Fuel Charging and Controls - System Operation and Component Description

System Operation

Air Fuel Ratio Imbalance Monitor

The air fuel ratio imbalance monitor is an on board diagnostic strategy designed to monitor the air fuel ratio.

Air Fuel Ratio Imbalance Monitor — Heated Oxygen Sensor (HO2S) Monitor

The air fuel ratio imbalance monitor estimates the cylinder to cylinder air fuel ratio difference using the universal HO2S high frequency signal. The high frequency signal is updated at least once per engine combustion event to determine the amount the universal HO2S signal is affected by individual cylinders. The result is a measurement of individual cylinder effect on the universal HO2S . If the measurement exceeds a calibrated threshold, it is added to a differential signal accumulation window. An accumulation window is at least 50 engine revolutions. The differential signal accumulation is then compared to a calibrated signal threshold. A counter is incremented if the threshold is exceeded. This process is repeated for a calibrated number of total windows. After completing the calibrated number of windows the air fuel ratio imbalance index is calculated. The air fuel ratio imbalance index is a ratio of failed RPM windows over total RPM windows required to complete the monitor. If the air fuel ratio imbalance index exceeds the threshold value the test fails.

The MIL is activated after a concern is detected on 2 consecutive drive cycles.

Air Fuel Ratio Imbalance Monitor — Torque Monitor

The air fuel ratio imbalance torque monitor is supplemented by the air fuel ratio imbalance monitor HO2S monitor. The air fuel ratio imbalance monitor torque monitor is used to detect small levels of cylinder to cylinder air fuel ratio imbalance. The monitor uses the CKP to calculate an acceleration term during each cylinder firing event. The calculated acceleration value is proportional to engine torque during the firing event. The monitor will modulate each cylinder to generate an air fuel ratio deviation relative to stoichiometric operation. The monitor generates five total torque values for each cylinder. Two torque values richer than stoichiometric, two torque values leaner than stoichiometric and one torque value at stoichiometric. The monitor uses a calibrated torque curve defined by the five generated values compared to an ideal torque curve to estimate each cylinder air fuel ratio deviation. The monitor estimates each cylinder air fuel ratio deviation compared to the other cylinders to determine if a concern exists.

The MIL is activated after a concern is detected during a drive cycle.

Deceleration Fuel Shut Off (DFSO)

During a DFSO event the PCM disables the fuel injectors. A DFSO event occurs during closed throttle, deceleration; similar to exiting a freeway. This strategy improves fuel economy, allows for increased rear HO2S concern detection, and allows for misfire profile correction learning. On vehicles with direct fuel injection, the PCM may also disable the ignition coils. This strategy extends spark plug life during the fuel shutoff events.

Flex Fuel

Flex fuel vehicles are designed to be compatible with any combination of ethanol and gasoline up to 85% ethanol (E85). The percentage of ethanol content in the fuel is inferred by the PCM flex fuel strategy.

The fuel level input (FLI) determines if a refueling event has occurred after an ignition ON or while the engine is running. If a refueling event is detected, the PCM saves the current inferred ethanol value. The PCM flex fuel strategy recognizes a refueling event as gasoline or E85, and enables the flex fuel learn procedure. The flex fuel strategy will infer the correct air to fuel ratio, based on the oxygen sensor input, to maintain stoichiometry after the vehicle refueling event occurs.

The new fuel is calculated to reach the engine after a calibrated amount of fuel has been consumed from the fuel lines and fuel rails. Normal long term fuel trim learning and EVAP purge control are temporarily disabled to allow the new ethanol content to gasoline percentage to be inferred. Ethanol content learning continues until the inference is stabilized within the engine operating conditions.

Typical flex fuel vehicle operation:

- The initial air to fuel ratio and flex fuel percentage is calculated for gasoline after a KAM reset. Vehicles that have E85 in the fuel tank after having a KAM reset may result in a hard start when cold, or a cold engine acceleration lack of power, until the PCM flex fuel strategy calculates the correct percentage of ethanol content in the fuel.
- A cold start with alcohol blended fuel may be more difficult than with gasoline, due to the lower volatility of alcohol blended fuel.
- Ethanol requires more fuel flow than gasoline, and flex fuel vehicles require a higher flow injector.
- Vehicles with flex fuel capability have the fuel type identified on the fuel filler pipe.

Fuel Injection Systems

There are 2 types of fuel injection systems, direct fuel injection and port fuel injection. The direct fuel injection system delivers fuel directly into the engine cylinder. The port fuel injection system delivers fuel into the intake manifold ports where the fuel is mixed with air and enters the engine cylinder through the intake valve.

On engines with dual fuel injection systems, both the direct fuel injection system and the port fuel injection system are used to deliver fuel to the engine. During heavy acceleration, or higher engine loads, the direct fuel injection system is used to deliver fuel to the engine. During idle, or low engine load conditions, the port fuel injection system is used to deliver fuel to the engine. Both fuel injection systems may not be active at the same time. The PCM will ignore any related fuel system sensor inputs, if either fuel injection system is inactive. Related fuel injector DTCs can only be set while the direct fuel injection system or the port fuel injection system is active. A scan tool may be used to activate either system to assist in isolating the fuel injector concerns.

Fuel System Monitor

The fuel system monitor is an on board strategy designed to monitor the fuel control system. The fuel control system uses fuel trim tables stored in the PCM KAM to compensate for the variability that occurs in fuel system components due to normal wear and aging. Fuel trim tables are based on air mass. During closed loop fuel control, the fuel trim strategy learns the corrections needed to correct a biased rich or lean fuel system. The correction is stored in the fuel trim tables. The fuel trim has 2 means of adapting: long term fuel trim and a short term fuel trim. Long term fuel trim relies on the fuel trim tables and short term fuel trim refers to the desired air to fuel ratio parameter called LAMBSE. LAMBSE is calculated by the PCM from the universal HO2S inputs and helps maintain a 14.7 to 1 (9 to 1 E100) air to fuel ratio during closed loop operation. Short term fuel trim and long term fuel trim work together. If the universal HO2S indicates the engine is running rich, the PCM corrects the rich condition by moving the short term fuel trim into the negative range, less fuel to correct for a rich combustion. If after a certain amount of time the short term fuel trim is still compensating for a rich condition, the PCM learns this and moves the long term fuel trim into the negative range to compensate and allow the short term fuel trim to return to a value near 0%. Inputs from the CHT sensor or the ECT sensor, the IAT sensor and the MAF sensor (if equipped) are required to activate the fuel trim system, which in turn activates the fuel system monitor. Once activated, the fuel system monitor looks for the fuel trim tables to reach the adaptive clip (adaptive limit) and LAMBSE to exceed a calibrated limit. The fuel system monitor stores the appropriate DTC when a concern is detected as

described below.

- The universal HO2S detects the presence of oxygen in the exhaust and provides the PCM with feedback indicating air to fuel ratio.
- A correction factor is added to the fuel injector pulse width calculation and the mass airflow calculation, according to the long and short term fuel trims as needed to compensate for variations in the fuel system.
- When deviation in the LAMBSE parameter increases, air to fuel control suffers and emissions increase. When LAMBSE exceeds a calibrated limit and the fuel trim table has clipped, the fuel system monitor sets a DTC. The DTCs associated with the monitor detecting a lean shift in fuel system operation are P0171 (Bank 1) and P0174 (Bank 2). The DTCs associated with the monitor detecting a rich shift in fuel system operation are P0172 (Bank 1) and P0175 (Bank 2).
- The MIL is activated after a concern is detected on 2 consecutive drive cycles.

Typical fuel system monitor entry conditions:

- Air mass range greater than 5.67 g/sec (0.75 lb/min)
- Purge duty cycle of 0%
- Engine coolant temperature is between 65.5° C to 110° C (150° F to 230° F)
- Engine load greater than 12%
- Intake air temperature -34° C to 65° C (-30° F to 150° F)

Typical fuel monitor thresholds:

- Lean Condition Concern: LONGFT greater than 25%, SHRTFT greater than 5%
- Rich Condition Concern: LONGFT less than 25%, SHRTFT less than 10%

Fuel Trim

Short Term Fuel Trim

If the oxygen sensors are warmed up and the PCM determines the engine can operate near the 14.7 to 1 (9 to 1 E100) stoichiometric air to fuel ratio, the PCM enters closed loop fuel control mode. Since an oxygen sensor can only indicate rich or lean, the fuel control strategy continuously adjusts the desired air to fuel ratio between rich and lean causing the oxygen sensor to switch around the stoichiometric point. If the time between rich and lean switches is the same, then the system is actually operating at stoichiometric. The desired air to fuel control parameter is called short term fuel trim (SHRTFT1 and SHRTFT2) where stoichiometric is represented by 0%. Richer (more fuel) is represented by a positive number and leaner (less fuel) is represented by a negative number. Normal operating range for short term fuel trim is between -25% and 25%. Some calibrations have time between switches and short term fuel trim excursions that are not equal. These unequal excursions run the system slightly lean or rich of stoichiometric. This practice is referred to as using bias. For example, the fuel system can be biased slightly rich during closed loop fuel to help reduce nitrogen oxides (NO_x).

Values for SHRTFT1 and SHRTFT2 may change significantly on a scan tool as the engine is operated at different RPM and load points. This is because SHRTFT1 and SHRTFT2 react to fuel delivery variability that changes as a function of engine RPM and load. Short term fuel trim values are not retained after the engine is turned OFF.

Long Term Fuel Trim

While the engine is operating in closed loop fuel control, the short term fuel trim corrections are learned by the PCM as long term fuel trim (LONGFT1 and LONGFT2) corrections. These corrections are stored in the KAM fuel trim tables. Fuel trim tables are based on engine speed and load and by bank for engines with 2

HO2S forward of the catalyst. Learning the corrections in KAM improves both open loop and closed loop air fuel ratio control. Advantages include:

- Short term fuel trim does not have to generate new corrections each time the engine goes into closed loop.
- Long term fuel trim corrections can be used while in open loop and closed loop modes.

Long term fuel trim is represented as a percentage, similar to the short term fuel trim, however it is not a single parameter. A separate long term fuel trim value is used for each RPM and load point of engine operation. Long term fuel trim corrections may change depending on the operating conditions of the engine (RPM and load), ambient air temperature, and fuel quality (% alcohol, oxygenates). When viewing the LONGFT1 and LONGFT2 PIDs, the values may change a great deal as the engine is operated at different RPM and load points. The LONGFT1 and LONGFT2 PID display the long term fuel trim correction currently being used at that RPM and load point.

High Pressure Fuel System

The high pressure fuel system receives low pressure fuel from the fuel pump assembly and delivers fuel at high pressure to the direct injection fuel injectors.

The high pressure fuel system consists of the fuel injection pump, the fuel volume regulator, the FRP sensor, the fuel supply line, the fuel rail, and the fuel injectors.

The fuel injection pump receives fuel from the fuel pump assembly, increases the fuel pressure from approximately 448 kPa (65 psi) to a PCM determined pressure up to as high as 15 MPa (2175 psi), and delivers it to the fuel rails.

The fuel volume regulator controls the volume of low pressure fuel that enters the inlet check valve and the pump piston inside the fuel injection pump. The PCM regulates fuel pressure by controlling the timing of the fuel volume regulator solenoid.

High pressure fuel exits the fuel injection pump and is delivered to the fuel rails through the fuel supply line. The fuel rails distribute and channel high pressure fuel to the fuel injectors.

The FRP sensor provides a feedback signal to indicate the fuel rail pressure so the PCM can command the correct injector timing and pulse width for correct fuel delivery at all speed and load conditions.

The fuel injectors meter fuel flow to the engine. A given cylinder fuel injector can deliver single or multiple injections for each cylinder event. The amount of fuel is controlled by the length of time the fuel injectors are held open.

Heated Oxygen Sensor (HO2S) Monitor

The HO2S monitor is an on board strategy designed to monitor the heated oxygen sensors for concerns or deterioration which can affect emissions. The fuel control or stream 1 HO2S are checked for correct output voltage and response rate. Response rate is the time it takes to switch from lean to rich or rich to lean. The rear or stream 2 HO2S is monitored for correct output voltage and is used for catalyst monitoring and fore aft oxygen sensor (FAOS) control. Input is required from the CMP sensor, the CKP sensor, the ECT sensor or the CHT sensor, the fuel rail pressure temperature (FRPT) sensor, the fuel tank pressure (FTP) sensor, the IAT sensor, the MAF sensor (if equipped), the MAP sensor, the TP sensor and vehicle speed to activate the HO2S monitor. The fuel system monitor and misfire detection monitor must also have completed successfully before the HO2S monitor is enabled.

The HO2S senses the oxygen content in the exhaust flow. Lean of stoichiometric, air to fuel ratio of approximately 14.7 to 1 (9 to 1 E100), the HO2S generates a voltage less than 0.45 volt. Rich of stoichiometric, the HO2S generates a voltage greater than 0.45 volt. The current required to maintain the

universal HO2S at 0.45 volt is used by the PCM to calculate the air to fuel ratio. The HO2S monitor evaluates the HO2S for correct function.

The time between HO2S switches is monitored after vehicle startup and during closed loop fuel conditions. Excessive time between switches or no switches since startup indicates a concern. Since lack of switching concerns can be caused by HO2S concerns or by shifts in the fuel system, DTCs are stored that provide additional information for the lack of switching concern. Different DTCs indicate whether the sensor always indicates lean, rich, or disconnected. The HO2S signal is also monitored for high voltage. An over voltage condition is caused by a HO2S heater or battery power short to the HO2S signal line.

A functional test of the rear HO2S is done during normal vehicle operation. The peak rich and lean voltages are continuously monitored. Voltages that exceed the calibrated rich and lean thresholds indicate a functional sensor. If the voltages have not exceeded the thresholds after a long period of vehicle operation, the air to fuel ratio may be forced rich or lean in an attempt to get the rear sensor to switch. This situation normally occurs only with a green, less than 804.7 km (500 miles), catalyst. If the sensor does not exceed the rich and lean peak thresholds, a concern is indicated. Also, a deceleration fuel shut off (DFSO) rear HO2S response test is done during a deceleration fuel shut off (DFSO) event. Carrying out the HO2S response test during a DFSO event helps to isolate a sensor concern from a catalyst concern. The response test monitors how quickly the sensor switches from a rich to lean voltage. It also monitors if there is a delay in the response to the rich or lean condition. If the sensor responds very slowly to the rich to lean voltage switch or is never greater than a rich voltage threshold or less than a lean voltage threshold, a concern is indicated.

The MIL is activated after a concern is detected on 2 consecutive drive cycles.

Idle Air Trim

Idle air trim is designed to adjust the idle air control calibration to correct for wear and aging of components. When the engine conditions meet the learning requirement, the strategy monitors the engine and determines the values required for ideal idle calibration. The idle air trim values are stored in a table for reference. This table is used by the PCM as a correction factor when controlling the idle speed. The table is stored in the KAM and retains the learned values even after the engine is shut OFF. A DTC is set if the idle air trim has reached its learning limits.

Whenever an idle air control component is replaced, or a repair affecting idle is carried out, it is recommended the KAM be reset. This is necessary so the idle strategy does not use the previously learned idle air trim values. It is important to note that erasing DTCs with a scan tool does not reset the idle air trim table.

Once the KAM has been reset, the engine must idle for 15 minutes (actual time varies between strategies) to learn new idle air trim values. Idle quality improves as the strategy adapts. Adaptation occurs in 4 separate modes as shown in the following table.

Idle Air Trim Learning Modes

NEUTRAL	A/C ON
NEUTRAL	A/C OFF
DRIVE	A/C ON
DRIVE	A/C OFF

Torque Based Electronic Throttle Control (ETC)

The torque based ETC is a hardware and software strategy that delivers an engine output torque (via throttle angle) based on driver demand (pedal position). It uses an electronic throttle body throttle actuator control (TAC), the PCM , and an accelerator pedal assembly to control the throttle opening and engine torque.

Torque based ETC enables aggressive automatic transmission shift schedules (earlier upshifts and later downshifts). This is possible by adjusting the throttle angle to achieve the same wheel torque during shifts, and by calculating this desired torque, the system prevents engine lugging (low RPM and low manifold vacuum) while still delivering the performance and torque requested by the driver. It also enables many fuel economy/emission improvement technologies such as VCT , which delivers same torque during transitions.

The torque based ETC system illuminates a powertrain malfunction indicator (wrench) on the instrument panel cluster (IPC) when a concern is present. Concerns are accompanied by diagnostic trouble codes (DTCs) and may also illuminate the MIL .

Electronic Throttle Control (ETC) System Strategy

The ETC strategy was developed to improve fuel economy and to accommodate variable camshaft timing. This is possible by not coupling the throttle angle to the driver pedal position. Uncoupling the throttle angle (produce engine torque) from the pedal position (driver demand) allows the powertrain control strategy to optimize fuel control and transmission shift schedules while delivering the requested wheel torque.

The ETC monitor system is distributed across 2 processors within the PCM : the main powertrain control processor unit (CPU) and a separate monitoring processor. The primary monitoring function is carried out by the independent plausibility checker software, which resides on the main processor. It is responsible for determining the driver demanded torque and comparing it to an estimate of the actual torque delivered. If the generated torque exceeds driver demand by a specified amount, appropriate corrective action is taken.

ETC System Failure Mode and Effects Management:

Effect	Failure Mode
No Effect On Driveability	A loss of redundancy or loss of a non critical input could result in a concern that does not affect driveability. The powertrain malfunction indicator (wrench) illuminates, but the MIL does not illuminate in this mode. However, cruise control and PTO may be disabled. A DTC sets to indicate the component or circuit with the concern.
Delayed APP Sensor Response With Brake Override	This mode is caused by the loss of one APP sensor input due to sensor, wiring, or PCM concerns. The system is unable to verify the APP sensor input and driver demand. The throttle plate response to the APP sensor input is delayed as the accelerator pedal is applied. The engine returns to idle RPM whenever the brake pedal is applied. The powertrain malfunction indicator (wrench) illuminates, but the MIL does not illuminate in this mode. An APP sensor related DTC sets.
Time Based Driver Demand With Brake Override	This mode is caused by the loss of one BPP and one APP sensor input or both APP sensor inputs due to sensor, wiring, or PCM concerns. The system is unable to determine driver demand. There is no response when the accelerator pedal is applied. The engine returns to idle RPM whenever the brake pedal is applied. When the brake pedal is released, the PCM slowly increases the APP signal to a fixed value. The powertrain malfunction indicator (wrench) illuminates, but the MIL does not illuminate in this mode. An APP or BPP sensor related DTC sets.
RPM Guard With Pedal Follower	In this mode, torque control is disabled due to the loss of a critical sensor or PCM concern. The throttle is controlled in pedal follower mode as a function of the APP sensor input only. A maximum allowed RPM is determined based on the position of the accelerator pedal (RPM Guard). If the actual RPM exceeds this limit, spark and fuel are used to bring the RPM below the limit. The powertrain malfunction indicator (wrench) and

	the MIL illuminate in this mode and a DTC for an ETC related component sets. The EGR and VCT outputs are set to default values and cruise control is disabled.
RPM Guard With Default Throttle	In this mode, the throttle plate control is disabled due to the loss of both TP sensor inputs, loss of throttle plate control, stuck throttle plate, significant processor concerns, or other major electronic throttle body concern. The spring returns the throttle plate to the default (limp home) position. A maximum allowed RPM is determined based on the position of the accelerator pedal (RPM Guard). If the actual RPM exceeds this limit, spark and fuel are used to bring the RPM below the limit. The powertrain malfunction indicator (wrench) and the MIL illuminate in this mode and a DTC for an ETC related component sets. The EGR and VCT outputs are set to default values and cruise control is disabled.

Component Description

Electronic Throttle Body Throttle Actuator Control (TAC)

The electronic throttle body TAC is a DC motor controlled by the PCM . There are 2 designs for the electronic throttle body TAC, parallel and inline. The parallel design has the motor under the bore parallel to the plate shaft. The motor housing is integrated into the main housing. The inline design has a separate motor housing. Both designs use an internal spring to return the throttle plate to a default position. The default position is typically a throttle angle of 7 to 8 degrees from the hard stop angle. The closed throttle plate hard stop prevents the throttle from binding in the bore. This hard stop setting is not adjustable and is set to result in less airflow than the minimum engine airflow required at idle.

Electronic Throttle Body Throttle Position Sensor (ETBTPS)

The ETBTPS has one digital signal output from the sensor. There is one reference voltage circuit (ETCREF) and one signal return circuit (ETCRTN) for the sensor dedicated to the ETBTPS.

Fuel Injection Pump

NOTE: *Do not apply battery positive (B+) voltage directly to the fuel volume regulator solenoid electrical connector pins. Internal damage to the solenoid may occur in a matter of seconds.*

The engine driven fuel injection pump increases fuel rail pressure to the desired level to support fuel injection requirements. Unlike conventional port fuel injection systems, with direct injection the desired fuel rail pressure ranges widely over operating conditions. The pump receives fuel from the fuel pump (FP) assembly, increases the fuel pressure from approximately 448 kPa (65 psi) to a variable pressure up to 20 MPa (2900 psi), and delivers it to the fuel rails. The fuel injection pump is driven by a dedicated intake camshaft lobe and is located on top of the engine.

The fuel volume regulator is a solenoid valve permanently mounted to the pump assembly. The PCM commands the fuel volume regulator to meter in a specified fuel volume with each pump stroke. The PCM regulates the fuel volume entering the rail to achieve the desired fuel rail pressure.

The fuel volume regulator control is synchronous to the cam position on which the pump is mounted. The fuel volume regulator control takes into account that camshaft phasing varies during engine operation for purposes of valve control.

Fuel Injectors

NOTICE: Do not apply battery positive (B+) voltage directly to the fuel injector electrical connector pins. Internal damage to the solenoid may occur in a matter of seconds.

The fuel injector is a solenoid operated valve that meters fuel flow to the engine. The fuel injector opens and

closes a constant number of times per crankshaft revolution. The amount of fuel is controlled by the length of time the fuel injector is held open.

The fuel injector is normally closed and is operated by a 12 volt source. The ground signal is controlled by the PCM .

The fuel injector is a deposit resistant injector (DRI) type and does not have to be cleaned. Install a new fuel injector if the flow is checked and found to be out of specification.

Fuel Injectors — Direct Injection

The gasoline direct fuel injection fuel injector delivers fuel directly into the cylinder under high pressure. Each injector is controlled by 2 circuits from the PCM .

A boosted voltage supply, up to 65 volts, is generated in the PCM and used to initially open the injector. The injector driver controls three transistor switches that apply the boost voltage to open the injector and then modulates the current to hold the injector open. If boost voltage is unavailable, the correct injector opening current may not be generated in the time required.

The PCM contains a smart driver that monitors and compares high side and low side injector currents to diagnose numerous concerns. Each fuel injector high side circuit is paired inside the PCM with another fuel injector high side circuit. All injector concerns are reported with a single DTC per injector.

Fuel Rail Pressure (FRP) Sensor

The FRP sensor sensor is a diaphragm strain gauge device. The FRP sensor sensor measures the pressure difference between the fuel rail and atmospheric pressure. The FRP sensor sensor nominal output varies between 0.5 and 4.5 volts, with 0.5 volts corresponding to 0 MPa (0 psi) gauge and 4.5 volts corresponding to 26 MPa (3771 psi) gauge. The FRP sensor can read vacuum and may lower the output voltage to slightly below 0.5 volts. This condition is normal and is usually the case after several hours of cold soak.

The FRP sensor sensor is located on the fuel rail and provides a feedback signal to indicate the fuel rail pressure to the PCM . The PCM uses the fuel rail pressure (FRP) signal to command the correct injector timing and pulse width for correct fuel delivery at all speed and load conditions. The FRP sensor, along with the fuel volume regulator (part of the fuel injection pump), form a closed loop fuel pressure control system. An electrically faulted FRP sensor sensor results in the deactivation of the fuel injection pump. Fuel pressure to injectors is then provided only by the fuel pump (FP) assembly. When the fuel injection pump is de-energized and the injectors are active, the fuel rail pressure is approximately 70 kPa (10 psi) lower than fuel pump (FP) assembly pressure due to the pressure drop across the fuel injection pump. Thus, if the fuel pump (FP) assembly pressure is 448 kPa (65 psi), then the fuel rail pressure would be approximately 379 kPa (55 psi) if the injectors are active.

Fuel Rail Pressure Temperature (FRPT) Sensor

The temperature component of the fuel rail pressure temperature (FRPT) sensor is a thermistor device in which resistance changes with temperature. The electrical resistance of a thermistor decreases as the temperature increases, and resistance increases as the temperature decreases. The varying resistance affects the voltage drop across the sensor terminals and provides electrical voltage signals to the PCM corresponding to temperature.

The pressure component of the fuel rail pressure temperature (FRPT) sensor provides a signal to the PCM indicating fuel rail pressure. The PCM supplies a 5 volt reference (VREF) signal, as well as supplying 5 volts on the fuel rail pressure (FRP) circuit. As pressure increases, the sensor signal voltage decreases.

The fuel rail pressure temperature (FRPT) sensor measures the pressure and temperature of the fuel in the fuel rail and sends these signals to the PCM . The PCM uses the fuel pressure and temperature sensor

inputs to command the correct fuel pump speed. The relationship between the fuel pressure and the fuel temperature is also used to determine the possible presence of fuel vapor in the fuel rail.

Heated Oxygen Sensor (HO2S)

The HO2S detects the presence of oxygen in the exhaust and produces a variable voltage according to the amount of oxygen detected. A high concentration of oxygen (lean air to fuel ratio) in the exhaust produces a voltage signal less than 0.4 volt. A low concentration of oxygen (rich air to fuel ratio) produces a voltage signal greater than 0.6 volt. The HO2S provides feedback to the PCM indicating air to fuel ratio in order to achieve a near stoichiometric air to fuel ratio of 14.7 to 1 (9 to 1 E100) during closed loop engine operation.

When the oxygen sensor is cold, disconnected or on initial start up, the voltage may read between 1.5 to 1.7 volts. The oxygen sensor voltage will decrease to the normal operating range of 0.0 to 1.1 volts during warm, stabilized engine running conditions.

The HO2S heater is embedded with the sensing element. The heating element heats the sensor to a temperature of 800°C (1,472°F). At approximately 300°C (572°F) the engine enters closed loop operation. The VPWR circuit supplies voltage to the heater. The PCM turns the heater ON by providing the ground when the correct conditions occur. The heater allows the engine to enter closed loop operation sooner. The use of this heater requires the HO2S heater control to be duty cycled, to prevent damage to the heater.

Universal Heated Oxygen Sensor (HO2S)

The universal HO2S , sometimes referred to as a wideband oxygen sensor, uses the typical HO2S combined with a current controller in the PCM to infer an air to fuel ratio relative to the stoichiometric air to fuel ratio. This is accomplished by balancing the amount of oxygen ions pumped in or out of a measurement chamber within the sensor. The typical HO2S within the universal HO2S detects the oxygen content of the exhaust gas in the measurement chamber. The oxygen content inside the measurement chamber is maintained at the stoichiometric air to fuel ratio by pumping oxygen ions in and out of the measurement chamber. As the exhaust gasses get richer or leaner, the amount of oxygen that must be pumped in or out to maintain a stoichiometric air to fuel ratio in the measurement chamber varies in proportion to the air to fuel ratio. The amount of current required to pump the oxygen ions in or out of the measurement chamber is used to measure the air to fuel ratio. The measured air to fuel ratio is actually the output from the current controller in the PCM and not a signal that comes directly from the sensor.

The universal HO2S also uses a self contained reference chamber to make sure an oxygen differential is always present. The oxygen for the reference chamber is supplied by pumping small amounts of oxygen ions from the measurement chamber into the reference chamber. The universal HO2S does not need access to outside air.

Part to part variance is compensated for by placing a resistor in the connector. This resistor trims the current measured by the current controller in the PCM .

The universal HO2S heater is embedded with the sensing element allowing the engine to enter closed loop operation sooner. The heating element heats the sensor to a temperature of 780°C to 830°C (1,436°F to 1,526°F). The VPWR circuit supplies voltage to the heater. The PCM controls the heater ON and OFF by providing the ground to maintain the sensor at the correct temperature for maximum accuracy.