# CDS G3 and the PCM 09

## Section 2B - PCM 09 and Emissions Control Overview



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# Section Overview

This section deals with examining the data returned by the engine sensors, resolving faults that have been detected, and adjusting engine operation to achieve optimal engine running conditions. In the case of emission-controlled engines, that means achieving an air/fuel ratio that is neither too rich nor lean, producing the least amount of harmful emissions. Refer to **Section 1C** - **Emissions Control** for information on the components of exhaust fumes.

Faults can indicate an operation condition such as an overheating engine, or they can indicate a failure in a sensor or actuator circuit. There are also special OBD-M faults that indicate that the emissions control system is not functioning correctly. If an engine cannot enter closed-loop control, it will revert to using predefined look-up tables as described in **Section 1B** - **Speed/ Density Theory**.

When connected to the CDS G3, the PCM 09 provides valuable live data, providing insight into engine operation, and interactive tests, to aid you in diagnosing engine faults. **Section D** contains an explanation of each of these items. Taking the time to become familiar with the typical and expected values of these data items will help increase your proficiency with the system.

# An Overview of Emissions Control

An air/fuel mixture that is neither rich nor lean will burn all of the fuel and all of the oxygen. This equilibrium point where the mixture is neither rich nor lean is called **stoichiometry**. An air-to-fuel ratio that is less than stoichiometric is considered rich, while an air-to-fuel ratio that is greater than stoichiometric is considered lean.

In practice, the actual stoichiometric ratio can change based upon factors such as fuel blend. For a 10% ethanol blend, the ratio may be 14.1:1, while for a pure gasoline fuel, the ratio is 14.7:1. To allow for these differences, we use the **equivalency ratio**. This is defined as the ratio of the actual air/fuel ratio to the stoichiometric air/fuel ratio: actual/ideal = equivalency. An equivalency ratio of 1.00 means that the combustion is stoichiometric. A ratio of 1.03 means the blend is 3% rich. A blend of 0.97 means that it is 3% lean.

Using oxygen (O2) sensors before and after the catalysts, the PCM can measure the air/fuel ratio and make adjustments accordingly, adding or subtracting fuel to the values found in the legacy look-up charts. When it is in this state, it is in **closed**-**loop control** or using a **proportional**-**integral**-**differential control strategy (PID)**. To implement this strategy, the PCM must ensure that all sensors are working and then constantly measure the engine's output.

*NOTE: It is possible for one engine bank to be in closed-loop control while the other is using legacy fueling tables due to a bank-specific fault.*

In discussing the PCM, there are a few other terms to become familiar with:

- **Closed**-**loop control** or **Proportional**-**Integral**-**Differential Control Strategy (PID)**: This is when the PCM 09 is monitoring and adjusting the air/fuel ratio to ensure compliance with emission control standards. When the engine is operating above 80% load, it is no longer under closed-loop control. When the engine is out of closed-loop control, either because it is operating above 80% load or because the system is unable to enter closed-loop control, the system reverts to **legacy fuel delivery**, a predetermined table of air/fuel values.
- **Error**: The difference between where the system is and where we want the system to be, in regards to the air-to-fuel mixture. It may also be referred to as **ITerm**.
- **EWMA or Exponentially Weighted Moving Average**: A statistical method for averaging the oxygen storage capacity of a catalyst.
- **Legacy fuel delivery**: The term used for the amount of fueling that occurs along a predefined power curve from idle to wide-open throttle. When the system is unable to enter closed-loop or PID, it will revert to this table for values to be used in determining the appropriate air/fuel ratio in accordance with the **fuel density theory** (**Section 1B** - **Speed/Density Theory**).
- **Oxidizing**: Running the air-to-fuel ratio lean to saturate the catalyst with oxygen.
- **OBD**-**II**: This stands for **Onboard Diagnostics Second Generation**. This was developed for automobiles in the United States in the 1990s.
- **OBD**-**M**: This means **Onboard Diagnostics** - **Marine**.
- **OSC (oxygen storage capacity)**: The amount of oxygen that can be stored in the cerium layer of the catalyst washcoat.
- **Perturbation**: Having the fuel cycle between rich and lean in a very short period of time.
- **Reducing**: Running the air-to-fuel ratio rich to remove all of the oxygen from the catalyst.
- **Pre O2 or Post O2 Sensor**: Shorthand for precatalyst or postcatalyst O2 sensors.

# PCM 09 Operation, Faults, and Data Fields

When the engine is started, the PCM begins checking the various engine sensors and actuators for proper operation. On an emission-controlled engine, it then checks the components of the emission control systems for proper operation and begins monitoring and adjusting the air/fuel ratio as long as the engine is running and at less than 80% load. During this time, the system is said to be in **closed-loop control** also known as using a **Proportional-Integral-Differential (PID) Control Strategy**. If for some reason, the PCM cannot enter closed-loop control, it will remain in **open-loop control** and revert to **legacy look-up tables** to control the engine.

The PCM 09 also constantly checks for **engine misfires**, events which could damage the catalyst. In response to changing inputs, it sends control information to the various systems, such as to control the pulse width of the fuel injectors in response to a throttle change by the operator.

## Live Data

Not every engine issue triggers a fault; however, live data can provide important clues to the engine's operation.

Live data is available once the CDS G3 system has been correctly connected to the engine, the correct engineering bill of materials (EBOM) has been selected, the key switch is in the run position, and the engine module has been selected under the **Module Data** screen in CDS G3. CDS G3's **Live Data Screen** provides real-time feedback from the engine, identifying the values reported from the various sensors, how the emissions control system is working, how much spark and fuel is being added or subtracted, and many other data items. Live data takes time and experience to interpret. With experience, you will be able to determine which values are out of range or inconsistent with other data. For an explanation of the data included in the live data stream, refer to **Section 2E - CDS G3 Live Data Screen**.

## Faults

A fault indicates that the PCM has either sensed that the circuit in question has recorded a sensor value outside of its acceptable window, meaning that the sensor circuit has failed, or that a sensor value has gone outside its normal range, as when the engine is running too hot.

There are two types of OBD-M faults:

### OBD-M 1 Faults

These faults are set after the first failure. This fault is used on most comprehensive components, and occurs when the fault requires immediate action. A throttle position fault on a DTS engine is a good example. We cannot wait until a second run cycle before we initiate the backup control strategies.

These faults can be generated by issues with:

- MAP sensor
- MAT sensor
- Crankshaft position sensor (CPS)
- Throttle position sensor (TPS)
- O2 sensors
- Injectors
- Ignition coils
- Idle air control devices
- Catalyst
- Engine controller

### OBD-M 2 Faults

OBD-M 2 faults are used mainly for emissions control components. If the cause of the fault will not endanger the engine or occupant, then the fault is not set until the problem can be confirmed on a subsequent run cycle. OBD-M 2 faults are set after failures on two subsequent run cycles.

With OBD-M 2 faults, after the first run cycle, the fault is set to **pending**, although it is not shown in CDS G3 active or freeze frame data. On the next run cycle, the following things can happen:

1. The PCM records a fault, setting the pending fault to active, putting the fault information in the freeze frame buffer, and notifying the operator through the horn or malfunction indicator lamp (MIL).
2. The system monitor passes, clearing the pending status. It is then as if the fault never occurred.
3. If the monitor never runs, the fault will remain as pending. This status will not change until the monitor runs.

For an explanation of the fault codes, refer to **Section 2G - CDS G3 Fault Tables**. Faults are listed both numerically, as on the **Freeze Frame Screens**, and alphabetical, as on the **View Faults** screen under the **Module Data** screen.

# System Diagnostics Overview

## Order of Execution

The PCM 09 performs a series of tests, starting with the most fundamental tests. If the diagnostics fail to complete, the engine will remain in open-loop control and use the default legacy tables.

The order of events is:

1. Comprehensive components testing is completed
2. The fuel system monitor begins, and will continue while the engine is in closed-loop control
3. O2 sensor rational strategies are tested to ensure proper sensor operation
4. Catalyst monitor begins and tests the catalysts for proper operation and oxygen storage capacity

*NOTE: The misfire monitor always runs in the background. The fuel system monitor always runs when the engine is in closed-loop control.*

## Comprehensive Component Diagnostics

Upon engine start-up, the PCM 09 will conduct **Comprehensive Component Diagnostics**. This includes **open- and short-circuit checks** of circuits and sensors, as well as **rationality checks** to ensure that the sensors are returning expected values.

The system must be able to identify components that are not functioning properly. These components include:

- MAP sensor
- MAT sensor
- Crankshaft position sensor (CPS)
- Throttle position sensor (TPS)
- O2 sensors
- Injectors
- Ignition coils
- Idle air control devices

While a short or open circuit will show a value that is at the extreme of its range and is fairly easy to detect, a **rationality check** checks the value of the sensor against an expected value. For example, the barometric pressure reading shows 61.2 kPa, which equates to approximately 14,000 feet. This would be the altitude of Pikes Peak, in the US. Since there are no lakes that high where engines will be run, it will not pass the rationality check for barometer.

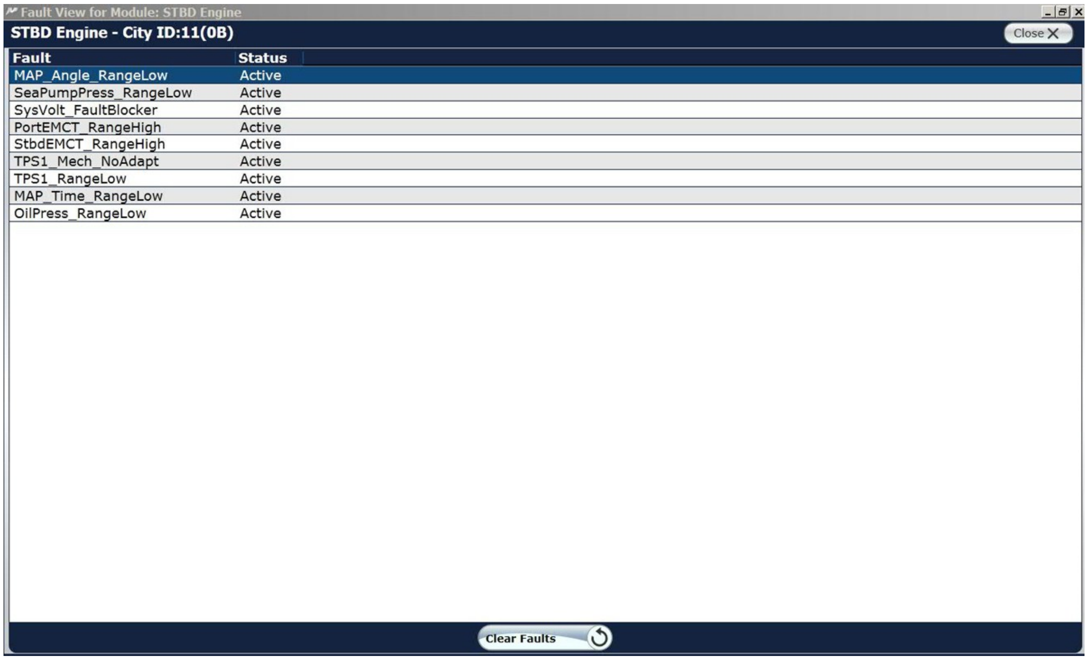
The **time-to-closed loop fault** is a rationality check of the cooling system. Because the engine will not enter closed-loop fuel control until the engine coolant temperature reaches its normal operating temperature, a rationality check is required to determine if:

1. The thermostat is stuck at a lower temperature, and/or
2. The ECT sensor is stuck at a lower temperature.

The engine must enter closed-loop fuel control within a defined amount of time, based on startup engine coolant temperature. If the engine does not enter closed-loop fuel control, then the time to closed-loop fault is set, and the engine will not enter closed-closed loop control, relying instead on legacy look-up tables.

If the engine idles for a majority of the time during the current running cycle, however, then this rationality check is ignored. It is as if the engine was never started and the fault status will not change.

A component that fails one of these tests will trigger a fault that can be viewed on the CDS G3 **Module Data** screen, as well as on the **Freeze Frame Data** screen. The freeze frame data screen takes a snapshot of other sensor values and conditions at the time that the fault was triggered.




52534

A fault screen image capture

## Proportional-Integral-Differential (PID) Control Strategy or Closed-Loop Control

The first data item in the OBD-M emissions area displays the terms "Full_PID means Closed Loop." Remember, both PID and closed-loop control mean that the engine is now responding to feedback from the O2 sensors and incorporating that information into its fuel control strategy. There are a variety of status flags that can appear in this field. They are:

- **Full_PID** means that the engine is in the closed-loop fuel control mode. At approximately 80% load, the engine will leave the Full_PID mode and return to a disabled status. When not in Full_PID, fuel is being delivered in the open-loop or legacy fuel mode.
- **Disabled** means the engine has not yet met the requirements to go into the closed-loop mode, or, the engine is operating above 80% load and will be delivering fuel in the open-loop mode.
- **Diagnostic** means that there are other diagnostic tests being run. This will be displayed during the post O2 stuck monitor and catalyst monitor tests.

An example of O2ControlState in Full_PID using CDS G3 would look like the following:


49021

Live data screen image capture

## Pre/Postcatalyst O2 Sensors

The precatalyst oxygen sensor measures the amount of oxygen in the exhaust **before** the exhaust gas goes through the catalyst.

The postcatalyst oxygen sensor measures the amount of oxygen in the exhaust **after** the exhaust gas goes through the catalyst.

The catalyst O2 sensor data item displays the data in counts. **Analog to Digital Counts (ADC)** translate a voltage or other signal into a number. (*Note: O2 sensors generate a voltage based on the difference between the oxygen content of the exhaust gas and outside reference air.*) The total operating range for this sensor is 0 on the bottom end, and 2048 on the top end, although numbers above 1100 are beyond the normal range.

Typically, 50 to 629 counts indicates that the air/fuel ratio is **lean** (below stoichiometry) and 630 to 1100 counts is **rich**, or above stoichiometry.

| | | | |
|---|---|---|---|
| O2A_ADC | **131** | Counts | PORT Pre-Catalyst O2 Sensor (A) |
| O2B_ADC | **871** | Counts | STBD Pre-Catalyst O2 Sensor (B) |
| O2C_ADC | **93** | Counts | PORT Post-Catalyst O2 Sensor (C) |
| O2D_ADC | **1029** | Counts | STBD Post-Catalyst O2 Sensor (D) |

49027

**Live Data screen image capture of O2 sensor AD counts of air/fuel data**

When it comes to diagnosing catalyst system problems, it is important to note that you are not going to focus on specific numbers. You will be looking for numbers in a range that don't seem to agree. Then you will compare the precatalyst O2 sensor AD counts to the postcatalyst O2 sensor AD counts. This will provide clues as to where you should be focusing your attention.

# Fuel System Monitor

The **fuel system monitor** starts next. It receives data from several components in order to adjust the fuel air/fuel ratio that reaches the cylinders. It will continue to monitor the fuel system while the engine is in closed-loop control, and continually adjust **fuel adjustment percentages**, also known as **ITerm** values, to maintain an air/fuel ratio that is neither too rich nor too lean.

Any of the four ITerm faults—319 O2Control_ITermHighPort, 320 O2Control_ITermLowPort, 321 O2Control_ITermHighStbd, or 322 O2Control_ITermLowStbd—may be triggered by issues with:

- Injectors
- Spark plugs
- Spark plug wires
- Coils
- O2 sensors
- Voltage irregularity
- High or low fuel pressure
- Wiring harness
- Stuck thermostat
- Bad sensors
- Bad fuel
- Leaky exhaust
- Blocked exhaust
- Other

With so many possible fault sources, it is necessary to approach the diagnostic process methodically and to develop a sense of what are normal values and what values you would expect to see change concurrently with others.

## Error and Fuel Trim Adaption

The PCM 09 does not achieve stoichiometry and then maintain that value. Not only do conditions change, the PCM needs to know that the system is responding and that no sensors are stuck. To accomplish this, it perturbates the fuel, quickly alternating the air/fuel ratio above and below the ideal stoichiometric ratio. It then compares what it believes is the air/fuel ratio that it is supplying to what the O2 sensor is reporting. The difference between the two values is called the **error**.

This error is broken up into two parts. First is the **short-term and long-term combined error**, also called **short-term fuel trim**. Second, is the **long-term error** that will be remembered for the next key cycle. These errors are translated into **fuel trim** values, or the amount of fuel the PCM must add or subtract to achieve stoichiometry or an equivalency of 1.00—meaning the ratio is neither rich nor lean.

There are limits to determine how much the short-term fuel trim number can raise or lower from the legacy fuel amount before the engine computer says, "That’s enough; something must be wrong."

The **short-term fuel trim** is limited to ± 25% for a four- or eight-cylinder engine (33% for a six-cylinder engine). The PCM 09 will add this much fuel above or below the values in the look-up table.

### Short-Term Fuel Trim

Short-term fuel trim is a percentage that the normal fuel delivery is being adjusted from the legacy fuel amount.

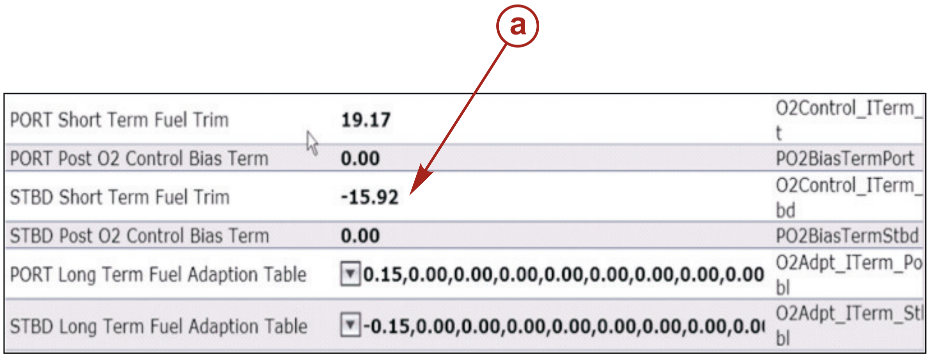
**Legacy fuel delivery** is the term used for the amount of fueling that occurs along a predefined power curve from idle to wide-open throttle. This could also be understood as the **base fueling curve**.

The amount of modification from the legacy value can be a positive or negative number. The system is either adding or subtracting fuel based on the O2 sensor feedback.

The numbers in this data field can appear as follows:

Up to +25 (25%). It means that the adjustment is **rich.**

Down to –25 (25%). It means that the adjustment is **lean.**




49023

**Live Data screen image capture**

a - The short-term fuel trim is subtracting 15.92% from the look-up value to achieve stochiometry

The limits are based on the number of cylinders per bank. As an example; a V8 has four cylinders per bank or 25% per cylinder, and a V6 has three cylinders per bank, or 33% per cylinder.

On a V8 engine, you may see data values that are slightly different between the port and starboard banks. One side might show positive numbers, while the opposite side may be displaying negative numbers. This is OK.

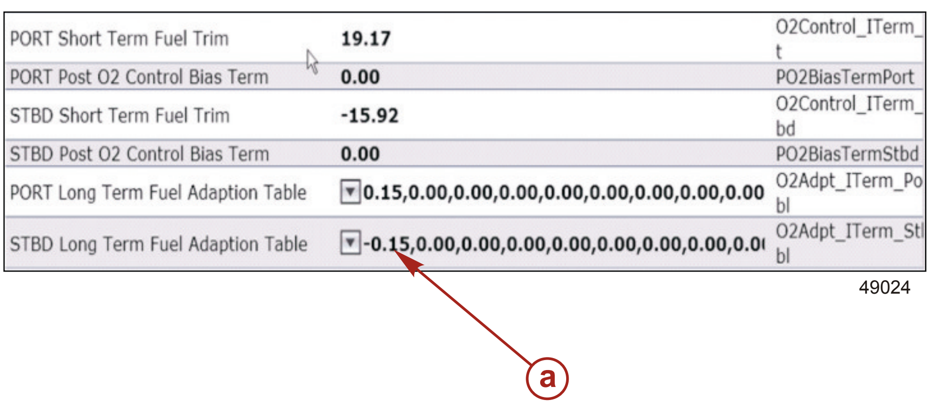
The numbers should be similar in the amount of adjustment that is occurring. The further the number gets away from zero, the more the PCM has to adjust the amount of fuel, whether plus or minus, from the legacy fuel amounts.

Numbers that are in the extreme ranges, from negative to positive, may indicate a need to further investigate the integrity of the system or the components that are supplying input data to the PCM.

### Long-Term Fuel Adaption Table

This data field displays data values for nine points equally spaced on the normal power curve of the engine. Each cell in the memory storage location contains a fuel trim data value that is the best known value for the specific RPM data point in the power curve. This is done so that the PCM can use that value as a starting point for the amount of fuel that's needed in that part of the power curve, during the next run cycle.

The last storage location will always display 0. This last storage cell is located in the top end of the wide-open throttle RPM range, which should not see any fuel trim anyway because in this range the engine should be operating in the open-loop fueling mode.




49024

**Live Data screen image capture**

a - This shows the highest long-term fuel adaption (both rich/lean) for a 4-cylinder/bank engine

The maximum values for long-term errors are: 4- or 8-cylinder: ± 0.15 (± 15%); V6: ± 0.20 (20%).

## Port/Starboard Post O2 Control Bias Term

The **Post O2 Control Bias Term** is the fuel system's correction based on the post O2 sensor readings. This bias term is used to move the pre O2 sensor fuel target to optimize emissions reductions. It can be viewed as a fine-tuning of the fuel delivery to keep the ideal air-to-fuel ratio spot-on the desired target.

This term is limited to ± 3%. A number higher than 3% may dictate that further investigation is needed to find out why the PCM is having to work so hard at the fine-tuning process.

| | | | |
|---|---|---|---|
| PORT Short Term Fuel Trim | **0.00** | O2Control_ITerm_Port | % |
| PORT Post O2 Control Bias Term | **0.00** | PO2BiasTermPort | % |
| STBD Short Term Fuel Trim | **0.00** | O2Control_ITerm_Stbd | % |
| STBD Post O2 Control Bias Term | **0.00** | PO2BiasTermStbd | % |
| PORT Long Term Fuel Adaption Table | **0.00,0.00,0.00,0.00,0.00,0.00,** | O2Adpt_ITerm_PortTbl | |
| | **0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00** | | |
| STBD Long Term Fuel Adaption Table | **0.00,0.00,0.00,0.00,0.00,0.00,** | O2Adpt_ITerm_StbdTbl | |
| | **0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00 0.00** | | |

49022

Live Data screen image capture. The Post O2 Control Bias Term is highlighted.

# O2 Sensor Rational Strategies

The pre and post O2 sensors respond differently. The pre O2 sensor perturbates with the fuel. However, the post O2 sensor remains almost constant since it is measuring the exhaust after the catalyst when variations should be smoothed out.

## Post O2 Sensor Stuck Monitor

In the post O2 sensor stuck monitor test, the PCM 09 moves the fuel rich and lean three times, waits long enough for the post O2 sensor to respond, and then looks for movement in the data. If the post O2 sensor doesn't follow the pre O2 sensor, a problem with the post O2 sensor is indicated.

In this example, the O2 sensor is waiting to adapt.

| | | |
|---|---|---|
| PO2S_e_DisableReason | **FuelSysAdapt** | Post O2 Sensor Monitor |

49028

Live Data screen image capture

This monitor only runs from 1300 to 3100 RPM in gear under load. If the post O2 sensor is replaced, a complete OBD-M cycle must be run to determine if the catalyst is good. The live data screen will show the test's status and may show reasons for the test to be disabled.

Possible Values for Post O2 Sensor Stuck Monitor

| Diagnostic Status | Description |
|---|---|
| FuelSysAdapt | Fuel system adapting |
| PID Time | A stability timer is waiting for the engine to stabilize |
| None | Running diagnostics |
| Finished | Completed |
| Ind Work | Warm-up timer |
| ECT | Low coolant temperature |
| SS MAP | Fluctuations in MAP values are keeping the test from continuing |
| SS RPM | Fluctuations in RPM values are keeping the test from continuing |
| MAP Range | Calculated air flow range is too high/low |
| RPM Range | RPM too high or low |
| Common Enable | Comprehensive components test has not been run or cannot successfully complete |
| BARO | The MAP values are outside of the normal range, showing a fault in the rationality test |

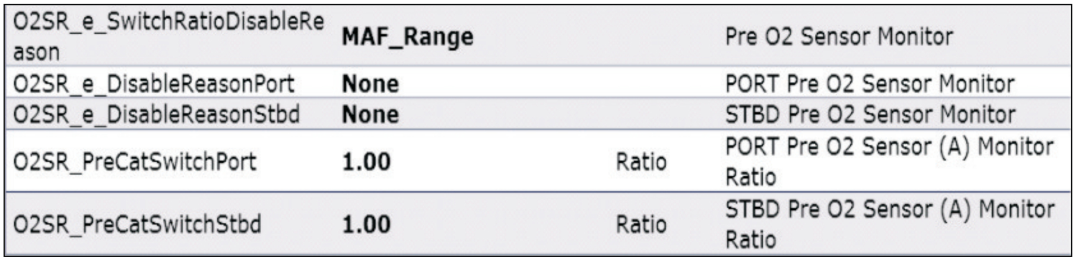
## Precatalyst O2 Sensor Switch Ratio Monitor

The **pre O2 sensor switch ratio monitor** perturbates the fuel rich and lean 25 times, and then compares the pre and post O2 sensor measurements. If the ratio of the amount of changes detected by the O2 sensor to the perturbations generated by the PCM 09 is less than 0.25 **(detected perturbations ÷ actual perturbations < 0.25)** the sensor is defective. A value of 1.00 indicates that all of the perturbations were detected.

If the ratio (detected ÷ actual) drops to 0.25 or less (less than 25%) one of the following corresponding fault codes is set:

- 303 O2SR_r_PreSwitchRatioPort
- 305 O2SR_r_PreSwitchRatioStbd

**O2SR_e_SwitchRatioDisableReason** indicates if the test has run or why it has not. It runs when the engine is in the closed-loop, Full-PID fuel-control mode. The test only runs if the previous post O2 stuck test was successful. If that test failed, this one will not start. Refer to **Section 2E** - **CDS G3 Live Data Screen** for more information.



| | | | |
|---|---|---|---|
| O2SR_e_SwitchRatioDisableReason | **MAF_Range** | | Pre O2 Sensor Monitor |
| O2SR_e_DisableReasonPort | **None** | | PORT Pre O2 Sensor Monitor |
| O2SR_e_DisableReasonStbd | **None** | | STBD Pre O2 Sensor Monitor |
| O2SR_PreCatSwitchPort | **1.00** | Ratio | PORT Pre O2 Sensor (A) Monitor Ratio |
| O2SR_PreCatSwitchStbd | **1.00** | Ratio | STBD Pre O2 Sensor (A) Monitor Ratio |

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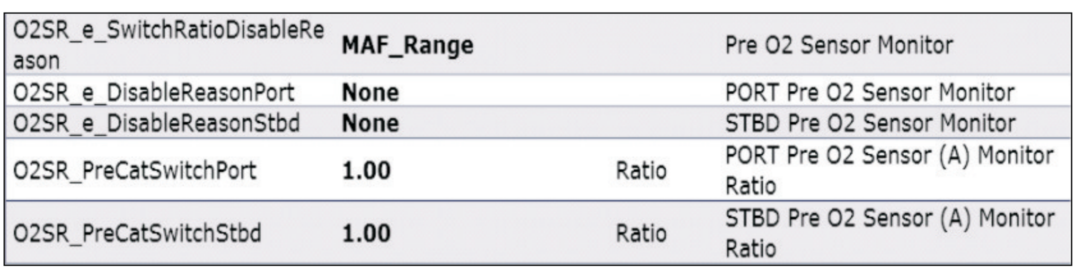
Live Data screen image capture of O2SR_e_SwitchRatioDisableReason

One of the following status codes will be displayed.

O2SR_e_SwitchRatioDisableReason Data Field

| Status | Description |
|---|---|
| None | Ready |
| DiagnosticChecks | Comprehensive components are being checked |
| ECT | Low coolant temperature |
| PID_Time | A 35-second timer is running, allowing the engine to stabilize |
| DeltaMAP | Fluctuations in MAP values are keeping the test from continuing |
| DeltaRPM | Fluctuations in RPM are keeping the test from continuing |
| MAP_Range | MAP range is too high or low |
| MAF_Range | Calculated air flow is too high or low |
| BARO | MAP values are out of range, failing the rationality check |
| DelayTime | A stability timer is allowing the engine to stabilize before continuing |
| IntrusiveDiagnosticFuel | The post O2 stuck monitor is running. |
| FinishedKey | Complete |

The port and starboard banks have individual statuses O2SR_e_DisableReasonPort and O2SR_e_DisableReasonStbd.



| | | | |
|---|---|---|---|
| O2SR_e_SwitchRatioDisableReason | **MAF_Range** | | Pre O2 Sensor Monitor |
| O2SR_e_DisableReasonPort | **None** | | PORT Pre O2 Sensor Monitor |
| O2SR_e_DisableReasonStbd | **None** | | STBD Pre O2 Sensor Monitor |
| O2SR_PreCatSwitchPort | **1.00** | Ratio | PORT Pre O2 Sensor (A) Monitor Ratio |
| O2SR_PreCatSwitchStbd | **1.00** | Ratio | STBD Pre O2 Sensor (A) Monitor Ratio |

49029

Live Data screen image capture. See legend below.

- **O2SR_e_DisableReasonPort**—Port bank pre O2 switch ratio monitor status
- **O2SR_e_DisableReasonStbd**—Starboard bank pre O2 switch ratio monitor status. One of the following status codes will appear in these fields.

| Status | Description |
|---|---|
| None | Ready |
| CommonDisable | Comprehensive components |

| Status | Description |
|---|---|
| PO2 Error | Stability timer |
| PO2 Adapt Error | Stability timer |
| Fuel Adapt Error | Stability timer |
| In Delay | Stability timer |
| PO2Diagnostic | Failed post O2 stuck monitor |

- **O2SR_PreCatSwitchPort and O2SR_PreCatSwitchStbd** is where the system displays the results of the test that's been running. The PCM perturbates the fuel system rich and lean 25 times and watches for the number of reliable responses that it receives back. The data that you see in this field is the ratio, or results of those 25 changes from rich to lean.
  - Example: 25 divided by 25 equals 1.00, which means that the O2 sensor responded to every perturbation.
  - If the ratio displayed in this field falls below 0.25 the test fails and a fault code will be logged.

# Catalyst Monitor Tests

## Catalyst Oxygen Storage Capacity

If all of the tests up to this point have passed, we know that the fuel system is correctly adjusted and that the O2 sensors are responding properly to the fuel commands. The system now runs a catalyst health check, measuring the amount of oxygen that the catalyst can store.

The time it takes for the pre O2 sensor to transition from rich to lean compared to what the post O2 sensor sees is directly related to the catalyst's **oxygen storage capacity (OSC)**. The OSC is measured in milligrams.

Typical minimum values for oxygen storage capacity per engine model are:

| Engine | Lowest allowable raw oxygen storage capacity |
|---|---|
| 3.0L | 150 mg |
| 4.3L | 100 mg |
| 5.0L, 5.7L, 6.2L | 200 mg |
| 8.2L triple-catalyst exhaust system | 330 mg |
| 8.2L single-catalyst exhaust system | 210 mg |

When the catalyst monitor is running, the values of the test can be read on the **Live Data** screen.

**CATM_e_DisableReasonCommon** shows the Overall Catalyst Monitor status. The engine must be operating between 1800 and 3000 RPM under load.

| | | |
|---|---|---|
| CATM_e_DisableReasonCommon | **CommonDiagnosticChecks** | OVERALL Catalyst Monitor |
| CATM_e_StatusPort | **Disabled** | PORT Catalyst Monitor |
| CATM_e_StatusStbd | **Disabled** | STBD Catalyst Monitor |

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### Possible CATM_e_DisableReasonCommon Values

| Status | Description |
|---|---|
| IndWork | Warm-up timer |
| ECT | Low coolant temperature |
| DeltaMAP | Engine not at steady state |
| DeltaRPM | Engine not at steady state |
| MAF Range | Calculated air flow range too high or low |
| MAP Range | MAP range too high or low |
| RPM Range | RPM too high or low |
| CommonDiagnosticChecks | Comprehensive components |
| BARO | MAP values are violating the rationality check |
| TempRange | Catalyst temperature too high or low |
| PID_Time | A 35-second stability timer is allowing the engine to stabilize |
| None | Ready |

Port and starboard banks have individual status displays.

| | | |
|---|---|---|
| CATM_e_DisableReasonCommon | **CommonDiagnosticChecks** | OVERALL Catalyst Monitor |
| CATM_e_StatusPort | **Disabled** | PORT Catalyst Monitor |
| CATM_e_StatusStbd | **Disabled** | STBD Catalyst Monitor |

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### Values for CATM_e_ StatusPort/Stbd (Port and Starboard Catalyst Monitors)

| Status | Description |
|---|---|
| Disabled | Ready |
| Reducing | Engine running rich to purge oxygen from catalyst |
| Oxidizing | Engine running lean to saturate catalyst with oxygen |
| Re-reducing | Engine running rich to purge oxygen from catalyst again |
| Abort | Bad catalyst monitor cycle |
| AbortedKey | Too many bad catalyst monitor cycles |
| FinishKey | Completed |

The OSC is compared to a table of values generated by a catalyst with marginal emissions, which sets the minimum value. If the value of the catalyst divided by the table value is greater than 1, the catalyst passes the test. The value reflects how many times greater than the minimum capability to clean the exhaust gases. If it is less than 1, it does not pass and a fault is set for the appropriate cylinder bank, port or starboard.

For example, a 2 would indicate that the catalyst generally has twice the capability of what is needed to pass the test, and this number can indicate the general health of the catalyst; however, it is not reflective of remaining catalyst life.

If the catalyst monitor test fails to run properly, usually due to a slow-responding O2 sensor, the system may show a CATM_r_OSCExcessAbortPort/Stbd faults. Refer to **Section 2G** - **CDS G3 Fault Tables** for an explanation of fault codes. Refer to **Precatalyst O2 Sensor Response Time Monitor** for an explanation of slow-responding O2 sensors.

| | | | |
|---|---|---|---|
| CATM_r_OSCIndexEWMAPort | **0.87** | Ratio | PORT Catalyst Monitor Ratio |
| CATM_t_OSCRawPort | **210.45** | mg | PORT Catalyst Monitor Raw C |
| CATM_r_OSCIndexEWMAStbd | **0.73** | Ratio | STBD Catalyst Monitor Ratio |
| CATM_t_OSCRawStbd | **175.26** | mg | STBD Catalyst Monitor Raw C |

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CATM_r_OSCIndexEWMAPort/Stbd shows port and starboard values

If either a port or starboard catalyst fails the test, one of the following faults will be set:

Catalyst Monitor OSC

| Condition | Fault Set |
|---|---|
| CATM_r_OSCIndexEWMAPort/Stbd < 1.00 | 311 CATM _OSCIndexPort |
| | 315 CATM_OSCIndexStbd |

## Precatalyst O2 Sensor Response Time Monitor

The precatalyst O2 sensor response time is measured while the catalyst monitor is running. The O2 sensors respond faster when going from lean to rich. Typical values are: lean to rich—0.06 to 0.2 seconds; rich to lean—0.09 to 0.2 seconds. Note that the O2 sensors respond faster when going from lean to rich.

The oxygen storage capacity (OSC) measurement is based on the response time of the sensors; thus, a slow responding pre O2 sensor can artificially reduce the oxygen storage capacity (OSC) measurement.

If the data readings for **OSC Index EWMA** (port or starboard) fall below 1.00, we need CATM_O2 (lean or rich) response times (port or starboard) to determine if the O2 sensor is influencing the catalyst monitor measurement. **Double-check these sensor response times, before you replace the catalyst.**

| | | | |
|---|---|---|---|
| CATM_O2LeanRespTimePort | **0.235** | ms | PORT Pre O2 Sensor (A) Lean Response |
| CATM_O2RichRespTimePort | **0.190** | ms | PORT Pre O2 Sensor (A) Rich Response |
| CATM_O2LeanRespTimeStbd | **0.315** | ms | STBD Pre O2 Sensor (B) Lean Response |
| CATM_O2RichRespTimeStbd | **0.215** | ms | STBD Pre O2 Sensor (B) Rich Response |

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Live Data screen shot of O2 sensor response times

Precatalyst O2 Sensor Response Time

| Condition | Fault Set |
|---|---|
| CATM_O2LeanResponsePort/Stbd >0.92 seconds (920 ms)<br>CATM_O2RichResponsePort/Stbd >0.92 seconds (920 ms) | 312 CATM_O2LeanResponsePort |
| | 313 CATM_O2RichResponsePort |
| | 316 CATM_O2LeanResponseStbd |
| | 317 CATM_O2LeanResponseStbd |

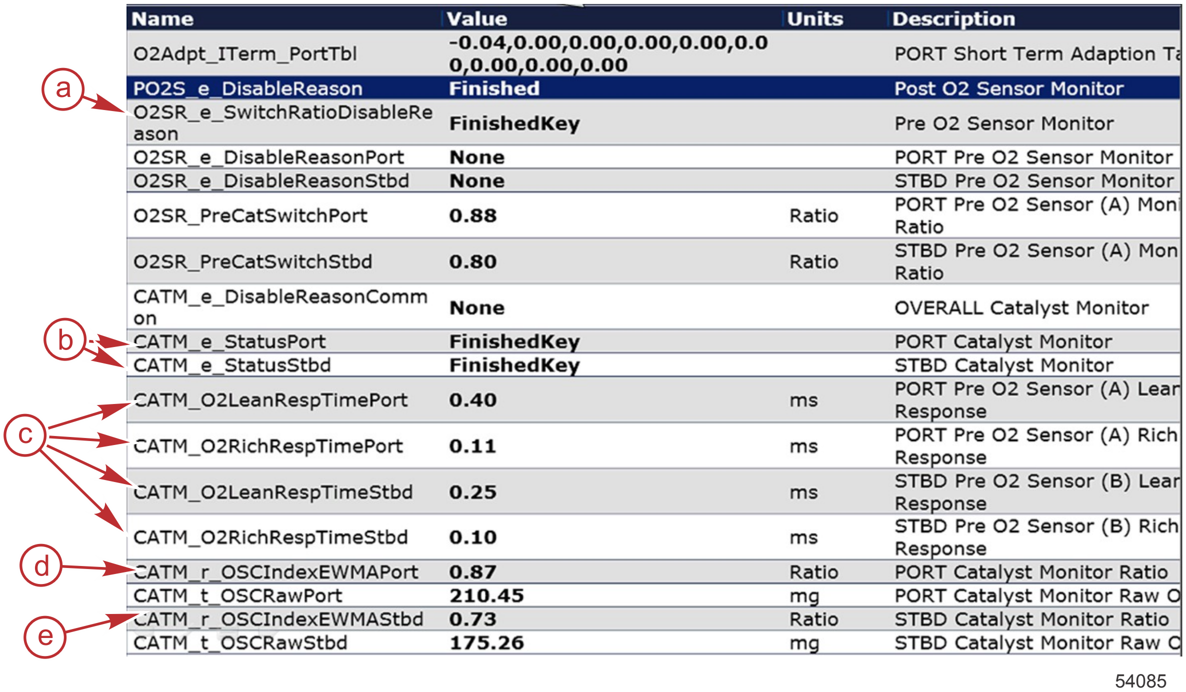
These limits are set as part of the precatalyst O2 sensor response test, to determine the condition of the systems ability to communicate a timely response between the engine computer and the pre O2 sensors. A response time greater than 920 milliseconds (0.920 seconds) will set these codes.

During this test, the engine computer needs to know the communication speed when switching from rich-to-lean, as well as from lean-to-rich. Both must be less than the specified 920 milliseconds.

If the response time is greater than 0.92 seconds it will be considered a failed response.

## Completion of Tests

When all of the OBD-M monitors have completed their diagnostic testing, the live data screen will display **finished** and **finished**-**key** messages in the appropriate rows, as shown following:



| Name | Value | Units | Description |
|---|---|---|---|
| O2Adpt_ITerm_PortTbl | -0.04,0.00,0.00,0.00,0.00,0.0 0,0.00,0.00,0.00 | | PORT Short Term Adaption Ta |
| PO2S_e_DisableReason | Finished | | Post O2 Sensor Monitor |
| O2SR_e_SwitchRatioDisableRe ason | FinishedKey | | Pre O2 Sensor Monitor |
| O2SR_e_DisableReasonPort | None | | PORT Pre O2 Sensor Monitor |
| O2SR_e_DisableReasonStbd | None | | STBD Pre O2 Sensor Monitor |
| O2SR_PreCatSwitchPort | 0.88 | Ratio | PORT Pre O2 Sensor (A) Moni Ratio |
| O2SR_PreCatSwitchStbd | 0.80 | Ratio | STBD Pre O2 Sensor (A) Mon Ratio |
| CATM_e_DisableReasonComm on | None | | OVERALL Catalyst Monitor |
| CATM_e_StatusPort | FinishedKey | | PORT Catalyst Monitor |
| CATM_e_StatusStbd | FinishedKey | | STBD Catalyst Monitor |
| CATM_O2LeanRespTimePort | 0.40 | ms | PORT Pre O2 Sensor (A) Lear Response |
| CATM_O2RichRespTimePort | 0.11 | ms | PORT Pre O2 Sensor (A) Rich Response |
| CATM_O2LeanRespTimeStbd | 0.25 | ms | STBD Pre O2 Sensor (B) Lear Response |
| CATM_O2RichRespTimeStbd | 0.10 | ms | STBD Pre O2 Sensor (B) Rich Response |
| CATM_r_OSCIndexEWMAPort | 0.87 | Ratio | PORT Catalyst Monitor Ratio |
| CATM_t_OSCRawPort | 210.45 | mg | PORT Catalyst Monitor Raw O |
| CATM_r_OSCIndexEWMAStbd | 0.73 | Ratio | STBD Catalyst Monitor Ratio |
| CATM_t_OSCRawStbd | 175.26 | mg | STBD Catalyst Monitor Raw C |



Example of a Live Data screen at completion of tests. Actual values may differ. Note that the catalyst monitor ratios indicate that both catalysts are damaged.

- a - Pre O2 sensor monitor—finished
- b - Port and starboard catalyst monitors—finished
- c - Catalyst response times (all less than 0.92 seconds)
- d - Port catalyst monitor ratio—failed (value is less than 1)
- e - Starboard catalyst monitor ratio—failed (value is less than 1)

In the example above, **FinishedKey** is shown in the status of the port and starboard catalyst monitors, the last monitors to run. Note that the catalyst monitor ratios for both the port and starboard catalysts are less than one and the response times are less the 0.92 seconds, indicating that the catalysts have been damaged and need replacement.

# Notes: