INTRODUCTION

A system that contains the HVAC plenum, ducts, and air doors is called the air management system, or air distribution system, and controls the airflow to the passenger compartment. Airflow is usually controlled by three or more doors, which are called flap doors or valves by some manufacturers. Figure 1.

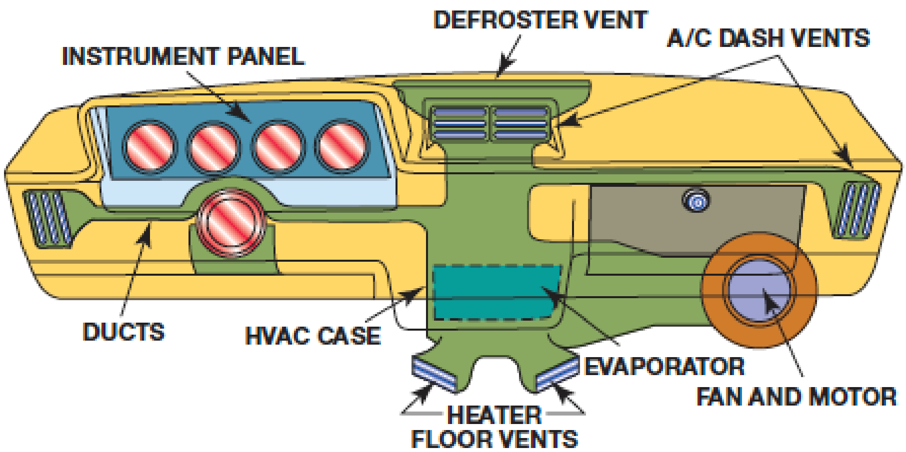

Figure 1. The HVAC airflow is directed toward the windshield, dash or floor vents, or combinations depending on the system settings.

The HVAC control head or panel is mounted in the instrument panel cluster or console. The control head is connected to various components through electrical connections, vacuum connections, mechanical cables, or a combination of these. Figure 2.

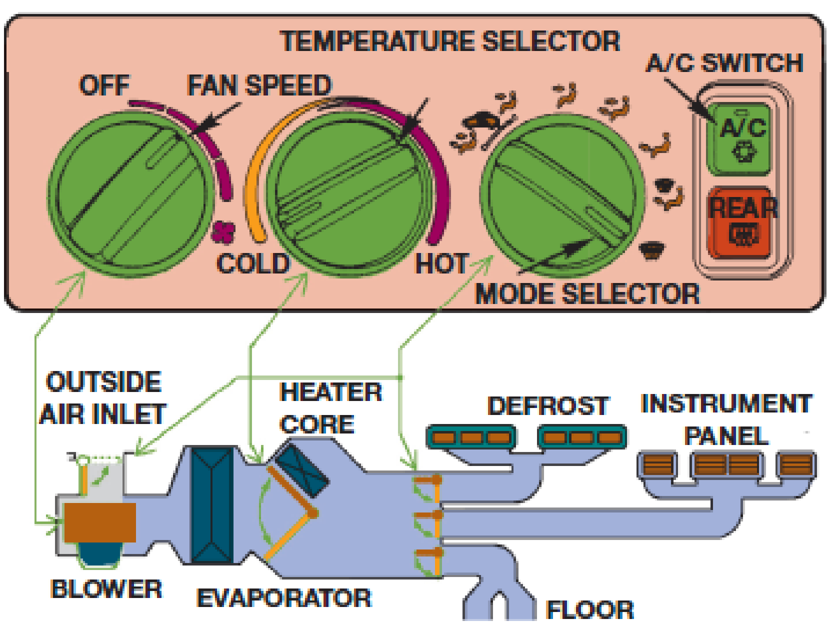

Figure 2. Most HVAC control heads include a control for turning units on and setting the mode of operation, a control for adjusting the temperature, and a control for the fan speed.

Most early control heads used purely mechanical operation for the doors, and one or more cables connected the function lever to the air inlet and mode doors. The temperature lever was also connected to the temperature blend door by another cable. Figure 3.

Figure 3. A cable operated A/C system. The temperature blend door and the mode door are cable operated.

Many vehicles use vacuum actuators, sometimes called vacuum motors, to operate the air inlet and mode doors. The doors are controlled by vacuum valves that are operated by the control head. Figure 4.

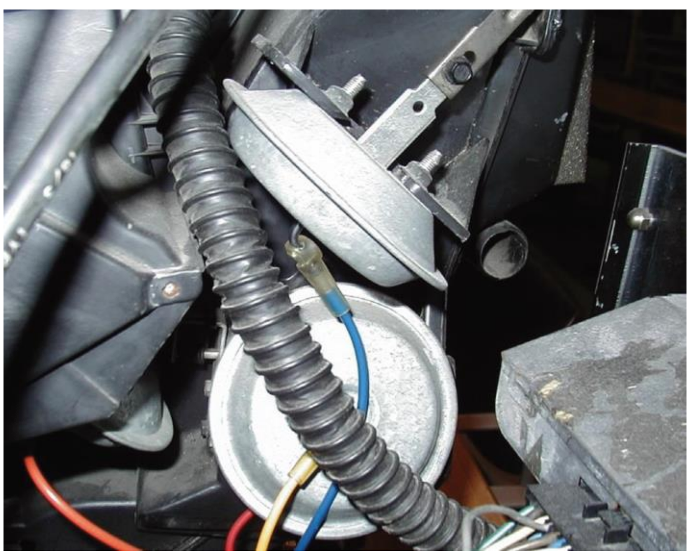

Figure 4. Many older vehicles used vacuum actuators to move the HVAC doors.

Most recent vehicles use electrical function switches at the HVAC control head. These are often called electromechanical controls. These switches Are usually inputs to the BCM or an HVAC controller. The HVAC controller uses electric actuators (motors) to operate the air distribution and temperature-blend doors. Figure 5.

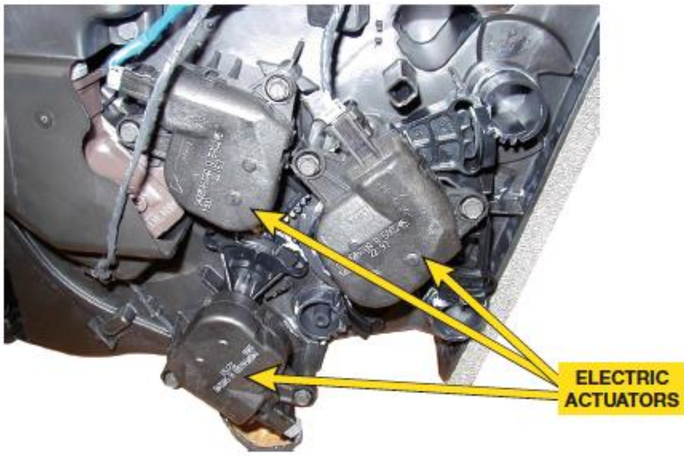

Figure 5. Electric HVAC door actuators.

ASE TEST TOPICS

► **Electrical**

1. Diagnose the cause of failures in the electrical control system of heating, ventilating, and A/C (HVAC) systems; determine needed repairs.

All electrical circuits require the following to operate:

1. A voltage source
2. Protection (fuse)
3. Control (switch)
4. An electrical load (compressor clutch, blower relay, etc.)
5. A ground connection

Fuses are used in HVAC circuits to protect the wiring from overheating and damage caused by excessive current flow as a result of a short circuit or other malfunction. To save space, many vehicles use mini (small) blade fuses. Figure 6.

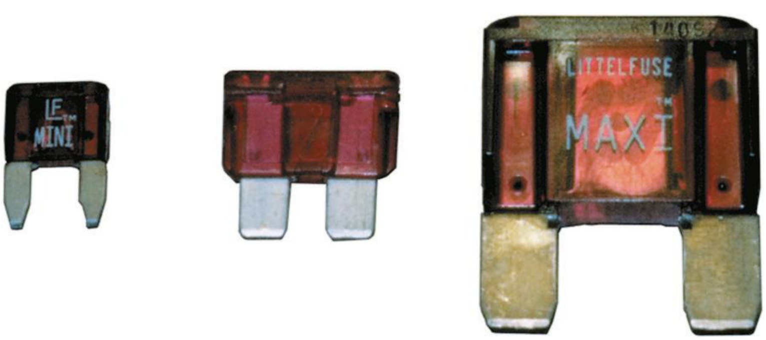

Figure 6. Typical fuses that may be used in HVAC systems.

2. Inspect, test, repair, and replace HVAC heater blower motors, blower motor speed controls, resistors, switches, relays/modules, wiring, and protection devices.

The blower motor turns a squirrel cage-type fan. A squirrel cage-type fan is able to move air without creating a lot of noise. Figure 7.

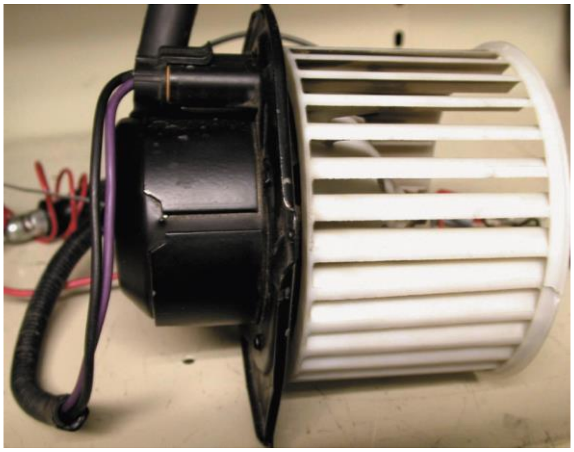

Figure 7. Blower motor and fan.

The fan switch controls the path of current through a resistor pack to obtain different fan speeds of the blower motor. The electrical path can be:

- Full battery voltage for high-speed operation
- Through one or more resistors to reduce the voltage and the current to the blower motor which then rotates at a slower speed Figure 8.

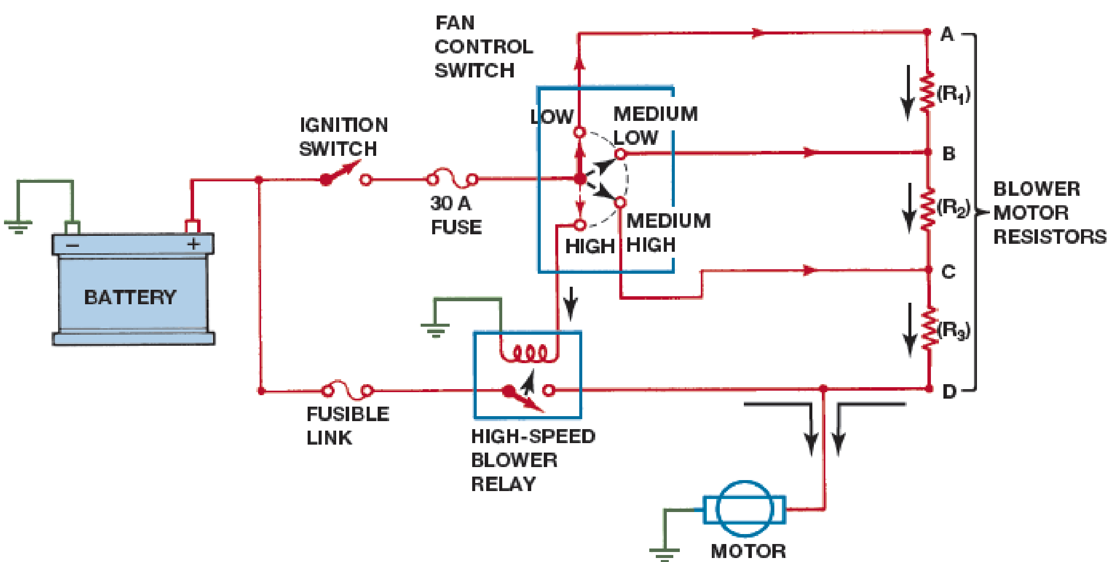

Figure 8. Blower motor circuit for a four speed fan control.

The resistors are located near the blower motor and mounted in the duct where the airflow from the blower can cool the resistors. The current flow through the resistor is controlled by the switch and often uses a relay to carry the heavy current (10 to 12 amperes) needed to power the fan on high speed. Figure 9.

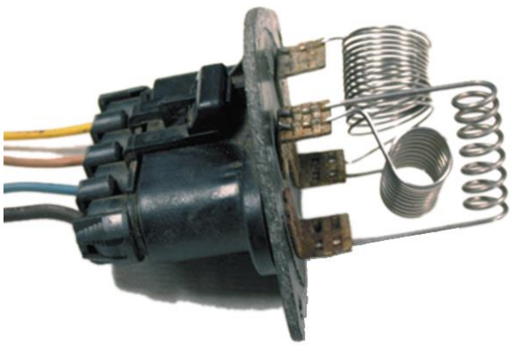

Figure 9. Blower motor resistor pack.

Some blower motors are electronically controlled by the body control module and include electronic circuits to achieve a variable speed.

3. Inspect, test, repair, and replace A/C compressor clutch coil, relay/ modules, wiring, sensors, switches, diodes, and protection devices.

Most air-conditioning compressors use an electromagnetic clutch. A coil of wire inside the clutch creates a strong magnetic field that when activated connects the input shaft of the compressor to the drive pulley. The coil assembly has between 3 ohms and 4 ohms of resistance. According to Ohm's law, about 3 amperes to 4 amperes of current are required to energize the air-conditioning compressor clutch. Figure 10.

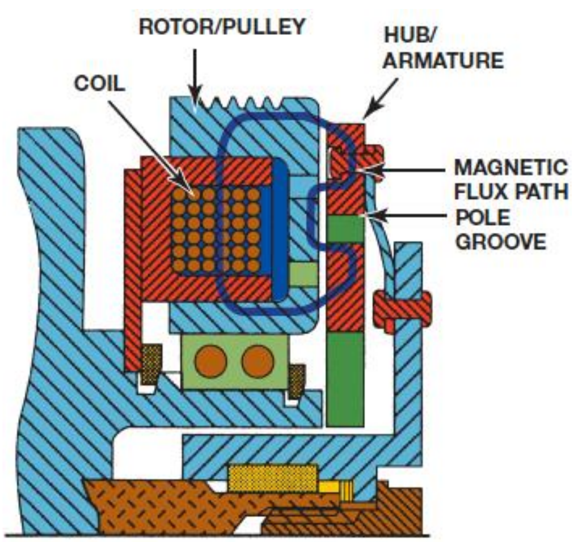

Figure 10. A/C compressor clutch cross section.

Some systems may connect one or more switches in series with the compressor clutch so that all have to be functioning before the compressor clutch can be engaged. A low- and high-pressure switch or sensor may also be an input to the PCM or HVAC controller for use in controlling the compressor. Figure 11.

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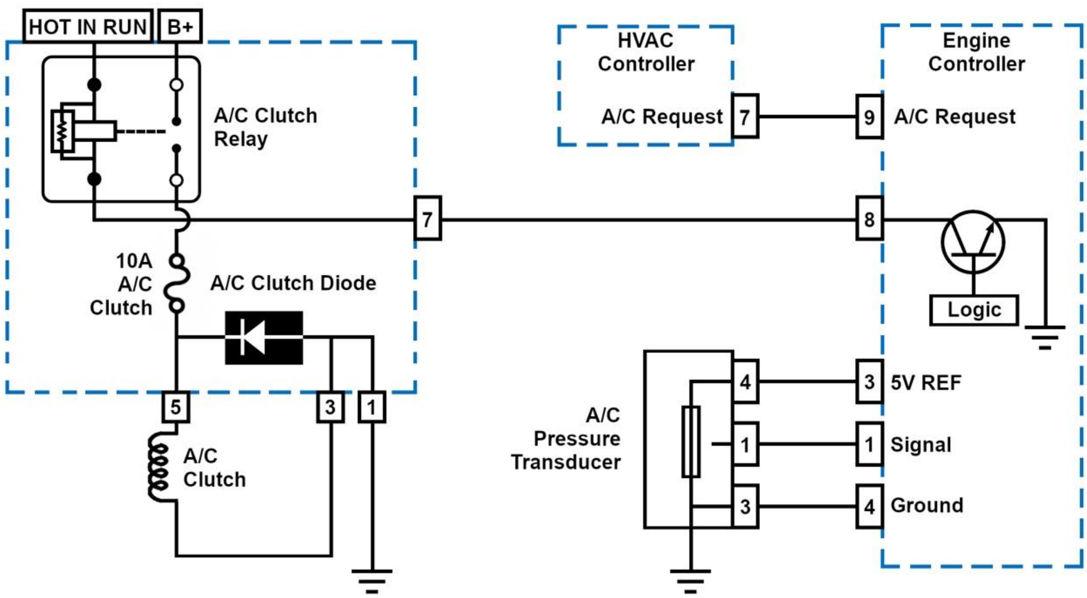

Figure 11. Example A/C compressor clutch control circuit.

Most air-conditioning compressor clutch circuits contain a diode that is used to suppress the high-voltage spike that is generated whenever the compressor clutch coil is disengaged (turned off). Figure 12.

Figure 12. A/C compressor clutch spike suppression diode.

4. Inspect, test, repair, and replace A/C-related vehicle control systems and components.

Most vehicles have control systems that compensate for the added load from the A/C compressor. Some systems use an idle air control (IAC) motor to regulate idle bypass air. The IAC is computer-controlled and is either a solenoid operated valve or a stepper motor that regulates the airflow around the throttle plate. The idle speed on newer vehicles is controlled by the electric throttle control (ETC) system.

The electronic throttle control (ETC) system is tested using a scan tool. Use a factory scan tool or an aftermarket scan tool with original equipment capability and check for DTCs.

- If there are stored ETCs, follow service information instructions for diagnosing the system.

- If there are no stored ETCs, check scan tool data for possible fault areas in the system. For example:
    - Accelerator pedal position (APP) indicated angle. The scan tool will display a percentage ranging from 0% to 100%.
    - Throttle position (TP) desired angle. The scan tool will display a percentage ranging from 0% to 100%.
    - Throttle position (TP) indicated angle. The TP indicated angle is the angle of the measured throttle opening and it should agree with the TP desired angle.

5. Inspect, test, repair, and replace load sensitive A/C compressor control systems.

Engines use a throttle position (TP) sensor to signal to the powertrain control module (PCM) the position of the throttle. The TP sensor is used as an input sensor for air-conditioning compressor operation. If the PCM detects that the throttle is at or close to wide open, the air-conditioning compressor is disengaged. A scan tool is used for diagnosis.

6. Inspect, test, repair, and replace engine cooling/condenser fan motors, relays/modules, switches, sensors, wiring, and protection devices.

Two types of electric cooling fans used on many engines, including the following:

- One two-speed cooling fan, Figure 13.
- Two cooling fans (one for normal cooling and one for high heat conditions).

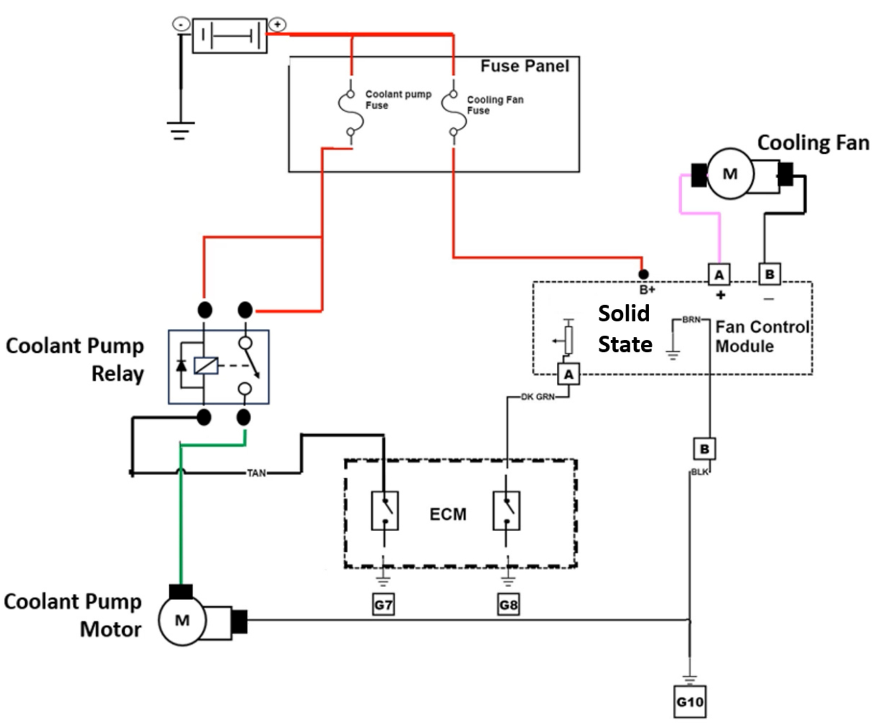

Figure 13. Schematic showing the two-speed fan motor and the coolant pump.

The PCM commands low-speed fans on under the following conditions:

- Engine coolant temperature (ECT) exceeds approximately 223°F (106°C).
- A/C refrigerant pressure exceeds 190 PSI (1,310 kPa).

The PCM commands the high-speed fan on under the following conditions:

- Engine coolant temperature (ECT) reaches 230°F (110°C).
- A/C refrigerant pressure exceeds 240 PSI (1,655 kPa).
- When certain diagnostic trouble codes (DTCs) are set.

7. Inspect, test, adjust, repair, and replace climate control system electric actuator motors, relays/ modules, switches, sensors, wiring, and protection devices (including dual/multi-zone systems); calibrate, program, code, or initialize as required.

HVAC actuators (motors) can be two, three, or five wire actuators.

- A typical two-wire actuator rotates when electric pulses are sent to the brushes by the HVAC control head. It reverses by changing the polarity of the electric pulses.
- A typical three-wire actuator uses a power, ground, and an input signal wire from the HVAC control module. There is a module (logic chip) inside the motor assembly that receives a 0–5 volt signal from the HVAC control module.
- A five-wire actuator uses two wires to power the motor (power and ground) and three wires for a potentiometer that is used to signal the HVAC control module of the position of the motor. Figure 14.

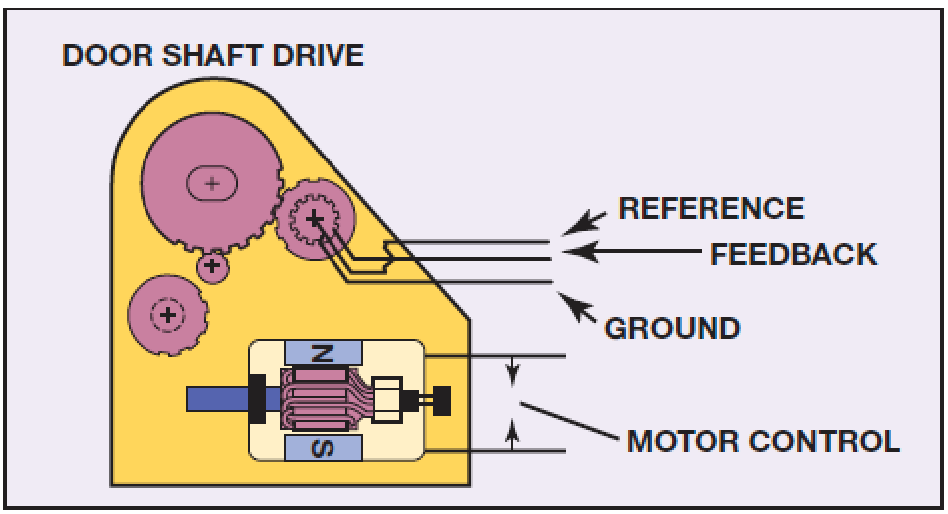

Figure 14. A five wire actuator with feedback potentiometer.

An HVAC actuator may need to be calibrated after the actuator has been replaced. A typical calibration procedure uses a scan tool. Install the replacement actuator and reconnect all mechanical and electrical connections then start the engine and select motor recalibration program on the scan tool under the functions menu.

Dual-zone systems allow the driver and front seat passenger to set their own desired temperature. Dual-zone systems contain two separately commanded temperature-blend doors and related actuators.

8. Inspect, test, service, or replace HVAC user controls/interfaces.

The HVAC control head or panel on older systems is mounted in the instrument panel cluster or console. If faulty it is normally replaced as a unit. Figure 15.

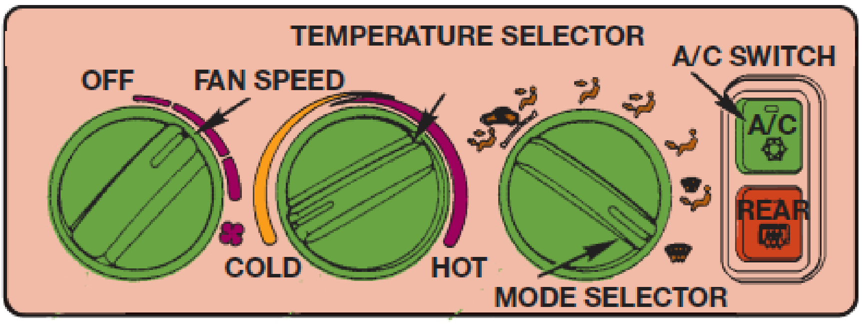

Figure 15. HVAC control panel.

In late model vehicles, HVAC controls and settings are usually integrated into the center control panel, often with the navigation and audio systems. Repair or replacement requires the use of factory service information and programming software. Figure 16.

Figure 16. A navigation system with the HVAC controls below.

► **Vacuum/Mechanical**

9. Diagnose the cause of failures of the heating, ventilating, and A/C (HVAC) vacuum and mechanical control systems; determine needed repairs.

Most early control heads used purely mechanical operation for the doors, and one or more cables connected the function lever to the air inlet and mode doors. The temperature lever was also connected to the temperature blend door by another cable. These mechanical levers were rather simple and usually trouble free, but they had some disadvantages. They tended to bind and could require a good deal of effort to operate.

The stiff wire cable may be called a Bowden cable in service information. Common faults are broken cable ends, loose housing clamps, and stiff or binding cables.

Many vehicles use vacuum actuators, sometimes called vacuum motors, to operate the air inlet and mode doors. The doors are controlled by a vacuum valve that is operated by the control head. Vacuum controls operate more easily than cables. Figure 17.

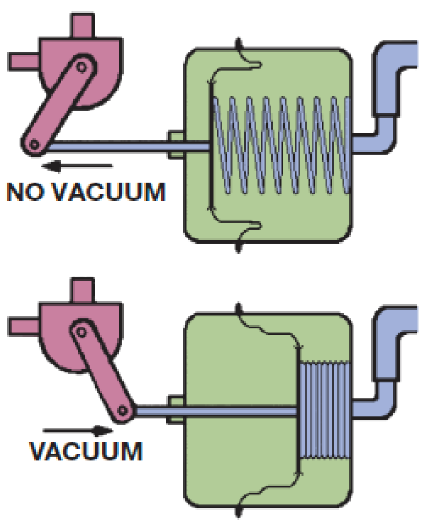

Figure 17. A two-position vacuum motor.

Vacuum system diagnosis

- If the airflow is mostly directed to the windshield, check under the hood for a broken, disconnected, or missing vacuum hose.
- Check the vacuum reserve container for cracks or rust (if metal) that could prevent the container from holding vacuum.
- Check all vacuum hose connections at the intake manifold and trace each carefully, inspecting for cracks, splits, or softened areas that may indicate a problem.

10. Inspect, test, service, or replace HVAC user controls/interfaces.

The control panel for mechanical systems require removal of the dashboard trim in order to service or replace the assembly. Once the trim is removed the panel is held onto the dash with screws. Figure 18.

Figure 18. Cable-operated temperature and mode controls.

11. Inspect, test, adjust, and replace HVAC control cables and linkages.

HVAC control cables use clamps and brackets to hold the cable housings in place. The inner cable usually has a loop on the end that fits over the vent door pin or arm. Figure 19.

Figure 19. Typical control cables and clips.

12. Inspect, test, and replace HVAC vacuum system actuators (diaphragms/motors), hoses, reservoir(s), check valve(s), and restrictors.

Vacuum operated actuators are located on the HVAC housing, usually accessed after removing lower trim panels or the glove box. Vacuum hoses may be color coded like electrical wiring. Figure 20.

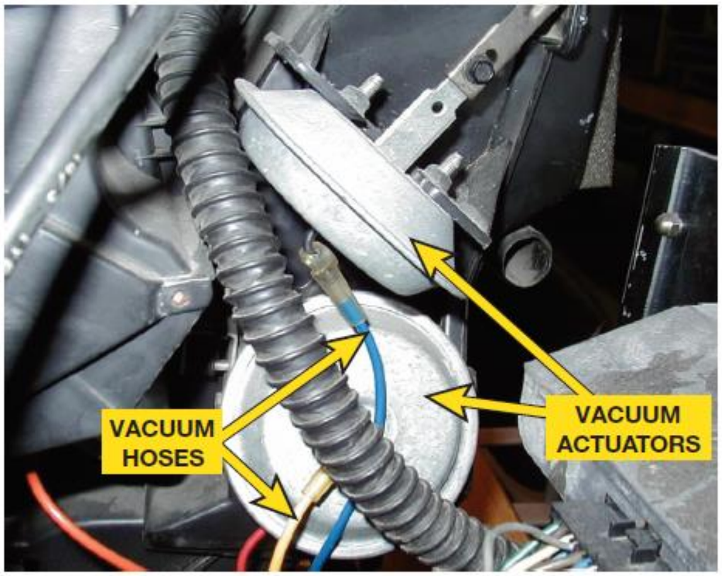

Figure 20. Vacuum motors and hoses.

Most vehicles with vacuum operated HVAC controls have a vacuum reservoir somewhere under the hood. There is a check valve either in the reservoir or in the vacuum supply line that retains vacuum in the system when manifold vacuum is low. Figure 21.

Figure 21. A vacuum reservoir.

13. Inspect, test, adjust, repair, or replace HVAC ducts, doors, and outlets (including dual/multi-zone systems).

A system that contains the HVAC plenum, ducts, and air doors is called the air management system. Airflow is usually controlled by three or more doors. Figure 22.

- The air inlet door is used to select outside or inside air inlet.
    - Outside air, often called fresh air
    - Inside air, usually called recirculation.

- The temperature-blend door is used to adjust air temperature. Dual-zone systems split the duct and airflow past the heater core and use two air mix doors with each air mix temperature door controlled by a separate actuator.
- The mode door is used to select air discharge location.

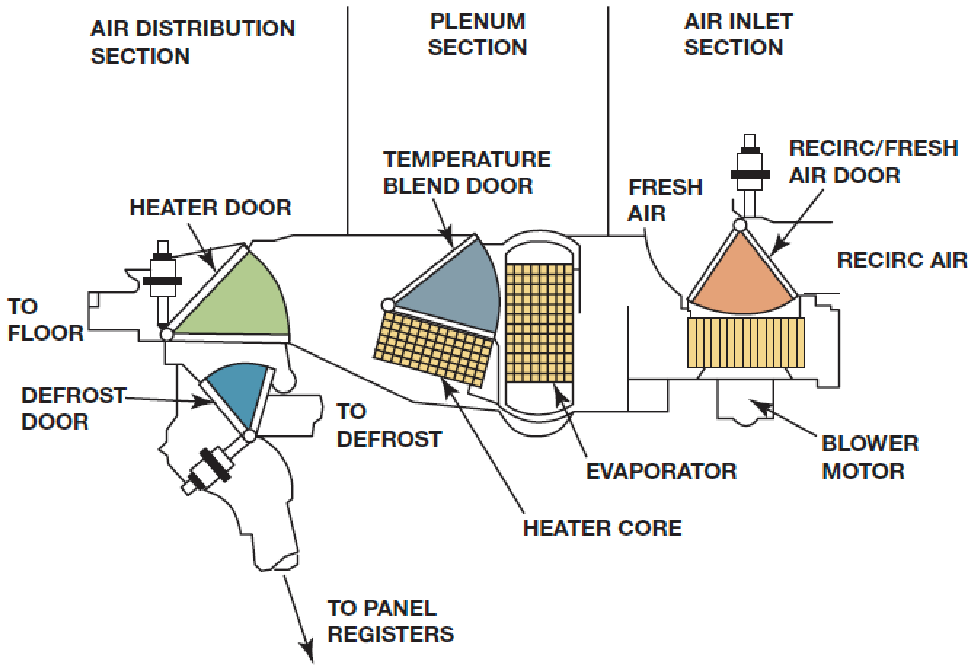

Figure 22. Air control doors of a typical HVAC system.

Most systems use a flap door that swings about 45° to 90°. Since the doors are inside the HVAC case it is necessary to remove the case before the doors can be accessed for repair. Figure 23.

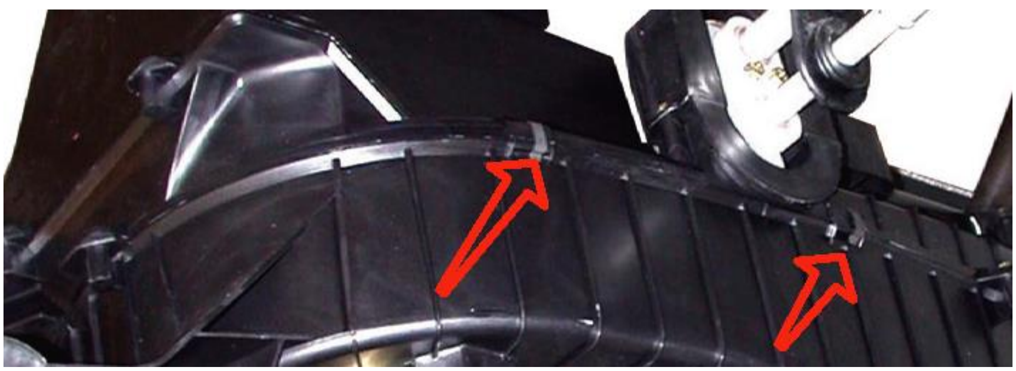

Figure 23. The plastic HVAC case is held together with metal clips (arrows).

► Automatic and Semi-Automatic Heating, Ventilating, and A/C Systems

14. Diagnose temperature control system problems; determine needed repairs (including dual/multi-zone systems).

If a fault occurs in the automatic climatic system, check service information for the specified procedure to follow. Most vehicle service information includes the following steps:

STEP 1 Verify the customer concern. Check that the customer is operating the system correctly.

STEP 2 Perform a thorough visual inspection of the heating and cooling system for any obvious faults.

STEP 3 Use a factory scan tool or a factory level aftermarket scan tool and check for diagnostic trouble codes (DTCs).

STEP 4 If there are stored diagnostic trouble codes, follow service information instructions for diagnosing the system.

STEP 5 If there are no stored diagnostic trouble codes, check scan tool data for possible fault areas in the system.

All factory scan tools are designed to provide bidirectional capability. ATC components that may be able to be controlled or checked using a scan tool include:

- Blower speed control (faster and slower to check operation)
- Command the position of airflow doors to check for proper operation and to check for proper airflow from the vents and ducts
- Values of all sensors
- Pressures of the refrigerant in the high and low sides of the systems

15. Diagnose blower system problems; determine needed repairs (including dual/multi-zone systems).

Some blower motors are electronically controlled by the body control module and include electronic circuits to achieve a variable speed. A scan tool is the best way to test the blower circuits. If the blower motor does not operate at any speed, the problem could be any of the following:

- Defective ground wire or ground wire connection.
- Defective blower motor (not repairable; must be replaced).
- Open circuit in the power-side circuit, including fuse, wiring, and connector at the blower.

16. Diagnose air distribution system problems; determine needed repairs (including dual/multi-zone systems).

In many vehicles, the HVAC system is capable of supplying discharge air of more than one temperature to different areas in the vehicle. This type of system is usually referred to as a Dual-Zone System and allows the driver and front seat passenger to set their own desired temperature. Figure 24.

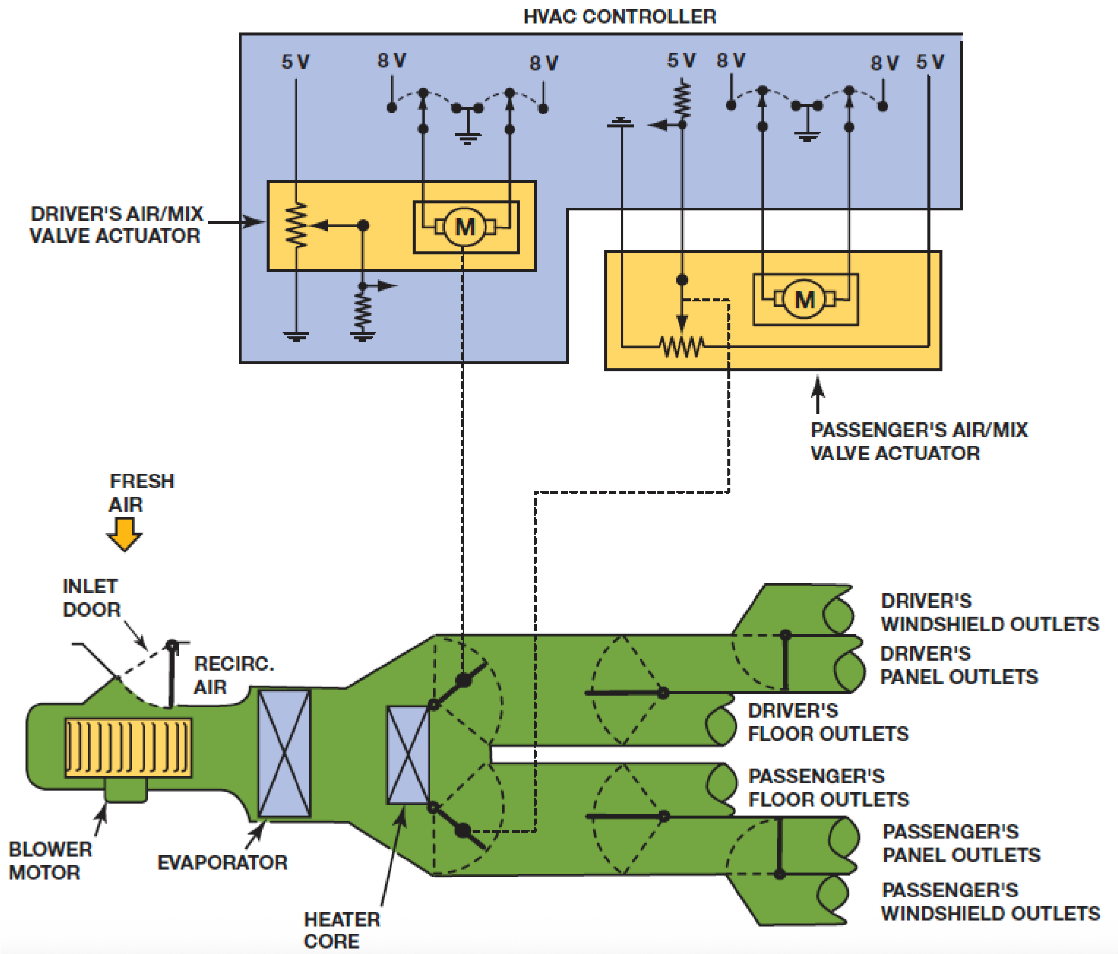

Figure 24. A dual-climate control system showing the airflow and how it splits.

Tri-Zone and Quad-Zone systems are usually found in passenger vans, sport utility vehicles, and luxury cars, which allow the passengers in the rear of the vehicle to control the temperature at their location.

Diagnose air distribution systems by operating the HVAC controls at the control panel. Activate each setting and confirm that the air flows from the proper outlets when selected. If the airflow in not correct, use the scan tool to command the different airflow outlets. This may confirm that either the control panel or an actuator is at fault.

17. Diagnose compressor clutch control system; determine needed repairs.

Most air-conditioning compressors use an electromagnetic clutch. Some systems may connect one or more switches in series with the compressor clutch so that all have to be functioning before the compressor clutch can be engaged. A low- and high-pressure switch or sensor may also be an input to the PCM or HVAC controller for use in controlling the compressor.

The discharge air temperature (DAT) sensor is used to measure the temperature of the air leaving the dash vents. Discharge air temperature data can be used to determine the proper temperature door position or control compressor output.

18. Inspect, test, or replace climate and blower control sensors.

The purpose of using sensors is to provide information to the HVAC controller regarding the conditions outside as well as inside the vehicle. Pressure and temperature sensors are used to determine the condition in the air-conditioning system so that the controller can do the following functions:

- Provide the most efficient use of energy.
- Provide a comfortable interior environment for the driver and passengers.
- Reduce the load on the engine and electrical system as much as possible to improve fuel economy.

The various sensors can be read using a scan tool Most automatic HVAC systems use these sensors to control the climate control system:

- The outside air temperature (OAT) sensor, also called the ambient temperature sensor, measures outside air temperature and is often mounted at the radiator shroud or in the area behind the front grill.
- The in-vehicle temperature sensor is often mounted behind the instrument panel, and a set of holes or a small grill allows air to pass by it.
- A pressure transducer can be used in the low- and/or high-pressure refrigerant line. The pressure signal can be used by the controller to:
    - cycle the compressor to prevent evaporator freeze-up.
    - change the compressor displacement.
    - shut off the compressor or speedup cooling fan operation because of high pressures.
    - prevent compressor operation if the refrigerant level is low or empty.
- The sun load sensor (also called a solar sensor) is normally mounted on top of the instrument panel and is used to measure radiant heat load that might cause an increase of the in-vehicle temperature. Figure 25.

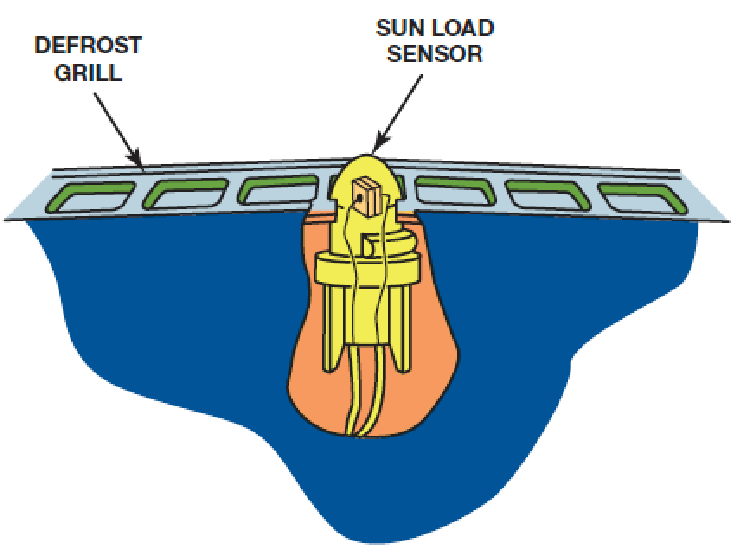

Figure 25. The sunload sensor is located at the base of the windshield inside the vehicle.

Other sensors that may be used are:

- Some systems use an air quality sensor, which detects hydrocarbons (HC) or ozone (O3). When the system detects an air quality issue, it automatically switches to using mostly inside air, about 80%, and reduces the amount of outside air entering the system to about 20%.
- A few vehicles use a relative humidity (RH) sensor to determine the level of in-vehicle humidity. The HVAC controller uses the information to control the air inlet door and the air-conditioning compressor operation to achieve the desired level of humidity (20% to 40%) in the passenger compartment.
- A few vehicles that are equipped with a global positioning system (GPS) for navigation will have a sun position strategy that tracks the angle of the sunlight entering the vehicle. Cooler in-vehicle temperatures are required if the vehicle is positioned so sunlight enters through the windshield or side windows.

19. Inspect, test, and replace door actuator(s).

Electric actuator motors are used to move air doors. Electric door actuators can be either continuous-position or two-position units (open or closed). Variable-position actuators can stop anywhere in their range and need a feedback circuit so the ECM will know their position. Use a scan tool to test the actuators. Figure 26.

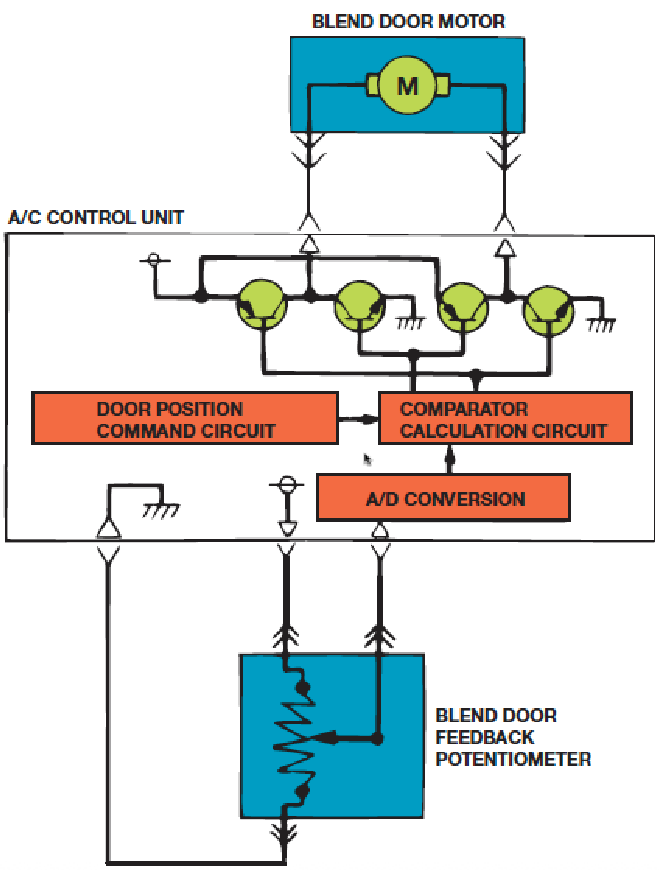

Figure 26. The potentiometer and motor are contained in the blend door actuator.

NOTE: A clicking noise from the actuator motor assembly as it tries to move could be a broken door inside the HVAC housing.

20. Inspect, test, and replace heater coolant control valve and controls.

Some vehicles have a control valve in the heater inlet hose that allows coolant flow to be shut off when MAX cooling is selected to keep hot coolant from flowing through the heater core. The valve is usually vacuum operated, if used.

21. Inspect, test, and replace electric and vacuum motors, solenoids, and switches.

Some vehicles use electrical function switches at the HVAC control head. These are often called electromechanical controls. These switches operate a group of solenoid valves that control the vacuum flow to the vacuum motors. The vacuum motors (actuators) are located under the dash or behind the glove box. Figure 27.

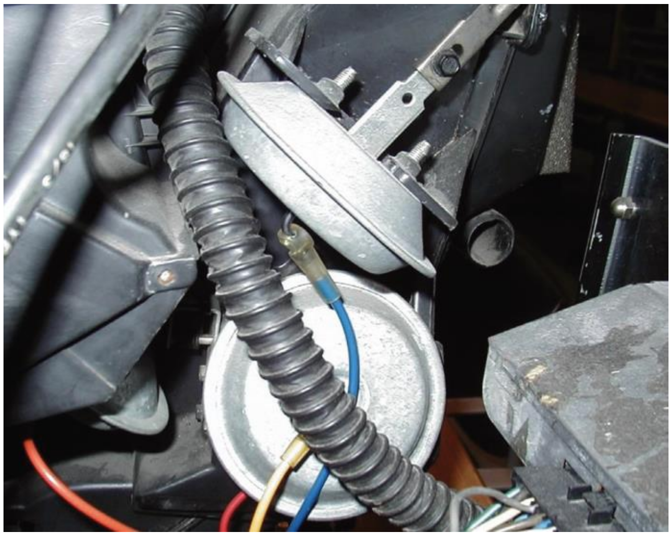

Figure 27. Vacuum motors.

22. Inspect, test, or replace automatic temperature control (ATC) user controls/interfaces and/or climate control computer/module; program, code, or initialize as required.

The automatic temperature control (ATC) system is normally located in the center of the vehicle dash. The button and knobs are inputs to the HVAC control unit. Figure 28.

Figure 28. HVAC operator input panel (control panel).

The control module used for automatic climatic control systems can be referred by various terms depending on the exact make and model of vehicle. Some commonly used terms include the following:

- ECM (Electronic control module)
- BCM (Body control module)
- HVAC control module (often is built into the smart control head)
- HVAC controller or programmer

The control modules are programmed to open or close circuits to the actuators based on the values of the various sensors. An ECM is programmed with various strategies to suit the requirements of the particular vehicle. If the ECM or controller is replaced it usually must be reprogrammed to match the vehicle, following service information procedures. Figure 29.

Figure 29. Tools required for module reprogramming.

23. Check and adjust calibration of automatic temperature control (ATC) system.

An HVAC actuator may need to be calibrated after the actuator has been replaced. Check service information for the specified procedure to follow to perform a calibration if needed. A typical calibration procedure to use when installing a new actuator using a scan tool includes the following steps:

STEP 1 Clear all diagnostic trouble codes (DTCs).

STEP 2 Turn the ignition switch to the off position.

STEP 3 Install the replacement actuator and reconnect all mechanical and electrical connections.

STEP 4 Start the engine and select motor recalibration program on the scan tool under the functions menu.

STEP 5 Verify that no diagnostic trouble codes have been set.

24. Diagnose data communication issues, including diagnostic trouble codes (DTCs) that affect climate control system operation.

Since the 1990s, vehicles have used modules to control the operation of most electrical components. A typical vehicle has 10 or more modules, and they communicate with each other over data lines or hard wiring, depending on the application.

All vehicle manufacturers must use high-speed serial data to communicate with scan tools on all vehicles effective with the 2008 model year. The standard is called controller area network (CAN). This serial data method uses a two-twisted-wire circuit, which is connected to the data link connector on pins 6 and 14. Figure 30.

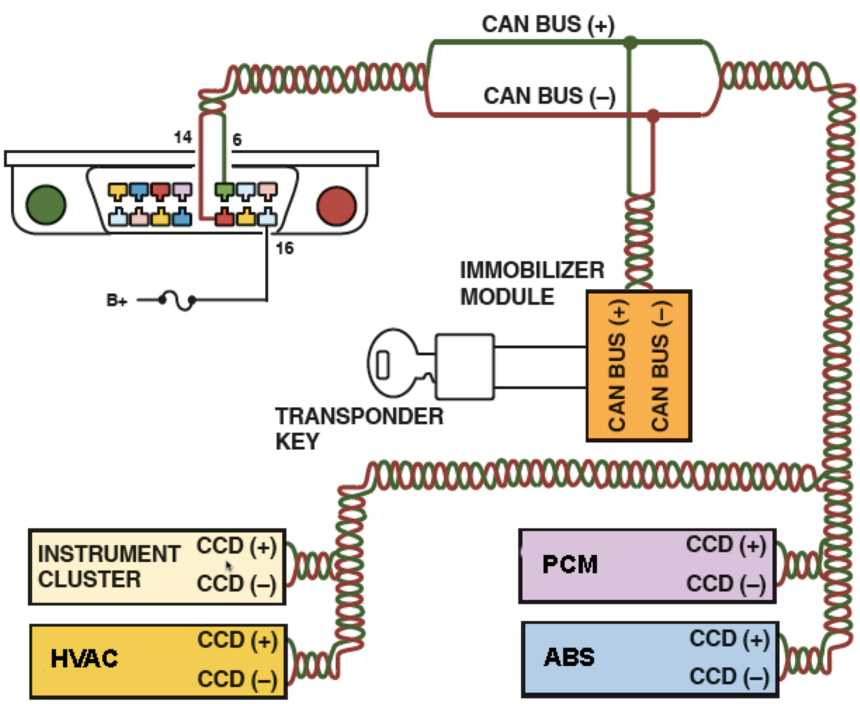

Figure 30. CAN allows the scan tool to communicate with the HVAC controller to view data and check for DTCs.

A factory scan tool or a factory level aftermarket scan tool can check for diagnostic trouble codes (DTCs). If there are stored diagnostic trouble codes, follow service information instructions for diagnosing the system. Figure 10.

ATC-RELATED DIAGNOSTIC TROUBLE CODES	
BODY DIAGNOSTIC TROUBLE CODE (DTC)	DESCRIPTION
B0126	Right Panel Discharge Temperature Fault
B0130	Air Temperature/Mode Door Actuator Malfunction
B0131	Right Heater Discharge Temperature Fault
B0145	Auxiliary HAVC Actuator Circuit
B0159	Outside Air Temperature Sensor Circuit Range/Performance
B0160/B0162	Ambient Air Temperature Sensor Circuit

Figure 31. A sample of typical automatic temperature control (ATC) DTCs.