Engine Control Components

Note: *Transmission inputs, which are not described in this section are discussed in the applicable Workshop Manual transmission section.*

Accelerator Pedal Position (APP) Sensor

The APP sensor is an input to the powertrain control module (PCM) and is used to determine the torque demand. There are 3 pedal position signals in the sensor. Signal 1, APPS1, has a negative slope (increasing angle, decreasing voltage) and signals 2 and 3, APPS2 and APPS3, both have a positive slope (increasing angle, increasing voltage). During normal operation APPS1 is used as the indication of pedal position by the strategy. The 3 pedal position signals make sure the PCM receives a correct input even if 1 signal has a concern. There are 2 reference voltage circuits and 2 signal return circuits for the sensor. For additional information, refer to Torque Based Electronic Throttle Control (ETC) in this section.

Air Conditioning (A/C) Clutch Relay (A/CCR)

Note: *The PCM PIDs WAC and wide open throttle air conditioning cutoff fault (WACF) are used to monitor the A/CCR output.*

The A/CCR (may be referred to as the wide open throttle A/C cutoff [WAC] relay) is wired normally open. There is no direct electrical connection between the A/C switch or EATC module and the A/C clutch. The PCM receives a signal indicating that A/C is requested (for some applications, this message is sent through the communications network). When A/C is requested, the PCM will check other A/C related inputs that are available (such as ACPSW, ACCS). If these inputs indicate A/C operation is OK, and the engine conditions are OK (such as coolant temperature, engine RPM, throttle position), the PCM grounds the A/CCR output, closing the relay contacts and sending voltage to the A/CC.

Air Conditioning (A/C) Cycling Switch

The A/C cycling switch may be wired to either the ACCS or ACPSW PCM input. When the A/C cycling switch opens, the PCM will turn off the A/C clutch. For information on the specific function of the A/C cycling switch, refer to the Workshop Manual Section 412-00 Climate Control System. Also, refer to the applicable Wiring Diagram Manual for vehicle specific wiring.

If the ACCS signal is not received by the PCM, the PCM circuit will not allow the A/C to operate. For additional information, refer to PCM outputs, wide open throttle air conditioning cutoff (WAC).

Some applications do not have a dedicated (separate) input to the PCM indicating that A/C is requested. This information is received by the PCM through the communication link.

Air Conditioning Evaporator Temperature (ACET) Sensor

The ACET sensor measures the evaporator air discharge temperature. The ACET sensor is a thermistor device in which resistance changes with temperature. The electrical resistance of a thermistor decreases as the temperature increases, and the resistance increases as the temperature decreases. The PCM sources a low current 5 volts on the ACET circuit. With SIG RTN also connected to the ACET sensor, the varying resistance affects the voltage drop across the sensor terminals. As A/C evaporator air temperature changes, the varying resistance of the ACET sensor changes the voltage the PCM detects.

The ACET sensor is used to more accurately control A/C clutch cycling, improve defrost/demist performance, and reduce A/C clutch cycling.

Note: *These values can vary 15 percent due to sensor and VREF variations. Voltage values were calculated for VREF equals 5.0 volts.*

A/C EVAPORATOR TEMPERATURE (ACET) SENSOR VOLTAGE AND RESISTANCE

°C	°F	Volts	Resistance (K ohms)
100	212	0.47	2.08
90	194	0.61	2.80
80	176	0.80	3.84
70	158	1.05	5.34
60	140	1.37	7.55

°C	°F	Volts	Resistance (K ohms)
50	122	1.77	10.93
40	104	2.23	16.11
30	86	2.74	24.25
20	68	3.26	37.34
10	50	3.73	58.99
0	32	4.14	95.85
-10	14	4.45	160.31
-20	-4	4.66	276.96

Air Conditioning (A/C) High Pressure Switch

The A/C high pressure switch is used for additional A/C system pressure control. The A/C high pressure switch is either dual function for multiple speed, relay controlled electric fan applications, or single function for all others.

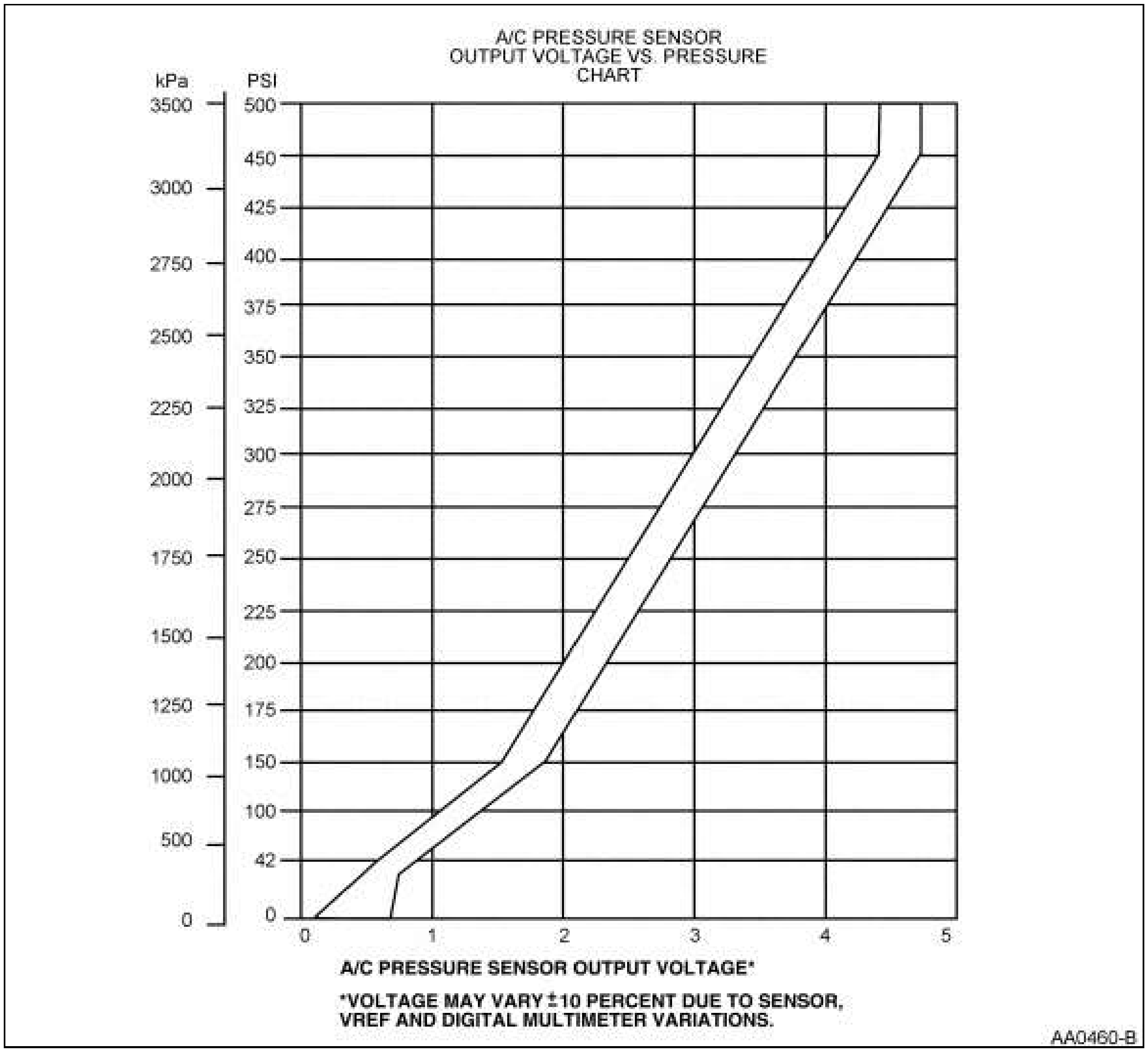
For refrigerant containment control, the normally closed high pressure contacts open at a predetermined A/C pressure. This results in the A/C turning off, preventing the A/C pressure from rising to a level that would open the A/C high pressure relief valve.

For fan control, the normally open medium pressure contacts close at a predetermined A/C pressure. This grounds the ACPSW circuit input to the PCM. The PCM then turns on the high speed fan to help reduce the pressure.

For additional information, refer to the Workshop Manual Section 412-00 Climate Control System or the Wiring Diagram Manual.

Air Conditioning Pressure (ACP) Sensor

The ACP sensor is located in the high pressure (discharge) side of the A/C system. The ACP sensor provides a voltage signal to the PCM that is proportional to the A/C pressure. The PCM uses this information for A/C clutch control, fan control and idle speed control.



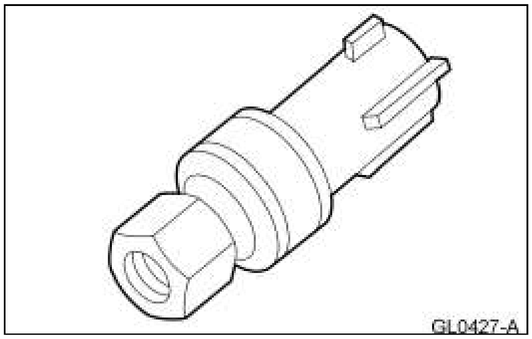


Figure 1 : Typical A/C Pressure Sensor

Brake Pedal Position (BPP) Switch

The BPP switch is sometimes referred to as the stoplamp switch. The BPP switch provides a signal to the PCM indicating that the brakes are applied. The BPP switch is normally open and is mounted on the brake pedal support. Depending on the vehicle application the BPP switch can be hardwired as follows:

- BPP switch is hardwired to the PCM supplying battery positive voltage (B+) when the vehicle brake pedal is applied.
- BPP switch is hardwired to the Anti-Lock Brake System (ABS) Module, Lighting Control Module (LCM), or Rear Electronic Module (REM), the BPP signal is then broadcast over the network to be received by the PCM.
- BPP switch is hardwired to the anti-lock brake system (ABS) traction control/stability assist module. The ABS module interprets the BPP switch input along with other ABS inputs and generates an output called the driver brake application (DBA) signal. The DBA signal is then sent to the PCM and to other BPP signal users.

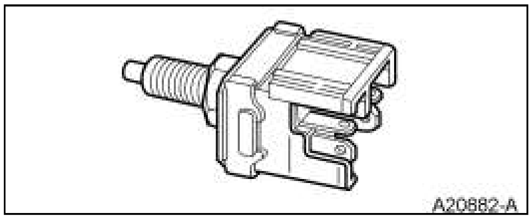


Figure 2 : Typical BPP Switch

Brake Pedal Switch (BPS)/Brake Deactivator Switch

The BPS, also called the brake deactivator switch, is for vehicle speed control deactivation. A normally closed switch supplies battery positive voltage (B+) to the PCM when the brake pedal is not applied. When the brake pedal is applied, the normally closed switch opens and power is removed from the PCM.

On some applications the normally closed BPS, along with the normally open BPP switch, are used for a brake rationality test within the PCM. The PCM misfire monitor profile learn function may be disabled if a brake switch concern occurs. If one or both brake pedal inputs to the PCM is not changing states when they were expected to, a diagnostic trouble code is set by the PCM strategy.

Camshaft Position (CMP) Sensor

The CMP sensor detects the position of the camshaft. The CMP sensor identifies when piston No. 1 is on its compression stroke. A signal is then sent to the PCM and used for synchronizing the sequential firing of the fuel injectors. Coil-on-plug (COP) ignition applications use the CMP signal to select the correct ignition coil to fire.

Vehicles with 2 CMP sensors are equipped with variable camshaft timing (VCT). They use the second sensor to identify the position of the camshaft on bank 2 as an input to the PCM.

There are 2 types of CMP sensors: the 3-pin connector Hall-effect type sensor and the 2-pin connector variable reluctance type sensor.

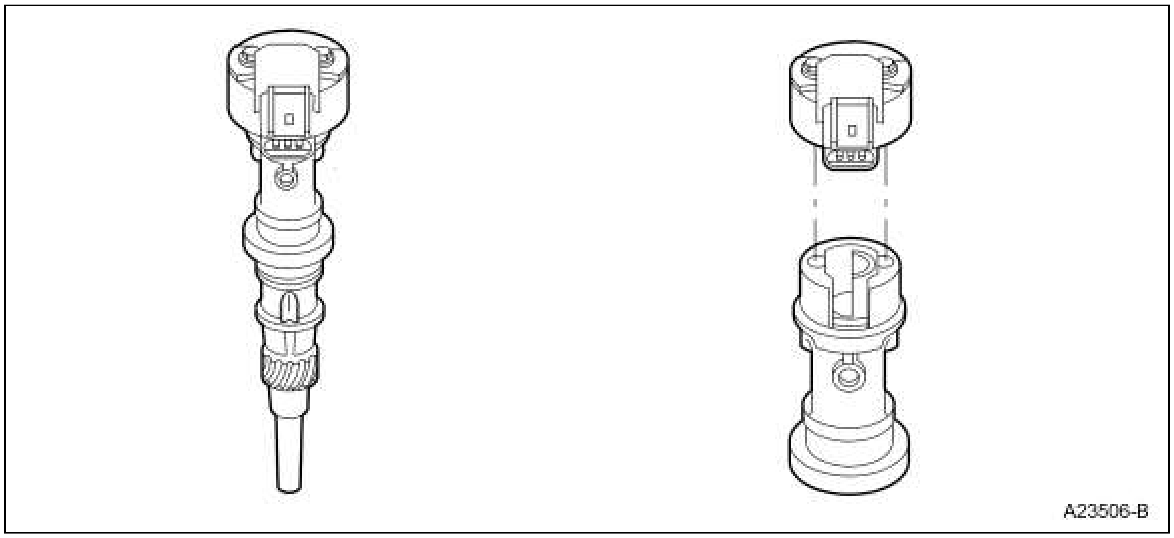


Figure 3 : Typical Synchronizer Hall-Effect CMP Sensor

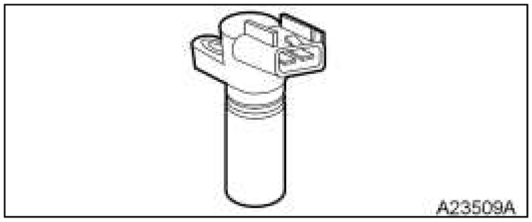


Figure 4 : Typical Variable Reluctance CMP Sensor

Canister Vent (CV) Solenoid

During the evaporative emissions (EVAP) leak check monitor, the CV solenoid seals the EVAP canister from the atmospheric pressure. This allows the EVAP canister purge valve to obtain the target vacuum in the fuel tank during the EVAP leak check monitor.

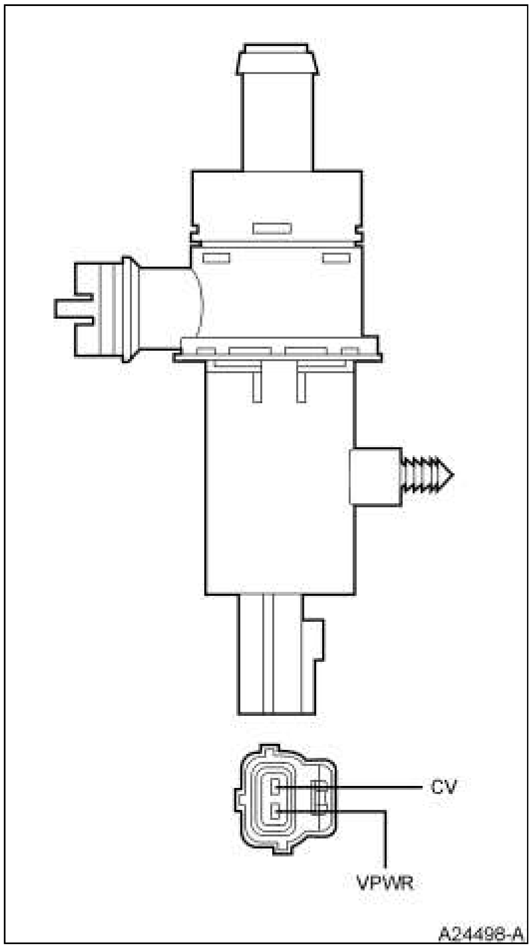


Figure 5 : Typical Canister Vent (CV) Solenoid

Check Fuel Cap Indicator

Note: *The check fuel cap indicator on the Ranger is a dedicated output signal that is controlled by the PCM.*

The check fuel cap indicator is a communications network message sent by the PCM. The PCM sends the message to illuminate the lamp when the strategy determines that there is a failure in the vapor management system due to the fuel filler cap not being sealed correctly. This would be detected by the inability to pull vacuum in the fuel tank, after a fueling event.

Clutch Pedal Position (CPP) Switch

The CPP switch is an input to the PCM indicating the clutch pedal position. The PCM provides a low current voltage on the CPP circuit. When the CPP switch is closed, this voltage is pulled low through the SIG RTN circuit. The CPP input to the PCM is used to detect a reduction in engine load. The PCM uses the load information for mass air flow and fuel calculations.

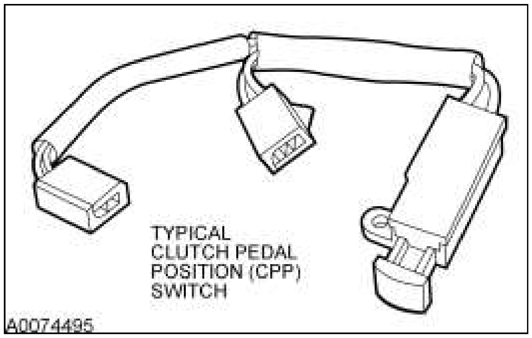


Figure 6 : Typical Clutch Pedal Position (CPP) Switch

Coil On Plug (COP)

The COP ignition operates similar to a standard coil pack ignition except each plug has one coil per plug. The COP has 3 different modes of operation: engine crank, engine running, and CMP failure mode effects management (FMEM). For additional information, refer to Ignition Systems in this section.

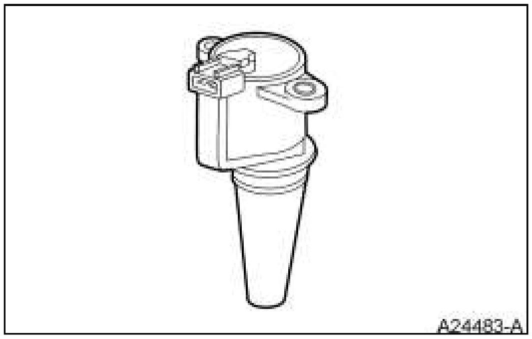


Figure 7 : Coil On Plug (COP)

Coil Pack

The PCM provides a grounding switch for the coil primary circuit. When the switch is closed, voltage is applied to the coil primary circuit. This creates a magnetic field around the primary coil. The PCM opens the switch, causing the magnetic field to collapse, inducing the high voltage in the secondary coil windings and firing the spark plug. The spark plugs are paired so that as one spark plug fires on the compression stroke, the other spark plug fires on the exhaust stroke. The next time the coil is fired the order is reversed. The next pair of spark plugs fire according to the engine firing order.

Coil packs come in 4-tower, 6-tower horizontal and series 5 6-tower models. Two adjacent coil towers share a common coil and are called a matched pair. For 6-tower coil pack (6 cylinder) applications, the matched pairs are 1 and 5, 2 and 6, and 3 and 4. For 4-tower coil pack (4 cylinder) applications, the matched pairs are 1 and 4, and 2 and 3.

When the coil is fired by the PCM, spark is delivered through the matched pair towers to their respective spark plugs. The spark plugs are fired simultaneously and are paired so that as one fires on the compression stroke, the other spark plug fires on the exhaust stroke. The next time the coil is fired, the situation is reversed. The next pair of spark plugs fire according to the engine firing order.

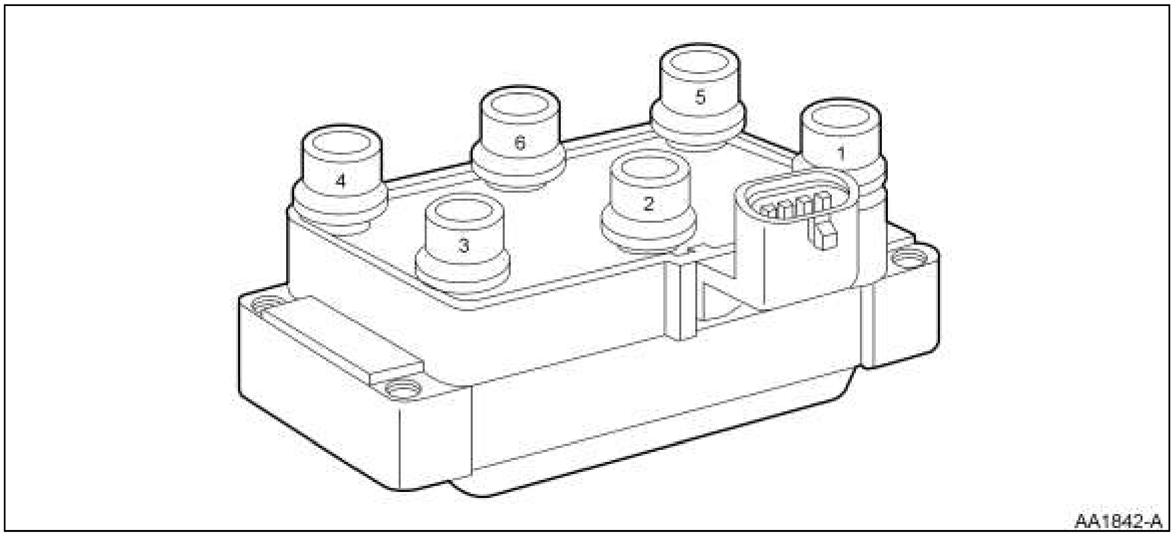


Figure 8 : Typical Six-Tower Coil Pack

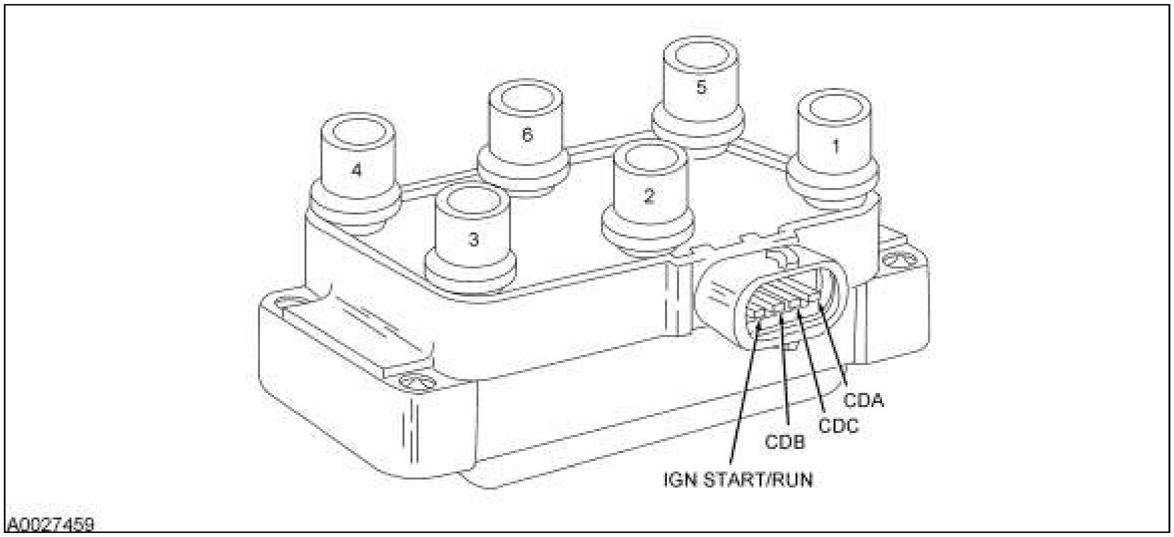


Figure 9 : Horizontal Connector 6-Tower Coil Pack

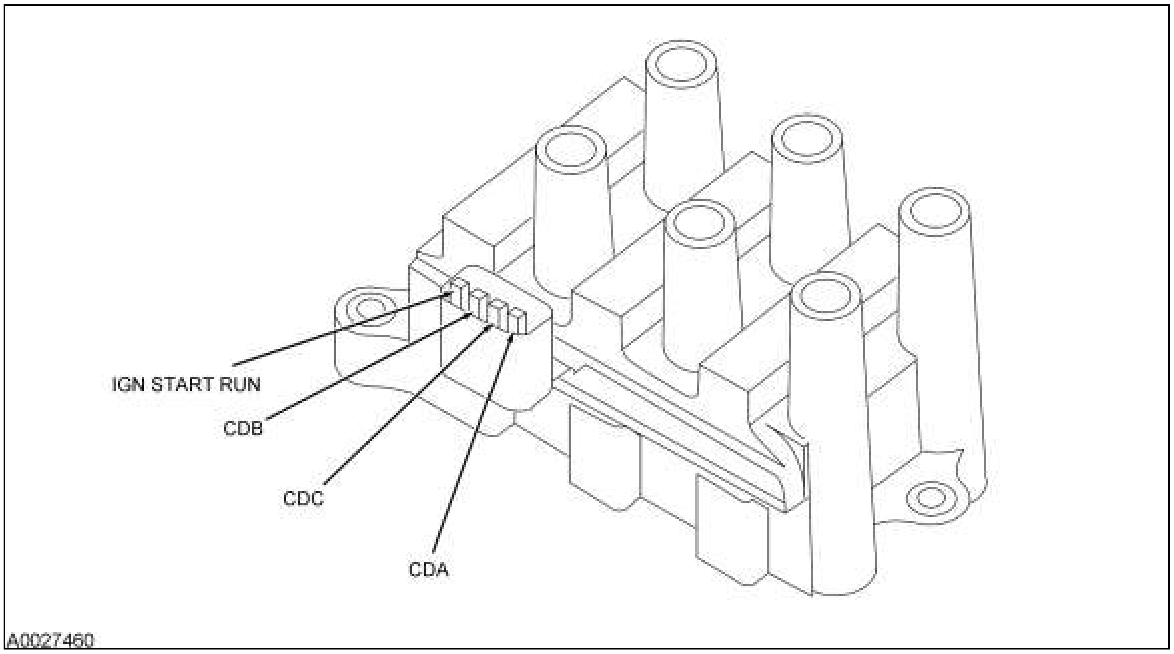


Figure 10 : Series 5 6-Tower Coil Pack

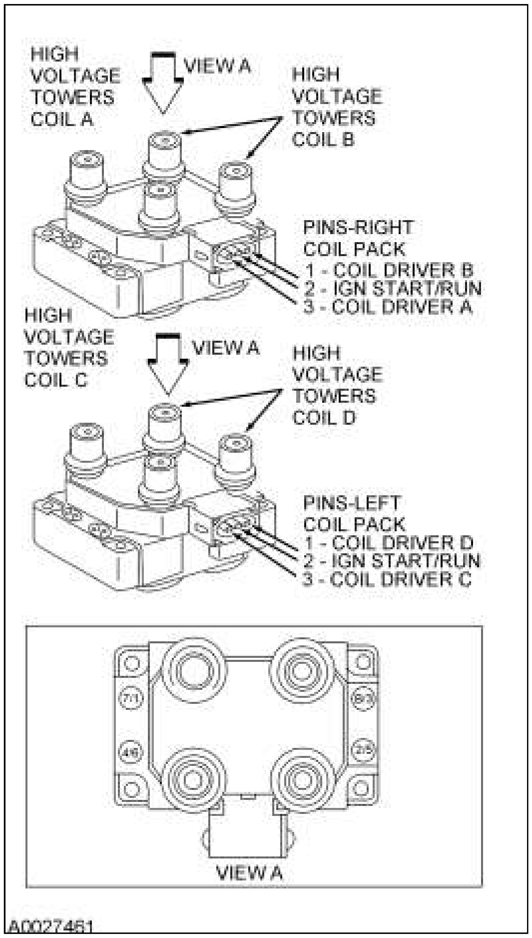


Figure 11 : Four-Tower Coil Packs

Cooling Fan Clutch

The cooling fan clutch is an electrically actuated viscous clutch that consists of 3 main elements:

- a working chamber
- a reservoir chamber
- a cooling fan clutch actuator valve and a fan speed sensor (FSS)

The cooling fan clutch actuator valve controls the fluid flow from the reservoir into the working chamber. Once viscous fluid is in the working chamber, shearing of the fluid results in fan rotation. The cooling fan clutch actuator valve is activated with a pulse width modulated (PWM) output signal from the powertrain control module (PCM). By opening and closing the fluid port valve, the PCM can control the cooling fan clutch speed. The cooling fan clutch speed is measured by a Hall-effect sensor and is monitored by the PCM during closed loop operation.

The PCM optimizes fan speed based on engine coolant temperature (ECT), engine oil temperature (EOT), transmission fluid temperature (TFT), intake air temperature (IAT), or air conditioning requirements. When an increased demand for fan speed is requested for vehicle cooling, the PCM monitors the fan speed through the Hall-effect sensor. If a fan speed increase is required, the PCM outputs the PWM signal to the fluid port, providing the required fan speed increase.

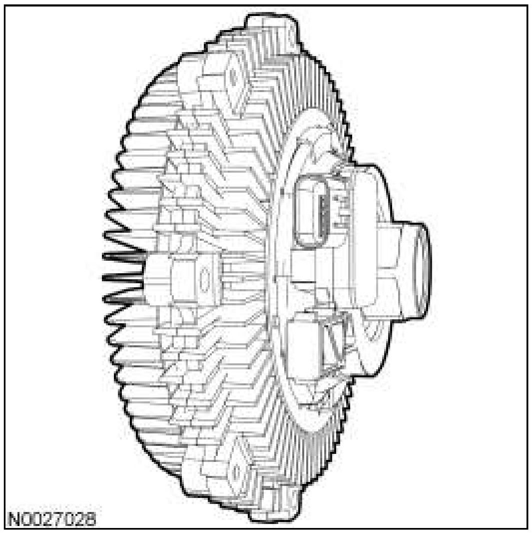


Figure 12 : Cooling Fan Clutch with Fan Speed Sensor (FSS)

Crankshaft Position (CKP) Sensor

The CKP sensor is a magnetic transducer mounted on the engine block adjacent to a pulse wheel located on the crankshaft. By monitoring the crankshaft mounted pulse wheel, the CKP is the primary sensor for ignition information to the PCM. The pulse wheel has a total of 35 teeth spaced 10 degrees apart with one empty space for a missing tooth. The 6.8L 10-cylinder pulse wheel has 39 teeth spaced 9 degrees apart and one 9 degree empty space for a missing tooth. By monitoring the pulse wheel, the CKP sensor signal indicates crankshaft position and speed information to the PCM. By monitoring the missing tooth, the CKP sensor is also able to identify piston travel in order to synchronize the ignition system and provide a way of tracking the angular position of the crankshaft relative to a fixed reference for the CKP sensor configuration. The PCM also uses the CKP signal to determine if a misfire has occurred by measuring rapid decelerations between teeth.

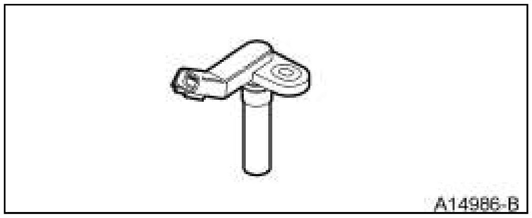


Figure 13 : Typical Crankshaft Position (CKP) Sensor

Cylinder Head Temperature (CHT) Sensor

The CHT sensor is a thermistor device in which resistance changes with temperature. The electrical resistance of a thermistor decreases as temperature increases, and the resistance increases as the temperature decreases. The varying resistance affects the voltage drop across the sensor terminals and provides electrical signals to the PCM corresponding to temperature.

The CHT sensor is installed in the aluminum cylinder head and measures the metal temperature. The CHT sensor can provide complete engine temperature information and can be used to infer coolant temperature. If the CHT sensor conveys an overheating condition to the PCM, the PCM initiates a fail-safe cooling strategy based on information from the CHT sensor. A cooling system concern such as low coolant or coolant loss could cause an overheating condition. As a result, damage to major engine components could occur. Using both the CHT sensor and fail-safe cooling strategy, the PCM prevents damage by allowing air cooling of the engine and limp home capability. For additional information, refer to Powertrain Control Software for Fail-Safe Cooling Strategy in this section.

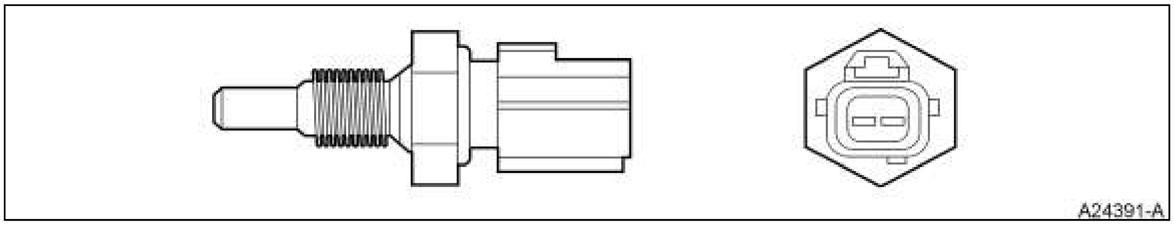
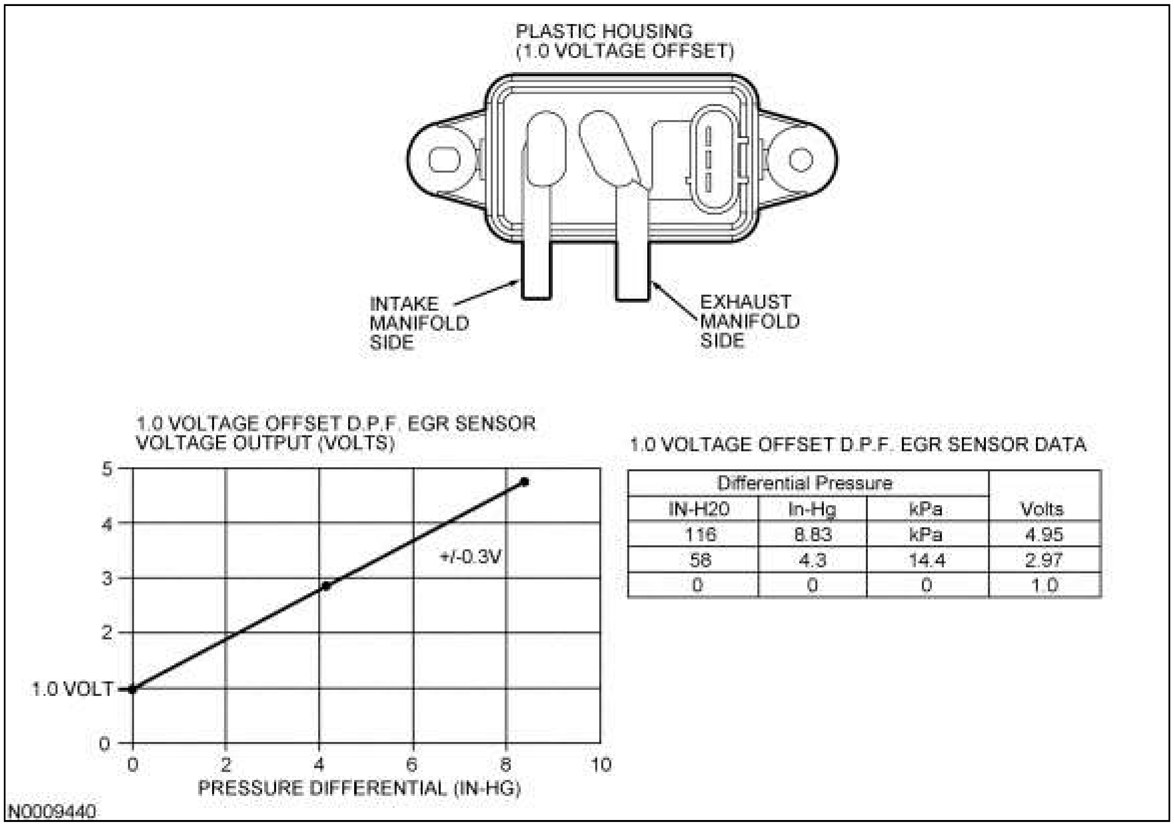


Figure 14 : Typical Cylinder Head Temperature (CHT) Sensor

Differential Pressure Feedback Exhaust Gas Recirculation (EGR) (DPFE) Sensor

The DPFE sensor is a ceramic, capacitive-type pressure transducer that monitors the differential pressure across a metering orifice located in the orifice tube assembly. The differential pressure feedback sensor receives this signal through 2 hoses referred to as the downstream pressure hose (REF SIGNAL) and upstream pressure hose (HI SIGNAL). The HI and REF hose connections are marked on the DPFE sensor housing for identification (note that the HI signal uses a larger diameter hose). The DPFE sensor outputs a voltage proportional to the pressure drop across the metering orifice and supplies it to the powertrain control module (PCM) as EGR flow rate feedback.



1.0 VOLTAGE OFFSET D.P.F. EGR SENSOR DATA

Differential Pressure			Volts
IN-H20	In-Hg	kPa	
116	8.83	kPa	4.95
58	4.3	14.4	2.97
0	0	0	1.0

Figure 15 : DPFE Sensor

Differential Pressure Feedback Exhaust Gas Recirculation (EGR) (DPFE) Sensor — Tube Mounted

The tube mounted DPFE sensor is identical in operation as the larger plastic DPFE sensors and uses a 1.0 volt offset. The HI and REF hose connections are marked on the side of the sensor.

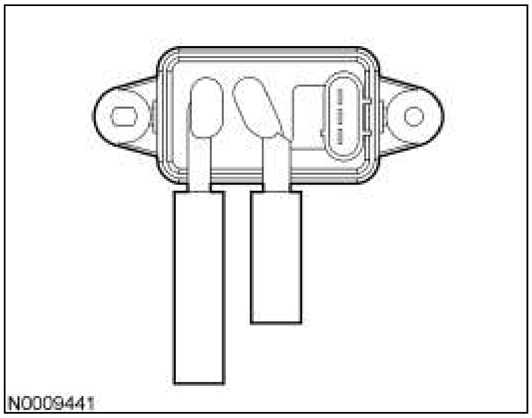


Figure 16 : DPFE Sensor — Tube Mounted

Electric Exhaust Gas Recirculation (EEGR) Valve

Depending on the application, the EEGR valve is a water cooled or an air cooled motor/valve assembly. The motor is commanded to move in 52 discrete steps as it acts directly on the EEGR valve. The position of the valve determines the rate of EGR. The built-in spring works to close the valve (against the motor opening force).

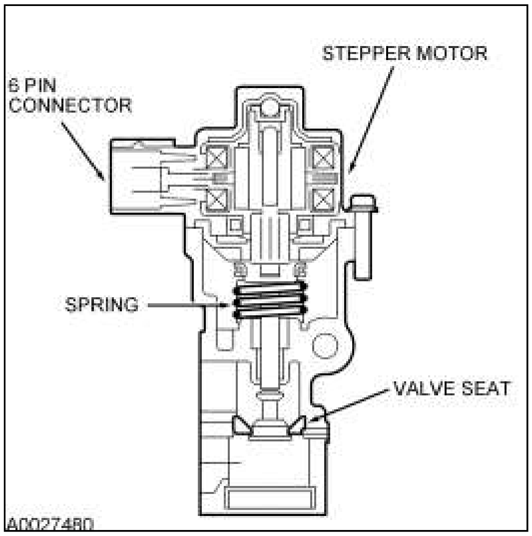


Figure 17 : EEGR Motor/Valve Assembly

Electronic Throttle Actuator Control (TAC)

The electronic TAC is a DC motor controlled by the PCM (requires 2 wires). The gear ratio from the motor to the throttle plate shaft is 17:1. There are 2 designs for the TAC, parallel and in-series. The parallel design has the motor under the bore parallel to the plate shaft. The motor housing is integrated into the main housing. The in-series design has a separate motor housing. Two springs are used; one is used to close the throttle (main spring) and the other is in a plunger assembly that results in a default angle when no power is applied. The force of the plunger spring is 2 times stronger than the main spring. The default angle is usually set to result in a top vehicle speed of 48 km/h (30 mph). Typically this throttle angle is 7 to 8 degrees from the hard stop angle. The closed throttle plate hard stop is used to prevent the throttle from binding in the bore (~0.75 degree). This hard stop setting is not adjustable and is set to result in less airflow than the minimum engine airflow required at idle. For additional information, refer to Torque Based Electronic Throttle Control (ETC) in this section.

Electronic Throttle Body (ETB) Position Sensor

The ETB position sensor has 2 signal circuits in the sensor for redundancy. The redundant ETB position signals are required for increased monitoring. The first ETB position sensor signal (TP1) has a negative slope (increasing angle, decreasing voltage) and the second signal (TP2) has a positive slope (increasing angle, increasing voltage). During normal operation the negative slope ETB position sensor signal (TP1) is used by the control strategy as the indication of throttle position. The 2 ETB position sensor signals make sure the PCM receives a correct input even if 1 signal has a concern. There is 1 reference voltage circuit and 1 signal return circuit for the sensor. For additional information, refer to Torque Based Electronic Throttle Control (ETC) in this section.

Engine Coolant Temperature (ECT) Sensor

The ECT sensor is a thermistor device in which resistance changes with temperature. The electrical resistance of a thermistor decreases as the temperature increases, and the resistance increases as the temperature decreases. The varying resistance affects the voltage drop across the sensor terminals and provides electrical signals to the PCM corresponding to temperature.

Thermistor-type sensors are considered passive sensors. A passive sensor is connected to a voltage divider network so that varying the resistance of the passive sensor causes a variation in total current flow. Voltage that is dropped across a fixed resistor in a series with the sensor resistor determines the voltage signal at the PCM. This voltage signal is equal to the reference voltage minus the voltage drop across the fixed resistor.

The ECT measures the temperature of the engine coolant. The PCM uses the ECT input for fuel control and for cooling fan control. There are 3 types of ECT sensors, threaded, push-in, and twist-lock. The ECT sensor is located in an engine coolant passage.

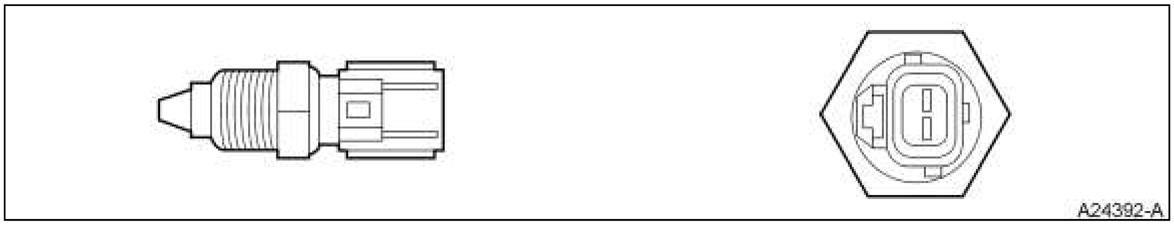


Figure 18 : Typical Thread Type Engine Coolant Temperature (ECT) Sensor

Engine Oil Temperature (EOT) Sensor

The EOT sensor is a thermistor device in which resistance changes with temperature. The electrical resistance of a thermistor decreases as the temperature increases and the resistance increases as the temperature decreases. The varying resistance affects the voltage drop across the sensor terminals and provides electrical signals to the PCM corresponding to temperature.

Thermistor-type sensors are considered passive sensors. A passive sensor is connected to a voltage divider network so that varying the resistance of the passive sensor causes a variation in total current flow. Voltage that is dropped across a fixed resistor in a series with the sensor resistor determines the voltage signal at the PCM. This voltage signal is equal to the reference voltage minus the voltage drop across the fixed resistor.

The EOT sensor measures the temperature of the engine oil. The sensor is typically threaded into the engine oil lubrication system. The PCM can use the EOT sensor input to determine the following:

- On variable camshaft timing (VCT) applications the EOT input is used to adjust the VCT control gains and logic for camshaft timing.
- The PCM can use EOT sensor input in conjunction with other PCM inputs to determine oil degradation.
- The PCM can use EOT sensor input to initiate a soft engine shutdown. To prevent engine damage from occurring as a result of high oil temperatures, the PCM has the ability to initiate a soft engine shutdown. Whenever engine RPM exceeds a calibrated level for a certain period of time, the PCM begins reducing power by disabling engine cylinders.

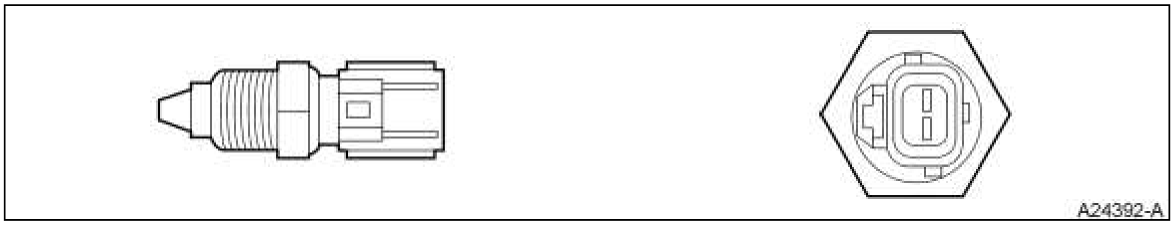


Figure 19 : Typical Engine Oil Temperature (EOT) Sensor

Evaporative Emission (EVAP) Canister Purge Valve

Note: *The EVAP canister purge valve may also be referred to as a vapor management valve (VMV).*

The EVAP canister purge valve is part of the enhanced EVAP system that is controlled by the PCM. This valve controls the flow of vapors (purging) from the EVAP canister to the intake manifold during various engine operating modes. The EVAP canister purge valve is a normally closed valve. The electronic EVAP canister purge valve controls the flow of vapors electronically by way of a solenoid thereby, eliminating the need for an electronic vacuum regulator and vacuum diaphragm. The PCM outputs a signal between 0% and 100% duty cycle to control the EVAP canister purge valve. On applications with an electronic EVAP canister purge valve, the PCM outputs a signal between 0 mA and 1,000 mA to control the solenoid.

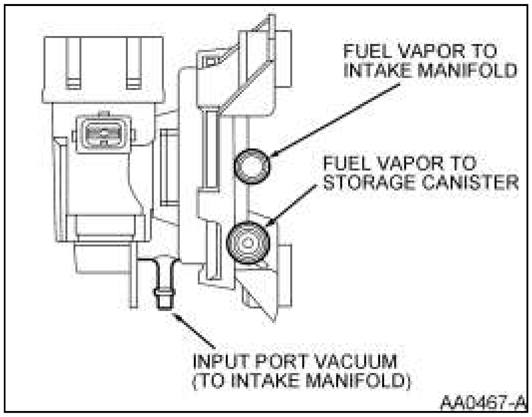


Figure 20 : EVAP Canister Purge Valve

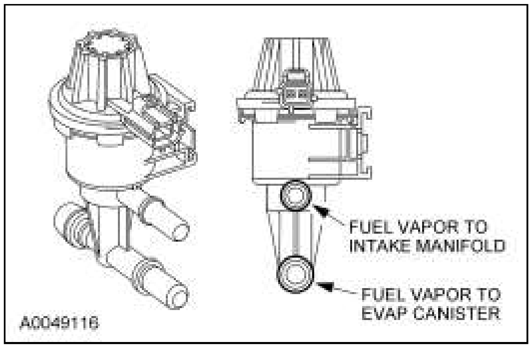


Figure 21 : Electronic EVAP Canister Purge Valve

Exhaust Gas Recirculation (EGR) Orifice Tube Assembly

The orifice tube assembly is a section of tubing connecting the exhaust system to the intake manifold. The assembly provides the flow path for the EGR to the intake manifold and also contains the metering orifice and 2 pressure pick-up tubes. The internal metering orifice creates a measurable pressure drop across it as the EGR valve opens and closes. This pressure differential across the orifice is picked up by the differential pressure feedback EGR (DPFE) sensor which provides feedback to the powertrain control module (PCM).

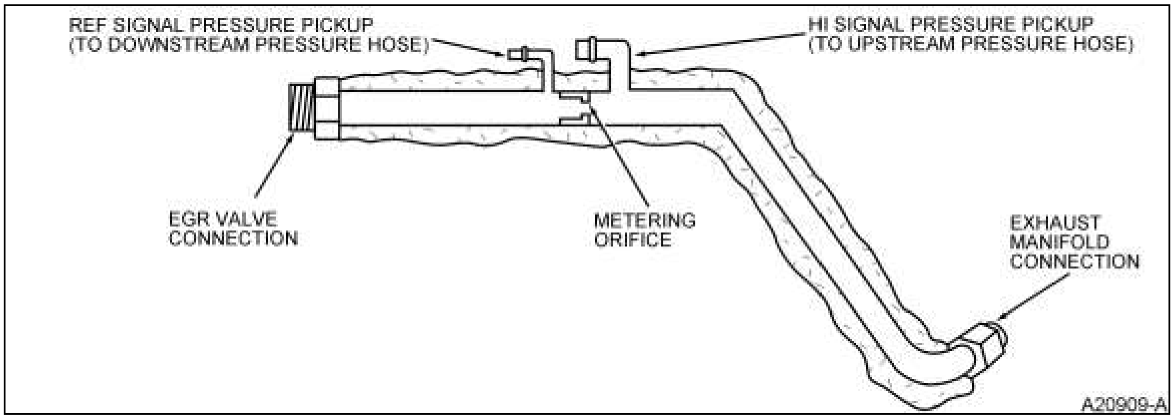
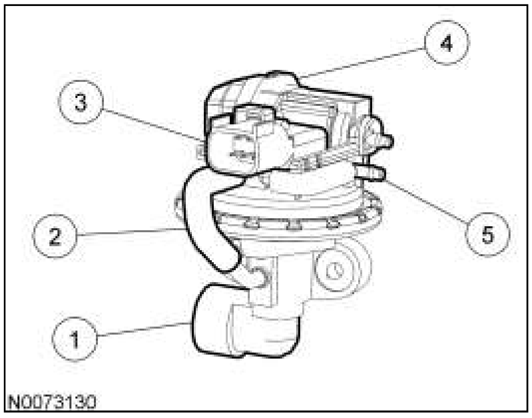


Figure 22 : EGR Orifice Tube Assembly

Exhaust Gas Recirculation (EGR) System Module (ESM)

The ESM is an integrated differential pressure feedback EGR (DPFE) system. It functions in the same manner as the conventional DPFE system, however the various system components have been integrated into a single component called the ESM. The flange of the valve portion of the ESM bolts directly to the intake manifold with a metal gasket that forms the measuring orifice. This arrangement increases system reliability, response time, and system precision. By relocating the EGR orifice from the exhaust to the intake side of the EGR valve, the downstream pressure signal measures manifold absolute pressure (MAP). The system provides the powertrain control module (PCM) with a differential DPFE signal, identical to a traditional DPFE system.

ESM



Item	Number	Description

1	—	Exhaust Flow
2	—	Upstream Differential Pressure Feedback EGR Port
3	—	Differential Pressure Feedback EGR and MAP Sensor
4	—	EGR Vacuum Regulator Integrated into Upper Body
5	—	Downstream Differential Pressure Feedback EGR Port
6	—	To Intake Manifold Plenum

Figure 23

Exhaust Gas Recirculation (EGR) Vacuum Regulator (EVR) Solenoid

The EVR solenoid is an electromagnetic device which is used to regulate the vacuum supply to the EGR valve. The solenoid contains a coil which magnetically controls the position of a disc to regulate the vacuum. As the duty cycle to the coil increases, the vacuum signal passed through the solenoid to the EGR valve also increases. Vacuum not directed to the EGR valve is vented through the solenoid vent to atmosphere. Note that at 0% duty cycle (no electrical signal applied), the EVR solenoid allows some vacuum to pass, but not enough to open the EGR valve.

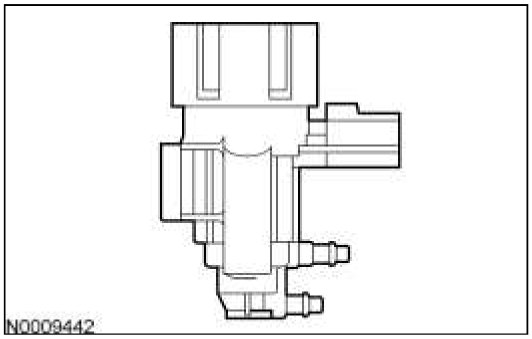
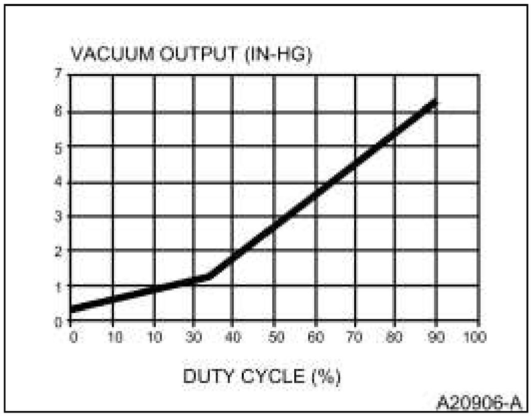


Figure 24 : EVR Solenoid



EVR SOLENOID DATA

Duty Cycle (%)	Vacuum Output					
	Minimum		Nominal		Maximum	
	In-Hg	kPa	In-Hg	kPa	In-Hg	kPa
0	0	0	0.38	1.28	0.75	2.53
33	0.55	1.86	1.3	4.39	2.05	6.9
90	5.69	19.2	6.32	21.3	6.95	23.47
EVR resistance: 26-40 Ohms						

Exhaust Gas Recirculation (EGR) Valve

The EGR valve in the differential pressure feedback EGR (DPFE) system is a conventional, vacuum-actuated. The valve increases or decreases the flow of EGR. As vacuum applied to the EGR valve diaphragm overcomes the spring force, the valve begins to open. As the vacuum signal weakens, at 5.4 kPa (1.6 in-Hg) or less, the spring force closes the valve. The EGR valve is fully open at about 15 kPa (4.5 in-Hg).

Since EGR flow requirement varies greatly, providing repair specifications on flow rate is impractical. The on-board diagnostic (OBD) system monitors the EGR valve function and triggers a diagnostic trouble code (DTC) if the test criteria is not met. The EGR valve flow rate is not measured directly as part of the diagnostic procedures.

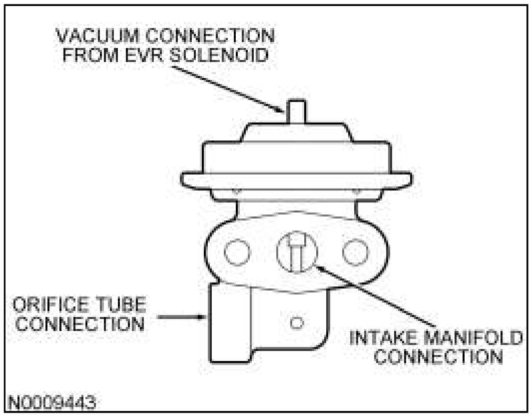
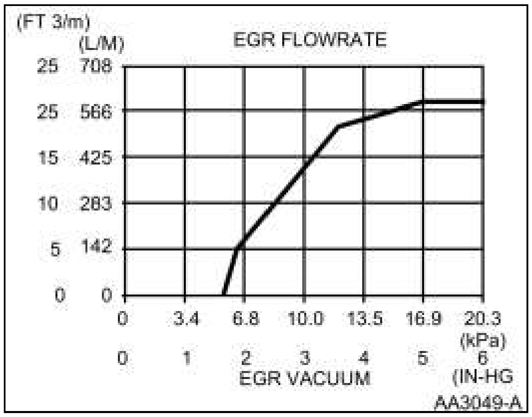


Figure 25 : Typical EGR Valve



Fan Control

The PCM monitors certain parameters (such as engine coolant temperature, vehicle speed, A/C on/off status, A/C pressure) to determine engine cooling fan needs.

For variable speed electric fan(s):

The PCM controls the fan speed and operation using a duty cycle output on the fan control variable (FCV) circuit. The fan controller (located at or integral to the engine cooling fan assembly) receives the FCV command and operates the cooling fan at the speed requested (by varying the power applied to the fan motor).

FIVE HUNDRED/FREESTYLE/MONTEGO, FUSION/MILAN/ZEPHYR, CROWN VICTORIA/GRAND MARQUIS, TOWN CAR: FCV DUTY CYCLE OUTPUT FROM PCM (negative duty cycle)

FCV Duty Cycle Command (NEGATIVE (-) duty cycle)	Cooling Fan Response/Speed
Greater than 0 but less than 5%	Fan off, controller inactive
Greater than 5% but less than 10%	Fan off, controller is in active/ready state
Crown Victoria/Grand Marquis, Town Car: 10% - 90%	Crown Victoria/Grand Marquis, Town Car: Linear speed increase from 20% to 100%
Five Hundred/Freestyle/Montego, Fusion/Milan/Zephyr:	Five Hundred/Freestyle/Montego, Fusion/Milan/Zephyr:

FCV Duty Cycle Command (NEGATIVE (-) duty cycle)	Cooling Fan Response/Speed
30% - 90%	Linear speed increase from 50% to 100%
Greater than 90% but less than 95%	100%
Greater than 95% but less than 100%	Fan off

LS: FCV DUTY CYCLE OUTPUT FROM PCM

FCV Duty Cycle Command (positive (+) duty cycle)	Cooling Fan Response/Speed
Greater than 0 but less than 4%	100% (default maximum)
Greater than 4% but less than 6%	100% if duty cycle is increasing 0% (off) if duty cycle is decreasing
Greater than 6% but less than 12%	0% (off)
Greater than 12% but less than 16%	20% if duty cycle is increasing 0% if duty cycle is decreasing
16% - 90%	Linear speed increase from 20% to 100%
Greater than 90% but less than 100%	100% (default maximum)

For relay controlled fans:

The PCM controls the fan operation through the fan control (FC) (single speed fan applications), low fan control (LFC), medium fan control (MFC), and/or high fan control (HFC) outputs. Some applications will have the xFC circuit wired to 2 separate relays.

For 3-speed fans, although the PCM output circuits are called low, medium, and high fan control (FC), cooling fan speed is controlled by a combination of these outputs. Refer to the following table.

2.0L FOCUS (with A/C) and TAURUS: PCM FC OUTPUT STATE FOR COOLING FAN SPEEDS

PCM OUTPUT	LOW SPEED	MEDIUM SPEED	HIGH SPEED	FAN OFF
LFC (FC1)	ON	ON	ON	OFF
MFC (FC2)	ON	OFF	ON	OFF
HFC (FC3)	ON	OFF	OFF	OFF

2.3L ESCAPE: PCM FC OUTPUT STATE FOR COOLING FAN SPEEDS

PCM OUTPUT	LOW SPEED	MEDIUM SPEED	HIGH SPEED	FAN OFF
LFC (FC1)	ON	ON	ON	OFF
MFC (FC2)	OFF	ON	OFF (or ON)	OFF
HFC (FC3)	OFF	OFF	ON	OFF

FREESTAR, MONTEREY: PCM FC OUTPUT STATE FOR COOLING FAN SPEEDS

PCM OUTPUT	LOW SPEED	MEDIUM SPEED	HIGH SPEED	FAN OFF
LFC (FC1)	OFF	ON	ON	OFF
MFC (FC2)	ON	OFF	ON	OFF
HFC (FC3)	ON	ON	ON	OFF

Fan Speed Sensor (FSS)

The FSS is a Hall-effect sensor that measures the cooling fan clutch speed by generating a waveform with a frequency proportional to the fan speed. If the cooling fan clutch is moving at a relatively low speed, the sensor produces a signal with a low frequency. As the cooling fan clutch speed increases, the sensor generates a signal with a higher frequency. The powertrain control module (PCM) uses the frequency signal generated by the FSS as a feedback for closed loop control of the cooling fan clutch. For additional information on the cooling fan clutch, refer to the Cooling Fan Clutch in this section.

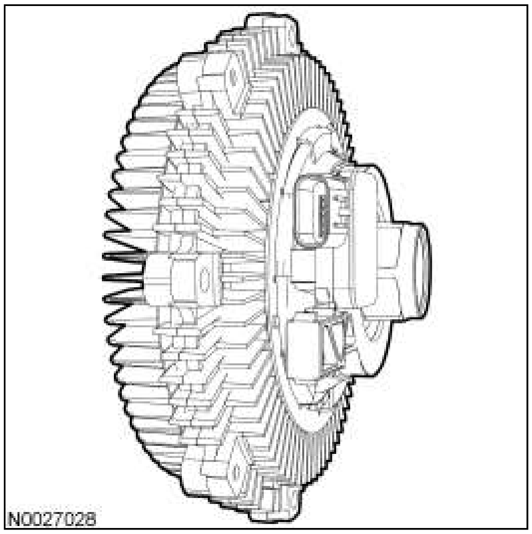


Figure 26 : Cooling Fan Clutch with Fan Speed Sensor (FSS)

Fuel Injectors

NOTICE: 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 fuel injector 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.

The injector is the deposit resistant injector (DRI) type and does not have to be cleaned. However, it can be flow checked and, if found outside of specification, a new fuel injector should be installed.

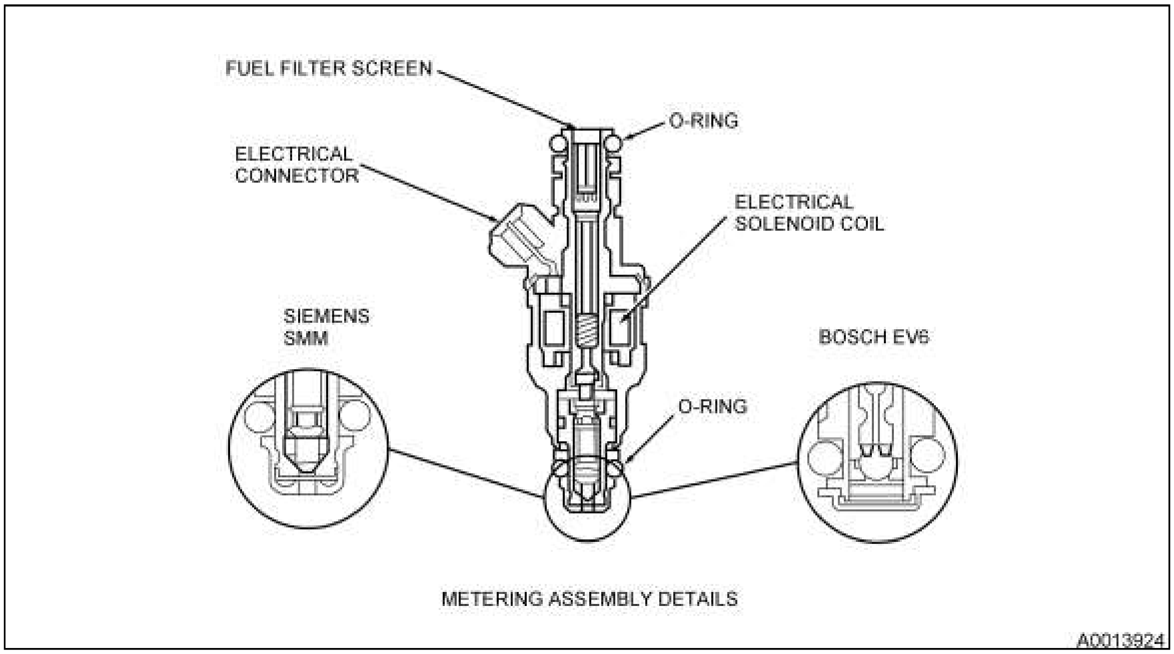


Figure 27 : Fuel Injectors

Fuel Level Input (FLI)

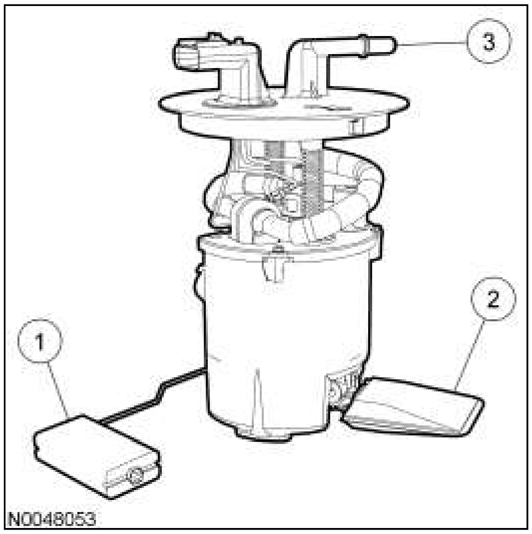
Note: *The Ford GT uses a piezoelectric sonar type fuel level sensor. The sensor is located in the tank and the sensor signal is provided as a communications network message by the instrument cluster to the PCM.*

The FLI is either a hard wire signal input to the PCM from the fuel pump (FP) module or a communications network message. Most vehicle applications use a potentiometer type FLI sensor connected to a float in the FP module to determine fuel level.

Fuel Pump (FP) Module

The 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.

Typical Electronic Returnless Fuel Pump (FP) Module



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

Figure 28

Typical Mechanical Returnless Fuel Pump (FP) 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 29

Fuel Pump Module and Reservoir

The fuel pump module is mounted inside the fuel tank in a reservoir. The pump has a discharge check valve that maintains the 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 Rail Pressure (FRP) Sensor

The FRP sensor is a diaphragm strain gauge device in which resistance changes with pressure. The electrical resistance of a strain gauge increases as pressure increases, and the resistance decreases as the pressure decreases. The varying resistance affects the voltage drop across the sensor terminals and provides electrical signals to the PCM corresponding to pressure.

Strain gauge type sensors are considered passive sensors. A passive sensor is connected to a voltage divider network so that varying the resistance of the passive sensor causes a variation in total current flow. Voltage that is dropped across a fixed resistor in series with the sensor resistor determines the voltage signal at the PCM. This voltage signal is equal to the reference voltage minus the voltage drop across the fixed resistor.

The FRP sensor 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.

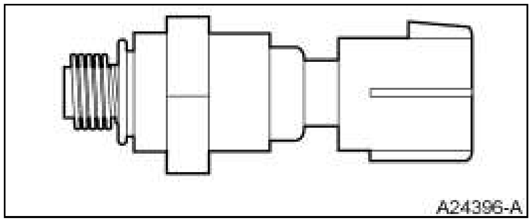


Figure 30 : Fuel Rail Pressure (FRP) Sensor

Fuel Rail Pressure Temperature (FRPT) Sensor

The FRPT sensor measures the pressure and temperature of the fuel in the fuel rail and sends these signals to the PCM. The sensor uses the intake manifold vacuum as a reference to determine the pressure difference between the fuel rail and the intake manifold. The relationship between fuel pressure and fuel temperature is used to determine the possible presence of fuel vapor in the fuel rail. Both pressure and temperature signals are used to control the speed of the fuel pump. The speed of the fuel pump sustains fuel rail pressure which preserves fuel in its liquid state. The dynamic range of the fuel injectors increase because of the higher rail pressure, which allows the injector pulse width to decrease.

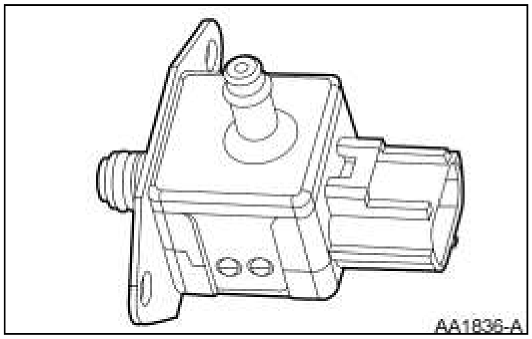


Figure 31 : Typical Fuel Rail Pressure Temperature (FRPT) Sensor

Fuel Rail Pulse Damper

The fuel rail pulse damper is located on the fuel rail and reduces the 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 if the pulse damper diaphragm ruptures. The fuel rail pulse damper should not be confused with a fuel pressure regulator; it does not regulate the fuel rail pressure.

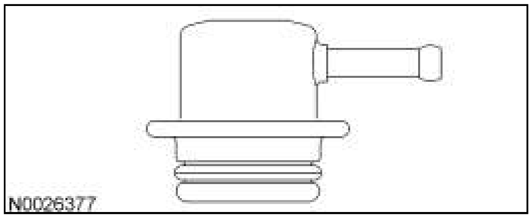


Figure 32 : Typical Fuel Rail Pulse Damper

Fuel Rail Temperature (FRT) Sensor

The FRT sensor is a thermistor device in which resistance changes with temperature. The electrical resistance of a thermistor decreases as the temperature increases, and the resistance increases as the temperature decreases. The varying resistance affects the voltage drop across the sensor terminals and provides electrical signals to the PCM corresponding to temperature.

Thermistor-type sensors are considered passive sensors. A passive sensor is connected to a voltage divider network so that varying the resistance of the passive sensor causes a variation in total current flow. Voltage that is dropped across a fixed resistor in series with the sensor resistor determines the voltage signal at the PCM. This voltage signal is equal to the reference voltage minus the voltage drop across the fixed resistor.

The FRT sensor measures the temperature 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.

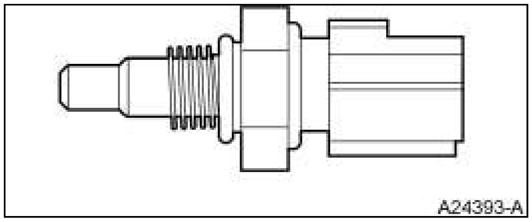


Figure 33 : Fuel Rail Temperature (FRT) Sensor

Fuel Tank Pressure (FTP) Sensor

The FTP sensor or in-line FTP sensor is used to measure the fuel tank pressure.

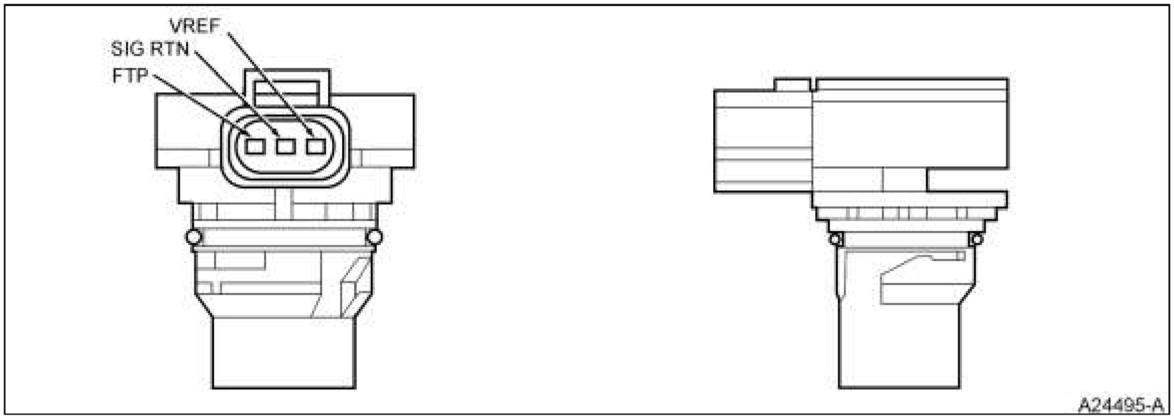


Figure 34 : Fuel Tank Pressure (FTP) Sensor

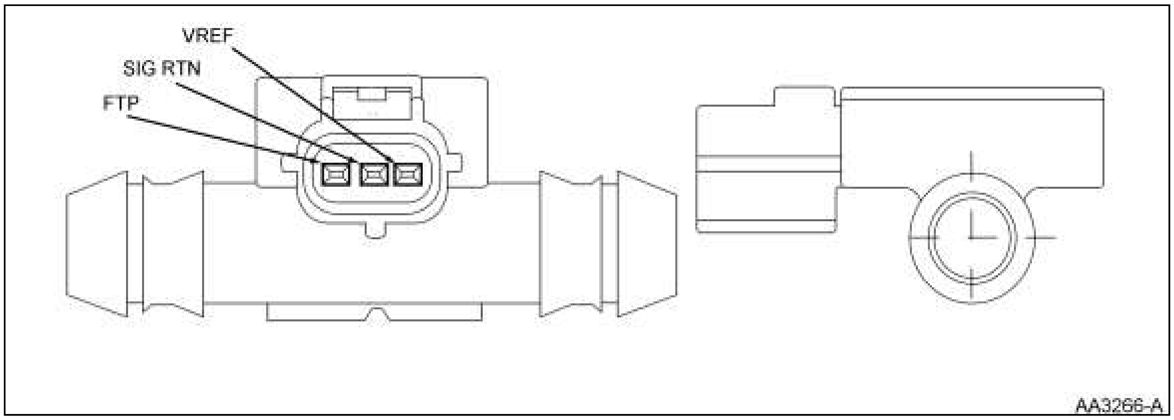


Figure 35 : In-Line Fuel Tank Pressure (FTP) Sensor

Heated Oxygen Sensor (HO2S)

The HO2S detects the presence of oxygen in the exhaust and produces a variable voltage according to the amount of oxygen detected. A high concentration of oxygen (lean air/fuel ratio) in the exhaust produces a voltage signal less than 0.4 volt. A low concentration of oxygen (rich air/fuel ratio) produces a voltage signal greater than 0.6 volt. The HO2S provides feedback to the PCM indicating air/fuel ratio in order to achieve a near stoichiometric air/fuel ratio of 14.7:1 during closed loop engine operation. The HO2S generates a voltage between 0.0 and 1.1 volts.

Embedded with the sensing element is the HO2S heater. The heating element heats the sensor to a temperature of 800°C (1,472°F). At approximately 300°C (572°F) the engine can enter closed loop operation. The VPWR circuit supplies voltage to the heater. The PCM turns the heater on by providing the ground when the correct conditions occur. The heater allows the engine to enter closed loop operation sooner. The use of this heater requires the HO2S heater control to be duty cycled, to prevent damage to the heater.

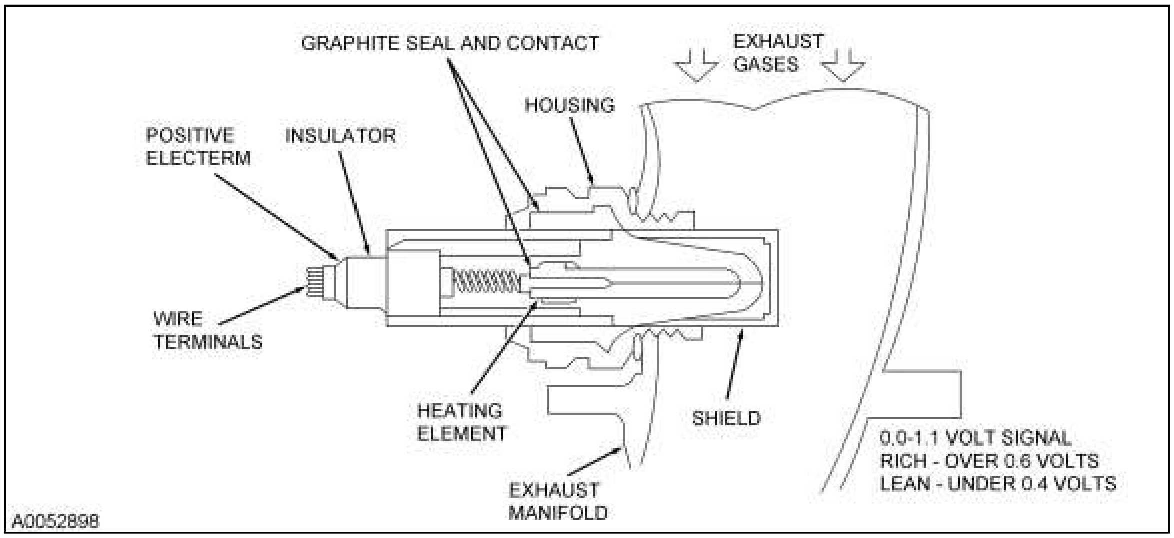


Figure 36 : Heated Oxygen Sensor (HO2S)

Idle Air Control (IAC) Valve

Note: *The IAC valve assembly is not adjustable and cannot be cleaned, also some IAC valves are normally open and others are normally closed. Some IAC valves require engine vacuum to operate.*

The IAC valve assembly controls the engine idle speed and provides a dashpot 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.

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 dashpot function)
- over-temperature idle boost

Inertia Fuel Shutoff (IFS) Switch

The IFS switch is used in conjunction with the electric fuel pump. The purpose of the IFS switch is to shutoff the fuel pump if a collision 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 shuts off the electric fuel pump. Once the switch is open, it must be manually reset before restarting the vehicle. Refer to the Owner's Literature for the location of the IFS.

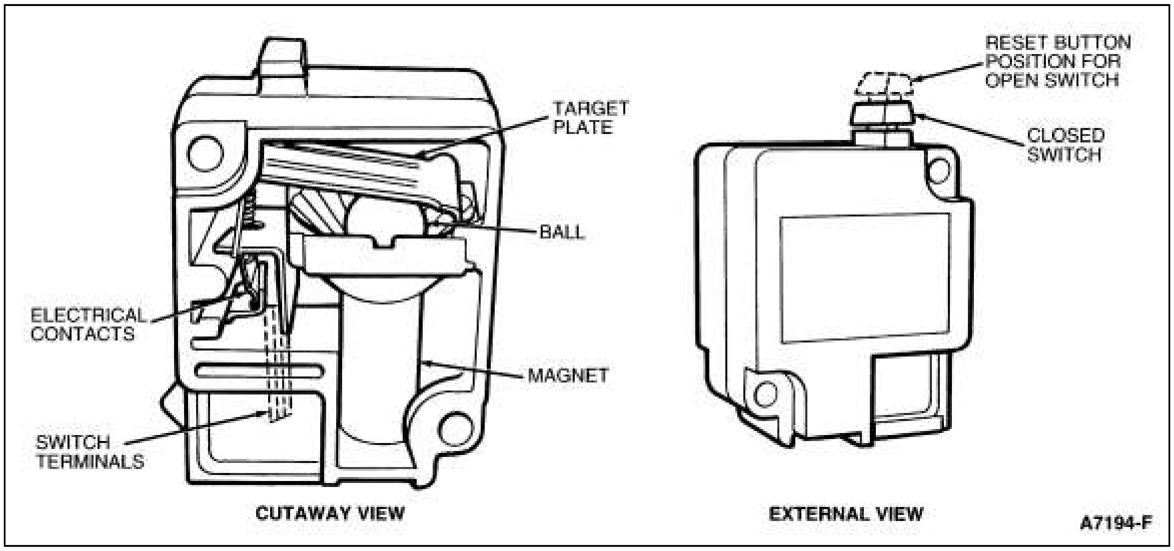


Figure 37 : Typical Inertia Fuel Shutoff (IFS) Switch

Intake Air Temperature (IAT) Sensor

The IAT sensor is a thermistor device in which resistance changes with temperature. The electrical resistance of a thermistor decreases as the temperature increases, and the resistance increases as the temperature decreases. The varying resistance affects the voltage drop across the sensor terminals and provides electrical signals to the PCM corresponding to temperature.

Thermistor-type sensors are considered passive sensors. A passive sensor is connected to a voltage divider network so that varying the resistance of the passive sensor causes a variation in total current flow. Voltage that is dropped across a fixed resistor in a series with the sensor resistor determines the voltage signal at the PCM. This voltage signal is equal to the reference voltage minus the voltage drop across the fixed resistor.

The IAT provides air temperature information to the PCM. The PCM uses the air temperature information as a correction factor in the calculation of fuel, spark, and air flow.

The IAT sensor provides a quicker temperature change response time than the ECT or CHT sensor.

Currently there are 2 design types of IAT sensors used, a stand-alone/non-integrated type and a integrated type. Both types function the same, however the integrated type is incorporated into the mass air flow (MAF) sensor instead of being a stand alone sensor.

Supercharged vehicles use 2 IAT sensors. Both sensors are thermistor type devices and operate as described above. However, one is located before the supercharger at the air cleaner for standard OBD/cold weather input, while a second sensor (IAT2) is located after the supercharger in the intake manifold. The IAT2 sensor located after the supercharger provides air temperature information to the PCM to control border-line spark and to help determine intercooler efficiency.

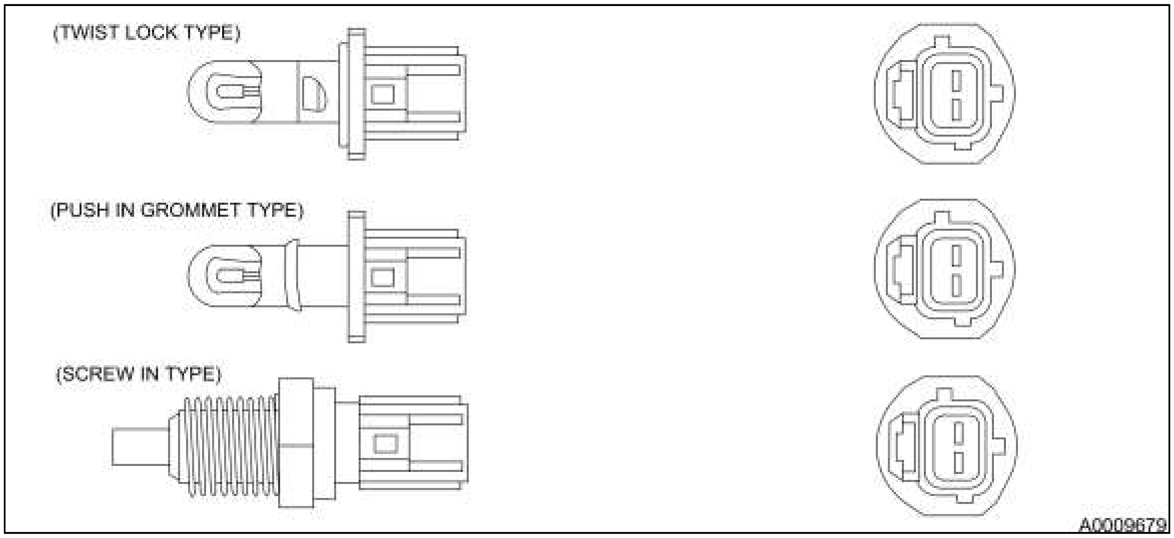


Figure 38 : Typical Stand-Alone/Non-Integrated Intake Air Temperature (IAT) Sensors

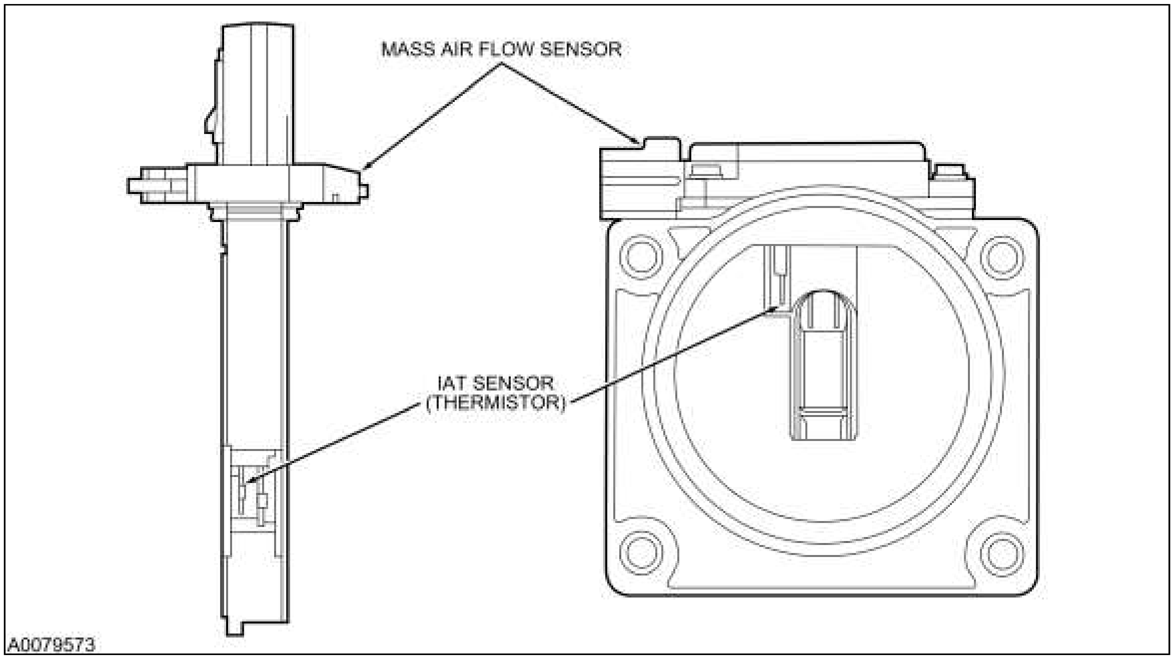


Figure 39 : Typical Integrated Intake Air Temperature (IAT) Sensor Incorporated Into a Drop-in or Flange-type MAF sensor

Intake Manifold Tuning Valve (IMTV)

⚠**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.**

The IMTV 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 is not energized below approximately 2,600 RPM. The shutter is in the closed position not allowing airflow blend to occur in the intake manifold. Above approximately 2,600 RPM the motorized unit is energized. The motorized unit is 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.

Knock Sensor (KS)

The KS is a tuned accelerometer on the engine which converts engine vibration to an electrical signal. The PCM uses this signal to determine the presence of engine knock and to retard spark timing.

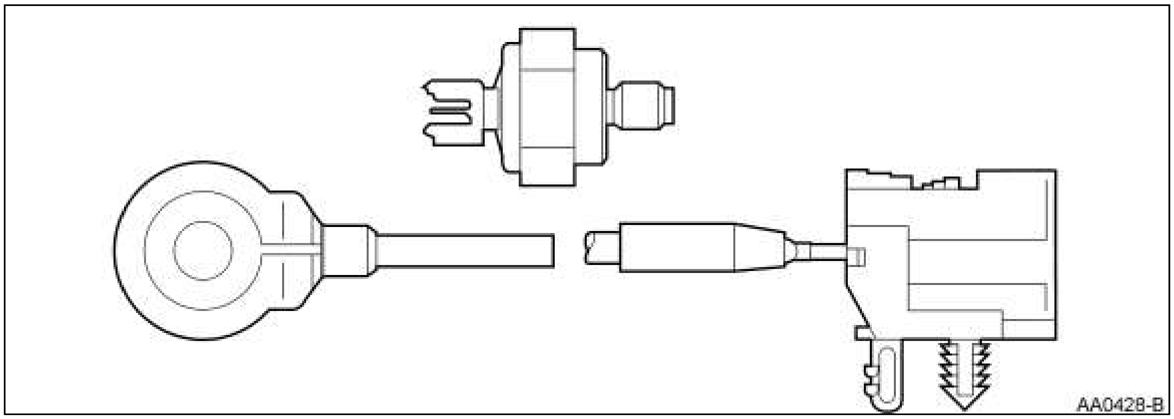


Figure 40 : Two Types of Knock Sensor (KS)

Mass Air Flow (MAF) Sensor

The MAF sensor uses a hot wire sensing element to measure the amount of air entering the engine. Air passing over the hot wire causes it to cool. This hot wire is maintained at 200°C (392°F) above the ambient temperature as measured by a constant cold wire. If the hot wire electronic sensing element must be replaced, then the entire assembly must be replaced. Replacing only the element may change the air flow calibration.

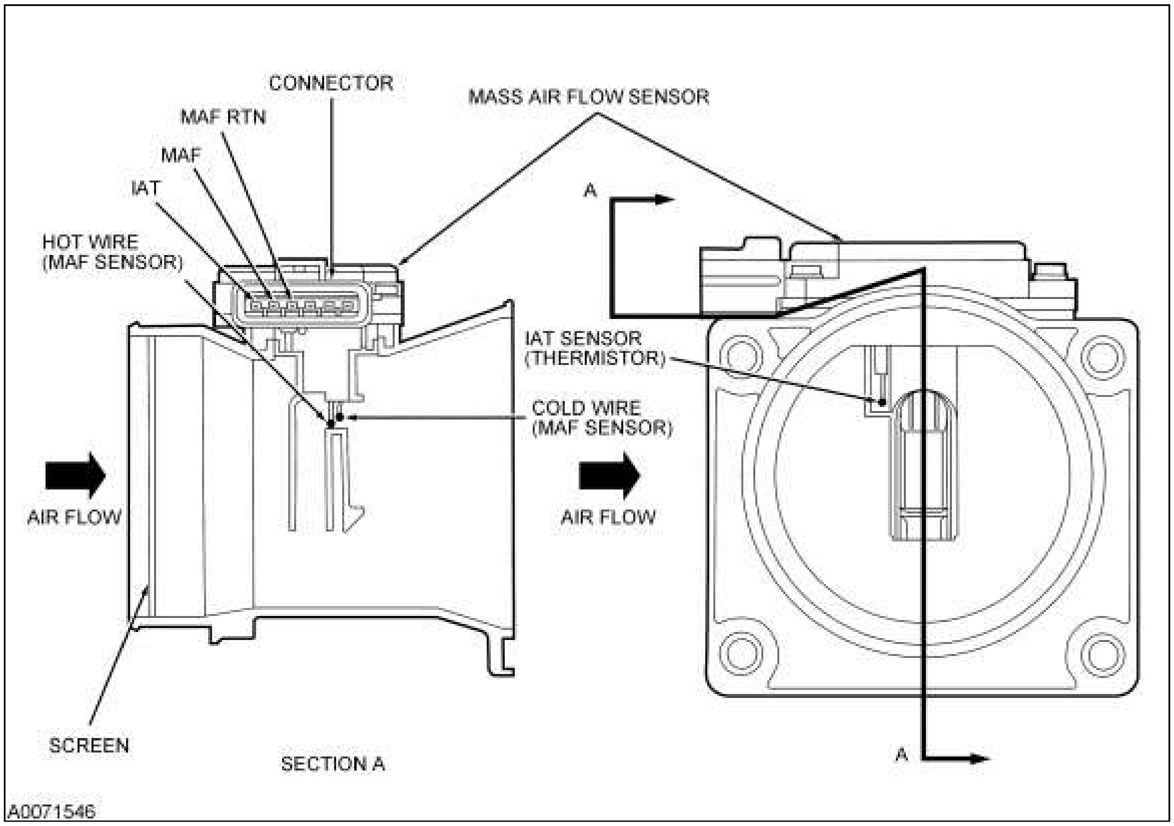


Figure 41 : Diagram of Air Flow Through Throttle Body Contacting MAF Sensor Hot and Cold Wire (and IAT Sensor Wire Where Applicable) Terminals.

The current required to maintain the temperature of the hot wire is proportional to the mass air flow. The MAF sensor then outputs an analog voltage signal to the PCM proportional to the intake air mass. The PCM calculates the required fuel injector pulse width in order to provide the desired air/fuel ratio. This input is also used in determining transmission electronic pressure control (EPC), shift and torque converter clutch scheduling.

Most MAF sensors have integrated bypass technology (IBT) with an integrated intake air temperature (IAT) sensor.

The MAF sensor is located between the air cleaner and the throttle body or inside the air cleaner assembly.

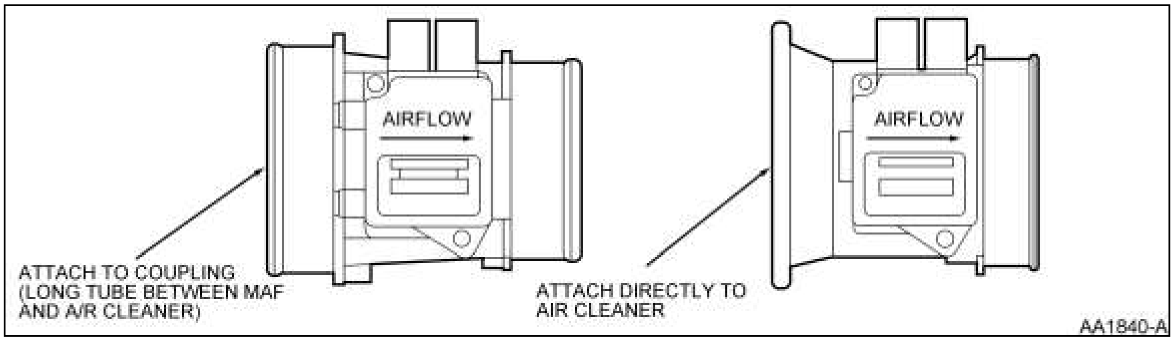


Figure 42 : Typical Mass Air Flow (MAF) Sensor

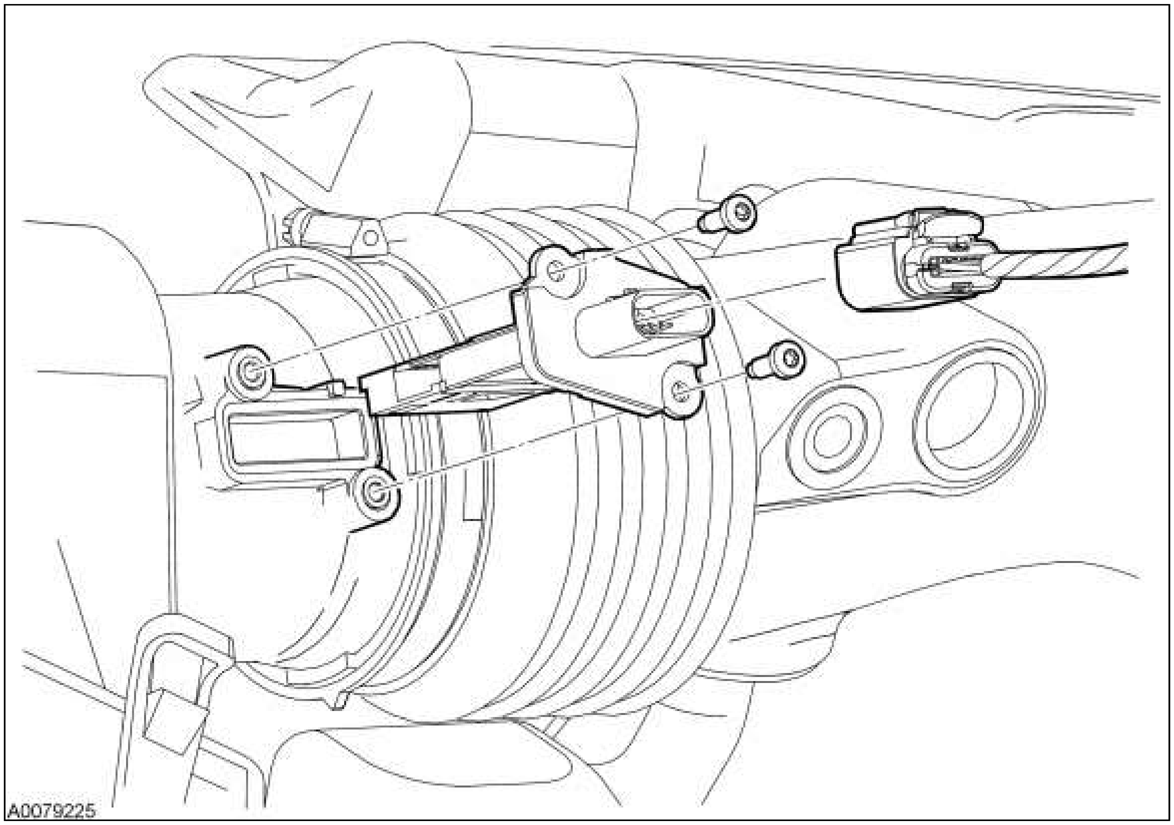


Figure 43 : Typical Drop-in Mass Air Flow (MAF) Sensor

Output Shaft Speed (OSS) Sensor

The OSS sensor provides the PCM with information about the rotational speed of an output shaft. The PCM uses the information to control and diagnose powertrain behavior. In some applications, the sensor is also used as the source of vehicle speed. The sensor may be physically located in different places on the vehicle, depending upon the specific application. The design of each speed sensor is unique and depends on which powertrain control feature uses the information generated.

Power Steering Pressure (PSP) Sensor

The PSP sensor monitors the hydraulic pressure within the power steering system. The PSP sensor voltage input to the PCM changes as the hydraulic pressure changes. The PCM uses the input signal from the PSP sensor to compensate for additional loads on the engine by adjusting the idle RPM and preventing engine stall during parking maneuvers. Also, the PSP sensor signals the PCM to adjust the transmission electronic pressure control (EPC) pressure during increased engine load, for example during parking maneuvers.

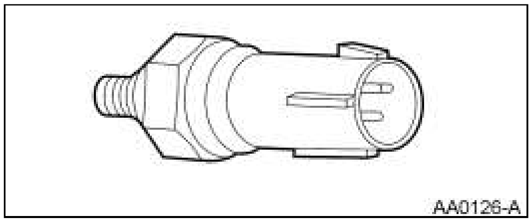


Figure 44 : Typical Power Steering Pressure (PSP) Sensor

Power Steering Pressure (PSP) Switch

The PSP switch monitors the hydraulic pressure within the power steering system. The PSP switch is a normally closed switch that opens as the hydraulic pressure increases. The PCM provides a low current voltage on the PSP circuit. When the PSP switch is closed, this voltage is pulled low through the SIG RTN circuit. The PCM uses the input signal from the PSP switch to compensate for additional loads on the engine by adjusting the idle RPM and preventing engine stall during parking maneuvers. Also, the PSP switch signals the PCM to adjust the transmission electronic pressure control (EPC) pressure during increased engine load, for example during parking maneuvers.

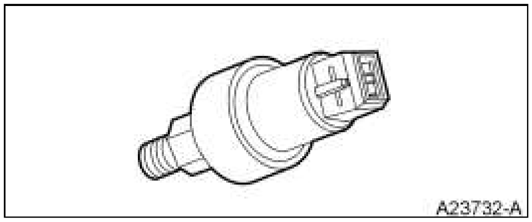


Figure 45 : Typical Power Steering Pressure (PSP) Switch

Power Take-Off (PTO) Switch and Circuits

The PTO circuit is used by the PCM to disable some of the on-board diagnostics (OBD) monitors during PTO operation. The PTO switch is normally open. When the PTO unit is activated, the PTO switch is closed and battery voltage is supplied to the PTO input circuit. This indicates to the PCM that an additional load is being applied to the engine. The PTO indicator lamp illuminates when the PTO system is functioning correctly and flashes when the PTO system is damaged.

When the PTO unit is activated, the PCM disables some OBD monitors, which may not function reliably during PTO operation. Without the PTO circuit information to the PCM, false diagnostic trouble codes (DTCs) may be set during PTO operation. Prior to an Inspection/Maintenance test, the vehicle will have to be operated with the PTO disengaged long enough to successfully complete the OBD Monitors.

PTO Circuits Description

The 3 PTO input circuits are PTO mode, PTO engage, and PTO RPM.

The PTO engage circuit is used when the operator is requesting the PCM to check the needed inputs required to initiate the PTO engagement.

The PTO RPM circuit is used for the operator to request additional engine RPM for PTO operation.

Powertrain Control Module - Vehicle Speed Output (PCM-VSO)

The PCM-VSO speed signal subsystem generates vehicle speed information for distribution to the vehicle's electrical/electronic modules and subsystems that require vehicle speed data. This subsystem senses the transmission output shaft speed with a sensor. The data is processed by the PCM and distributed as a hardwired signal or as a message on the vehicle communication network (SCP or high speed CAN).

The key features of the PCM-VSO system are to:

- infer vehicle movement from the output shaft speed (OSS) sensor signal.
- convert transmission output shaft rotational information to vehicle speed information.
- compensate for tire size and axle ratio with a programmed calibration variable.
- use a transfer case speed sensor (TCSS) for four wheel drive (4WD) applications.
- distribute vehicle speed information as a multiplexed message and/or an analog signal.

The signal from a non-contact shaft sensor OSS or TCSS mounted on the transmission (automatic, manual, or 4WD transfer case) is sensed directly by the PCM. The PCM converts the OSS or TCSS information to 8,000 pulses per mile, based on a tire and axle ratio conversion factor. This conversion factor is programmed into the PCM at the time the vehicle is assembled and can be reprogrammed in the field for servicing changes in the tire size and axle ratio. The PCM transmits the computed vehicle speed and distance traveled information to all the vehicle speed signal users on the vehicle. VSO information can be transmitted by a hardwired interface between the vehicle speed signal user and the PCM, or by a speed and odometer data message through the vehicle communication network data link.

The PCM-VSO hardwired signal wave form is a DC square wave with a voltage level of 0 to VBAT. Typical output operating range is 1.3808 Hz per 1 km/h (2.22 Hz per mph).

Secondary Air Injection (AIR) Bypass Solenoid

The secondary AIR bypass solenoid is used by the PCM to control vacuum to the secondary air injection diverter (AIR diverter) valve. The secondary AIR bypass solenoid is a normally closed solenoid. The secondary AIR bypass solenoid also has a filtered vent feature to permit vacuum release.

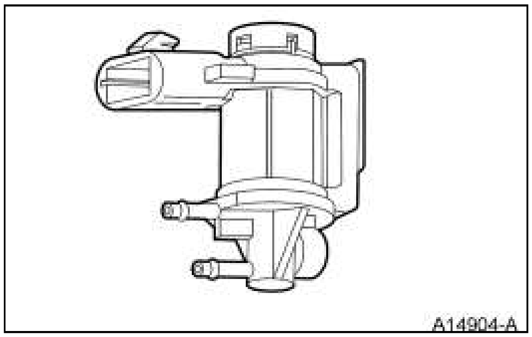


Figure 46 : Secondary AIR Bypass Solenoid

Secondary AIR Diverter Valve

The secondary AIR diverter valve is used with the secondary AIR pump to provide on/off control of air to the exhaust manifold and catalytic converter. When the secondary AIR pump is on and vacuum is supplied to the AIR diverter valve, air passes the integral check valve disk. When the secondary AIR pump is off, and vacuum is removed from the AIR diverter valve, the integral check valve disk is held on the seat and stops air from being drawn into the exhaust system and prevents the back flow of the exhaust into the secondary AIR system.

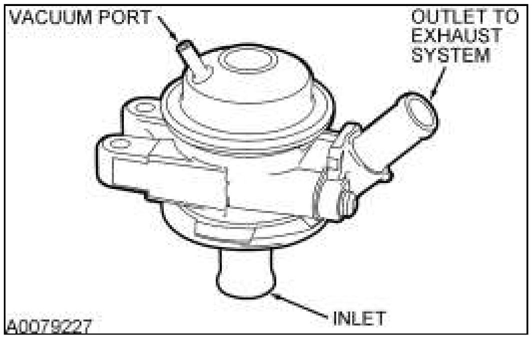


Figure 47 : Secondary AIR Diverter Valve

Secondary AIR Pump

The secondary AIR pump provides pressurized air to the secondary AIR system. The secondary AIR pump functions independently of RPM and is controlled by the PCM. The secondary AIR pump is only used for short periods of time. Delivery of air is dependent on the amount of system backpressure and system voltage. The secondary AIR pump draws dry filtered air from the Intake Air System down stream of the MAF/IAT sensor. For additional information on the secondary AIR injection system, refer to Secondary Air Injection (AIR) System in this section.

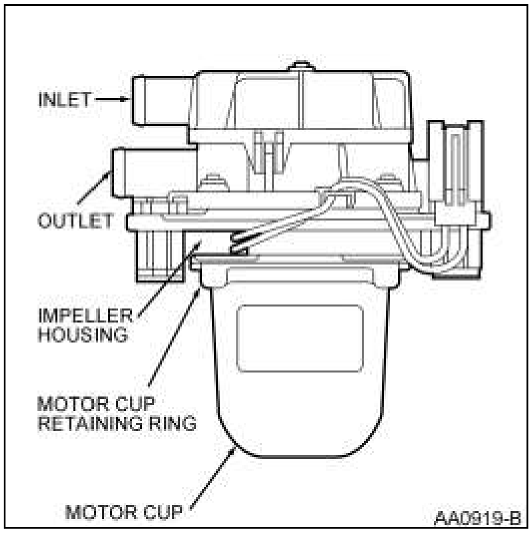


Figure 48 : Secondary Air Pump

Starter Motor Request (SMR) Circuit

The SMR circuit provides the PCM with a signal from the ignition switch to the PCM. The input is pulled high when the key is in the START position and the transmission range sensor ignition lockout circuit allows the starter to engage.

Throttle Position (TP) Sensor

The TP sensor is a rotary potentiometer sensor that provides a signal to the PCM that is linearly proportional to the throttle plate/shaft position. The sensor housing has a 3-blade electrical connector that may be gold plated. The gold plating increases corrosion resistance on terminals and increases connector durability. The TP sensor is mounted on the throttle body. As the TP sensor is rotated by the throttle shaft, 4 operating conditions are determined by the PCM from the TP. Those conditions are closed throttle (includes idle or deceleration), part throttle (includes cruise or moderate acceleration), wide open throttle (includes maximum acceleration or de-choke on crank), and throttle angle rate.

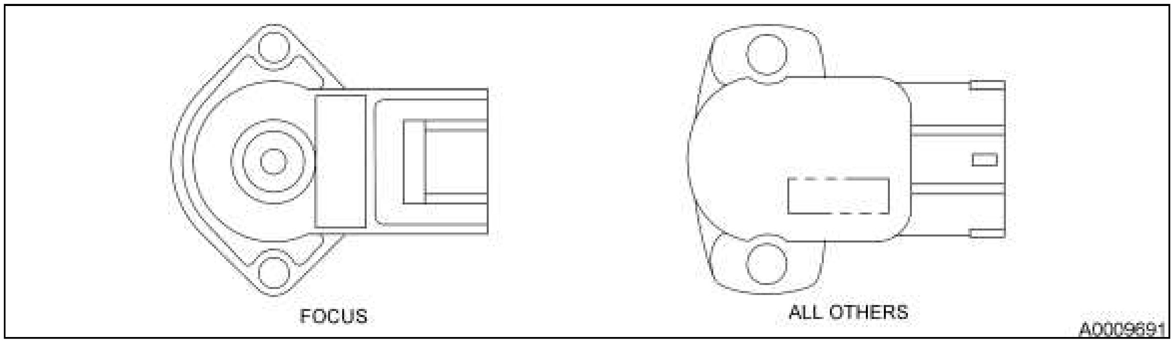


Figure 49 : Typical TP Sensor

Transmission Control Indicator Lamp (TCIL)

The TCIL is an output signal from the PCM that controls the lamp on/off function depending on the engagement or disengagement of overdrive.

Transmission Control Switch (TCS)

The TCS signals the PCM with VPWR whenever the TCS is pressed. On vehicles with this feature, the transmission control indicator lamp (TCIL) illuminates when the TCS is cycled to disengage overdrive.

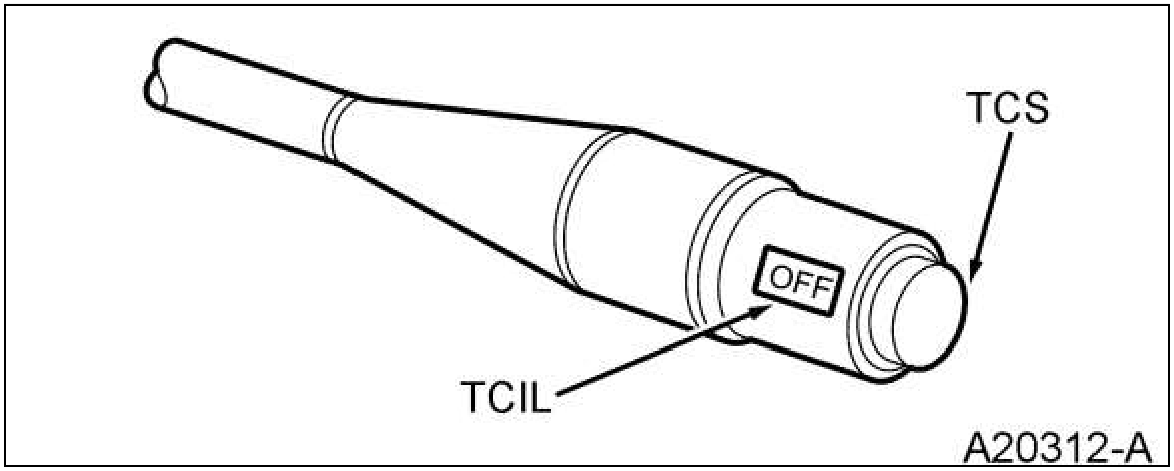


Figure 50 : Typical Transmission Control Switch (TCS)

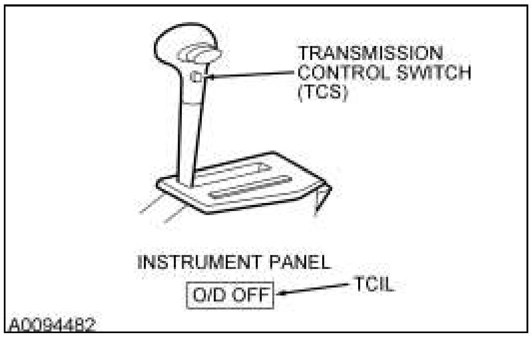


Figure 51 : Typical Transmission Control Switch (TCS)

Vapor Management Valve (VMV)

See the description of the EVAP canister purge valve in this section.

Vehicle Speed Sensor (VSS)

The VSS is a variable reluctance or HALL-effect sensor that generates a waveform with a frequency that is proportional to the speed of the vehicle. If the vehicle is moving at a relatively low velocity, the sensor produces a signal with a low frequency. As the vehicle velocity increases, the sensor generates a signal with a higher frequency. The PCM uses the frequency signal generated by the VSS (and other inputs) to control such parameters as fuel injection, ignition control, transmission/transaxle shift scheduling, and torque converter clutch scheduling.

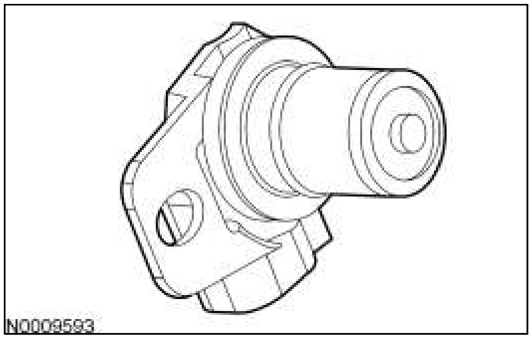


Figure 52 : Typical Vehicle Speed Sensor (VSS)

Wide Open Throttle A/C Cut-Off (WAC)

Refer to the air conditioning clutch relay (A/CCR) in this section.