

2010 ENGINE PERFORMANCE

Engine Controls and Fuel - 2.8L, 3.0L, 3.2L, or 3.6L - Equinox & Terrain

DESCRIPTION AND OPERATION

AIR INTAKE SYSTEM DESCRIPTION (W/LF1)

The mass air flow (MAF) sensor measures the amount of air coming into the engine. This direct airflow measurement is more accurate than the calculated airflow information obtained from the other sensor inputs. The MAF sensor also houses an integrated intake air temperature (IAT) sensor. The MAF sensor uses the following circuits:

- An ignition voltage circuit
- A signal circuit
- A ground circuit
- An IAT signal circuit
- An IAT low reference circuit

The MAF sensor that is used on this vehicle is a hot film type and is used in order to measure the air flow rate. The air flow through the sensor passes over a temperature sensor, is then heated, and then passes over another temperature sensor. The difference in air temperature before and after the heater is measured. The air temperature difference is proportional to the amount of air flow. This air temperature difference also allow for determination of whether the air is flowing in the forward or reverse directions. As the air flow increases the delta temperature between the two sensors increases. The MAF sensor converts the temperature difference into a frequency signal that the engine control module (ECM) monitors. The ECM calculates the air flow based on this signal.

The ECM monitors the MAF sensor signal frequency and can determine if the sensor signal is too low or too high. The ECM can also detect airflow that is inappropriate for a given operating condition based on the signal frequency.

The scan tool displays the MAF sensor value in grams per second (g/s) and hertz (Hz). Values should change rather quickly on acceleration, but should remain fairly stable at any given engine speed. If the ECM detects a condition with the MAF sensor circuits, the following DTCs set:

- P0101 Mass Air Flow (MAF) Sensor Performance
- P0102 Mass Air Flow (MAF) Sensor Circuit Low Voltage
- P0103 Mass Air Flow (MAF) Sensor Circuit High Voltage

CAMSHAFT ACTUATOR SYSTEM DESCRIPTION

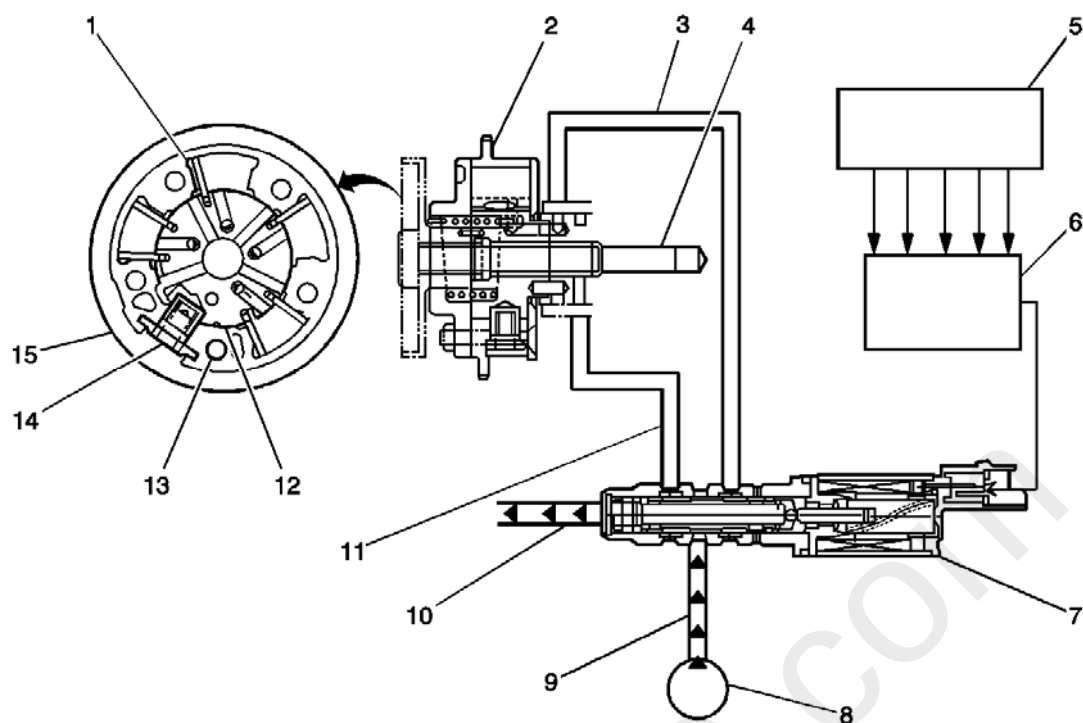


Fig. 1: Camshaft Actuator System Components
Courtesy of GENERAL MOTORS CORP.

Callout	Component Name
1	Camshaft Actuator Vane
2	Timing Chain Sprocket
3	Engine Oil Pressure-For retarding the camshaft
4	Camshaft
5	Input Signals from Engine Sensors
6	Engine Control Module (ECM)
7	Camshaft Actuator Solenoid
8	Engine Oil Pump
9	Engine Oil Pressure Supply
10	Engine Oil Drain
11	Engine Oil Pressure-For advancing the camshaft
12	Camshaft Actuator Rotor
13	Camshaft Position Sensor Reluctor
14	Camshaft Actuator Lock Pin
15	Camshaft Actuator Housing

The camshaft actuator system enables the engine control module (ECM) to change camshaft timing of all 4 camshafts while the engine is operating. The CMP actuator assembly (15) 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 (7) 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 coolant temperature (ECT) sensor
- The calculated engine oil temperature (EOT)
- The mass air flow (MAF) sensor
- The throttle position (TP) sensor
- The vehicle speed sensor (VSS)
- The volumetric efficiency

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 (11). Oil flowing thru 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 (3). 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 (14) 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 (EI) 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 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 EI system consists of the following components:

Crankshaft Position Sensor

The crankshaft position sensor works in conjunction with a 58 tooth reluctor wheel on the crankshaft. 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. The reluctor wheel teeth are 6 degrees apart. Having only 58 teeth leaves a 12 degree span that is uncut. 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.

Camshaft Position Sensor

This engine uses camshaft position sensor for each camshaft. The camshaft position sensor signals are a digital ON/OFF pulse, 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.

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 one 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 are dependant 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 time, or 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:

- The throttle position sensor
- The engine coolant temperature (ECT) sensor
- The mass air flow (MAF) sensor
- The intake air temperature (IAT) sensor
- The vehicle speed sensor (VSS)
- The transmission gear position or range information sensors
- The engine knock sensors
- Ambient pressure sensor (BARO)

Noteworthy Ignition Information

The cylinder 1 intake camshaft position sensor is used for injector and ignition system synchronization. A stalling condition will occur if the CMP sensor signal is intermittent and a DTC will not set. Inspect all cylinder

1 intake camshaft position sensor circuits for poor connections.

ENGINE CONTROL MODULE DESCRIPTION

The engine control module (ECM) interacts with many emission related components and systems, and monitors the 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 malfunction indicator lamp (MIL) operation and the 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 in the engine compartment. The ECM is the control center of the engine controls system. The ECM controls the following components:

- The fuel injection system
- The ignition system
- The emission control systems
- The on-board diagnostics
- The A/C and fan systems
- The throttle actuation control (TAC) system

The ECM constantly monitors the information from various sensors and other inputs, and controls the systems that affect the vehicle performance and the emissions. The ECM also performs diagnostic tests on various parts of the system. The ECM can recognize operational problems and alert the driver via the MIL. 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 engine control module (ECM) can supply 5 V or 12 V to the various sensors or switches. This is done through pull-up resistors to the regulated power supplies within the ECM. In some cases, even an ordinary shop voltmeter will not give an accurate reading because the resistance is too low. Therefore, a DMM with at least 10 Mohms 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 the transistors or a device called an output driver module.

EEPROM

The electronically erasable programmable read only memory (EEPROM) is a permanent memory that is physically part of the engine control module (ECM). The EEPROM contains program and calibration information that the ECM needs in order to control the powertrain 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) is a 16-pin connector that provides the technician a means of accessing serial data for aid in the diagnosis. This connector allows the technician to use a scan tool in order to monitor the various serial data parameters, and display the DTC information. The DLC is located inside of the drivers compartment, underneath the dash.

Malfunction Indicator Lamp (MIL)

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

ECM Service Precautions

The engine control module (ECM), by design, can withstand the normal current draws that are associated with the 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.

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 vehicles on-board diagnostic system (ECM) detect a condition that could result in excessive emissions, the ECM turns ON the malfunction indicator lamp (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 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 vehicles 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 engine control module (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. The electronic components are susceptible to damage caused by electrostatic discharge. Less than 100 V of static electricity can cause damage to some electronic components.

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 and setting procedures. In the upper right corner is the exhaust emission information. This identifies the year, the manufacturing division of the engine, the displacement of the engine in liters, the class of the vehicle, and type of fuel metering system. There is also an illustrated emission components and vacuum hose schematic.

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).

Underhood Inspection

NOTE: **This inspection is very important and must be done carefully and thoroughly.**

Perform a careful underhood inspection when performing any diagnostic procedure or diagnosing the cause of an emission test failure. This can often lead to repairing a condition without further steps. Use the following guidelines when performing an inspection:

- Inspect all of the vacuum hoses for correct routing, pinches, cuts, or disconnects.
- Inspect any hoses that are difficult to see.
- Inspect all of the wires in the engine compartment for the following conditions:
 - Burned or chafed spots
 - Pinched wires

- Contact with sharp edges
- Contact with hot exhaust manifolds

EVAPORATIVE EMISSION CONTROL SYSTEM DESCRIPTION

Typical Evaporative Emission (EVAP) System Hose Routing Diagram

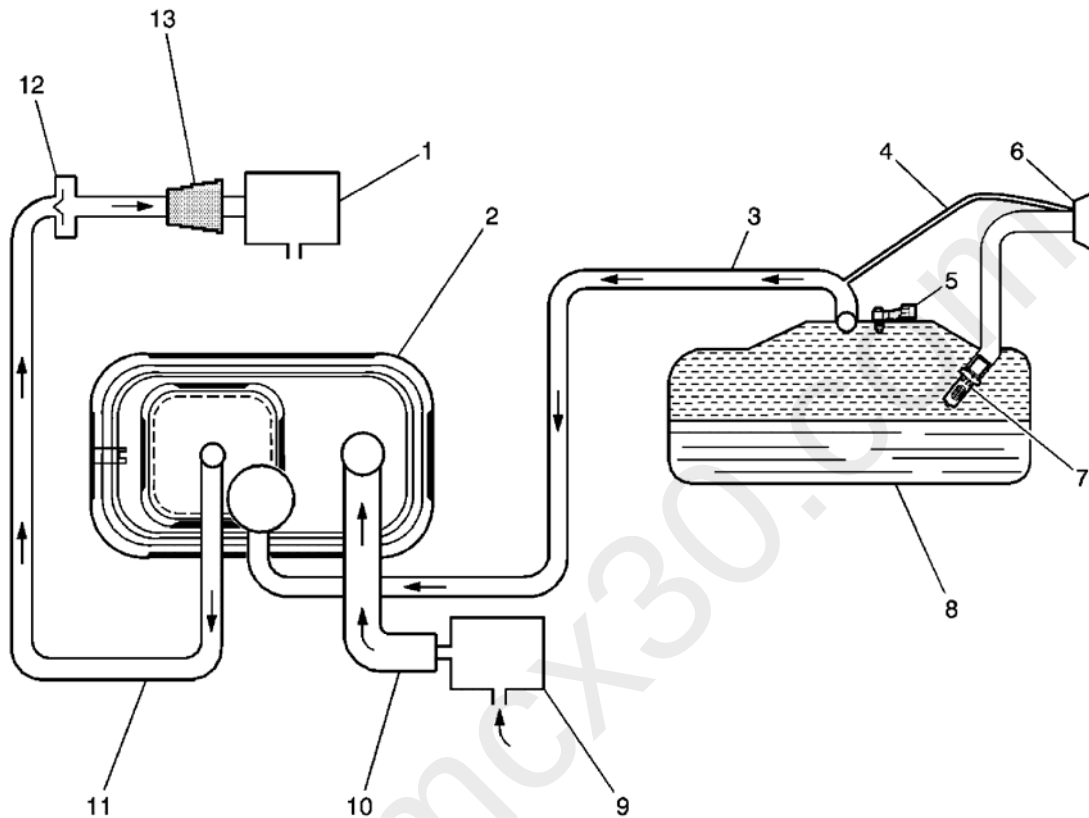


Fig. 2: Typical Evaporative Emission System Hose Routing Diagram
 Courtesy of GENERAL MOTORS CORP.

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
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
13	EVAP Canister Purge Tube Connector

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 canister 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 canister 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 control module uses several tests to determine if the EVAP system is leaking or restricted.

Purge Solenoid Valve Leak Test

If the evaporative emission (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 canister 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 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 control module commands the normally open EVAP canister 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 log a fault if it detects a weaker than expected vacuum level under these test conditions.

Canister Vent Restriction Test

If the evaporative emission (EVAP) vent system is restricted, fuel vapors will not be properly purged from the EVAP canister. The control module tests this by commanding the EVAP purge solenoid valve ON while commanding the EVAP canister 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 evaporative emission

(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 control module to remain active for up to 40 minutes 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 evaporative emission (EVAP) system consists of the following components:

EVAP Canister Purge Solenoid Valve

The EVAP canister 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 control module. This normally closed valve is pulse width modulated (PWM) by the control module 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 control module 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 the either end of the system.

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. The control module provides a 5 V reference and a ground to the fuel tank pressure 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 fuel tank pressure sensor provides a signal voltage back to the control module that can vary between 0.1-4.9 V. 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 Canister 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.

FUEL SYSTEM DESCRIPTION (LF1)

Fuel System Overview

The fuel system is an electronic returnless on-demand design. A 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 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. A 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 flow control module via a GMLAN serial data message. A liquid fuel pressure sensor provides the feedback the fuel pump flow control module requires for Closed Loop fuel pressure control.

Fuel Pump Flow Control Module

The fuel pump flow control module is a serviceable GMLAN module. The fuel pump flow 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 flow 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 liquid fuel pressure sensor provides fuel pressure feedback to the fuel pump flow control module.

Fuel Pressure Sensor

The fuel pressure sensor is a serviceable 5V, 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 through a vehicle wiring harness. The sensor provides a fuel pressure signal to the fuel pump flow control module, 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.

Fuel Fill Pipe

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

Fuel Filler Cap

The fuel fill pipe has a tethered fuel filler cap. A torque-limiting device prevents the cap from being over-tightened. To install the cap, turn the cap clockwise until you hear audible clicks. This indicates that the cap is correctly torqued and fully seated.

Fuel Pump Module

An electric turbine style fuel pump attaches to the fuel pump module inside the fuel tank. The fuel pump supplies fuel through the fuel feed pipe to the high pressure fuel pump. The 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.

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. The engine control module (ECM) sends the fuel level information via the High Speed CAN-Bus to the body control module (BCM). The BCM then sends the fuel level percentage via the Low Speed CAN-Bus to the instrument cluster in order to control the fuel gauge.

Fuel Pump

The fuel pump is mounted in the fuel pump module reservoir. The fuel pump is an electric pump. Fuel is pumped to the high pressure fuel pump at a pressure that is based on feedback from the 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 flow control module defaulting to 100 percent 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.

Fuel Feed Pipes

The low pressure fuel feed pipe carries fuel from the fuel tank to the high pressure fuel pump.

The fuel feed pipe assembly located in the engine compartment connects the chassis fuel pipe to the high pressure fuel pump. This pipe contains the fuel pulse dampener and the fuel pressure service valve, and is constructed of stainless steel.

The fuel feed intermediate pipe is a high pressure pipe that carries fuel from the high pressure fuel pump to the fuel rail. The fuel feed intermediate pipe is constructed of stainless steel.

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 115°C (239°F) for more than one hour, or more than 90°C (194°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 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.

High Pressure Fuel Pump

The high pressure fuel pump is a mechanical one-cylinder design driven by an additional three lobe cam on the camshaft. 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 fuel pump. The ECM provides battery voltage on the actuator high control circuit and ground on the actuator low control circuit. Both circuits are controlled through output drivers within the ECM. When deactivated, both drivers are disabled and the inlet valve is held open with spring pressure. When activated, the actuator low control circuit driver connects the low control circuit to ground, and the actuator high control circuit driver pulse-width modulates the high control circuit. The ECM uses the camshaft and the crankshaft position sensor inputs to synchronize the actuator with the position of each of the three camshaft lobes. 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 Assembly

The fuel rail assembly attaches to the cylinder head. The fuel rail distributes 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 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 65V. This is controlled by a boost capacitor in the ECM. During the 65V boost phase, the capacitor is discharged through an injector, allowing for initial injector opening. The injector is then held open with 12V.

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 5V reference voltage on the 5V 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 Pulse Dampener

The fuel pulse dampener is a part of the low pressure fuel feed pipe assembly. The fuel pulse dampener is diaphragm-operated, with fuel pump pressure on one side and with spring pressure on the other side. The function of the dampener is to dampen the fuel pump pressure pulsations.

Fuel Metering Modes of Operation

The control module monitors voltages from several sensors in order to determine how much fuel to give the engine. The control module 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

When the ignition is first turned ON, the control module energizes the fuel pump for 2 seconds. This allows the fuel pump to build pressure in the fuel system. The control module 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.

Clear Flood Mode

If the engine floods, clear the engine by pressing the accelerator pedal down to the floor and then crank the engine. When the throttle position sensor is at wide open throttle (WOT), the control module reduces the fuel injector pulse width in order to increase the air to fuel ratio. The control module 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 control module 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 control module ignores the signal from the heated oxygen sensor (HO2S). The control module 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 control module 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 control module increases the pulse width to the injectors to provide extra fuel during acceleration. This is also known as power enrichment. The control module determines the amount of fuel required based upon the throttle position, the engine coolant temperature (ECT), the manifold absolute pressure (MAP), the mass air flow (MAF), and the engine speed.

Deceleration Mode

When the driver releases the accelerator pedal, air flow into the engine is reduced. The control module monitors the corresponding changes in the throttle position, the mass air flow (MAF), and the manifold absolute pressure (MAP). The control module 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 control module 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 control module 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 control module controls the air/fuel metering system in order to provide the best possible combination of driveability, fuel economy, and emission control. The control module 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 percent for both short and long term fuel trim. A positive fuel trim value indicates the control module is adding fuel in order to compensate for a lean condition by increasing the pulse width. A negative fuel trim value indicates that the control module 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 control module selects the cells based on the engine speed and engine load. If the control module detects an excessively lean or rich condition, the control module will set a fuel trim diagnostic trouble code (DTC).

THROTTLE ACTUATOR CONTROL (TAC) SYSTEM DESCRIPTION

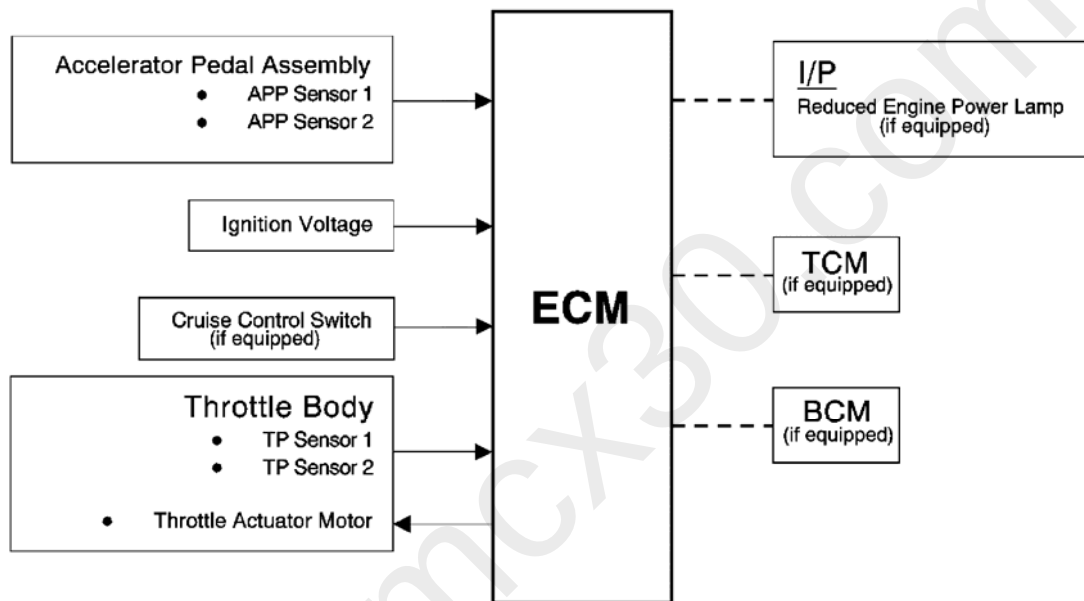


Fig. 3: Throttle Actuator Control (TAC) System
Courtesy of GENERAL MOTORS CORP.

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.
- Minimum pedal value-At key-up, the ECM updates the learned minimum pedal value.
- Battery saver mode-After a predetermined time without engine RPM, 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 idle positioning the throttle position, or by controlling the fuel and spark if the throttle is turned OFF.
 - Ignore the accelerator pedal input.
- Engine shutdown mode-The ECM will disable fuel and de-energize the throttle actuator.