

2021 ENGINE PERFORMANCE

Engine Controls And Fuel - 2.5L (LCV) - Description And Operation - Canyon, Colorado

DESCRIPTION AND OPERATION

CAMSHAFT ACTUATOR SYSTEM DESCRIPTION

Circuit/System Description

The camshaft position actuator solenoid valve - Intake and camshaft position actuator solenoid valve - exhaust system enables the engine control module (ECM) to change camshaft timing while the engine is running. The camshaft position actuator assembly varies camshaft position in response to directional changes in oil pressure. The camshaft position actuator solenoid valve - Intake and camshaft position actuator solenoid valve - exhaust controls the oil pressure that is applied to advance or retard the camshaft. Modifying camshaft timing under changing engine demand provides better balance between the following performance concerns:

- Engine power output
- Fuel economy
- Lower exhaust emissions

The ECM uses information from the following sensors in order to calculate the desired camshaft position:

- The engine coolant temperature (ECT) sensor
- The mass air flow (MAF) sensor
- The throttle position sensor
- The vehicle speed sensor (VSS)

Camshaft Position Actuator System Operation

The ECM operates the camshaft position actuator solenoid valve - Intake and camshaft position actuator solenoid valve - exhaust by pulse width modulation (PWM) of the solenoid coil. The higher the PWM duty cycle, the larger the change in camshaft timing. Oil pressure that is applied to the advance side of the fixed vanes will rotate the camshaft in a clockwise direction. The clockwise movement of the camshaft will advance the timing up to a maximum of 21B°. When oil pressure is applied to the return side of the vanes, the camshaft will rotate counterclockwise until returning to 0B°.

Oil flowing to the camshaft position actuator solenoid valve - intake and camshaft position actuator solenoid valve - exhaust housing from the camshaft position actuator solenoid valve - Intake and camshaft position actuator solenoid valve - exhaust advance passage applies pressure to the advance side of the vane wheel in the camshaft position actuator assembly. At the same time the camshaft position actuator solenoid valve - Intake and camshaft position actuator solenoid valve - exhaust retard passage is open, allowing oil pressure to decrease on the retard side of the vane wheel. These two simultaneous actions cause the vane wheel to rotate clockwise, advancing camshaft advance timing.

When the oil flowing to the camshaft position actuator solenoid valve - Intake and camshaft position actuator solenoid valve - exhaust housing is from the camshaft position actuator solenoid valve - Intake and camshaft position actuator solenoid valve - exhaust retard passage, oil pressure is applied to the retard side of the vane wheel. Because the solenoid advance passage is open, allowing oil pressure to decrease on the advance side of the vane wheel, the camshaft position retards.

The ECM can also command the camshaft position actuator solenoid valve - Intake and camshaft position actuator solenoid valve - exhaust to stop oil flow from both passages in order to hold the current camshaft position. The ECM is continuously comparing camshaft position sensor - intake and camshaft position sensor - exhaust input with camshaft position actuator solenoid valve - Intake and camshaft position actuator solenoid valve - exhaust input in order to monitor camshaft position and detect any system malfunctions. The following table provides camshaft phase commands for common driving conditions:

Driving Conditions	Change in Camshaft Position	Objective	Result
Idle	No change	Minimize valve overlap	Stabilize idle speed
Light engine load	Retard valve timing	Decrease valve overlap	Stable engine output
Medium engine load	Advance valve timing	Increase valve overlap	Better fuel economy with lower emissions
High RPM with heavy load	Retard valve timing	Retard intake valve closing	Improve engine output

Intake Camshaft Mid Park Lock (if Equipped)

The intake camshaft position actuator park lock solenoid valve is supplied a dedicated ground control circuit from the ECM and an ignition voltage supply circuit. The ECM operates the intake camshaft position actuator park lock solenoid valve by applying ground to the solenoid valve control circuit to control the oil flow that applies the pressure to disengage the intake camshaft actuator park pin. This allows the ECM to advance or retard the camshaft. When the ECM determines that cam phasing is not desired, it will command the camshaft to the lock position at 0B°. At that stage, the ECM control circuit ground is then removed from the solenoid, oil pressure is unapplied, and the camshaft actuator park pin will re-engage preventing cam phasing. The ECM can also determine if the park pin is engaged by applying a slight amount of camshaft advance or retard to verify if movement is present.

CATALYTIC CONVERTER DESCRIPTION AND OPERATION

Three-Way Catalytic Converter

A 3-way catalyst controls emissions of hydrocarbons, carbon monoxide (CO) and nitrogen oxide (NOx). The catalyst within the converter promotes a chemical reaction, which oxidizes the hydrocarbons and the CO that are present in the exhaust gas. This process converts the hydrocarbons and the CO into water vapor and carbon dioxide (CO₂), and reduces the NOx, converting the NOx into nitrogen. The catalyst also stores oxygen. The engine control module (ECM) monitors this process by using heated oxygen sensors (HO₂S) that are in the exhaust stream before and after the 3-way catalyst. The HO₂S produces an output signal that the ECM uses to calculate the oxygen storage capacity of the catalyst. This indicates the ability of the catalyst to convert the exhaust emissions efficiently. The ECM monitors the efficiency of the catalyst by monitoring the HO₂S during an off-idle, decel fuel cut off (DFCO) event. When the catalyst is functioning properly, the post catalyst HO₂S response to the fuel conditions during the DFCO event is slow compared to the response of the pre catalyst HO₂S. When the post HO₂S response is near that of the pre HO₂S, the oxygen storage capability and efficiency of the catalyst may be degraded below an acceptable threshold.

The catalyst must be warmed to efficiently reduce the emissions. The cold start strategy is to reduce the amount of time it takes to warm the catalyst. During a cold start, the engine spark timing is altered to allow the catalyst to warm quickly. This diagnostic monitors the following to build an exhaust energy model:

- Spark advance
- Engine airflow
- Engine coolant temperature
- Engine run time
- Engine idle speed
- Catalyst temperature

The actual model is then compared to the expected exhaust energy model.

Fuel trim bias is used to keep the post catalyst air/fuel ratio within a predetermined range. This allows optimal catalyst efficiency under various operating conditions. The engine control module (ECM) constantly monitors how lean or rich the fuel trim bias is commanded, to determine if the fuel trim bias is greater than a calibrated amount.

ELECTRONIC IGNITION SYSTEM DESCRIPTION

The electronic ignition system produces and controls a high-energy secondary spark. This spark is used to ignite the compressed air/fuel mixture at precisely the correct time. This provides optimal performance, fuel economy, and control of exhaust emissions. This ignition system uses an individual coil for each cylinder. The ignition coils are mounted near each cylinder with short integrated boots or high tension wires connecting the coils to the spark plugs. The driver modules within each ignition coil are commanded ON/OFF by the Engine Control Module (ECM). The ECM uses engine speed, the mass air flow (MAF) sensor signal, and position information from the crankshaft position and the camshaft position sensors to control the sequence, dwell, and timing of the spark.

The electronic ignition system consists of the following components:

Crankshaft Position Sensor

The crankshaft position sensor works in conjunction with a reluctor wheel on the crankshaft (front mounted crankshaft position sensor) or a reluctor wheel that is part of the flywheel (rear mounted crankshaft position sensor). The ECM monitors the voltage frequency on the crankshaft position sensor signal circuit. As each reluctor wheel tooth rotates past the sensor, the sensor creates a digital ON/OFF pulse. This digital signal is processed by the ECM. This creates a signature pattern that enables the ECM to determine the crankshaft position. The ECM uses the signal to determine which pair of cylinders is approaching top dead center based on the crankshaft position signal alone. The camshaft position sensor signals are used in order to determine which of these 2 cylinders is on a firing stroke, and which is on the exhaust stroke. The ECM uses this to properly synchronize the ignition system, the fuel injectors, and the knock control. This sensor is also used in order to detect misfire.

The ECM also has a dedicated replicated crankshaft position sensor signal output circuit that may be used as an input signal to other modules for monitoring engine RPM.

Camshaft Position Sensor

This engine uses a camshaft position sensor for each camshaft. The camshaft position sensor is a three wire hall effect type sensor. The ECM supplies the camshaft position sensor with a 5 V reference circuit, a signal circuit and a low reference circuit. The camshaft position sensor signals are an input to the ECM. These signals are also used to detect camshaft alignment with the crankshaft. The camshaft position sensor does not directly affect the operation of the ignition system. The camshaft position sensor information is used by the ECM to determine the position of the camshaft relative to the crankshaft position. By monitoring the camshaft position and crankshaft position signals the ECM can accurately time the operation of the fuel injectors.

The ECM also has a dedicated replicated camshaft position sensor signal output circuit that may be used as an input signal to other modules for monitoring engine RPM.

Knock Sensor

The knock sensor system enables the ECM to control the ignition timing for the best possible performance while protecting the engine from potentially damaging levels of detonation, also known as spark knock. The knock sensor system uses 1 or 2 flat response 2-wire sensors. The sensor uses piezo-electric crystal technology that produces an AC voltage signal of varying amplitude and frequency based on the engine vibration or noise level. The amplitude and frequency depend upon the level of knock that the knock sensor detects. The ECM receives the knock sensor signal through the high and low signal circuits.

The ECM learns a minimum noise level, or background noise, at idle from the knock sensor and uses calibrated values for the rest of the RPM range. The ECM uses the minimum noise level to calculate a noise channel. A normal knock sensor signal will ride within the noise channel. As engine speed and load change, the noise channel upper and lower parameters will change to accommodate the normal knock sensor signal, keeping the signal within the channel. In order to determine which cylinders are knocking, the ECM only uses knock sensor signal information when each cylinder is near top dead center (TDC) of the firing stroke. If knock is present, the signal will range outside of the noise channel.

If the ECM has determined that knock is present, it will retard the ignition timing to attempt to eliminate the knock. The ECM will always try to work back to a zero compensation level, or no spark retard. An abnormal knock sensor signal will stay outside of the noise channel or will not be present. Knock sensor diagnostics are calibrated to detect faults with the knock sensor circuitry inside the ECM, the knock sensor wiring, or the knock sensor voltage output. Some diagnostics are also calibrated to detect constant noise from an outside influence such as a loose/damaged component or excessive engine mechanical noise.

Ignition Coils

Each ignition coil has an ignition voltage feed and a ground circuit. The engine control module (ECM) supplies a low reference and an ignition control (IC) circuit. Each ignition coil contains a solid state driver module. The ECM will command the IC circuit ON, which allows the current to flow through the primary coil windings. When the ECM commands the IC circuit OFF, this will interrupt current flow through the primary coil windings. The magnetic field created by the primary coil windings will collapse across the secondary coil windings, which induces a high voltage across the spark plug electrodes.

Engine Control Module (ECM)

The ECM controls all ignition system functions and constantly corrects the spark timing. The ECM monitors information from various sensor inputs that may include the following components, if applicable:

- Throttle position sensor
- Engine coolant temperature (ECT) sensor
- Mass air flow (MAF) sensors
- Intake air temperature (IAT) sensors
- Vehicle speed sensor (VSS)
- Transmission gear position or range information sensors
- Engine knock sensors
- Ambient pressure sensors (BARO)

ENGINE CONTROL MODULE DESCRIPTION

The Engine Control Module (ECM) interacts with many emission related components and systems, and monitors emission related components and systems for deterioration. OBD II diagnostics monitor the system performance and a diagnostic trouble code (DTC) sets if the system performance degrades. The ECM is part of a network and communicates with various other vehicle control modules.

Malfunction indicator lamp (MIL) operation and DTC storage are dictated by the DTC type. A DTC is ranked as a Type A or Type B if the DTC is emissions related. Type C is a non-emissions related DTC.

The ECM is the control center of the engine controls system. Review the components and wiring diagrams in order to determine which systems are controlled by the ECM.

The ECM constantly monitors the information from various sensors and other inputs, and controls the systems that affect engine performance and emissions. The ECM also performs diagnostic tests on various parts of the system and can turn on the MIL when it recognizes an operational problem that affects emissions. When the ECM detects a malfunction, the ECM stores a DTC. The condition area is identified by the particular DTC that is set. This aids the technician in making repairs.

ECM Function

The ECM can supply 5 V or 12 V to various sensors or switches. This is done through pull-up resistors to regulated power supplies within the ECM. In some cases, even an ordinary shop voltmeter will not give an accurate reading due to low input resistance. Therefore, a digital multimeter (DMM) with at least 10 megaohms input impedance is required in order to ensure accurate voltage readings.

The ECM controls the output circuits by controlling the ground or the power feed circuit through transistors or a device called an output driver module.

EEPROM

The electronically erasable programmable read only memory (EEPROM) is an integral part of the ECM. The EEPROM contains program and calibration information that the ECM needs in order to control engine operation.

Special equipment, as well as the correct program and calibration for the vehicle, are required in order to reprogram the ECM.

Data Link Connector (DLC)

The data link connector (DLC) provides serial data communication for ECM diagnosis. This connector allows the technician to use a scan tool in order to monitor various serial data parameters, and display DTC information. The DLC is located inside the driver's compartment, underneath the instrument panel.

Malfunction Indicator Lamp (MIL)

The malfunction indicator lamp (MIL) is inside the instrument panel cluster (IPC). The MIL is controlled by the ECM and illuminates when the ECM detects a condition that affects vehicle emissions.

ECM Service Precautions

The ECM, by design, can withstand normal current draws that are associated with vehicle operations. However, care must be used in order to avoid overloading any of these circuits. When testing for opens or shorts, do not ground or apply voltage to any of the ECM circuits unless the diagnostic procedure instructs you to do so. These circuits should only be tested with a DMM unless the diagnostic procedure instructs otherwise.

Emissions Diagnosis For State I/M Programs

This OBD II equipped vehicle is designed to diagnose any conditions that could lead to excessive levels of the following emissions:

- Hydrocarbons (HC)
- Carbon monoxide (CO)
- Oxides of nitrogen (NOx)
- Evaporative emission (EVAP) system losses

Should this vehicle's on-board diagnostic system (ECM) detect a condition that could result in excessive emissions, the ECM turns ON the MIL and stores a DTC that is associated with the condition.

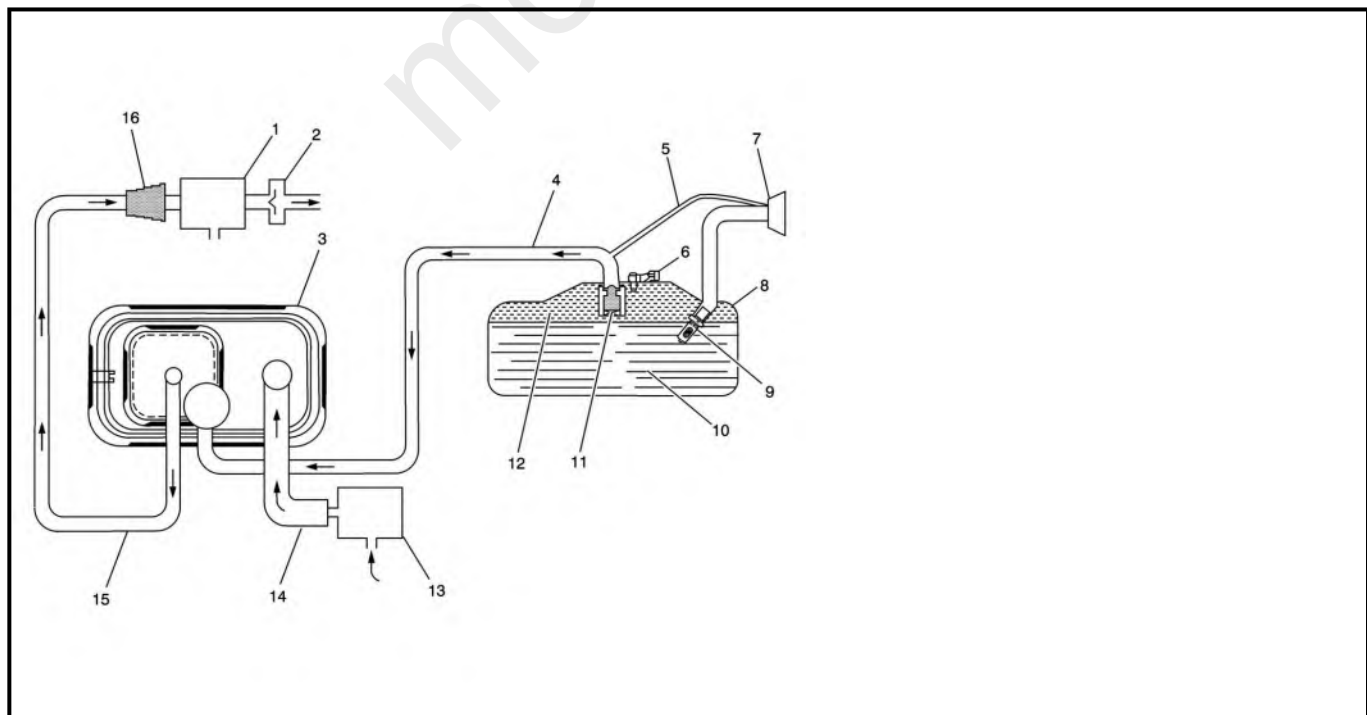
Aftermarket (Add-On) Electrical And Vacuum Equipment

CAUTION: Do not attach add-on vacuum operated equipment to this vehicle. The use of add-on vacuum equipment may result in damage to vehicle components or systems.

CAUTION: Connect any add-on electrically operated equipment to the vehicle's electrical system at the 12 V battery (power and ground) in order to prevent damage to the vehicle.

Aftermarket, add-on, electrical and vacuum equipment is defined as any equipment installed on a vehicle after leaving the factory that connects to the vehicle's electrical or vacuum systems. No allowances have been made in the vehicle design for this type of equipment.

Add-on electrical equipment, even when installed to these strict guidelines, may still cause the powertrain system to malfunction. This may also include equipment not connected to the vehicle electrical system, such as



Callout	Component Name
1	Evaporative Emissions (EVAP) Purge Solenoid Valve
2	Purge Tube Check Valve, Turbo-Charged Applications Only
3	EVAP Canister
4	EVAP Vapor Tube
5	Vapor Recirculation Tube (ORVR)
6	Fuel Tank Pressure Sensor
7	Fuel Filler Cap (Some Vehicles May Have A Capless Design)
8	Fuel Tank
9	Fuel Fill Pipe Inlet Check Valve
10	Liquid Fuel
11	Fill Limit Vent Valve (FLVV)
12	Fuel Vapor
13	EVAP Canister Vent Solenoid Valve
14	Vent hose
15	EVAP Purge Tube
16	EVAP Canister Purge Tube Connector

EVAP System Operation

The EVAP control system limits fuel vapors from escaping into the atmosphere. Fuel tank vapors are allowed to move from the fuel tank, due to pressure in the tank, through the EVAP vapor tube, into the EVAP canister. Carbon in the canister absorbs and stores the fuel vapors. Excess pressure is vented through the vent hose and EVAP vent solenoid valve to the atmosphere. The EVAP canister stores the fuel vapors until the engine is able to use them. At an appropriate time, the engine control module (ECM) will command the EVAP purge solenoid valve ON, allowing engine vacuum to be applied to the EVAP canister. With the normally open EVAP vent solenoid valve OFF, fresh air is drawn through the vent solenoid valve and the vent hose to the EVAP canister. Fresh air is drawn through the canister, pulling fuel vapors from the carbon. The air/fuel vapor mixture continues through the EVAP purge tube and EVAP purge solenoid valve into the intake manifold to be consumed during normal combustion. The ECM uses several tests to determine if the EVAP system is leaking or restricted.

Purge Solenoid Valve Leak Test

If the EVAP purge solenoid valve does not seal properly fuel vapors could enter the engine at an undesired time, causing driveability concerns. The ECM tests for this by commanding the EVAP purge solenoid valve OFF and the vent solenoid valve ON which seals the system. With the engine running, the ECM then monitors the fuel tank pressure sensor for an increase in vacuum. The ECM will set a DTC if a vacuum develops in the tank under these test conditions.

Large Leak Test

This diagnostic creates a vacuum condition in the EVAP system. When the enabling criteria has been met, the ECM commands the normally open EVAP vent solenoid valve closed and the EVAP purge solenoid valve open, creating a vacuum in the EVAP system. The ECM then monitors the fuel tank pressure sensor voltage to verify that the system is able to reach a predetermined level of vacuum within a set amount of time. Failure to achieve the expected level of vacuum indicates the presence of a large leak in the EVAP system or a restriction in the purge path. The ECM will set a DTC if it detects a weaker than expected vacuum level under these test conditions.

Canister Vent Restriction Test

If the EVAP vent system is restricted, fuel vapors will not be properly purged from the EVAP canister. The ECM tests this by commanding the EVAP purge solenoid valve ON while commanding the EVAP vent solenoid valve OFF, and then monitoring the fuel tank pressure sensor for an increase in vacuum. If the vacuum increases more than the expected amount, in a set amount of time, a fault will be logged by the ECM.

Small Leak Test

The engine off natural vacuum diagnostic is the small-leak detection diagnostic for the EVAP system. The engine off natural vacuum diagnostic monitors the EVAP system pressure with the ignition OFF. Because of this, it may be normal for the ECM to remain active for up to 40 min after the ignition is turned OFF. This is important to remember when performing a parasitic draw test on vehicles equipped with engine off natural vacuum.

When the vehicle is driven, the temperature rises in the tank due to heat transfer from the exhaust system. After the vehicle is parked, the temperature in the tank continues to rise for a period of time, then starts to drop. The engine off natural vacuum diagnostic relies on this temperature change, and the corresponding pressure change in a sealed system, to determine if an EVAP system leak is present.

The engine off natural vacuum diagnostic is designed to detect leaks as small as 0.51 mm (0.020 in).

EVAP System Components

The EVAP system consists of the following components:

EVAP Purge Solenoid Valve

The EVAP purge solenoid valve controls the flow of vapors from the EVAP system to the intake manifold. The purge solenoid valve opens when commanded ON by the ECM. This normally closed valve is pulse width modulated (PWM) by the ECM to precisely control the flow of fuel vapor to the engine. The valve will also be opened during some portions of the EVAP testing when the engine is running, allowing engine vacuum to enter the EVAP system.

Purge Tube Check Valve

NOTE: **The presence of this one-way check valve prevents pressure testing the EVAP system for leaks at the EVAP canister purge tube connector.**

Turbocharged vehicles have a check valve in the purge tube between the EVAP purge solenoid valve and the intake manifold to prevent pressurization of the EVAP system under boost conditions. Some applications may have this check valve between the EVAP purge solenoid valve and the EVAP canister.

EVAP Canister

The canister is filled with carbon pellets used to absorb and store fuel vapors. Fuel vapor is stored in the canister until the ECM determines that the vapor can be consumed in the normal combustion process.

Vapor Recirculation Tube

A vapor path between the fuel fill pipe and the vapor tube to the carbon canister is necessary for Vehicle Onboard Diagnostics to fully diagnose the EVAP system. It also accommodates service diagnostic procedures by allowing the entire EVAP system to be diagnosed from either end of the system.

The On-Board Refueling Vapor Recovery System is an on-board vehicle system designed to recover fuel vapors during the vehicle refueling operation. The flow of liquid fuel down the fuel filler pipe provides a liquid seal which prevents vapor from leaving the fuel filler pipe. An EVAP pipe transports the fuel vapor to the EVAP canister for use by the engine.

Fuel Tank Pressure Sensor

The fuel tank pressure sensor measures the difference between the pressure or vacuum in the fuel tank and outside air pressure. Depending on the vehicle, the sensor can be located in the vapor space on top of the fuel tank, in the vapor tube between the canister and the tank, or on the EVAP canister. A high fuel tank pressure sensor voltage indicates a low fuel tank pressure or vacuum. A low fuel tank pressure sensor voltage indicates a high fuel tank pressure.

Fuel Fill Pipe Check Valve

The check valve on the fuel fill pipe is there to prevent spit-back during refueling.

EVAP Vent Solenoid Valve

The EVAP vent solenoid valve controls fresh airflow into the EVAP canister. The valve is normally open. The canister vent solenoid valve is closed only during EVAP system tests performed by the ECM like large leak and engine off natural vacuum test.

Fuel Fill Cap

The fuel fill cap is equipped with a seal and a vacuum relief valve and is tethered. A torque-limiting device prevents the cap from being over tightened. To install the cap, turn the cap clockwise until you hear clicks. This indicates that the cap is correctly torqued and fully seated. A built-in device indicates that the fuel filler cap is fully seated. A fuel filler cap that is not fully seated may cause a malfunction in the emission system.

Capless Fuel Fill

Some vehicles may have a capless fuel fill design behind a locking fuel door. There is no fuel fill cap to remove. One just fully inserts the fuel nozzle into the fill neck, making sure it latches before refueling. Flapper valves close to seal this interface once the fill nozzle is removed.

Fill Limit Vent Valve

This acts as a shut off valve during refueling. This will vary based on fuel tank design. The fill limit vent valve has the following functions:

- This valve is not serviced separately. Depending on design, will be located in the top of the fuel tank or on the underside of the pump module flange.
- Controls the fuel tank fill level by closing the primary vent from the fuel tank and forcing the fuel fill nozzle to shut off.
- Prevents liquid fuel from exiting the fuel tank via the EVAP pipe to the canister.
- Provides fuel-spillage protection in the event of a vehicle rollover by closing the vapor path from the tank to the EVAP canister.

FUEL SYSTEM DESCRIPTION

Fuel System Overview

The fuel system is an electronic returnless on-demand design. The returnless fuel system reduces the internal temperature of the fuel tank by not returning hot fuel from the engine to the fuel tank. Reducing the internal temperature of the fuel tank results in lower evaporative emissions.

An electric turbine style fuel pump attaches to the fuel tank fuel pump module inside the fuel tank. The fuel pump supplies fuel through the fuel feed pipe to the high pressure fuel pump. The high pressure fuel pump supplies fuel to a variable-pressure fuel rail. Fuel enters the combustion chamber through precision multi-hole fuel injectors. The high pressure fuel pump, fuel rail pressure, fuel injection timing, and injection duration are controlled by the engine control module (ECM).

Electronic Returnless Fuel System

The electronic returnless fuel system is a microprocessor controlled fuel delivery system which transports fuel from the tank to the fuel rail. It functions as an electronic replacement for a traditional, mechanical fuel pressure regulator. The pressure relief regulator valve within the fuel tank provides an added measure of over-pressure protection. Desired fuel pressure is commanded by the engine control module (ECM), and transmitted to the fuel pump power control module via a GMLAN serial data message. A fuel pressure sensor located on the fuel feed pipe provides the feedback the ECM requires for Closed Loop fuel pressure control.

Fuel Pump Power Control Module

The fuel pump power control module is a serviceable GMLAN module. The fuel pump power control module receives the desired fuel pressure message from the engine control module (ECM) and controls the fuel pump located within the fuel tank to achieve the desired fuel pressure. The fuel pump power control module sends a 25 kHz PWM signal to the fuel pump, and pump speed is changed by varying the duty cycle of this signal. Maximum current supplied to the fuel pump is 15 amps. A fuel pressure sensor located on the fuel feed pipe provides fuel pressure feedback to the ECM.

Fuel Pressure Sensor

The fuel pressure sensor is a serviceable 5 V, 3-pin device. It is located on the fuel feed pipe forward of the fuel tank, and receives power and ground from the ECM through a vehicle wiring harness. The sensor provides a fuel pressure signal to the ECM, which is used to provide Closed Loop fuel pressure control.

Fuel Tank

The fuel tank stores the fuel supply. The fuel tank is located in the rear of the vehicle. The fuel tank is held in place by 2 metal straps that attach to the underbody of the vehicle. The fuel tank is molded from high-density polyethylene.

The fuel limit vent valve which is mounted inside the fuel tank, as part of the tank assembly is designed to close the fuel tank vent when the fuel level reaches a calibrated level during fueling. When the fuel limit vent valve is closed the tank pressure increases during the filling process. This increase in tank pressure causes the filling station fuel pump nozzle to turn OFF. When the fuel limit vent valve is opened fuel vapors in the fuel tank are allowed to vent through the fuel limit vent valve and hose to the EVAP canister.

Fuel Fill Pipe

The fuel fill pipe has a built-in restrictor in order to prevent refueling with leaded fuel.

Fuel Tank Fuel Pump Module

The electric turbine style fuel pump attaches to the fuel tank fuel pump module inside the fuel tank and supplies fuel through the fuel feed pipe to the high pressure fuel pump. The fuel tank fuel pump module contains a reverse flow check valve. The check valve maintains fuel pressure in the fuel feed pipe in order to prevent long cranking times.

The fuel tank fuel pump module consists of the following major components:

- The fuel level sensor
- The fuel pump and reservoir assembly
- The fuel filter
- The pressure relief regulator valve

Fuel Level Sensor

The fuel level sensor consists of a float, a wire float arm, and a ceramic resistor card. The position of the float arm indicates the fuel level. The fuel level sensor contains a variable resistor which changes resistance in correspondence with the position of the float arm.

Fuel Pump

The fuel pump is mounted in the fuel tank fuel pump module reservoir. The fuel pump is an electric turbine style pump which pumps fuel to the high pressure fuel pump at a pressure that is based on feedback from the fuel feed pipe fuel pressure sensor. The fuel pump delivers a constant flow of fuel even during low fuel conditions and aggressive vehicle maneuvers. The fuel pump flex pipe acts to dampen the fuel pulses and noise generated by the fuel pump.

Pressure Relief Regulator Valve

The pressure relief regulator valve replaces the typical fuel pressure regulator used on a mechanical returnless fuel system. The pressure relief regulator valve is closed during normal vehicle operation. The pressure relief regulator valve is used to vent pressure during hot soaks and also functions as a fuel pressure regulator in the event of the fuel pump power control module defaulting to 100% pulse width modulation (PWM) of the fuel pump. Due to variation in the fuel system pressures, the opening pressure for the pressure relief regulator valve is set higher than the pressure that is used on a mechanical returnless fuel system pressure regulator.

Nylon Fuel Pipes

WARNING: In order to reduce the risk of fire and personal injury observe the following items:

- **Replace all nylon fuel pipes that are nicked, scratched or damaged during installation, do not attempt to repair the sections of the nylon fuel pipes**
- **Do not hammer directly on the fuel harness body clips when installing new fuel pipes. Damage to the nylon pipes may result in a fuel leak.**
- **Always cover nylon vapor pipes with a wet towel before using a torch near them. Also, never expose the vehicle to temperatures higher than 115B°C (239B°F) for more than one hour, or more than 90B°C (194B°F) for any extended period.**
- **Apply a few drops of clean engine oil to the male pipe ends before connecting fuel pipe fittings. This will ensure proper reconnection and prevent a possible fuel leak. (During normal operation, the O-rings located in the female connector will swell and may prevent proper reconnection if not lubricated.)**

Nylon pipes are constructed to withstand maximum fuel system pressure, exposure to fuel additives, and changes in temperature.

Heat resistant rubber hose or corrugated plastic conduit protect the sections of the pipes that are exposed to chafing, high temperature, or vibration.

Nylon fuel pipes are somewhat flexible and can be formed around gradual turns under the vehicle. However, if nylon fuel pipes are forced into sharp bends, the pipes may kink and restrict the fuel flow. Also, once exposed to fuel, nylon pipes may become stiffer and are more likely to kink if bent too far. Take special care when working on a vehicle with nylon fuel pipes.

Quick-Connect Fittings

Quick-connect fittings provide a simplified means of installing and connecting fuel system components. The fittings consist of a unique female connector and a compatible male pipe end. O-rings, located inside the female connector, provide the fuel seal. Integral locking tabs inside the female connector hold the fittings together.

Fuel Injection Fuel Feed Pipe Dampener

The fuel feed pipe dampener is located just before the high-pressure fuel pump and is used to dampen the high-pressure fuel pump's significant pulsations. The dampener is a spring-loaded check valve that allows fuel to free flow to the high-pressure fuel pump but prevents high pressure fuel pulsations from flowing back to the fuel tank. The valve has an integral bypass that allows a controlled bleed back to the fuel tank. The purpose of the bleed is to prevent excessive pressure from building up in the low-pressure fuel lines and potentially damaging components of the low-pressure fuel circuit.

High Pressure Fuel Pump

The high fuel pressure necessary for direct injection is supplied by the high pressure fuel pump. The pump is mounted on the rear of the engine and is driven by a three-lobe cam on the camshaft. This pump also regulates

the fuel pressure using an actuator in the form of an internal solenoid-controlled valve. In order to keep the engine running efficiently under all operating conditions, the engine control module (ECM) requests pressure ranging from 2 to 15 MPa (290 to 2176 PSI), depending on engine speed and load. Output drivers in the ECM provide the pump control circuit with a 12 V pulse-width modulated (PWM) signal, which regulates fuel pressure by closing and opening the control valve at specific times during pump strokes. This effectively regulates the portion of each pump stroke that is delivered to the fuel rail. When the control solenoid is NOT powered, the pump operates at minimum flow rate. In the event of pump control failure, the high pressure system is protected by a relief valve in the pump.

Fuel Rail Assembly

The fuel rail assembly attaches to the cylinder head and distributes the high pressure fuel to the fuel injectors. The fuel rail assembly consists of the following components:

- The direct fuel injectors
- The fuel rail pressure sensor

Fuel Injectors

The fuel injection system is a high pressure, direct injection, returnless on-demand design. The fuel injectors are mounted in the cylinder head beneath the intake ports and spray fuel directly into the combustion chamber. Direct injection requires high fuel pressure due to the fuel injector's location in the combustion chamber. Fuel pressure must be higher than compression pressure requiring a high pressure fuel pump. The fuel injectors also require more electrical power due to the high fuel pressure. The ECM supplies a high voltage supply circuit and a high voltage control circuit for each fuel injector. The injector high voltage supply circuit and the high voltage control circuit are both controlled by the ECM. The ECM energizes each fuel injector by grounding the control circuit. The ECM controls each fuel injector with 65 V. This is controlled by a boost capacitor in the ECM. During the 65 V boost phase, the capacitor is discharged through an injector, allowing for initial injector opening. The injector is then held open with 12 V.

The fuel injector assembly is an inside opening electrical magnetic injector. The injector has six precision machined holes that generate a cone shaped oval spray pattern. The fuel injector has a slim extended tip in order to allow a sufficient cooling jacket in the cylinder head.

Fuel Injection Fuel Rail Fuel Pressure Sensor

The fuel rail pressure sensor detects fuel pressure within the fuel rail. The engine control module (ECM) provides a 5 V reference voltage on the 5 V reference circuit and ground on the reference ground circuit. The ECM receives a varying signal voltage on the signal circuit. The ECM monitors the voltage on the fuel rail pressure sensor circuits. When the fuel pressure is high, the signal voltage is high. When the fuel pressure is low, the signal voltage is low.

Fuel Metering Modes of Operation

The ECM monitors voltages from several sensors in order to determine how much fuel to give the engine. The ECM controls the amount of fuel delivered to the engine by changing the fuel injector pulse width. The fuel is delivered under one of several modes.

Starting Mode

The ECM supplies voltage to the fuel pump power control module when the ECM detects that the ignition is ON. The voltage from the ECM to the fuel pump power control module remains active for 2 s, unless the engine is in Crank or Run. While this voltage is being received, the fuel pump power control module closes the ground switch of the fuel tank fuel pump module and also supplies a varying voltage to the fuel tank fuel pump module in order to maintain the desired fuel line pressure. The ECM calculates the air/fuel ratio based on inputs from the engine coolant temperature (ECT), manifold absolute pressure (MAP), mass air flow (MAF), and throttle position sensors. The system stays in starting mode until the engine speed reaches a predetermined RPM.

During a cold start, the ECM commands dual-pulse mode during Open Loop operation to improve cold start emissions. In dual-pulse mode, the injectors are energized twice during each injection event.

Clear Flood Mode

If the engine floods, the engine can be cleared by pressing the accelerator pedal down to the floor and then cranking the engine. When the throttle position sensor is at wide open throttle (WOT), the ECM reduces the fuel injector pulse width in order to increase the air to fuel ratio. The ECM holds this injector rate as long as the throttle stays wide open and the engine speed is below a predetermined RPM. If the throttle is not held wide open, the ECM returns to the starting mode.

Run Mode

The run mode has 2 conditions called Open Loop and Closed Loop. When the engine is first started and the engine speed is above a predetermined RPM, the system begins Open Loop operation. The ECM ignores the signal from the heated oxygen sensor (HO2S). The ECM calculates the air/fuel ratio based on inputs from the engine coolant temperature (ECT), manifold absolute pressure (MAP), mass air flow (MAF), and throttle position sensors. The system stays in Open Loop until meeting the following conditions:

- The HO2S has varying voltage output, showing that the HO2S is hot enough to operate properly.
- The ECT sensor is above a specified temperature.
- A specific amount of time has elapsed after starting the engine.

Specific values for the above conditions exist for each different engine, and are stored in the electrically erasable programmable read-only memory (EEPROM). The system begins Closed Loop operation after reaching these values. In Closed Loop, the ECM calculates the air/fuel ratio, injector ON time, based upon the signal from various sensors, but mainly from the HO2S. This allows the air/fuel ratio to stay very close to 14.7:1.

Acceleration Mode

When the driver pushes on the accelerator pedal, air flow into the cylinders increases rapidly. To prevent possible hesitation, the ECM increases the pulse width to the injectors to provide extra fuel during acceleration. This is also known as power enrichment. The ECM determines the amount of fuel required based upon throttle position, engine coolant temperature (ECT), manifold absolute pressure (MAP), mass air flow (MAF), and engine speed.

Deceleration Mode

When the driver releases the accelerator pedal, air flow into the engine is reduced. The ECM monitors the corresponding changes in throttle position, mass air flow (MAF), and manifold absolute pressure (MAP). The ECM shuts OFF fuel completely if the deceleration is very rapid, or for long periods, such as long, closed-throttle coast-down. The fuel shuts OFF in order to prevent damage to the catalytic converters.

Battery Voltage Correction Mode

When the battery voltage is low, the ECM compensates for the weak spark delivered by the ignition system in the following ways:

- Increasing the amount of fuel delivered
- Increasing the idle RPM
- Increasing the ignition dwell time

Fuel Cutoff Mode

The ECM cuts OFF fuel from the fuel injectors when the following conditions are met in order to protect the powertrain from damage and improve driveability:

- The ignition is OFF. This prevents engine run-on.

- The ignition is ON but there is no ignition reference signal. This prevents flooding or backfiring.
- The engine speed is too high, above red line.
- The vehicle speed is too high, above rated tire speed.
- During an extended, high speed, closed throttle coast down - This reduces emissions and increases engine braking.
- During extended deceleration, in order to prevent damage to the catalytic converters

Fuel Trim

The ECM controls the air/fuel metering system in order to provide the best possible combination of driveability, fuel economy, and emission control. The ECM monitors the heated oxygen sensor (HO2S) signal voltage while in Closed Loop and regulates the fuel delivery by adjusting the pulse width of the injectors based on this signal. The ideal fuel trim values are around 0% for both short and long term fuel trim. A positive fuel trim value indicates the ECM is adding fuel in order to compensate for a lean condition by increasing the pulse width. A negative fuel trim value indicates that the ECM is reducing the amount of fuel in order to compensate for a rich condition by decreasing the pulse width. A change made to the fuel delivery changes the long and short term fuel trim values. The short term fuel trim values change rapidly in response to the HO2S signal voltage. These changes fine tune the engine fueling. The long term fuel trim makes coarse adjustments to fueling in order to re-center and restore control to short term fuel trim. A scan tool can be used to monitor the short and long term fuel trim values. The long term fuel trim diagnostic is based on an average of several of the long term speed load learn cells. The ECM selects the cells based on the engine speed and engine load. If the ECM detects an excessively lean or rich condition, the ECM will set a fuel trim diagnostic trouble code (DTC).

HEATED OXYGEN SENSOR DESCRIPTION AND OPERATION

The ECM controls a closed loop air/fuel metering system in order to provide the best possible combination of driveability, fuel economy, and emission control. The ECM monitors the heated oxygen sensor (HO2S) signal voltage and adjusts the fuel delivery based on the signal voltage while in closed loop. The short term fuel trim values change rapidly in response to the HO2S signal voltages. These changes fine tune the engine fueling. The long term fuel trim values change in response to trends in the short term fuel trim. The long term fuel trim makes coarse adjustments to fueling in order to re-center and restore control to short term fuel trim.

Heated Oxygen Sensor

When the engine is started, the control module operates in an Open Loop mode, ignoring the HO2S signal voltage while calculating the air-to-fuel ratio. While the engine runs, the HO2S heats up and begins to generate a voltage within a range of 0 - 1, 000 mV. Once sufficient HO2S voltage fluctuation is observed by the control module, Closed Loop is entered. The control module uses the HO2S voltage to determine the air-to-fuel ratio. An HO2S voltage that increases toward 1, 000 mV indicates a rich fuel mixture. An HO2S voltage that decreases toward 0 mV indicates a lean fuel mixture.

Heated oxygen sensors (HO2S) are used for fuel control and post catalyst monitoring. Each HO2S compares the oxygen content of the surrounding air with the oxygen content in the exhaust stream. The HO2S must reach operating temperature to provide an accurate voltage signal. A heating element inside the HO2S minimizes the time required for the sensors to reach operating temperature. This allows the system to enter Closed Loop earlier and the control module to calculate the air-to-fuel ratio sooner. Voltage is provided to the heater by an ignition voltage circuit through a fuse. With the engine running, ground is provided to the heater by the HO2S heater low control circuit through a low side driver within the engine control module (ECM). The ECM uses pulse width modulation (PWM) to control the HO2S heater operation to maintain a specific HO2S operating temperature range.

Wide Band Heated Oxygen Sensor

The wide band heated oxygen sensor (HO2S) measures the amount of oxygen in the exhaust system and provides more information than the switching style HO2S. The wide band sensor consists of an oxygen sensing cell, an oxygen pumping cell, and a heater. The exhaust gas sample passes through a diffusion gap between the sensing cell and the pumping cell. The engine control module (ECM) supplies a voltage to the HO2S and uses this voltage as a reference to the amount of oxygen in the exhaust system. An electronic circuit within the ECM

controls the pump current through the oxygen pumping cell in order to maintain a constant voltage in the oxygen sensing cell. The ECM monitors the voltage variation in the sensing cell and attempts to keep the voltage constant by increasing or decreasing the amount of current flow, or oxygen ion flow, to the pumping cell. By measuring the amount of current required to maintain the voltage in the sensing cell, the ECM can determine the concentration of oxygen in the exhaust. The HO₂S voltage is displayed as a lambda value. A lambda value of 1 is equal to a stoichiometric air fuel ratio of 14.7:1. Under normal operating conditions, the lambda value will remain around 1. When the fuel system is lean, the oxygen level will be high and the lambda signal will be high or more than 1. When the fuel system is rich, the oxygen level will be low, and the lambda signal will be low or less than 1. The ECM uses this information to maintain the correct air/fuel ratio. If the ECM detects that the HO₂S signal voltage is low, this DTC sets.

The heating elements inside each HO₂S heats the sensor to bring the sensor up to operating conditions faster. This allows the system to enter Closed Loop earlier and the control module to calculate the air-to-fuel ratio sooner.

SPEED LIMITING DESCRIPTION

A message will be displayed when the vehicle top speed has been limited to the speed indicated. The message will no longer display when the speed decreases below 5 kph (3 mph) of the indicated limited speed. The limited speed is a protection for various propulsion and vehicle systems, such as lubrication, thermal, suspension, Teen Driver, or tires.

The ECM takes the lowest value from the following list to determine the final vehicle speed limit. The vehicle speed is not limited when the vehicle is in Park or Neutral.

Functions that will limit the vehicle speed

- Tire Rating
- Prop-shaft/Transfer case speed rating
- Protection from reduced lubrication
- Electric motor speed rating
- Powertrain Thermal Protection
- Diesel Exhaust Fluid legislated limits
- Valet or Teen Driver Modes
- OnStar Stolen Vehicle Feature
- Commercial Truck / Rental Vehicle Speed Limits
- Powertrain control system faults
- Braking system faults
- Damping system faults
- Leveling system faults

System Components

Engine Control Module (ECM)

The engine control module monitors the inputs from various modules on the serial data to determine the final top speed limiting value by selecting the lowest requested top speed limit.

Body Control Module (BCM)

The body control module monitors the top speed limiting requests from serial data communication modules (listed below) along with internally set values (tire, propshaft, valet, and teen limits) to determine the lowest top speed limit and transmits the value to engine control module for final top speed limit determination.

Electronic Brake Control Module (EBCM)

The electronic brake control module (EBCM) monitors the brake system to determine if a speed limiting signal should be sent to the BCM.

Suspension and Damping System

The suspension and damping system monitors the active suspension to determine if a speed limiting signal should be sent to the BCM.

OnStar Enhanced Services

The OnStar Module communicates with OnStar to determine if a speed limiting signal should be sent to the ECM.

Automatic Leveling Control

The automatic leveling control monitors the leveling system to determine if a speed limiting signal should be sent to the BCM.

Integrated Chassis Control Module

The integrated chassis control module monitors chassis controls to determine if a speed limiting signal should be sent to the BCM.

Rear Driveline Control Module / Transfer Case Control Module

The rear driveline control module / transfer case control module monitors the rear driveline or transfer case to determine if a speed limiting signal should be sent to the BCM.

Hybrid Module

The hybrid module monitors the hybrid system to determine if a speed limiting signal should be sent to the ECM.

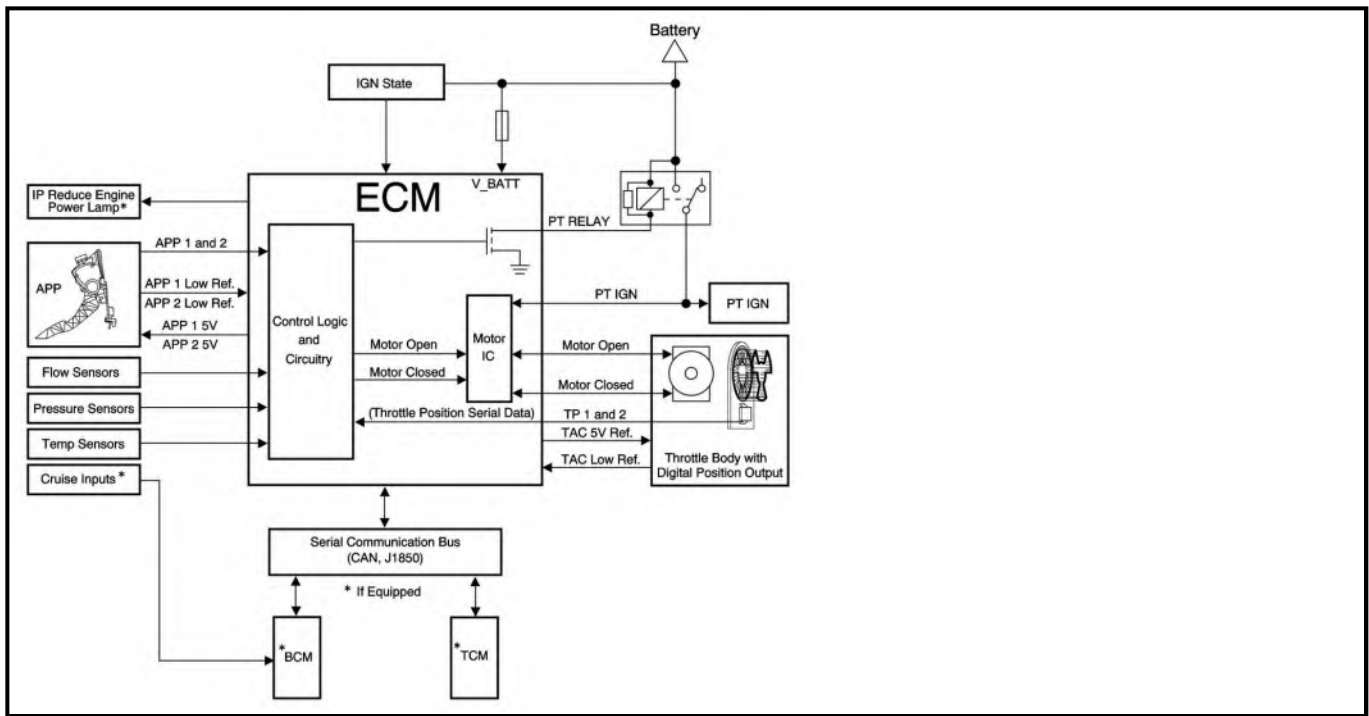
Transmission Control Module

The transmission control module monitors the transmission to determine if a speed limiting signal should be sent to the ECM.

Driver Information Center

The driver information center alerts the driver when the top vehicle speed is being limited.

THROTTLE ACTUATOR CONTROL (TAC) SYSTEM DESCRIPTION



The engine control module (ECM) is the control center for the throttle actuator control (TAC) system. The ECM determines the driver's intent based on input from the accelerator pedal position sensors, then calculates the appropriate throttle response based on the throttle position sensors. The ECM achieves throttle positioning by providing a pulse width modulated voltage to the throttle actuator motor. The throttle blade is spring loaded in both directions, and the default position is slightly open.

Modes Of Operation

Normal Mode

During the operation of the TAC system, several modes, or functions, are considered normal. The following modes may be entered during normal operations:

- Minimum pedal value - At key-up, the ECM updates the learned minimum pedal value.
- Minimum throttle position values - At key-up, the ECM updates the learned minimum throttle position value. In order to learn the minimum throttle position value, the throttle blade is moved to the closed position.
- Ice break mode - If the throttle blade is not able to reach a predetermined minimum throttle position, the ice break mode is entered. During the ice break mode, the ECM commands the maximum pulse width several times to the throttle actuator motor in the closing direction.
- Battery saver mode - After a predetermined time without engine speed, the ECM commands the battery saver mode. During the battery saver mode, the TAC module removes the voltage from the motor control circuits, which removes the current draw used to maintain the idle position and allows the throttle to return to the spring loaded default position.

Reduced Engine Power Mode

When the ECM detects a condition with the TAC system, the ECM may enter a reduced engine power mode. Reduced engine power may cause one or more of the following conditions:

- Acceleration limiting - The ECM will continue to use the accelerator pedal for throttle control, however, the vehicle acceleration is limited.
- Limited throttle mode - The ECM will continue to use the accelerator pedal for throttle control, however, the maximum throttle opening is limited.
- Throttle default mode - The ECM will turn OFF the throttle actuator motor, and the throttle will return to the spring loaded default position.

- Forced idle mode - The ECM will perform the actions listed below:
 - Limit engine speed to the idle position
 - Ignore the accelerator pedal input.

Engine Shutdown Mode

There are 4 reasons the ECM commands shutdown. All 4 reasons involve a throttle that has been commanded to default position - Reduced Engine Power. Default Throttle is latched for the key-cycle, disabling the throttle motor and letting the spring return the throttle to its default position. Default Throttle by itself does not cause a commanded shutdown. Shutdown will only occur with Default Throttle and another issue. A throttle is commanded to Default Throttle when any of the following occurs:

- SENT Sensor Communication Faults - P16A0 - P16A2, U0606, or U0607
- Performance Faults - P0068, P2101, or P2176
- Sensor Reference Voltage Fault - P06A3
- Analog Sensor Faults - (P0122 or P0123) & (P0222, or P0223), or P2135

The ECM commands engine shutdown when any of the following occurs:

- Default Throttle & Catalyst Temperature to high - In order to idle in Default Throttle the spark is often retarded quite a bit, dumping a lot of heat into the catalyst.
- Default Throttle & P2119 High - The throttle sensors detect that the throttle position is higher than default position and throttle hasn't safely returned to default position.
- Default Throttle & (P16F3 or P0606) - Calibration does not trust the ECM to determine if the throttle has safely returned to default position.
- P0068 and (Any SENT Communication Faults or Reference Voltage Fault, or any of the 5 Analog Sensor Faults) - MAF/MAP are detecting excess air flow based on expected default throttle position suggesting that we are at a throttle position higher than default. Also calibration does not trust the faulted throttle sensors to determine if the throttle has safely returned to default position.

Throttle/Idle Learn or Throttle Body Idle Air Flow Compensation Reset

The engine control module (ECM) learns the airflow through the throttle body to ensure the correct idle. The learned airflow values are stored within the ECM. These values are learned to adjust for production variation and will continuously learn during the life of the vehicle to compensate for reduced airflow due to throttle body coking. Anytime the throttle body airflow rate changes, for example due to cleaning or replacing, the values must be relearned.

An engine that had a heavily coked throttle body that has been cleaned or replaced may take several drive cycles to unlearn the coking. To accelerate the process, the scan tool has the ability to reset the learned value back to zero. A new ECM will also have values set to zero. Cleaning the throttle body when the ECM is replaced can reduce the time it takes for the ECM to relearn the minimum idle speed.

The idle may be unstable or a DTC may set if the learned values do not match the actual airflow.

A un-metered air leak in the induction system or a small vacuum leak may not set a DTC. If the condition goes undetected, the ECM may learn an incorrect Throttle Body Idle Airflow Compensation value over time. The incorrectly learned value may cause various symptoms to occur such as rough or unstable idle speeds, and/or engine stall. If this condition is detected and repaired it will be necessary to perform the Throttle/Idle Learn or Throttle Body Idle Air Flow Compensation Reset procedure to ensure any symptoms are corrected.
