

2018 ENGINE PERFORMANCE

Engine Controls And Fuel - 1.6L (LH7) Diesel - Description And Operation - Equinox & Terrain

DESCRIPTION AND OPERATION

ACCELERATOR PEDAL POSITION SYSTEM DESCRIPTION

The accelerator pedal position (APP) system along with the engine control module (ECM) and other components is used to calculate and control the amount of acceleration and deceleration by controlling the amount of fuel delivery.

The APP system includes the following components:

- The APP sensor assembly.
- The engine control module (ECM).

Accelerator Pedal Position (APP) Sensor

The APP sensor is mounted on the accelerator pedal control assembly. The sensor is made up of 2 individual sensors within one housing. Two separate signals, low reference, and 5 V reference circuits are used in order to interface the accelerator pedal sensor assembly with the engine control module (ECM). Each sensor has a unique functionality to determine pedal position. The ECM uses the APP sensor to determine the amount of acceleration or deceleration desired by the person driving the vehicle. The APP sensor 1 voltage should increase as the accelerator pedal is depressed, from below 0.7 V at 0% pedal travel to 4.5 V at 100% pedal travel. APP sensor 2 voltage should increase from above 0.3 V at 0% pedal travel to 2.2 V at 100% pedal travel.

ENGINE CONTROL MODULE DESCRIPTION

The engine control module (ECM) interacts with many emission related components and systems. The ECM also monitors emission related components, and systems, for deterioration. The on-board diagnostics monitor the system performance and a diagnostic trouble code (DTC) sets if the system performance degrades.

The malfunction indicator lamp (MIL) operation and DTC storage are dictated by the DTC type. DTCs are ranked as a Type A, B or C. Types A and B DTCs are emissions related. A Type C DTC is non emissions related.

The ECM is the control center of the engine controls system. The ECM controls the following components:

- The fuel injection system
- The internal glow plug control module
- The emission control systems
- The fuel filter heater
- The on-board diagnostics
- The A/C and fan systems
- The throttle plate actuator
- The turbocharger boost actuator
- The switchable engine coolant pump (If applicable)
- The switchable oil pump (If applicable)

The ECM constantly monitors the information from various sensors and other inputs, and controls the systems that affect the vehicle performance and 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, 12 V, or ground to various sensors or switches. Voltage is supplied through pull-up resistors to the regulated power supplies within the ECM. In some cases an ordinary shop voltmeter will not give an accurate reading due to low input resistance. A DMM with at least 10 M Ω 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.

ECM Default Actions

When a malfunction occurs within the engine control system, the engine control module (ECM) maintains control of the system with Default Actions. Default Actions are calculated values, and/or calibrated default values, that are stored within the ECM. A certain level of engine performance is possible when a malfunction occurs dependant on the Default Actions taken. The ECM Default Actions prevent a complete loss of engine performance.

ECM Output Controls

The scan tool can control certain solenoids, valves, motors, and relays. The Output Controls can be found under the Control Functions selection of the scan tool. Some Output Controls may be disabled by the engine control module (ECM) during certain types of vehicle operation.

Data Link Connector (DLC)

The data link connector (DLC) provides the technician a means of accessing serial data for aid in diagnosis. This connector allows the technician to use a scan tool in order to monitor the various serial data parameters, and to display DTC information. The DLC is located inside the drivers compartment, underneath the dash.

Malfunction Indicator Lamp (MIL)

The malfunction indicator lamp (MIL) is located on the instrument cluster or the driver information center. 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) is designed to withstand the normal current draws that are associated with vehicle operation. Care must be used in order to avoid overloading any circuits during testing. Do not ground, or apply voltage, to any ECM circuits unless a diagnostic procedure instructs you to do so. Circuits should only be tested with a DMM.

Powertrain Expansion Bus

The ECM has an additional CAN bus, the powertrain expansion bus.

FUEL SYSTEM DESCRIPTION

LFS Fuel System Diagram with Fuel Pump Driver Control Module

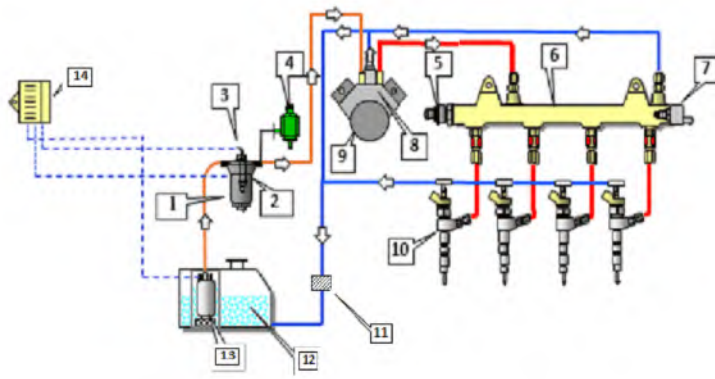


Fig. 1: LFS Fuel System Diagram With Fuel Pump Driver Control Module Components
Courtesy of GENERAL MOTORS COMPANY

Callout	Component Name
1	Fuel Filter with Water in Fuel Sensor
2	Fuel Heater
3	Fuel Temperature Sensor
4	Fuel Pressure Sensor
5	Dual Fuel Rail Pressure Sensor (Contains Fuel Rail Pressure Sensor 1 and Fuel Rail Pressure Sensor 2)
6	Fuel Rail Assembly
7	Fuel Rail Pressure Regulator 2
8	Fuel Pressure Regulator 1 (Located in Fuel Injection Pump)
9	Fuel Injection Pump
10	Fuel Injectors
11	Fuel Tank
12	Electric 3 - Phase Fuel Pump
13	Fuel Pump Driver Control Module

The fuel tank stores the fuel supply and contains a 3 - phase electric fuel pump that is controlled by the fuel pump driver control module and engine control module. Fuel is pumped from the fuel tank through the fuel feed line to the fuel filter assembly. The fuel filter assembly consists of a fuel filter/water separator, fuel heater, fuel temperature sensor, and a water in fuel sensor. Fuel flows out of the fuel filter assembly through the rear fuel feed pipe to the fuel pressure sensor and fuel injection pump. The belt driven fuel injection pump is mounted on the upper right corner of the engine block. High pressure fuel is supplied through the high pressure fuel line to the fuel rail and then through the fuel injector lines to the fuel injectors. High pressure fuel is controlled by the ECM, fuel pressure regulator 1 and fuel pressure regulator 2. Excess fuel returns to the fuel tank through the fuel return pipes.

Fuel Tank

The fuel tank (1) stores the fuel supply. The fuel tank is held in place by 2 metal straps. The fuel tank is molded from high density polyethylene.

Fuel Filler Cap

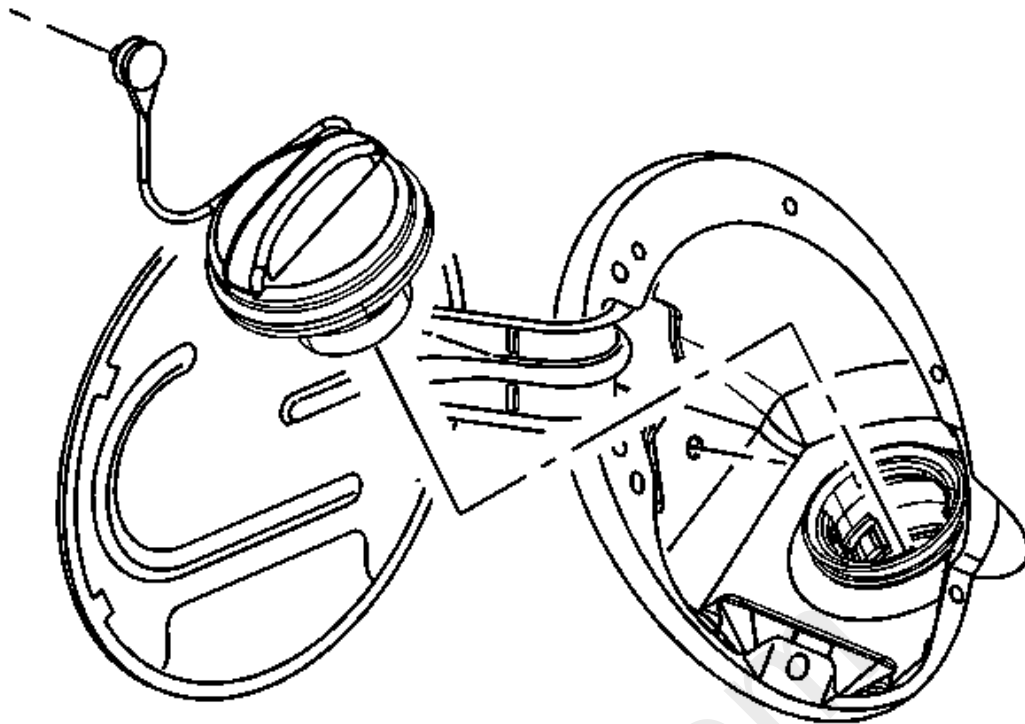


Fig. 2: Filler Door And Tethered Fuel Filler Cap
Courtesy of GENERAL MOTORS COMPANY

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

Fuel Tank Fuel Pump Module

The fuel tank fuel pump module is located inside of the fuel tank. The fuel tank module consists of the following major components:

- The fuel level sensor
- The fuel pump and reservoir assembly
- The fuel strainer

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 amount of fuel in the fuel tank. The fuel pump driver control module sends the fuel level information via the engine control module (ECM) to the instrument panel cluster (IPC). This information is used for the instrument panel (I/P) fuel gauge and the low fuel warning indicator. The fuel pump driver control module also monitors the fuel level input for various diagnostics.

Fuel Pump

The fuel pump is mounted in the primary fuel tank module reservoir. The engine control module (ECM) supplies voltage to the fuel pump driver control module for 30 s when the ignition is turned on and continuously when the engine is running. While this voltage is being received, the ECM sends a serial data signal to the fuel pump driver control module containing the desired fuel pump speed. The fuel

pump driver control module actuates the brushless fuel pump by means of a three phase signal and controls the fuel pump speed according to serial data signals received from the ECM containing the desired fuel pump speed.

Fuel Strainer

The fuel strainer attaches to the lower end of the fuel sender. The fuel strainer is made of woven plastic. The functions of the fuel strainer are to filter contaminants and to wick fuel. The fuel strainer is self-cleaning and normally requires no maintenance. Fuel stoppage at this point indicates that the fuel tank contains an abnormal amount of sediment.

Fuel Filter Assembly

The fuel filter assembly (3) is mounted to the right side of the fuel tank. The paper filter element traps particles in the fuel that may damage the fuel injection system. The fuel filter assembly consists of the following major components:

- Fuel Filter/Water Separator
- Fuel Heater
- Fuel Temperature Sensor
- Water in Fuel Sensor

Fuel Filter/Water Separator

The paper filter element traps particles in the fuel that may damage the fuel injection system and is designed to allow trapped water particles to settle to the bottom of the filter assembly.

Fuel Heater

The fuel heater located in the fuel conditioning module is controlled by the engine control module (ECM). When the temperature of the fuel is below the calibrated level the ECM will command the fuel heater relay ON. With the relay ON battery voltage is supplied to the fuel heater to assist in cold weather operation.

Fuel Temperature Sensor

The fuel temperature sensor is a thermistor that is located in the fuel filter assembly. The ECM monitors the fuel temperature sensor through the fuel pump driver control module in order to calculate the temperature of the fuel entering the fuel injection pump.

Water in Fuel Sensor

The water in fuel sensor is a sensor that monitors for the presence of diesel fuel and water. When water is present the fuel pump driver control module detects low voltage on the signal circuit and sends a message to the ECM. The ECM sends a serial data message to the instrument panel cluster to display the WATER IN FUEL SERVICE REQUIRED message.

Fuel Feed and Return Pipes

The fuel feed pipe carries fuel from the fuel tank to the fuel filter/heater element housing. The fuel return pipe carries fuel from the fuel rail assemblies back to the fuel tank. The fuel pipes consist of 2 sections:

- The rear fuel pipe assemblies are located from the top of the fuel tank to the chassis fuel pipes. The rear fuel pipes are constructed of nylon.
- The chassis fuel pipes are located under the vehicle and connect the rear fuel pipes to the fuel rail pipes.
- Nylon fuel pipes are somewhat flexible and can be shaped around gradual turns under the vehicle. However, if nylon fuel pipes are forced into sharp bends, the pipes may kink and restrict the flow of fuel. Also, once exposed to fuel, nylon pipes may become stiffer and are more likely to kink if bent too far. Exercise special care when working on a vehicle with nylon fuel pipes.

Quick-Connect Fittings

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

Fuel Pipe O-Rings

O-rings seal the connections in the fuel system. Fuel system O-ring seals are made of special material. Service the O-ring seals with the correct service part.

Fuel Injection Pump

The fuel injection pump (5) is a mechanical high pressure pump. The fuel injection pump is located on the upper right side of the engine. Fuel is pumped to the fuel rail (8) at a specified pressure. Fuel pressure is regulated by two fuel pressure regulators located in the fuel injection pump and the end of the fuel rail, both are controlled by the engine control module (ECM). Excess fuel from the fuel injection pump returns to the fuel tank through the fuel return pipe.

Fuel Pressure Regulator

The engine control module (ECM) controls the fuel rail pressure using a pulse width modulated fuel rail pressure regulator. The fuel pressure regulator is located in the fuel injection pump and meters the amount of fuel that enters the high pressure side of the pump. From the high pressure pump, the fuel moves to the fuel rail through a high pressure steel line. The fuel rail distributes high pressure fuel to all 4 fuel injectors.

Fuel Pressure Regulator 2 (if equipped)

Fuel Pressure Regulator 2 Filter Screen

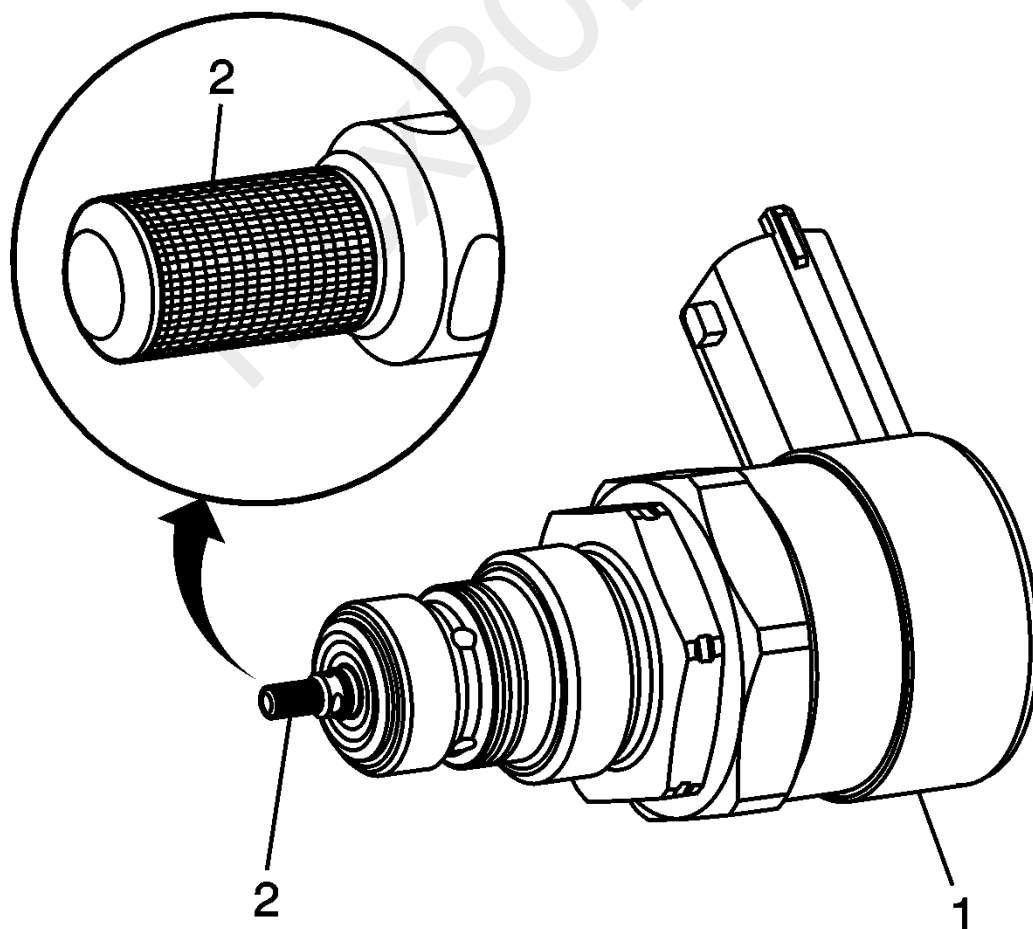


Fig. 3: Fuel Pressure Regulator 2 Filter And Screen
Courtesy of GENERAL MOTORS COMPANY

Callout	Component Name
1	Fuel Pressure Regulator 2
2	Filter Screen

At engine start, the engine control module (ECM) commands the fuel pressure regulator 2 to control fuel pressure at idle. The engine will remain in this mode if the fuel temperature is below 15°C (59°F), or until the fuel pressure regulator 2 adapts (which occurs at higher engine loads), or until fuel temperature reaches 60°C (140°F). The adaptation is a learned factor that adjusts the fuel pressure regulator 2 current to compensate for manufacturing tolerances and component aging. Once the adaptation is complete, the vehicle will use fuel pressure regulator 1 for rail pressure control at idle. The fuel pressure regulator 2 adaptation will attempt to run again at the next drive cycle.

Fuel Rail Pressure Sensor

The fuel rail pressure sensor is located in the rear of the fuel rail assembly. The fuel rail pressure sensor provides the engine control module (ECM) an indication of the actual fuel rail pressure. The ECM uses this information to regulate the fuel pressure, by commanding the fuel pressure regulator to obtain the desired fuel pressure.

Fuel Rail Pressure Sensor - Dual (if equipped)

The dual fuel rail pressure sensor contains fuel pressure regulator 1 and fuel pressure regulator 2 and is located in the rear of the fuel rail assembly. The dual fuel rail pressure sensor provides the ECM an indication of the actual fuel rail pressure. The ECM uses this information to regulate the fuel pressure, by commanding the fuel pressure regulator to obtain the desired fuel pressure.

Fuel Injection Fuel Rail Assembly

The fuel rail assembly attaches to the cylinder head. The fuel rail assembly distributes pressurized fuel to the fuel injectors through the fuel lines.

Fuel Pressure Sensor (if equipped)

The fuel pressure sensor is located in the fuel feed pipe. The engine control module (ECM) monitors the fuel pressure sensor by serial data received from the fuel pump driver control module. The ECM monitors the voltage of the fuel pressure sensor in order to provide fuel pressure control.

Fuel Injectors and Return Lines

The fuel injectors are located above each cylinder and deliver fuel directly into the cylinder. Each injector has a high pressure fuel pipe from the fuel rail and a return line.

A fuel injector is a solenoid device, controlled by the ECM, that meters pressurized fuel to a single engine cylinder. Fuel pressure is released from above the fuel injector pintle, and is returned to the fuel tank through the fuel return lines. The difference in fuel pressure above and below the pintle causes the pintle to open. Fuel from the fuel injector tip is sprayed directly into the combustion chamber on the compression stroke of the engine.

EXHAUST AFTERTREATMENT SYSTEM DESCRIPTION

System Overview

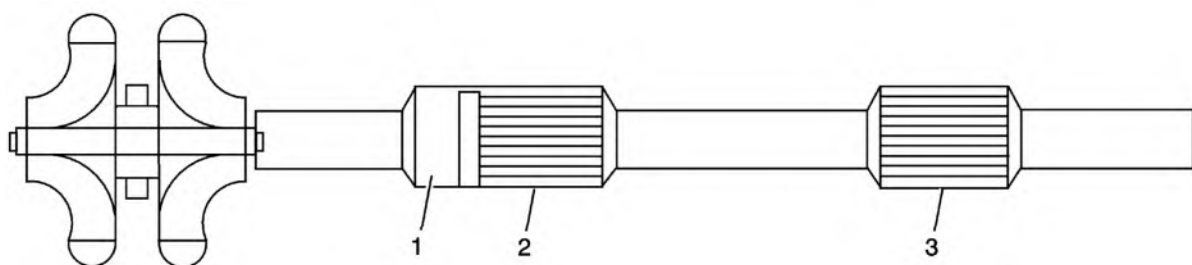


Fig. 4: Exhaust After Treatment System 3 Stage Description
Courtesy of GENERAL MOTORS COMPANY

The diesel exhaust aftertreatment system is designed to reduce the levels of hydrocarbons (HC), carbon monoxide (CO), oxides of nitrogen (NO_x), and particulate matter remaining in the vehicle's exhaust gases. Reducing these pollutants to acceptable levels is achieved through a 3 stage process:

1. A diesel oxidation catalyst (DOC) stage
2. A diesel particulate filter (DPF) stage
3. A selective catalyst reduction (SCR) stage

In stage 1, the DOC removes exhaust HC and CO through an oxidation process. After stage 1, particulate matter consisting of extremely small particles of carbon remaining after combustion are removed from the exhaust gas by the large surface area of the DPF. In the final or stage 3 process, reductant, also known as diesel exhaust fluid (DEF) or urea, is injected into the exhaust gases prior to entering the SCR stage. Within the SCR, NO_x is converted to nitrogen (N₂), carbon dioxide (CO₂), and water vapor (H₂O) through a catalytic reduction fueled by the injected reductant.

Exhaust Aftertreatment System

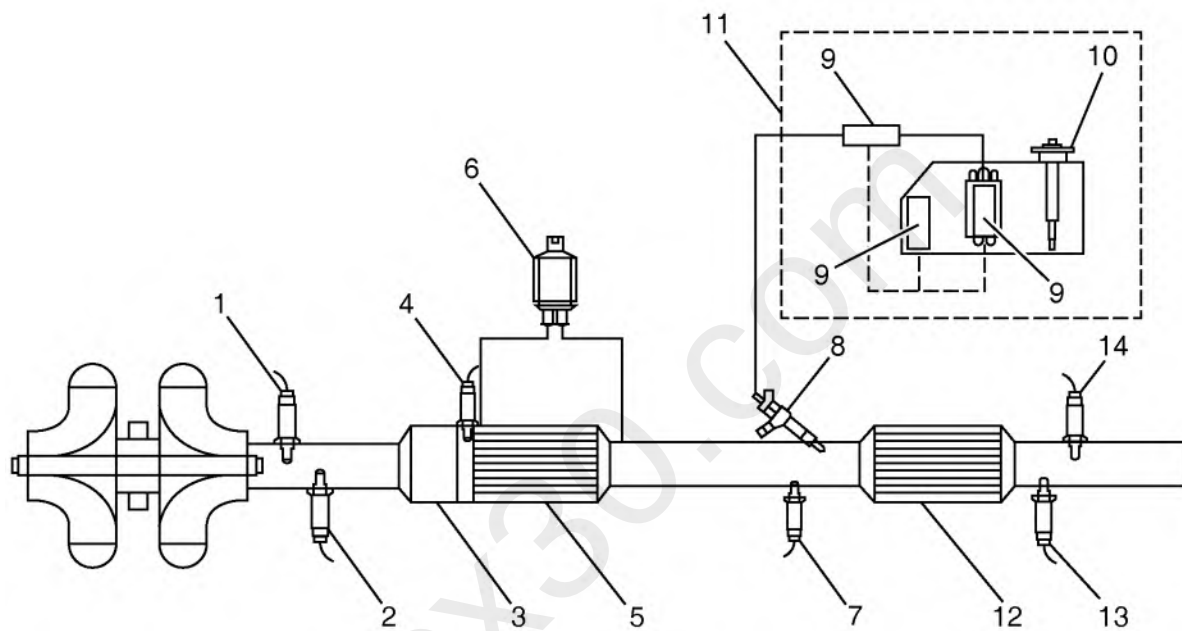


Fig. 5: Exhaust Aftertreatment System Components
Courtesy of GENERAL MOTORS COMPANY

Callout	Component Name
1	NO _x Sensor 1 (Upstream)
2	Exhaust Gas Temperature (EGT) 1
3	Diesel Oxidation Catalyst (DOC)
4	Exhaust Gas Temperature (EGT) 2
5	Diesel Particulate Filter (DPF)
6	DPF Pressure Sensor (DPS)
7	Exhaust Gas Temperature (EGT) 3
8	Reductant Injector and Dosing Module
9	SCR Pump, Tank and Line Heaters
10	Reductant Level and Temperature Sensors
11	Reductant Tank and Supply Module
12	Selective Catalyst Reduction (SCR)
13	NO _x Sensor 2 (Downstream)
14	Particulate Matter Sensor (PMS)

Diesel Oxidation Catalyst (DOC) Operation

The DOC functions much like the catalytic converter used with gasoline fueled engines. As with all catalytic converters, the DOC must be hot in order to effectively convert the exhaust HC and CO into CO₂ and H₂O. On cold starts, the exhaust gases are not hot enough to create temperatures within the DOC high enough to support full HC and CO conversion. The temperature at which full conversion occurs is known as light-off.

In addition to reducing emissions, the DOC also generates the exhaust heat needed by the SCR stage. Exhaust gas temperature (EGT) sensors are located upstream (EGT 1) and downstream (EGT 2) of the DOC. By monitoring the temperature differential between these two sensors, the ECM is able to confirm DOC light-off. Light-off is confirmed by a DOC output temperature that is greater than its input temperature.

In order to generate the high exhaust temperatures needed for regeneration, the aftertreatment system increases exhaust temperatures by injecting diesel fuel into the exhaust gases entering the DOC. This is accomplished by means post-injection using the engines fuel injectors.

Proper DOC function requires the use of ultra-low sulfur diesel (ULSD) fuel containing less than 15 parts-per-million (ppm) sulfur. Levels above 15 ppm will reduce catalyst efficiency and eventually result in poor driveability and one or more DTCs being set.

Diesel Particulate Filter (DPF)

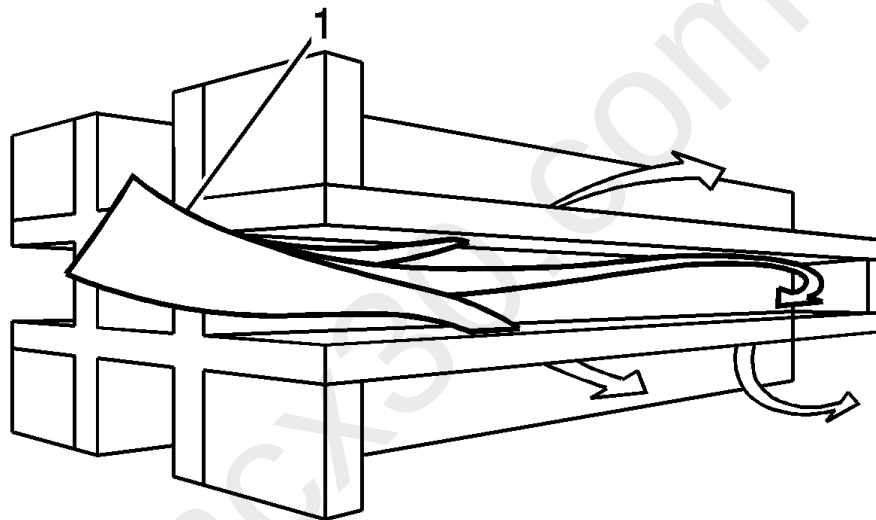


Fig. 6: Identifying Diesel Particulate Filter (DPF)
Courtesy of GENERAL MOTORS COMPANY

The DPF captures diesel exhaust gas particulates, also known as soot, preventing their release into the atmosphere. This is accomplished by forcing particulate-laden exhaust through a filter substrate consisting of thousands of porous cells. Half of the cells are open at the filter inlet but are capped at the filter outlet. The other half of the cells are capped at the filter inlet and open at the filter outlet. This forces the particulate-laden exhaust gases (1) through the porous walls of the inlet cells into the adjacent outlet cells trapping the particulate matter. The DPF is capable of removing more than 90% of particulate matter, or soot carried in the exhaust gases.

Particulate Matter Sensor (PMS)

The PM sensor determines the amount of the particulates (soot) in the diesel exhaust gas exiting the tailpipe by monitoring the collection efficiency of the DPF and to aid in OBD-II emission diagnostics.

The PM sensor is similar to the heated oxygen sensor with a ceramic element but also includes an individually calibrated control unit. The PM sensor sensing element includes two comb-shaped inter-digital electrodes, a heater and a positive temperature coefficient (PTC) resistor for temperature measurement.

The operation of the PM sensor is based on the electrical conductivity characteristic of the soot. As the exhaust gas flows over the sensing element, soot is absorbed in the combs between the electrodes, eventually creating a conductive path. When the path is formed, it generates a current based on the

voltage being applied to the element. The measurement process continues until a preset current value is reached. To avoid misleading readings, the sensor operates on a "regenerative" principle, where the soot is cleaned off by heating up the element to burn off the carbon, before the measurement phase begins. The amount of regenerations is based on vehicle strategy; when the amount of regeneration is reached, the cumulative current readings are used to determine the amount of soot concentration in the exhaust gas, and thus the collection efficiency of the DPF.

The PM sensor is operated in 3 successive modes:

1. Standby mode after power-up to ensure protective heating. On power-up, the control unit starts the heating process to avoid condensation of liquids on the sensing element. Presence of liquid can cause thermal shock during the heating process, resulting in damage to the ceramic element. Regeneration is not initiated until the dew point temperature has been exceeded.
2. Regeneration mode is conducted before each measurement to ensure a soot free sensing element. Before starting measurements, absorbed soot is burned off the sensing element by heating it up; this ensures each measurement start off at the same condition. Regeneration is conducted for a pre-determined period of time based on soot level.
3. Measurement mode is when soot is actively collected on the sensing element. The sensor heater is deactivated during measurement, so the temperature on the element is equivalent to that of the exhaust gas. Voltage is applied until a preset 12 micro-amp current threshold is achieved due to increasing current as the soot builds up on the element. The time from the end of the regeneration to reach the threshold is used to calculate the concentration of soot in the exhaust gas.

Differential Pressure Sensor (DPS)

Pressure connections at the DPF inlet and outlet allow the DPS to measure the pressure drop across the diesel particulate filter. This pressure drop increases as trapped soot collects in the cells of the DPF during vehicle operation. The rate at which soot collects varies with the power demands placed on the engine. If left unchecked, the increasing backpressure will eventually result in a driveability problem. There are two sensing elements in the DPS; one for the upstream side of the DPF, and the other for the downstream side. Pressure from each side of the DPF is applied to the bottom side of a silicon diaphragm in each sensing element; atmospheric pressure is applied to the top side of each diaphragm. Relative pressure differences in each sensing element is converted to a voltage (V1 & V2). The difference in these voltages is sent to the ECM. As the DPF becomes clogged, the pressure on the upstream side increases because of back pressure due to the restriction of the exhaust gas flow through the DPF.

Normal DPF Regeneration

Over time, the soot trapped on the cell walls acts to restrict exhaust flow through the DPF reducing its effectiveness as well as reducing engine efficiency. This restriction in exhaust flow produces a pressure drop across the DPF that increases as the once porous cell walls become saturated with trapped soot. A DPS monitors the pressure drop across the DPF and provides the ECM with a voltage signal proportional to soot buildup. Once soot buildup reaches a specified limit, (usually around 22 - 25 grams) as signaled by the increased pressure drop across the DPF, the ECM commands a regeneration event to burn-off the collected soot during normal vehicle operation. Regeneration events occurring during vehicle operation are known as normal regenerations as they occur automatically and without driver knowledge. In general, the vehicle will need to be operating continuously at speeds above 48 km/h (30 mph) for approximately 20 - 30 minutes for a full and effective regeneration to complete.

The frequency of normal DPF regeneration is a function of the engine run time, miles driven, and fuel consumed since the last regeneration event. Under normal operating conditions, the normal DPF regeneration is initiated after approximately 85 gallons of fuel used or a maximum distance traveled of 2009 km (1250 miles.) To initiate a normal DPF regeneration event, the ECM commands additional fuel via post-injection in order to create the additional exhaust heat in the DOC necessary to promote regeneration and burn-off the collected soot.

During regeneration exhaust temperatures may exceed 550°C (1,022°F) due to the rapid catalytic combustion of soot within the DPF. Conversely, under low engine speed or light loads, exhaust temperatures may be too low to promote proper regeneration. To protect the DPF catalyst from thermal damage due to excessive soot combustion or from sulfate poisoning at low temperatures, the ECM monitors EGT sensors upstream and downstream of the DPF during regeneration. If the vehicle is

slowed to idle speed during a normal DPF regeneration, the engine may maintain an elevated idle of 800 RPM until the DPF is cooled to a calibrated temperature.

Should the EGT sensors indicate that regeneration temperatures have exceeded a calibrated threshold, regeneration will be temporally suspended until the sensors return to a normal temperature. If regeneration temperatures fall below a calibrated threshold, regeneration is terminated and a corresponding DTC is set in the ECM.

Under most conditions, the soot collected within the DPF burns off during normal regeneration cycles. Periodic regeneration prevents the buildup of soot from reaching a level where its burn-off could produce damaging high temperatures within the DPF. Vehicles operated at prolonged low speed or low loads where normal regeneration does not occur will eventually reach a high soot load condition. When the increased pressure drop across the DPF is detected by the DPS, the ECM illuminates the DPF lamp in the instrument cluster and sends a Clean Exhaust Filter message to the driver information center (DIC). The owner's manual diesel supplement describes how the vehicle should be driven in order to enable normal regeneration.

Service Regeneration

WARNING: Tailpipe outlet exhaust temperature will be greater than 300°C (572°F) during this procedure. To help prevent personal injury or property damage from fire or burns, perform the following:

1. Do not connect any shop exhaust removal hoses to the vehicle tailpipe.
2. Park the vehicle outdoors and keep people, other vehicles, and combustible material away during this procedure.
3. Do not leave the vehicle unattended.

Should the vehicle operator fail to drive the vehicle within the conditions necessary to initiate a normal regeneration cycle, the ECM illuminates the Service Engine Soon lamp and displays a REDUCED ENGINE POWER message on the DIC once the soot buildup exceeds a calibrated value. The vehicle will remain in the reduced power model until service regeneration is performed.

Service regeneration is required because the amount of soot collected in the DPF, known as soot load, is too high to be burned off without possible thermal damage to the DPF's ceramic substrate.

Service regeneration is one of several output control functions available on the scan tool. When service regeneration is commanded, the ECM takes control of engine operation until the service regeneration is completed in about 35 minutes or until the service regeneration is either cancelled by the technician or is aborted by the ECM when it detects unexpected conditions. The ECM commands additional fuel via post-injection in order to create the additional exhaust heat in the DOC necessary to promote regeneration and burn-off the collected soot.

The service regeneration can be terminated by applying the brake pedal, commanding service regeneration Off using the scan tool, or disconnecting the scan tool from the vehicle.

Service Regeneration Precautions

Exhaust temperatures at the tailpipe may exceed 300°C (572°F) during service regeneration. Observe the following precautions:

- Service regeneration must be performed outdoors. Most exhaust removal hoses cannot withstand the high exhaust temperatures generated during regeneration.
- Park the vehicle outdoors and keep people, other vehicles, and combustible material away during service regeneration.
- Park the vehicle in an area that provides a clearance area of at least 10 feet on all sides of the vehicle and open the hood.
- Ensure the tailpipe is not obstructed by mud or debris.
- Do not leave the vehicle unattended during service regeneration.

The ECM uses two EGT sensors to measure the temperature of the exhaust gases at the inlet (EGT 2) and outlet (EGT 3) of the particulate filter. Optimum particulate filter temperature is crucial for emission reduction and for ensuring complete regeneration. Excessive particulate filter temperatures could damage the ceramic substrate. The ECM monitors the inlet and outlet exhaust gas temperature sensors in order to maintain the particulate filter at its optimum temperature.

Ash Loading

Ash is a non-combustible by-product from normal oil consumption. Low Ash content engine oil (CJ-4 API) is required for vehicles with the DPF system. Ash accumulation will eventually cause a restriction in the DPF. Being non-combustible, ash is not burned off during regeneration. An ash loaded DPF will need to be removed from the vehicle and replaced.

Selective Catalyst Reduction (SCR) Operation

While diesel engines are more fuel efficient and produce less HC and CO than gasoline engines, as a rule they generate much higher levels of NOx. In order to meet today's tighter NOx limits, an SCR catalyst, along with reductant, is used to convert NOx into N₂, CO₂, and H₂O.

NOx Sensor

The ECM uses two smart NOx sensors to control exhaust NOx levels. The first NOx sensor is located at the turbocharger outlet and monitors the engine out NOx. The second NOx sensor is located in the exhaust pipe downstream of the SCR and monitors NOx levels exiting the aftertreatment system. The smart NOx sensors communicate with the ECM over the serial data line.

The NOx sensors incorporate an electric heater to quickly bring the sensors to operating temperature. As moisture remaining in the exhaust pipe could interfere with sensor operation, the ECM delays turning on the heaters until the exhaust temperature exceeds a calibrated value. This allows any moisture remaining in the exhaust pipe to boil off before it can effect NOx sensor operation. Depending on engine temperature at start up, the delay can be less than a minute or as long as two minutes. Typically, NOx sensor 1 will reach operating temperature faster than NOx sensor 2 as it's closer to the engine's hot exhaust. At idle or low engine speeds, NOx sensor 2 may require up to 5 minutes to reach operating temperature. The sensors must be hot before accurate exhaust NOx readings are available to the ECM.

Reductant (Diesel Exhaust Fluid or DEF)

Reductant is a mixture of deionized water and urea. Within the SCR, exhaust heat converts the urea into ammonia (NH₃) that reacts with NOx to form nitrogen, CO₂, and water vapor. Optimum NOx reduction occurs at SCR temperatures above 250°C (480°F). At temperatures below 250°C, the incomplete conversion of urea forms sulfates that can poison the catalyst. To prevent this poisoning, the ECM suspends reductant injection when exhaust temperature falls below a calibrated limit.

Exhaust Gas Temperature (EGT) sensor

The 1.6L (LH7) engine uses exhaust gas temperature management to maintain the SCR catalyst within the optimum NOx conversion temperature range of 200 - 400°C (390 - 750°F). The ECM monitors EGT sensors located upstream (EGT 2) and downstream (EGT 3) of the SCR in order to determine if the SCR catalyst is within the temperature range where maximum NOx conversion occurs.

Diesel Exhaust Fluid (DEF) System

order to determine if reductant temperature is below its freeze point. If the module determines that the reductant may be frozen, it energizes the reductant heaters.

Reductant pump operation is disabled for a calibrated amount of time to allow the heaters time to thaw the frozen reductant. Once the thaw period expires, the module energizes the reductant pump to circulate warm reductant back to the reservoir to speed thawing. The ECM looks for an increase in the reductant temperature to verify that the reductant reservoir heater is working.

EXHAUST GAS RECIRCULATION (EGR) SYSTEM DESCRIPTION

The exhaust gas recirculation (EGR) system is used to reduce the amount of nitrogen oxide (NO_x) emission levels caused by high combustion temperatures. At temperatures above 1 371Â°C (2, 500Â°F), oxygen and nitrogen combine to form oxides of nitrogen (NO_x). Introducing small amounts of exhaust gas back into the combustion chamber displaces the amount of oxygen entering the engine. With less oxygen in the air/fuel mixture, the combustion pressures are reduced, and as a result, combustion temperatures are decreased, restricting the formation of NO_x.

Exhaust Gas Recirculation (EGR) System Operation

The exhaust gas recirculation (EGR) cooler bypass solenoid valve is controlled by the Engine Control Module (ECM). At engine cold start, the EGR cooler bypass allows hot exhaust gas to heat the intake air in the manifold. Once the engine operating temperature is reached, the ECM will close the EGR cooler bypass

The mass air flow (MAF) sensor signal is used by the engine control module (ECM) to detect the proper amount of EGR flow. The ECM will close the EGR valve, then open the EGR valve to 100%. The ECM will then calculate the MAF difference and determine if the proper EGR flow has been detected.

GLOW PLUG SYSTEM DESCRIPTION

In the diesel engine, air alone is compressed in the cylinder. Then, after the air has been compressed, a charge of fuel is sprayed into the cylinder and ignition occurs, due to the heat of compression. Glow plugs are used as an aid to starting.

The glow plug control module is integrated in the engine control module (ECM) and is a solid state device which operates the glow plugs. The temperature and the power consumption is controlled within a wide range to suit the engine pre-heating requirements. The glow plug initial ON time will vary based on the system voltage and temperature. Lower temperatures cause longer ON times.

A normal functioning system operates as follows:

- Turn the ignition ON with the engine OFF, and at room temperature.
- The glow plugs turn ON and heat up in 2 seconds and then are pulse-width modulated (PWM) for another 2 seconds.
- The glow plug wait lamp is ON for 1 second during cold start.
- The glow plug wait lamp may not illuminate during a warm engine start.
- If the engine is cranked during or after the above sequence, the glow plugs may cycle ON and OFF after the ignition switch is returned from the start position, whether the engine starts or not. The engine does not have to be running to terminate the glow plug cycling.

The glow plug initial ON time will vary based on the system voltage and temperature. Lower temperatures cause longer ON times.

The ECM provides glow plug operation after starting a cold engine. This post-start operation is initiated when the ignition switch is returned to Run, from the Start position. This function helps clean up excessive white smoke and/or poor idle quality after starting.

Glow Plugs

The glow plugs are heaters in each of the cylinders that turn ON, they are pulse-width modulated when the ignition switch is turned to the RUN position prior to starting the engine. The ECM remains pulsing the glow plugs a short time after starting, then are turned OFF.

A Wait to Start lamp on the instrument panel provides information on engine starting conditions. The Wait to Start lamp will not illuminate during post-start glow plug operation.

TURBOCHARGER SYSTEM DESCRIPTION

The variable vane position turbocharger is used to increase the power output of the engine by increasing the mass of the oxygen and therefore the fuel entering the engine. The turbocharger is mounted to the exhaust manifold and is driven by the energy generated by the flow of exhaust gas through the turbine, which is connected by a shaft to the compressor mounted in the induction system. The turbocharger utilizes a vane control actuator to vary the vane angle to manage the boost pressure as necessary.

Turbocharger Pressure Sensor

The manifold absolute pressure (MAP) sensor is mounted on the intake manifold and is used to measure boost pressure.

Turbocharger Vane Control Actuator

The turbocharger uses a vacuum operated vane position actuator with an integral vane position sensor, to control the turbocharger vane angle. The actuator utilizes a remotely mounted solenoid valve to regulate the vacuum. The solenoid is controlled by the engine control module (ECM), which provides ignition voltage and a pulse width modulation (PWM) low side drive control circuit. The turbocharger vane angles are varied to control the amount of boost pressure, dependent upon the load requirements of the engine. The turbocharger vanes are mounted to a drive ring that can be rotated by the actuator to change the vane angle. The ECM uses the turbocharger vane position sensor to monitor the turbocharger vane angle.

The Engine Control Module (ECM) performs the turbocharger learn procedure automatically when the enabling criteria have been met. After each ignition cycle, and before the enable criteria have been met, the ECM will use the previously learned value. If the ECM does not have a previously learned value, it will default to a stored calibrated value.

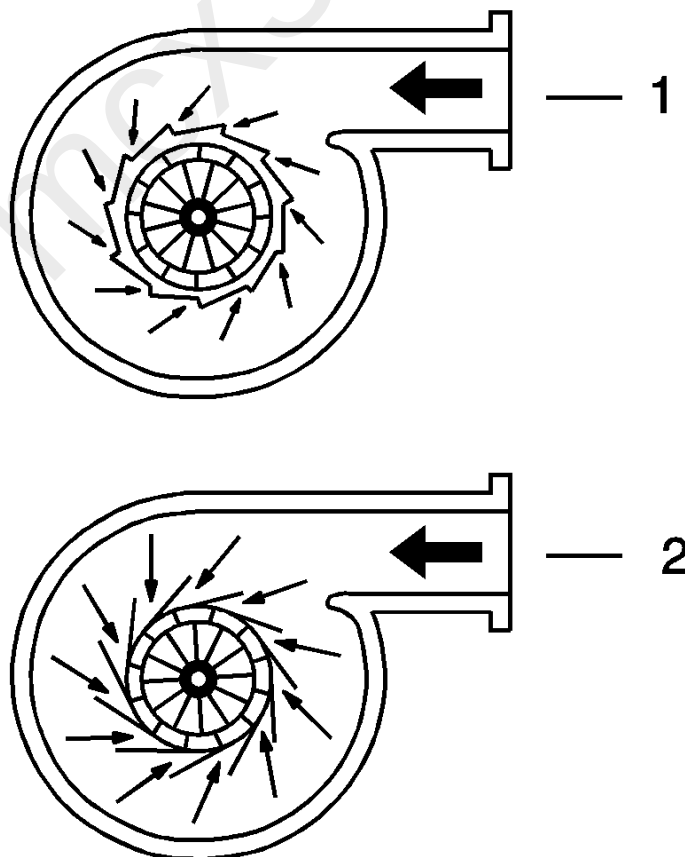


Fig. 8: Turbocharger Vanes

Courtesy of GENERAL MOTORS COMPANY

The turbocharger vanes (2) are normally open when the engine is not under a load. The ECM commands the boost pressure actuator to close the turbocharger vanes (1) to increase engine power by increasing boost pressure.

The ECM may close the vanes (1) to create back pressure to drive exhaust gas through the exhaust gas recirculation (EGR) valve as required. At extreme cold temperatures, the ECM may close the vanes (1) at low load conditions in order to accelerate engine coolant heating. The ECM may also close the vanes (1) under exhaust braking conditions.

The Charged Air Cooler (Turbocharger Intercooler)

The charged air cooler is located in front of the radiator. The turbocharger supplies hot compressed air from the turbine to the engine to increase power. The airflow through the radiator cools the hot compressed air from the turbocharger.

Engine Control Module (ECM)

The ECM controls all turbocharger control functions. The ECM monitors information from various sensor inputs that include the following:

- Accelerator pedal position sensor.
- Engine coolant temperature (ECT) sensor.
- Mass air flow (MAF) sensor.
- Manifold absolute pressure (MAP) sensor.
- Vehicle speed sensor (VSS).
- Transmission gear position or range information sensors.

INTAKE AIRFLOW VALVE SYSTEM DESCRIPTION

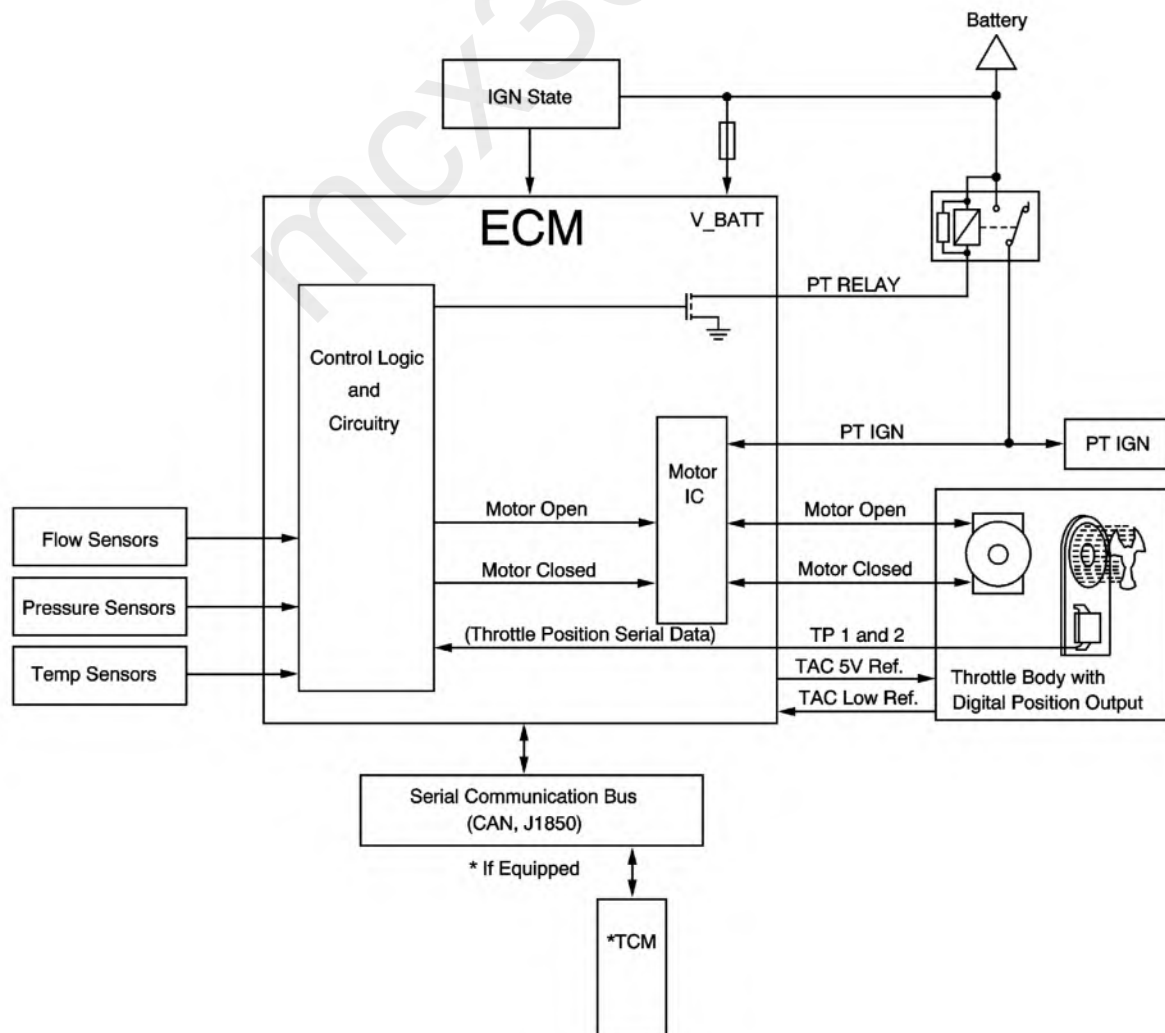


Fig. 9: Intake Airflow Valve System
Courtesy of GENERAL MOTORS COMPANY

The intake airflow valve is a throttle plate actuator and is used to achieve high exhaust gas recirculation rates. It increases the pressure difference between exhaust and intake so that the appropriate exhaust quantity can be mixed with the intake air. The intake airflow valve contains a contact-less inductive throttle position sensing element that is managed by a customized integrated circuit. The throttle position sensor is mounted within the valve assembly and is not serviceable. The engine control module (ECM) supplies the valve assembly with a 5 V reference circuit, a low reference circuit, an H-bridge motor directional control circuit, and an asynchronous signal/serial data circuit. The asynchronous signal means communication is only going from the valve assembly to the ECM. The valve assembly cannot receive data from the ECM over the signal/serial data circuit. The throttle position sensor provides a signal that changes relative to throttle blade angle. The customized integrated circuit translates the signal based position information into serial data using the Society of Automotive Engineers (SAE) J2716 Single Edge Nibble Transmission (SENT) protocol. The throttle position sensor information is transmitted between the valve assembly and the ECM on the signal/serial data circuit. The ECM decodes the serial data signal into separate voltages which are displayed on a scan tool as the voltage inputs from TP sensors 1 and 2.

SPEED LIMITING DESCRIPTION

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

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

Functions that will limit the vehicle speed

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

System Components

Engine Control Module (ECM)

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

Body Control Module (BCM)

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

Electronic Brake Control Module (EBCM)

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

Suspension and Damping System

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

OnStar Enhanced Services

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

Automatic Leveling Control

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

Integrated Chassis Control Module

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

Rear Driveline Control Module/Transfer Case Control Module

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

Hybrid Module

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

Transmission Control Module

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

Driver Information Center

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