Engine Control Components

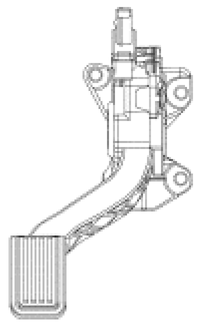
Note: Transmission inputs which are not described in this section, are discussed in the applicable Workshop Manual transmission section.

Accelerator Pedal Position (APP) Sensor

The APP sensor is an input to the powertrain control module (PCM) and is used to determine the amount of torque requested by the operator. Depending on the application either a 2-track or 3-track APP sensor is used.

2-Track APP Sensor

There are two pedal position signals in the sensor. Both signals, APP1 and APP2, have a positive slope (increasing angle, increasing voltage), but are offset and increase at different rates. The two pedal position signals make sure the PCM receives a correct input even if one signal has a concern. The PCM determines if a signal is incorrect by calculating where it should be, inferred from the other signals. If a concern is present with one of the circuits the other input is used. There are two reference voltage circuits, two signal return circuits, and two signal circuits (a total of six circuits and pins) between the PCM and the APP sensor assembly. The reference voltage circuits and the signal return circuits are shared with the reference voltage circuit and signal return circuit used by the electronic throttle body (ETB) throttle position (TP) sensor. The pedal position signal is converted to pedal travel degrees (rotary angle) by the PCM. The software then converts these degrees to counts, which is the input to the torque based strategy. For additional information, refer to Torque Based Electronic Throttle Control (ETC) in this section.

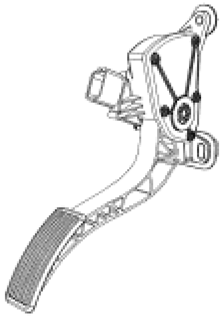


N0072972

Typical 2-Track APP Sensor

3-Track APP Sensor

There are three pedal position signals in the sensor. Signal 1, APP1, has a negative slope (increasing angle, decreasing voltage) and signals 2 and 3, APP2 and APP3, both have a positive slope (increasing angle, increasing voltage). During normal operation APP1 is used as the indication of pedal position by the strategy. The three pedal position signals make sure the PCM receives a correct input even if one signal has a concern. The PCM determines if a signal is incorrect by calculating where it should be, inferred from the other signals. If a concern is present with one of the circuits the other inputs are used. The pedal position signal is converted to pedal travel degrees (rotary angle) by the PCM. The software then converts these degrees to counts, which is the input to the torque based strategy. There are two reference voltage circuits, two signal return circuits, and three signal circuits (a total of seven circuits and pins) between the PCM and the APP sensor assembly. The reference voltage circuits and the signal return circuits are shared with the reference voltage circuit and signal return circuit used by the electronic throttle body (ETB) throttle position sensor. For additional information, refer to Torque Based Electronic Throttle Control (ETC) in this section.



N0072973

Typical 3-Track APP Sensor

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

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

The A/CCR is wired normally open. There is no direct electrical connection between the A/C switch or electronic automatic temperature control (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 checks other A/C related inputs that are available, such as A/C pressure switch and A/C cycling switch. If these inputs indicate A/C operation and the engine conditions are OK (coolant temperature, engine RPM, throttle position), the PCM grounds the A/CCR output, closing the relay contacts and sending voltage to the A/CCR.

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 turns 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 Air Conditioning System Overview. Also, refer to the applicable Wiring Diagrams 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 wide open throttle air conditioning cutoff (WAC) in this section.

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 changes 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 and improve defrost/demist performance.

Note: These values can vary 15% 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
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 for electric fan applications, or single function for all others.

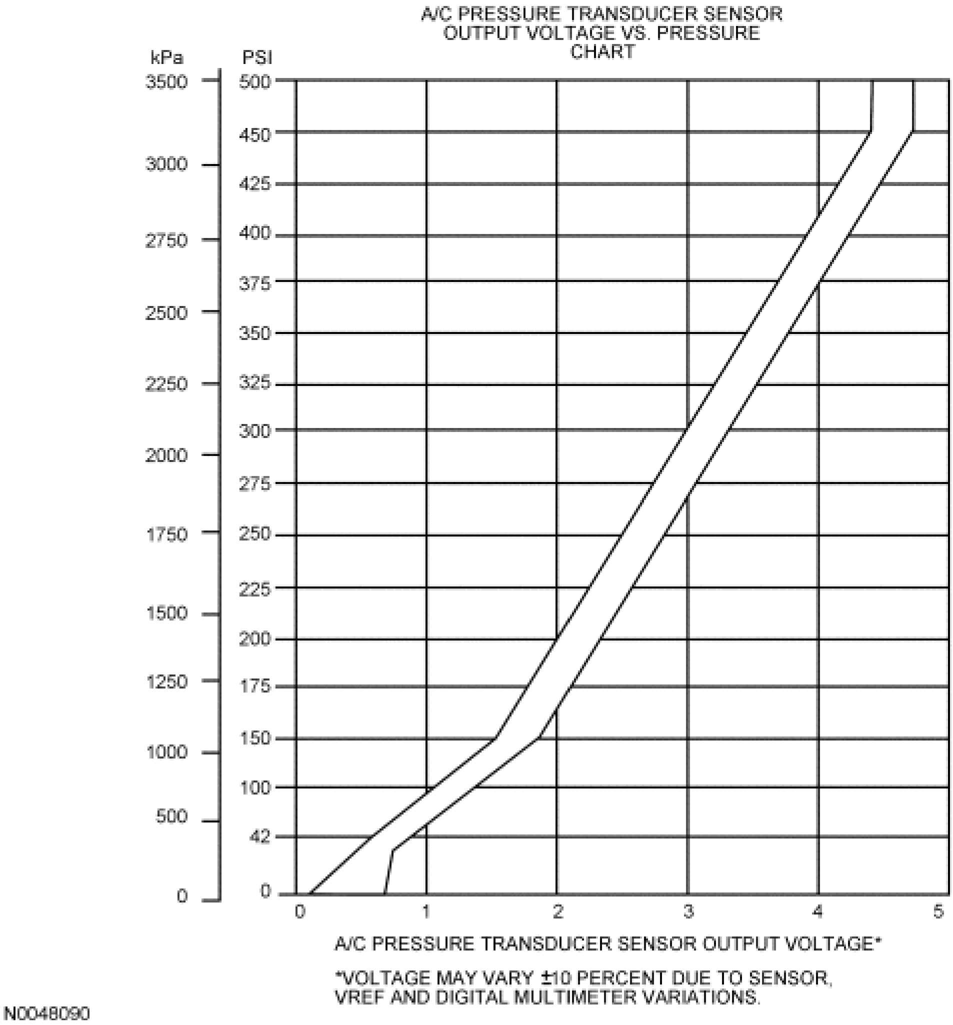
For refrigerant containment control, the normally closed high pressure contacts open at a predetermined A/C pressure. This results in the A/C turning off, preventing the A/C pressure from rising to a level that would open the A/C high pressure relief valve.

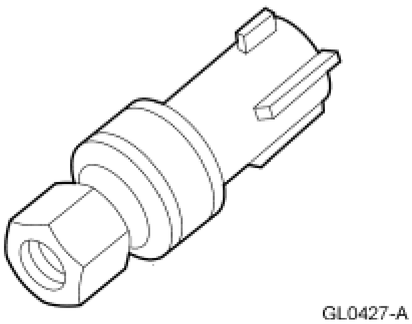
For fan control, the normally open medium pressure contacts close at a predetermined A/C pressure. This grounds the ACPSW circuit input to the PCM. The PCM then turns on the high speed fan to help reduce the pressure.

For additional information, refer to the Workshop Manual Section 412-00, Climate Control System, Air Conditioning System Overview or the Wiring Diagrams Manual.

Air Conditioning Pressure (ACP) Transducer Sensor

The ACP transducer sensor is located in the high pressure (discharge) side of the A/C system. The ACP transducer 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.



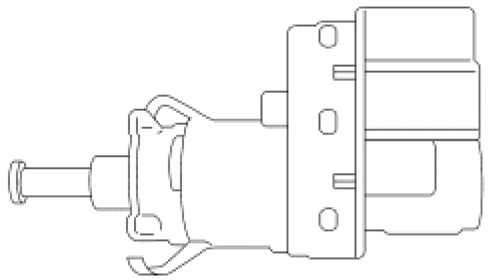


Typical ACP Transducer Sensor

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 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:

- to the PCM supplying battery positive voltage (B+) when the vehicle brake pedal is applied.
- to the anti-lock brake system (ABS) module, or lighting control module (LCM), the BPP signal is then broadcast over the network to be received by the PCM.
- to the 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.



N0073048

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.

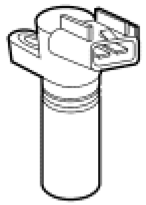
On some applications the normally closed BPS, along with the normally open BPP switch, are used for a brake rationality test within the PCM. The PCM misfire monitor profile learn function may be disabled if a brake switch concern occurs. If one or both brake pedal inputs to the PCM is not changing states when they were expected to, a diagnostic trouble code (DTC) 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 number 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 two CMP sensors are equipped with variable camshaft timing (VCT). The second sensor is used to identify the position of the camshaft on bank 2.

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



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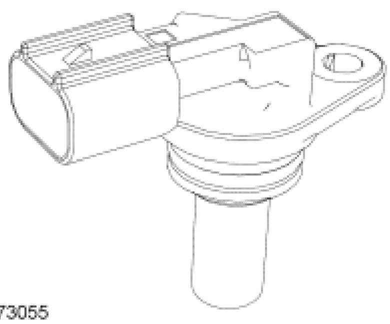
Typical Variable Reluctance CMP Sensor

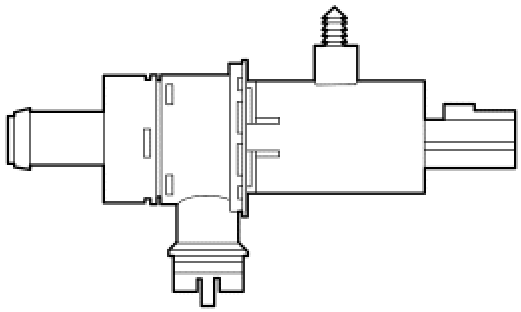


N0073055

Typical Hall-effect 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.



N0027900

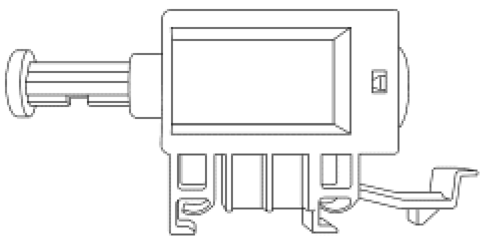
Typical Canister Vent (CV) Solenoid

Check Fuel Cap Indicator

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 there is a concern in the EVAP system due to the fuel filler cap or capless fuel tank filler pipe not being sealed correctly. This is 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.

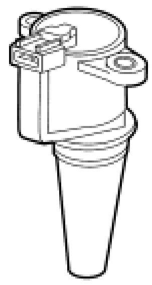


N0073047

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.



A24483-A

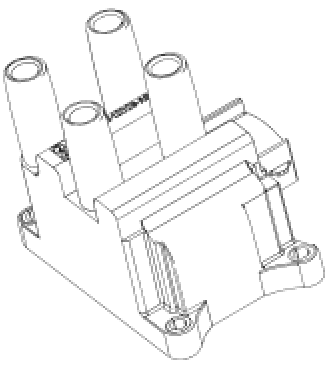
Typical Coil On Plug (COP)

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.

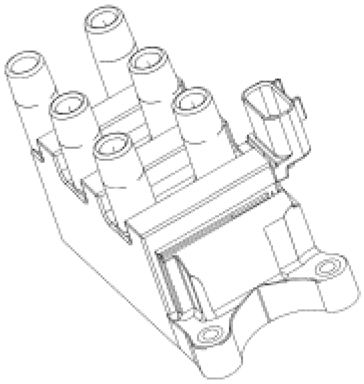
Coil packs come in 4-tower, 6-tower horizontal and 6-tower series 5 models. Two adjacent coil towers share a common coil and are called a matched pair. For 6-tower coil pack (6 cylinder) applications, the matched pairs are 1 and 5, 2 and 6, and 3 and 4. For 4-tower coil pack (4 cylinder) applications,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



N0047966

Typical Four-Tower Coil Pack



N0047967

Typical Six-Tower Coil Pack

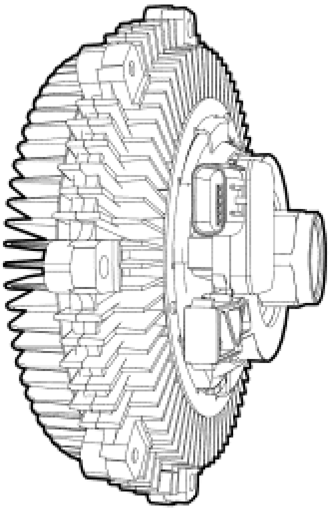
Cooling Fan Clutch

The cooling fan clutch is an electrically actuated viscous clutch that consists of three 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 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.

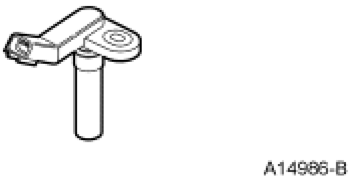


N0027028

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.

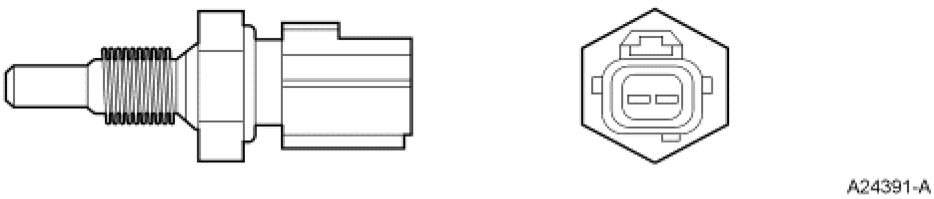


Typical Crankshaft Position (CKP) Sensor

Cylinder Head Temperature (CHT) Sensor

The CHT sensor is a thermistor device in which resistance changes with the 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.

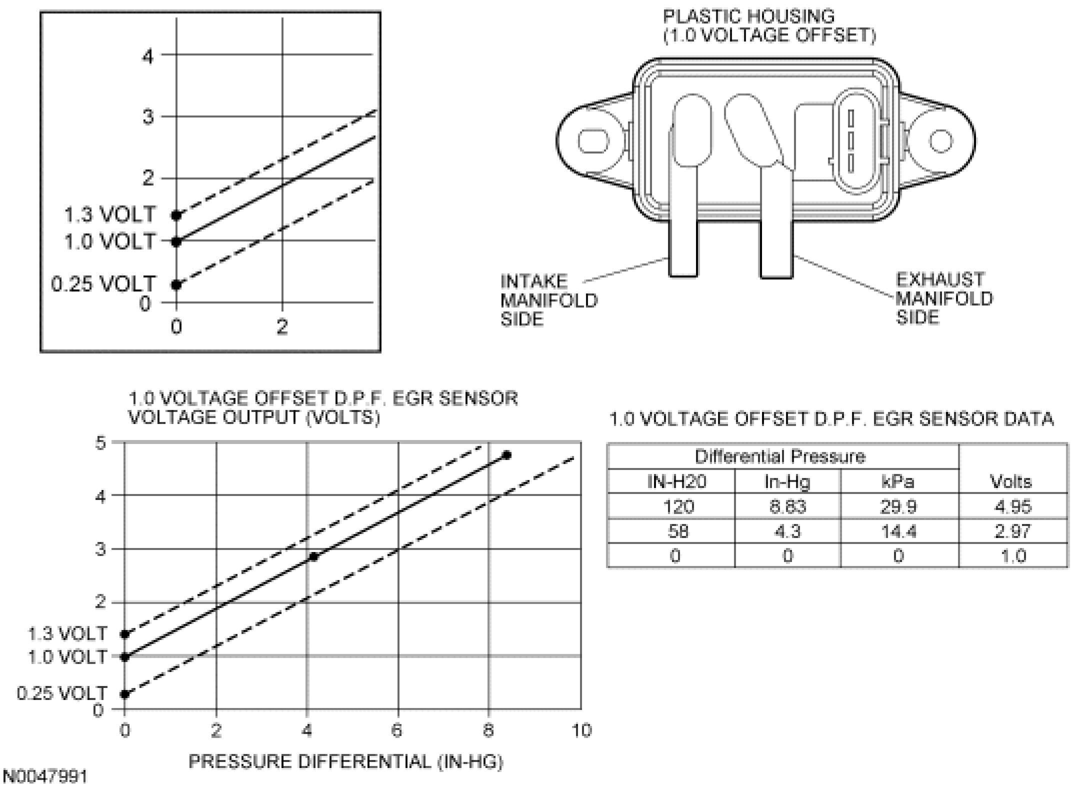
The CHT sensor is installed in the cylinder head and measures the metal temperature. The CHT sensor can provide complete engine temperature information and can be used to infer coolant temperature. If the CHT sensor conveys an overheating condition to the PCM, the PCM initiates a fail-safe cooling strategy 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.



Typical CHT Sensor

Differential Pressure Feedback Exhaust Gas Recirculation (EGR) Sensor

The differential pressure feedback EGR 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 EGR 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 differential pressure feedback EGR sensor housing for identification (note that the HI signal uses a larger diameter hose). The differential pressure feedback EGR sensor outputs a voltage proportional to the pressure drop across the metering orifice and supplies it to the PCM as EGR flow rate feedback.

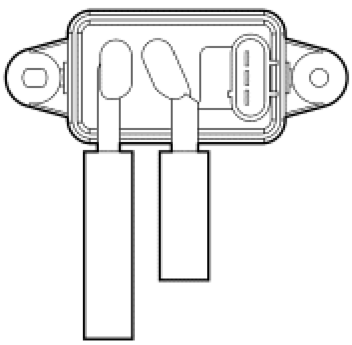


N0047991

Differential Pressure Feedback Exhaust Gas Recirculation (EGR) Sensor

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

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

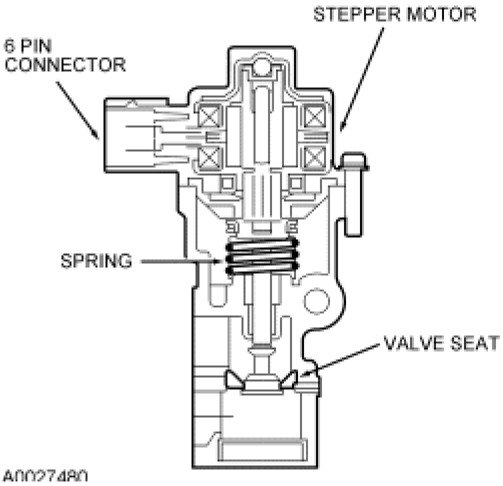


N0009441

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

Electric Exhaust Gas Recirculation (EEGR) Valve

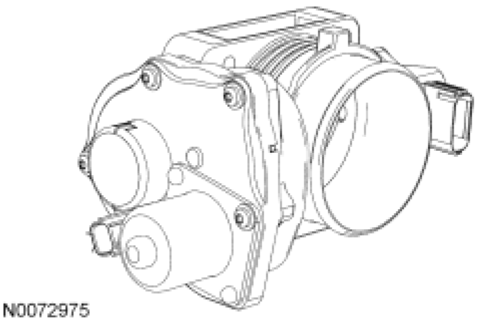
Depending on the application, the EEGR valve is a water cooled or an air cooled motor/valve assembly. The motor is commanded to move in 52 discrete steps as it acts directly on the EEGR valve. The position of the valve determines the rate of EGR. The built-in spring works to close the valve (against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



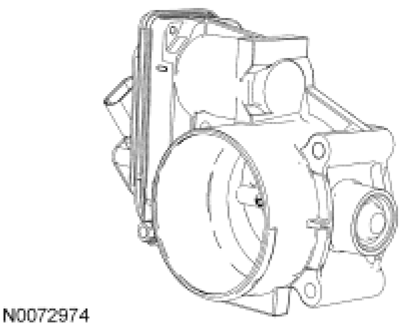
EEGR Motor/Valve Assembly

Electronic Throttle Actuator Control (TAC)

The electronic TAC is a DC motor controlled by the PCM (requires 2 wires). There are 2 designs for the TAC, parallel and in-line. 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-line design has a separate motor housing. An internal spring is used in both designs to return the throttle plate to a default position. The default position is typically a throttle angle of 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. 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.



Typical In-line TAC Design



Typical Parallel TAC Design

Electronic Throttle Body (ETB) Throttle Position Sensor

The ETB throttle position sensor has 2 signal circuits in the sensor for redundancy. The redundant ETB throttle position signals are required for increased monitoring. The first ETB throttle 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). The 2 ETB throttle 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. The reference voltage circuit and the signal return circuit is shared with the reference voltage circuits and signal return circuits used by the APP 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 changes 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 three types of ECT sensors, threaded, push-in, and twist-lock. The ECT sensor is located in an engine coolant passage.

Typical Thread Type 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 changes 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:

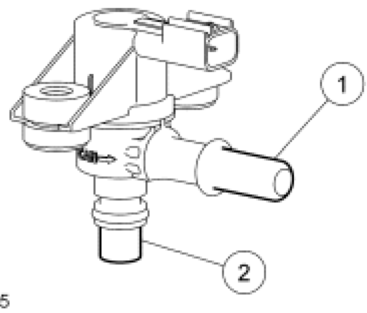
- On variable camshaft timing (VCT) applications the EOT input is used to adjust the VCT control gains and logic for camshaft timing.
- The PCM can use EOT sensor input in conjunction with other PCM inputs to determine oil degradation.
- The PCM can use EOT sensor input to initiate a soft engine shutdown. 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.

Typical EOT Sensor

Evaporative Emission (EVAP) Canister Purge Valve

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 EVAP canister purge valve controls the flow of vapors by way of a solenoid, eliminating the need for an electronic vacuum regulator and vacuum diaphragm. For E-Series, Escape/Mariner, Expedition, F-Series, and Navigator, the PCM outputs a duty cycle between 0% and 100% to control the EVAP canister purge valve. For all others, the PCM outputs a variable current between 0 mA and 1,000 mA to control the EVAP canister purge valve.

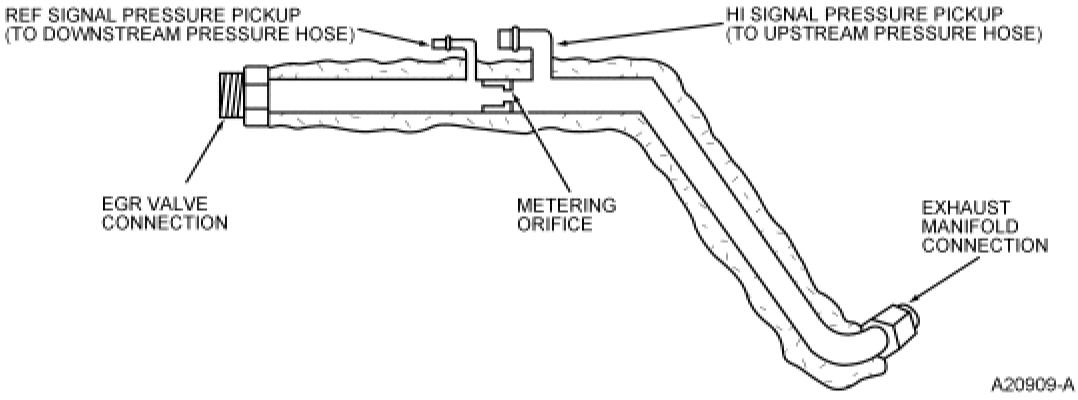
Typical EVAP Canister Purge Valve



Item	Number	Description
1	—	Fuel Vapor to EVAP Canister
2	—	Fuel Vapor to Intake Manifold

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 two 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 sensor which provides feedback to the PCM.

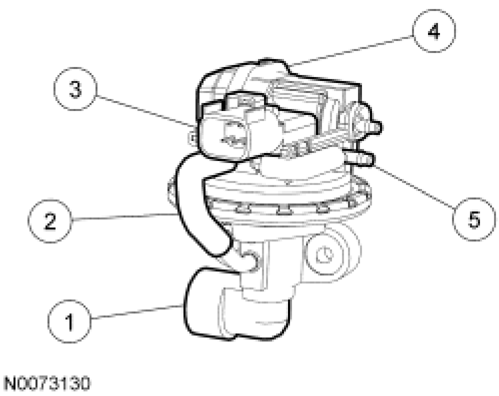


EGR Orifice Tube Assembly

Exhaust Gas Recirculation (EGR) System Module (ESM)

The ESM is an integrated differential pressure feedback EGR system that functions in the same manner as a conventional differential pressure feedback EGR system. 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 metering 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). This MAP signal is used for EGR correction and inferred barometric pressure (BARO) at ignition on. The system provides the PCM with a differential pressure feedback EGR signal, identical to a traditional differential pressure feedback EGR system.

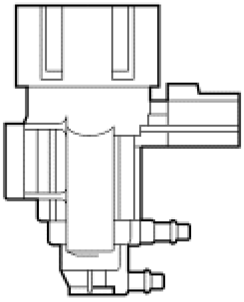
ESM



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

Exhaust Gas Recirculation (EGR) Vacuum Regulator Solenoid

The EGR vacuum regulator solenoid is an electromagnetic device 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 EGR vacuum regulator solenoid allows some vacuum to pass, but not enough to open the EGR valve.



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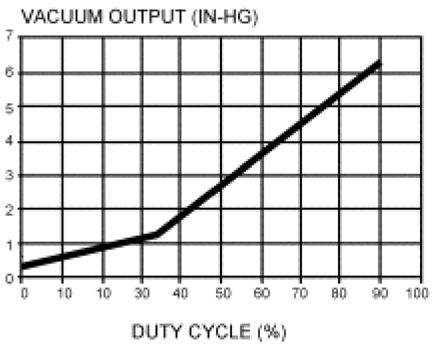
EGR Vacuum Regulator Solenoid



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EGR VACUUM REGULATOR SOLENOID DATA

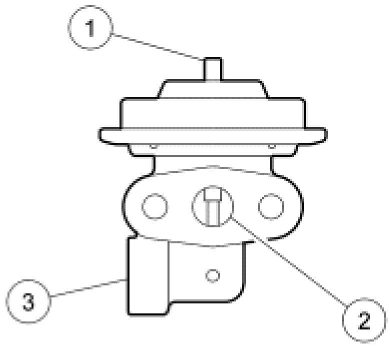
	Vacuum Output					
	Minimum		Nominal		Maximum	
Duty Cycle (%)	**In-Hg**	**kPa**	**In-Hg**	**kPa**	**In-Hg**	**kPa**
0	0	0	0.38	1.28	0.75	2.53
33	0.55	1.86	1.3	4.39	2.05	6.9
90	5.69	19.2	6.32	21.3	6.95	23.47
EGR vacuum regulator resistance: 26-40 Ohms						

Exhaust Gas Recirculation (EGR) Valve

The EGR valve in the differential pressure feedback EGR system is a conventional, vacuum-actuated valve. 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.

Typical EGR Valve



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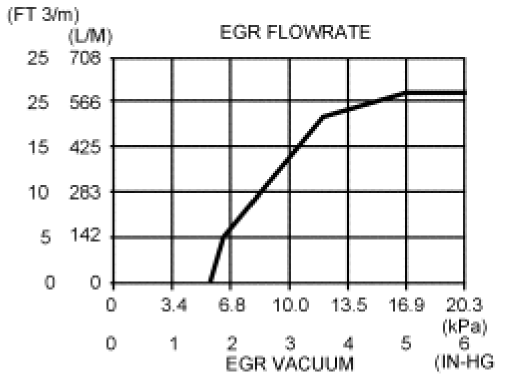
Item	Number	Description
1	—	Vacuum Connection from EGR Vacuum Regulator Solenoid
2	—	Intake Manifold Connector
3	—	Orifice Tube Connection



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).

The fan controller has the capability to detect certain failure modes within the fan motors. Under certain failure modes, such as a motor that is drawing excessive current, the fan controller will shut off the fans. Fan motor concerns will not set a specific DTC. With the fan motor disconnected from the fan controller, voltage may not be present at the fan controller.

EDGE/MKX, FLEX, MKS, TAURUS/TAURUS X/SABLE, FUSION/MILAN/MKZ, 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

Edge/MKX, Crown Victoria/Grand Marquis, Town Car: 10% - 90%	Edge/MKX, Crown Victoria/Grand Marquis, Town Car: Linear speed increase from 30% to 100%
Flex, MKS, Taurus/Taurus X/Sable, Fusion/Milan/MKZ: 30% - 90%	Flex, MKS, Taurus/Taurus X/Sable, Fusion/Milan/MKZ: Linear speed increase from 50% to 100%
Greater than 90% but less than 95%	100%
Greater than 95% but less than 100%	Fan off

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 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 cooling fan speed is controlled by a combination of these outputs. Refer to the following table.

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

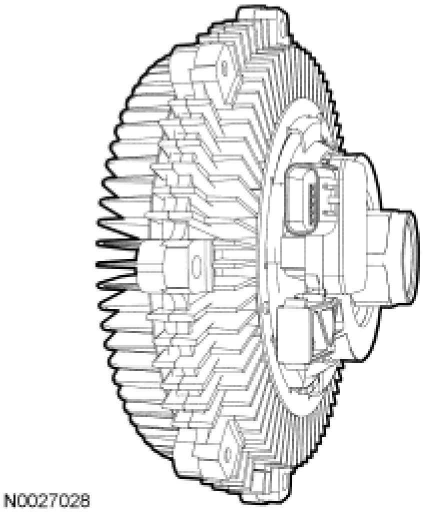
PCM OUTPUT	LOW SPEED	MEDIUM SPEED	HIGH SPEED	FAN OFF
LFC (FC1)	ON	ON	ON	OFF
MFC (FC2)	ON	OFF	ON	OFF
HFC (FC3)	ON	OFF	OFF	OFF

2.5L 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

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 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.



Cooling Fan Clutch with FSS

Fuel Injectors

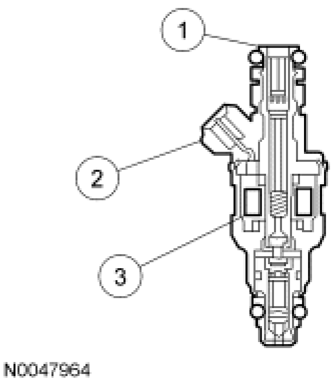
NOTICE: Do not apply battery positive voltage (B+) directly to the fuel injector electrical connector terminals. The solenoids may be damaged internally in a matter of seconds.

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 a 12-volt source from either the electronic engine control (EEC) power relay or fuel pump 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. Install a new fuel injector if the flow is checked and found to be out of specification.

Typical Fuel Injector



Item	Number	Description
1	—	Fuel Filter Screen
2	—	Connector
3	—	Solenoid Coil

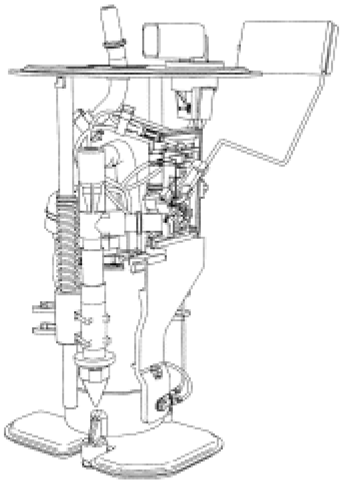
Fuel Level Input (FLI)

The FLI is 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



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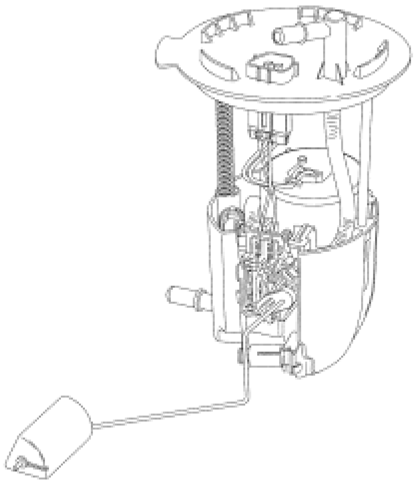
Typical Electronic Returnless Fuel Pump (FP) Module



N0073083

Typical Mechanical Returnless Fuel Pump (FP) Module

Fuel Pump (FP) Module and Reservoir

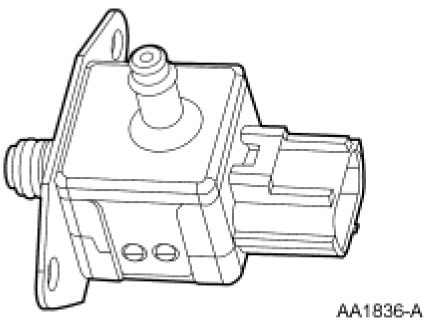
The FP module is mounted inside the fuel tank in a reservoir. The pump has a discharge check valve that maintains the system pressure after the ignition has been turned off to minimize starting concerns. The reservoir prevents fuel flow interruptions during extreme vehicle maneuvers with low tank fill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

Fuel Rail Pressure 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.

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

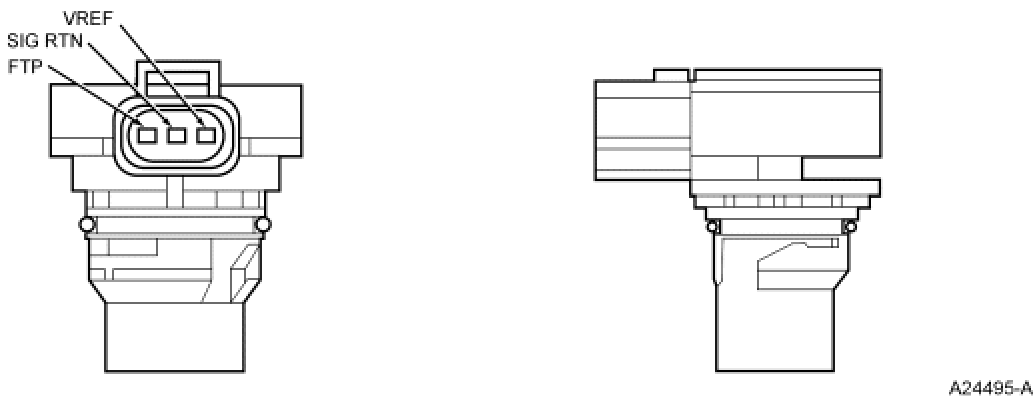
Both the pressure and temperature signals are used to control the speed of the fuel pump. The speed of the fuel pump sustains fuel rail pressure which preserves fuel in its liquid state. The dynamic range of the fuel injectors increase because of the higher rail pressure, which allows the injector pulse width to decrease.



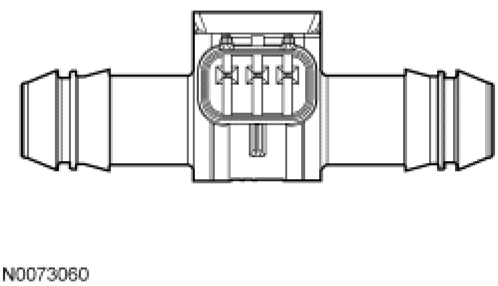
Typical Fuel Rail Pressure Temperature (FRPT) Sensor

Fuel Tank Pressure (FTP) Sensor

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



Fuel Tank Pressure (FTP) Sensor

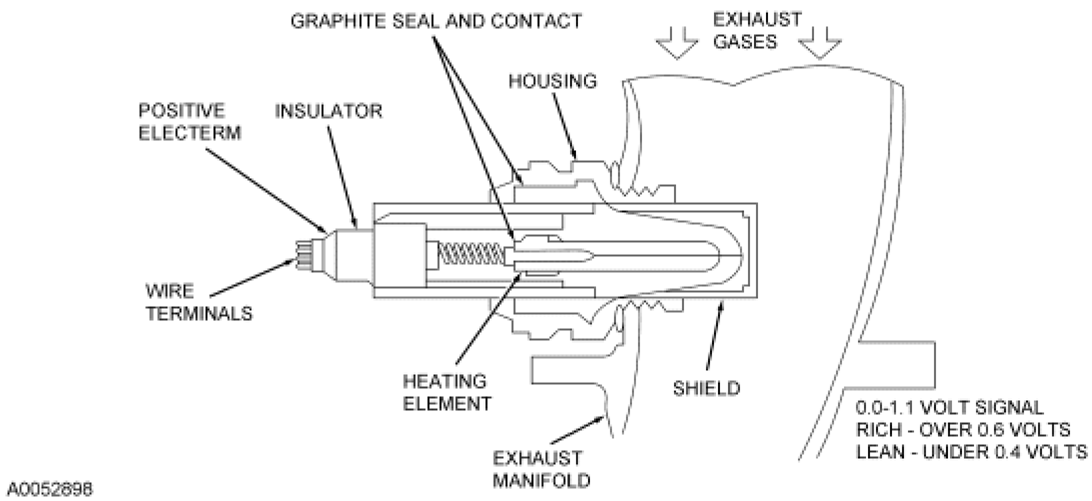


In-line Fuel Tank Pressure (FTP) Sensor

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℃ (1,472℉). At approximately 300℃ (572℉) 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.



Typical 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.

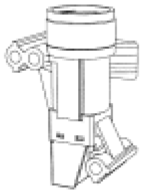
The IAC valve assembly controls the engine idle speed and provides a dashpot function. The IAC valve assembly meters intake air around the throttle plate through a bypass within the IAC valve assembly and throttle body. The PCM determines the desired idle speed or bypass air and signals the IAC valve 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 Shut-off (IFS) Switch

The IFS switch is used in conjunction with the electric fuel pump. The purpose of the IFS switch is to shut off the fuel pump if a collision occurs. It consists of a steel cone held in place by a magnet. When a sharp impact occurs, the cone 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, Roadside Emergencies for the location of the IFS switch.



N0048162

Typical Inertia Fuel Shut-off (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.

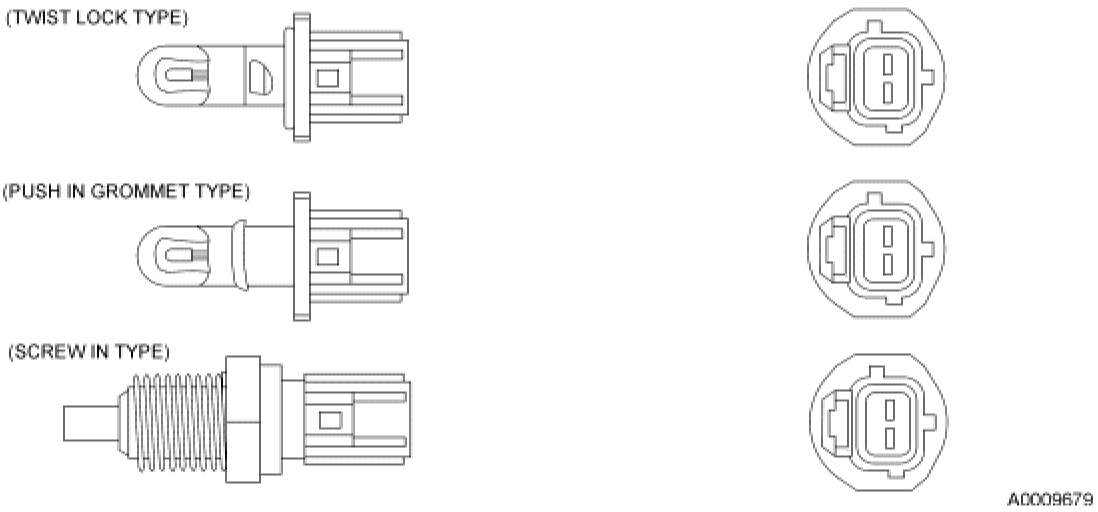
Thermistor-type sensors are considered passive sensors. A passive sensor is connected to a voltage divider network so that varying the resistance of the passive sensor causes a variation in total current flow. Voltage that is dropped across a fixed resistor in a series with the sensor resistor determines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

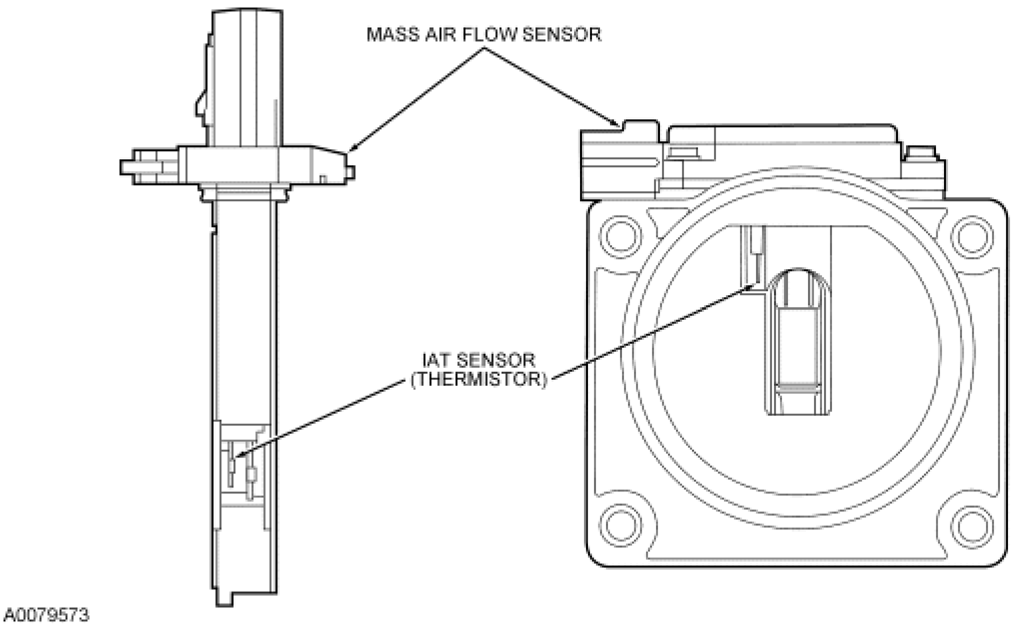
The IAT sensor provides a quicker temperature change response time than the ECT or CHT sensor.

Currently there are two 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 two IAT sensors. Both sensors are thermistor type devices and operate as described above. 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 spark and to help determine charge air cooler (CAC) efficiency.



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



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

Intake Manifold Tuning Valve (IMTV)

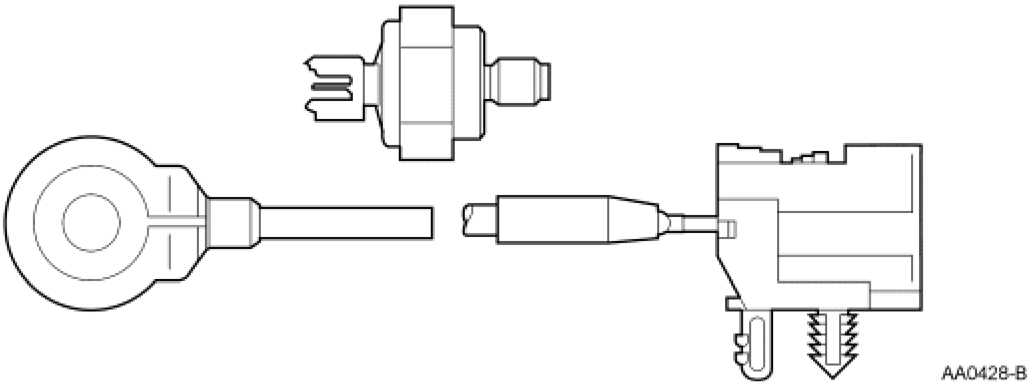
WARNING: SUBSTANTIAL OPENING AND CLOSING TORQUE IS APPLIED BY THIS SYSTEM. TO PREVENT INJURY, BE CAREFUL TO KEEP FINGERS AWAY FROM LEVER MECHANISMS WHEN ACTUATED. FAILURE TO FOLLOW THESE INSTRUCTIONS MAY RESULT IN PERSONAL INJURY.

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 a calibrated RPM. The shutter is in the closed position to prevent airflow blend from occurring in the intake manifold. The motorized unit is energized above a calibrated RPM. 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)

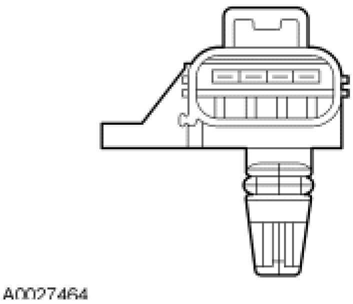
The KS is a tuned accelerometer on the engine which converts engine vibration to an electrical signal. The PCM uses this signal to determine the presence of engine knock and to retard spark timing.



Two Types of Knock Sensor (KS)

Manifold Absolute Pressure (MAP) Sensor

The MAP sensor measures intake manifold absolute pressure. The PCM uses information from the MAP sensor to measure how much exhaust gas is introduced into the intake manifold.



Typical Manifold Absolute Pressure (MAP) Sensor

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℃ (392℉) above the ambient te mperature as measured by a constant cold wire. 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 (TCC) scheduling.

The MAF sensor is located between the air cleaner and the throttle body or inside the air cleaner assembly. Most MAF sensors have integrated bypass technology with an integrated IAT sensor. The hot wire electronic sensing element must be replaced as an assembly. Replacing only the element may change the air flow calibration.

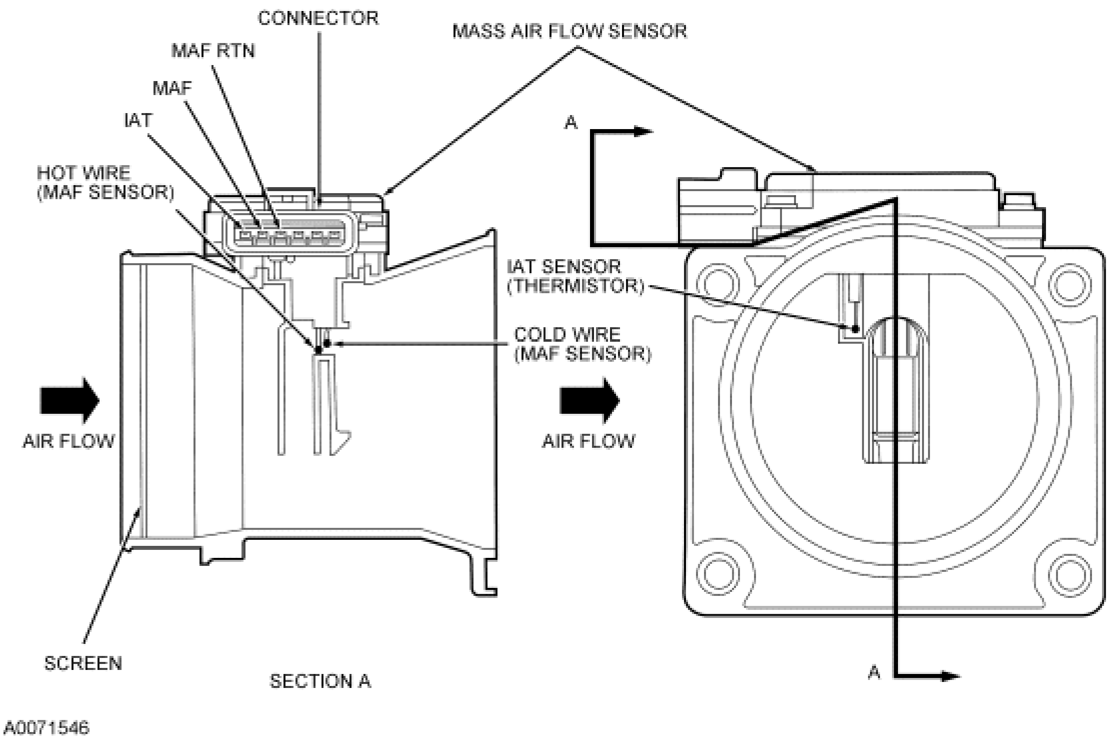
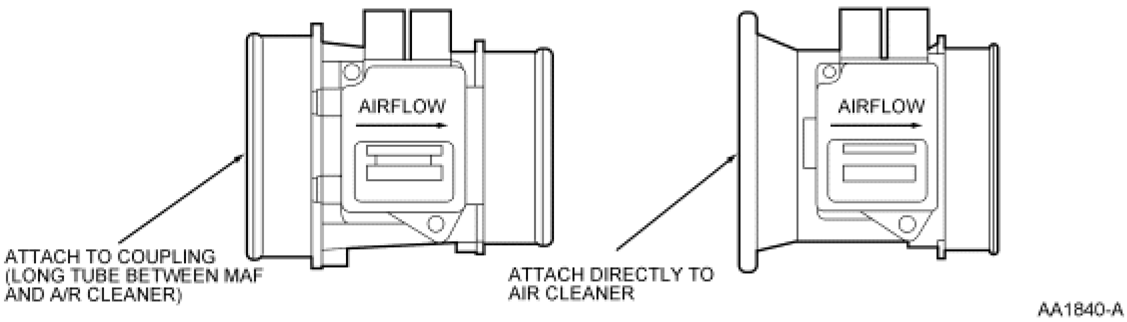
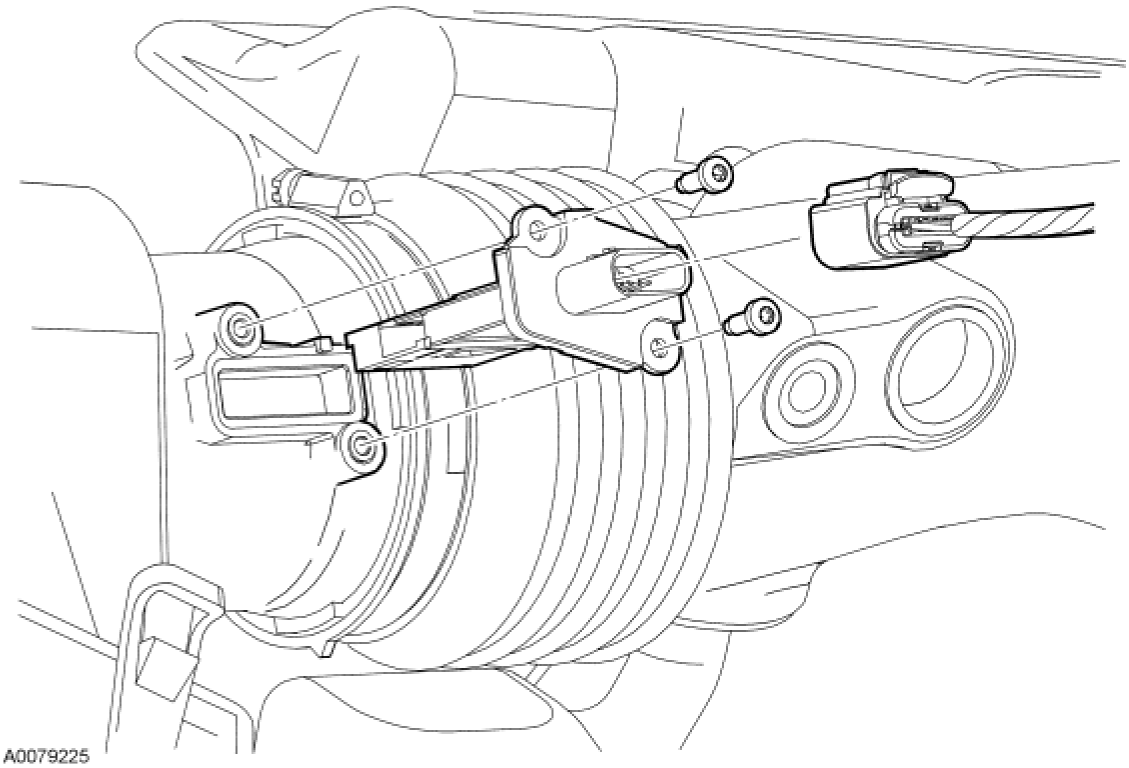


Diagram of Air Flow Through Throttle Body Contacting MAF Sensor Hot and Cold Wire (and IAT Sensor Wire Where Applicable) Terminals.



Typical Mass Air Flow (MAF) Sensor



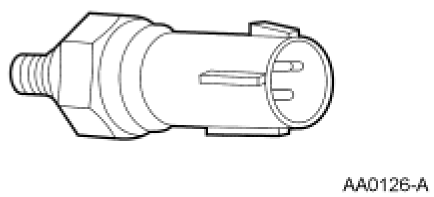
Typical Drop-in Mass Air Flow (MAF) Sensor

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 that is generated.

Power Steering Pressure (PSP) Sensor

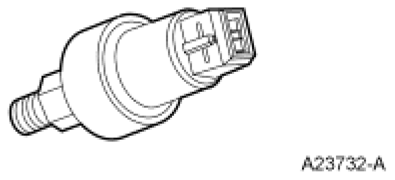
The PSP sensor monitors the hydraulic pressure within the power steering system. The PSP sensor voltage input to the PCM changes as the hydraulic pressure changes. The PCM uses the input signal from the PSP sensor to compensate for additional loads on the engine by adjusting the idle RPM and preventing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



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 EPC pressure during increased engine load, for example during parking maneuvers.



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 DTCs may be set during PTO operation. Prior to an Inspection/Maintenance (I/M) test, operate the vehicle with the PTO disengaged long enough to successfully complete the OBD Monitors.

PTO Circuits Description

The three 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 when the operator is requesting 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 those electrical/electronic modules and subsystems that require vehicle speed data. This subsystem senses the transmission OSS 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.

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

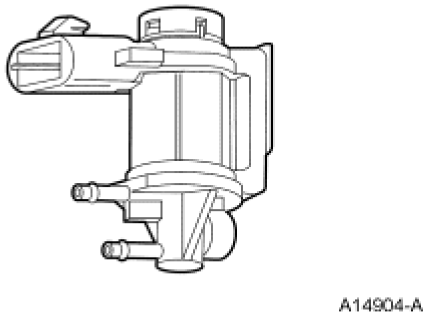
- infer vehicle movement from the OSS sensor signal.
- convert transmission output shaft rotational information to vehicle speed information.
- compensate for tire size and axle ratio with a programmed calibration variable.
- use a transfer case speed sensor (TCSS) for four wheel drive (4WD) applications.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

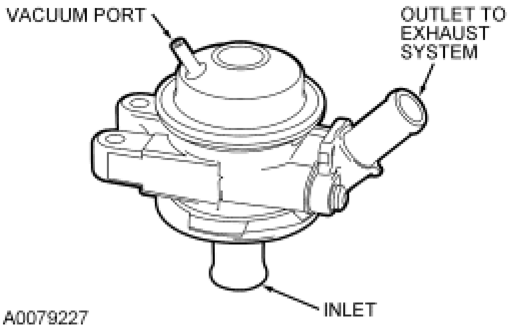
The secondary AIR bypass solenoid is used by the PCM to control vacuum to the secondary air injection diverter (AIR diverter) valve. The secondary AIR bypass solenoid is a normally closed solenoid. The secondary AIR bypass solenoid also has a filtered vent feature to permit vacuum release.



Secondary AIR Bypass Solenoid

Secondary AIR Diverter Valve

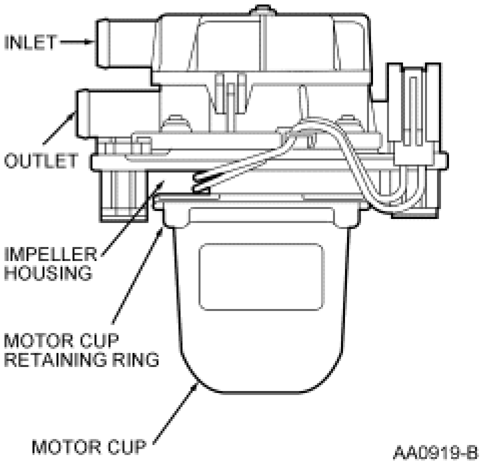
The secondary AIR diverter valve is used with the secondary AIR pump to provide on/off control of air to the exhaust manifold and catalytic converter. When the secondary AIR pump is on and vacuum is supplied to the AIR diverter valve, air passes the integral check valve disk. When the secondary AIR pump 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.



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 downstream of the mass air flow/intake air temperature sensor. For additional information on the secondary AIR injection system, refer to [Secondary Air Injection (AIR) System](#) in this section.



Secondary Air Pump

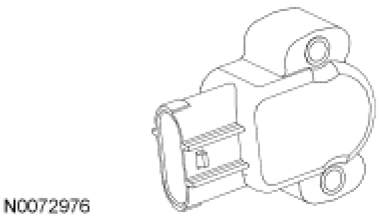
Starter Motor Request (SMR) Circuit

The SMR circuit provides the PCM with a signal from the ignition switch to the PCM. The input is pulled high when the ignition 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 the corrosion resistance on the terminals and increases the connector durability. The TP sensor is mounted on the throttle body. As the TP sensor is rotated by the throttle shaft, four operating conditions are determined by the PCM from the TP. These 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)
- throttle angle rate



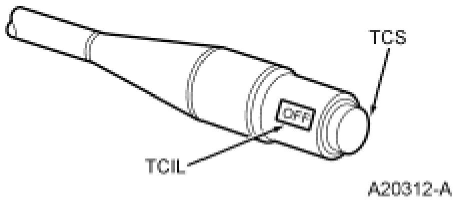
Typical TP Sensor

Transmission Control Indicator Lamp (TCIL)

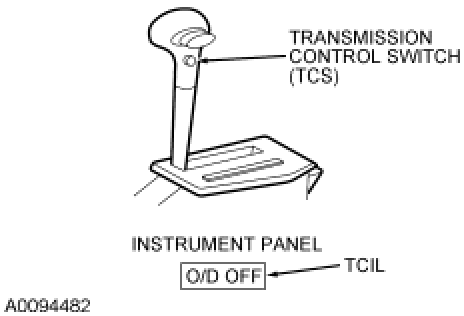
The TCIL is an output signal from the PCM that controls the lamp on/off function depending on the engagement or disengagement of overdrive.

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.



Typical Transmission Control Switch (TCS)



Typical Transmission Control Switch (TCS)

Universal Heated Oxygen Sensor (HO2S)

The universal HO2S, sometimes referred to as a wideband oxygen sensor, uses the typical HO2S combined with a current controller in the PCM to infer an air/fuel ratio relative to the stoichiometric air/fuel ratio. This is accomplished by balancing the amount of oxygen ions pumped in or out of a measurement chamber within the sensor. The typical HO2S within the universal HO2S is used to detect the oxygen content of the exhaust gas in the measurement chamber. The oxygen content inside the measurement chamber is maintained at the stoichiometric air/fuel ratio by pumping oxygen ions in and out of the measurement chamber. As the exhaust gasses get richer or leaner, the amount of oxygen that must be pumped in or out to maintain a stoichiometric air/fuel ratio in the measurement chamber varies in proportion to the air/fuel ratio. The amount of current required to pump the oxygen ions in or out of the measurement chamber is used to measure the air/fuel ratio. The measured air/fuel ratio is actually the output from the current controller in the PCM and not a signal that comes directly from the sensor.

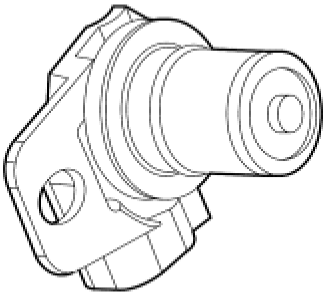
The universal HO2S also uses a self-contained reference chamber to make sure an oxygen differential is always present. The oxygen for the reference chamber is supplied by pumping small amounts of oxygen ions from the measurement chamber into the reference chamber. The universal HO2S does not need access to outside air.

Part to part variance is compensated for by placing a resistor in the connector. This resistor is used to trim the current measured by the current controller in the PCM.

Embedded with the sensing element is the universal HO2S heater. The heater allows the engine to enter closed loop operation sooner. The heating element heats the sensor to a temperature of 780℃ (1,436℉). The V PWR circuit supplies voltage to the heater. The PCM controls the heater on and off by providing the ground to maintain the sensor at the correct temperature for maximum accuracy.

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 speed, 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.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Typical Vehicle Speed Sensor (VSS)