

2014 ENGINE PERFORMANCE**Engine Controls and Fuel - 3.6L (LLT) - Description and Operation - Acadia, Enclave And Traverse****DESCRIPTION AND OPERATION****CAMSHAFT ACTUATOR SYSTEM DESCRIPTION**

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

- Engine power output
- Fuel economy
- Lower tailpipe emissions

The CMP actuator solenoid valve is controlled by the ECM. The crankshaft position (CKP) sensor and the CMP sensors are used to monitor changes in camshaft positions. The ECM uses the following information in order to calculate the desired camshaft positions:

- The engine speed
- The engine load
- The camshaft position (CMP) sensors
- The crankshaft position (CKP) sensor
- The manifold absolute pressure (MAP) sensor
- The throttle position (TP) sensors
- The barometric pressure (BARO)

Operation

The CMP actuator assembly has an outer housing that is driven by an engine timing chain. Inside the assembly is a rotor with fixed vanes that is attached to the camshaft. Oil pressure that is applied to the fixed vanes will rotate a specific camshaft in relationship to the crankshaft. The movement of the intake camshafts will advance the intake valve timing. The movement of the exhaust camshafts will retard the exhaust valve timing. When oil pressure is applied to the return side of the vanes, the camshafts will return to 0 crankshaft degrees or top dead center (TDC). The CMP actuator solenoid valve directs the oil flow that controls the camshaft movement. The ECM commands the CMP solenoid to move the solenoid plunger and spool valve until oil flows from the advance passage. Oil flowing through the CMP actuator assembly from the CMP solenoid advance passage applies pressure to the advance side of the vanes in the CMP actuator assembly. When the camshaft position is retarded, the CMP actuator solenoid valve directs oil to flow into the CMP actuator assembly from the retard passage. The ECM can also command the CMP actuator solenoid valve to stop oil flow from both passages in order to hold the current camshaft position.

The ECM operates the CMP actuator solenoid valve by pulse width modulation (PWM) of the solenoid coil. The higher the PWM duty cycle, the larger the change in camshaft timing. The CMP actuator assembly also contains a lock pin that prevents movement between the outer housing and the rotor vane assembly. The lock pin is released by oil pressure before any movement in the CMP actuator assembly takes place. The ECM is continuously comparing CMP sensor inputs with CKP sensor input in order to monitor camshaft position and detect any system malfunctions. If a condition exists in either the intake or exhaust camshaft actuator system, the opposite bank, intake or exhaust, camshaft actuator will default to 0 crankshaft degrees.

CMP Actuator System Operation

Driving Condition	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
Low to Medium RPM with Heavy Load	Advance Valve Timing	Advance Intake Valve Closing	Improve Low to Mid-range Torque
High RPM with Heavy Load	Retard Valve Timing	Retard Intake Valve Closing	Improve Engine Output

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 in the center of each camshaft cover with short integrated boots 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 primarily uses engine speed, the mass air flow (MAF) sensor signal and position information from the crankshaft position and the camshaft position sensors. This controls 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 engine control module (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 signals are a digital ON/OFF pulse and output 4 times per revolution of the camshaft. The camshaft position sensor does not directly affect the operation of the ignition system. The camshaft position sensor information is used by the engine control module (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 supplies the camshaft position sensor with a 5 V reference 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 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 control module 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 control module receives the knock sensor signal through the signal circuit. The knock sensor ground is supplied by the control module through the low reference circuit.

The control module 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 control module 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 control module 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 control module has determined that knock is present, it will retard the ignition timing to attempt to eliminate the knock. The control module 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 control module, 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 contains a solid state driver module as its primary element. The engine control module (ECM) signals the coil driver to initiate a firing event by applying ignition control (IC) circuit voltage for the appropriate amount of time otherwise known as dwell. When the voltage is removed the coil fires the spark plug.

Engine Control Module (ECM)

The engine control module (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) sensor
- Intake air temperature (IAT) sensor
- Vehicle speed sensor (VSS)
- Transmission gear position or range information sensors
- Engine knock sensors
- Ambient pressure sensor (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 (NO_x)
- 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 portable telephones and radios. Therefore, the first step in diagnosing any powertrain condition is to eliminate all of the aftermarket electrical equipment from the vehicle. After this is done, if the problem still exists, the problem may be diagnosed in the normal manner.

Electrostatic Discharge (ESD) Damage

NOTE: In order to prevent possible electrostatic discharge damage to the ECM, DO NOT touch the connector pins on the ECM.

The electronic components that are used in the control systems are often designed to carry very low voltage. These electronic components are susceptible to damage caused by electrostatic discharge. Less than 100 V of static electricity can cause damage to some electronic components. By comparison, it takes as much as 4,000 V for a person to even feel a static discharge.

There are several ways for a person to become statically charged. The most common methods of charging are by friction and by induction. An example of charging by friction is a person sliding across a car seat.

Charging by induction occurs when a person with well insulated shoes stands near a highly charged object and momentarily touches ground. Charges of the same polarity are drained off leaving the person highly charged with the opposite polarity. Static charges can cause damage, therefore, it is important to use care when handling and testing electronic components.

Emissions Control Information Label

The underhood Vehicle Emissions Control Information Label contains important emission specifications. This identifies the year, the displacement of the engine in liters and the class of the vehicle.

This label is located in the engine compartment of every General Motors vehicle. If the label has been removed, it can be ordered from GM service parts operations (GMSPO).

EVAPORATIVE EMISSION CONTROL SYSTEM DESCRIPTION

Typical Evaporative Emission (EVAP) System Hose Routing Diagram

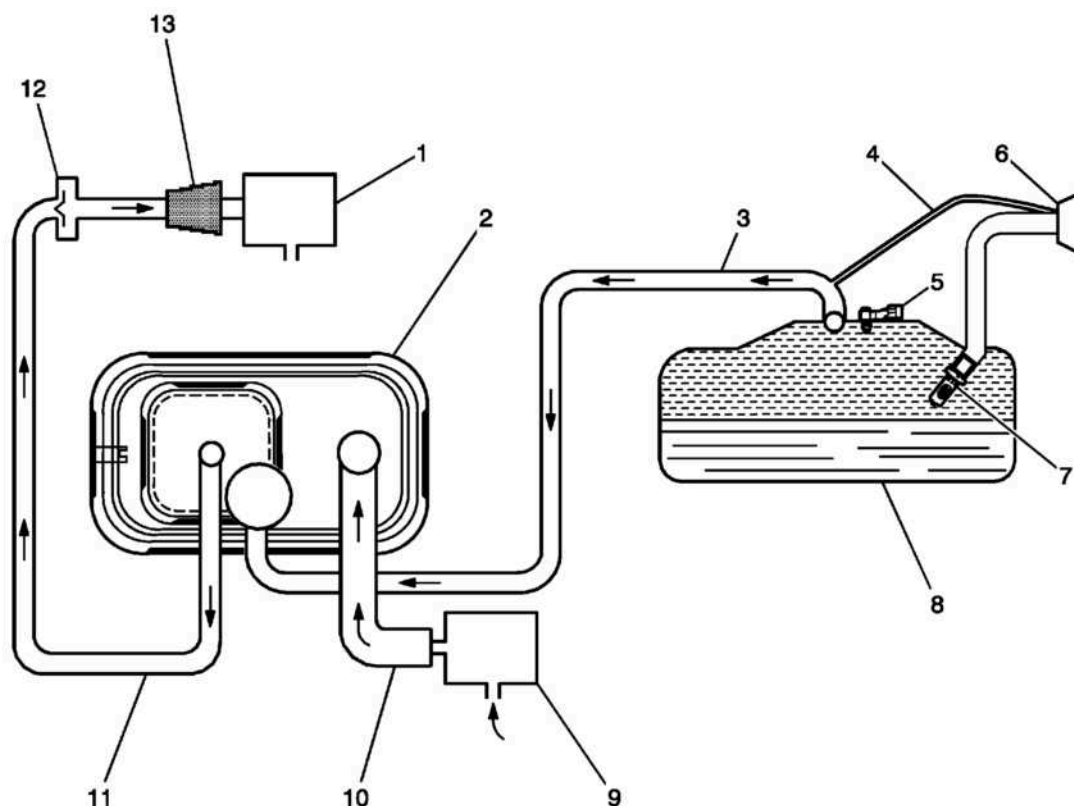


Fig. 1: View Of Evaporative Emission (EVAP) System Hose Routing Diagram
Courtesy of GENERAL MOTORS COMPANY

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

EVAP System Operation

The evaporative emission (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 (FTP) sensor for an increase in vacuum. The ECM will log a fault 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 FTP 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 log a fault 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 FTP 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

Turbocharged vehicles have a check valve in the purge tube between the EVAP purge solenoid valve and the EVAP canister to prevent pressurization of the EVAP system under boost conditions. Note that the presence of this one-way check valve prevents pressure testing the EVAP system for leaks at the EVAP canister purge tube connector.

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.

Fuel Tank Pressure Sensor

The FTP sensor measures the difference between the pressure or vacuum in the fuel tank and outside air pressure. The ECM provides a 5 V reference and a ground to the FTP sensor. 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. The FTP sensor provides a signal voltage back to the ECM that can vary between 0.1-4.9 V. A high FTP sensor voltage indicates a low fuel tank pressure or vacuum. A low FTP 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.

Fuel Fill Cap

The fuel fill cap is equipped with a seal and a vacuum relief valve.

Capless Fuel Fill

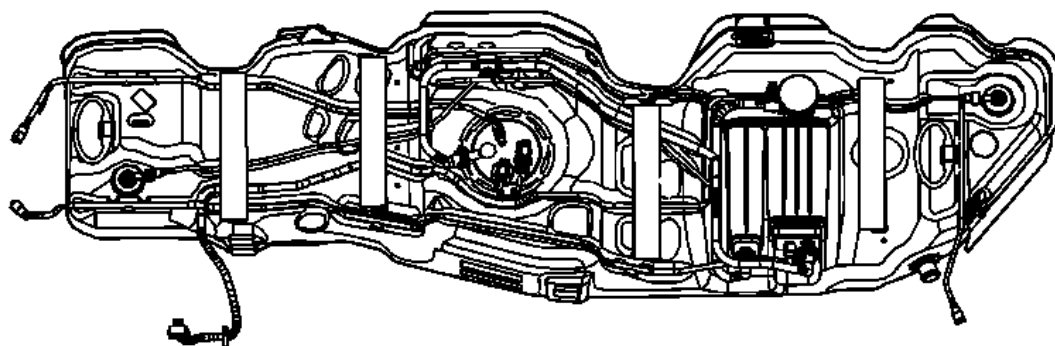
Some vehicles may have a capless fuel fill design behind a locking fuel door. There is no fuel fill cap to remove. One just fully inserts the fuel nozzle into the fill neck, making sure it latches before refueling. Flapper valves close to seal this interface once the fill nozzle is removed.

FUEL SYSTEM DESCRIPTION

Fuel System Overview

The fuel tank stores the fuel supply. The fuel pump module, located in the fuel tank, 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 in-tank fuel pump is controlled with a fuel pump control module (FPCM). The engine control module (ECM) enables the FPCM and sends the desired fuel line pressure to the FPCM via GMLAN. The FPCM sends a pulse width modulated (PWM) voltage to the in-tank fuel pump allowing the fuel line pressure to be varied as commanded by the ECM. The high pressure fuel pump, fuel rail pressure, fuel injection timing and injection duration are controlled by the ECM.

Fuel Tank

**Fig. 2: Identifying Fuel Tank**

Courtesy of GENERAL MOTORS COMPANY

The fuel storage tank is made of high density polyethylene. The fuel storage tank is held in place by metal straps that are attached to the under body of the vehicle. The tank shape includes a sump in order to maintain a constant supply of fuel around the fuel pump strainer during low fuel conditions or during aggressive maneuvers.

On-Board Refueling Vapor Recovery (ORVR) System

The on-board refueling vapor recovery (ORVR) system is an on-board vehicle system to recover fuel vapors during the vehicle refueling operation. The flow of liquid fuel down to the fuel tank filler neck provides a liquid seal. The purpose of ORVR is to prevent refueling vapor from exiting the fuel tank filler neck. The ORVR components are listed below, with a brief description of their operation:

- The fuel tank-The fuel tank contains the modular fuel sender assembly.
- The fuel filler pipe-The fuel filler pipe carries fuel from the fuel nozzle to the fuel tank.
- The evaporative emission (EVAP) canister-The EVAP canister receives refueling vapor from the fuel system, stores the vapor and releases the vapor to the engine upon demand.
- The vapor lines-The vapor lines transport fuel vapor from the tank assembly to the EVAP canister and engine.
- The check valve-The check valve limits fuel spit-back from the fuel tank during the refueling operation by allowing fuel flow only into the fuel tank. The check valve is located at the bottom of the fuel filler pipe.

- The modular fuel sender assembly-The modular fuel sender assembly pumps fuel to the engine from the fuel tank.
- The fuel tank pressure (FTP) sensor is located on top of the fuel sender assembly.
- The FLVV-The FLVV acts as a shut-off valve. The FLVV is located in the fuel sender assembly. This valve has the following functions:
 - Controlling the fuel tank fill level by closing the primary vent from the fuel tank
 - Preventing fuel from exiting the fuel tank via the vapor line to the canister
 - Providing fuel spillage protection in the event of a vehicle rollover by closing the vapor path from the tank to the engine
- The pressure vacuum relief valve-The pressure vacuum relief valve provides venting of excessive fuel tank pressure and vacuum. The valve is located in the fuel fill cap.
- The vapor recirculation line-The vapor recirculation line is used to transport vapor from the fuel tank to the top of the fill pipe during refueling to reduce vapor loading to the enhanced EVAP canister.

Fuel Tank Filler Pipe

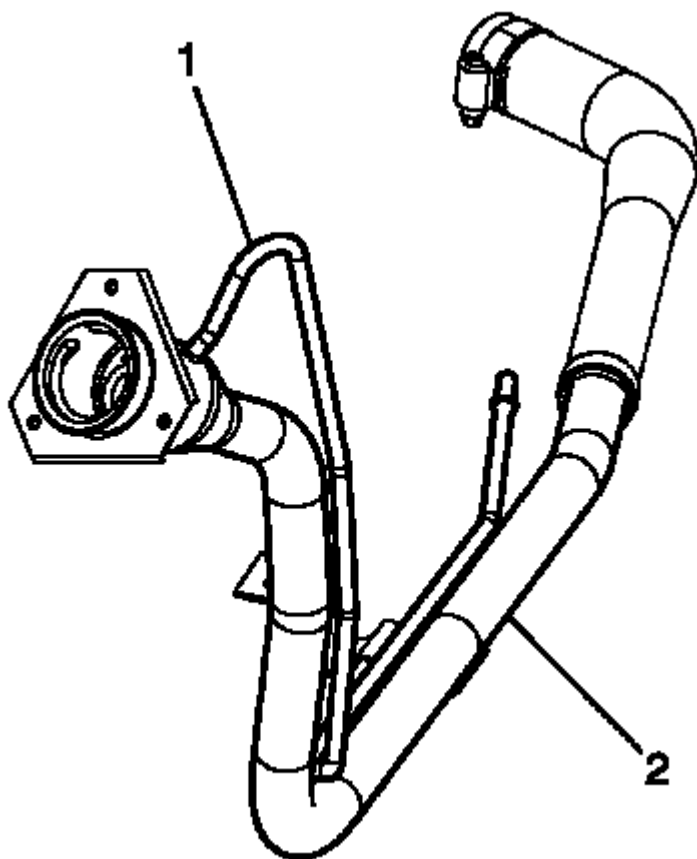


Fig. 3: Identifying Fuel Fill Pipe
Courtesy of GENERAL MOTORS COMPANY

In order to prevent refueling with leaded fuel, the fuel filler pipe has a built-in restrictor and a deflector. The opening in the restrictor will accept only the smaller unleaded gasoline fuel nozzle which must be fully inserted in order to bypass the deflector. The tank is vented during filling by an internal vent tube inside of the filler pipe.

Fuel Filler Cap

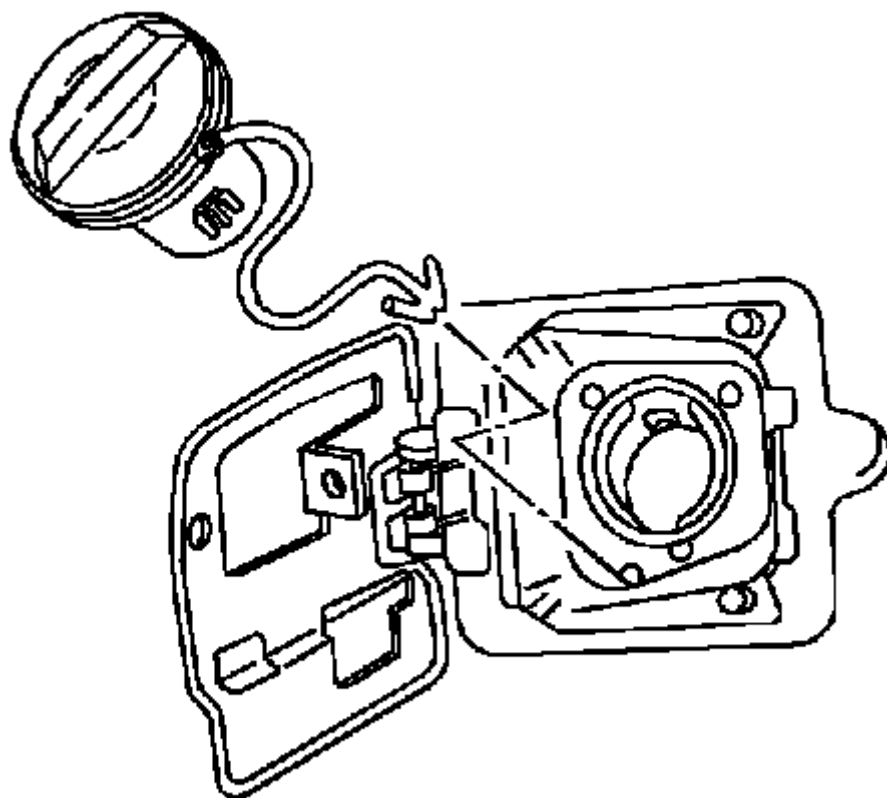


Fig. 4: View Of Fuel Filler Cap & Tether

Courtesy of GENERAL MOTORS COMPANY

CAUTION: Use a fuel tank filler pipe cap with the same features as the original when a replacement is necessary. Failure to use the correct fuel tank filler pipe cap can result in a serious malfunction of the fuel system.

The fuel tank filler pipe is equipped with a turn to vent, screw on type cap, which incorporates a ratchet action in order to prevent over-tightening.

The turn to vent feature allows for fuel tank pressure relief prior to removal. Instructions for proper use are imprinted on the cap cover. A vacuum safety relief valve is incorporated into this cap.

Fuel Sender Assembly

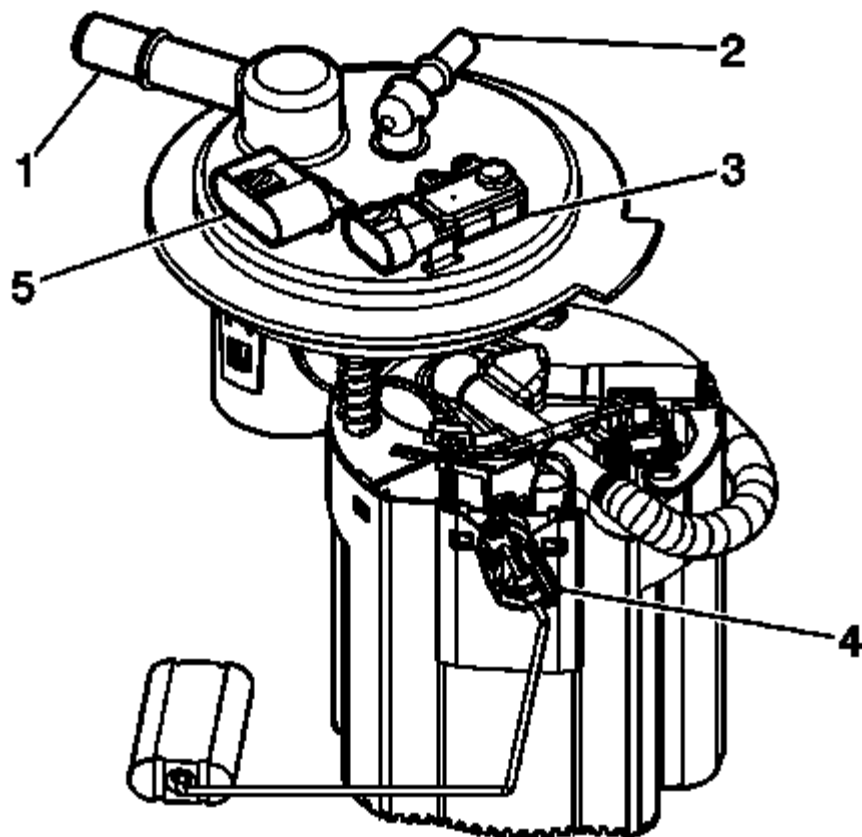


Fig. 5: View Of Fuel Sender Assembly
 Courtesy of GENERAL MOTORS COMPANY

The fuel sender assembly consists of the following major components:

- The fill limit vent valve (1)
- The fuel feed pipe (2)
- The fuel tank pressure sensor (3)
- The fuel level sensor (4)
- The fuel pump electrical connector (5)

The modular fuel sender assembly mounts to the threaded opening of the plastic fuel tank with a seal and a retainer ring. The reservoir, containing the exterior inlet strainer, the electric fuel pump and the fuel filter, maintains contact with the tank bottom. This design provides:

- Optimum fuel level in the integral fuel reservoir during all fuel tank levels and during driving conditions
- An improved tank fuel level measuring accuracy
- An improved coarse straining and added pump inlet filtering
- More extensive internal fuel pump isolation for noiseless operation

Fuel Pump

The electric fuel pump is a turbine pump which is located inside of the modular fuel sender. The electric fuel pump operation is controlled by the fuel pump control module (FPCM).

Fuel Sender Strainer

The strainer acts as a coarse filter to perform the following functions:

- Filter contaminants
- Separate water from fuel
- Provide a wicking action that helps draw fuel into the fuel pump

Fuel stoppage at the strainer indicates that the fuel tank contains an abnormal amount of sediment or water. Therefore, the fuel tank will need to be removed and cleaned and the filter strainer should be replaced.

Fuel Feed Hose/Pipe

The fuel feed pipe carries fuel from the fuel tank to the fuel rail assembly. The fuel pipes consist of 2 sections:

- The rear fuel pipe assembly connects from the top of the fuel tank module to the chassis fuel pipe. The rear fuel pipe is constructed of nylon.
- The chassis fuel hose/pipe is located under the vehicle and connects the rear fuel hose/pipe to the fuel inlet pipe at the high pressure fuel pump. The chassis fuel hose/pipe is constructed of steel and braided Teleflex® hose.

CAUTION: Refer to Fuel and Evaporative Emission Hose/Pipe Connection Cleaning Caution .

NOTE: **Precautions must be taken to prevent any form of contamination, that may cause the check valve to stick open, when servicing the fuel system. Particles in the fuel system larger than 75 microns may cause a condition.**

The flexible portion of the chassis fuel hose/pipe contains a check flow valve. The check valve does not hold pressure. It is designed to reduce the pressure pulsations going back to the in-tank fuel pump from the high pressure fuel pump. It is also designed to bleed off pressure from the high pressure fuel pump to the chassis fuel pipe during a hot soak.

Fuel Pump Flow Control Module (FPCM)

The fuel pump flow control module (FPCM) is a serviceable GMLAN module. The FPCM 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 FPCM sends a PWM signal to the fuel pump and pump speed is changed by varying the duty cycle of this signal.

Liquid Fuel Pressure Sensor

The fuel pressure sensor is a serviceable 5-volt, 3-pin device. It is located on the fuel feed line forward of the fuel tank and receives power and ground from the fuel pump flow control module (FPCM) through a vehicle wiring harness. The sensor provides a fuel pressure signal to the FPCM, which is used to aid Closed Loop fuel pressure control.

Fuel Filter

The fuel filter is contained in the fuel sender assembly inside the fuel tank. The paper filter element of the fuel filter traps particles in the fuel that may damage the fuel injection system. There is no service interval for fuel filter replacement.

EVAP Lines and Hoses

The EVAP line extends from the fuel tank vent valve to the EVAP canister and into the engine compartment. The EVAP line is made of nylon and connects to the EVAP canister with a quick connect fitting.

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 flow control module defaulting to 100 percent pulse width modulation (PWM) of the fuel pump. Due to variation in 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.

High Pressure Fuel Pump

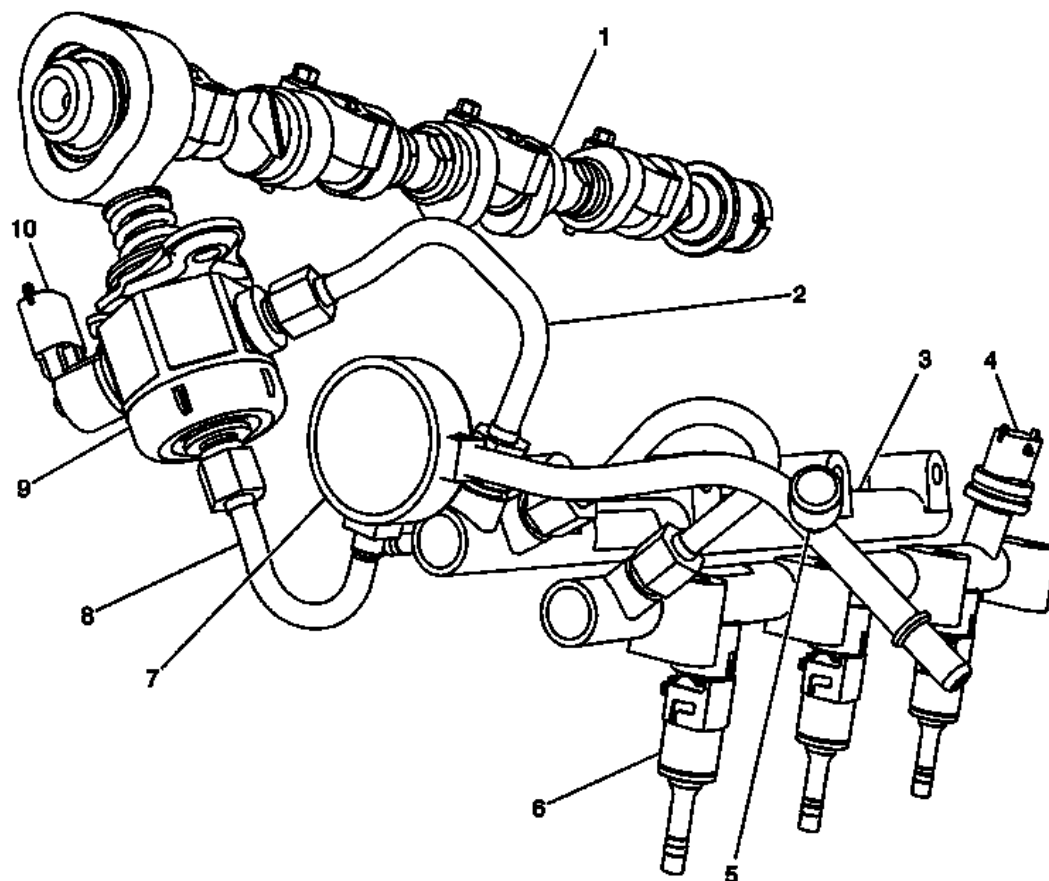


Fig. 6: Identifying High Pressure Fuel Pump Components
Courtesy of GENERAL MOTORS COMPANY

The high pressure fuel pump (9) is a mechanical one cylinder design driven by an eccentric on the exhaust camshaft (1) of bank 2. High pressure fuel is regulated by the high pressure fuel pump actuator, which is a part of the high pressure fuel pump. The high pressure fuel pump actuator is a magnetic actuator which controls the inlet valve of the high pressure pump. The ECM provides battery voltage on the actuator high control circuit and ground on the actuator low control circuit. Both circuits are controlled by the ECM. When the ECM deactivates the high pressure fuel pump actuator, both circuits are disabled and the inlet valve is held open with spring pressure. When the ECM activates the high pressure fuel pump actuator, the low control circuit driver connects the low control circuit to ground and the high control circuit driver pulse-width modulates (PWM) the high control circuit. The ECM uses the camshaft and crankshaft position sensor inputs to synchronize the high pressure fuel pump actuator with the position of the eccentric on the camshaft. The ECM regulates fuel pressure by adjusting the portion of each pump stroke that provides fuel to the rail. The high pressure fuel pump also contains an integrated pressure relief valve.

Fuel Rail Fuel Pressure Sensor

The fuel rail pressure sensor (4) detects fuel pressure within the fuel rail. The engine control module (ECM)

provides a 5 volt reference voltage on the 5 volt reference circuit and ground on the low reference circuit. The ECM receives a varying signal voltage on the signal circuit. The ECM monitors the voltage on the FRP 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 Rail Assembly

The fuel rail assembly (3) attaches to each cylinder head. The fuel rail distributes high pressure fuel to the fuel injectors. The fuel rail assembly consists of the following components:

- Six fuel injectors
- A fuel rail pressure (FRP) sensor

Fuel Injectors

The fuel injection system is a high pressure, direct injection, returnless on-demand design. The fuel injectors (6) 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 separate 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 volts. This is controlled by a boost capacitor in the ECM. During the 65 volt boost phase, the capacitor is discharged through an injector, allowing for initial injector opening. The injector is then held open with 12 volts.

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.

The fuel injectors will cause various driveability conditions if the following conditions occur:

- If the injectors will not open
- If the injectors are stuck open
- If the injectors are leaking
- If the injectors have a low coil resistance

Engine Fueling

The engine is fueled by six individual injectors, one for each cylinder, that are controlled by the ECM. The ECM controls each injector by energizing the injector coil for a brief period once every other engine revolution. The length of this brief period or pulse, is carefully calculated by the ECM to deliver the correct amount of fuel for proper driveability and emissions control. The period of time when the injector is energized is called the pulse width and is measured in milliseconds, thousandths of a second.

While the engine is running, the ECM is constantly monitoring the inputs and recalculating the appropriate

pulse width for each injector. The pulse width calculation is based on the injector flow rate, mass of fuel the energized injector will pass per unit of time, the desired air/fuel ratio and actual air mass in each cylinder and is adjusted for battery voltage, short term and long term fuel trim. The calculated pulse is timed to occur as each cylinders intake valves are closing to attain largest duration and most vaporization.

Fueling during a crank is slightly different than fueling during an engine run. As the engine begins to turn, a prime pulse may be injected to speed starting. As soon as the ECM can determine where in the firing order the engine is, the ECM begins pulsing the injectors. The pulse width during the crank is based on the coolant temperature and the engine load.

The fueling system has several automatic adjustments in order to compensate for the differences in the fuel system hardware, the driving conditions, the fuel used and the engine aging. The basis for the fuel control is the pulse width calculation that is described above. Included in this calculation are an adjustment for the battery voltage, the short term fuel trim and the long term fuel trim. The battery voltage adjustment is necessary since the changes in the voltage across the injector affect the injector flow rate. The short term and the long term fuel trims are fine and coarse adjustments to the pulse width that are designed in order to maximize the driveability and emissions control. These fuel trims are based on the feedback from the oxygen sensors in the exhaust stream and are only used when the fuel control system is in a Closed Loop operation.

Under certain conditions, the fueling system will turn OFF the injectors for a period of time. This is referred to as fuel shut-off. Fuel shut-off is used in order to improve traction, save fuel, improve emissions and protect the vehicle under certain extreme or abusive conditions.

In case of a major internal problem, the ECM may be able to use a back-up fuel strategy for limp in mode that will run the engine until service can be performed.

Sequential Fuel Injection (SFI)

The ECM controls the fuel injectors based on information that the ECM receives from several information sensors. Each injector is fired individually in the engine firing order, which is called sequential fuel injection. This allows precise fuel metering to each cylinder and improves the driveability under all of the driving conditions.

The ECM has several operating modes for fuel control, depending on the information that has been received from the sensors.

Starting Mode

When the ECM detects reference pulses from the CKP sensor, the ECM will enable the fuel pump. The fuel pump runs and builds up pressure in the fuel system. The ECM then monitors the MAF, IAT, engine coolant temperature (ECT) and the throttle position (TP) sensor signal in order to determine the required injector pulse width for starting.

Clear Flood Mode

If the engine is flooded with fuel during starting and will not start, the Clear Flood Mode can be manually selected. To select Clear Flood Mode, push the accelerator to wide open throttle (WOT). With this signal, the

ECM will completely turn OFF the injectors and will maintain this stage as long as the ECM indicates a WOT condition with engine speed below 1,000 RPM.

Run Mode

The Run Mode has 2 conditions: Open Loop operation and Closed Loop operation. When the engine is first started and the engine speed is above 480 RPM, the system goes into Open Loop operation. In Open Loop operation, the ECM ignores the signals from the oxygen sensors and calculates the required injector pulse width based primarily on inputs from the MAF, IAT and ECT sensors.

In Closed Loop, the ECM adjusts the calculated injector pulse width for each bank of injectors based on the signals from each oxygen sensor.

Acceleration Mode

The ECM monitors the changes in the TP and the MAF sensor signals in order to determine when the vehicle is being accelerated. The ECM will then increase the injector pulse width in order to provide more fuel for improved performance.

Deceleration Mode

The ECM monitors changes in TP and MAF sensor signals to determine when the vehicle is being decelerated. The ECM will then decrease injector pulse width or even shut OFF injectors for short periods to reduce exhaust emissions and for better (engine braking) deceleration.

Battery Voltage Correction Mode

The ECM can compensate in order to maintain acceptable vehicle driveability when the ECM sees a low battery voltage condition. The ECM compensates by performing the following functions:

- Increasing the injector pulse width in order to maintain the proper amount of fuel being delivered
- Increasing the idle speed to increase the generator output

Fuel Shut-Off Mode

The ECM has the ability to completely turn OFF all of the injectors or selectively turn OFF some of the injectors when certain conditions are met. These fuel shut-off modes allow the ECM to protect the engine from damage and also to improve the vehicles driveability.

The ECM will disable all of the six injectors under the following conditions:

- Ignition OFF-Prevents engine run-on
- Ignition ON but no CKP signal-Prevents flooding or backfiring
- A high engine speed-Above the red line
- A high vehicle speed-Above the rated tire speed
- Closed throttle coast down-Reduces the emissions and increases engine braking.

The ECM will selectively disable the injectors under the following conditions:

- The torque management enabled-Transmission shifts or abusive maneuvers.
- The traction control enabled-In conjunction with the front brakes applying

THROTTLE ACTUATOR CONTROL (TAC) SYSTEM DESCRIPTION

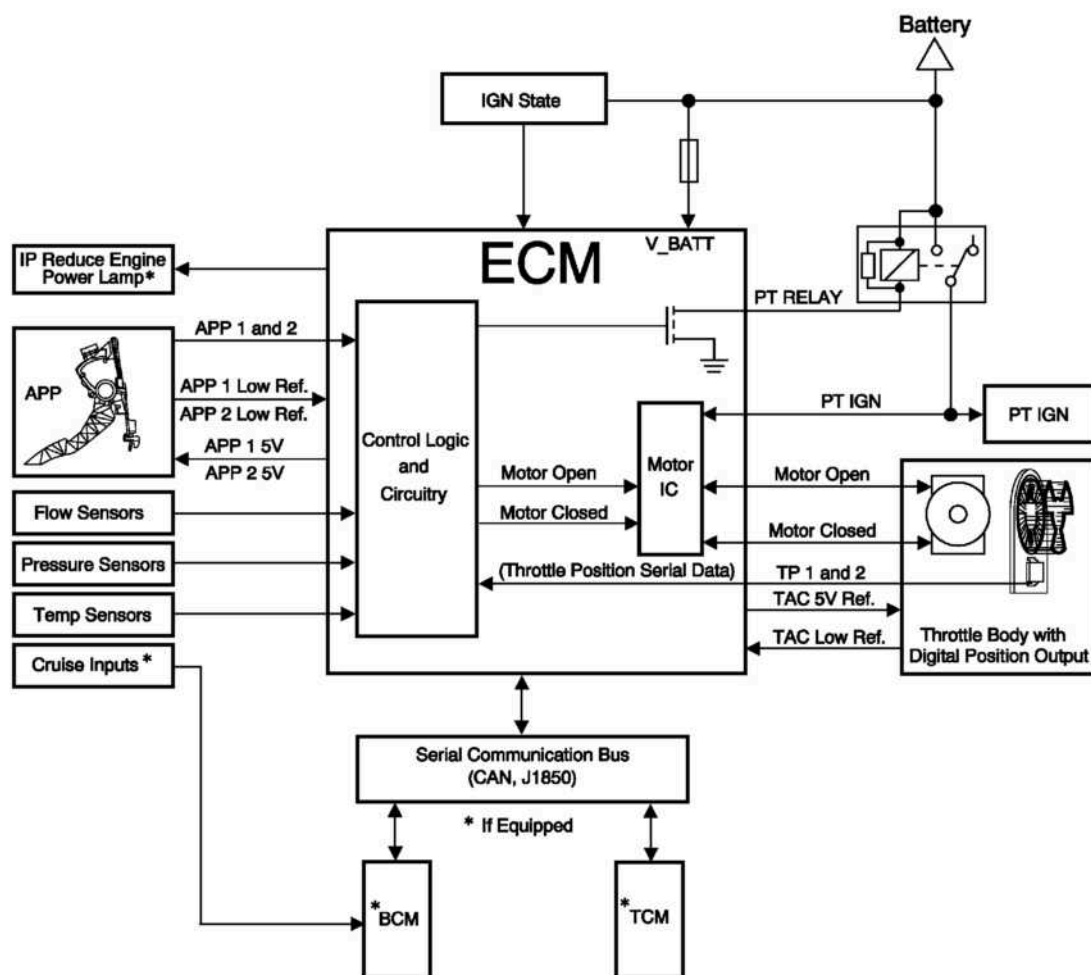


Fig. 7: Throttle Actuator Control (TAC) System Diagram
Courtesy of GENERAL MOTORS COMPANY

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 following actions:
 - Limit engine speed to the idle position
 - Ignore the accelerator pedal input.
- Engine shutdown mode-The ECM will disable fuel and de-energize the throttle actuator.