

## INTRODUCTION

Vehicles today are equipped with many safety and convenience features. Some of them are listed below.

All vehicles are equipped with warning lights on the instrument panel (IP) and they are often confusing to drivers. Symbols are used instead of words because they are universal in a global vehicle market. The dash warning lights are often called telltale lights as they are used to notify the driver of a situation or fault.

- Green or white symbols are used to notify the driver that certain functions are working, such as the headlights are on, or the turn signals have been activated.
- Amber-colored symbols mean that a fault or an issue has occurred that may require attention soon.
- Red symbols mean that a serious fault has been detected and that immediate attention is required.

*Power windows* use electric motors to raise and lower door glass. They can be operated by both a master control switch located beside the driver and additional independent switches located at each electric window. Figure 1.

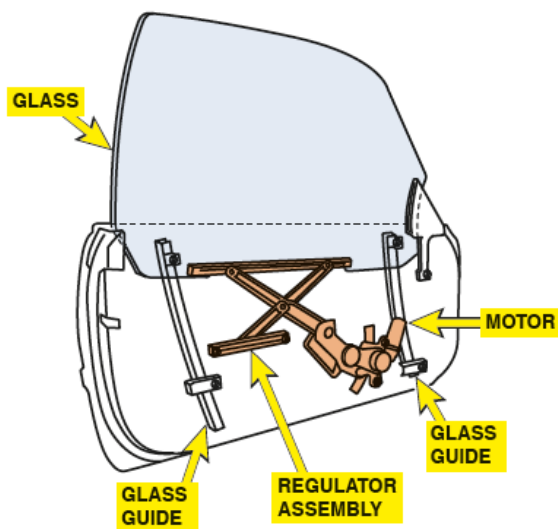


Figure 1. An electric motor and a regulator assembly raise and lower the glass on a power window.

*Electric power door locks* use a permanent magnet (PM) reversible motor to lock or unlock all vehicle door locks from a control switch or switches.

A typical *power-operated seat* includes a reversible electric motor and a transmission assembly that may have three solenoids or motors, and six drive cables that turn the six seat adjusters. A six-way power seat offers seat movement forward and backward, plus seat cushion movement up and down at the front and the rear. Figure 2.



Figure 2. A power seat uses electric motors under the seat, which drive cables that extend to operate screw jacks (up and down) or gears to move the seat forward and back.

*Heated seats* use electric heating elements in the seat bottom, as well as in the seat back, in many vehicles. The heating element is designed to warm the seat and/or back of the seat to about 100°F (38°C) or close to normal body temperature (98.6°F [37°C]).

Most *keyless entry* systems use a wireless transmitter built into the key fob or remote. The transmitter broadcasts a signal that is received by the electronic control module, which is generally mounted in the trunk or under the instrument panel. The electronic control unit sends a voltage signal to the door lock actuator(s) located in the doors.

A *passive system* uses the key fob as a transmitter, which communicates with the vehicle as it comes close. The key is identified using one of several antennas around the body of the vehicle and a radio pulse generator in the key housing. Vehicles with a *smart key system* can be started without inserting a key in the ignition, provided the driver has the key fob inside the vehicle. Figure 3.

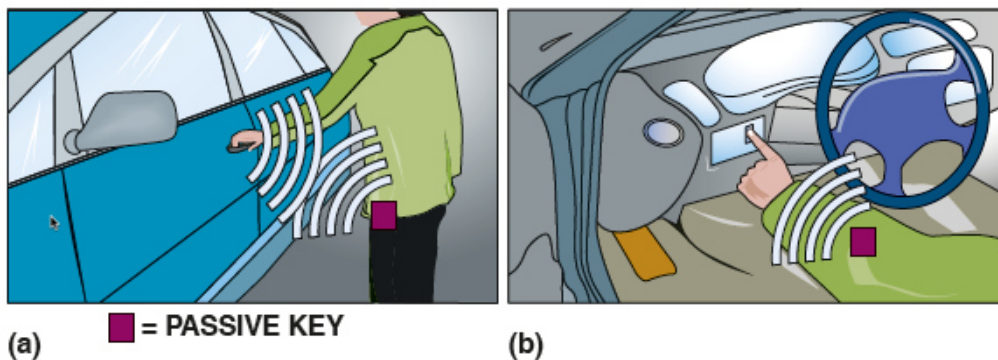


Figure 3. (a) If the passive key is within about 15 feet (5 m) of the vehicle when the door handle is touched, the door unlocks, allowing access to the interior. (b) The engine starts if the smart key is detected being inside the vehicle.

A *virtual display* is a dash that allows the driver to select what data is being displayed. Many vehicles are equipped with an LCD dash display that can be changed to display various functions based on the driver's preference. Figure 4.



Figure 4. A virtual instrument panel and driver information center.

Vehicles have additional safety systems such as supplemental restraint systems, wipers, washers, horn, speed control, collision mitigation, telematics, head-up display, park assist, and camera systems.

## ASE TEST TOPICS

**1. Diagnose operation of human machine interface (HMI) systems (such as: instrument cluster, driver information, entertainment/infotainment, and navigation); determine needed repairs.**

The human-machine interface (HMI) was very basic in the past because the vehicles were equipped with most of the following to let the driver know what the vehicle (the machine) was doing:

- Speedometer
- Fuel level gauge
- Outside air temperature
- Instrument panel/dashboard warning icons

Vehicles with advanced technology need to communicate to the driver or occupants using the following:

- Visual displays (eyes).
- Sounds.
- Tactile (called “haptic” feedback). Vibrations of the seat or the steering wheel

The hardware involved includes the following:

- A display
- Speakers
- Input devices, such as a mouse, joystick, or touch screen
- Microphone for voice commands

Behind the scenes, software is used to sort out the vast amount of information and reduce it to the levels where the driver can understand and react to situations as needed.

Diagnosis of these interconnected systems requires a manufacturer specific scan tool and the related service information. Most of the modules involved will set a DTC in case of a fault.

## **2. Inspect, test, repair and/or replace components, connectors, terminals, and wiring of human machine interface (HMI) systems.**

To inspect and test HMI systems, factory service information and a vehicle-specific scan tool is required.

Terminals are retained in connectors by the use of a lock tang. Using a pick in the slot in the plastic connector where the lock tang is located, depress the lock tang, and gently remove the terminal from the connector. Figure 5.

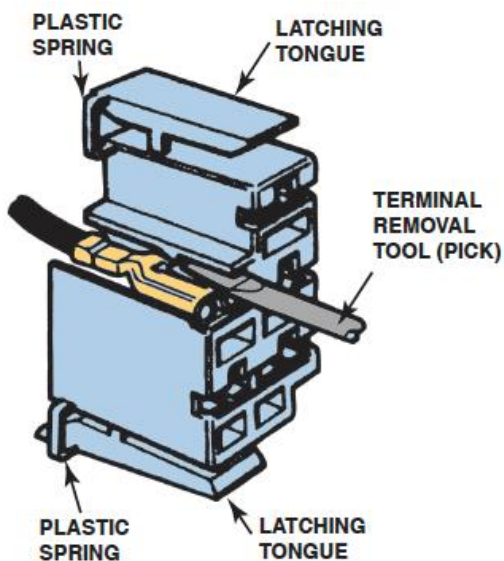


Figure 5. Removing a terminal from the plastic connector.

For splicing wires, some manufacturers recommend the use of crimp-and-seal connectors as the method for wire repair. Crimp-and-seal connectors contain a sealant and shrink tubing in one piece.

This type of connector is first crimped to retain the ends of the wires and then it is heated. The tubing shrinks around the wire splice, and thermoplastic glue melts on the inside to provide an effective weather-resistant seal. Figure 6.



Figure 6. Crimp-and-seal connectors.

**3. Diagnose operation of comfort and convenience accessories and related circuits (such as: power windows, power seats, adjustable pedal height, power locks, trunk locks, remote start, moon roof, sunroof, sunshade, keyless entry, voice activation, phone pairing technology, wireless connectivity, steering wheel controls, camera systems, park assist, cruise control, and automated exterior lighting); determine needed repairs.**

Power windows. Power windows use electric motors to raise and lower door glass. They can be operated by both a master control switch located beside the driver and additional independent switches located at each electric window. Figure 7.

Troubleshooting Power Windows. A scan tool can be used to perform the following:

- Check for B (body) or U (network) diagnostic trouble codes (DTCs)
- Operate the power windows using the bidirectional control feature
- Relearn or program the operation of the power windows after a battery disconnect

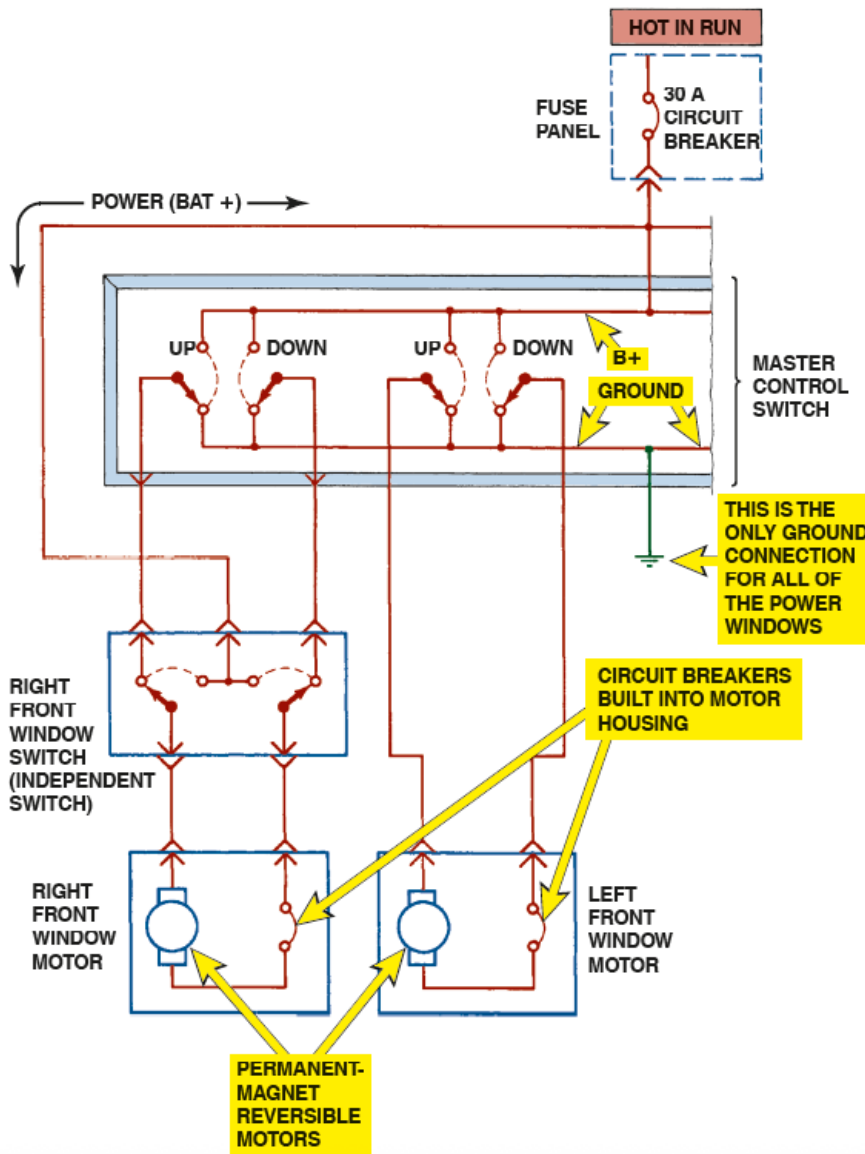


Figure 7. A typical power window circuit.

**Power door locks.** Electric power door locks use a permanent magnet (PM) reversible motor to lock or unlock all vehicle door locks from a control switch or switches. The electric motor uses a built-in circuit breaker and operates the lock-activating rod.

**Troubleshooting Power Locks.** If all power door locks are inoperative, use a factory or factory-level aftermarket scan tool and try operating the locks using the bidirectional control. If the door locks do not operate using a scan tool, refer to service information for the exact procedure to follow.

If only the power door lock is inoperative, check for the power and ground, as well as possible physical binding of the lock mechanism. Repair or replace as needed. Figure 8.

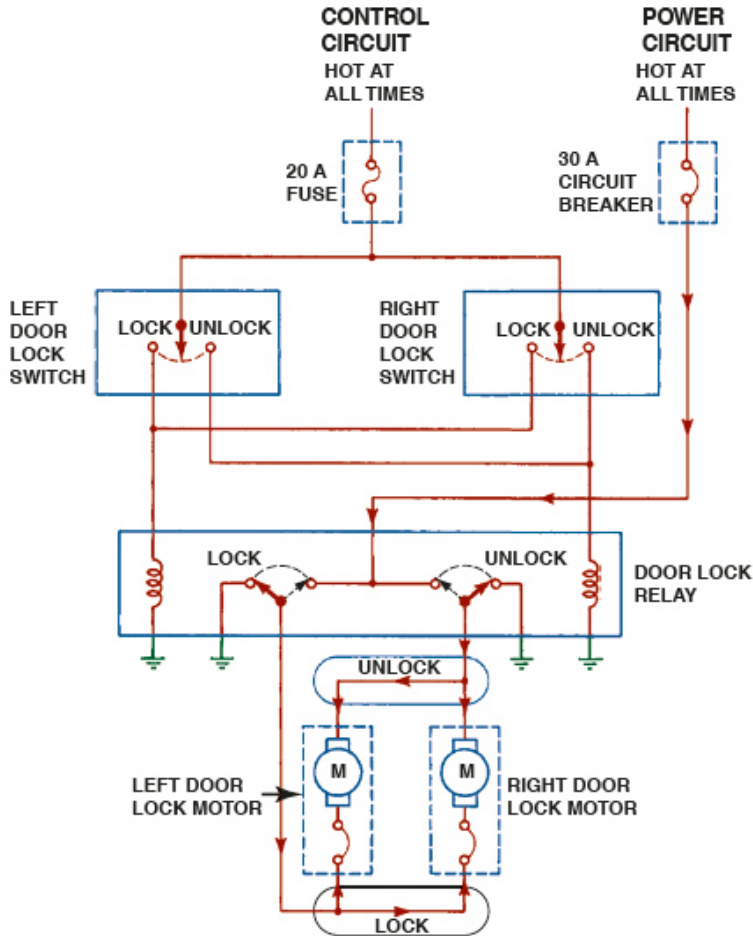


Figure 8. A schematic helps to verify power and ground.

Moon/sunroof. Most moon or sunroof systems use permanent magnet (PM) electric motors to open and close the moveable glass panel. The open and close, or tilt up or down, motion of the moon roof motors is controlled by double-pole, double-throw (DPDT) switches. Figure 9.

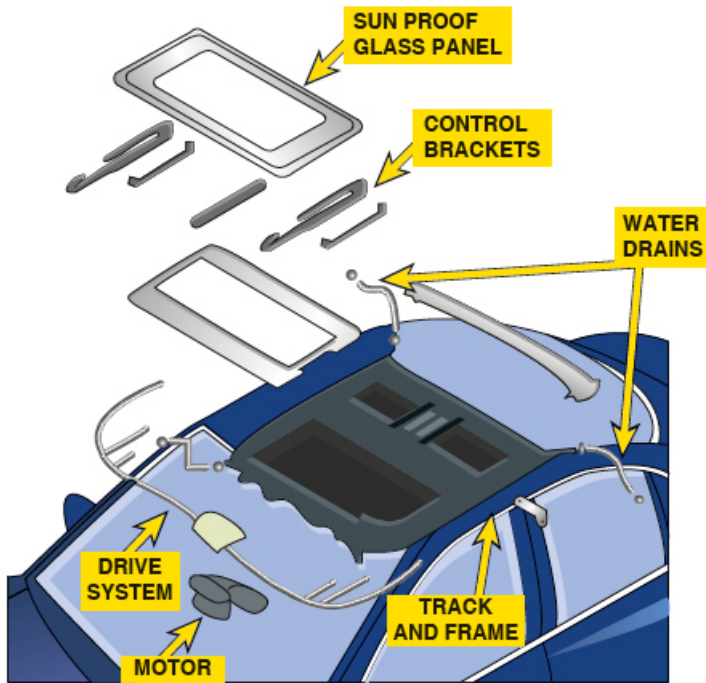


Figure 9. Sunroof motor, drive cables, and water drains.

Power seats. A typical power-operated seat includes a reversible electric motor and a transmission assembly that may have three solenoids or motors, and six drive cables that turn the six seat adjusters. The drive cables rotate inside a cable housing and connect the power output of the seat transmission to a gear or screw jack assembly that moves the seat.

Memory seats use a potentiometer to sense the position of the seat. The seat position can be programmed into the BCM or memory seat module, and stored by position number 1, 2, or 3. On some vehicles, the memory seat position is also programmed into the remote keyless entry (RKE) key fob.

Figure 10.

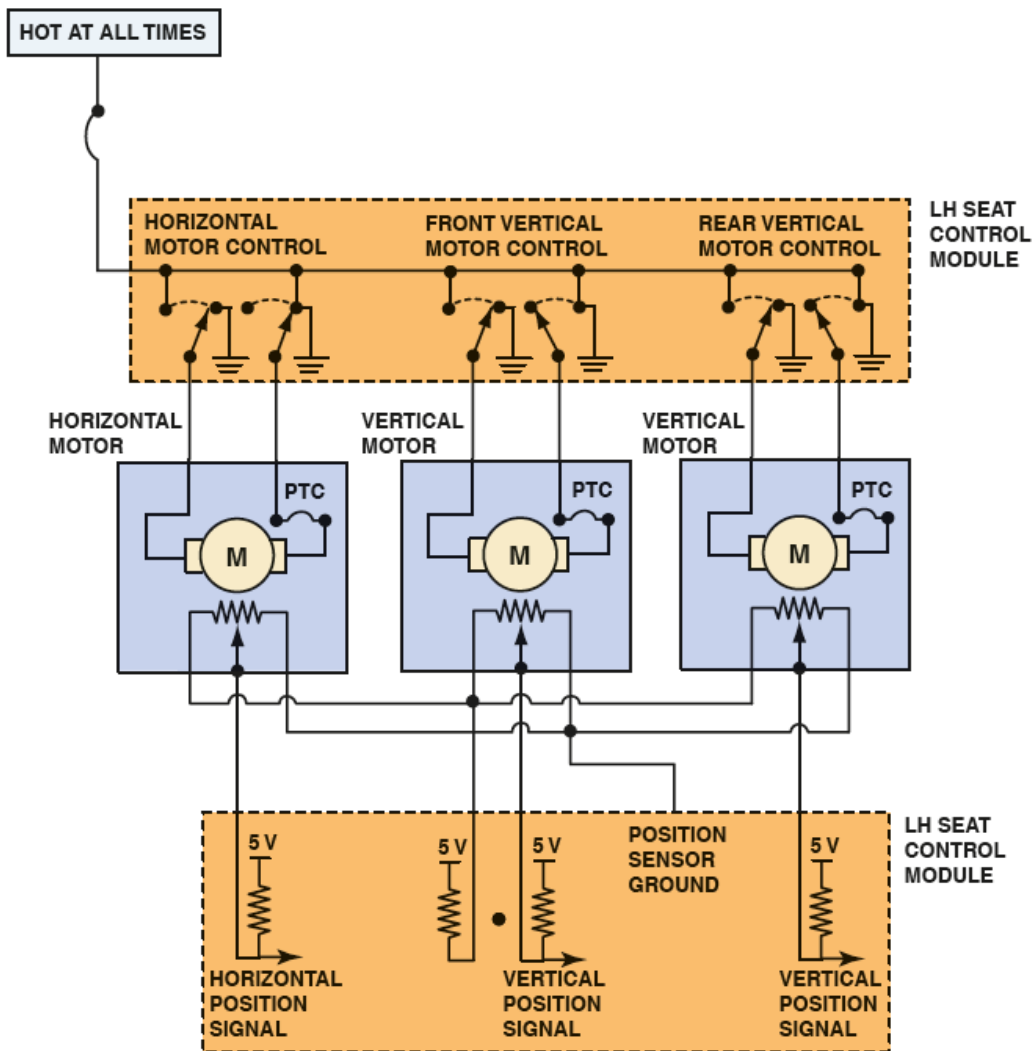


Figure 10. Driver's side memory seat diagram, showing the feedback potentiometers and seat module.

**Cruise control.** Cruise control, also called vehicle speed control, is used to maintain a preset vehicle speed, even up gentle grades. Computer-controlled cruise control systems use the vehicle's speed sensor input to the powertrain control module (PCM) for speed reference.

The cruise control on a vehicle equipped with an electronic throttle control system consists of a switch to set the desired speed. The PCM receives the vehicle speed information from the vehicle speed (VS) sensor. The PCM then commands the ETC throttle to open or close the throttle valve as needed to maintain the desired vehicle speed.

Any fault in the accelerator pedal position (APP) sensor, brake switch, or ETC system disables the cruise control function. Always follow the specified troubleshooting procedures, which usually include the use of a scan tool to properly diagnose the ETC system.

**System Diagnosis.** The body control module (BCM) and other electronic modules are used to operate the various vehicle systems. The number of these modules and the purpose of them varies among the vehicle manufacturers. All these systems use the different controller area networks (CAN) to connect all

these modules together. A bidirectional factory level scan tool is needed to diagnose the diagnostic trouble code(s).

**4. Inspect, test, repair and/or replace components, connectors, terminals, and wiring of comfort and convenience accessories.**

To inspect and test comfort and convenience accessories, factory service information and a vehicle-specific scan tool is required. Service of connectors, terminals, and wiring is covered in ASE Task #2, above.

**5. Diagnose operation of heated and cooled accessories and related circuits (such as: heated/cooled seats, heated steering wheel, heated mirror, heated glass, and heated/cooled cup holders); determine needed repairs.**

Heated seats. Heated seats use electric heating elements in the seat bottom, as well as in the seat back, in many vehicles. A temperature sensor in the seat cushion is used to regulate the temperature. The sensor is a variable resistor, which changes with temperature and is used as an input signal to a heated seat control module.

The heated seat module uses the seat temperature input , as well as the input from the high–low (or variable) temperature control, to turn the current on or off to the heating element in the seat.

When diagnosing a heated seat concern, start by verifying that the switch is in the on position and that the temperature of the seat is below normal body temperature.

Most electrically heated or cooled seats use a thermoelectric device (Peltier elements) located under the seat cushion and seat back. When the heated and cooled seats are turned on, air is forced through a filter and then through the thermoelectric modules. The air is then directed through passages in the foam of the seat cushion and seat back. Figure 11.

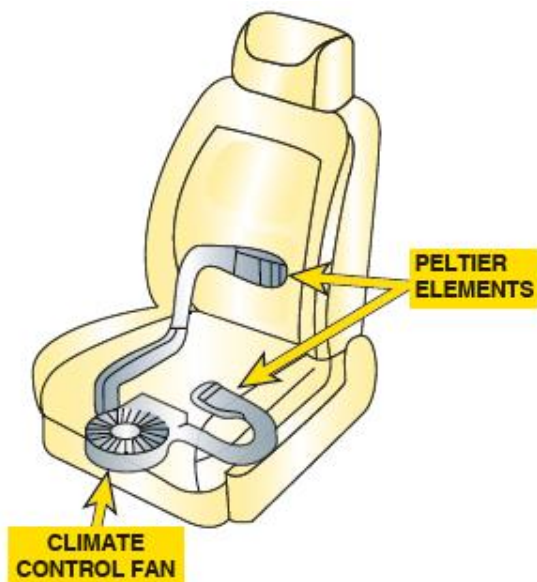


Figure 11. A seat that can be either heated or cooled.

Heated steering wheel. A heated steering wheel usually consists of the following components:

- Steering wheel with a built-in heater in the rim
- Heated steering wheel control switch
- Heated steering wheel control module

When the steering wheel heater control switch is turned on, a signal is sent to the control module and electrical current flows through the heating element in the rim of the steering wheel.

Rear defogger. An electrically heated rear window defogger system uses an electrical grid baked on the glass that warms the glass to about 85°F (29°C) and clears it of fog or frost. The rear window defogger system is controlled by a driver-operated switch and a timer relay.

Heated mirrors. The purpose of heated outside mirrors is to heat the surface of the mirror, which evaporates moisture on the surface. Heated outside mirrors are often tied into the same electrical circuit as the rear window defogger. Therefore, when the rear defogger is turned on, the heating grid on the backside of the mirror is also turned on. Figure 12.

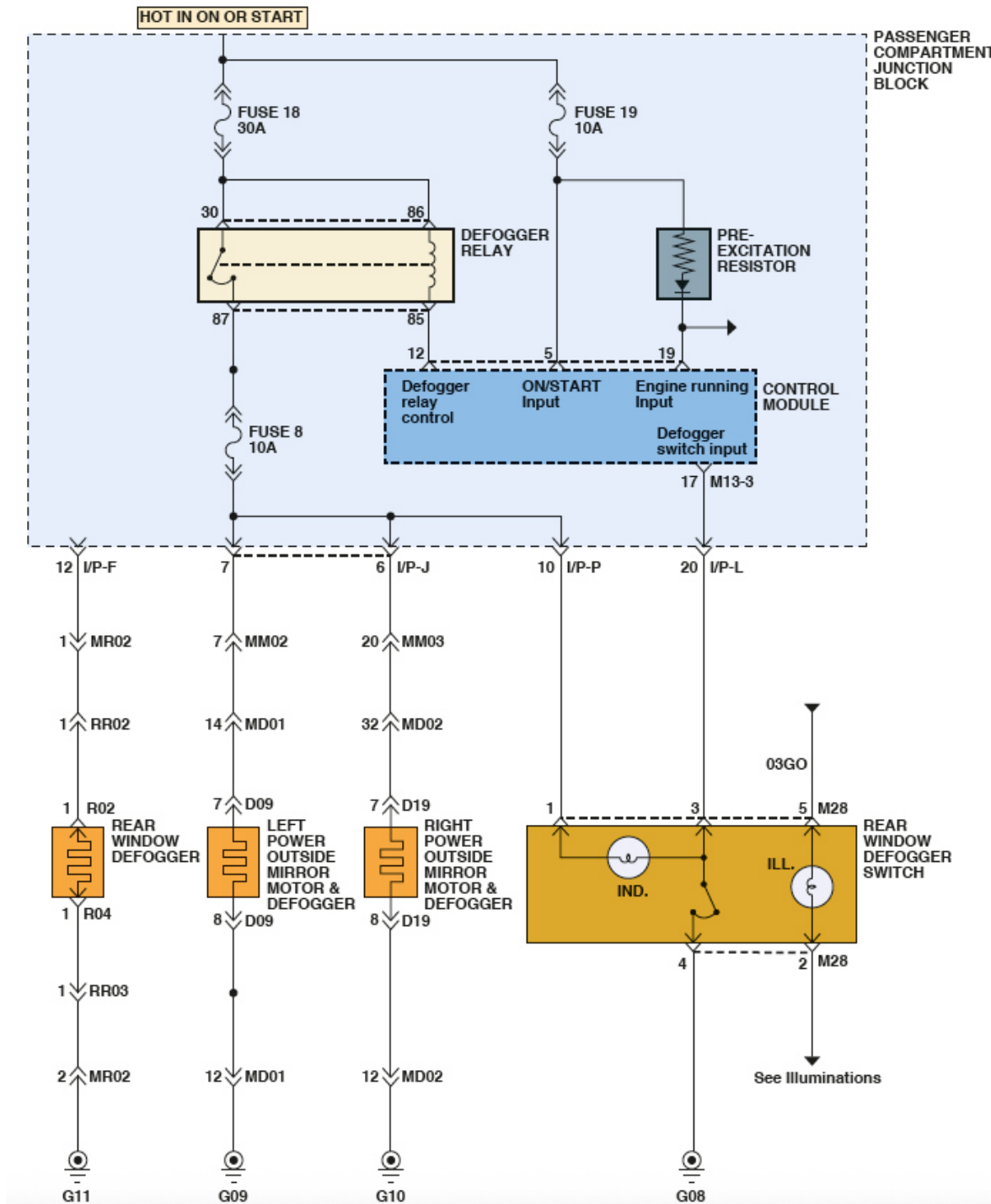


Figure 12. Schematic for rear defogger and heated mirrors.

**6. Inspect, test, repair and/or replace components, connectors, terminals, and wiring of heated and cooled accessories.**

To inspect and test heated and cooled accessories, factory service information and a vehicle-specific scan tool may be required. Service of connectors, terminals, and wiring is covered in ASE Task #2, above.

Heated seat. Most vehicle manufacturers recommend replacing the entire heating element if it is defective. Figure 13.



Figure 13. Heated seat heating pad.

Heated mirrors. Check the owner's manual or service information for the proper method to use to turn on the heated mirrors. If a fault has been detected, check service information instructions for the exact procedure to follow. If the mirror itself is found to be defective, it is usually replaced as an assembly, instead of being repaired.

Rear defogger. Electric grid-type rear window defoggers can be damaged easily by careless cleaning or scraping of the inside of the rear window glass. If damaged, the entire rear window needs to be replaced.

### **7. Diagnose operation of security/anti-theft systems and related circuits (such as: theft deterrent, door locks, keyless entry, remote start, and starter/fuel disable); determine needed repairs.**

The purpose of a security system on a vehicle is to prevent the unauthorized use (theft) of the vehicle. This function is accomplished by installing the following locks:

1. A lock on the doors to help prevent unauthorized entry to the interior of the vehicle.
2. A lock for the ignition so a key is needed to crank and start the engine and unlock the steering wheel, starting in 1970.

Early vehicle theft security systems only monitored the doors for a valid unlock signal. If the vehicle did not receive this signal, an alarm would go off when the door was opened.

An immobilizer system prevents the vehicle from being started or driven if the correct ignition key is not used. If an intruder gets access to the interior of the vehicle and tries to use an invalid key, the dash symbol will flash continuously and the engine will not start or if it does crank and start, the engine will not continue to run.

Most security systems today use a Radio Frequency Identification (RFID) security system. The RFID chip part of the key fob has a transponder mounted in the key or the body of the key fob. A transceiver is inside the vehicle and receives the signal transmitted by the transponder in the key or key fob. The antenna for

the transceiver is a coil of wire mounted within the plastic ring that mounts around the lock cylinder.

Figure 14.

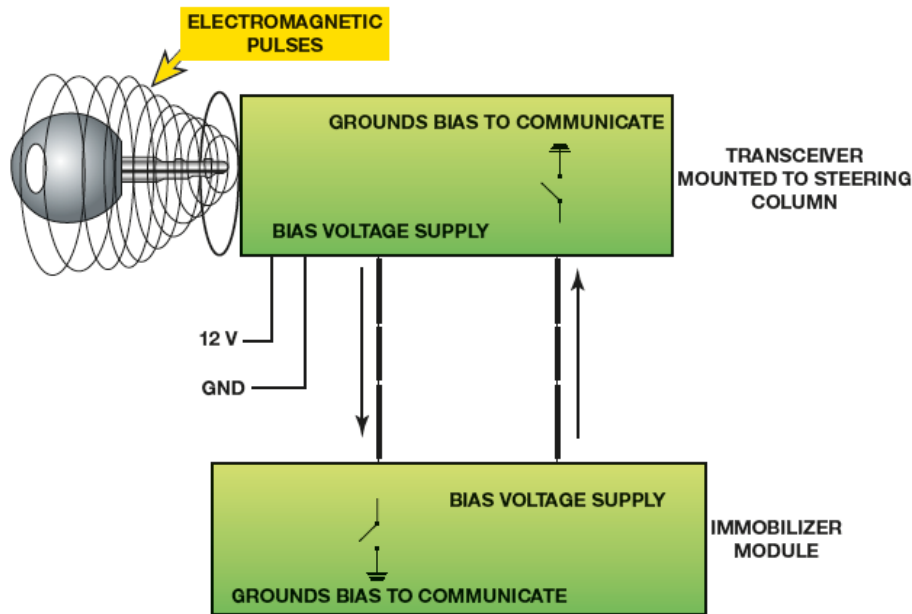


Figure 14. If the key is valid the immobilizer module will send a signal to the PCM, allowing the engine to run.

A factory or enhanced factory level aftermarket scan tool is used to retrieve diagnostic trouble codes.

Figure 15.

DTC	DESCRIPTION OF FAULT
P0513	Incorrect Immobilizer Key
P1570	Fault in antenna detected
P1517	Reference code not compatible with ECM
P1572	Communications failure with ECM
B2957	Security System Data Circuit Low

Figure 15. Sample immobilizer DTCs.

Remote start is the ability to start the engine of the vehicle from a distance by using a remote control. The remote start system uses a signal from the transmitter (usually the key fob on factory systems) to start the engine. The engine runs for about 10 minutes, depending on the system, and then shuts off.

**8. Inspect, test, repair and/or replace components, connectors, terminals, and wiring of security/anti-theft systems.**

To inspect and test security/anti-theft systems, factory service information and a vehicle-specific scan tool is required. Service of connectors, terminals, and wiring is covered in ASE Task #2, above.

**9. Diagnose operation of safety systems and related circuits (such as: supplemental restraint systems, wipers, washers, horn, speed control, collision mitigation, telematics, head-up display, park assist, and camera systems); determine needed repairs.**

Supplemental restraint systems. Airbag passive restraints are designed to cushion the driver (or passenger, if the passenger side is so equipped) during a frontal collision. The system consists of one or more nylon bags folded up in compartments located in the steering wheel, dashboard, interior panels, and/or side pillars of the vehicle.

Most airbags are designed to supplement the safety belts in the event of a collision, and front airbags are meant to be deployed only in the event of a frontal impact within 30 degrees of center.

The parts of a supplemental restraint system (SRS) are:

1. Sensors
2. Airbag (inflator) module
3. Clockspring wire coil in the steering column
4. Control module
5. Wiring and connectors

The sensing and diagnostic module (SDM) includes the arming sensor, as well as the electronics that continuously check the circuits for continuity, and the capacitors that are discharged to deploy the airbags. Figure 16.

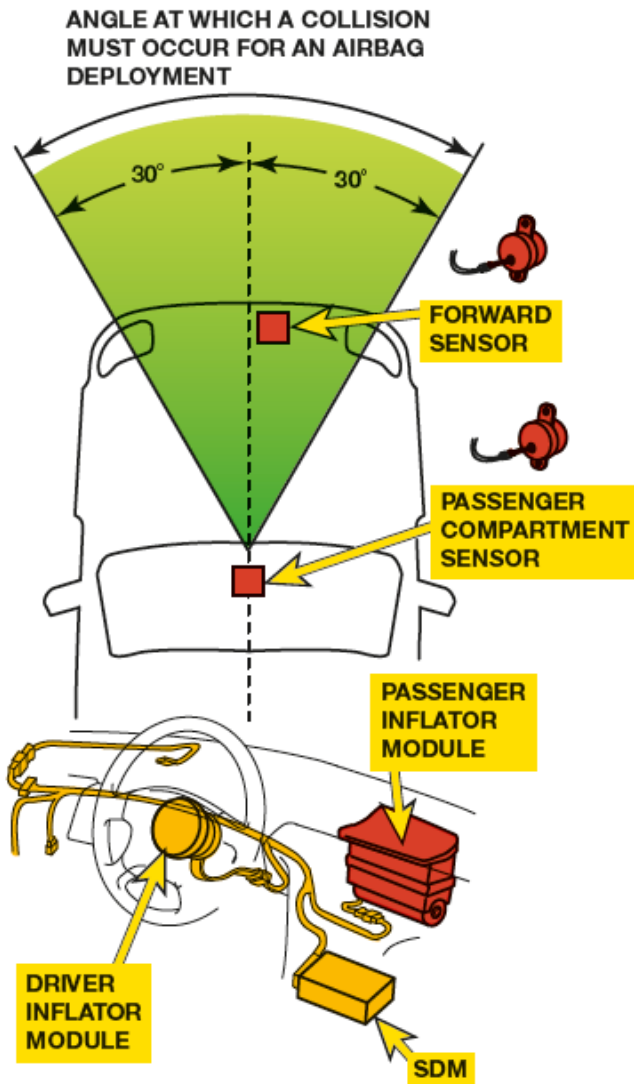


Figure 16. A typical airbag system.

Both the arming sensor and at least one of the discriminating sensors must be activated at the same time. The arming sensor provides the power, and either one of the discriminating sensors can provide the ground for the circuit. Figure 17.

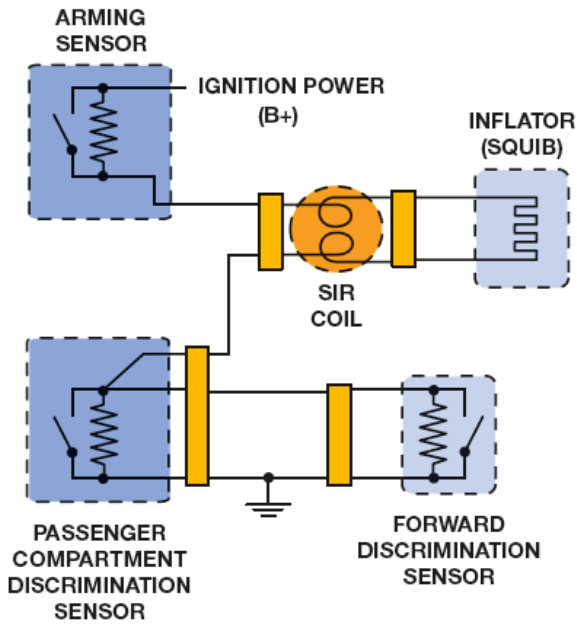


Figure 17. Simplified SRS schematic.

The electrical portion of airbag systems is constantly checked by the circuits within the airbag-energizing power unit or through the airbag controller (SDM). If an open or short circuit occurs, a dash warning light is lighted, and a possible diagnostic trouble code (DTC) is stored. Follow manufacturer's recommended procedures for accessing and erasing airbag DTCs. Figure 18.

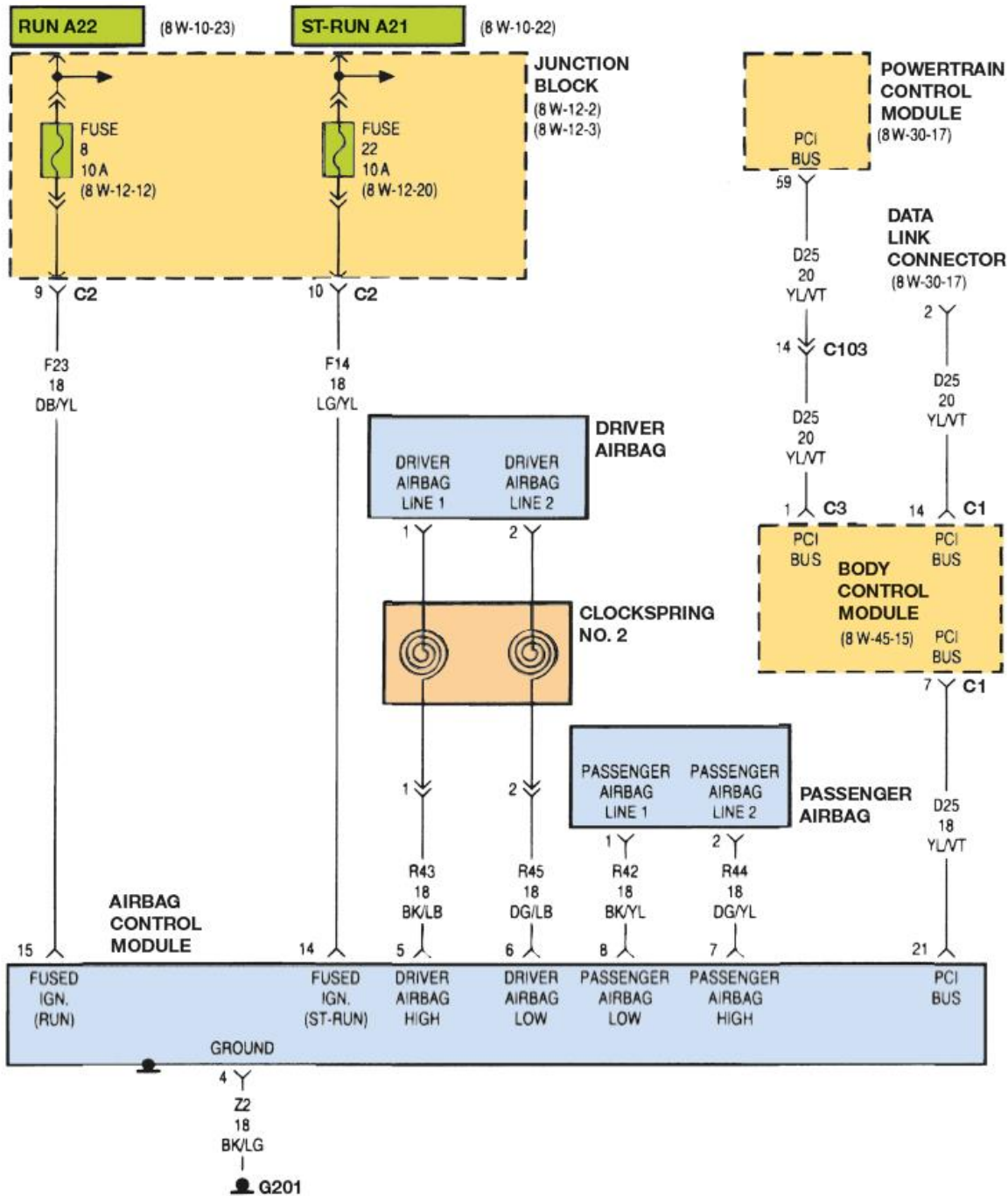


Figure 18. The airbag control module is linked to the powertrain control module (PCM) and the body control module (BCM) on this system.

**Horn Circuits.** On most recent model vehicles, the horn button is an input to the body control module (BCM) or electronic control unit (ECU). The BCM controls the operation of the horn relay. The horn relay may also be controlled by the BCM, which “beeps” the horn when the vehicle is locked or unlocked, using the key fob remote. Figure 19.

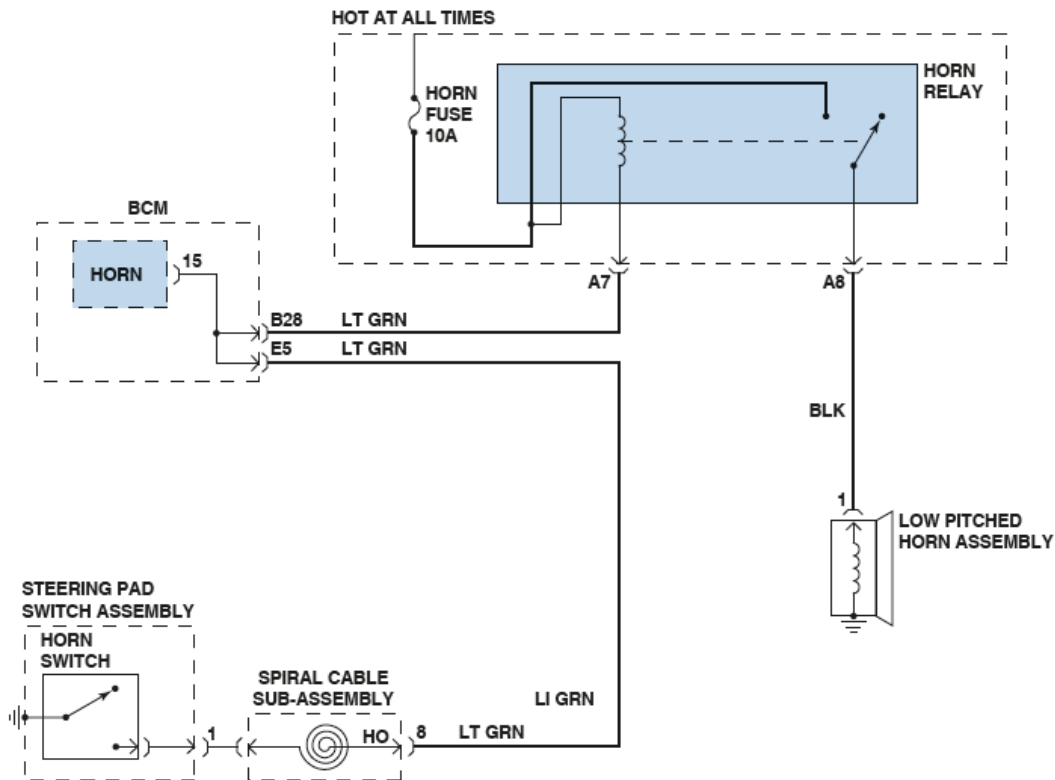


Figure 19. Typical horn circuit.

A scan tool can be used to test a horn that is computer controlled by using the bidirectional feature of a factory or factory-level aftermarket scan tool. The horn relay is in a centralized power distribution center along with other relays, circuit breakers, and fuses. Check the relay to determine if the coil is being energized when commanded by the scan tool.

Windshield wipers/washers. Windshield wipers are used to keep the viewing area of the windshield clear of rain. Windshield wiper systems and circuits vary greatly between manufacturers as well as between models. Some vehicles combine the windshield wiper and windshield washer functions into a single system.

Most wipers, since the 1990s, have used the BCM to control the actual operation of the wiper. The wiper controls are an input to the control module and may also turn on the headlights whenever the wipers are on, which is the law in some states. Figure 20.

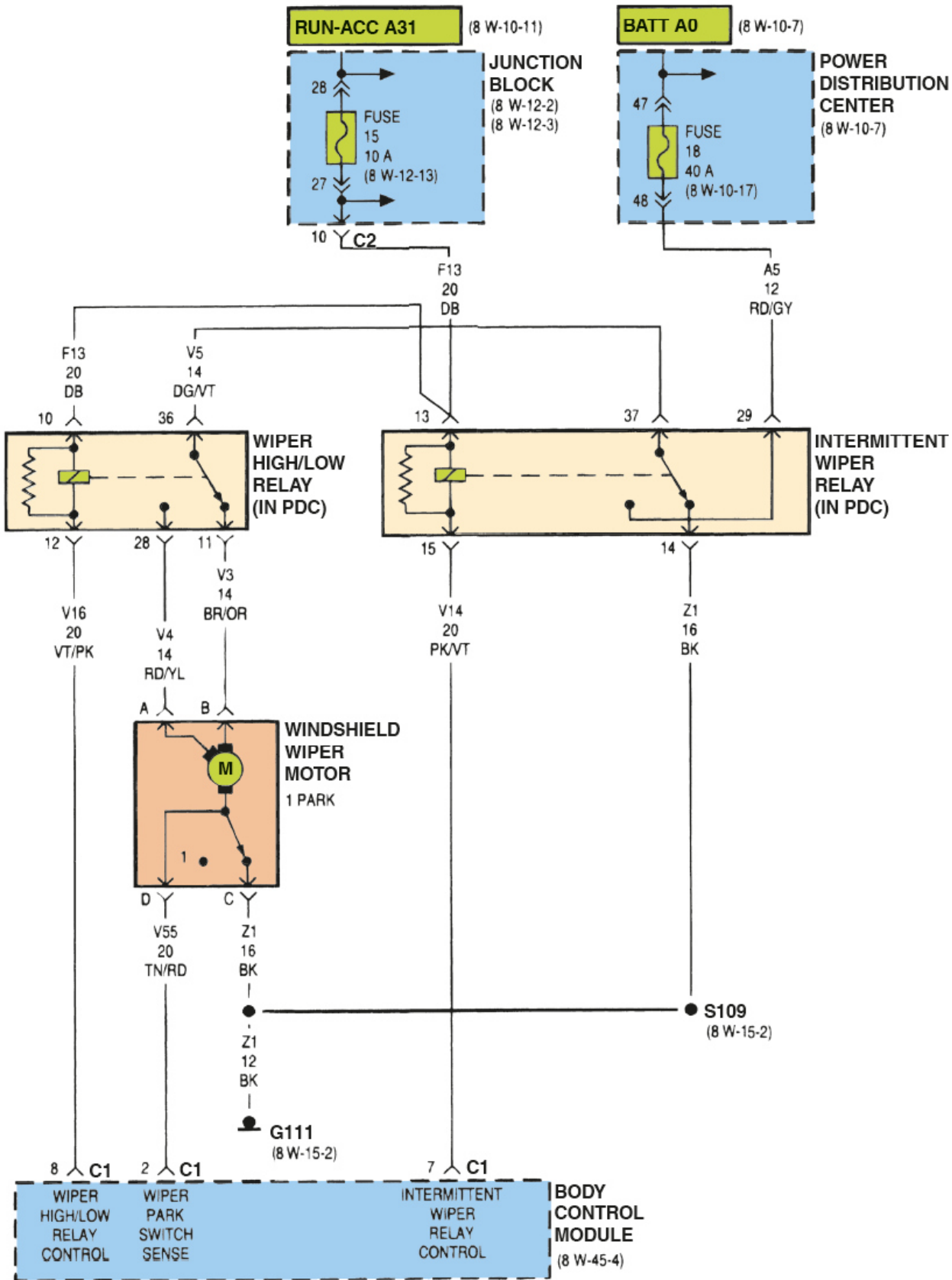


Figure 20. Wiper/washer circuit.

If the windshield wipers are not working, use a factory or factory-level scan tool and check for operation using the bidirectional controls.

- If the wipers function when commanded by the scan tool, check service information for the exact procedures to follow when checking the switch input and BCM connections.
- If the wipers do not function when being commanded by the scan tool, perform circuit testing, which usually includes determining if the fault is electrical or mechanical.

**Park assist.** The parking-assist system is used to help drivers avoid contact with another object while moving slowly. When backing up at speed of less than 5 MPH (8 km/h), the system constantly monitors for objects located around the vehicle. The system alerts the driver with warning tones with the frequency indicating object distance. The faster the tone sounds, the closer is the vehicle to the object. Figure 21.

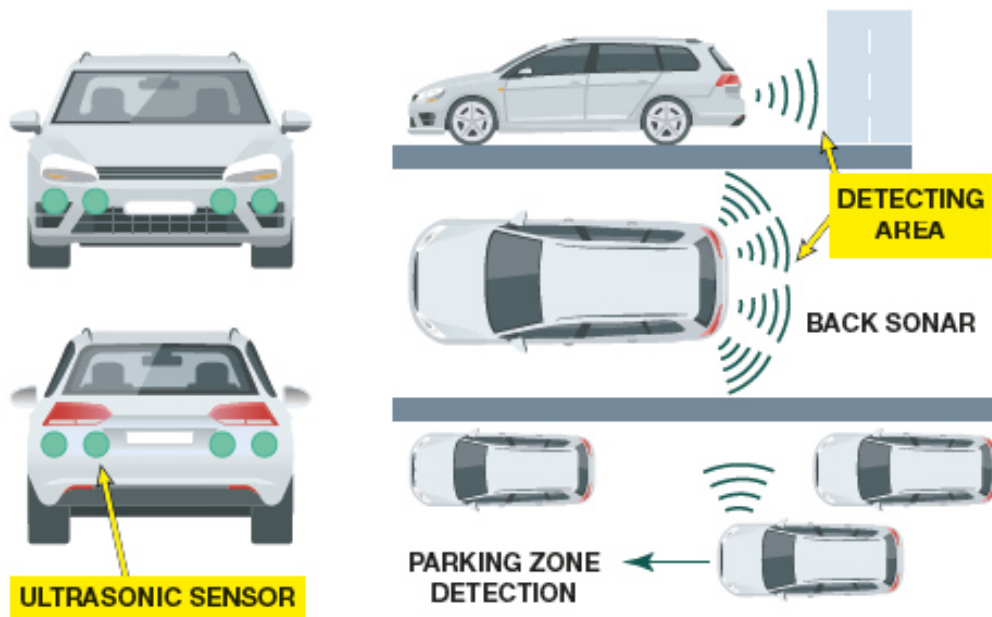


Figure 21. Parking-assist detection zones.

Self-parking vehicles, use camera(s) and control the electric power steering to guide the vehicle into a parking space. The driver must control the throttle and brakes in early systems. The driver may or may not have to control anything in many advanced systems.

The parking-assist control module can detect faults and store diagnostic trouble codes. If a fault has been detected by the control module, the red lamp flashes and the system is disabled. Follow service information diagnostic procedures because the parking-assist module cannot usually be accessed using a scan tool.

**Emergency braking.** An automatic emergency braking (AEB) system intervenes and automatically applies the brakes if needed. Automatic braking is often part of a safety package that includes radar cruise control and will apply the brakes in the event of a possible collision. Sensors such as radar, sonar, and/or cameras are used, depending on the system to detect the distance to another object. Figure 22.

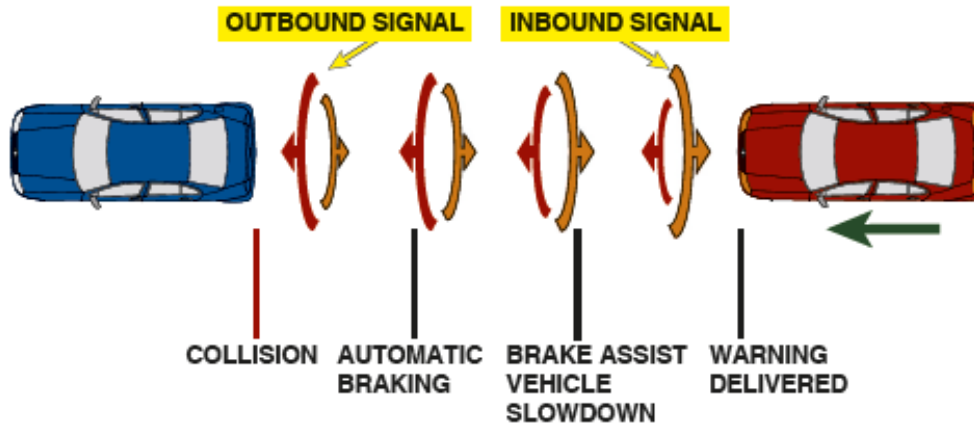


Figure 22. Sensors are used to detect when the distance is closing fast enough that a collision may be possible, and the system intervenes to automatically apply the brakes if needed.

Diagnosis of a camera-based system begins by reading the DTCs. The operation of the camera can be affected by heavy rain, snow, or an accumulation of ice or mud. Before making any repairs, it is important to verify the lens of the camera is free of anything that obstructs its view. Calibration is required when one or more cameras are replaced or a mounting component, such as a windshield, bumper cover, mirror, or door, is replaced.

### **10. Inspect, test, repair and/or replace components, connectors, terminals, and wiring of safety systems.**

To inspect and test safety systems, factory service information and a vehicle-specific scan tool is required. Service of connectors, terminals, and wiring is covered in ASE Task #2, above.

**Airbags.** The airbags should be disarmed (temporarily disconnected) whenever performing service work on the steering wheel, steering column, or instrument panel.

Check service information for the exact procedure, which usually includes the following steps:

STEP 1 Disconnect the negative battery cable.

STEP 2 Remove the airbag fuse (has a yellow cover).

STEP 3 Disconnect the yellow electrical connector located at the base of the steering column to disable the driver's-side airbag.

STEP 4 Disconnect the yellow electrical connector for the passenger side airbag.

**Horns.** Once the cause of an inoperative horn has been reduced to the horn wiring circuit, the wiring needs to be checked. Typically, a digital multimeter (DMM) is used to perform voltage drop and continuity checks to isolate the failure.

To replace the horn, remove the fasteners and lift the old horn from its mounting bracket. Clean the attachment area on the mounting bracket and chassis before installing the new horn.

Wipers. Wiper motors are replaced if defective. The motor usually mounts on the bulkhead (firewall). Bulkhead-mounted units are accessible from under the hood. The cowl panel needs to be removed to service a motor mounted in the cowl. Figure 23.

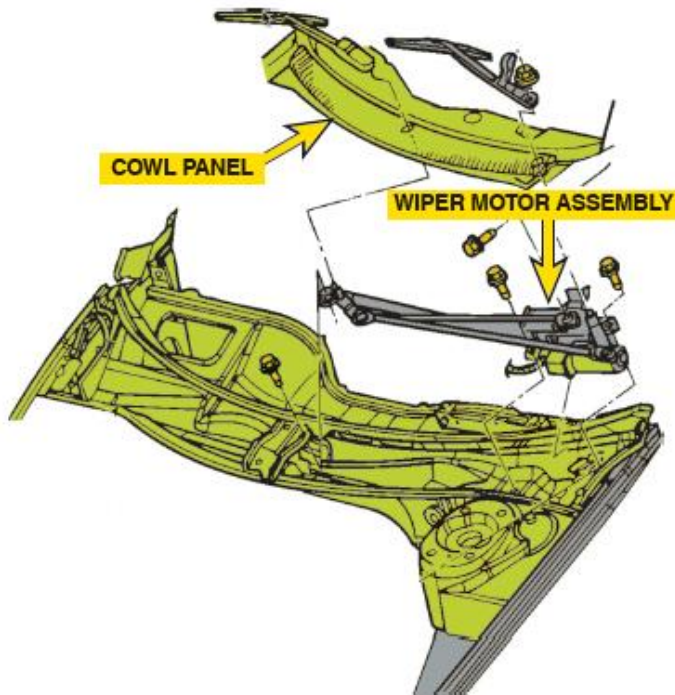


Figure 23. The wiper motor and linkage mount under the cowl panel on many vehicles.

Replacing cameras. Calibration of the camera is required when one or more cameras are replaced on a mounting component, such as a windshield, bumper cover, mirror, or door. The calibration is an in-shop, static process. Large, patterned mats are placed around the vehicle at specific locations, and the scan tool is used to initiate the process.

Some vehicles do not require a special target. These will often use lines that are taped to the floor around the vehicle to use as a target. A factory or factory-level scan tool imitates the learning process. Figure 24.

A6-E. Body Electrical Systems Diagnosis and Repair

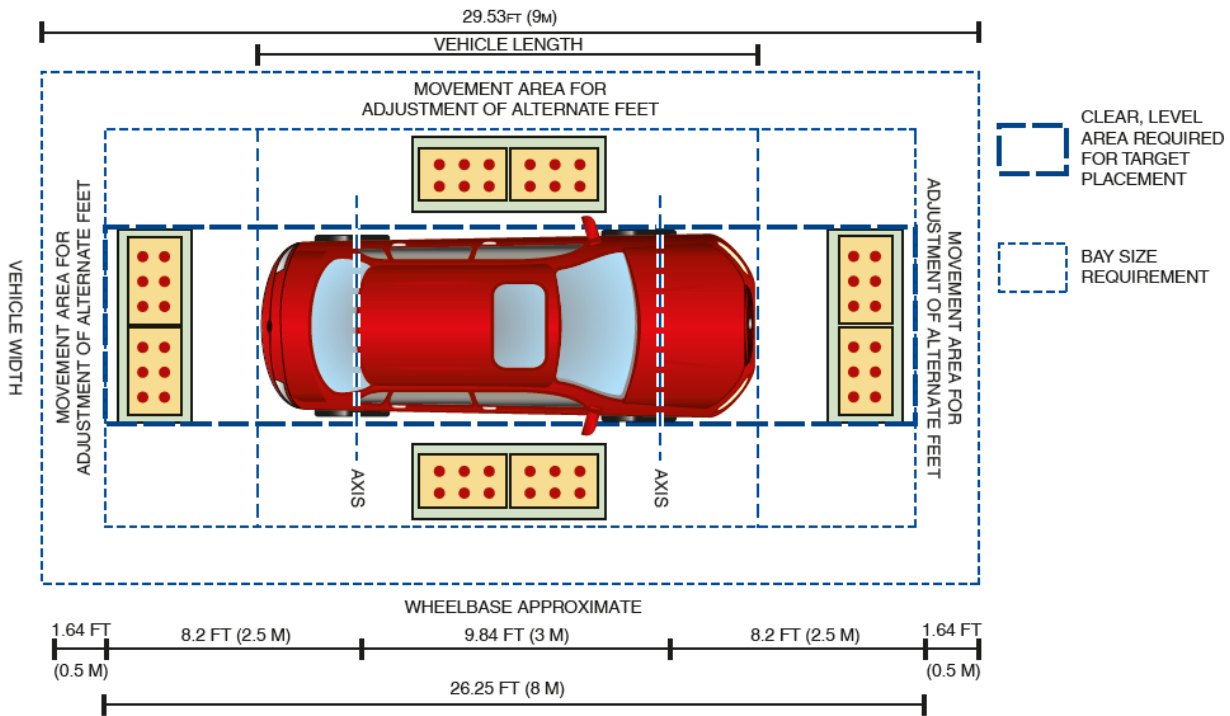


Figure 24. Camera calibration setup.