ASE 7 - Heating, Ventilation & Air Conditioning

Module 5
Automatic HVAC Systems
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Introduction

This module is about a type of HVAC control that came into being some time after manually controlled HVAC systems were introduced. An overview of the unique features of the automatic HVAC control systems, detailed information on unique control system components, and some tips on diagnosing customer concerns will be discussed. In automatic HVAC operation, the HVAC control module will maintain the comfort level inside of the vehicle by controlling the A/C compressor clutch, the blower motor, the air temperature actuators, mode actuator and recirculation. This module will discuss these controlled operations.

This module will further explore:

1. The automatic dual zone system
2. Automatic rear (auxiliary) HVAC systems
3. Steering Wheel controls
4. Automatic Blower operation
5. Types of sensors and operation
6. Unique operational features designed into automatic HVAC systems

Objectives

1. Be able to identify and explain the basic functions, controls and designs of an automatic HVAC system.
2. Be able to identify and understand the operation of sensor components.
3. Be able to explain the function and operation of an automatic dual zone air distribution system.
4. Obtain knowledge of the components and operations of an automatic rear air distribution system.
5. Be able to explain automatic blower operation.
6. Understand the function and operation of steering wheel controls.
7. Given the parameters of a particular automatic HVAC customer concern, a student will be able to apply strategy based diagnostic procedures to resolve the problem.
NATEF Area VII.

1. Diagnose temperature control problems in the heater/ventilation system; determine necessary action.

2. Diagnose malfunctions in the electrical controls of heating, ventilation, and A/C (HVAC) systems; determine necessary action.

3. Inspect and test A/C heater control panel assembly; determine necessary action.

4. Check operation of automatic and semi-automatic heating, ventilation, and air conditioning (HVAC) control systems; determine necessary action.

STC Tasks:

1. Describe the air distribution system used in HVAC systems.

2. Understand automatic HVAC system components, function and design.

3. Locate automatic HVAC system components.

4. Understand unique automatic HVAC component operation.

5. Understand the cause of automatic HVAC system malfunctions.

6. Understand the components, function, design and operation of automatic dual-zone HVAC systems.

7. Understand the components and operation used in automatic rear HVAC systems.

8. Understand the operation of automatic dual-zone, rear HVAC systems.

9. Understand steering wheel components, operation, function and design.

10. Apply the GM SBD process to automatic and dual-zone HVAC concerns.
Lesson 1: Automatic HVAC Overview

The automatic HVAC system (or automatic climate control system) is designed to provide a comfortable environment inside the passenger compartment, regardless of weather conditions outside of the vehicle. This is achieved by cooling, dehumidifying, heating and circulating the air that enters the passenger compartment. The automatic HVAC systems are equipped with a controller containing a microprocessor that uses inputs and outputs to control the operation of the HVAC system. The microprocessor can be located in either the control head, Body Control Module (BCM) or Instrument Panel Module (IPM). The automatic HVAC system allows the vehicle operator to choose either automatic control or manual control (refer to Figure 5-1). When automatic control is selected, the only input required from the operator is the desired interior temperature (the SET temperature). When the desired temperature is input, the controller automatically selects the appropriate air intake, discharge outlet(s), fan speed and discharge air temperature to maintain the SET temperature. The system can automatically regulate and maintain the inside air temperature from 65°F (18°C) to 85°F (29°C) regardless of changes in ambient air temperature. The desired temperature can also be set to 60°F (16°C) and 90°F (32°C). At these SET temperatures, the system provides unregulated max cooling or max heating. The controller will not try to maintain these temperatures.

Figure 5-1, Full Automatic Mode versus Full Manual Mode
Manual control allows the operator to take control over the mode door positions and/or the blower speed. The controller will continue to maintain the SET temperature (if possible) even when manual selections are made. Some manual selections make it difficult or impossible for the controller to maintain the SET temperature. Like manual HVAC systems, the automatic HVAC systems have the following sub-systems (refer to Figure 5-2):

- Refrigeration System (one of two types):
  - Cycling Clutch Orifice Tube (CCOT) System
  - Variable Displacement Orifice Tube (VDOT) System
- Cooling System (includes the following):
  - Heater Core
  - Radiator
  - Air Intake System
- Air Distribution System

*Figure 5-2, Automatic HVAC Sub-Systems*
Air Distribution System

The air distribution system contains air door/valves that control the air inlets and outlets (mode doors) and a door/valve (temp, blend or mix door) that controls the temperature. On dual zone air distribution systems there are two temperature doors (refer to Figure 5-3). The air distribution system also contains a blower motor and fan that is used to circulate the air. The position of the mode doors, temperature door(s) and blower motor speed is determined by the selections made by the vehicle operator. In the automatic mode of operation, the controller determines the appropriate operation of the HVAC system to maintain the SET temperature. In the manual modes of operation, the selections made at the control head directly affect door positions and blower speed.

There are two control methods used to control the air doors in an automatic HVAC system:

- Vacuum
- Electronic

Some automatic HVAC air distribution systems use different control methods to control different doors. Therefore, it is common to see a system with mode doors controlled by vacuum solenoids and a temperature door controlled electronically. When the doors are controlled by vacuum solenoids, the solenoids can be located in either the HVAC programmer or inside a solenoid box. All automatic HVAC systems use electric motors to control the temperature door(s).

![Figure 5-3, Automatic HVAC Air Distribution Systems (Single and Dual Zone)](image-url)
Figure 5-4 shows an auto HVAC air distribution system that uses electric motors to control both the mode doors and the temperature doors. All of these motors are the new style two-wire motors. These actuators are two-wire bi-directional electric motors. Two control circuits enable the actuator to operate. The control circuits use either a 0 or 12-volt value to coordinate the movement. When the actuator is at rest, both control circuits have a value of 12 volts. In order to move the actuator, the HVAC control module grounds the appropriate control circuit for the commanded direction. The HVAC control module reverses the polarity of the control circuits to move the actuator in the opposite direction.

The HVAC control module determines the door position by counting motor pulses on one of the control circuits. These pulses are small voltage fluctuations that occur when the brush is shorted across two commutator contacts as the motor rotates. As the actuator shaft rotates, the HVAC control module monitors the voltage drop across an internal resistance to detect the pulses. The HVAC control module uses a range of 0-255 counts to index the actuator position.

The system in Figure 5-4 is a dual zone system with an auxiliary rear HVAC system. This system has an additional motor to allow the passenger to control the passenger side temperature door and an auxiliary motor to control the rear temperature.

![Figure 5-4, Automatic HVAC System using two-wire motors (Cadillac)](image)
Figure 5-5 shows an automatic Dual Zone HVAC air distribution system that uses vacuum solenoids located inside a solenoid box. The HVAC control head controls the groundside of the solenoids. When a solenoid is grounded, vacuum is applied to the vacuum actuator for a specific door(s). When the ground path is removed, the vacuum actuator is allowed to vent.

The temperature door is operated by a new style five-wire motor. The logic circuits inside the motor, control the bi-directional electric motor based on the input voltage provided by the control head on the signal wire. When 0 volts is applied to the signal circuit, the motor logic circuits rotate the motor in one direction. When 5 volts is applied to the signal circuit, the motor logic circuit rotates the motor in the other direction. If 2.5 volts is applied to the signal circuit, the motor will stop rotating.

Inside the motor is a potentiometer that is mechanically linked to the air door. The control head uses the potentiometer for feedback on the actual position of the door.

Using this feedback, the controller will operate the motor until the desired position is achieved.

Figure 5-5, Automatic HVAC System using Vacuum Solenoids (Buick)
Lesson 2: Modes of Operation

The automatic HVAC systems use a controller, Body Control Module (BCM) or an Instrument Panel Module (IPM) to control the various functions of the HVAC system. The amount of control it has over the system is based on the selections made by the vehicle operator. If the vehicle operator selects the AUTO mode of operation, the controller will have control of the mode doors and/or blower. Although manual control prevents the controller from automatically operating certain HVAC functions, it will try to reach or maintain the SET temperature.

The SET temperature is the desired temperature that is selected by the vehicle operator. It allows the operator to select a specific temperature at which the controller will maintain the passenger compartment. In order for the controller to reach and maintain the SET temperature, it must have information on the heat load, engine coolant temperature and the difference between the actual interior temperature and the SET temperature. Although heat load is not a major factor when heating is required, it is critical when the interior needs to be cooled. The controller uses the following inputs to determine this information:

- Interior Temperature
- Exterior (Ambient) Temperature
- Sun Load
- Outlet (Duct) Temperature
- SET Temperature
- Engine Coolant Temperature
- Vehicle Speed

Based on these inputs, the controller generates a program number. The controller uses this number to determine how the temperature door(s), mode doors, and blower should be controlled to reach and maintain the SET temperature (refer to Figure 5-6). This number can be from 0 to 255 (0% to 100%) and indicates the amount of heating or cooling required. The controller commands maximum cooling when the program number is 0 and maximum heating when the number is 255. This number will fluctuate as the heating and cooling requirements change.

Figure 5-6, The Effect of Program Number on the HVAC System in AUTO Mode
If the vehicle operator takes manual control of the mode doors and/or blower, it can impact the heating and cooling requirements. This will impact the program number. The amount of change in the program number during manual control is based on the manual selections and how they impact the cooling and heating requirements. If the operator takes control of the blower using the fan control switch, it can affect the heat exchange rates at both the evaporator and the heater core. This can affect the passenger compartment temperature. To compensate for this, the controller may have to change the temperature door position and possibly the position of the mode doors if they are still under automatic control (refer to Figure 5-7). This change in strategy will be reflected in the program number.

![Figure 5-7, HVAC system Operation when Manual Blower Control is Selected](image)

During manual control of the mode doors, the controller loses automatic control over the mode doors. Manual mode selections force the controller to move the inlet and outlet doors to the correct positions for the selected mode and maintain these positions until the operator changes the mode. Manual mode selections do not affect the automatic control of the temperature. However, the controller may need to adjust the control strategy for the temperature door and the blower (if it still has control of the blower) to maintain the SET temperature (refer to Figure 5-8). Some manual modes greatly restrict the controller in its ability to reach and maintain the SET temperature by preventing operation of the A/C compressor and the blower.

Manually selecting mode door positions does not necessarily affect the controller's ability to automatically control the blower speed. The controller will continue to automatically operate the blower to maintain the SET temperature unless the manual mode prevents blower operation or the operator has taken manual control of the blower.
Figure 5-9 shows the effects of the vehicle operator taking manual control of both the blower and the mode doors (full manual control). The only automatic control that the HVAC controller has is over the positions of the temperature door and the A/C compressor. However, some modes will prevent compressor operation. In full manual mode, the controller will still try to reach and maintain the SET temperature, but its ability to do this can be greatly affected by the manual selections.
The following pages explain the operation of the automatic HVAC system in the various modes of operation. Many of the modes of operation can be selected manually or are selected by the controller in AUTO mode as part of the strategy to reach and maintain the SET temperature. Those modes of operation that are strictly manual modes can only be accessed by manual selections on the control head (Figure 5-10). The controller cannot automatically select these modes.

The following is an example of the manual selections and the selections that can be automatically made by the controller (2003 Park Avenue)
- OFF (manual mode selection)
- AUTO (manual mode selection)
- VENT (manual mode selection)
- DEFOG or FLOOR/WINDSHIELD (manual mode selection)
- BI-LEVEL or MID/FLOOR (automatic and manual mode selection)
- A/C or MID (automatic and manual mode selection)
- HEATER or FLOOR (automatic and manual mode selection)
- FRONT DEFROSTER (automatic and manual mode selection)
- RECIRC or MAX A/C (automatic and manual mode selection)

Figure 5-10, Manual and Automatic Selection Using the Control Head
OFF Mode

When OFF is selected on an automatic HVAC system, the blower motor and the A/C compressor will not operate. However, in this mode the controller still remains active and tries to reach the desired SET temperature. On some dual zone systems, the OFF button must be pressed twice to turn the system off. The first press of the button will disable passenger control of the passenger side temperature door.

If the SET temperature is 70°F (21°C) when the system is in the OFF mode and it is a cold day, the system will try to achieve the SET temperature by allowing air to flow through the heater core (Figure 5-11). Since the blower does not operate in this mode, airflow is only generated when the vehicle is moving. The air flowing over the exterior

The vehicle increases the air pressure just ahead of the windshield and forces some air into the air distribution system, creating a small airflow. The air exits the system through the heater (floor) and defrost (windshield) outlets.

When the outside temperature is higher than the SET temperature, the system can only lower the inside temperature to the same temperature as the outside (ambient) air. This is because the compressor will not operate in the OFF mode.

The period of time that it takes to reach the SET temperature in the OFF mode may take longer than if another mode was selected that allows blower operation. The OFF position does not affect the rear defog, ambient temperature or SET temperature.

Figure 5-11, Automatic HVAC Air Distribution OFF Mode
AUTO Mode

In AUTO mode, all HVAC functions are controlled automatically by the controller, based on various inputs (including the SET temperature). During automatic control, the controller will select the correct blower speed and door positions to reach and maintain the SET temperature. In the AUTO mode, the controller can control the inlet, outlet and temperature doors. It can also control blower speed and the operation of the A/C compressor.

The position of the inlet air door is based on interior, exterior and SET temperatures (Figure 5-12). In most situations, the inlet door will be positioned to allow outside air to flow into the air distribution system. However, during A/C compressor operation, the inlet door may be positioned in the recirculation position. This will allow the air in the passenger compartment to be recirculated. This usually occurs when the passenger compartment air temperature has dropped below the temperature of the outside air. The inlet door is not typically positioned in the recirculation position when the interior air temperature is higher than the outside air temperature since the interior air has a higher heat load.

Figure 5-12, Inputs and Outputs used in AUTO Modes
The position of the temperature door is also based on the interior, exterior and SET temperatures. The controller will determine the heating and cooling requirements by comparing the SET temperature to the interior temperature. The controller will also compensate for the exterior air temperature if the air is being pulled from the outside.

The temperature door controls the amount of air that flows through or bypasses the heater core. If the interior temperature must be lowered, the controller will restrict the airflow through the heater core and may enable the compressor. If the interior temperature must be increased, the controller will position the temperature door to allow more air through the heater core. This strategy is used regardless of the operation of the A/C compressor.

The exit path that the conditioned air (heated or cooled) takes is based on the heating and cooling requirements.

In general, the controller will provide one of the following three exit paths:

- Floor/heater and rear outlets
- A/C and rear outlets
- Heater, A/C and rear outlets

The operation of the blower and the A/C compressor are also directly related to the heating and cooling requirements. The blower speed is increased when more airflow is required to achieve the SET temperature and decreased when maintaining the SET temperature.

On some systems, the blower speed can be adjusted by the vehicle operator in AUTO mode by pressing the fan control switch once. This results in a slight increase or decrease (AUTO HI or AUTO LO) over the speed selected by the controller. Pressing the fan control switch twice in the same direction, causes the fan to operate at a fixed speed. On other systems, adjusting the fan control switch overrides automatic blower control and allows the operator to manually select the blower speed.

Compressor operation can occur at both high and low ambient temperatures. When the ambient temperature is high, the refrigeration system is used to lower the temperature of the air entering the passenger compartment. When the ambient temperature is low, approximately 40°F (4°C), the refrigeration system is used to dehumidify the air before it exits the air distribution system. This is used to decrease the amount of condensation on the windows.
DEFOG or FLOOR/WINDSHIELD Mode

The defog mode is a manual selection used to remove humidity from the interior of the vehicle. When the ambient air temperature is low, the humidity inside the passenger compartment can condense on the windows and obstruct vision. To remove the humidity, the controller positions the inlet air door to the outside air position and uses the refrigeration system to dehumidify the air (Figure 5-14).

The controller will only enable the A/C compressor when the temperature is above approximately 40°F (4°C) and will continue to operate the compressor to maintain an evaporator temperature of approximately 33°F (1°C). The dehumidified air is forced out of both the heater (floor) outlets and defrost (windshield) outlets.

Although the DEFOG mode allows the vehicle operator to manually select the position of the outlet air doors(s), the controller will continue to automatically maintain the temperature (using the temperature door) and blower speed. The fan control switch can be used to override or slightly adjust (system dependent) the automatic control of the blower. On systems that utilize an AIR FLOW button (Buick) or a MODE button (Pontiac), this mode of operation will be indicated by FLOOR/WINDSHIELD on the display.

Figure 5-14, Air Distribution System in DEFOG Mode
DEFROST Mode

The DEFROST mode (manually or automatically selected) is used to remove condensation and frost on the front windshield. It also helps prevent additional frost and condensation from forming. In this mode, the controller positions the inlet air door to the outside air position and uses the refrigeration system to dehumidify the air (Figure 5-15).

The controller will only enable the A/C compressor when the temperature is above approximately 40°F (4°C) and will continue to operate the compressor to maintain an evaporator temperature of approximately 33°F (1°C). Unlike the DEFOG mode, the majority of the dehumidified air is forced out of the defrost outlets with a slight bleed to the floor outlets.

Although manual selection of the DEFROST mode allows the vehicle operator to manually select the position of the outlet air door(s), the controller will continue to automatically maintain the temperature (using the temperature door) and blower speed. The fan control switch can be used to override or slightly adjust (system dependent) the automatic control of the blower.

On some systems (Cadillac E/K), the DEFROST mode is not stored in the controller memory after the ignition is turned to the OFF position. In this case, the system will switch to the AUTO mode in the next key cycle.

Figure 5-15, Air Distribution System in DEFROST Mode
RECIRC Mode

The RECIRC or MAX A/C (on some systems) mode is used to position the inlet air door to the recirculation position, allowing a 90% recirculation of the passenger compartment air (Figure 5-16). This mode is automatically selected when the SET temperature is 60°F (16°C). Some systems have a separate RECIRC button, which allows recirculating passenger compartment air in other modes. On all systems, a slight amount of outside air is allowed to bleed into the air distribution system for ventilation.

The air outlets used in the RECIRC mode are based on whether the system is in AUTO mode or in one of the other modes. When 60°F (16°C) is selected in AUTO mode, the refrigeration system is operating and the air exits through the A/C (panel) outlets with a slight bleed to the floor outlets. If the RECIRC mode is selected in one of the other modes, the position of the outlet door(s) will be based on that mode. RECIRC is not available for use in the DEFROST mode since it could cause windshield fogging.

In the RECIRC mode, the controller will continue to automatically maintain the temperature (using the temperature door) and blower speed. The fan control switch can be used to override or slightly adjust (system dependent) the automatic control of the blower.

On many systems, the RECIRC mode will continue to operate throughout the entire ignition cycle, unless manually stopped by pressing the RECIRC button with the system in the OFF position. This will return the system to the last setting prior to being turned OFF. On other systems (2003 H and C cars), the RECIRC mode will operate for about 10 minutes before it automatically turns off and the inlet door moves to the outside air position. On these systems, any mode changes or ignition cycles will cancel the RECIRC mode and position the inlet air door to the outside air position.

The recirculation actuator will also move automatically when coolant temperatures reach 117°C (243°F). This allows the refrigerant gases to cool and takes some of the load off the A/C compressor. When coolant temperatures reach 112°C (234°F), the HVAC controller will return the actuator to the previous setting.
NORM A/C or MID Mode

The controller can select the Norm A/C or A/C mode automatically during AUTO mode operation or the vehicle operator can manually select this mode. In this mode of operation, the air exits the air distribution system through the A/C (panel outlets with a slight bleed to the heater outlets (Figure 5-17). On systems that utilize an AIR FLOW or MODE button, this mode will be indicated as the MID setting.

The inlet air door will be positioned in the outside air position unless the RECIRC mode is manually selected. The controller will command the compressor on when the outside air temperature is above approximately 40°F (4°C). This will cool and dehumidify the air entering the passenger compartment. The controller will automatically maintain the temperature (using the temperature door) and blower speed. The fan control switch can be used to override or slightly adjust (system dependent) the automatic control of the blower.

Figure 5-17, Air Distribution System in Norm A/C Mode
HEATER or FLOOR Mode

The controller can select the HEATER mode automatically during AUTO mode operation or the vehicle operator can manually select this mode. In this mode of operation, the air exits the air distribution system through the heater (floor) outlets with a slight bleed to the defrost outlets on some applications (Figure 5-18). On systems that utilize an AIR FLOW or MODE button, this mode will be indicated as the FLOOR setting.

On most systems the inlet door will be positioned in the outside air position unless the RECIRC mode is manually selected. On other systems, the inlet air door is automatically placed in the recirculate position in this mode (Aurora). Certain systems will command the compressor on when the outside air temperature is above approximately 40°F (4°C). This will dehumidify the air entering the passenger compartment. The controller will automatically maintain the temperature and blower speed. The fan control switch can be used to override or slightly adjust (system dependent) the automatic control of the blower.

![Figure 5-18, Air Distribution System in HEATER Mode](image-url)
**BI-LEVEL or MID/FLOOR Mode**

The controller can select the BI-LEVEL mode automatically during AUTO mode operation or the vehicle operator can manually select this mode. In this mode of operation, the air exits the air distribution system through the A/C and heater outlets (Figure 5-19). On systems that utilize an AIR FLOW or MODE button, this mode will be indicated as the MID/FLOOR setting.

The inlet air door will be positioned in the outside air position unless the RECIRC mode is manually selected. The compressor will be commanded on by the controller when the outside air temperature is above approximately 40°F (4°C). This will cool and dehumidify the air entering the passenger compartment. The controller will automatically maintain the temperature and blower speed. The fan control switch can be used to override or slightly adjust (system dependent) the automatic control of the blower.

*Figure 5-19, Air Distribution System in BI-LEVEL Mode*
**ECON / VENT Mode**

The ECON or VENT mode prevents the operation of the compressor and positions the inlet air door in the outside air position. In this mode, the controller tries to automatically maintain the SET temperature but it is limited since the compressor will not operate. The interior air can only be cooled to ambient air temperature. The controller still has the ability to heat the air by positioning the temperature door to allow airflow through the heater core. The controller will automatically select the outlet door position unless manually selected by the vehicle operator (Figure 5-20).

The blower speed is also automatically controlled. The fan control switch can be used to override or slightly adjust (system dependent) the automatic control of the blower.

VENT and RECIRC cannot be selected at the same time, since they command opposite inlet door positions. If VENT is selected when the system is in RECIRC mode, the system will change to vent mode. When the system is in DEFROST mode, pressing the VENT button will have no effect on the system.

![Figure 5-20, Air Distribution System in ECON/VENT Mode](image-url)

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Re-Calibrating Actuators or HVAC Controller.

When an electronic actuator is replaced on a manual or automatic HVAC control system, a re-calibration procedure may need to be performed to allow the system to work properly. There are two procedures that are generally used to re-calibrate the actuator. Examine the service information to determine which method is to be used on a particular vehicle.

Calibration Procedure with a Scan Tool

Using the following steps to perform the calibration update:

1. Install a scan tool
2. Turn ON the ignition, with the engine OFF
3. With a scan tool, select Heating and Air Conditioning
4. Select Special Functions
5. Select Miscellaneous Test
6. Select HVAC Re-calibration
7. Follow scan tool prompts.

Calibration Procedure without a Scan Tool

1. Turn OFF the ignition.
2. Remove the battery positive voltage circuit fuse of the Instrument Panel Control Module (HVAC Controller)
3. Wait 60 seconds.
4. Install the fuse

The module memory will not clear if the battery positive voltage circuit fuse is installed in less than 60 seconds.
Lesson 3: Special Operating Modes and Blower Controls

There are special situations where the controller changes its normal blower and door control strategy. The controller will still maintain automatic control of the blower but will adjust the blower speed and door position to compensate for these situations.

The controller resumes normal automatic control when the conditions no longer exist.

Normal Purge:

In the normal purge mode, the controller delays blower operation and positions the mode doors to direct any air blowing out of the heater outlets. When the engine coolant temperature reaches approximately 126°F, the blower will operate at a reduced speed for about 30 seconds to further purge the air distribution system of moist air. The controller then resumes normal system operation.

On certain systems (Cadillac E/K), the airflow is directed to the heater outlets and then the blower is operated at low speed until normal system operation can begin.

Normal system operation will occur after either of the following conditions exists:

• Program number command indicates cooling
• Coolant temperature is greater then 97°F (36°C)

If neither of the above conditions exists within one to four minutes (dependent on ambient temperature), the controller will automatically resume normal operation.

Cold Purge:

In the cold purge mode, the controller positions the inlet air door to the outside air position and directs air out the windshield outlet. This decreases windshield fogging from the moist breath of vehicle occupants. The blower motor operates at approximately 60% of its maximum speed for several seconds. After cold purge is completed, the controller resumes normal operation.

A/C Purge:

In the A/C purge mode, the controller positions the air doors to direct the airflow out the heater outlets. This removes residual moisture from the air distribution system when the controller determines refrigeration operation is required to reach SET temperature. After A/C purge is completed, the controller resumes normal operation. This mode will be by-passed if the fan is operated in a manual mode or the vehicle operator selects a manual mode.
**Instrument Panel Cluster (IPC) Cooling:**

In the IPC cooling mode, the controller will activate the blower and direct air out of the A/C outlets when the interior temperature could cause damage to the IPC components. The IPC cooling mode will be initiated only when the following conditions are present:

- Ignition is in the RUN position
- Engine is not running or the HVAC system is OFF
- Inside air temperature is above 125°F (38°C)
- Blower override modes are not operating

Once this mode of operation is enabled, the minimum run time is four minutes. The IPC cooling mode will be disabled if any of the following occur:

- Inside air temperature is below 121°F (35°C)
- Engine is running or HVAC system is ON
- Diagnostic mode is entered or a PCM-IPC Class 2 serial data fault is present

**Snow Ingestion Mode:**

The snow ingestion mode of operation is used to reduce the possibility of snow being pulled into the air distribution system and blown out of the outlets. In the snow ingestion mode, the controller limits the blower to 7 volts until the coolant temperature exceeds approximately 100°F for three minutes. This mode is initiated if the operator selects DEFROST mode when the ambient temperature is below 25°F.

The reduced blower speed decreases the possibility of drawing snow through the inlet air door. The 7-volt blower limit will be overridden if the operator selects HI FAN during this mode.

**Afterblow:**

Afterblow is a feature that dries the evaporator core by operating the blower motor after the engine is turned off. This reduces the amount of microbial growth that can create undesirable odors. The vehicle does not come equipped with the afterblow feature turned on. If the afterblow feature is required due to an odor concern, it must be turned on by reprogramming the HVAC control module, refer to in Vehicle Control Systems.
After the HVAC control module has been programmed for afterblow, the following conditions must be met for afterblow to operate:

1. The engine has been turned off for at least 30 minutes.
2. The ambient air temperature is at least 21°C (70°F).
3. The A/C compressor operated for more than 2 minutes.
4. The system voltage is at least 12 volts.

Once the above conditions have been met, the following sequence of events will occur:

1. The blower motor will run for 20 seconds.
2. The blower motor will be off for 10 minutes.
3. The blower motor will run for an additional 20 seconds.
Blower Control

Blower speed is controlled by a blower control module, which follows commands from the HVAC system controller. The controller determines the correct blower speed using information from sensor inputs and the control strategy within the controller. The controller provides the blower control module with a pulse-width modulated signal that indicates the desired blower speed. By using pulse-width modulation, the controller can vary the average voltage 0 volt signal and commands the maximum blower speed by providing 12 volts on the signal circuit. By increasing/decreasing the average signal voltage, the controller can command the blower control module to operate the blower at increased/decreased speeds.

The blower control module also uses pulse-width modulation (PWM). Based on the signal from the HVAC controller, the blower control module applies a PWM signal on the blower motor circuit. By using pulse-width modulation, the blower control module can control the average voltage applied to the blower motor circuit, varying from 0 to 12 volts. The average voltage that is applied to the circuit results in a specific current flow through the blower, which controls the speed of the blower motor.

When an average of 4 volts is applied to the blower motor circuit, the blower motor will operate at its slowest speed. The blower motor will operate at its maximum speed when 12 volts is applied. Increasing the average voltage above 4 volts produces an increase in the blower motor speed. On some systems, the blower motor control voltage is also provided to the HVAC controller as feedback to insure blower motor speed stability and to allow the HVAC controller to detect failures in the blower motor circuitry.

The blower can be operated in either manual fan mode or in automatic fan mode. The fan speeds in manual mode are limited and remain constant until the operator selects a different speed or AUTO mode. In AUTO fan mode, the speed can be varied anywhere between the maximum and minimum speeds. The blower motor speed in AUTO mode is determined by the HVAC controller based on the following inputs:

- Inside Air Temperature Sensor
- Outlet Temperature Sensor
- Ambient Air Temperature Sensor
- Sun Load Sensor(s)
- Engine Coolant Temperature
- Vehicle Speed
The controller uses these inputs and its internal control strategy to generate a program number. This number (0 to 255) is used to determine the blower speed for the heating and cooling requirements.

**Figure 5-21, Blower Module Control Circuit**

**Figure 5-22, Automatic HVAC Blower Control through Pulse Width Modulation**
Lesson 4: Sensors

Various sensors are used by the HVAC controller to determine the correct strategy for reaching and maintaining the SET temperature. The sensors used include outside air temperature sensors, inside air temperature sensors, outlet temperature sensors and sun load sensors. These are the main inputs used by the HVAC controller; however, the controller also uses powertrain inputs like the vehicle speed sensor to further adjust the control strategy. There are even more inputs when considering compressor controls. The following pages will focus on the temperature and sun load sensors. Information on the inputs used for compressor control is located in Module 3 "HVAC Controls".

Outside Air Temperature Sensor

The outside air temperature sensor, also called the ambient air temperature sensor, is an NTC thermistor. It is located at the front of the vehicle near the bumper or grill area. The outside air temperature sensor provides the HVAC controller with an input signal based on surrounding air temperature. The controller uses this input in determining heating and cooling requirements.

The operation of the ambient air temperature sensor is similar to that of the outlet air temperature sensors. A 5-volt reference signal is sent from the controller to the outside air temperature sensor over the input circuit. A thermistor inside the sensor varies the voltage. The HVAC controller measures the voltage drop across the sensor to determine the resistance of the sensor and to calculate the temperature. As the ambient air temperature increases, resistance decreases. The reference low provides ground to the sensor.

Since the sensor is mounted under the hood it can be affected by city traffic, idling and hot engine restarts. A temperature memory feature is used in the controller ambient software programming to help provide greater accuracy under engine restart conditions. If the engine coolant temperature is not more the 10°C (18°F) above the ambient air temperature sensor reading, or if the engine has not been started in two hours, the actual outside air temperature is displayed. This is the last displayed temperature sensed when the engine was operating at vehicle speeds greater then 16 km/h (10 mph).

The ambient air temperature displayed may be allowed to increase, but only after a built-in 300-second time delay which allows for outside air to cool the sensor. The delay starts after the vehicle reaches 10 mph. If the sensor reading is ever less than the displayed value, then the ambient air temperature changes are displayed as rapidly as possible.
Figure 5-23, Outside Air Temperature Sensor Location (Radiator Support Bracket)

Figure 5-24, Outside Air Temperature Sensor (Ambient)

<table>
<thead>
<tr>
<th>Resistance (Ω)</th>
<th>°C</th>
<th>°F</th>
<th>Analog-Digital (A/D) Counts</th>
</tr>
</thead>
<tbody>
<tr>
<td>169,400</td>
<td>-40</td>
<td>40</td>
<td>241</td>
</tr>
<tr>
<td>88,740</td>
<td>-20</td>
<td>22</td>
<td>229</td>
</tr>
<tr>
<td>71,635</td>
<td>-16</td>
<td>22</td>
<td>224</td>
</tr>
<tr>
<td>48,580</td>
<td>-4</td>
<td>4</td>
<td>211</td>
</tr>
<tr>
<td>27,670</td>
<td>14</td>
<td>16</td>
<td>167</td>
</tr>
<tr>
<td>19,315</td>
<td>26</td>
<td>16</td>
<td>168</td>
</tr>
<tr>
<td>16,330</td>
<td>32</td>
<td>26</td>
<td>158</td>
</tr>
<tr>
<td>9,950</td>
<td>50</td>
<td>127</td>
<td></td>
</tr>
<tr>
<td>6,245</td>
<td>68</td>
<td>88</td>
<td></td>
</tr>
<tr>
<td>5,280</td>
<td>75</td>
<td>88</td>
<td></td>
</tr>
<tr>
<td>4,030</td>
<td>86</td>
<td>73</td>
<td></td>
</tr>
<tr>
<td>2,663</td>
<td>104</td>
<td>54</td>
<td></td>
</tr>
<tr>
<td>1,600</td>
<td>122</td>
<td>39</td>
<td></td>
</tr>
<tr>
<td>1,245</td>
<td>140</td>
<td>29</td>
<td></td>
</tr>
<tr>
<td>875</td>
<td>158</td>
<td>21</td>
<td></td>
</tr>
<tr>
<td>630</td>
<td>176</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td>400</td>
<td>202</td>
<td>10</td>
<td></td>
</tr>
</tbody>
</table>
Inside Air Temperature Sensor

The inside air temperature sensor is an NTC thermistor. It is located in the dashboard within a small grill-like opening. It may also be located in the headliner or near the driver’s door. The sensor provides the HVAC controller with a sample of the inside air temperature. The controller uses this input to determine heating and cooling requirements during the first 10 to 15 minutes of automatic control.

The operation of the inside air temperature sensor is similar to that of the outlet air temperature sensors. At HVAC system startup, the primary input for determining passenger compartment temperature is the inside air temperature sensor. However, AFTER a number of minutes, the controller uses the outlet temperature sensors as the primary inputs.

To provide accurate sensing of the car interior temperature, a small amount of air is drawn into the inside sensor housing and passed over the thermistor. This air movement is accomplished by two means a small motor or the use of an aspirator mounted on the HVAC module box.

The aspirator is a tube-within-a-tube arrangement. A small portion of the main air stream within the module box is discharged through the main outer tube. This exiting air stream causes a suction at the end of the inner tube so that compartment air is drawn into the inside sensor housing and flows out the inner tube at the aspirator.

A substitute temperature value of approximately 75°F (24°C) is used when this sensor fails to allow the HVAC system to continue to operate.

Figure 5-25, Inside Air Temperature Sensor and Aspirator
Upper (A/C) and Lower (Heater) Outlet Temperature Sensors

The upper A/C and lower heater outlet temperature sensors are NTC thermistors. The upper outlet sensor is located in the dashboard center vent duct near the outlet. The lower outlet sensor is located in the heater duct near the outlet.

The upper and lower outlet temperature sensors are used to monitor the discharge temperatures from the heater and A/C outlets.

After some time -10 to 15 minutes - the HVAC controller uses these sensor inputs as the primary inside temperature sensors.

On dual zone systems, upper and lower sensors are use on each side of the dash to monitor temperature on the driver and passenger sides of the vehicle.

The sensors react to the temperature with a resistance change. This causes a change in voltage to the HVAC controller that reflects the temperature values at each sensor.

Based on this voltage signal, the HVAC controller determines heating and/or cooling requirements and makes adjustments accordingly. The controller adjusts the position of the temperature door to meet the set temperature.

Figure 5-26, Inside and Outlet Air Temperature Sensor Circuit

Figure 5-27, Outlet Air Temperature Sensor
Solar (Sunload) Sensor

The sun load sensor is a photoconductive diode. It is designed to allow reverse current flow when exposed to light. It is located on the upper surface of the dashboard near the windshield. Dual zone automatic HVAC systems utilize two sensors, one on side of the dashboard.

Sun load sensors provide the controller with information on the amount of sunlight that is entering the passenger compartment so the controller can adjust the cooling requirement accordingly.

When more sunlight enters the passenger compartment, the heat load on the system increases due to the "greenhouse effect."

The sun load sensor sends a signal to the HVAC controller based on the intensity of the light. Based on this signal, the HVAC controller makes minor adjustments to the blower speed and the temperature and mode doors to compensate for the added heat load.

It is important to note that the operation of the sun load sensor(s) will be affected if covered. This will also impact how the controller determines the cooling requirements. Always make sure the solar sensors are not obstructed when diagnosing an automatic HVAC system.

Certain applications (Catera) will use a solar/twilight sensor (four-wire sensor). This is a photoelectric cell, which means it will produce voltage when exposed to light. On these applications, the photoelectric cell provides two inputs to the HVAC controller. One input is used for solar load and the other is used for the twilight sentinel.

Figure 5-28, Solar (Sunload) Sensor
Lesson 5: Automatic Dual Zone System

Automatic dual zone systems operate like single zone automatic systems. Like the manual dual zone systems, separate ductwork and doors are utilized for the passenger and driver side of the HVAC module. However, there are more sensors.

There are four outlet (duct) sensors, two solar sensors, one inside air temperature sensor, and one ambient air temperature sensor.

Also, the passenger control panel on the automatic dual zone HVAC control systems allows manual control over the passenger side temperature door.

The passenger side temperature control is located on either the passenger side of the main controls or on the dashboard or on the passenger door armrest.

Mode doors on automatic dual zone systems can be controlled by either vacuum solenoids or electrical motors. Temperature doors are controlled by electrical motors. The motors can be either old type five wire motors or new type five-wire motors.

Figure 5-29, Automatic Dual Zone System with Old and New Style Motors
The passenger or driver side temperature control sends signals to the HVAC controller. The HVAC controller will generate two program numbers (0-255) that will be used to command their respective doors to the proper position. Once the system temperature is set all functions of blower, mode door and temperature door will be adjusted to maintained the compartment temperature. Temperature changes are monitored through the outlet, ambient, and inside.

Changes in solar sensor readings generally result in changes to blower speed first to provide added air conditioning in the vehicle. If further cooling is needed then mode and temperature doors position adjustments will occur.

![Figure 5-30, Automatic Dual Zone System with Multiple Sensors](image)

Note:

When diagnosing battery draws on cars/trucks equipped with the automatic dual zone HVAC controls (RPO CJ2), technicians should keep in mind that the control head does not completely "go to sleep" until after 150-250 minutes, or up to 4-¼ hours, from when the ignition key is turned OFF. This is a normal condition. In these cases, DO NOT replace the control head.
Lesson 6: Automatic Rear HVAC System

The Automatic HVAC systems can have the option of being configured with either a manual or automatic (rear) auxiliary system. This lesson will discuss a variety of GM SUV’s and luxury vehicles utilizing the automatic rear HVAC systems.

Suburban, Escalade, Denali, Avalanche Automatic Rear HVAC

The number of auxiliary HVAC controls on these vehicles is dependent upon whether or not the vehicle is equipped with a sunroof. An automatic auxiliary HVAC system is only available without a sunroof. The automatic primary and auxiliary HVAC systems communicate using keyboard data display (KDD) protocol. The automatic primary system communicates with the rear auxiliary HVAC control module. It can be identified by the wording Computer Climate Control on the front faceplate of the auxiliary control modules.

The front auxiliary HVAC control assembly provides inputs to the rear auxiliary HVAC control module. It is located in the overhead console so that front seat occupants can control auxiliary HVAC operation. This assembly provides blower, air delivery mode, air temperature settings and control of which unit will operate the auxiliary HVAC system. When the REAR position is selected, inputs from this control assembly will not be processed by the rear auxiliary HVAC control module. Only the rear seat occupants can control the HVAC settings. When (front auxiliary) OFF position is selected the auxiliary system is inoperative.

Figure 5-31, Automatic Rear HVAC Control Head (2003 Suburban)
When AUTO is selected on the front auxiliary HVAC assembly, the rear auxiliary HVAC control module processes and controls all aspects of the automatic auxiliary HVAC system. The system receives inputs from the auxiliary upper air temperature sensor, auxiliary lower air temperature sensor, infrared temperature sensor, and feedback signals from the auxiliary mode actuator and the auxiliary air temperature actuator. Inputs from the front auxiliary HVAC control assembly also play a part in rear HVAC operations. The outputs are the auxiliary air temperature actuator, auxiliary mode actuator, auxiliary blower motor control processor and data communication with the HVAC control module.

The upper and lower auxiliary air temperature sensors are Negative temperature coefficient thermistors. When the air temperature is warm, the sensor resistance and signal voltage is low and vice versa when the temperature is cool. A fixed resistance inside the rear auxiliary control module makes the 5-volt signal circuit a series circuit.

The rear control module monitors the voltage drop of the circuit, which is needed to calculate the air temperature. The ground for the upper and lower auxiliary air temperature sensors are provided by the low reference circuit.

The rear auxiliary HVAC control module will use a default value for the upper and lower auxiliary air temperature signal if there is a fault with the input. The rear auxiliary HVAC control module will use a default to ensure auxiliary operation is still performed. The scan tool value will be the actual reading of the signal circuit. This means if signal circuit is shorted to a ground then the scan tool will read 0 counts. If the signal circuit is more than 5 volts than it will read 255 counts.

![Diagram of Automatic Rear HVAC System (Suburban)]
The auxiliary inside air temperature sensor is an infrared sensor. This component is integral to the rear auxiliary HVAC control module. There is a lens on the front face-plate that must not be cleaned or contaminated. The sensor can detect the amount of heat in the rear of the vehicle.

If the sensor lens is covered or contaminated the sensor cannot make a proper indication of heat. The sensor does not set a DTC. The sensor helps in making the proper automatic calculations to position the auxiliary mode and temperature doors. Starting in 2003, the infrared sensor was replaced with a thermistor design.

The auxiliary air temperature and mode actuator are 5-volt style components that uses the 0-5 volt reference circuit. As the actuator moves the feedback voltage on the door is monitored by the auxiliary HVAC control module. The temperature door position is determined by the inputs of the duct and inside temperature sensors.

The vehicle operator determines the mode setting by placing a mode switch in a desired position. Only upper and lower vent positions are available in the rear of the vehicle.

When the HVAC system is in AUTO setting the interior temperature is maintained by controlling the blower motor, air temperature and mode setting. We have discussed the air temperature controls but a major component that affects overall comfort is the blower motor.

The auxiliary blower motor circulates the air at the rear of the vehicle. The auxiliary blower motor can be controlled by either the auxiliary HVAC controls. With the setting of the front auxiliary control set to REAR position, the rear passenger determines the blower motor's speed by placing a blower motor switch in a desired speed position or by selecting automatic operation.

When any blower speed is selected on either of the auxiliary controls, the modules send a pulse width modulated (PWM) signal to the auxiliary blower. The speed remains constant until a new speed is selected. In automatic operation, the auxiliary HVAC module will determine what auxiliary blower speed is necessary in order to maintain desired temperatures. At startup in colder temperatures, the auxiliary blower motor will not begin operation at the same time as the primary blower motor. Warm coolant is circulated to the auxiliary heater core before the blower motor begins operating.
Lesson 7: Steering Wheel Controls

Steering wheel controls were added to some vehicles for driver safety and convenience in operating the HVAC or radio systems. Steering wheel controls were first introduced at a time when vehicles did not have airbags. The introduction of airbags made it necessary to adapt digital steering wheel controls of the past to a different technology. As a result, analog steering wheel controls are now typically found on airbag equipped vehicles. Analog steering wheel controls systems are used to provide communication from the steering wheel to the HVAC controller by means of hardwire connections rather than the complex designs of the past.

![Figure 5-34, Analog Steering Control](image)

The analog steering wheel controls are very similarly configured across vehicles because of the airbag limitations. All analog steering wheel control systems, commonly called SWC systems, allow the driver to change fan speed and the temperature settings. The steering wheel control consists of buttons mounted on either side of the airbag. In some vehicles, an interface box is used for communication on the E & C data line. In other vehicles, the radio is used as the interface.
A single line is used to carry the analog voltage from the button pad to the interface box or directly to the radio control head or to the dash integration module (DIM). Each button operates a switch that provides a different voltage drop. The amount of voltage drop depends on the number of resistors placed in the series circuit (Figure 5-35). Current flows through the resistors in a series through the SIR coil to the interface (DIM) or radio which in turn sends a command to the HVAC controller through the class 2 bus or E & C data line.

The HVAC controller carries out the command as if it had come from the instrument panel control head.

Figure 5-35, Analog Steering Wheel Control Circuit
The digital systems use a very elaborate optical-electrical network to transfer signals from the steering wheel to the E&C – entertainment and convenience – data line. When a selection is made on the steering control head, a signal is sent to the cancel cam assembly.

This triggers the appropriate optical emitter signal. The receiver transistor then sends this signal to the heater-A/C and radio interface module, which is transmitted over the E & C data line.
Lesson 8: Automatic HVAC System Diagnosis

General Motors provides specific A/C system "Strategy Based Diagnostic" charts and procedures for their various models and model years. These procedures should always be referred to during system diagnosis and repair because of the many changes that may occur by vehicle model, manufacturing year or A/C system content and configuration. Because of these varied systems no universal or standard A/C system diagnostic procedure exists. Yet a properly trained service technician can develop a logical diagnostic strategy by answering three simple questions. These include:

1. **What are the problem symptoms?** This is what has indicated a problem with system operation or component function. Usually, a customer concern with system performance indicates the problem symptoms. If not, the technician should request more information.

2. **What caused the problem symptoms?** This involves using certain diagnostic procedures to identify the cause of the problem. These may range from the technician's knowledge of common system failures and component malfunctions, through a visual inspection of the system for leaks and noise or odor, to specific system tests for control functions, sufficient cooling and overall performance.

3. **How can the problem be fixed?** This usually involves the adjustment, repair, or replacement of one or more components of the system. By accurately diagnosing the root cause of a given problem symptom, the service technician should be able to efficiently correct the problem.
Using a "strategy-based diagnostic thought process," the service technician proceeds from verifying the customer concern, through making quick checks, to performing more detailed diagnostic system checks similar to that shown in the chart in Figure 5-38. This process includes considering that the cause of the A/C performance concern may be traced to one or more of the three HVAC sub-systems. Once a cause has been identified, the technician can then make necessary system repairs and verify that the condition has been eliminated.

![Strategy Based Diagnosis Chart](image)

Figure 5-38, Strategy Based Diagnosis Chart

To troubleshoot problems with HVAC air distribution system controls, several standard charts can serve as a basic foundation for more specific system testing. These include a "Diagnostic Starting Point" Chart - (Heating, Ventilation and Air Conditioning), a "Diagnostic System Check" Chart and a “Symptoms Diagnosis Chart.”
The A/C system visual inspection and diagnostic charts can identify conditions within the air-delivery system. For instance, insufficient discharge air may indicate conditions within the blower motor or fan system. A malfunctioning mode control selector, sticking or damaged air doors/valves, or restrictions in the outlets themselves, may cause improper outlet selection. Not achieving desired temperature settings might be caused by an inoperative temperature door valve, sensor or other controls.

Vehicle "Service Information" (SI) contains diagnostic and service procedures for malfunctions in the air-delivery system. Most often, these conditions can be traced to either electrical control causes and, more rarely, mechanical malfunctions within the HVAC module.

Proper performance of the cooling and air-delivery sub-systems in an HVAC system is essential for proper operation of the refrigeration subsystem.

**Diagnostic Starting Point Chart - Heating, Ventilation and Air Conditioning**

The Heating, Ventilation and Air Conditioning (HVAC) system is divided into three sections. The first, Heating, Ventilation and Air Conditioning, has all procedures that pertain to a HVAC component or function that are not specifically associated with an automatic or manual control system. The second, HVAC Systems-Manual, has all procedures specific to the manual control system. The third, HVAC Systems-Automatic, has the entire procedures specific to the automatic control system.

For systems with DTCs, begin the system diagnosis with the following procedures:

- **Diagnostic System Check - HVAC Systems - Automatic** in HVAC Systems-Automatic

The Diagnostic System Check will provide the following information:

- The identification of the control modules, which command the system.
- The ability of the control modules to communicate through the Class 2 serial data circuit.

The use of the Diagnostic System Check will identify and lead the technician to the correct diagnostic procedure.
Review the Description and Operation information to help you determine the correct symptom diagnostic procedure when a malfunction exists. Reviewing the Description and Operation information will also help you determine if the condition described by the customer is normal operation. The HVAC Description and Operation information is divided into:

- **Air Delivery Description and Operation** in HVAC Systems-Manual
- **Air Temperature Description and Operation** in HVAC Systems-Manual
- **Air Delivery Description and Operation** in HVAC Systems-Automatic
- **Air Temperature Description and Operation** in HVAC Systems-Automatic

The Air Delivery Description and Operation contains the following topics:

- HVAC Control Components
- Air Speed
- Air Distribution
- Recirculation Operation
- Automatic Operation

**Diagnostic System Check Chart - HVAC Systems - Automatic**

**Test Description**

The number(s) below refer to the step number(s) on the diagnostic table.

3. Lack of communication may be due to a partial malfunction of the class 2 serial data circuit or due to a total malfunction of the class 2 serial data circuit. The specified procedure will determine the particular condition.

5. Determine if the Driver Door Module, Powertrain Control Module, Instrument Panel Integration Module or Dash Integration Module has set DTCs, which may affect HVAC operation, are present.

6. The presence of DTCs, which begin, with "U" indicate some other module is not communicating. The specified procedure will compile all the available information before tests are performed.

7. Answer Yes if the first three characters of the DTC name begin with B10; regardless of the last two characters. If a B1000 code is set, answer "No" to the question.

8. Be sure to follow the diagnostic table for B1000 in the HVAC Systems-Automatic section. Do not use the table in Body Control System. Check History Diagnostic Trouble Code(s) on the scan tool before proceeding.
<table>
<thead>
<tr>
<th>Step</th>
<th>Action</th>
<th>Yes</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Did you review A Diagnostic Starting Point - Heating, Ventilation and Air Conditioning?</td>
<td>Go to Step 2</td>
<td>Go to Diagnostic Starting Point - Heating, Ventilation and Air Conditioning in Heating, Ventilation and Air Conditioning</td>
</tr>
<tr>
<td>2</td>
<td>Install a scan tool.</td>
<td>Go to Step 3</td>
<td>Go to Scan Tool Does Not Power Up in Data Link Communications</td>
</tr>
<tr>
<td>3</td>
<td>1. Turn ON the ignition, with the engine OFF.</td>
<td></td>
<td>Go to Scan Tool Does Not Communicate with Class 2 Device in Data Link Communications</td>
</tr>
<tr>
<td></td>
<td>2. Attempt to establish communication with the following control modules:</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>o Driver Door Module</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>o Powertrain Control Module</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>o Instrument Panel Integration Module</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>o Dash Integration Module</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Does the scan tool communicate with the control modules?</td>
<td>Go to Step 4</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td><strong>Important</strong></td>
<td></td>
<td>Go to Power Mode Mismatch in Body Control System</td>
</tr>
<tr>
<td></td>
<td>The engine may start during the following step. Turn OFF the engine as soon as you have observed the Crank power mode.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>1. Access the Class 2 Power Mode in the Diagnostic Circuit Check on the scan tool.</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>2. Rotate the ignition switch through all positions while observing the ignition switch power mode parameter.</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Select the display DTCs function on the scan tool for the following control modules:
- Driver Door Module
- Powertrain Control Module
- Instrument Panel Integration Module
- Dash Integration Module

Does the scan tool display any DTCs?

<table>
<thead>
<tr>
<th>Step</th>
<th>Description</th>
<th>Go to</th>
</tr>
</thead>
<tbody>
<tr>
<td>5</td>
<td>Does the scan tool display any DTCs, which begin with a &quot;U&quot;?</td>
<td>Step 6</td>
</tr>
<tr>
<td>6</td>
<td>Does the scan tool display any DTCs, which begin with a &quot;U&quot;?</td>
<td>Scan Tool Does Not Communicate with Class 2 Device in Data Link Communications</td>
</tr>
<tr>
<td>7</td>
<td>Does the scan tool display DTC B10XX, except B1000?</td>
<td>Diagnostic Trouble Code (DTC) List in Body Control System</td>
</tr>
<tr>
<td>8</td>
<td>Does the scan tool display DTC B1327?</td>
<td>Diagnostic Trouble Code (DTC) List in Engine Electrical</td>
</tr>
<tr>
<td>9</td>
<td>Does the scan tool display any DTCs, which are not associated with the HVAC system?</td>
<td>Diagnostic Trouble Code (DTC) List in Engine Controls - 3.8 L</td>
</tr>
</tbody>
</table>
Symptoms Chart - HVAC Systems - Automatic

Important

The following steps must be completed before using the symptom tables.

1. Perform the Diagnostic System Check - HVAC Systems - Automatic before using the Symptom Tables in order to verify that all of the following are true:
   - There are no DTCs set.
   - The control modules can communicate via the serial data link.

2. Review the system operation in order to familiarize yourself with the system functions. Refer to:
   - Air Delivery Description and Operation
   - Air Temperature Description and Operation

Visual/Physical Inspection

- Inspect for aftermarket devices, which could affect the operation of the HVAC System. Refer to Checking Aftermarket Accessories in Wiring Systems.
- Inspect the easily accessible or visible system components for obvious damage or conditions, which could cause the symptom.
- Verify the A/C compressor clutch turns freely and is not seized.
- Verify that the customer is using the correct key to enable personalization and is not inadvertently activating steering wheel or passenger HVAC controls, if equipped.
- The A/C compressor will not operate in cold ambient air temperatures. Refer to Air Temperature Description and Operation.
- The following conditions may cause window fogging:
  - Wet carpet or mats
  - High humidity
  - Interior water leak
  - Blocked A/C evaporator drain tube
  - Maximum passenger capacity
  - Blocked body pressure relief valves
- Inspect the air distribution system for causes of reduced air flow:
  - Obstructed or dirty passenger compartment air filter, if equipped
  - Blocked or damaged air inlet or outlet vents
Intermittent
Faulty electrical connections or wiring may be the cause of intermittent conditions. Refer to Testing for Intermittent and Poor Connections in Wiring Systems.

Symptom List
Refer to a symptom diagnostic procedure from the following list in order to diagnose the symptom:

- HVAC Compressor Clutch Does Not Engage
- HVAC Compressor Clutch Does Not Disengage
- Blower Motor Always On
- Blower Motor Inoperative
- Blower Motor Malfunction
- Temperature Variation Between Driver and Passenger Outlets
- Control Head Illumination/Display Does Not Operate Properly
- Too Hot in Vehicle
- Too Cold in Vehicle
- Outside Air Temperature Display Inaccurate or Inoperative
- Steering Wheel Controls Inoperative
- Passenger HVAC Control Does Not Operate Properly
- Air Delivery Improper
- Air Conditioning (A/C) System Does Not Maintain Set Temperature
- Air Recirculation Malfunction
- Afterblow Enable Procedure
- Leak Testing in Heating, Ventilation and Air Conditioning
- Noise Diagnosis - Blower Motor in Heating, Ventilation and Air Conditioning
- Noise Diagnosis - Air Conditioning (A/C) System in Heating, Ventilation and Air Conditioning
- Noise Diagnosis - HVAC Module in Heating, Ventilation and Air Conditioning
- Odor Diagnosis in Heating, Ventilation and Air Conditioning
Module #5 Post-test
Read each question carefully and choose the correct response.

1. Which of the following is a true statement about automatic HVAC control systems:
   a. Sensors provide all the inputs.
   b. The compressor does not run in all modes.
   c. The operator provides all input.
   d. The operator selects blower speed.

2. Which of the following is located on top of the dashboard:
   a. Sun Load Sensor
   b. Outlet Air Temperature Sensor
   c. Inside Air Temperature Sensor
   d. Ambient Air Sensor

3. After the cold purge mode is complete, the HVAC Controller automatically switches to:
   a. The A/C Purge mode
   b. The IPC Cooling mode
   c. Normal Operation
   d. The Defrost mode

4. In the manual mode of automatic HVAC control systems:
   a. Fan speed will vary according to various speeds.
   b. Fan speed will vary according to temperature sensor inputs.
   c. The position of the temperature door will vary once a temperature is selected.
   d. The HVAC controller will try to maintain set temperature as much as possible.
5. The primary function of outlet temperature sensors is to:
   a. Prevent evaporator freeze up.
   b. Monitor the discharge temperature from the heater and A/C duct outlets.
   c. Measure sunlight intensity.
   d. Determine if the outside temperature exceeds the set temperature.

6. When a customer sets the temperature in an automatic HVAC control system, the system can automatically regulate:
   a. Inside air temperature if the programmed number does not exceed 100°F.
   b. Inside air temperature only if the programmed number exceeds 100°F.
   c. Inside air temperature only if the outside air temperature is between 65° and 85°F.
   d. Inside air temperature from 65° to 85°F regardless of outside air temperature.

7. In analog steering wheel controls:
   a. The amount of voltage drop depends on the number of resistors placed in the series circuit.
   b. The voltage drop depends on the number of resistors placed in parallel.
   c. A very elaborate optical-electrical network is used for signal transfer.
   d. Communication from the steering wheel to the base of the steering column occurs without hardwire connections.

8. Which of the following best represents the difference between single zone and dual zone automatic HVAC control systems?
   a. Number of sensors.
   b. Number of mode doors.
   c. Number of air inlet doors.
   d. Number of air outlets.
9. In analog steering wheel controls, signals are transferred by means of:
   a. Optical signals.
   b. Radio waves.
   c. Optical/Electrical signals.
   d. Electrical signals.

10. Analog steering wheel controls use different __________ as signals to control the HVAC settings.
   a. Radio waves.
   b. Optical pulses.
   c. Voltage drops.
   d. Current flows.

11. HVAC controllers are normally located in the
   a. PCM
   b. Vehicle engine compartment
   c. HVAC module box
   d. Vehicle instrument panel

12. What is the primary function of the sun load sensor?
   a. To provide the controller with information about the temperature inside the vehicle.
   b. To allow the controller to adjust for the amount of sunlight entering the vehicle.
   c. To provide the controller with information about the ambient temperature.
   d. To provide the controller with information about instrument panel overheating.

13. Which of the following statements best describes the auto mode?
   a. The customer can control compression operation.
   b. Sensors provide the only inputs.
   c. The only parameter the customer can control is temperature.
   d. The customer can control blower speed.
14. Pulse Width Modulated (PWM) blower speed will:
   a. vary the average voltage signal from 13 to 15 volts
   b. decrease blower speed with an increase in PWM
   c. operate the blower at four predetermined speeds
   d. increase blower speed with an increase in PWM

15. The reference voltage for the in-car temperature sensors is:
   a. 0-12 volt, variable
   b. 5 volt
   c. 8 volt
   d. 12 volt

16. Based on vehicle operator settings, the controller selects a program number between _________ to maintain set temperature.
   a. 0 and 500
   b. 0 and 255
   c. 1 and 10
   d. 1 and 125

17. When OFF is selected on an automatic HVAC system, the:
   a. blower motor will operate
   b. compressor will operate
   c. controller remains active
   d. set temperature is ignored by the controller

18. After 10 to 15 minutes of AUTO operation, the HVAC controller uses which temperature sensor as the primary input to control SET temperature.
   a. Inside air temperature sensor
   b. Outside air temperature sensor
   c. Outlet temperature sensor(s)
   d. Solar sensor(s)
19. Automatic dual zone systems will have as many as ________
temperature sensors:
   a. 2
   b. 3
   c. 4
   d. 5

20. Automatic rear HVAC systems (Suburban) can use a number of
    ________ sensors to control temperature of the rear seating area.
    a. inside temperature
    b. infrared
    c. outlet sensor
    d. all of the above

21. When an actuator or HVAC controller is replaced on an automatic
    HVAC system, the system must be ____________.
    a. reprogrammed
    b. recalibrated
    c. performance checked
    d. checked for DTC’s

22. If the in-car air temperature sensor fails, the default temperature value
    used by the HVAC controller:
    a. is 65°F
    b. is 75°F
    c. reverts to manual operation
    d. shuts down

23. On a__________ wire actuator motor, the HVAC controller counts the
    commutator segment pulses and converts the them to a. 0-255 binary
    signal.
    a. two
    b. three
    c. five
    d. film
Exercise Lesson 1 & 2
Automatic HVAC Systems Overview

Directions: Use module 5 of the student workbook to answer the following questions.

1. In AUTO Mode, what is the temperature range that the HVAC controller will try to reach and maintain?
   Page: ______

2. Do any automatic HVAC systems use vacuum to control the temperature door?
   Page: ______

3. The HVAC controller uses the program number to determine the control of which HVAC system components in AUTO mode?
   Page: ______

4. In full manual control, what components of the HVAC system are still under the automatic control the controller?
   Page: ______

5. In OFF mode, can the controller operate any of the components of the HVAC system? If yes, which components?
   Page: ______

6. Why is the RECIRC mode not available in DEFROST?
   Page: ______
Exercise Lesson 2
Modes of Operation – Program Number

Directions: Use the classroom vehicle to answer the following questions.

Vehicle Information:
- Make: ________________
- Model: ________________
- Year: ________________

1. What is the range of the program number on this vehicle (0-100% or 0-255 counts)? ________________________________

2. What does a program number of 0% or 0 counts indicate (full cold, full hot or mid-position)? ______________________________

3. What does a program number of 100% or 255 counts indicate (full cold, full hot or mid-position)? ______________________________

4. In AUTO mode, what is the status of the following if 60°F (15°C) is selected as the desired temperature:
   - Program number: ________________________________
   - Airflow path: ________________________________
   - Blower speed: ________________________________
   - Temperature door position: ________________________________

5. In AUTO mode, what is the status of the following if 90°F (32°C) is selected as the desired temperature:
   - Program number: ________________________________
   - Airflow path: ________________________________
   - Blower speed: ________________________________
   - Temperature door position: ________________________________
6. What will be the status of the following if the selected temperature and the in-car temperature are equal?

   Program number: ________________________________
   Airflow path: ________________________________
   Blower speed: ________________________________
   Temperature door position: ________________________________

7. If an air door (mode or temperature) is inoperative or misadjusted, will it have an affect on the program number? Why or why not?
   ______________________________________________________
   ______________________________________________________

8. Is there any adjustment procedures that must be followed after a motor/actuator is replaced? If yes, what are the procedures?
   ______________________________________________________
   ______________________________________________________

9. Insert in the table both the commanded counts and volts (displayed on the TECH 2) for the doors in the modes of operation (some systems will use units other than volts or counts):

<table>
<thead>
<tr>
<th>Mode of Operation</th>
<th>Inlet Mode Door (Counts and Volts)</th>
<th>Outlet Mode Door (Counts and Volts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>DEFROST</td>
<td></td>
<td></td>
</tr>
<tr>
<td>HEATER (FLOOR)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BI-LEVEL</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(MID/FLOOR)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A/C (MID)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>DEFOG</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(WINDSHIELD/FLOOR)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>VENT</td>
<td></td>
<td></td>
</tr>
<tr>
<td>RECIRC</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

10. In the table below, record both the commanded counts and volts for the temperature door(s) with the system in AUTO mode. If the vehicle is not Dual Zone, do not fill out the passenger temperature door information.

<table>
<thead>
<tr>
<th>SET Temperature</th>
<th>Driver Temperature Door (Counts and Volts)</th>
<th>Passenger Temperature Door (Counts and Volts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>60°F</td>
<td></td>
<td></td>
</tr>
<tr>
<td>90°F</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
11. If the commanded counts, volts or other units does not match the actual counts or volts, what could be the malfunction?

______________________________________________________
______________________________________________________

12. Turn the key to the ON position with the engine off. Set the desired temperature to 72°F. Insert, in the table below, the values for the temperature sensors. If the vehicle does not have a specific sensor or information, insert N/A in the table.

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Temperature (F)</th>
<th>Counts</th>
</tr>
</thead>
<tbody>
<tr>
<td>Upper Left Hand Duct Sensor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Upper Right Hand Duct Sensor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower Left Hand Heater Sensor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lower Right hand Heater Sensor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>In-Car Temperature Sensor</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Outside Air Temperature Sensor</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

13. Start the engine and turn the HVAC system to AUTO mode with a SET temperature of 78°F. View the counts, volts or other units for the doors. Based on this information what mode of operation is the HVAC system commanding?

______________________________________________________
______________________________________________________

14. Is it commanding heating or cooling (approximate)?

______________________________________________________
______________________________________________________
Exercise Lesson 3
Special Operating Modes and Blower Control

1. What is the purpose of the A/C Purge mode?
   Page: ________ ________________________________________
   _______________________________________________________

2. How does the pulse-width modulation from the blower module control
   the speed of the blower motor?
   Page: ________ ________________________________________
   _______________________________________________________

3. Why does the controller filter the signal from the outside air
   temperature sensor?
   Page: ________ ________________________________________
   _______________________________________________________

4. What is the purpose of AFTERBLOW?
   Page: ________ ________________________________________
   _______________________________________________________

5. What is the purpose of A/C Purge mode?
   Page: ________ ________________________________________
   _______________________________________________________

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Exercise Lesson 4
Automatic HVAC Service Information

Directions: Answer the following questions using the Service Information (SI) on-line. The service information may not have answers to all of the questions.

Make: ________________
Model: ________________
Year: ________________

1. Place a check mark next to each sensor that is used on this vehicle:
   - In-car sensor
   - Outside sensor
   - Upper right duct sensor
   - Upper left duct sensor
   - Lower right duct sensor
   - Lower left duct sensor
   - Infrared sensor
   - Sunload sensor

2. How does the microprocessor determine when to update the outside air temperature display on the control head? __________________
   ______________________________________________________
   ______________________________________________________

3. How is the outside air temperature display on the control head manually updated on this vehicle? __________________
   ______________________________________________________
   ______________________________________________________
   ______________________________________________________

4. What component and circuit provides ECT DATA to the HVAC controller? __________________
   ______________________________________________________

5. The control head uses what data line to transfer information to the PCM? __________________
   ______________________________________________________

6. What is the Service Information (SI) number that contains the procedures to recalibrate the HVAC air temperature door? __________________
7. How many mode (inlet and outlet) door motors does this vehicle have?

8. During the diagnosis of a vehicle (customer concern: Incorrect airflow), you notice that the airflow is being directed towards the floor. The commanded HTR/DEF/AC door count is 243. The actual door count is 123 and the program number is 255. What could be the fault?
Exercise Lesson 8

Automatic HVAC Controls Diagnosis

Directions: Answer the following questions using the (SI) Service Information and a systematic procedure of “Strategy Based Diagnosis.” Diagnose and repair the following vehicle problem that has been set-up by your instructor.

Customer Concern: Owner of a 2002 S-10 Blazer 4WD
- No cold air for several days
- Blows only warm air

Step 1: Verify Customer Concern(s)

Does cold air come out of vent outlets? YES NO

Does Temperature of air change when setting is changed? YES NO

Is the problem intermediate? YES NO

Step 2: Preliminary Checks

Inspect the fuses and electrical connections.

Any problems found? YES NO

If so, describe problem. ________________________________________________________________

____________________________________________________________________________________

____________________________________________________________________________________
Step 3: Perform Diagnostic System Check

Perform a diagnostic system check as outlined in service information. Confirm system for proper and improper operation. You already know that the system blows no cold air.

Connect a scan tool to the DLC

Any trouble code(s) found? YES NO

If so, what code(s) was found? ________________________________

According to the diagnostic system check, where would you proceed next? ______________________________________________________

Step 4: Check for Bulletins

Check for bulletins using “Service Information” (SI).

Were any bulletins found related to the customers concern? YES NO

If so, what bulletin? __________________________________________

Step 5: Diagnosis

You will now proceed to troubleshoot the problem by using the appropriate chart. Keep in mind, you have already checked for DTC codes and have found B0161.

What chart will you be using to diagnose the problem? _____________

The chart tells you to change your scan data display DTC function to the real time sensor data function for ambient air.
The specifications is _____________°F to ______________°F

Is the ambient air data reading within the specified range?  YES  NO
What is the reading? ______________________________________
________________________________________________________

The next step of the diagnosis process asks you to disconnect the ambient sensor and read the scan data for the outside temperature sensor to see if it affects the circuit.

What does it read? ______________________________________
________________________________________________________

What does the reading tell you about the ambient sensor circuit?
________________________________________________________
________________________________________________________
As you progress to the next step use a fused jumper across the ambient connector and note the scan reading of the "outside temperature sensor."

What is the reading? ________________________________________

What does the reading tell you about the circuit?

__________________________________________________________

__________________________________________________________

Step 6: Isolate the Root Cause

The final step of the chart indicates to check the connectors on both ends of the ambient sensor harness. After checking you determine that the problem is: (Final solution to problem)

__________________________________________________________

__________________________________________________________

__________________________________________________________

Step 7: Repair and Verify Fix

Check with the instructor as to repairing the problem.