Fuel Delivery and Air Induction: Description and Operation
Standard Models (Non BI-Fuel)

Fuel Systems

FUEL SYSTEMS

Overview

The fuel system supplies the Sequential Multiport Fuel Injection **(SFI)** fuel injectors with clean fuel at controlled pressure. The Powertrain Control Module **(PCM)** controls the fuel pump and monitors the fuel pump circuit. The PCM also controls the duration of the on/off cycle providing correct timing of the fuel injectors. If the injectors have been replaced, it is necessary to clear learned values contained in the Keep Alive Random Access Memory **(KAM)** in the PCM. This can be done by disconnecting the battery or the PCM for **five minutes**. (Refer to Section 2, Resetting The Keep Alive Memory (KAM), for more information).

The three types of fuel Systems used are:

^ Returnable Fuel
^ Mechanical Returnless Fuel
^ Electronic Returnless Fuel

Returnable Fuel System

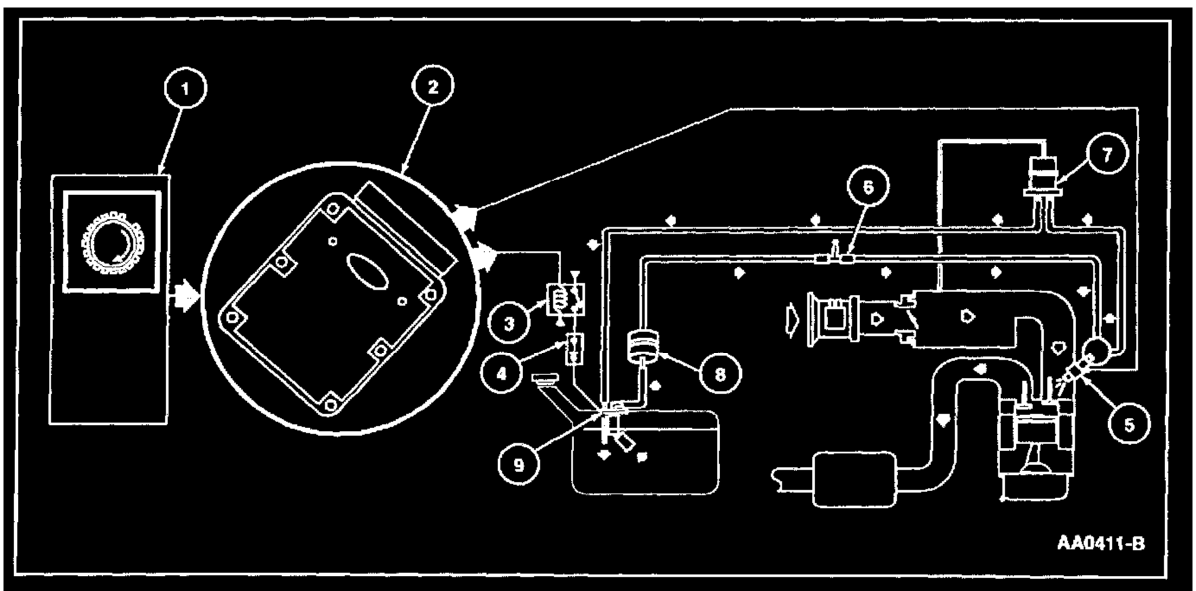


Figure 64: Fuel System - All others

Fuel System

The fuel system consists of a fuel tank with a reservoir, fuel pump module, fuel supply lines, fuel filter(s), schrader/pressure test point, fuel rail, fuel injectors, and fuel pressure regulator. Operation of the system is as follows (refer to (Figure 63) for all others):

1. The fuel delivery system uses the Crankshaft Position **(CKP)** sensor to signal the PCM that the engine is either cranking or running.
2. The fuel pump logic is defined in the Fuel System control strategy and is executed in the PCM. The PCM will ground the fuel pump relay for **one second** during key on and engine off. During crank the fuel pump relay is grounded as long as the PCM receives a CKP signal.
3. The fuel pump relay has a primary and a secondary circuit. The primary side is controlled by the PCM and the secondary side provides B+ to the fuel pump circuit when the relay is energized.
4. The Inertia Fuel Shut-Off **(IFS)** switch is used to de-energize the fuel delivery secondary circuit in the event of a collision. The IFS Switch is a safety device that should only be reset after a thorough inspection of the vehicle (following a collision).
5. The fuel injector is a solenoid-operated valve that meters fuel flow to each combustion cylinder. The fuel injector is opened and closed a constant number of times per crankshaft revolution. The amount of fuel is controlled by length of time the fuel injector is held open. The injector is normally closed and is operated by **12 volt** Vehicle Power **(VPWR)** from the power relay. The ground signal is controlled by the PCM.
6. A pressure test point valve (schrader valve) is located on the fuel rail. This is used to measure fuel injector supply pressure for service and diagnostic procedures. ON VEHICLES NOT EQUIPPED WITH A SCHRADER VALVE, USE ROTUNDA FUEL PRESSURE TEST KIT #134-R0087 OR EQUIVALENT.
7. The fuel pressure regulator is attached to the fuel rail downstream of the fuel injectors. It regulates fuel pressure supplied to the fuel injectors.

The fuel pressure regulator is a diaphragm-operated relief valve. One side of the diaphragm senses fuel pressure and the other side is connected to the intake manifold vacuum. Fuel pressure is established by a spring preload applied to the diaphragm. Balancing one side of the diaphragm with manifold vacuum maintains a constant fuel pressure drop across the fuel injectors. Fuel pressure is high when engine vacuum is low. Excess fuel is bypassed through the fuel pressure regulator and returned through the fuel return line to the fuel tank.

8. There are four filtering or screening devices in the fuel delivery system. The fuel intake sock or screen is a fine, nylon mesh mounted on the intake side of the fuel pump. There is a fuel filter screen located at the fuel rail side of the fuel injector. A fuel filter/screen is located in the inlet side of the fuel pressure regulator. The fuel filter assembly is located between the fuel pump and the pressure test point/schrader valve.
9. The Fuel Pump **(FP)** module is a device that contains both fuel pump and fuel sender assembly. The fuel pump is located inside the reservoir and supplies fuel through the fuel pump module manifold to the engine and the fuel pump module jet pump.

NOTE: Some vehicles have the relay located in the Power Distribution Box.

Mechanical Returnless Fuel System

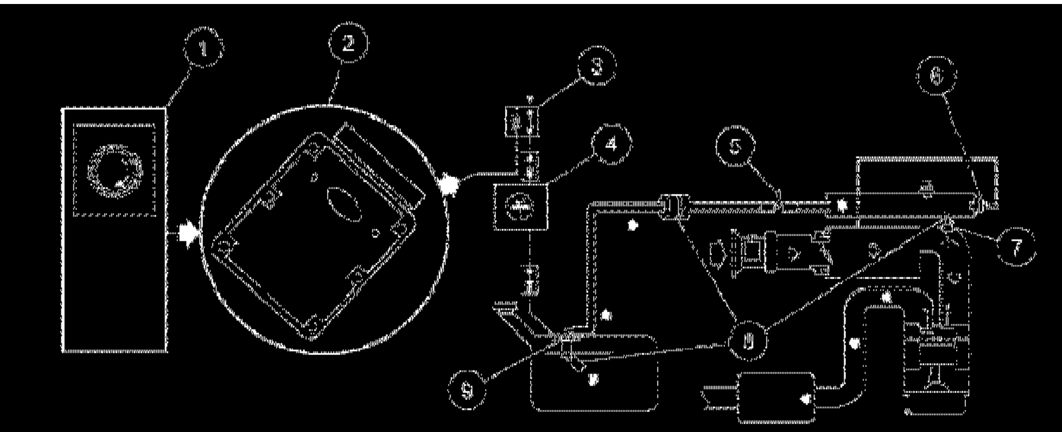


Figure 65: Fuel System—Mechanical Returnless

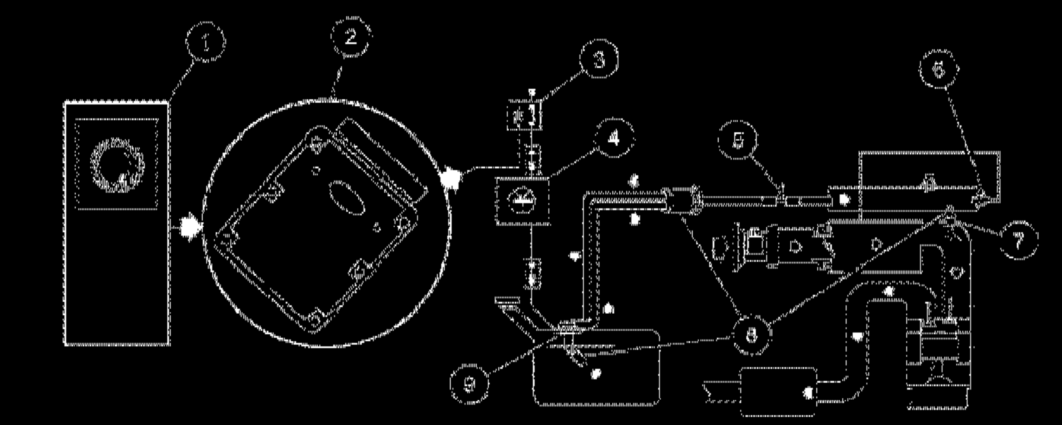


Figure 66: Fuel System—Mechanical Returnless with 3-Port Filter

The fuel system consists of a fuel tank with reservoir, fuel pump, fuel pressure regulator, fuel filter, fuel supply line, fuel rail, fuel rail pulse damper, fuel injectors, and schrader/pressure test point. Operation of the system is as follows (Figure 65) or (Figure 66):

1. The fuel delivery system is enabled during crank or running mode once the PCM receives a crankshaft position (CKP) sensor signal.
2. The fuel pump logic is defined in the fuel system control strategy and is executed by the PCM.
3. The PCM grounds the fuel pump relay, which provides VPWR to the fuel pump.
4. The inertia fuel shut-off (IFS) switch is used to de-energize the fuel delivery secondary circuit in the event of collision. The IFS switch is a safety device that should only be reset after a thorough inspection of the vehicle (following a collision).
5. A pressure test point valve (schrader valve) is located on the fuel rail. This is used to measure fuel injector supply pressure for diagnostic procedures and repairs. ON VEHICLES NOT EQUIPPED WITH A SCHRADER VALVE, USE ROTUNDA FUEL PRESSURE TEST KIT #134-R0087 OR EQUIVALENT.
6. Located on the fuel rail is a pulse damper. The pulse damper reduces fuel system noise caused by the pulsing of the fuel injectors. The

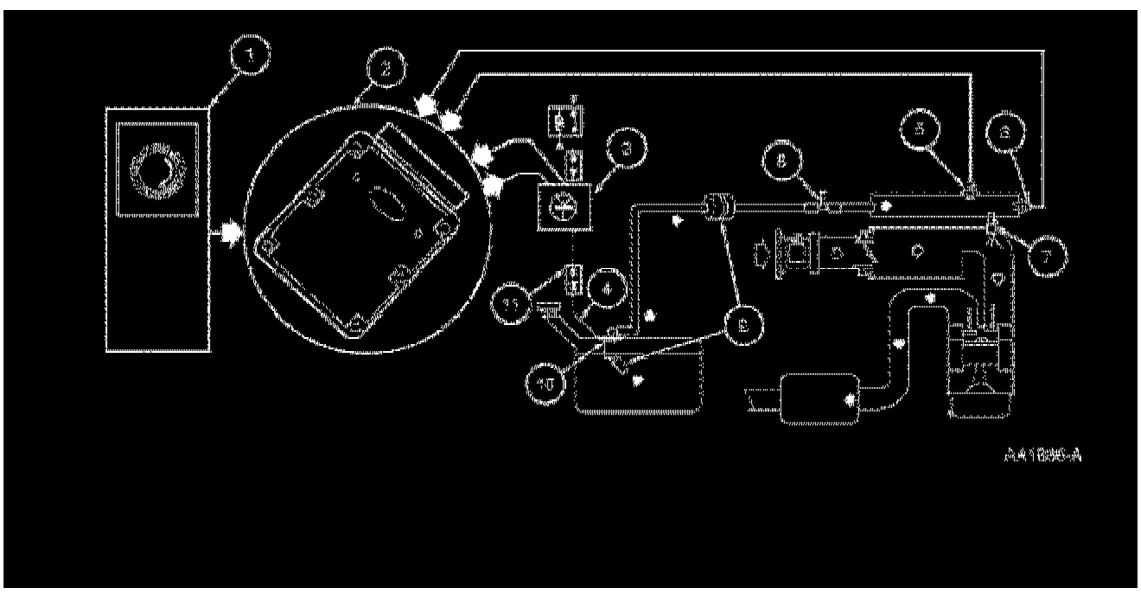
vacuum port located on the damper is connected to manifold vacuum to avoid fuel spillage in the event the pulse damper diaphragm were to rupture (the pulse damper should not be confused with a fuel pressure regulator).

7. The fuel injector is a solenoid-operated valve that meters the fuel flow to each combustion cylinder. The fuel injector is opened and closed a constant number of times per crankshaft revolution. The amount of fuel is controlled by the length of time the fuel injector is held open. The injector is normally closed and is operated by **12 volt** VPWR from the power relay. The ground signal is controlled by the PCM.
8. There are three filtering or screening devices in the fuel delivery system. The intake sock is a fine, nylon mesh screen mounted on the intake side of the fuel pump. There is a fuel filter screen located at the fuel rail side of the fuel injector. The fuel filter assembly is located between the fuel pump and the pressure test point/schrader valve.
9. The fuel pump (FP) module contains the fuel pump, fuel pressure regulator and the fuel sender assembly. The fuel pressure regulator is attached to the fuel pump in the fuel pump module located in the fuel tank. It regulates fuel pressure supplied to the fuel injectors. The fuel pressure regulator is a diaphragm-operated relief valve. Fuel pressure is established by a spring preload applied to the diaphragm. Excess fuel is bypassed through the regulator and returned to the fuel tank.

Electronic Returnless Fuel System

The fuel system consists of a fuel tank with reservoir, fuel pump, fuel rail pressure sensor, fuel filter, fuel supply line, engine fuel temperature sensor, fuel rail, fuel injectors, and schrader/pressure test point. Operation of the system is as follows (Figure 65) and (Figure 66):

1. The fuel delivery system is enabled during crank or running mode once the PCM receives a crankshaft position (CKP) sensor signal.
2. The fuel pump logic is defined in the fuel system control strategy and is executed by the PCM.
3. The PCM commands a duty cycle to the Fuel Pump Driver Module **(FPDM)**.
4. The fuel pump driver module modulates the voltage to the fuel pump (FP) to achieve the proper fuel pressure. Voltage for the fuel pump is supplied by the power relay or FPDM power supply relay. (For additional information on FPDM operation, refer to PCM Outputs-Fuel Pump and PCM Inputs-FPM.)
5. The Fuel Rail Pressure **(FRP)** sensor provides the PCM with the current fuel rail pressure. The PCM uses this information to vary the duty cycle output to the FPDM to compensate for varying loads.
6. The Engine Fuel Temperature **(EFT)** sensor measures current fuel temperatures in the fuel rail. This information is used to vary the fuel pressure and avoid fuel system vaporization.
7. The fuel injector is a solenoid-operated valve that meters the fuel flow to each combustion cylinder. The fuel injector is opened and closed a constant number of times per crankshaft revolution. The amount of fuel is controlled by the length of time the fuel injector is held open. The injector is normally closed and is operated by **12 volt** VPWR from the power relay. The ground signal is controlled by the PCM.
8. A pressure test point valve (schrader valve) is located on the fuel rail. This is used to measure fuel injector supply pressure for diagnostic procedures and repairs. ON VEHICLES NOT EQUIPPED WITH A SCHRADER VALVE, USE ROTUNDA FUEL PRESSURE TEST KIT #134-R0087 OR EQUIVALENT.
9. There are three filtering or screening devices in the fuel delivery system. The intake sock is a fine, nylon mesh screen mounted on the intake side of the fuel pump. There is a fuel filter screen located at the fuel rail side of the fuel injector. The fuel filter assembly is located between the fuel pump and the pressure test point/schrader valve.
10. The fuel pump (FP) module is a device that contains the fuel pump and the fuel sender assembly. The fuel pump is located inside the reservoir and supplies fuel through the fuel pump module manifold to the engine and the fuel pump module jet pump.
11. The inertia fuel shut-off (IFS) switch is used to de-energize the fuel delivery secondary circuit in the event of a collision. The IFS switch is a safety device that should only be reset after a thorough inspection of the vehicle (following a collision).



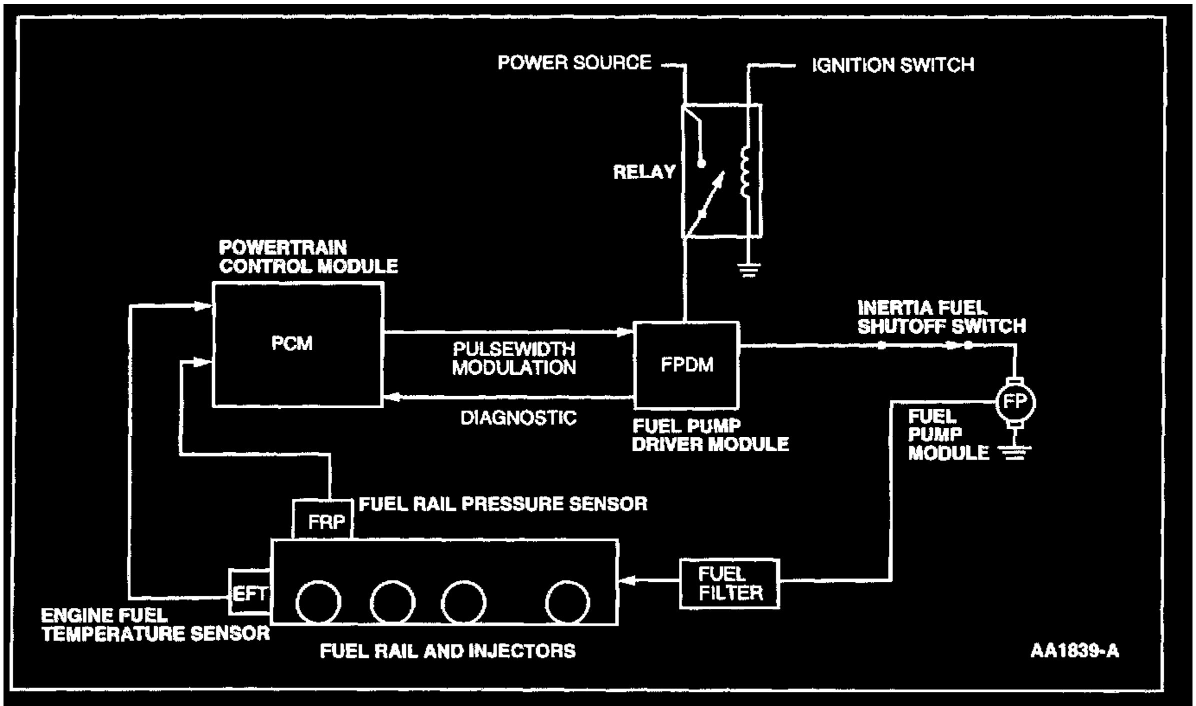


Figure 68: Typical Electronic Returnless Fuel System Schematic (NOTE: See wiring diagram for proper power source and relay usage.)

Electronic Returnless Fuel System Schematic

Fuel Pump and Reservoir

The fuel pump module is mounted inside the fuel tank in a reservoir. The pump has a discharge check valve that maintains system pressure after the ignition key has been turned off to minimize starting concerns. The reservoir prevents fuel flow interruptions during extreme vehicle maneuvers with low tank fill levels.

Fuel Pump Module

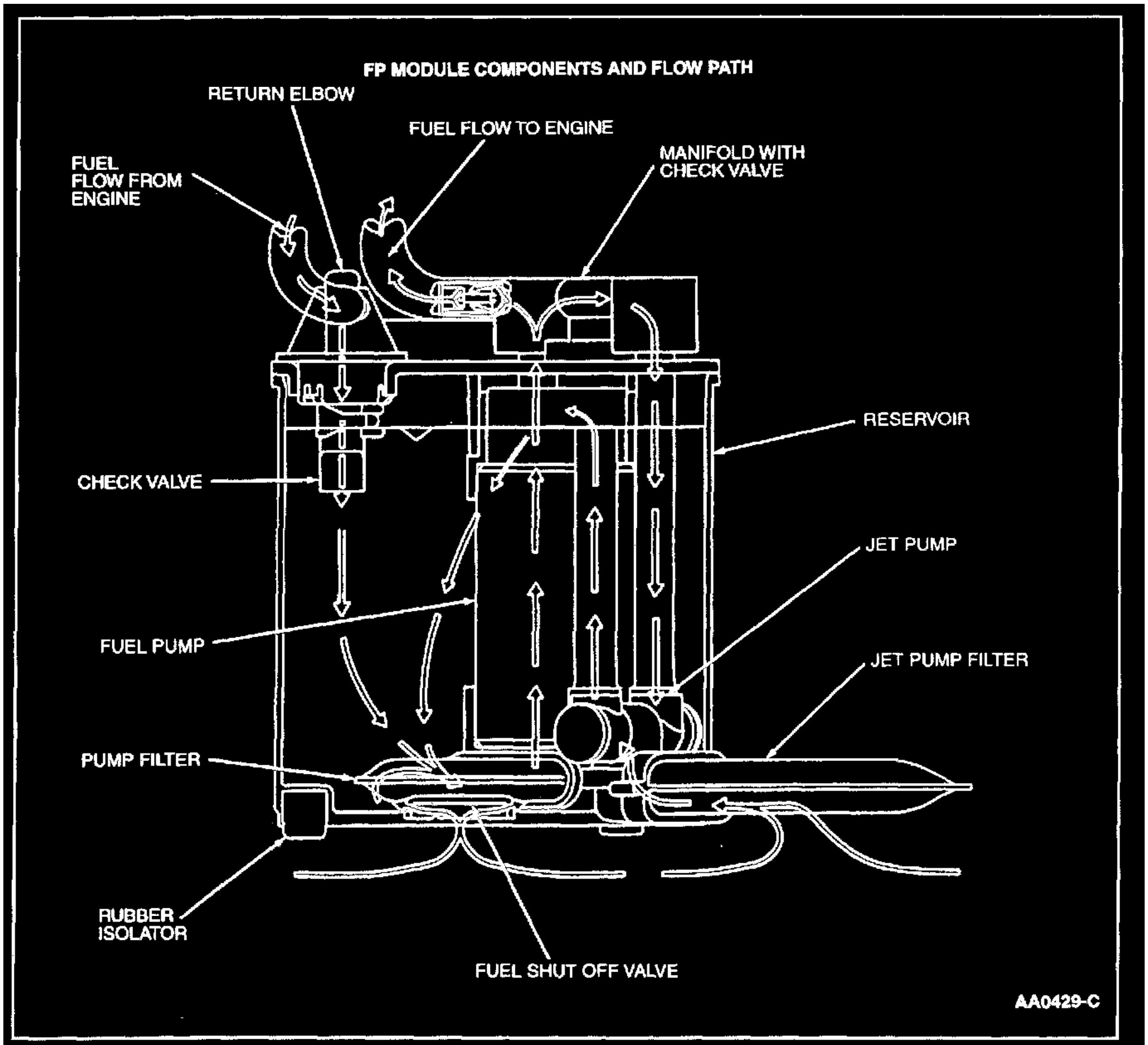
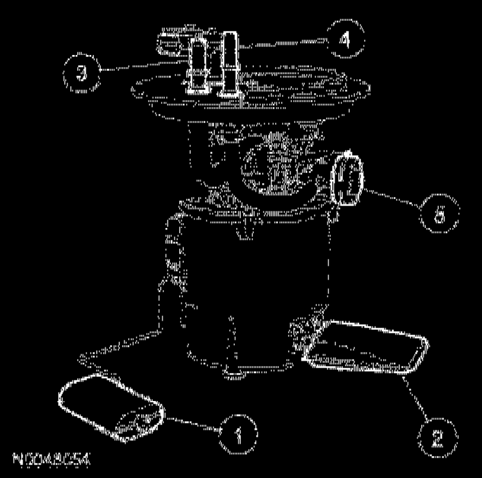


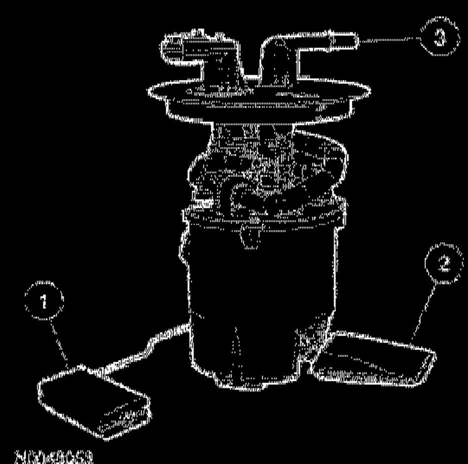
Figure 69: Fuel Pump Module (For Returnable Fuel Systems)

Fuel Pump Module



Item	Number	Description
1	—	Fuel Level Float
2	—	Fuel Intake Filter
3	—	Fuel Supply
4	—	Fuel Return from Fuel Filter
5	—	Fuel Pressure Regulator

Figure 70.



Item	Number	Description
1	—	Fuel Level Float
2	—	Fuel Intake Filter
3	—	Fuel Supply

Figure 71.

The fuel pump (FP) module is a device that contains the fuel pump and sender assembly. The fuel pump is located inside the FP module reservoir and supplies fuel through the FP module manifold to the engine and FP module jet pump. The jet pump continuously refills the reservoir with fuel, and a check valve located in the manifold outlet maintains system pressure when the fuel pump is not energized. A flapper valve located in the bottom of the reservoir allows fuel to enter the reservoir and prime the fuel pump during the initial fill.

Fuel Filters

The system contains four filtering or screening devices. Refer to the individual component pictorial for location.

1. The fuel intake sock or screen is a fine nylon mesh sock mounted on the intake side of the fuel pump. It is part of the assembly and cannot be serviced separately.
2. The filter/screen at the fuel rail port of the Injectors is part of the fuel injector assembly and cannot be serviced separately.
3. The filter/screen at fuel inlet side of the fuel pressure regulator is part of the regulator assembly and cannot be serviced separately.
4. The fuel filter assembly is located between the fuel pump (tank) and the pressure test point (schrader valve) or Injectors. This filter may be serviced.

Pressure Test Point

There is a pressure test point with a schrader fitting in the fuel rail that relieves fuel pressure and measures the fuel injector supply pressure for service and diagnostic procedures. Before servicing or testing the fuel system, read any CAUTION, WARNING, and HANDLING information. ON VEHICLES NOT EQUIPPED WITH A SCHRADER VALVE, USE ROTUNDA FUEL PRESSURE TEST KIT #134-R0087 OR EQUIVALENT.

Fuel Injector

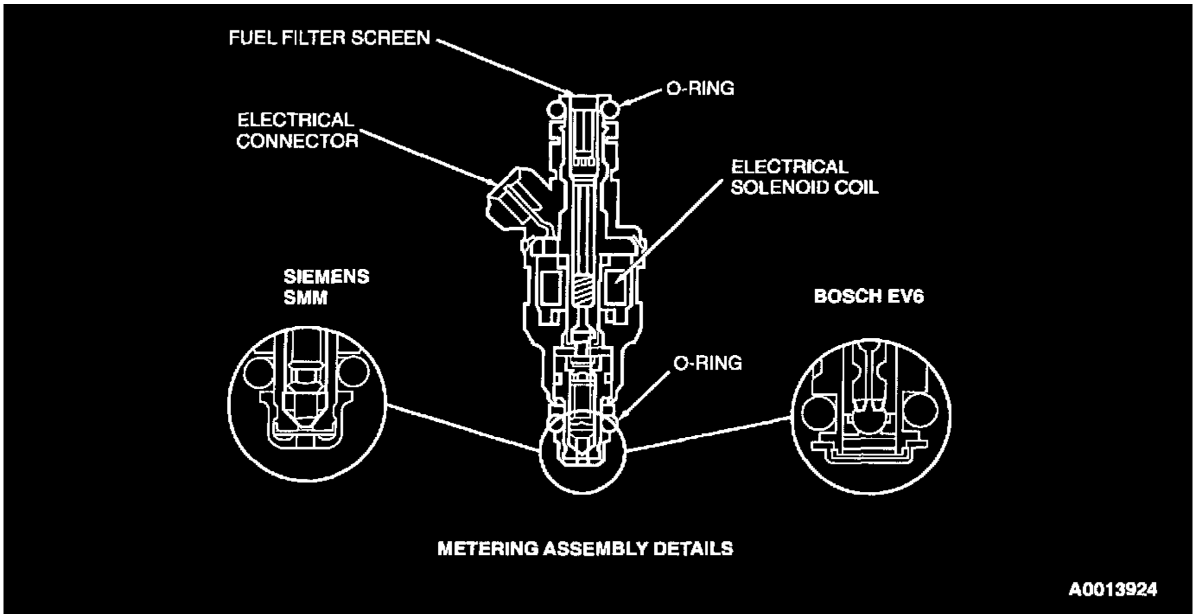


Figure 72: Fuel Injectors

Fuel Injectors

The fuel injector (Figure 70) is a solenoid-operated valve that meters fuel flow to the engine. The fuel injector is opened and closed a constant number of times per crankshaft revolution. The amount of fuel is controlled by the length of time the fuel injector is held open.

The fuel injector is normally closed and is operated by **12 volt** VPWR from the electronic engine control power relay. The ground signal is controlled by the PCM.

CAUTION: Do not apply battery positive voltage (B+) directly to the fuel injector electrical connector terminals. The solenoids may be damaged internally in a matter of seconds.

The injector is the Deposit Resistant Injection **(DRI)** type and does not have to be cleaned. However, it can be flow checked and, if found outside of specification, the fuel injector should be replaced.

Fuel Pressure Regulator

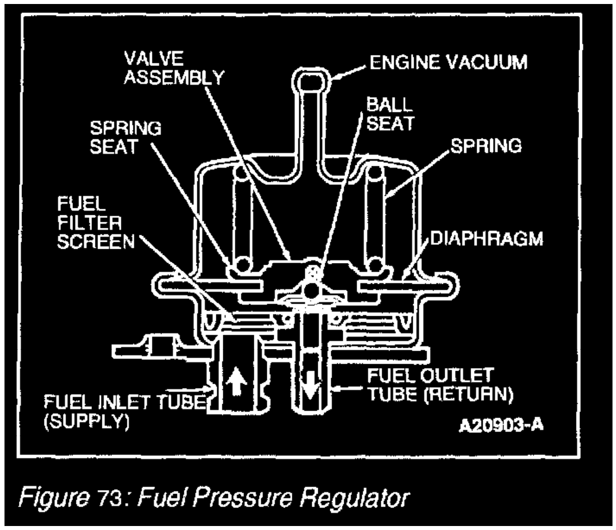


Figure 73: Fuel Pressure Regulator

Fuel Pressure Regulator

The fuel pressure regulator (Figure 71) is attached to the fuel rail downstream of the fuel injectors. It regulates fuel pressure supplied to the fuel injectors. The regulator is a diaphragm-operated relief valve. One side of the diaphragm senses fuel pressure and the other side is connected to the intake manifold vacuum. Fuel pressure is established by a spring preload applied to the diaphragm. Balancing one side of the diaphragm with manifold vacuum maintains a constant fuel pressure drop across the fuel injectors. Fuel pressure is high when engine vacuum is low. Excess fuel is bypassed through the fuel pressure regulator and returned through the fuel return line to the fuel tank.

Fuel Rail Pulse Damper

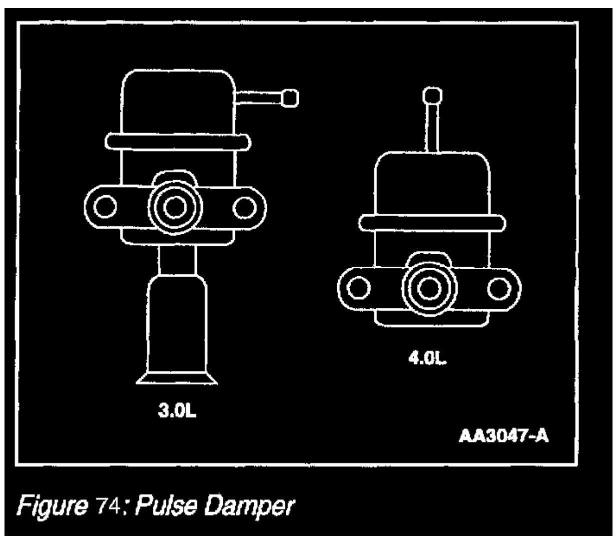


Figure 74: Pulse Damper

Pulse Damper

The fuel rail pulse damper (Figure 72) located on the fuel rail reduces fuel system noise caused by the pulsing of the fuel injectors. The vacuum port located on the damper is connected to manifold vacuum to avoid fuel spillage in the event the pulse damper diaphragm were to rupture. (The pulse damper should not be confused with a fuel pressure regulator, it does not regulate fuel rail pressure.)

Intake Air Systems

INTAKE AIR SYSTEMS

Overview

The Intake Air system (Figure 109) provides clean air to the engine, optimizes air flow and reduces unwanted induction noise. The Intake Air System consists of an air cleaner assembly, resonator assemblies and hoses. The main component of the intake air system is the air cleaner assembly. The air cleaner assembly houses the air cleaner element that removes potential engine contaminants, particularly abrasive types. The Mass Air Flow **(MAF)** sensor is attached internally or externally to the air cleaner assembly and measures the quantity of air delivered to the engine combustion chamber. The MAF sensor can be serviced or replaced as an individual component. The intake air system also contains a sensor that measures the Intake Air Temperature **(IAT)** which may also be integrated with the MAF sensor. (Refer to Electronic Engine Control **(EEC)** Hardware - Powertrain Control

Module **(PCM)** Inputs for additional information on the MAF and IAT sensors.) Air induction resonators can be separate components or part of the intake air housing (i.e., conical air cleaner). The function of a resonator is to reduce induction noise. The air induction components are connected to each other and to the throttle body assembly with hoses.

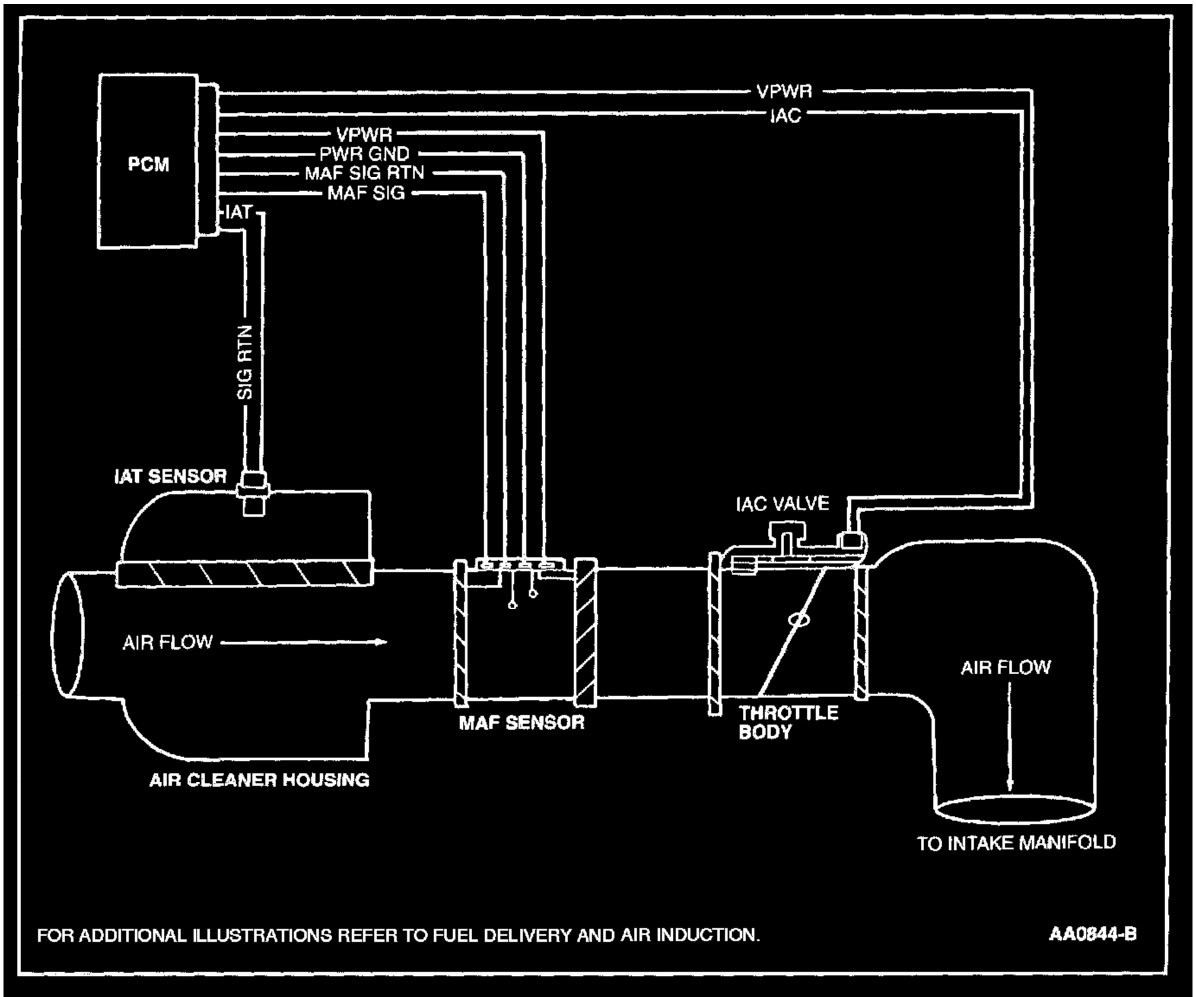


Figure 111: Intake Air System

Intake Air System

NOTE: For additional illustrations, refer to Fuel Delivery and Air Induction.

There are three basic types of intake air sub-systems:

^ Intake Manifold Runner Control **(IMRC)** electric actuated system
^ Intake Manifold Swirl Control **(IMSC)** vacuum actuated system
^ Intake Manifold Tuning Valve **(IMTV)**

These subsystems are used to provide increased intake airflow to improve torque, emissions and performance. The overall quantity of air metered to the engine is controlled by the throttle body.

Intake Manifold Runner Control (IMRC) Electric Actuated System

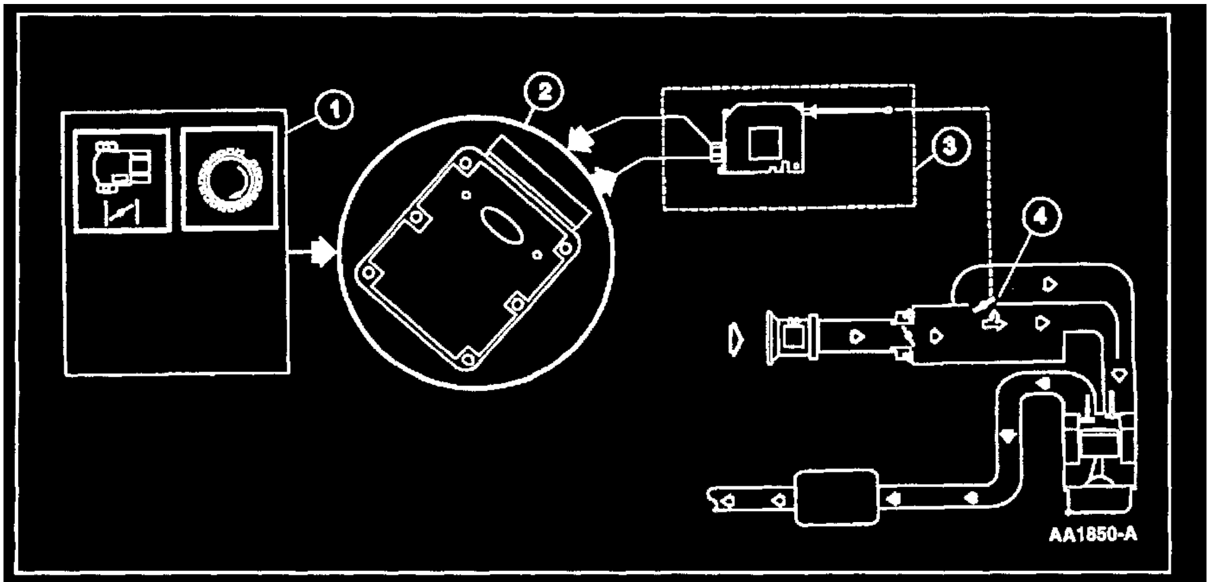


Figure 112: Intake Manifold Runner Control (IMRC) - Electric Actuated (Refer to the On Board Diagnostics Monitor System Overview for Icon Definitions.

Intake Manifold Runner Control (IMRC) - Electric Actuated

The Intake Manifold Runner Control (IMRC) Electric Actuated system (Figure 111) consists of a remote mounted motorized actuator with an attaching cable for each housing on each bank. Some applications will use one cable for both banks. The cable or linkage attaches to the housing butterfly plate levers. The 2.0L (2V) Focus/Escort IMRC uses a motorized actuator mounted directly to a single housing without the use of a cable. Each IMRC housing is an aluminum casting with two intake air passages for each cylinder. One passage is always open and the other is opened and closed with a butterfly valve plate. The housing uses a return spring to hold the butterfly valve plates closed. The motorized actuator houses an internal switch or switches, depending on the application, to provide feedback to the PCM indicating cable and butterfly valve plate position.

Below approximately **3000 rpm**, the motorized actuator will not be energized. This will allow the cable to fully extend and the butterfly valve plates to remain closed. Above approximately **3000 rpm**, the motorized actuator will be energized. The attaching cable will pull the butterfly valve plates into the open position. Some vehicles will activate the IMRC near **1500 rpm**.

WARNING: SUBSTANTIAL OPENING AND CLOSING TORQUE IS APPLIED BY THIS SYSTEM. TO PREVENT INJURY, BE CAREFUL TO KEEP FINGERS AWAY FROM LEVER MECHANISMS WHEN ACTUATED.

1. The PCM uses the Throttle Position **(TP)** sensor and Crankshaft Position **(CKP)** signals to determine activation of the IMRC system. There must be a positive change in voltage from the TP sensor along with the increase in rpm to open the valve plates.
2. The PCM uses the information from the input signals to control the IMRC motorized actuator based upon rpm and changes in throttle position.
3. The PCM energizes the actuator to pull the butterfly plates open with the cable(s) or linkage.
4. The IMRC housing contains butterfly plates to allow increased air flow.

Intake Manifold Swirl Control (IMSC) Vacuum Actuated System

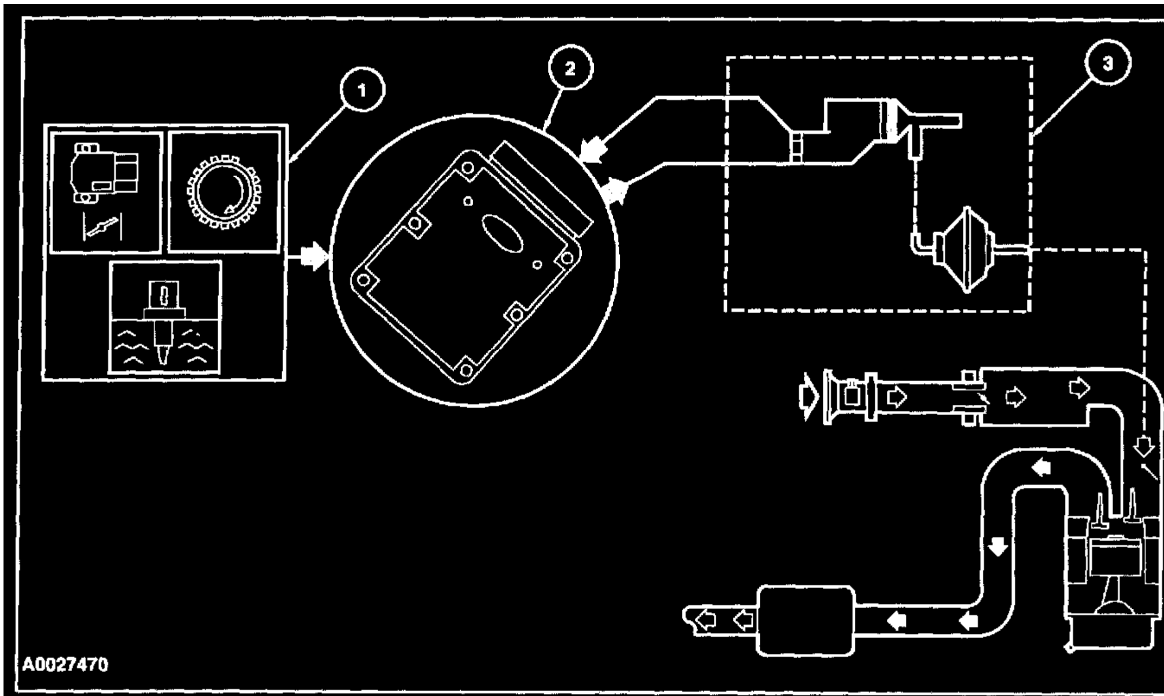


Figure 113: Intake Manifold Swirl Control (IMSC) -Vacuum Actuated (Refer to the On Board Diagnostics Monitor System Overview for Icon Definitions.

Intake Manifold Swirl Control (IMSC) - Vacuum Actuated

The Intake Manifold Swirl Control (IMSC) Vacuum Actuated system (Figure 112) consists of a manifold mounted vacuum actuator and a PCM controlled electric solenoid. The linkage from the actuator attaches to the manifold butterfly plate lever. The IMSC actuator and manifold are composite/plastic with a single intake air passage for each cylinder. The passage has a butterfly valve plate that blocks 60% of the opening when actuated, leaving the top of the passage open to generate turbulence. The housing uses a return spring to hold the butterfly valve plates open. The vacuum actuator houses an internal monitor circuit to provide feedback to the PCM indicating butterfly valve plate position.

Below approximately **3000 rpm**, the vacuum solenoid will be energized. This will allow manifold vacuum to be applied and the butterfly valve plates to remain closed. Above approximately **3000 rpm**, the vacuum solenoid will be de-energized. This will allow vacuum to vent from the actuator and the butterfly valve plates to open.

WARNING: SUBSTANTIAL OPENING AND CLOSING TORQUE IS APPLIED BY THIS SYSTEM. TO PREVENT INJURY, BE CAREFUL TO KEEP FINGERS AWAY FROM LEVER MECHANISMS WHEN ACTUATED.

1. The PCM monitors the TP sensor, Cylinder Head Temperature **(CHT)** and CKP signals to determine activation of the IMSC system. There must be a positive change in voltage from the TP sensor along with the increase in rpm at the proper engine temperature to open the valve plates.
2. The PCM uses the information from the input signals to control the IMSC electric solenoid based upon changes in throttle position, engine temperature and rpm.
3. The PCM energizes the solenoid with the key on engine running, vacuum is then applied to the actuator to pull the butterfly plates closed.

Intake Manifold Tuning Valve (IMTV)

The intake manifold tuning valve (IMTV) (Figure 113) is a motorized actuated unit mounted directly to the intake manifold. The IMTV actuator controls a shutter device attached to the actuator shaft. There is no monitor input to the PCM with this system to indicate shutter position.

The motorized IMTV unit will not be energized below approximately **2600 rpm** or higher on some vehicles. The shutter will be in the closed position not allowing airflow blend to occur in the intake manifold. Above approximately **2600 rpm** or higher, the motorized unit will be energized. The motorized unit will be commanded on by the PCM initially at a 100 percent duty cycle to move the shutter to the open position and then falling to approximately 50 percent to continue to hold the shutter open.

1. The PCM uses the TP sensor and CKP signals to determine activation of the IMTV system. There must be a positive change in voltage from the TP sensor along with the increase in rpm to open the shutter.
2. The PCM uses the information from the input signals to control the IMTV.
3. When commanded on by the PCM, the motorized actuator shutter opens up the end of the vertical separating wall at high engine speeds to allow both sides of the manifold to blend together.

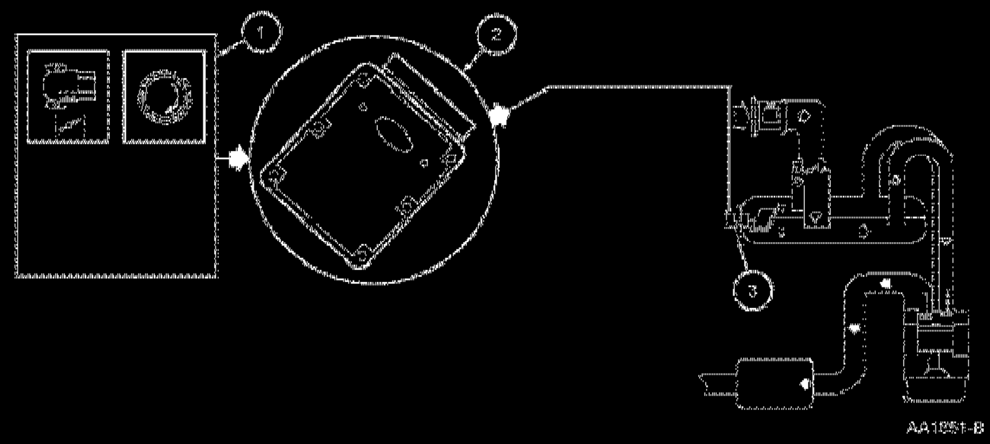


Figure 114: Intake Manifold Tuning Valve (IMTV) (Refer to the On Board Diagnostics Monitor System Overview for icon definitions.)

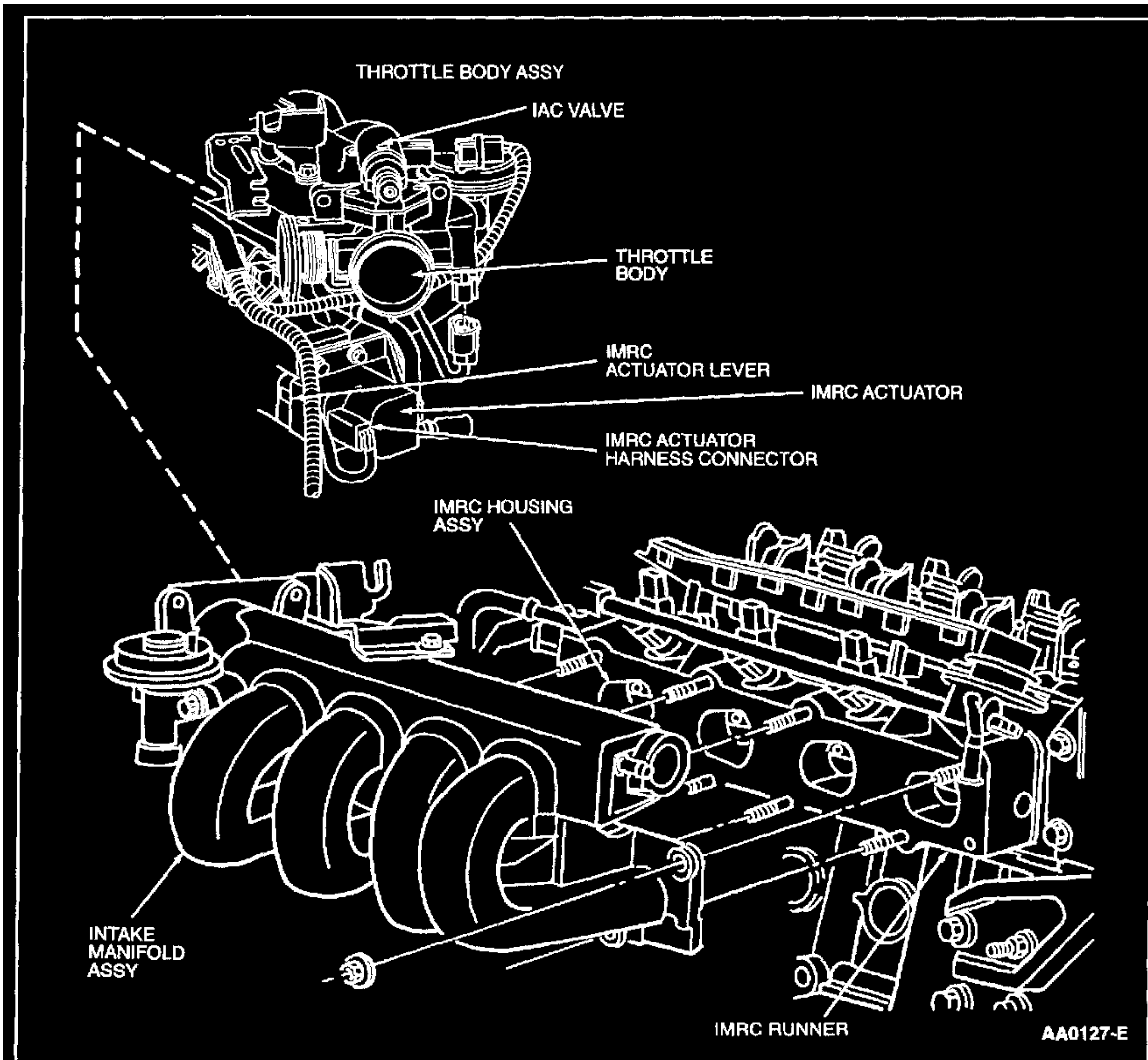


Figure 115: 2.0L 2V Focus/Escort Intake Air System

Intake Air System

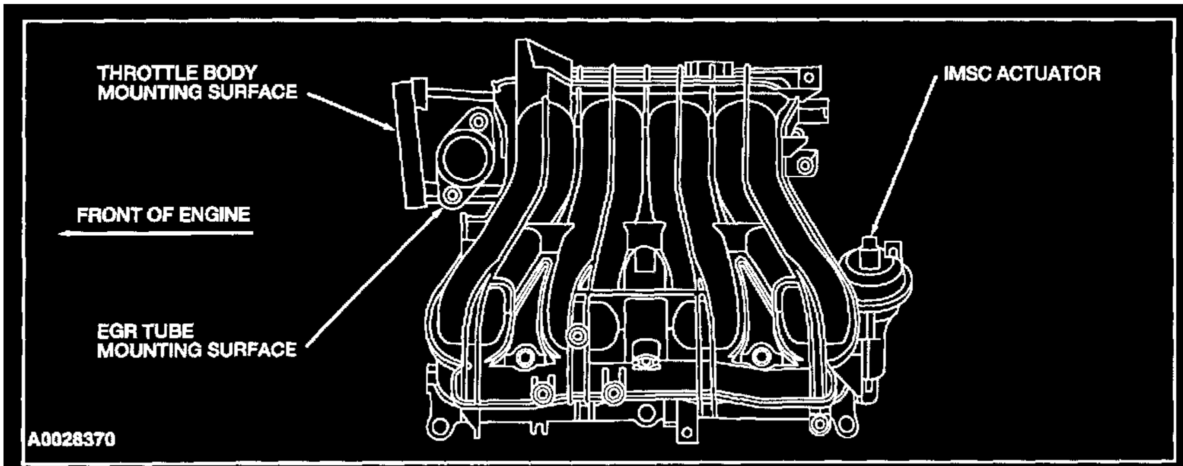


Figure 116: 2.3L 4V Ranger Intake Air System

Intake Air System

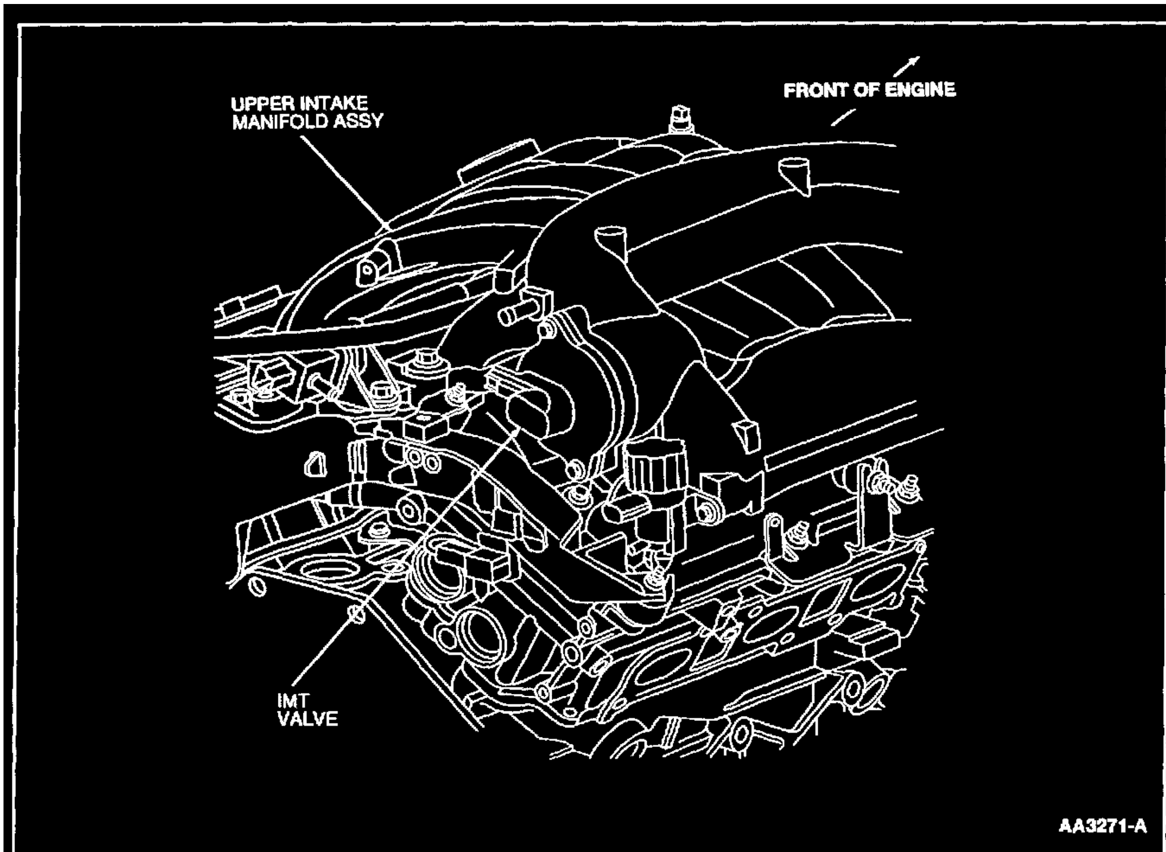


Figure 117: 3.0L LS6 Intake Air System

Intake Air System

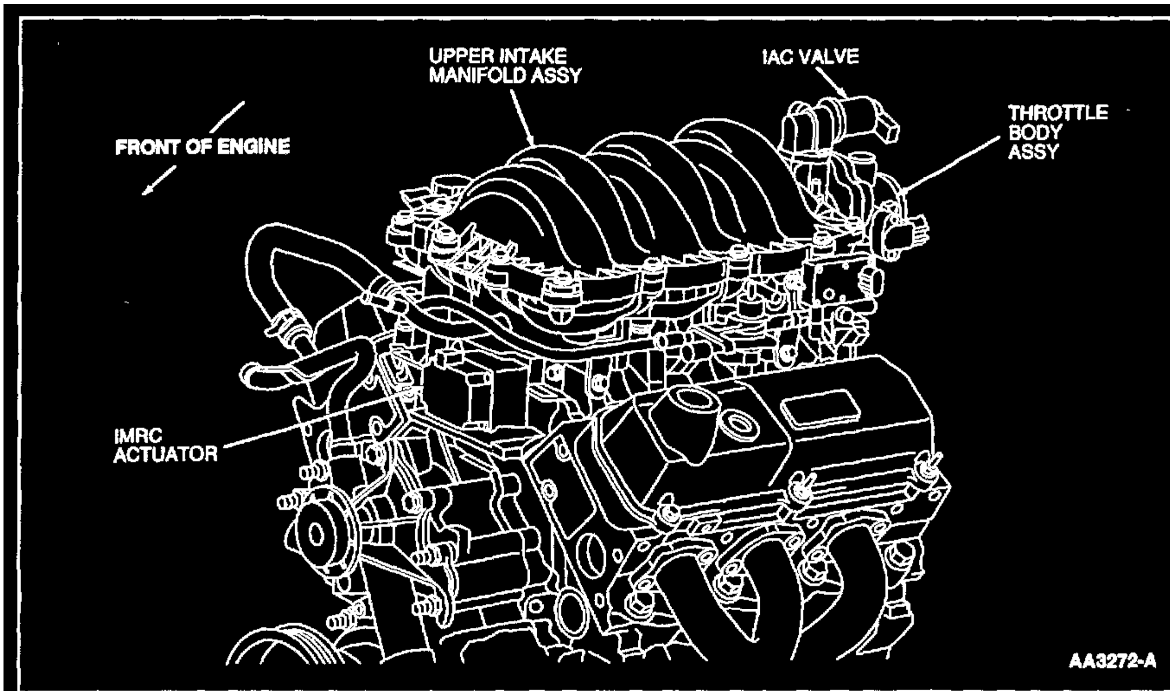


Figure 118: 3.8L Windstar Intake Air System

Intake Air System

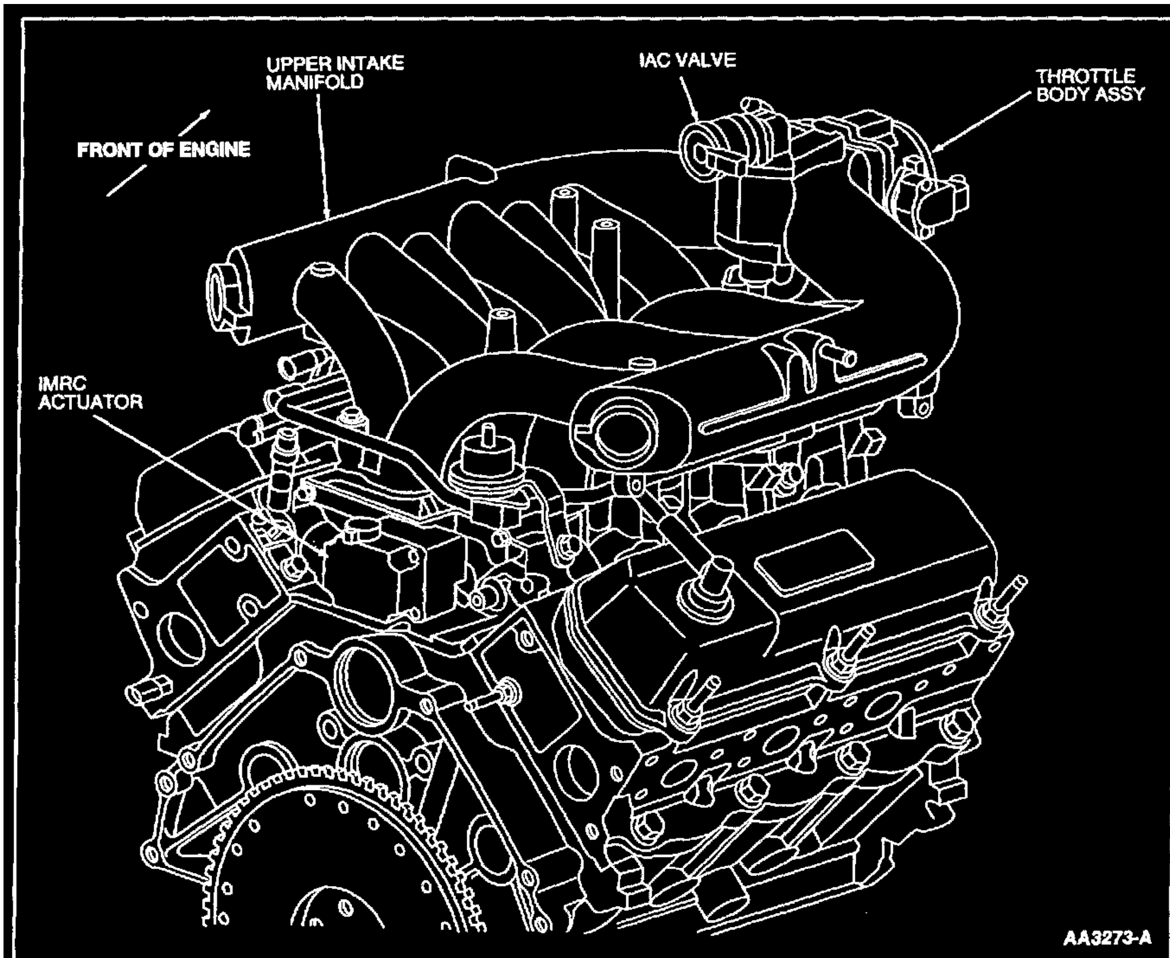


Figure 119: 4.2L E/F-Series Intake Air System

Intake Air System

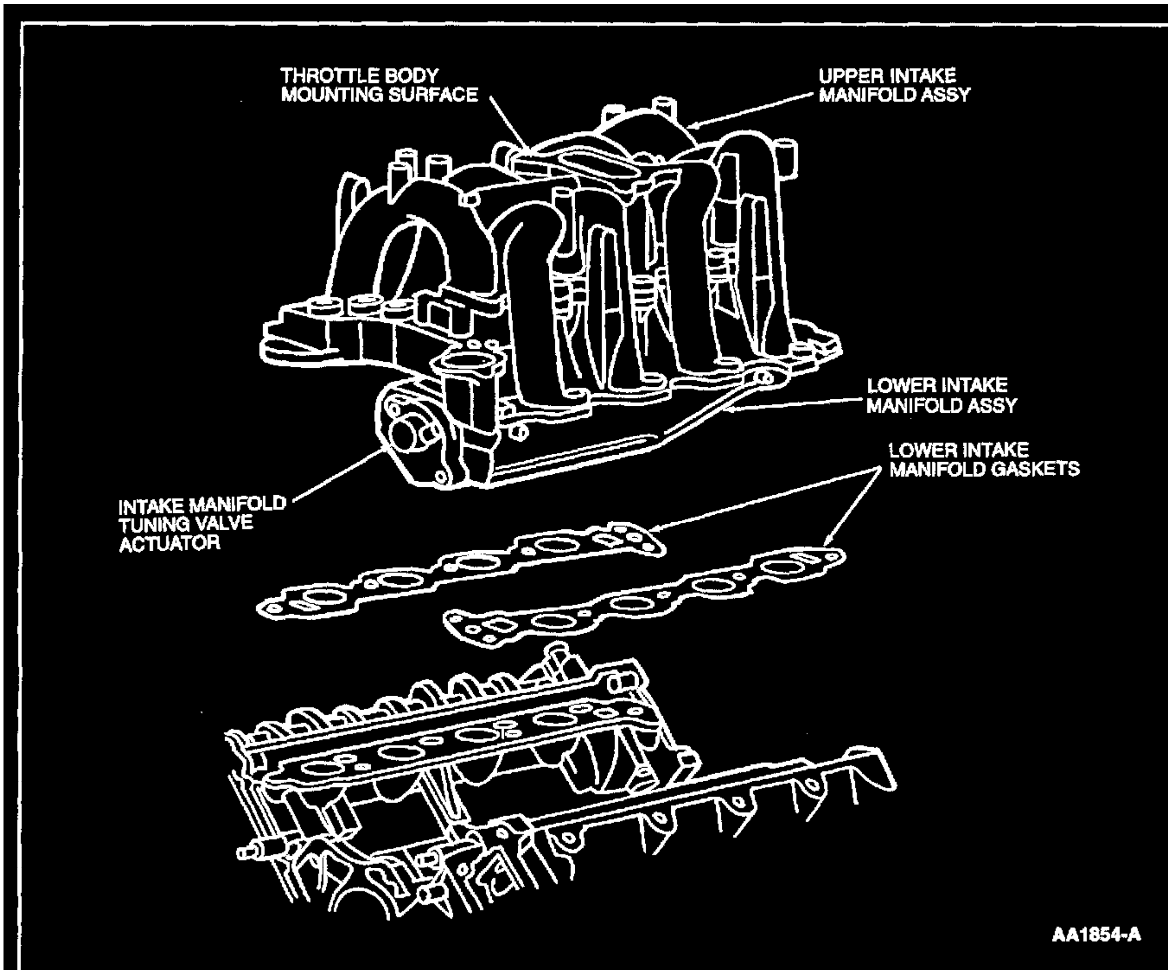


Figure 120: 4.6L E/F-Series Intake Air System

Intake Air System

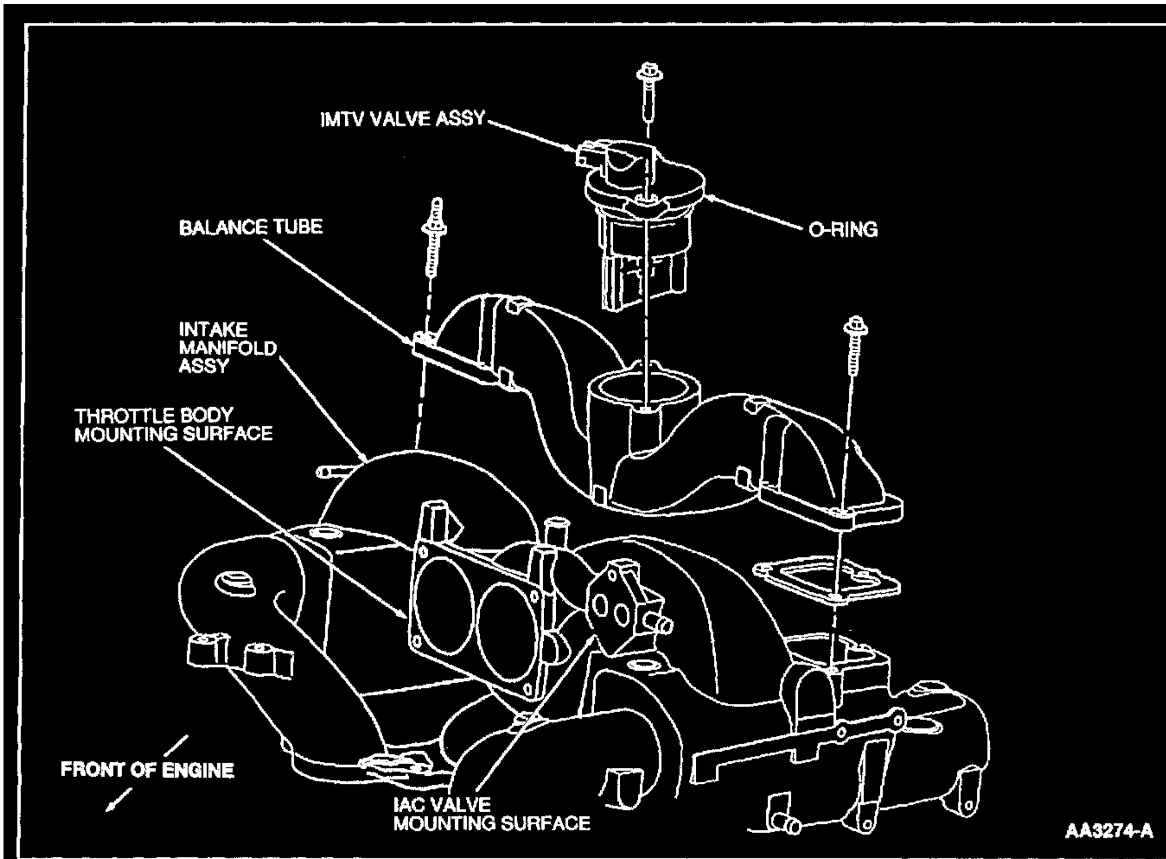


Figure 121: 5.4L (4V) Intake Air System

Intake Air System

Throttle Body System Overview

The throttle body system meters air to the engine during idle, part throttle, and Wide Open Throttle **(WOT)** conditions. The throttle body system consists of an Idle air control **(IAC)** valve assembly, idle air orifice, single or dual bores with butterfly valve throttle plates and a Throttle Position (TP) sensor. One other source of idle air flow is the Positive Crankcase Ventilation **(PCV)** system. The combined idle air flow (from idle air orifice IAC flow and PCV flow) is measured by the MAF sensor on all applications.

During idle, the throttle body assembly provides a set amount of air flow to the engine through the idle air passage and PCV valve. The IAC valve assembly provides additional air when commanded by the powertrain control module (PCM) to maintain the proper engine idle speed under varying conditions. The IAC valve assembly mounts directly to the throttle body assembly in most applications, but is remote-mounted to the intake manifold in some applications. Idle speed is controlled by the PCM and cannot be adjusted.

NOTE: The traditional idle air adjust procedure as well as throttle return screw are no longer used on OBD II applications.

Throttle rotation is controlled by a cam/cable linkage to slow the initial opening rate of the throttle plate. The TP sensor monitors throttle position and provides an electrical signal to the PCM. Some throttle body applications provide an air supply channel upstream of the throttle plate to provide fresh air to the Positive Crankcase Ventilation (PCV) or IAC systems. Other throttle body applications provide individual vacuum taps downstream of the throttle plate for PCV return, Exhaust Gas Recirculation **(EGR)**, Evaporative Emission **(EVAP)**, and miscellaneous control signals.

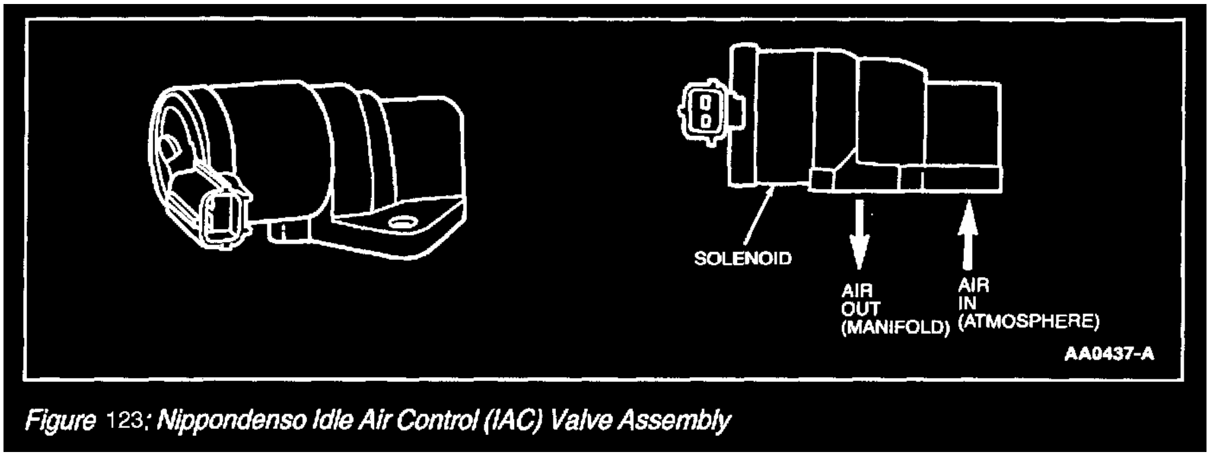
Throttle Body System Hardware

The major components of the throttle body assembly include the TP sensor, IAC valve assembly, and throttle body housing assembly.

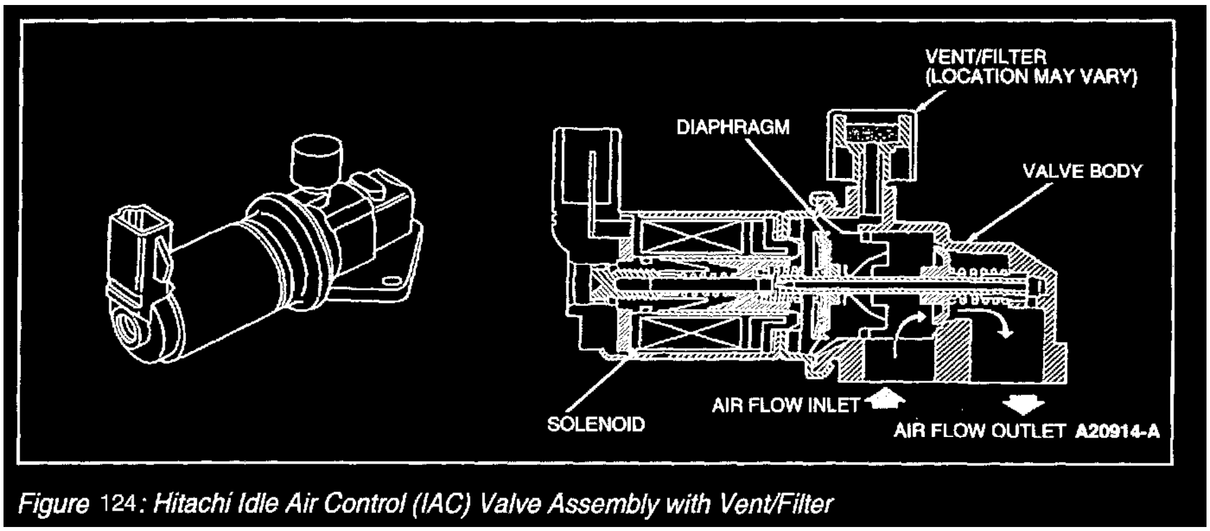
Throttle Position Sensor

The TP sensor monitors throttle position and provides an electrical signal to the PCM. It is monitored by the OBD II system for component integrity, system functionality, and faults that can cause emissions levels to exceed standards set in government regulations. For additional information on the TP sensor, refer to Electronic EC System Hardware-PCM Inputs.

Idle Air Control Valve



Nippondenso Idle Air Control (IAC) Valve Assembly



Hitachi Idle Air Control (IAC) Valve Assembly With Vent/Filter

The idle air control (IAC) valve assembly (Figure 121) and (Figure 122) controls engine idle speed and provides a dash pot function. The IAC valve assembly meters intake air around the throttle plate through a bypass within the IAC valve assembly and throttle body. The PCM determines the desired idle speed or bypass air and signals the IAC valve assembly through a specified duty cycle. The IAC valve responds by positioning the IAC valve to control the amount of bypassed air. The PCM monitors engine rpm and increases or decreases the IAC duty cycle in order to achieve the desired rpm.

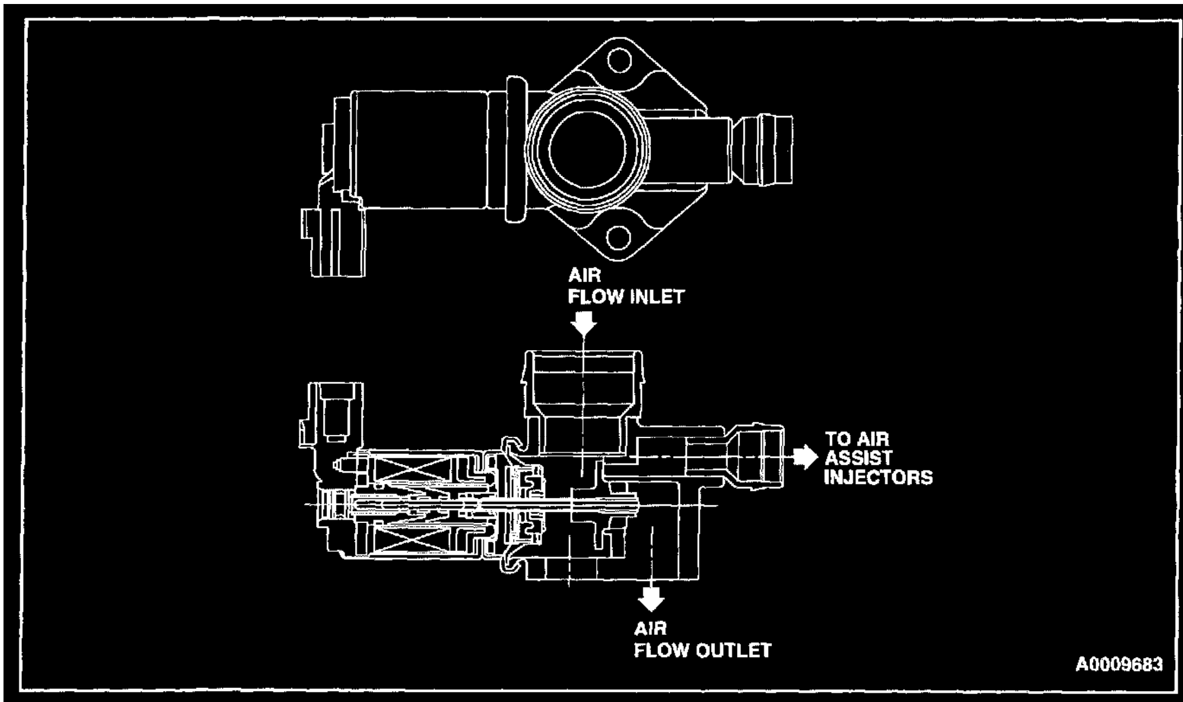


Figure 125 : Hitachi Idle Air Control (IAC) Valve Assembly with Air-Assist Injectors

Hitachi Idle Air Control (IAC) Valve Assembly With Air-Assist Injectors

On applications with air-assisted injectors, the IAC valve (Figure 123) also supplies a small amount of air into the path of the fuel injectors. The jet of air causes an increase in fuel atomization at low speed and light load conditions.

NOTE: The IAC Valve Assembly is NOT ADJUSTABLE and CANNOT BE CLEANED.

The IAC valve (part of throttle body assembly) has an internal diode on some applications. If the internal diode is measured in crossed terminal position with a digital multimeter, there will be an incorrect or negative reading. It is important that the mating component and harness connectors are correctly oriented. Diagnostic procedures emphasize this importance.

The PCM uses the IAC valve assembly to control:
^ No touch start
^ Cold engine fast idle for rapid warm-up
^ Idle (corrects for engine load)
^ Stumble or stalling on deceleration (provides a dash pot function)
^ Over-temperature idle boost.
^ Air Assist to Injectors.

Throttle Body Housing

The throttle body housing assembly is a single piece of aluminum casting with an air passage and a butterfly throttle plate with linkage mechanisms. When the throttle plate is in the idle (or closed) position, the throttle lever arm should be in contact with the Throttle Return Stop. The throttle return stop prevents the throttle plate from contacting the bore and sticking closed. The setting also establishes the amount of air flow between the throttle plate and bore. To minimize the closed plate air flow, a special coating is applied to the throttle plate and bore to help seal this area. This sealant/coating also makes the throttle body resistant to engine intake sludge accumulation.

Features of the Throttle Body Assembly include:

1. Idle air control (IAC) valve assembly mounted directly to the throttle body assembly (some vehicles).
2. A pre-set stop to locate the WOT position.
3. An air supply channel upstream of the throttle plate to provide fresh air to the PCV system (some vehicles only).
4. Individual vacuum taps for PCV, EGR, EVAP and miscellaneous control signals (some vehicles only).
5. PCV air return (if applicable).
6. A throttle body-mounted throttle position (TP) sensor.

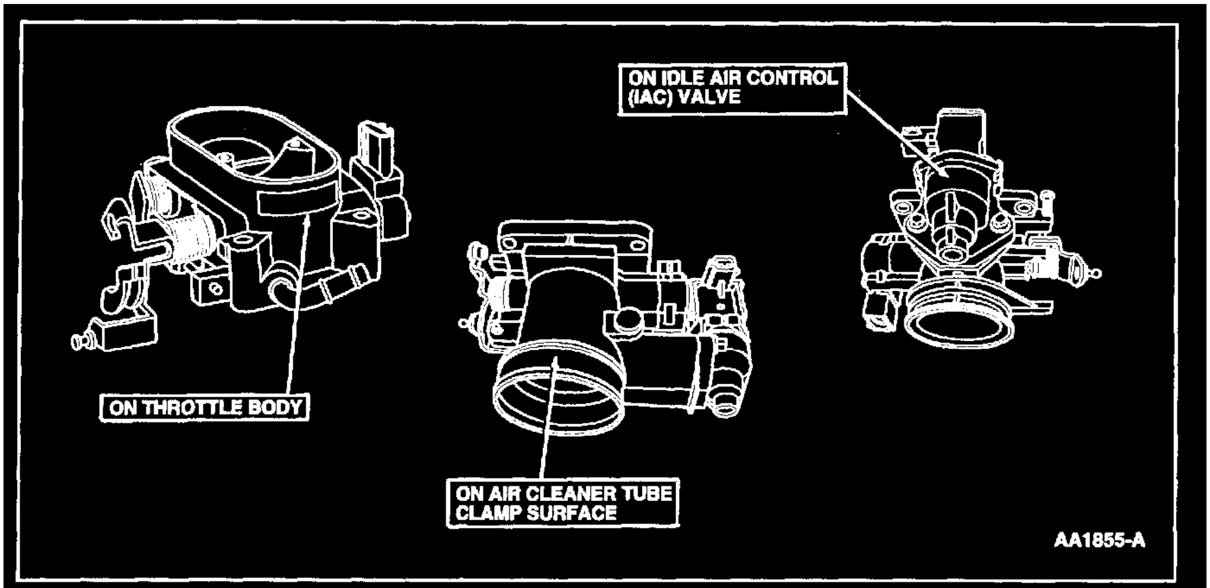


Figure 121: Typical Attention Decal Locations

Attention Decal Locations

7. A sealant/coating on the throttle bore and throttle plate makes the throttle body air flow tolerant to engine intake sludge accumulation. These throttle body assemblies MUST NOT BE CLEANED and have a white/black attention decal (Figure 121) advising not to clean.

Natural Gas Fuel System

NATURAL GAS FUEL SYSTEM

Overview

The Fuel System provides a means of transporting clean fuel from the fuel tank to the fuel injectors under a controlled pressure.

Natural Gas Fuel System

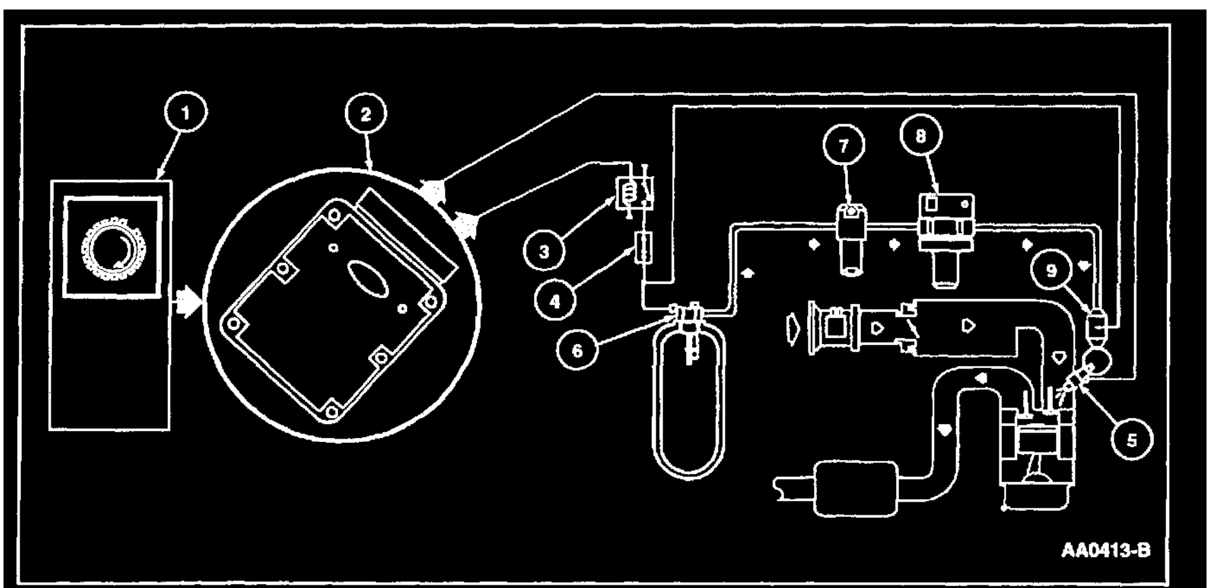


Figure 76: Natural Gas Fuel System

Natural Gas Fuel System

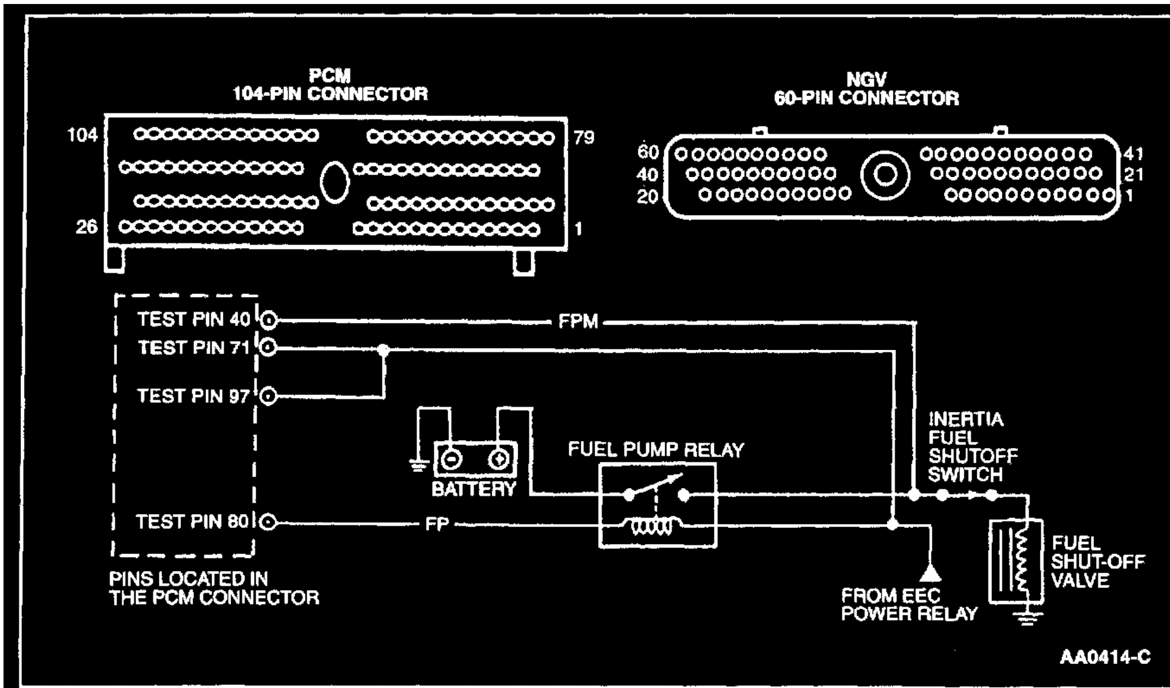


Figure 77: Natural Gas Fuel System Electrical Schematic— Typical

Natural Gas Fuel System Electrical Schematic - Typical

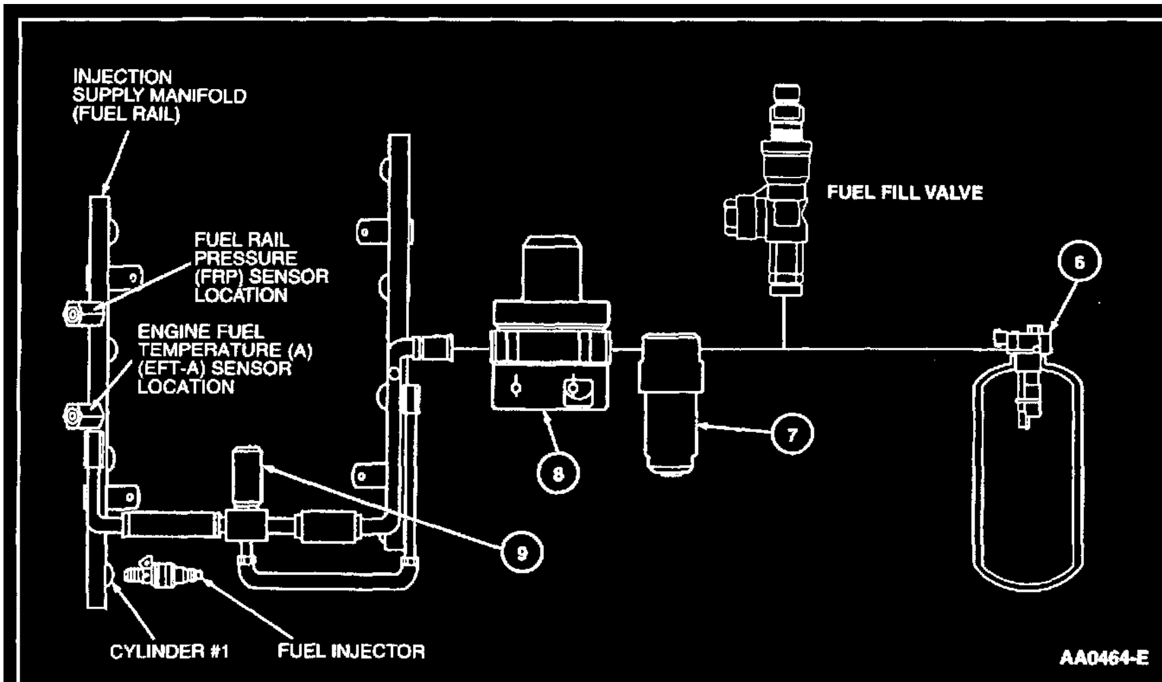


Figure 78: Natural Gas Fuel System

Natural Gas Fuel System

The fuel system consists of a fuel tank, fuel shut-off valve assemblies, fuel supply lines, fuel filter, schrader/service valve, manual fuel shut-off valve, fuel rail, and fuel pressure regulator. Operation of the system is as follows (Figure 74), (Figure 75) and (Figure 76):

1. The fuel delivery system uses the Crankshaft Position **(CKP)** sensor to signal the Powertrain Control Module **(PCM)** that the engine is either cranking or running.
2. The fuel shut-off valve logic is defined in the Fuel System control strategy and is executed in the PCM. The PCM will ground the fuel pump relay for **one second** during key on and engine off. During crank the fuel pump relay is grounded as long as the PCM receives a signal from the CKP.
3. The fuel pump relay has a primary and a secondary circuit. The primary side is controlled by the PCM and the secondary side provides B+ to the fuel shut-off valve circuit when the relay is energized.
4. The Inertia Fuel Shut-Off **(IFS)** switch is used to de-energize the fuel delivery circuit in the event of a collision. The IFS switch is a safety device

that should only be reset after a thorough inspection of the vehicle (following a collision).

5. The fuel injector is used to meter natural gas to each combustion cylinder. Although the NG fuel injector appears very similar to some gasoline fuel injectors, it is unique. Flow capacity of this fuel injector is 6 to 12 times as large as various gasoline fuel injectors.
6. The fuel tank shut-off solenoid valve is located in the fuel tank. The solenoid valves are on the same circuit as the fuel pump and utilize the same inertia fuel shut-off (IFS) switch as gasoline.
7. The high pressure fuel filter is used to protect the engine fuel system components. A natural gas coalescing and particulate filter is positioned on the high pressure side of the fuel system just prior to the fuel pressure regulator.
8. The fuel pressure regulator used on the NG vehicle is a single-staged pressure reducing regulator which expands natural gas from storage pressures of **1,379 to 20,685 kPa (200 to 3,000 psig)** to engine fuel pressures of **724 to 862 kPa (105 to 125 psig)**.
9. The fuel rail shut-off valve is a normally closed solenoid actuated valve that opens when grounded by the PCM. The valve isolates the fuel injectors from fuel line pressure when the engine is not operating. The fuel rail shut-off valve is wired in parallel with the fuel tank shut-off solenoid valves.

Hardware

Fuel Rail

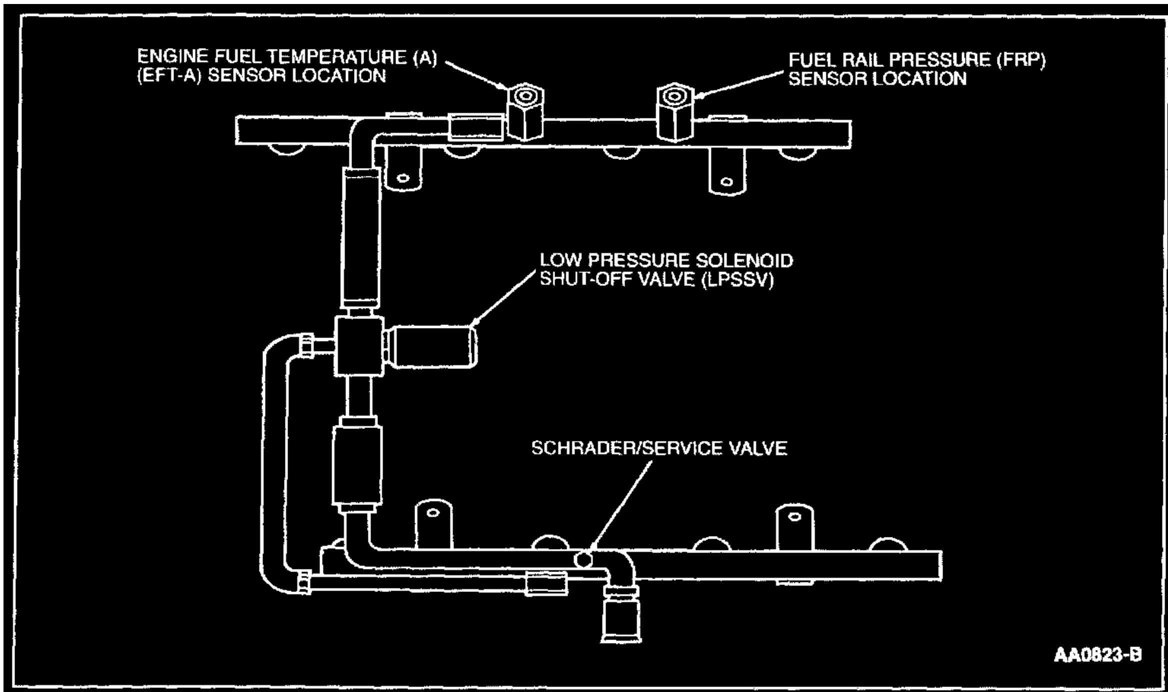


Figure 79: Fuel Rail Components

Fuel Rail Components

The fuel rail (Figure 77) distributes low pressure fuel from the chassis supply line to each fuel injector. Fuel pressure at the top of each fuel injector is maintained within 1% of the other fuel injectors at all times; this is done with nearly symmetric flow paths. The fuel rail is also designed to have minimal flow restriction by increasing the cross-sectional flow area and reducing the flow path length. The fuel rail contains several other Parts In Assembly **(PIA)** components that perform crucial functions. These include:

- **Injection pressure sensor** which measures the pressure of the fuel near the fuel injectors. This signal is used by the PCM to adjust the fuel injector pulse width and meter fuel to each engine combustion cylinder.
- **Engine fuel temperature sensor** which measures the pressure of the fuel near the fuel injectors. This signal is used by the PCM to adjust the fuel injector pulse width and meter fuel to each engine combustion cylinder.
- **Low pressure solenoid shut-off valve** which isolates the fuel rail from the upstream fuel system when the engine is OFF. This minimizes the amount of fuel available to flow through the fuel injectors when the engine is off or leak from a damaged fuel rail during and after a crash. The valve is controlled by the PCM fuel shut-off valve circuit and contains an inertia switch. The valve is only on for **one second** after a key-on or whenever CKP signals are being received by the PCM.
- **schrader/service valve** (if equipped) provides a service port to the low pressure fuel system. This valve is needed to relieve the pressure in the system before and during service. This valve could also be used to monitor the pressure near the injectors during diagnostic procedures.

Fuel Injector(s)

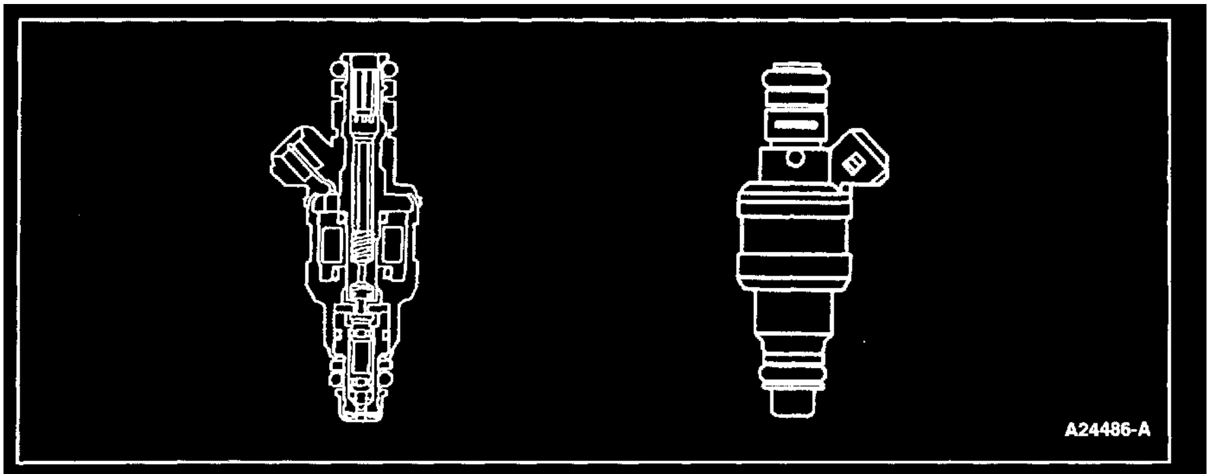


Figure 80: Fuel Injector

Fuel Injector

The fuel injector (Figure 78) is a solenoid-operated valve that meters fuel flow to the engine. The fuel injector is opened and closed every other crankshaft revolution. The amount of fuel is controlled by the length of time the fuel injector is held open.

The fuel injector is normally closed and is operated by **12 volt** Vehicle Power **(VPWR)** from the power relay. The ground signal is controlled by the PCM.

The fuel injectors are used to meter natural gas to each combustion cylinder. Although the natural gas fuel injectors appear very similar to some gasoline fuel injectors, they are unique. Flow capacity of these fuel injectors is 6 to 12 times as large as various gasoline fuel injectors. Electrical resistance is much lower than typical gasoline fuel injectors **(4.6 ohms as opposed to 14.5 ohms)**. To accommodate this lower resistance, a fuel injector driver module is used to convert the PCM fuel injector driver signal to the signal required by the fuel injector.

Fuel Pressure Regulator

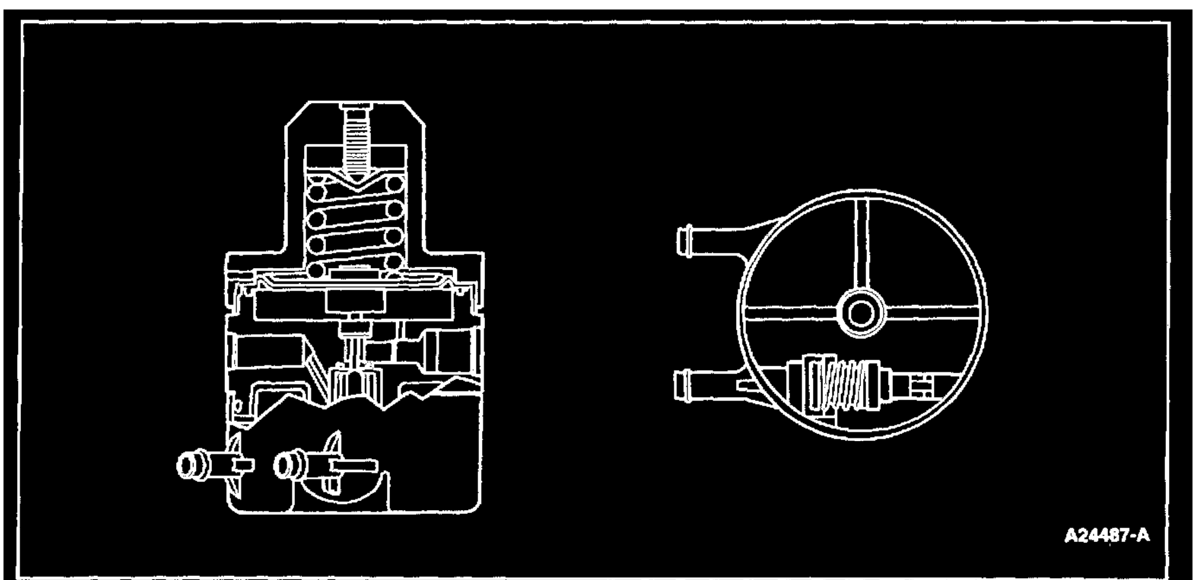


Figure 81: Fuel Pressure Regulator

Fuel Pressure Regulator

The fuel pressure regulator (Figure 79) used in the Natural Gas fuel system is a single-stage pressure reducing regulator which expands natural gas from storage pressures of **1,379 to 20,685 kPa (200 to 3,000 psig)** to engine fuel injector pressures of **724 to 862 kPa (105 to 125 psig)**

The regulator contains a pressure relief device, a **1,896 kPa (275 psig)** check valve, which protects the low pressure fuel system. The low pressure fuel system no longer must fulfill the design requirements of the high pressure fuel system, therefore reducing cost, weight and complexity.

When gas expands, the fuel temperature drops significantly causing extreme cold temperatures **(-177°C or -160°F)** that may damage synthetic fuel system components as well as cause water vapor within the fuel to condense, freeze and plug the lines, valve and injectors. To prevent this, engine coolant is routed through the fuel pressure regulator to warm the fuel before it expands.

The regulator has an internal thermostat to control the flow of engine coolant. This prevents overheating and subsequent thinning of the fuel which may cause lean combustion. Outlet coolant flow is restricted by the thermostat when it rises above approximately **82°C (100°F)**.

High Pressure Fuel Filter

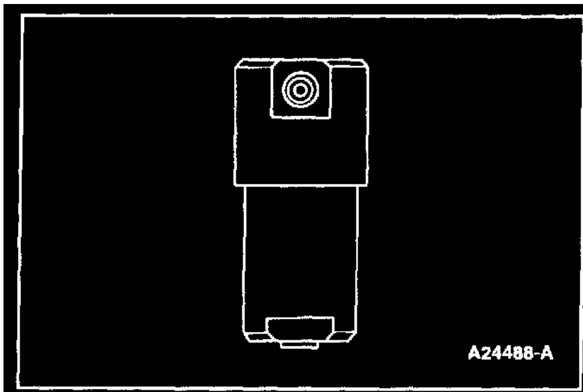


Figure 82: Fuel Filter

Fuel Filter

The high pressure fuel filter (Figure 80) is used to protect the engine fuel system components. A natural gas coalescing and particulate filter is positioned on the high pressure side of the fuel system just prior to the pressure regulator. The filter is part of the regulator assembly. The filter can be disassembled to service the element. The drain plug on the bottom of the housing can be removed to drain any water that accumulates.

Fuel Lines and Fittings

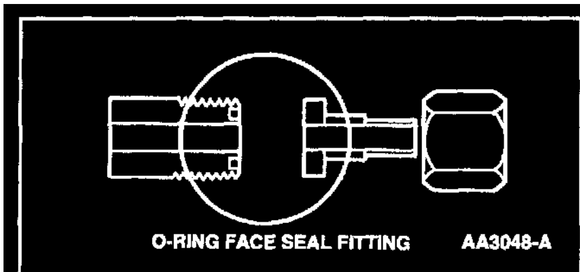


Figure 83: Fuel Line Assembly

Fuel Line Assembly

A fuel line assembly (Figure 81) consists of flexible hose and/or stainless steel seamless tubing, end fittings and tube nuts. The hose is a conductive polytetrafluoroethylene **(PTFE)** liner reinforced with a stainless steel wire braided covering. The fittings are inserted into the hose ends and crimped into place. The stainless steel tubing contains end fittings which are brazed to the tube. There are high pressure fuel lines that are identified by either **1/4-inch or 3/8-inch** outer diameter and a low pressure fuel line identified by a **1/2-inch** outer diameter. The low pressure fuel line has a quick-connect at one end for connection to the fuel rail. The other fittings used on the natural gas vehicle to connect fuel components are SAE O-ring face seal tube fittings. There are two end types: an O-ring face seal end and a straight thread end. On tee and elbow fittings, a washer and a positionable nut are provided to aid in orientation of the fitting.

Fueling Connector

Flange Assembly-Fuel Tank Fill

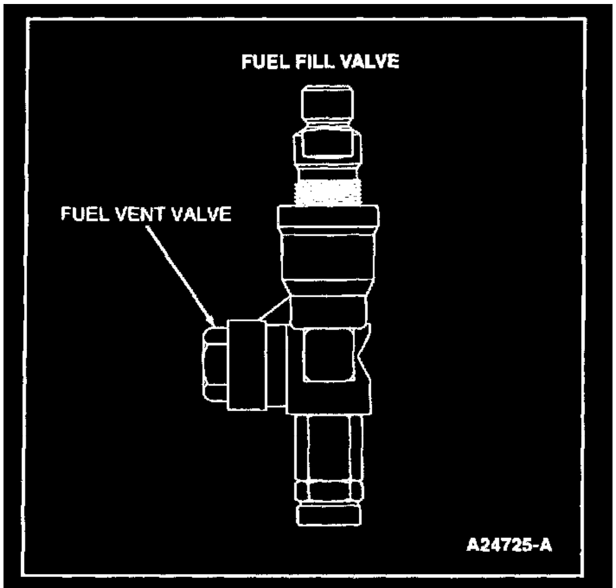


Figure 84: Flange Assembly

Flange Assembly

The flange assembly (Figure 82) is designed for **20,685 kPa (3,000 psi)** service pressure and is the refueling connection to fill the vehicle. The assembly is mounted behind the fuel filler door and attached to the fuel filler housing, similar to a gasoline vehicle. This assembly consists of an NGVP1 type receptacle with a **150 micron** filter (which can be serviced), a spring loaded check valve to allow filling of the vehicle and a manually opened bypass to provide safe venting of the fuel system. The vehicle is refueled by attaching the fuel station fill nozzle to the receptacle and locking into place.

Fuel Tank Shutoff Valve

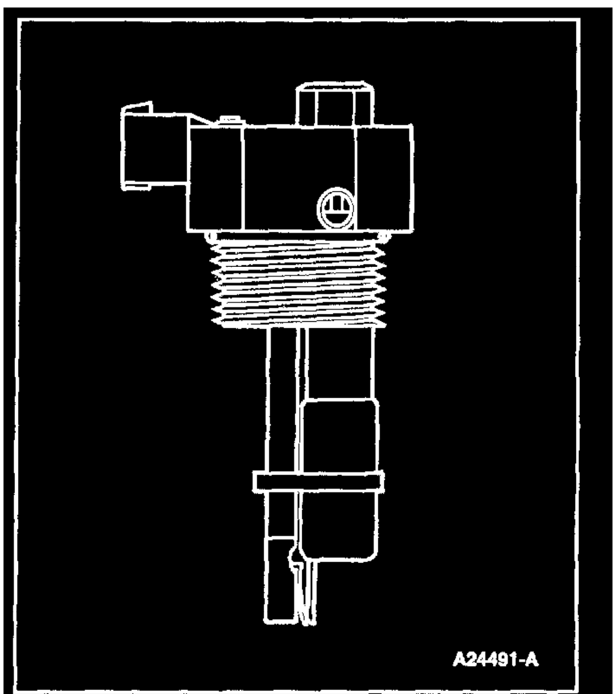


Figure 85: Fuel Tank Shutoff Valve

Fuel Tank Shutoff Valve

The fuel tank shutoff solenoid valve (Figure 83) is located in the fuel tank. The solenoid valves are on the same circuit as the gasoline fuel pump and utilize the same Inertia fuel shutoff (IFS) switch as gasoline. When the key is in the off position, the shutoff valves are closed and fuel in the tanks is isolated. During refueling, the shutoff valve acts as a check valve and allows flow due to pressure differential between the fuel being added from the fill station and the fuel in the tank.

The internal solenoid valves also have the capability of being "manually locked down." If, while servicing the vehicle, it becomes necessary to remove the fuel tank, the lock down feature provides an added measure of safety. In addition, the valve has an internal Canadian Gas Association **(CGA)** type 9 fusible link Pressure Relief Device **(PRD)** that senses the internal fuel tank gas temperature. The contents in the tank are vented when the internal fuel tank gas temperature reaches **199°C (217°F)** and melts the fusible link. The escaping gas is vented through a vent line to the atmosphere.

Inertia Fuel Shutoff (IFS) Switch

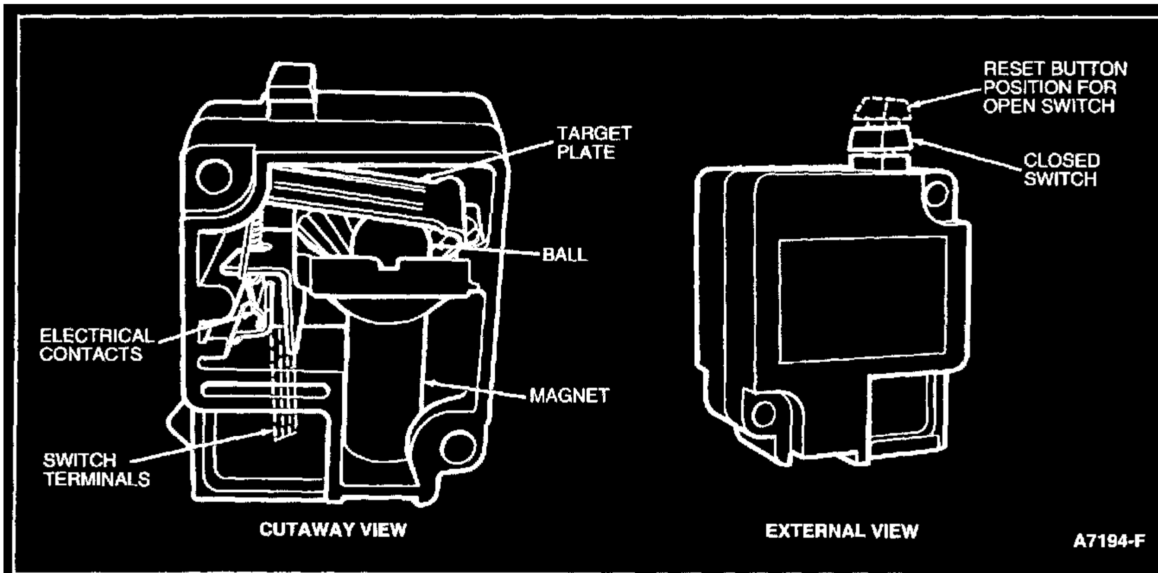


Figure 86: Inertia Fuel Shutoff (IFS) Switch

Inertia Fuel Shutoff (IFS) Switch

The inertia fuel shutoff (IFS) switch (Figure 84) is used in conjunction with electric fuel close valves. The purpose of the IFS switch is to close the fuel shut-off valves if a crash occurs. It consists of a steel ball held in place by a magnet. When a sharp impact occurs, the ball breaks loose from the magnet, rolls up a conical ramp and strikes a target plate which opens the electrical contacts of the switch and closes the electric fuel shut-off valve. Once the switch is open, it must be manually reset before restarting the vehicle. On some vehicles a fuel reset light illuminates. Refer to the Owner Guide for the location of the IFS.

Reset Instructions

1. Turn key off.
2. Check for natural gas leaks in the engine compartment.
3. **NOTE:** In the closed position, the button can be depressed an additional **1.57 cm (1/16 inch)** against a spring.

   If no natural gas leak is apparent, reset the IFS by pushing the reset button on the top of the switch (refer to Owner Guide).

4. Turn key to on or start position for a few seconds, then off again.
5. **WARNING: IF YOU SMELL NATURAL GAS AT ANY TIME OTHER THAN DURING FUELING, DO NOT RESET THE IFS SWITCH.**

   Again, check for leaking natural gas.

Fuel Rail Shut-Off Valve

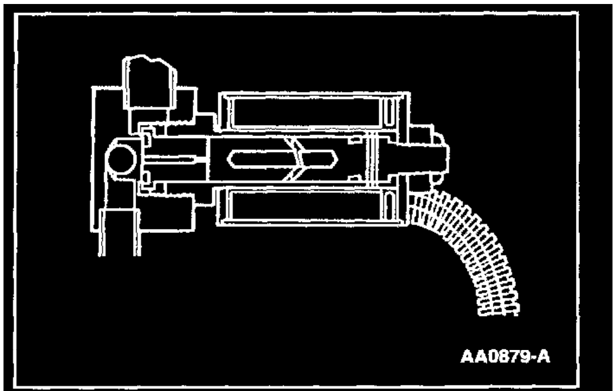


Figure 87: Fuel Rail Shut-Off Valve

Fuel Rail Shut-Off Valve

The fuel rail shut-off valve (Figure 86) is a normally closed solenoid actuated valve that opens when (along with all of the tank valves) Pin 80 is grounded by the PCM. The valve isolates the fuel injectors from fuel line pressure when the engine is off. Nominal resistance of the coil is **11 ohms**. The fuel rail shut-off valve is wired in parallel with the four tank valves.

Fuel Rail Valve Circuit Operation

When the key is turned to the ON position, the power relay is turned on. The power relay provides power to the PCM and the control side of the fuel shut off valve relay. The relay provides voltage to the fuel rail valve. If the ignition switch is not turned to the START position, the PCM will shut off the fuel rail valve after **one second**. The PCM will open the valve (along with the four tank valves) to provide fuel while cranking. The valve will remain open when the engine is running unless the inertia fuel shut-off switch is "tripped."

Supercharger and Intercooler Systems

SUPERCHARGER AND INTERCOOLER SYSTEMS

Supercharger Bypass System

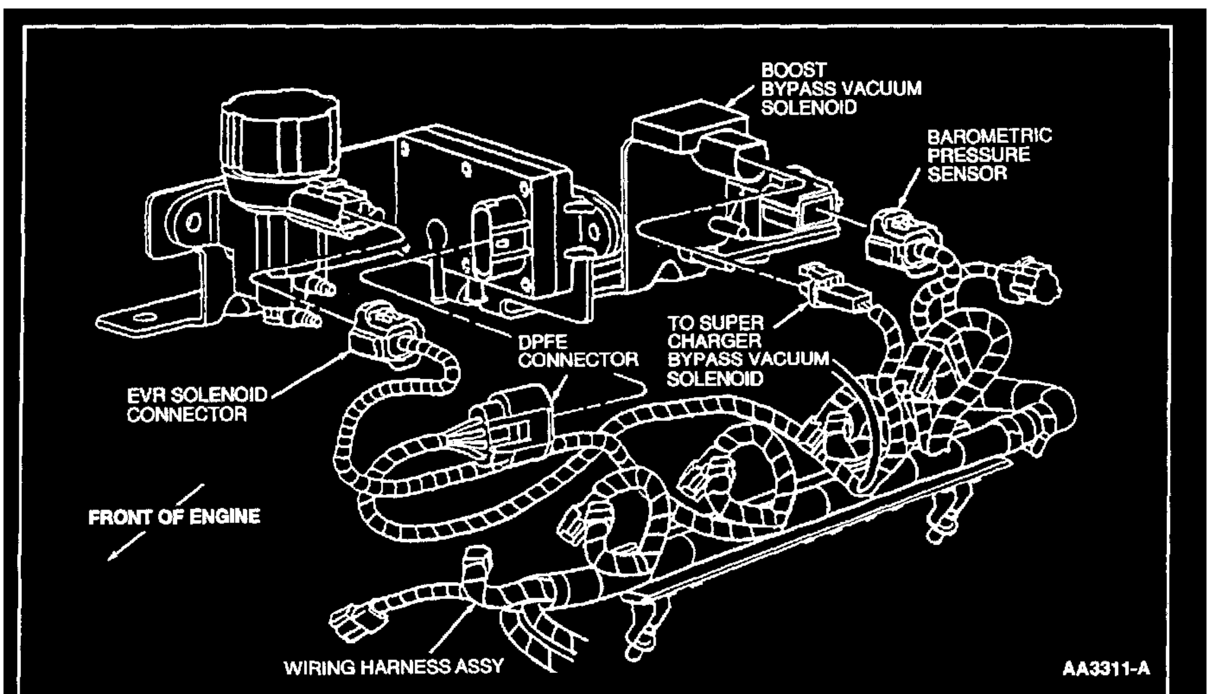


Figure 144: 5.4L Supercharger Controls— Wiring Harness Assembly

Supercharger Controls - Wiring Harness Assembly

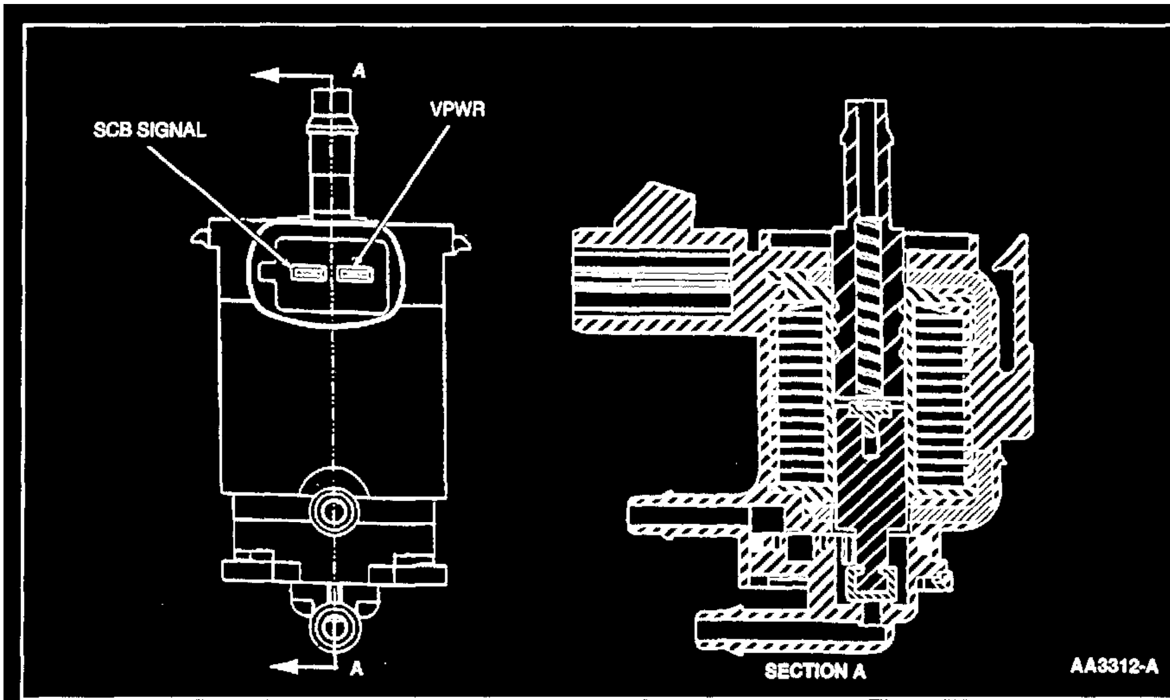


Figure 145: Supercharger (Boost) Bypass Solenoid (Thermactor Air Control Solenoid/Valve Assembly)

Supercharger (Boost) Bypass Solenoid

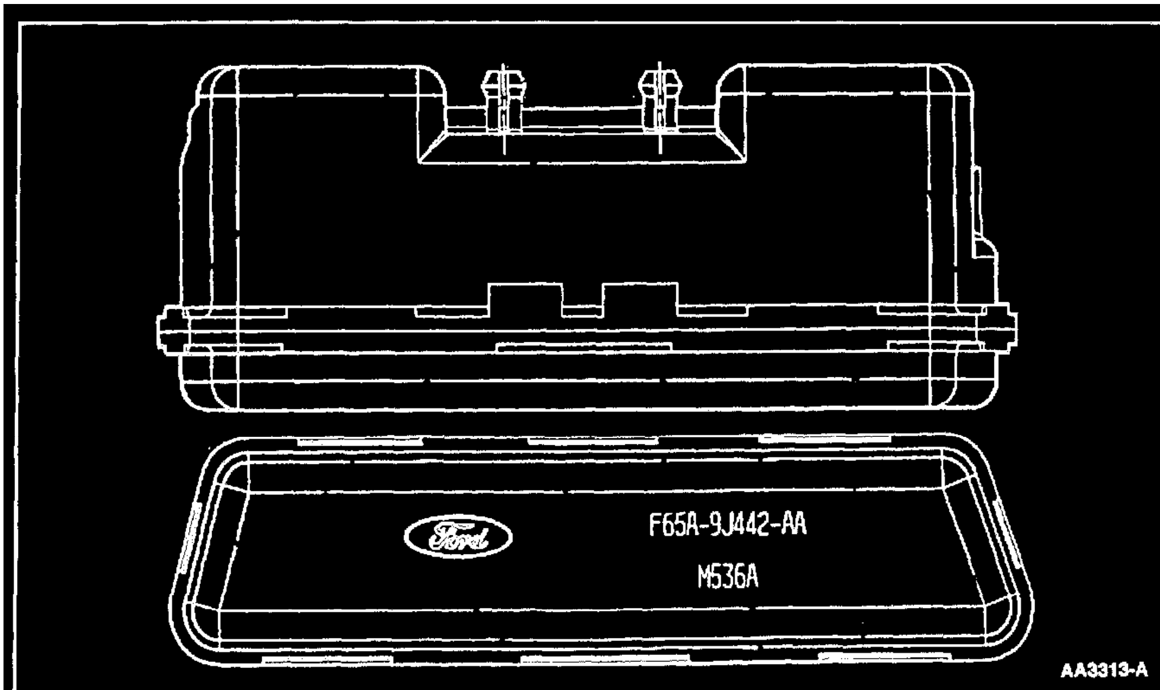


Figure 146: Vacuum Reservoir Assembly

Vacuum Reservoir Assembly

The Supercharger Bypass **(SCB)** System (Figure 142) allows the high pressure air at the outlet of the supercharger to vent back in the inlet of the supercharger, equalizing the pressure. This eliminates the boost (increased pressure that a supercharger produces) for times when supercharger function is undesirable. The components in this system are the vacuum bypass actuator (Figure 148) (which controls the bypass valve inside the supercharger), a supercharger (boost) bypass (SCB) solenoid (Figure 145) and a vacuum reservoir (Figure 146). The system normally operates with engine vacuum applied to the upper port of the vacuum bypass actuator, while the lower port references the air pressure in the clean air tube to cancel out any pressure difference in the intake air system. The actuator is set to open (bypassing the supercharger) during high vacuum engine conditions. As the throttle is opened, and engine vacuum decreases, the actuator closes to allow the supercharger to pressurize the air in the manifold. If an undesirable condition occurs in the engine, such as overheating or a critical Electric Engine Control **(Electronic EC)** sensor failure, the Powertrain

Control Module **(PCM)** also has the ability to control the SCB solenoid and direct the vacuum bypass actuator to bypass the supercharger. Once the engine condition has been corrected, the PCM allows the engine vacuum to control the vacuum bypass actuator.

Supercharger Assembly

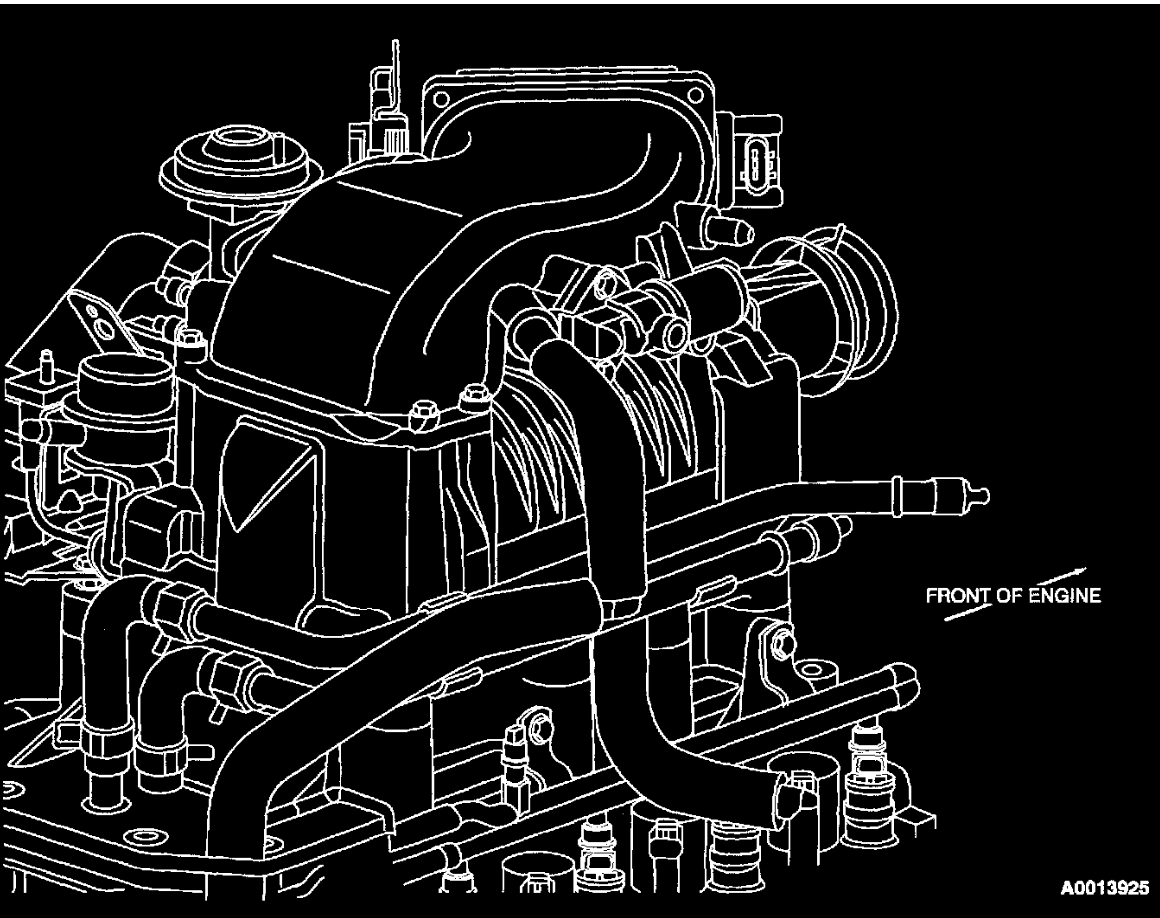


Figure 143: 5.4L Supercharger Assembly

Supercharger Assembly

The supercharger assembly (Figure 143) is a positive displacement pump. Its purpose is to supply an excess volume of intake air to the engine by increasing air pressure and density in the intake manifold. The supercharger assembly incorporates the bypass system to reduce air handling losses when boost is not required, resulting in better fuel economy. When integrated on the engine, the supercharger will increase torque across the entire engine operating range from 25 to 50 percent without compromising driveability or emissions. The supercharger is matched to the engine by its displacement and belt ratio, and can provide excess airflow at any engine speed. It contains two three-lobed rotors. The helical shape and specialized porting provide a smooth discharge flow and low level of noise during operation. The rotors are supported by ball bearings in front and needle bearings at the rear. The drive gears are pressed into place, therefore the supercharger is replaced as a unit, and is not serviceable.

Supercharger (Boost) Bypass Solenoid/(Thermactor Air Control Solenoid/Vacuum Valve Assembly)

The supercharger (boost) (SCB) solenoid (Figure 146) is used to control intake manifold vacuum to the vacuum bypass actuator. This part is replaced in field service diagnostics under the part name of a thermactor air control solenoid/vacuum valve assembly. The PCM transmits an output signal to the SCB solenoid, thereby activating the solenoid to apply stored vacuum from the reservoir to the actuator, when an undesirable condition occurs in the engine. Once the engine condition has been corrected, the solenoid will be de-activated by the PCM, allowing engine intake manifold vacuum to control the actuator. The SCB solenoid is normally de-energized.

Vacuum Reservoir Assembly

The vacuum reservoir assembly (Figure 146) stores vacuum that is applied to the vacuum actuator when a condition such as overheating or a critical sensor failure is generated. This allows the vacuum actuator to bypass the supercharger.

Intercooler System

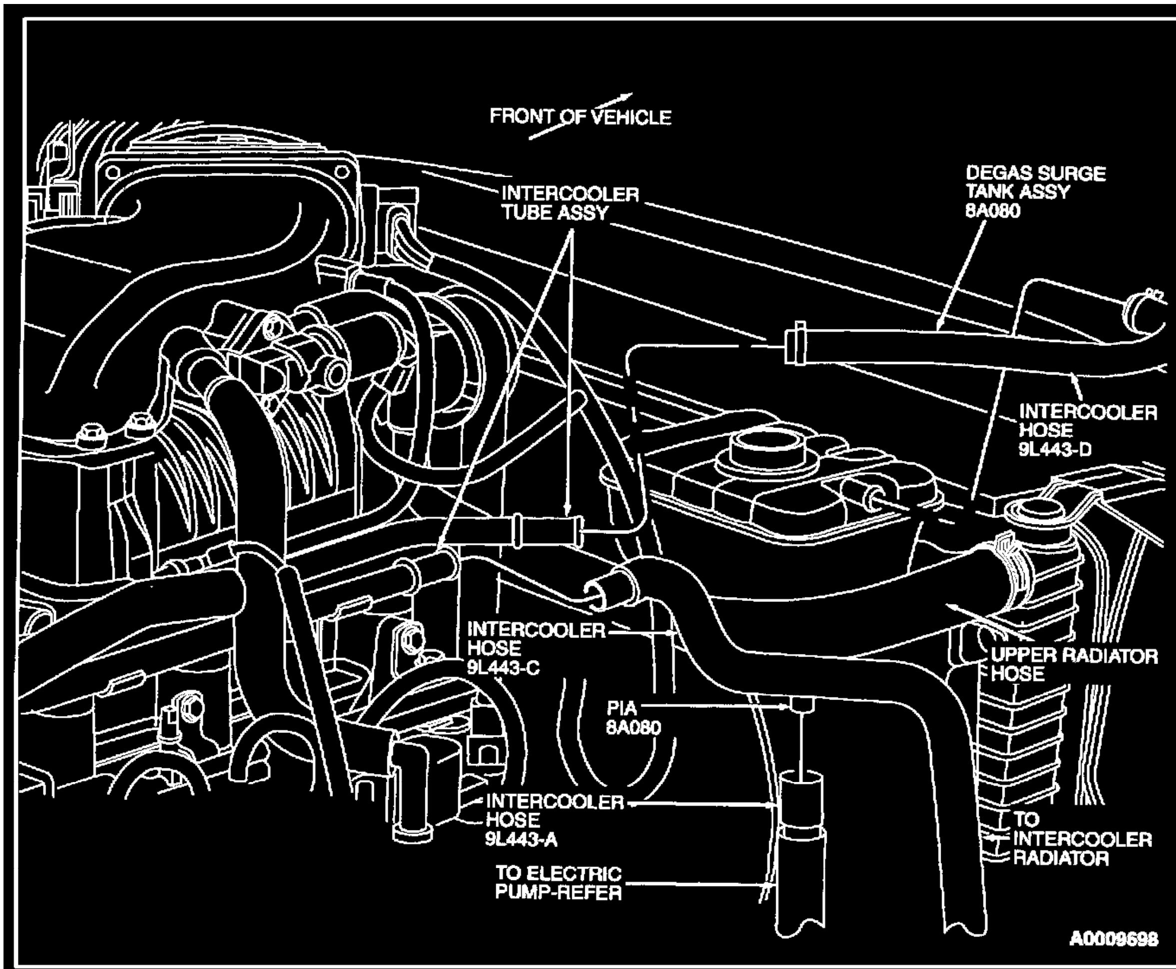


Figure 147: Intercooler Hoses

Intercooler Hoses

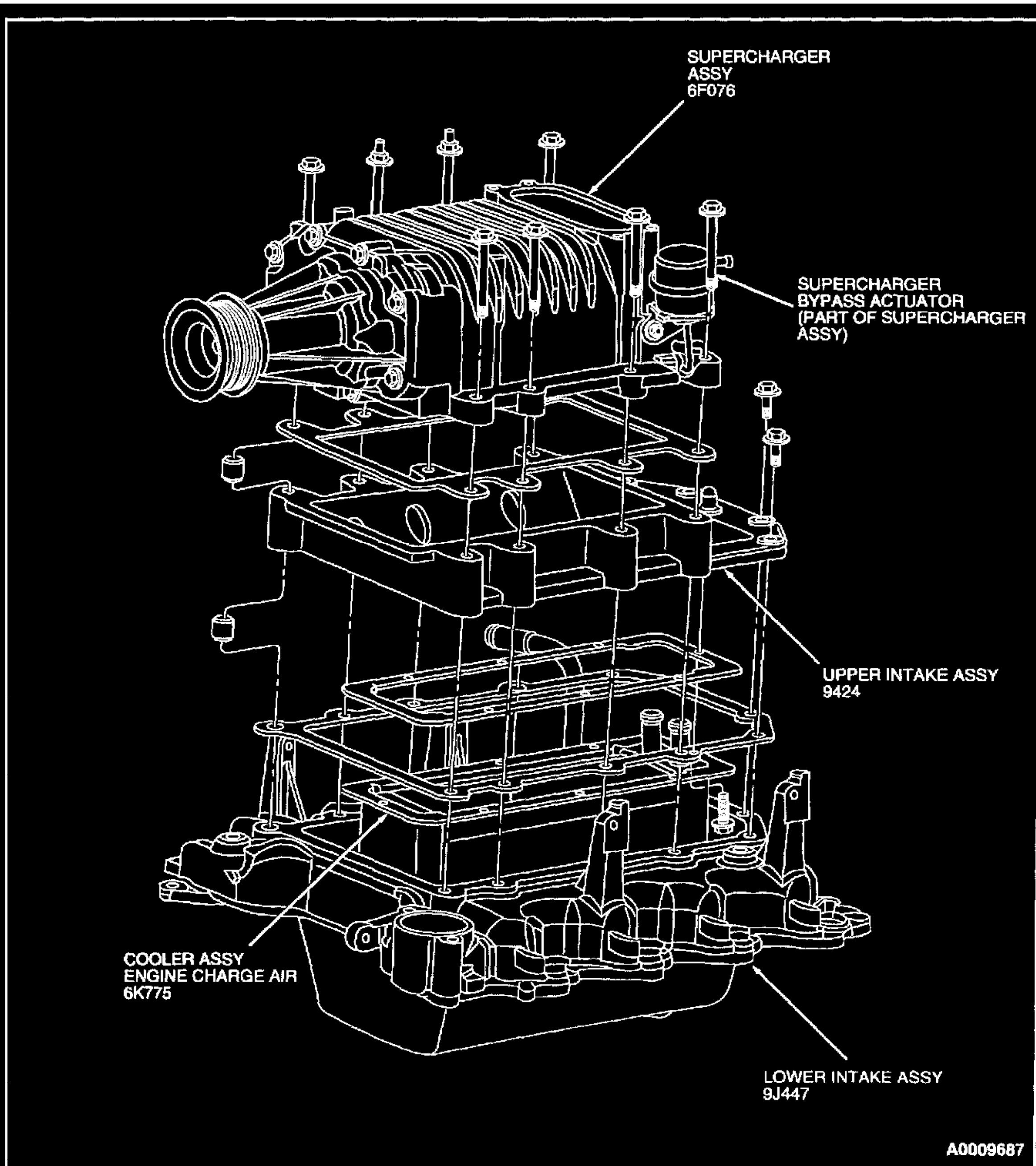


Figure 148: Unassembled Intercooler Hardware

Unassembled Intercooler Hardware

The Intercooler System (Figure 147) and (Figure 148) is designed to cool the induction air, which has been heated by the supercharger. The removal of heat from the pressurized air going into the intercooler increases the air density, which improves combustion efficiency, engine horsepower and torque. The system consists of an additional radiator in the grille, a reservoir (independent from engine cooling system), an electric water pump, a heat exchanger (intercooler) located in the lower intake manifold and tubing to interconnect these components. The intercooler is positioned after the supercharger, directly in the flow of the intake air. As the heated air flows through the intercooler, heat is transferred to the coolant which is circulated back to the intercooler radiator to be cooled by the airflow through the grille. The intercooler pump is controlled by the powertrain control module (PCM) to maintain a desirable intake air temperature by a second intake air temperature (IAT2) sensor in the lower intake manifold.