

2021 ENGINE PERFORMANCE

Engine Controls And Fuel - 2.8L (LWN) Diesel - Description And Operation - Canyon, Colorado

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:

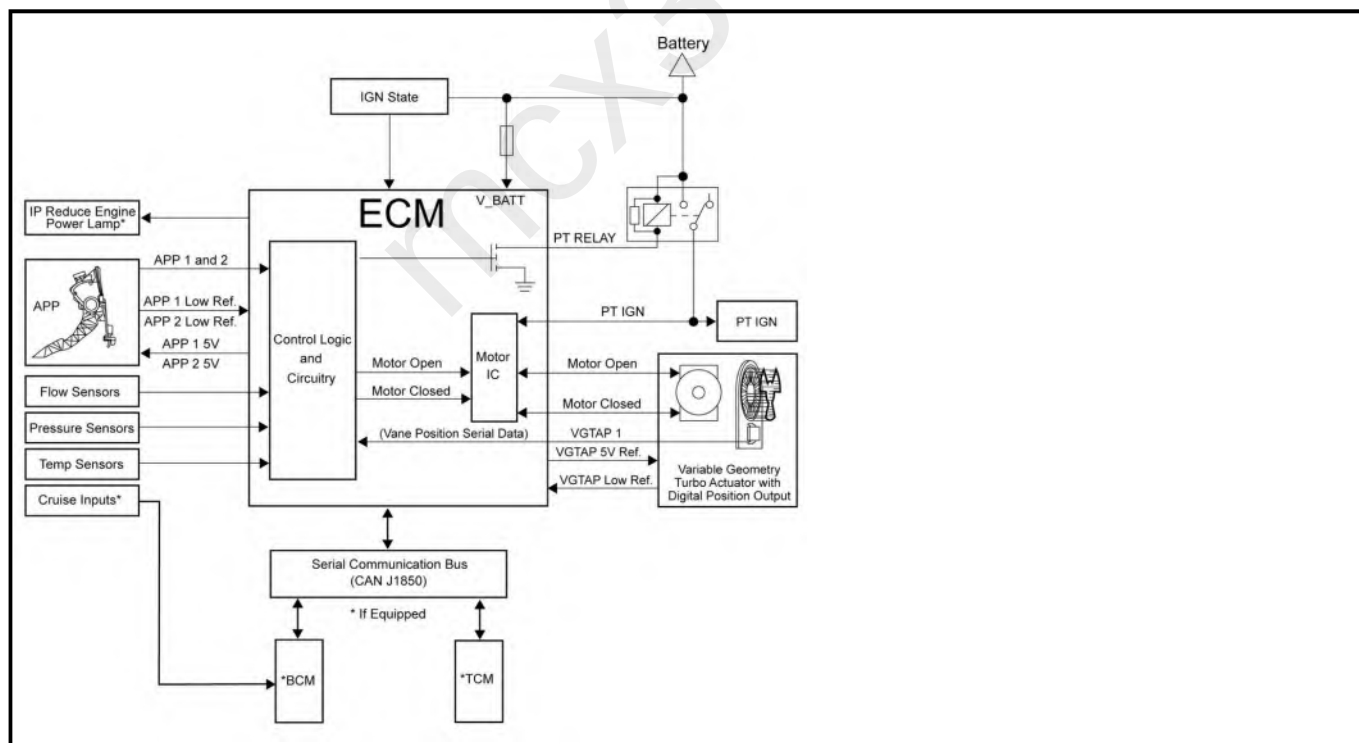
- The APP sensor assembly.
- The engine control module (ECM).

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.

COMPRESSOR AIR INTAKE TURBOCHARGER SYSTEM DESCRIPTION

Turbocharger Vane Position Actuator



A turbocharger increases engine power by pumping compressed air into the combustion chambers, allowing a greater quantity of fuel to combust at the optimal air/fuel ratio. The Variable Geometry Turbine (VGT) body assembly contains a contact-less inductive VGT position sensing element that is managed by a customized integrated circuit. The VGT position sensor is mounted within the VGT body assembly and is not serviceable. The engine control module (ECM) supplies the VGT body 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 VGT body to the ECM. The VGT body cannot receive data from the ECM over the signal/serial data circuit. The VGT position sensor provides a signal voltage that changes relative to VGT vanes angle. The customized integrated circuit translates the voltage based position information into serial data using the Society of Automotive Engineers (SAE) J2716 Single Edge Nibble Transmission (SENT) protocol. The VGT position sensor information is transmitted between the VGT body and the ECM on the signal/serial data circuit. The ECM decodes the serial data signal and is used as voltages for VGT position sensor.

The turbocharger vanes are normally closed at idle, greater than 70%, when the engine is not under a load. As the vehicle accelerates and the torque request stabilizes, the ECM will open the turbocharger vanes to regulate boost pressure.

The ECM will often close the turbocharger vanes to create back pressure to drive exhaust gas through the exhaust gas recirculation (EGR) valve as required. At extreme cold temperatures, the ECM may maintain a more closed vane position, at low load conditions, in order to accelerate engine coolant heating.

The Charged Air Cooler or Turbocharger Intercooler

The turbocharger is supported by an air-to-air charge air cooler system, which uses fresh air drawn through a heat exchanger to reduce the temperature of the warmer compressed air forced through the intake system. Inlet air temperature can be reduced by approximately 30 % or greater, which enhances performance. This is due to the higher density of oxygen in the cooled air, which promotes optimal combustion. The charge air cooler is connected to the turbocharger and to the throttle body by flexible ductwork that requires the use of special high torque fastening clamps. In order to prevent any type of air leak when servicing the duct work, the tightening specifications and proper positioning of the clamps is critical. The ECM monitors the efficiency of the Charge Air Cooler for deterioration that would cause vehicle's emissions to exceed specific emission levels. The overall efficiency of CAC is calculated using the absolute temperature difference between the applicable air temperature sensors for a given application. The efficiency is determined using calibrations that equate to DTC P0127 or P026A, depending on the available air temperature sensors.

Engine Control Module (ECM)

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

- The accelerator pedal position (APP) 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 manifold absolute pressure (MAP) sensor
- The EGR position - if equipped

Exhaust Brake Function - If Equipped

The exhaust brake feature can be used to provide additional braking when the vehicle is decelerating with a heavy load, and/or down a steep grade. A switch provides an input to the body control module (BCM). The BCM sends an exhaust brake request to the ECM via the control area network (CAN). The engine control module (ECM) processes the request and controls exhaust brake operation based on various sensor inputs. The ECM commands the turbocharger vane position to maximum boost for exhaust brake operation. Any malfunction of the Turbocharger or related engine controls hardware will set a powertrain DTC. If the exhaust brake feature does not function properly and there are no DTCs, the exhaust brake switch and related circuit should be diagnosed.

ENGINE CONTROL MODULE DESCRIPTION

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

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

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

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

ECM Function

The 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 an integral part of the ECM. The EEPROM contains program and calibration information that the ECM needs in order to control engine operation.

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

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

Malfunction Indicator Lamp (MIL)

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

Electrostatic Discharge (ESD) Damage

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

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

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

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

Powertrain Expansion Bus

The ECM has an additional CAN bus, the powertrain expansion bus. The following components are integrated the Recutnant Control Module, the Nitrogen Oxides Sensor 1, the Nitrogen Oxides Sensor 2 and the ECM.

EXHAUST AFTERTREATMENT SYSTEM DESCRIPTION

System Overview

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 4 stage process:

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

In stage 1, the close coupled DOC removes exhaust HC and CO through an oxidation process. After stage 1, 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. The exhaust then enters a second DOC. In the final or stage 4 process, 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

Close Coupled 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.

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.

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 NO_x. In order to meet today's tighter NO_x limits, an SCR catalyst, along with reductant, is used to convert NO_x into N₂, CO₂, and H₂O.

NO_x Sensor

The nitrogen oxides (NO_x) sensors are part of the selective catalytic reduction system, a device used to reduce NO_x emission on diesel engines. The ECM uses two smart NO_x sensors to control exhaust NO_x levels. The first NO_x sensor is located at the turbocharger outlet and monitors the engine out NO_x. The second NO_x sensor is located in the exhaust pipe downstream of the SCR and monitors NO_x levels exiting the aftertreatment system. Each NO_x sensor contains a sensing cell, a pumping cell, and a heater. A sample of exhaust gas passes through a diffusion gap between the sensing cell and the pumping cell.

The amount of current required to maintain the reference voltage in the sensing cell is proportional to the concentration of NO_x in the exhaust. The ECM varies the amount of diesel exhaust fluid (reductant) added by varying the reductant injector duty cycle in response to changes in engine exhaust NO_x levels. The smart NO_x sensors consist of two components, the NO_x module and the NO_x sensor element that are serviced as a unit. A circuit or performance condition with a NO_x sensor is detected by the NO_x sensor module. The smart NO_x sensor module communicates the condition to the ECM over the serial data line. The ECM sets a DTC when a serial data message is received from the NO_x sensor module.

The NO_x 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 NO_x sensor operation. Depending on engine temperature at start up, the delay can be less than a minute or as long as two minutes. Typically, NO_x sensor 1 will reach operating temperature faster than NO_x sensor 2 as it's closer to the engine's hot exhaust. At idle or low engine speeds, NO_x sensor 2 may require up to 5 minutes to reach operating temperature. The sensors must be hot before accurate exhaust NO_x 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 NO_x to form nitrogen, CO₂, and water vapor. Optimum NO_x reduction occurs at SCR temperatures above 250B°C (480B°F). At temperatures below 250B°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 engine uses exhaust gas temperature management to maintain the SCR catalyst within the optimum NO_x conversion temperature range of 200 - 400B°C (390 - 750B°F). The ECM monitors EGT sensors located upstream and downstream of the SCR in order to determine if the SCR catalyst is within the temperature range where maximum NO_x conversion occurs. The engine control module (ECM) supplies 5 V to the exhaust gas temperature signal circuit and supplies a ground to the low reference circuit. The exhaust gas temperature sensor temperature information is used by the ECM during the exhaust gas particulate filter cleaning process.

Diesel Exhaust Fluid (DEF) System

The DEF system consists of the following components located at the reductant reservoir:

- An electrically-operated reductant pump
- A integrated reductant level sensor and reductant temperature sensor

- Reductant system heaters
- Reductant Quality Sensor (if equipped)
- Reductant Sensor Module (if equipped)

The remaining reductant system component, an electrically-controlled reductant injector, is external to the reservoir.

The on-board reservoir holds approximately 19 liters (5 gallons) of reductant. An ECM controlled pump within the reservoir supplies pressurized reductant to the reductant injector located upstream of the SCR. A smart reductant level sensor within the reductant reservoir sends the ECM a serial data message indicating reductant level. The reductant pressure sensor provides the ECM with a voltage signal proportional to the reductant pressure generated by the reductant pump. The ECM varies the duty-cycle of the pump voltage to maintain reductant pressure within a calibrated range.

When the ignition is turned Off, the reductant pump is run in reverse for about 45 seconds in order to purge the supply line of reductant. There is a one minute delay between ignition off and the start of purge to allow the exhaust system to cool in order to prevent hot exhaust gas from being drawn into the reductant line. The ECM also commands the reductant injector open during the purge process. Purging prevents the reductant from freezing in the pump or supply line to the reductant injector.

The ECM energizes the reductant injector to dispense a precise amount of reductant upstream of the SCR in response to changes in exhaust NO_x levels. Feedback from NO_x sensors 1 and 2 allow the ECM to accurately control the amount of reductant supplied to the SCR. If more reductant is supplied to the SCR than is needed for a given NO_x level, the excess reductant results in what is called ammonia slip where significant levels of ammonia exit the SCR. Since the NO_x sensors are unable to differentiate between NO_x and ammonia, ammonia slip will cause NO_x sensor 2 to detect higher NO_x levels than actually exist.

Cold Weather Operation

As reductant will freeze at temperatures below 0B°C (32B°F), there are 2 reductant heaters. Reductant heater 1 is in the reductant reservoir and reductant heater 2 is in the supply line to the reductant injector. The reductant control module monitors the reductant temperature sensor located within the reservoir in 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.

Reductant Quality Sensor (if equipped)

The reductant quality sensor is located in the reductant tank and uses an ultrasonic signal to measure reductant fluid quality. The reductant quality sensor includes an integrated temperature sensor to measure reductant fluid temperature. The reductant quality sensor communicates with the reductant control module using serial data.

Reductant Sensor Module (if equipped)

The Quality Sensor, Reductant Level Sensor, and Reductant Temperature Sensor 2 are integrated into one module. Fluid level, quality, and temperature are communicated to the reductant control module using serial data.

Diesel Oxidation Catalyst (DOC) Operation

In addition to reducing emissions, the DOC also generates the exhaust heat needed by the SCR stage. Exhaust gas temperature sensors are located upstream and downstream 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 of a hydrocarbon injector (HCI) upstream of the DOC in the exhaust system.

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)

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 (PM) Sensor (if equipped)

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, 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 36 gallons of fuel used or a maximum distance traveled of 911 km (560 miles.) To initiate a normal DPF regeneration event, the ECM commands additional fuel via the hydrocarbon injector 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 640B°C (1, 184B°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 900 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 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 300B°C (572B°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 300B°C (572B°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 and outlet 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.

Intake Air (IA) Valve

The intake air (IA) valve is located upstream of the intake air heater, and is normally in the open position. The ECM commands the valve to close in order to precisely control combustion temperature during DPF regeneration. The IA valve will ensure the temperature of the exhaust gas remains in an efficient range under all operating conditions. The IA valve system uses a position sensor located within the valve assembly to monitor the position of the valve. The IA valve uses a motor to move the valve to a closed position and spring tension returns it to the open position. The motor is operated through Motor Control 1 and Motor Control 2 circuits.

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.

EXHAUST GAS RECIRCULATION (EGR) SYSTEM DESCRIPTION

The Engine Control Module (ECM) supplies the Exhaust Gas Recirculation (EGR) valve with a 5 V reference circuit, a low reference circuit, an H-bridge motor directional control circuit, and a signal circuit. The EGR position sensor provides a signal voltage that changes relative to EGR position. The EGR position sensor information is transmitted between the EGR valve and the ECM on the signal circuit.

The EGR system is used to reduce the amount of nitrogen oxide (NOx) emission levels caused by high combustion temperatures. At temperatures above 1,371B° C (2,500B° F) oxygen and nitrogen combine to form NOx. 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 NOx.

Exhaust Gas Recirculation (EGR) System Operation

Intake air is mixed with cooled exhaust gas coming from the exhaust gas recirculation EGR valve. The exhaust gas mixes with the intake air to satisfy emissions, performance, fuel economy and cool the combustion process. The Mass Air Flow (MAF) sensor signal is used by the 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. The recirculate gas also prevents the formation of NOx related gases, refer to as NOx emissions, which are a common cause for failing emissions testing. When a failure occurs both the air intake system and exhaust system should be checked in order to isolate the root cause.

Exhaust Gas Recirculation (EGR) Cooler Bypass (if equipped)

The engine vacuum pump, mounted in the front engine cover housing, supplies vacuum to the EGR cooler bypass solenoid valve during engine operation. When commanded by the Engine Control Module (ECM), the EGR cooler bypass solenoid valve supplies vacuum to the EGR Cooler Bypass Valve Actuator, allowing hot exhaust gas to heat the intake air in the manifold. Once the engine operating temperature is reached, the ECM will command the EGR cooler bypass solenoid valve to shut off the vacuum supply to the EGR cooler bypass valve actuator, closing the hot exhaust gas flow. The cooler bypass valve allows cooling of the exhaust gases during high engine load operation or exclusion of the cooling process during idle and light engine load applications.

Exhaust Gas Temperature Sensors

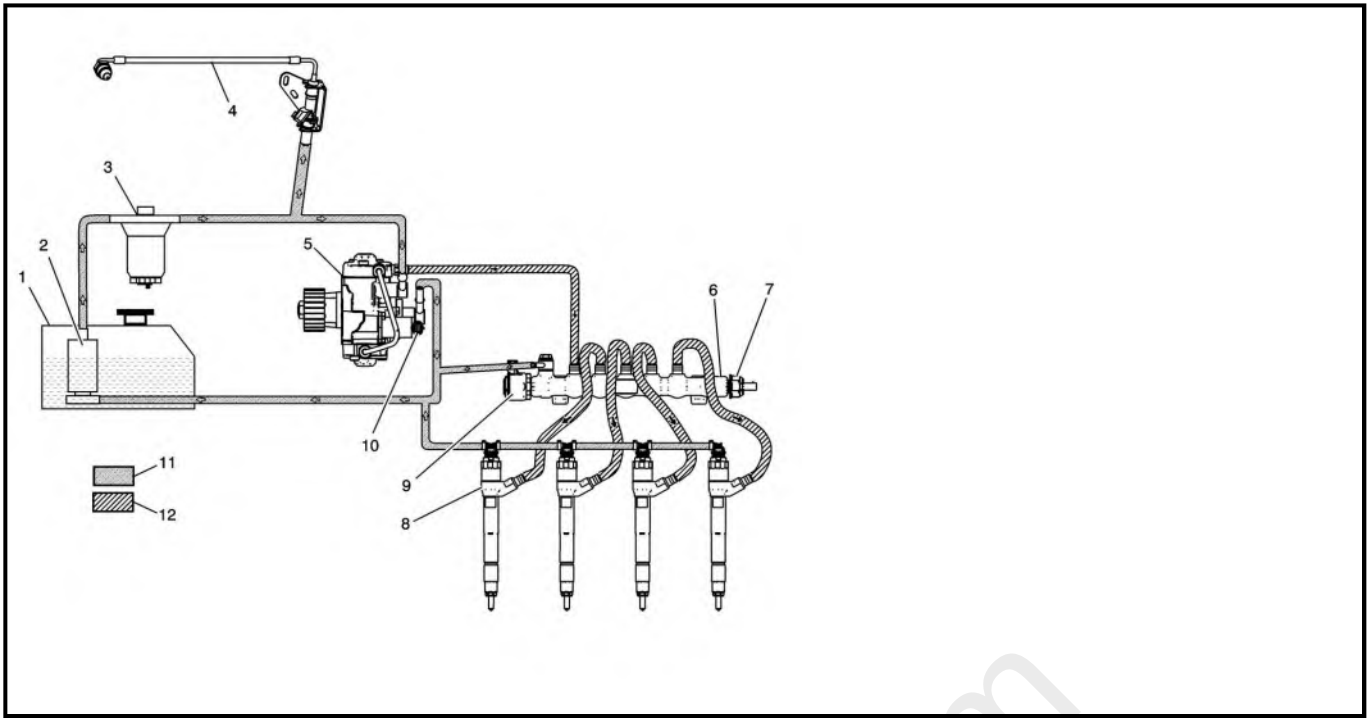
The exhaust gas temperature sensors are variable resistors that measures the temperature of the exhaust gas. The exhaust temperature sensor 1 is the first exhaust temperature sensor on the exhaust system, the following exhaust temperature sensors are counted upward from the engine outlet to the exhaust system end. The engine control module (ECM) supplies 5 V to the exhaust gas temperature signal circuit and supplies a ground to the low reference circuit. The exhaust gas temperature sensor temperature information is used by the ECM during the exhaust gas particulate filter cleaning process.

The following table illustrates the difference between temperature, resistance, and voltage:

Exhaust Gas Temperature	Exhaust Gas Temperature Resistance	Exhaust Gas Temperature Signal Voltage
Cold	Low	Low
Warm	High	High

FUEL SYSTEM DESCRIPTION

LKH, LP2, LWN Fuel System



Callout	Component Name
1	Fuel Tank
2	A7 Fuel Pump and Level Sensor Assembly
3	Fuel Filter Assembly {B48 Fuel Temperature Sensor & B116 Water in Fuel Sensor & E11 Fuel Heater}
4	Q67 Exhaust Aftertreatment Fuel Injector {If equipped}
5	G18 High Pressure Fuel Pump
6	Fuel Injection Fuel Rail Assembly
7	B47B Fuel Rail Pressure Sensor
8	Q17 Fuel Injector
9	Q18B Fuel Pressure Regulator 2
10	Q18A Fuel Pressure Regulator 1
11	Low Pressure Side of the Fuel System
12	High Pressure Side of the Fuel System

The fuel tank stores the fuel supply. An electric fuel pump mounted in the tank provides low pressure fuel to the high pressure fuel pump and exhaust aftertreatment fuel injector (if equipped). The engine control module (ECM) controls the fuel pump operation. Fuel is pumped through the fuel feed pipe 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 exhaust aftertreatment fuel injector (if equipped) and high pressure fuel pump. The belt driven high pressure fuel pump is mounted on the lower left corner of the engine block. High pressure fuel is supplied through the high pressure fuel line to the fuel injection fuel rail assembly and then through the fuel injector lines to the fuel injectors. Fuel pressure is controlled by the ECM, fuel pressure regulator 1 and fuel pressure regulator 2 (if equipped). Excess fuel then returns to the fuel tank through the fuel return pipes.

Exhaust Aftertreatment Fuel Injector (if equipped)

The exhaust aftertreatment fuel injector, also known as the low pressure diesel hydrocarbon injector is located on the passenger side frame rail. The exhaust aftertreatment fuel injector is used to inject fuel into the exhaust system to generate the required heat needed by the diesel oxidation catalyst to function properly.

Fuel Cooler (if equipped)

The fuel cooler is located under the vehicle and the returning fuel runs through it in order to cool the fuel before returning to the vehicle's fuel tank.

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.

Fuel Fill Cap

Fuel Fill Cap (if equipped)

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

Capless Fuel Fill (if equipped)

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

Fuel Filter Assembly

The fuel filter assembly is located near the left frame rail and contains the following 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 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. When the relay is 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 Injectors

A fuel injector is a solenoid device, controlled by the ECM, that meters pressurized fuel to a single engine cylinder. Fuel from the fuel injector tip is sprayed directly into the combustion chamber on the compression stroke of the engine. 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.

Fuel Pipe O-Rings

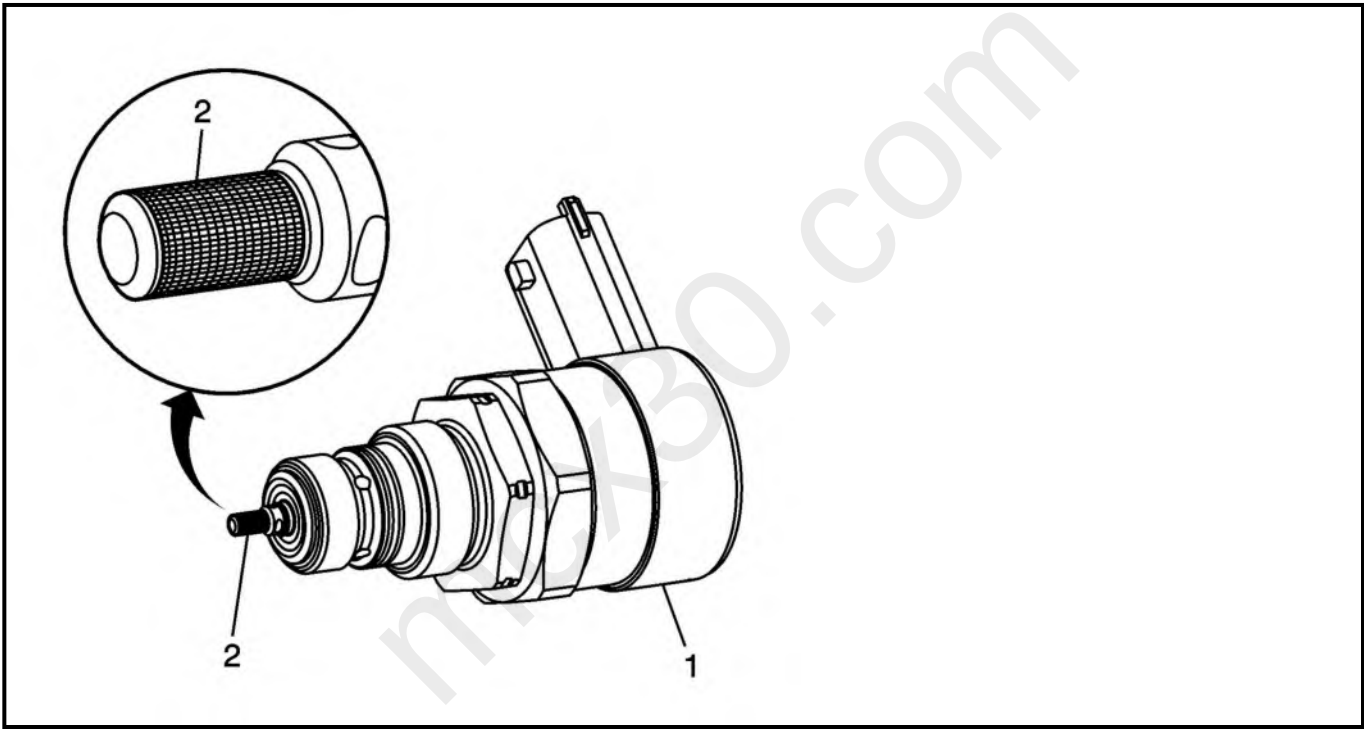
O-rings seal the connections in the fuel system. Fuel system O-ring seals are made of special material. Service the O-ring seals with the correct service part.

Fuel Pressure Regulator 1

The engine control module (ECM) controls the fuel rail pressure using two pulse width modulated fuel rail pressure regulators. Fuel pressure regulator 1 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



Callout	Component Name
1	Fuel Pressure Regulator 2
2	Filter Screen

The engine control module (ECM) controls the fuel rail pressure using two pulse width modulated fuel rail pressure regulators. Fuel pressure regulator 2 is located on the end of the fuel rail and meters the amount of fuel being returned to the fuel tank. The ECM varies the pulse width modulated voltage to the fuel pressure regulator 2 to relieve excessive fuel pressure which returns to the fuel tank. When the ignition is OFF, fuel pressure regulator 2 opens to bleed off the pressure in the fuel rail.

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 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 Rail Pressure Sensor

Fuel Rail Pressure Sensor - one signal analog

The fuel rail pressure sensor is a single analog sensor that provides a fuel rail pressure signal to the engine control module (ECM) and is located in the end of the fuel rail assembly. The ECM provides a 5 V reference voltage on the 5 V reference circuit and ground on the low reference circuit. When the fuel pressure is high, the fuel rail pressure sensor signal voltage is high. When the fuel pressure is low, the fuel rail pressure sensor signal voltage is low.

Fuel Rail Pressure Sensor - Dual signal analog

The fuel rail pressure sensor is a dual analog sensor that provides two fuel rail pressure signals to the engine control module (ECM) and is located in the end of the fuel rail assembly. The ECM provides a 5 V reference voltage on the 5 V reference circuit and ground on the low reference circuit. The ECM receives a varying signal voltage on both the fuel rail pressure sensor and fuel rail pressure sensor 2 signal circuits. The ECM monitors the voltage on both of the fuel rail pressure sensor circuits and compares the values to determine if the sensors are accurate. When the fuel pressure is high, the fuel rail pressure sensor signal voltage is high and the fuel rail pressure sensor 2 signal voltage is low. When the fuel pressure is low, the fuel rail pressure sensor signal voltage is low and the fuel rail pressure sensor 2 signal voltage is high.

Fuel Tank

The fuel tank stores the fuel supply. The fuel tank is held in place by 2 metal straps that attach to the frame. The fuel tank is molded from high density polyethylene.

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 engine control module (ECM) sends the fuel level information 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 ECM also monitors the fuel level input for various diagnostics.

Fuel Pump

The fuel pump is mounted in the primary fuel tank module reservoir. The fuel pump is an electric pump. Fuel is pumped to the mechanical fuel injection pump at a specified flow and pressure. The control module controls the electric fuel pump operation through a fuel pump relay.

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.

High Pressure Fuel Pump

The high pressure fuel pump is a mechanical pump. The high pressure fuel pump is located on the lower left side of the engine. The high pressure fuel pump provides high pressure fuel to the fuel rail at a specified pressure regulated by the fuel pressure regulators.

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.

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.

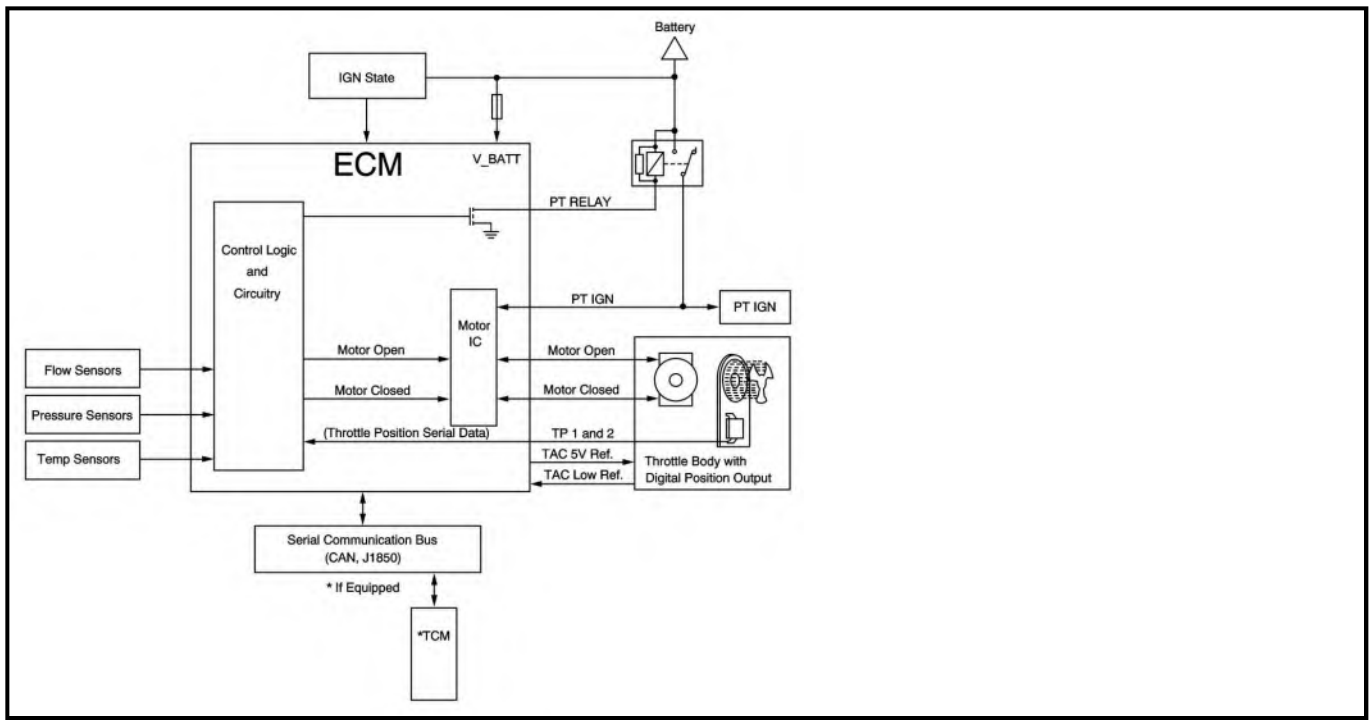
The ECM provides glow plug operation after starting a cold engine. This post-start operation is initiated when the ignition switch is returned to Run, from the Start position. This function helps clean up excessive white smoke and/or poor idle quality after starting.

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.

INTAKE AIRFLOW VALVE SYSTEM DESCRIPTION



The intake air flow valve actuator 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 air flow valve contains a contact-less inductive valve position sensing element that is managed by a customized integrated circuit. The intake air flow valve 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 intake air flow valve position sensor provides a signal that changes relative to air flow 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 intake air flow valve 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 a voltage which is displayed on a scan tool as intake air flow valve position sensor.

SPEED LIMITING DESCRIPTION

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

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

Functions that will limit the vehicle speed

- Tire Rating
- Prop-shaft/Transfer case speed rating
- Protection from reduced lubrication
- Electric motor speed rating
- Powertrain Thermal Protection
- Diesel Exhaust Fluid legislated limits
- Valet or Teen Driver Modes
- OnStar Stolen Vehicle Feature

- Commercial Truck / Rental Vehicle Speed Limits
- Powertrain control system faults
- Braking system faults
- Damping system faults
- Leveling system faults

System Components

Engine Control Module (ECM)

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

Body Control Module (BCM)

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

Electronic Brake Control Module (EBCM)

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

Suspension and Damping System

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

OnStar Enhanced Services

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

Automatic Leveling Control

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

Integrated Chassis Control Module

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

Rear Driveline Control Module / Transfer Case Control Module

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

Hybrid Module

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

Transmission Control Module

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

Driver Information Center

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

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