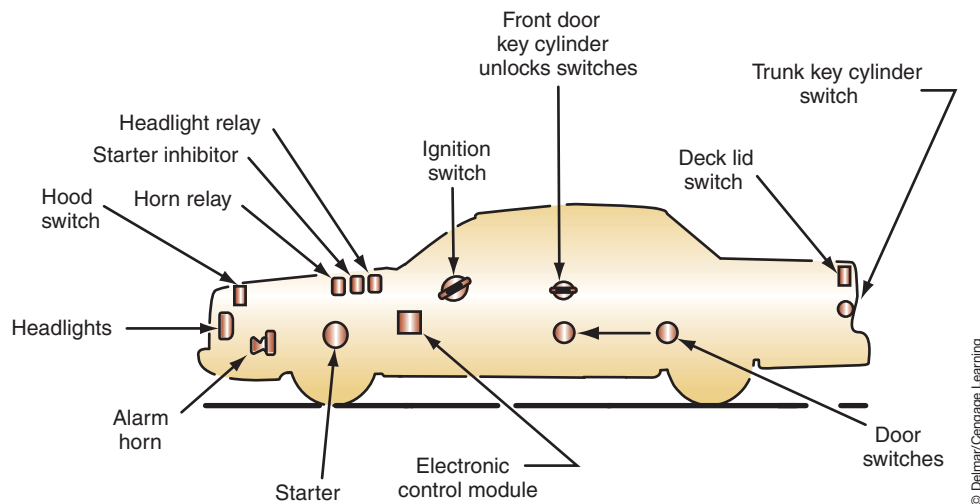


FIGURE 1-13 Typical components of an anti-theft system.

Automatic Door Locks. **Automatic door locks (ADL)** use a passive system to lock all doors when the required conditions are met. Many automobile manufacturers are incorporating automatic door locks as an additional safety and convenience system. Most systems lock the doors when the gear selector is placed in DRIVE, the ignition switch in RUN, and all doors are shut. Some systems will lock the doors when the gear shift selector is passed through the REVERSE position, while others do not lock the doors unless the vehicle is moving 15 mph or faster.

The system may use the body computer or a separate controller to control the door lock relays. The controller (or body computer) takes the place of the door lock switches for automatic operation.

Keyless Entry. The **keyless entry system** allows the driver to unlock the doors or the deck lid (trunk) from outside of the vehicle without the use of a key. The main components of the keyless entry system are the control module, a coded-button keypad located on the driver's door (Figure 1-14), and the door lock motors.

Some keyless entry systems can be operated remotely. Pressing a button on a hand-held transmitter will allow operation of the system from distances of 25 to 50 feet (Figure 1-15).

Recently, most manufacturers have made available systems of remote engine starting and keyless start. These are usually designed into the function of the remote keyless entry system.



FIGURE 1-14 Keyless entry system keypad.



FIGURE 1-15 Remote keyless entry system transponder.

Passive Restraint Systems

Federal regulations have mandated the use of automatic **passive restraint systems** in all vehicles sold in the United States after 1990. Passive restraints are ones that operate automatically, with no action required on the part of the driver or occupant.

Air bag systems are on all of today's vehicles. The need to supplement the existing restraint system during frontal collisions has led to the development of the supplemental inflatable restraint (SIR) or air bag systems (Figure 1-16).

A typical air bag system consists of sensors, a diagnostic module, a clock spring, and an air bag module. Figure 1-17 illustrates the typical location of the common components of the SIR system.

Alternate Propulsion Systems

Due to the increase in regulations concerning emissions and the public's desire to become less dependent on foreign oil, most major automotive manufacturers have developed alternative fuel or alternate power vehicles. Since the 1990s, most major automobile manufacturers have developed an **electric vehicle (EV)**. The primary advantage of an

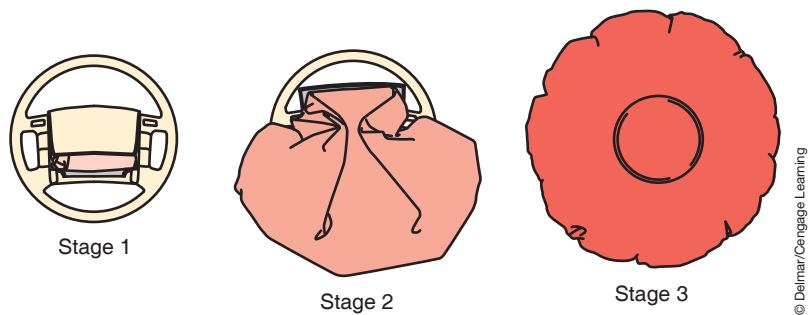


FIGURE 1-16 Air bag deployment sequence.

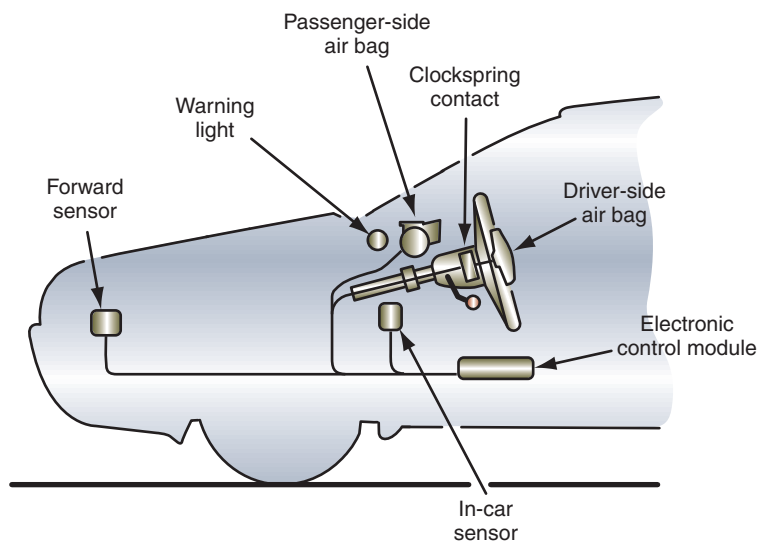


FIGURE 1-17 Typical location of components of the air bag system.

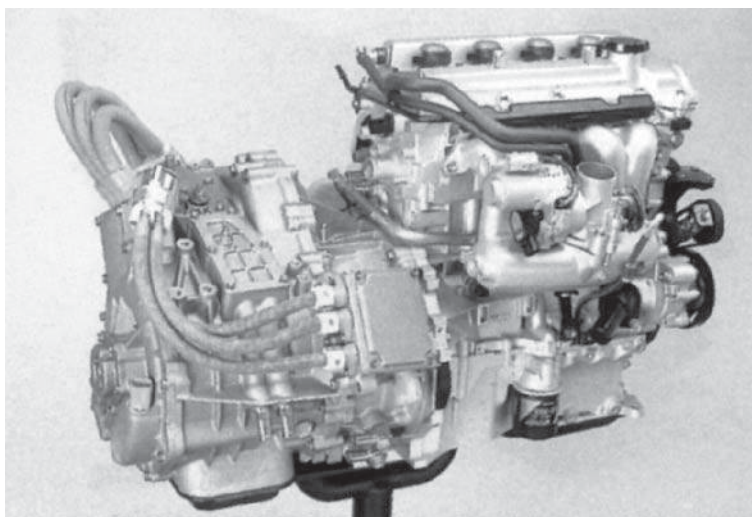
EV is a drastic reduction in noise and emission levels. General Motors introduced the EV1 electric car to the market in 1996. The original battery pack in this car contained twenty-six 12-volt batteries that delivered electrical energy to a three-phase 102-kilowatt (kW) AC electric motor. The electric motor is used to drive the front wheels. The driving range is about 70 miles (113 km) of city driving or 90 miles (145 km) of highway driving.

EV battery limitation was a major stumbling block to most consumers. One method of improving the electric vehicle resulted in the addition of an on-board power generator that is assisted by an internal combustion engine, resulting in the **hybrid electric vehicle (HEV)**.

Basically, the hybrid electric vehicle relies on power from the electric motor, the engine, or both (Figure 1-18). When the vehicle moves from a stop and has a light load, the electric motor moves the vehicle. Power for the electric motor comes from stored energy in the battery pack. During normal driving conditions, the engine is the main power source. Engine power is also used to rotate a generator that recharges the storage batteries. The output from the generator may also be used to power the electric motor, which is run to provide additional power to the powertrain. A computer controls the operation of the electric motor, depending on the power needs of the vehicle. During full throttle or heavy load operation, additional electricity from the battery is sent to the motor to increase the output of the powertrain.

Fuel cell–powered vehicles have a very good chance of becoming the drives of the future. They combine the reach of conventional internal combustion engines with high efficiency, low fuel consumption, and minimal or no pollutant emission. At the same time, they are extremely quiet. Because they work with regenerative fuel such as hydrogen, they reduce the dependence on crude oil and other fossil fuels.

A fuel cell–powered vehicle (Figure 1-19) is basically an electric vehicle. Like the electric vehicle, it uses an electric motor to supply torque to the drive wheels. The difference is that the fuel cell produces and supplies electric power to the electric motor instead of batteries. Most of the vehicle manufacturers and several independent laboratories are involved in fuel cell research and development programs. A number of prototype fuel cell vehicles have been produced, with many being placed in fleets in North America and Europe.



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FIGURE 1-18 HEV power system.

TERMS TO KNOW

Air bag systems
Antitheft system
Automatic door locks (ADL)
Bus
Charging system
Computer
Cruise control
Easy exit
Electric defoggers
Electric vehicle (EV)
Electrical accessories
Fuel cell
Heated windshield system
Horn
Hybrid electric vehicle (HEV)
Ignition switch
Intelligent windshield wiper systems
Keyless entry system
Lighting system
Memory seat
Multiplexing
Network
Neutral safety switch
Passive restraint systems
Power door locks
Power mirrors
Power windows
Starting system
Vehicle instrumentation systems
Voltage regulator
Windshield wipers

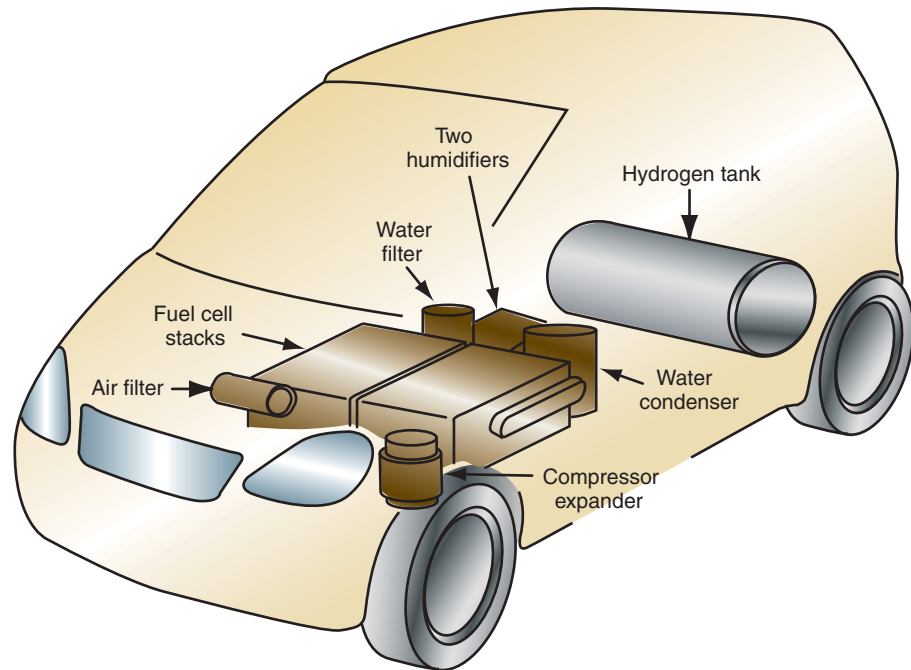


FIGURE 1-19 Fuel cell vehicle components.

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SUMMARY

- The starting system is a combination of mechanical and electrical parts that work together to start the engine.
- The charging system replaces the electrical power used by the battery and to provide current to operate all of the electrical accessories while the engine is running.
- The lighting system consists of all of the lights used on the vehicle.
- Vehicle instrumentation systems monitor the various vehicle operating systems and provide information to the driver.
- Electrical accessories provide additional safety and comfort.
- Many of the basic electrical accessory systems have electronic controls added to them to provide additional features and enhancement.
- Computers are electronic devices that gather, store, and process data.
- Most vehicles use a multiplexing system to share information between computer systems.
- The memory seat feature allows the driver to program different seat positions that can be recalled at the push of a button.
- Some manufacturers have introduced electronic control of their electric sunroofs. These systems incorporate a pair of relay circuits and a timer function into the control module.
- Antitheft systems are deterrent systems designed to scare off would-be thieves by sounding alarms and/or disabling the ignition system.
- Automatic door locks is a passive system used to lock all doors when the required conditions are met. Many automobile manufacturers are incorporating the system as an additional safety and convenience feature.
- Passive restraints operate automatically, with no action required on the part of the driver or occupant.
- Electric vehicles powered by an electric motor run off a battery pack.
- The hybrid electric vehicle relies on power from the electric motor, the engine, or both.
- A fuel cell-powered vehicle is basically an electric vehicle, except that the fuel cell produces and supplies electric power to the electric motor instead of batteries.

REVIEW QUESTIONS

Short-Answer Essays

1. Describe your level of comfort concerning automotive electrical systems.
 2. Explain why you feel it is important to understand the operation of the automotive electrical system.
 3. Explain how the use of computers has changed the automotive electrical system.
 4. Explain the difference between an electric vehicle and a fuel-cell vehicle.
 5. Explain the basics of HEV operation.
 6. What is the purpose of the keyless entry system?
 7. What safety benefits can be achieved from the automatic door lock system?
 8. What is the purpose of the starting system?
 9. What is the purpose of the charging system?
 10. What is the function of the air bag system?
2. Vehicle instrumentation systems _____ the various operating systems and provide information to the driver about their correct operation.
 3. A _____ is an electronic device that stores and processes data.
 4. The starting system is designed to change the _____ energy into mechanical energy.
 5. The _____ _____ feature is an additional function of the memory seat that provides for easier entrance and exit of the vehicle.
 6. The _____ _____ is the power distribution point for most of the vehicle's primary electrical systems.
 7. The _____ system is a deterrent system.
 8. The purpose of the charging system is to convert the _____ energy of the engine into _____ energy.
 9. _____ restraints operate automatically with no action required on the part of the driver.
 10. The _____ _____ uses an on-board power generator that is assisted by an internal combustion engine.

Fill in the Blanks

1. Today, most manufactures _____ their electrical systems together through computers.

MULTIPLE CHOICE

1. Electric vehicles power the motor by:
 - A. A generator.
 - B. A battery pack.
 - C. An engine.
 - D. None of the above.
2. The charging system:
 - A. Provides all electrical energy to operate the electrical system while the engine is running.
 - B. Restores the energy to the battery after starting the engine.
 - C. Uses the principle of magnetic induction to generate electrical power.
 - D. All of the above.
3. The memory seat system:
 - A. Operates separately of the power seat system.
 - B. Requires the vehicle to be moving before the seat position can be recalled.
 - C. Allows for the driver to program different seat positions that can be recalled at the push of a button.
 - D. Can only be equipped on vehicles with manual position seats.
4. The following are true about the easy exit feature EXCEPT:
 - A. It is an additional function of the memory seat.
 - B. The driver's door is opened automatically.
 - C. The seat is moved all the way back and down.
 - D. The system may move the steering wheel up.

5. The following are components of the starting system EXCEPT:
- A. The flywheel ring gear.
 - B. Neutral safety switch.
 - C. Harmonic balancer.
 - D. Battery.
6. Which of the following is the most correct statement?
- A. Automotive electrical systems are interlinked with each other.
 - B. All automotive electrical systems function the same on every vehicle.
 - C. Manufactures are required by Federal legislation to limit the number of computers used on today's vehicles.
 - D. All of the above.
7. Automotive horns operate on the principle of:
- A. Induced voltage.
 - B. Depletion zone bonding.
 - C. Frequency modulation.
 - D. Electromagnetism.
8. The purpose of multiplexing is to:
- A. Increase circuit loads to a sensor.
 - B. Prevent electromagnetic interference.
 - C. Allow computers to share information.
 - D. Prevent multiple system failures from occurring.
9. The following are true about the air bag system EXCEPT:
- A. It is an active system.
 - B. It is a supplemental system.
 - C. It is mandated by the federal government.
 - D. Deployment is automatic.
10. Alternate propulsion systems include:
- A. Electric vehicles.
 - B. Hybrid vehicles.
 - C. Fuel cell vehicles.
 - D. All of the above.