2012 MY OBD System Operation

Summary for Fiesta

Table of Contents

Catalyst Efficiency Monitor

The Catalyst Efficiency Monitor uses an oxygen sensor after the catalyst to infer the hydrocarbon efficiency based on oxygen storage capacity of the ceria and precious metals in the wash coat. Under normal, closed-loop fuel conditions, high efficiency catalysts have significant oxygen storage. This makes the switching frequency of the rear HO2S very slow and reduces the amplitude of those. As catalyst efficiency deteriorates due to thermal and/or chemical deterioration, its ability to store oxygen declines and the post-catalyst HO2S signal begins to switch more rapidly with increasing amplitude. The predominant failure mode for high mileage catalysts is chemical deterioration (phosphorus deposition on the front brick of the catalyst), not thermal deterioration.

Integrated Air/Fuel Method

The Integrated Air/Fuel Catalyst Monitor assesses the oxygen storage capacity of a catalyst after a fuel cut event. The monitor integrates how much excess fuel is needed to drive the monitored catalyst to a rich condition starting from an oxygen-saturated, lean condition. Therefore, the monitor is a measure of how much fuel is required to force catalyst breakthrough from lean to rich. To accomplish this, the monitor runs during fuel reactivation following a Decel Fuel Shut Off (DFSO) event. The monitor completes after a calibrated number of DFSO monitoring events have occurred. The IAF catalyst monitor can be used with either a wide range O2 sensor (UEGO) or a conventional switching sensor (HEGO).

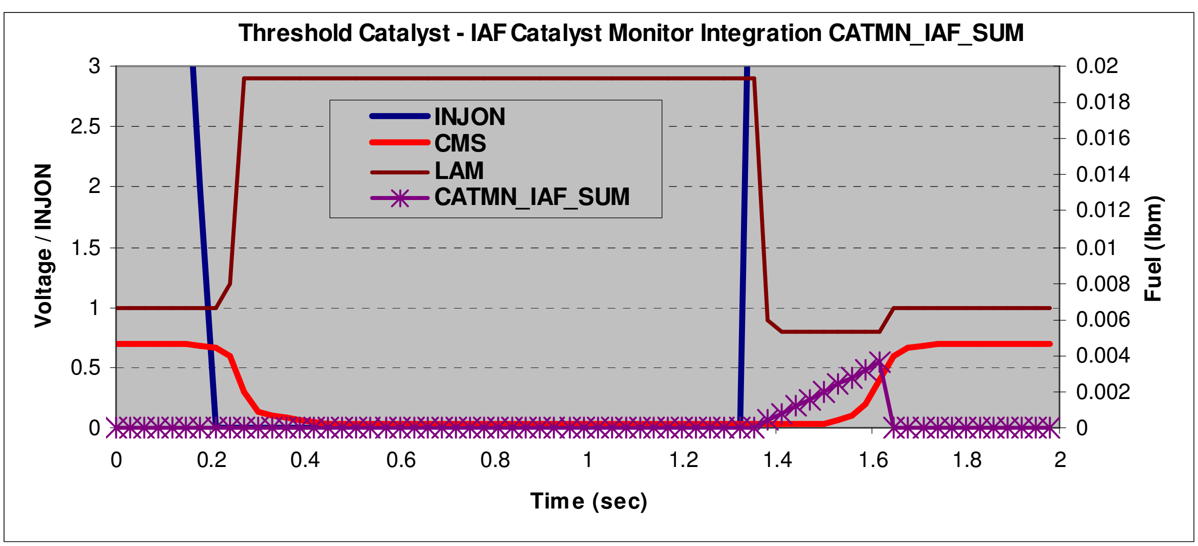
Functionally, the equation is:

$$IAF = \int \left(\frac{Fuel\_needed\_for\_stoich}{Fuel\_Measured} - Fuel\_needed\_for\_stoich \right)$$

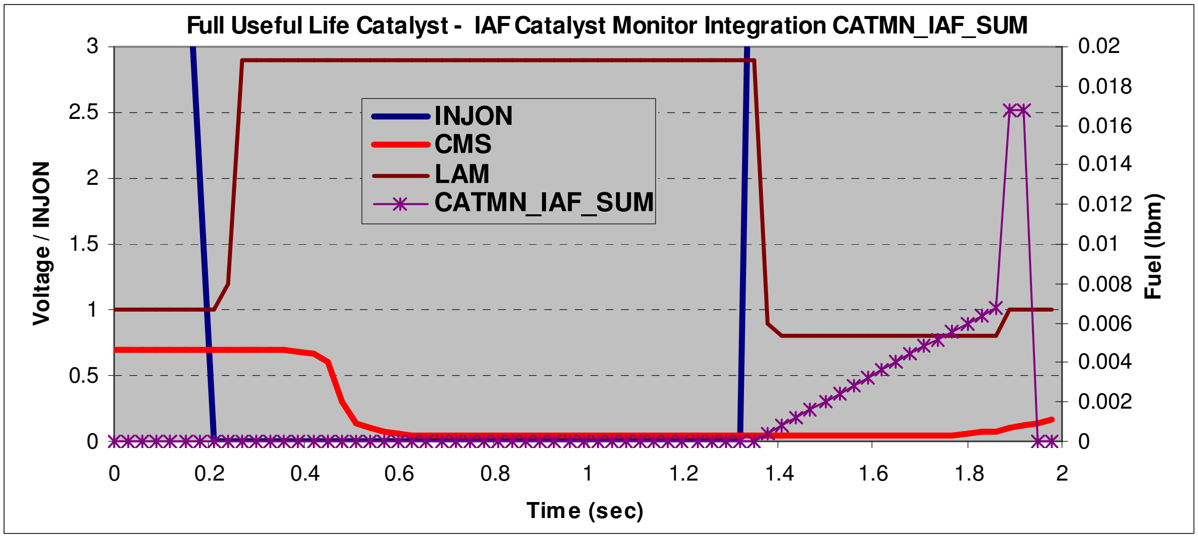
where the units are in pounds mass of fuel.

The monitor runs during reactivation fueling following an injector cut. The diagram below shows examples of one DFSO event with a threshold catalyst and with a Full Useful Life catalyst where:

- INJON = # of injectors on.
- CMS is the catalyst monitor sensor voltage. When the rear O2 sensor crosses 0.45 volts (i.e. rich) the monitor will complete for the given DFSO event.
- LAM (LAMBDA) is the front O2 sensor (UEGO) signal.
- CATMN_IAF_SUM is the integral from the equations above (Y axis on the right).



In the example above, CATMN_IAF_SUM is small because it doesn't take much fuel to break though a low oxygen storage threshold catalyst.



In the example above, CATMN_IAF_SUM is much larger because it takes a substantial amount of fuel to break though a high oxygen storage threshold catalyst.

There are two sets of entry conditions into the IAF catalyst monitor. The high level entry conditions determine that the monitor would like to run following the next injector fuel cut event. The lower level entry conditions determine that the fuel cut-off event was suitable for monitoring and the monitor will run as soon as the injectors come back on.

1. The high level entry conditions are met when:

- There are no sensor/hardware faults
- The base monitor entry conditions have been met (ECT, IAT, cat temp, fuel level, air mass)
- Required number of DFSO monitoring event have not yet completed

2. The lower level entry conditions are met when:

- The injectors are off
- The catalyst is believed to be saturated with oxygen (rear O2 indicates lean)
- The catalyst/rear O2 has been rich at least once since the last monitor event.

General Catalyst Monitor Operation

Rear HO2S sensors can be located in various ways to monitor different kinds of exhaust systems. In-line engines and many V-engines are monitored by individual bank. A rear HO2S sensor is used along with the front, fuel-control HO2S sensor for each bank. Two sensors are used on an in-line engine; four sensors are used on a V-engine. Some V-engines have exhaust banks that combine into a single underbody catalyst. These systems are referred to as Y-pipe systems. They use only one rear HO2S sensor along with the two front, fuel-control HO2S sensors. Y-pipe system systems use three sensors in all. For Y-pipe systems which utilize switching front O2 sensors, the two front HO2S sensor signals are combined by the software to infer what the HO2S signal would have been in front of the monitored catalyst. The inferred front HO2S signal and the actual single, rear HO2S signal is then used to calculate the switch ratio.

Most vehicles monitor less than 100% of the catalyst volume – often the first catalyst brick of the catalyst system. Partial volume monitoring is done on LEV and LEV-II vehicles in order to meet the 1.75 * emission-standard threshold for NMHC and NOx. The rationale for this practice is that the catalysts nearest the engine deteriorate first, allowing the catalyst monitor to be more sensitive and illuminate the MIL properly at lower emission standards.

Many applications that utilize partial-volume monitoring place the rear HO2S sensor after the first light-off catalyst can or, after the second catalyst can in a three-can per bank system. (A few applications placed the HO2S in the middle of the catalyst can, between the first and second bricks.)

The Integrated A/F catalyst monitor was designed to allow monitoring 100% of the catalyst volume. It can be used for both partial and full volume monitoring.

Vehicles with the Integrated Air/Fuel catalyst monitor employ an improved version of the EWMA algorithm.

The EWMA logic incorporates several important CARB requirements. These are:

- Fast Initial Response (FIR): The first 4 tests after a code clear will process unfiltered data to quickly indicate a fault. The FIR will use a 2-trip MIL. This will help the service technician determine that a fault has been fixed.

- Step-change Logic (SCL): The logic will detect an abrupt change from a no-fault condition to a fault condition. The SCL will be active after the 4th catalyst monitor cycle and will also use a 2-trip MIL. This will illuminate the MIL when a fault is instantaneously induced.

- Normal EWMA (NORM): This is the normal mode of operation and uses an Exponentially Weighted Moving Average (EWMA) to filter the catalyst monitor test data. It is employed after the 4th catalyst test and will illuminate a MIL during the drive cycle where the EWMA value exceeds the fault threshold. (1 trip MIL).

Catalyst Monitor Operation:	
DTCs	P0420
Monitor execution	once per driving cycle
Monitor Sequence	HO2S response test complete and no DTCs prior to calculating switch ratio, no evap leak check or fuel monitor DTCs,
Sensors OK	ECT (P0118, P0117, P0119, P0116), IAT (P0111, P0112, P0113, P009A),: MAF,(P0102, P0103), front and rear O2 (P0132, P0131, P0134, P0130, P2A00, P2297, P0133, P0136, P0138, P0137, P0140, P2A01, P0139), front and rear O2 heaters (P0036, P0037, P0038, P0141, P0030, P0031, P0032) fuel monitor (P0171, P0172)
Monitoring Duration	3 Decel Fuel Cutoff events for IAF catalyst monitor (approx 90 sec)

Typical IAF catalyst monitor entry conditions:		
Entry condition	Minimum	Maximum
Engine Coolant Temp	72.75 °C	110 °C
Intake Air Temp	-6.67 °C	110 °C
Inferred catalyst mid-bed temperature	649 °C	816 °C
Fuel Level	15%	
Air Mass		0.8 lb/min
No purge vapor flow for a minimum amount of time	0.5 sec	
Rear O2 sensor rich since last monitor attempt	0.45 volts	
Rear O2 sensor lean with injectors off (monitor will run when injectors turn back on)		0.1 volts
Short term fuel trim (STFT) OR absolute delta change in Average STFT		14.99 %

Typical malfunction thresholds:
Catalyst monitor index ratio > 0.75 (bank monitor)

Mode $06 reporting for IAF Catalyst Monitor

The catalyst monitor results are converted to a ratio for Mode $06 reporting to keep the same look and feel for the service technician. The equation for calculating the Mode $06 monitor result is:

1 – (Actual reactivation fuel/ Good catalyst reactivation fuel)

Good catalyst reactivation fuel is intended to represent what the monitor would measure for a green catalyst.

J1979 Catalyst Monitor Mode $06 Data			
Monitor ID	Test ID	Description	
$21	$91	Catalyst Oxygen Storage Capacity and max. limit	Unit less

** NOTE: In this document, a monitor or sensor is considered OK if there are no DTCs stored for that component or system at the time the monitor is running.

Misfire Monitor

The method used for engine misfire detection is based on evaluating the engine speed fluctuations; it is commonly referred to as Engine Roughness. Engine torque is a function of engine speed, engine load, and the moment of inertia. In order to detect a misfiring cylinder, the torque of each cylinder is evaluated by using the crankshaft position signal to measure the time between sensor wheel teeth for each ignition event. This time is a measure of the mean value of the speed of this angular segment. A change in engine torque also results in a change in engine speed. In addition, different road surfaces, pot holes etc. will affect engine speed. Because mean engine speed is used to detect misfire, the effects caused by road surfaces have to be eliminated. The misfire monitor consists of following main parts:

Data acquisition:

The duration of the crankshaft segment for each cylinder is measured continuously, every combustion cycle.

Sensor wheel adaptation:

Crankshaft sensor wheel adaptation software is used to "learn" and correct for mechanical inaccuracies in the crankshaft position wheel tooth spacing. To prevent any fueling or combustion differences from affecting the correction factors, learning is done during decel-fuel cutout. When operating in decel-fuel cutout within a defined engine speed range, misfire monitoring is suspended and adaptation of the sensor wheel tolerances takes place. The adaptation values are stored in memory and used as correction factors for the calculation of the engine roughness.

Calculation of the engine roughness:

The engine roughness is derived from the differences of the segment durations. Different statistical methods are used to distinguish between normal changes of the segment duration and the changes due to misfiring.

Misfire Determination:

Misfire detection is performed by comparing the calculated engine roughness value for each cylinder to the engine roughness threshold (a table value). If the threshold is exceeded, a misfire is detected and the counter is incremented. This counter counts the number of misfires for all cylinders. In addition, a cylinder specific counter is also incremented.

The engine roughness threshold can be adjusted to account for the following factors to prevent false misfire indications:

> If engine coolant temperature is very cold, the engine roughness threshold is adjusted by a coolant temperature dependent factor.
>
> If cold start emission reduction actions are active for improved catalyst warm-up (elevated idle speed, spark retard, VVT timing, etc), the engine roughness threshold is adjusted by a catalyst warm-up dependent factor.
>
> Rough road conditions can induce crankshaft speed changes via the drive train and result in false misfire indications. When these conditions are detected, misfire detection is temporarily suspended for a calibratable time period. After this time, with no rough road conditions present, misfire monitoring will resume.

Fault processing - Emission Threshold

The sum of the cylinder misfire counters is evaluated every 1000 rev period and compared to a single threshold value to indicate an emission-threshold malfunction, which can be either a single 1000 rev exceedence from startup or four subsequent 1000 rev exceedences on a drive cycle after start-up.

The cylinders with the highest misfire rate are flagged. If the misfire occurs again on a subsequent driving cycle, the MIL is illuminated and a cylinder specific fault is stored.

Fault processing - Catalyst Damage Threshold

The weighted sum of the cylinder misfire counters is evaluated every 200 revolution period and compared to a table of threshold values to indicate a catalyst-damaging malfunction. The MIL is illuminated immediately. (The MIL blinks at a 1 Hz rate.)

The cylinders with the highest misfire rate are flagged. If one of the cylinder-specific counters is exceeding the catalyst damage threshold the following actions take place:

1. Closed loop fuel control is set to open loop.

2. Downstream O2 sensor fuel trim is suspended

3. A cylinder-specific fault code is stored.

4. The fuel injector to the misfiring cylinder is turned off (a maximum of one cylinder)

All misfire counters are reset after each interval.

Similar Conditions

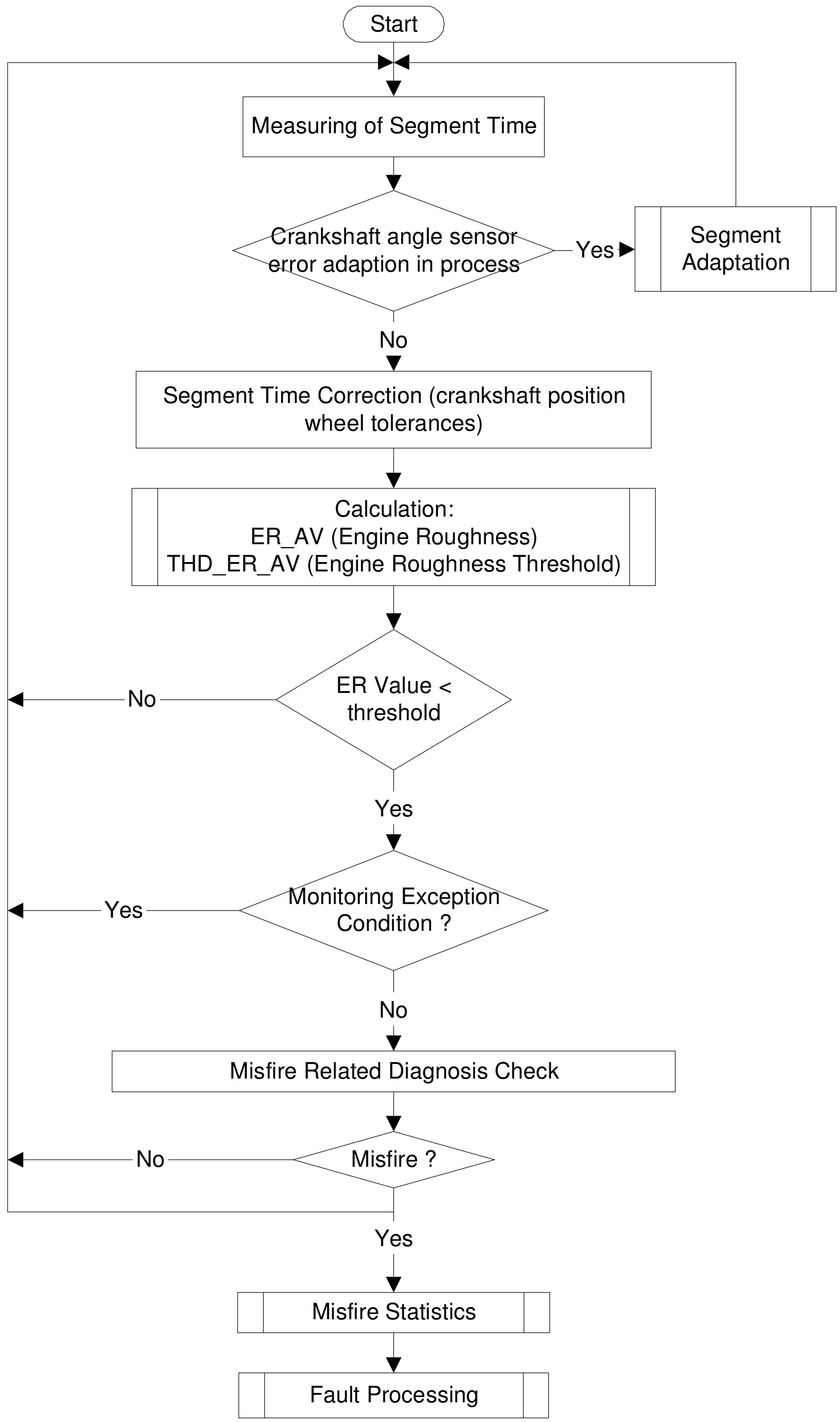
When the engine management system recognizes a failure in the misfire or fuel systems, the engine management system is required to record the conditions present when the fault occurred. These conditions recorded include engine speed, engine load (MAF), and warm up status of the first event that resulted in the storage of a code. These conditions stored are referred to as similar conditions.

Once the similar conditions are meant without a failure in the misfire or fuel system, the flag is set to 1. Once this flag is set the driving cycle counter for that failure can be decrement.

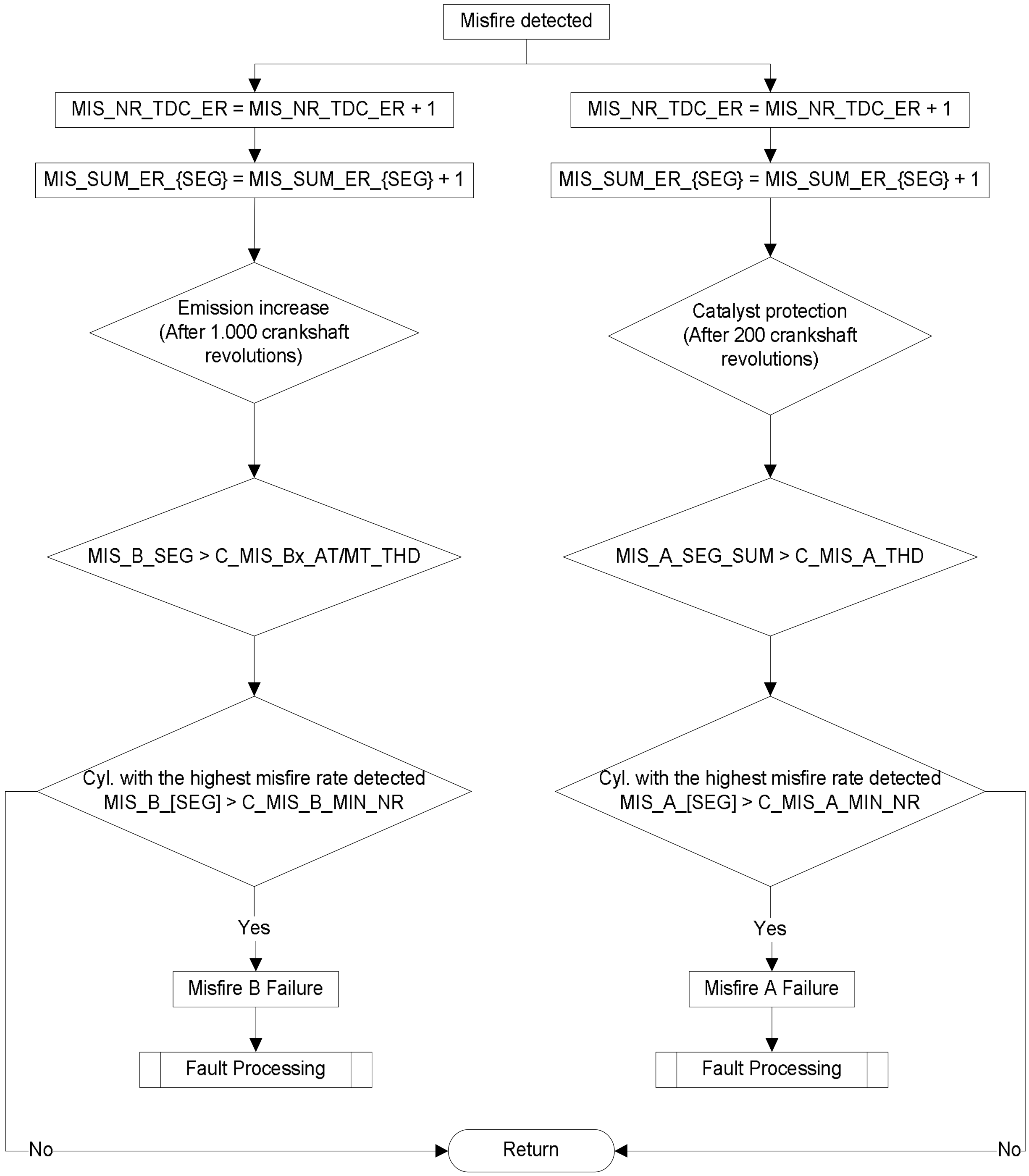
The code and stored freeze frame conditions may be erased if similar conditions are not encountered during the next 80 driving cycles immediately following the initial detection of the malfunction.

The MIL is extinguished after three consecutive cycles in which similar conditions have been encountered without exceeding the fuel system diagnostic thresholds.

Misfire Threshold Processing



Misfire Determination Processing



Misfire Monitor Operation:	
DTCs	P0300 (general misfire), P0301 P0302, P0303, P0304 (specific cylinder misfire) P315 (profile adaption values at limit)
Monitor execution	Continuous, misfire rate calculated every 200 or 1000 revs after start: (after 2 crankshaft revolutions)
Monitor Sequence	None
Sensors OK	CKP(P0335, P0336), BARO (P2227, P2228, P2229), TPS (P0122, P0123, P0222, P0223), ECT
Monitoring Duration	Entire driving cycle (see disablement conditions below)

Typical misfire monitor entry conditions:		
Entry condition	Minimum	Maximum
Time since engine start-up	+2 crankshaft revolutions	
Engine load	> zero load line; all positive torque range	
RPM Range (2 revs after exceeding 150 rpm below “drive” idle rpm)	550 rpm	6000 rpm
Engine Coolant Temperature	-7 °C	
Decel Fuel Cut Off	Not active	
BARO	75 kPa	
Fuel tank level	5 %	
Maximum engine speed threshold target wheel adaptation	5504	
Minimum engine speed threshold for target wheel adaptation	1696	

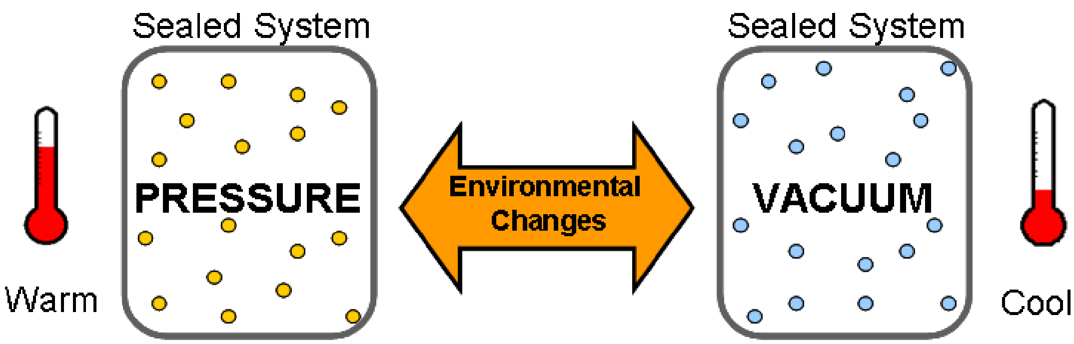
Typical misfire temporary disablement conditions:
Fuel shut-off due to vehicle-speed limiting or engine-rpm limiting mode
Not during torque interventions by traction control
High rate of change of torque (heavy throttle tip-in or tip out), > 503.8.to .949.0 deg/sec
High rate of change of MAF ((heavy throttle tip-in or tip out), > 35 to 40 mg/stroke

Typical misfire monitor malfunction thresholds:
Type A (catalyst damaging misfire rate): ≥ 5 %
Type B (emission threshold rate): ≥1%
Segment Adaptation values at the limit (Adaptation Tolerance): 10.1%
Signal Implausible / Missing/ Adding 1 tooth or more (Incorrect number of teeth per rotation):

J1979 Misfire Mode $06 Data			
Monitor ID	Test ID	Description	
A1	$0C	Total misfire counts for last/current driving cycle	events
A2	$0B	Cylinder #1 EWMA misfire counts for previous driving cycles	events
A2	$0C	Cylinder #1 Misfire counts for last/current driving cycle	events
A3	$0B	Cylinder #2 EWMA misfire counts for previous driving cycles	events
A3	$0C	Cylinder #2 Misfire counts for last/current driving cycle	events
A4	$0B	Cylinder #3 EWMA misfire counts for previous driving cycles	events
A4	$0C	Cylinder #3 Misfire counts for last/current driving cycle	events
A5	$0B	Cylinder #4 EWMA misfire counts for previous driving cycles	events
A5	$0C	Cylinder #4 Misfire counts for last/current driving cycle	events

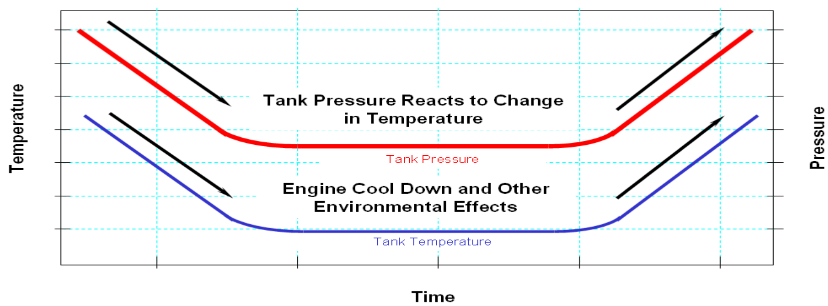
EVAP System Monitor – Natural Vacuum Leak Detection

This vehicle utilizes an engine off natural vacuum evaporative system integrity check that tests for 0.020" diameter leaks while the engine is off and the ignition key is off. The Natural Vacuum Leak Detection II (NVLD II) evap system integrity check uses a pressure switch to detect evap system leaks.

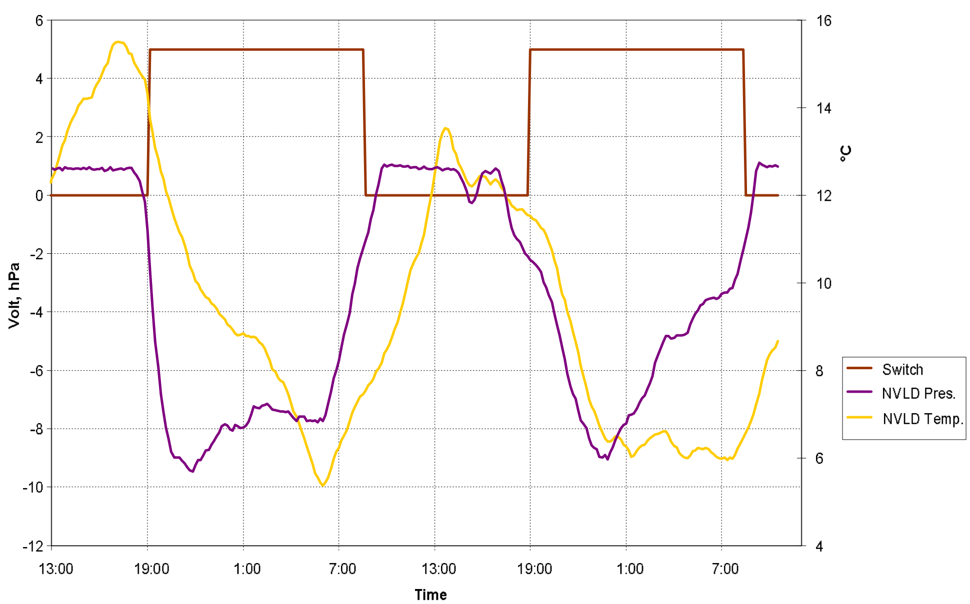


The correlation between pressure and temperature in a sealed system is used to generate a vacuum in the tank when the temperature drops. If a sufficient temperature drop of 8°C (14.5 °F) is detected for a minimum time of 2 hours, the vacuum level in the tank will exceed 0.04 psi and therefore close the NVLD II switch. If the switch closes the system is considered to be leak free. Therefore, if the switch does not close within these conditions, a leak is detected.

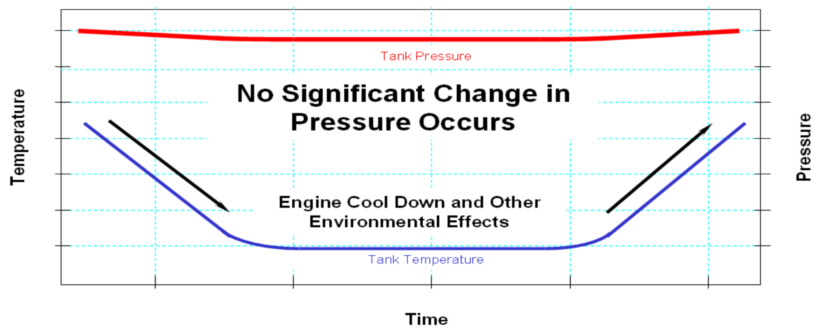
No Leak Switch Closed



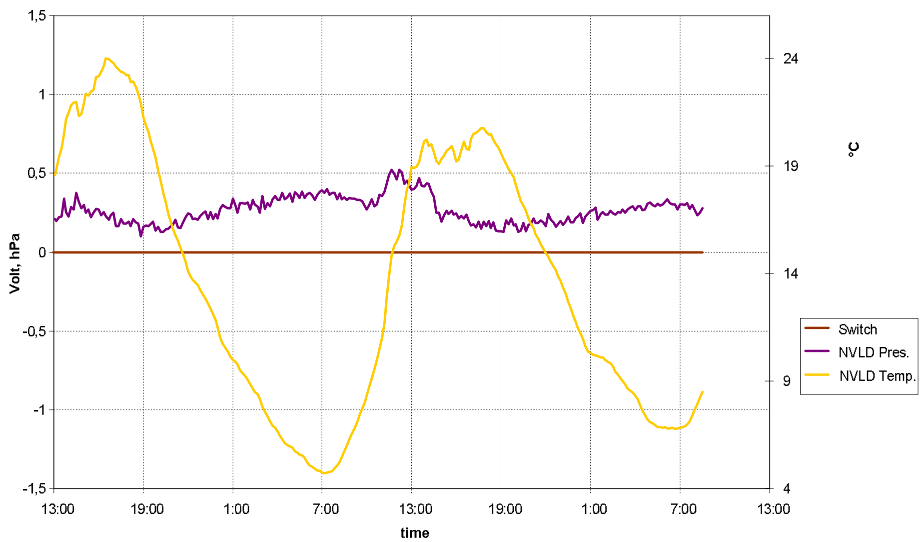
Typical vehicle response without leakage



.020" Leak Switch Open

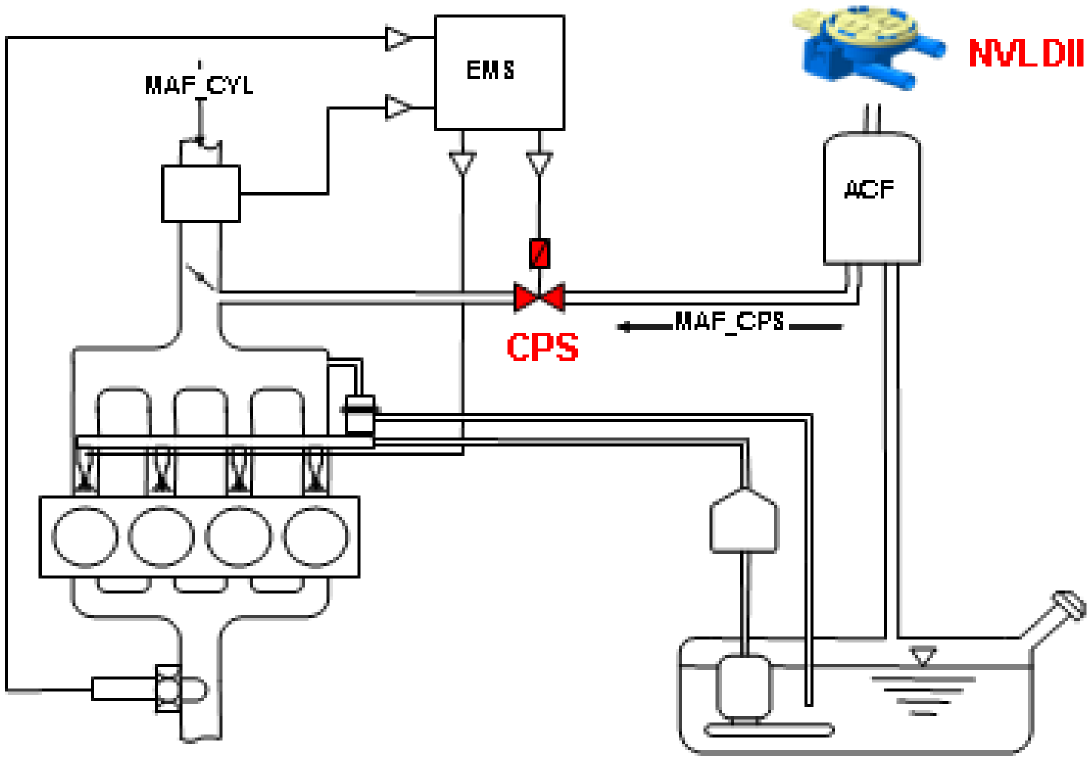


Typical vehicle response with .020" leak



NVLD II Overview

The NVLD II evaporative system monitor consists of an NVLD II module, the Canister Purge Solenoid (CPS) and software in the ECM that enables/disables the monitor, determines fault status and manages fault code storage, Mode $06 data, Mode $09 data, etc.



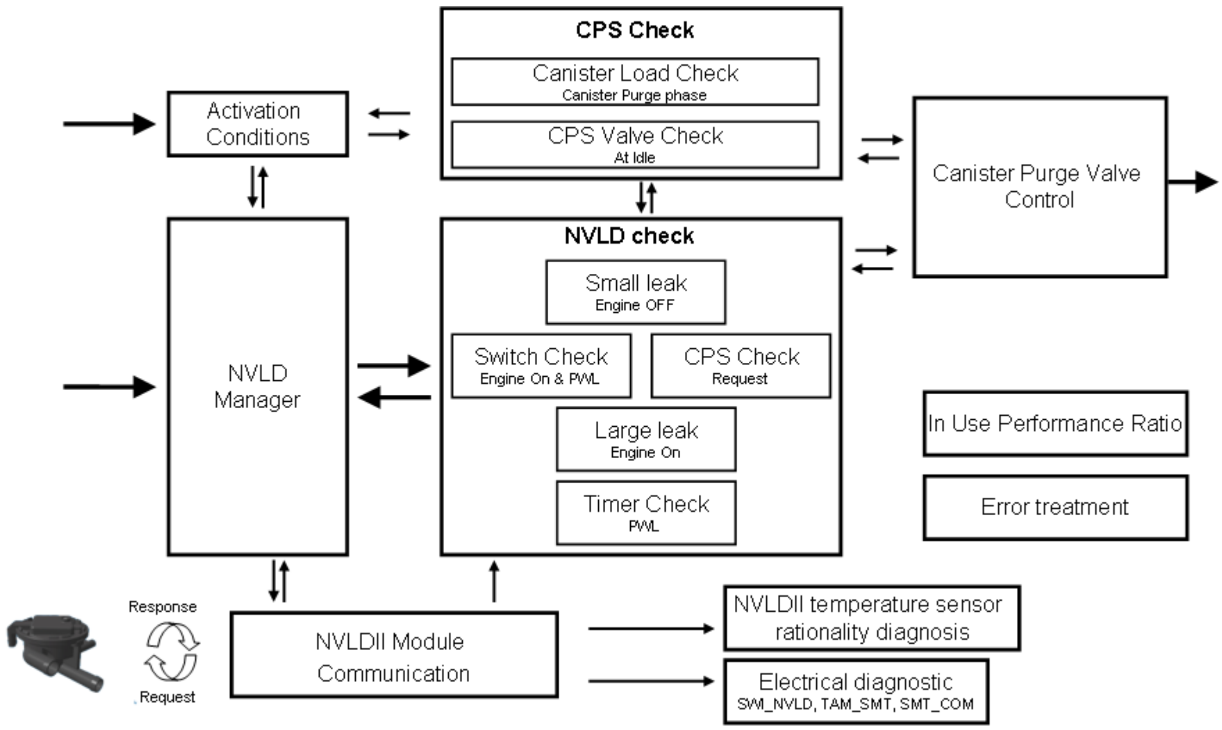
The NVLD II monitor performs a small (0.020“) leak check during engine off and a large leak check during engine running. The NVLD II module incorporates a pressure switch and temperature sensor so the monitor also includes a complete series of auxiliary checks to confirm the integrity of the mechanical and electrical components that make up the entire evap monitoring system. The NVLD II module is powered after the ignition key is turned off so that the entire ECM does not have to be powered to perform the engine-off small leak check. This saves a considerable amount of current draw from the battery.

The following functions are managed by the software in the ECM:

- 0.020” small leak detection enablement and fault decision (engine off)
- Large leak/fuel cap off detection enablement and fault decision (engine running)
- Canister purge solenoid (CPS) (electrical/wiring and mechanical rationality)
- NVLD II communications (protocol check and electrical/wiring)

The following functions are managed by the NVLD II module

- NVLD II pressure switch (electrical/wiring and mechanical rationality check)
- NVLD II temperature sensor (rationality and out of range check)
- NVLD II timer (rationality check)



CPS Check
Canister Load Check
Canister Purge phase
CPS Valve Check
At Idle
Activation Conditions
Canister Purge Valve Control
NVLD check
Small leak
Engine OFF
Switch Check
Engine On & PWL
CPS Check
Request
Large leak
Engine On
Timer Check
PWL
NVLD Manager
In Use Performance Ratio
Error treatment
Response
Request
NVLDII Module Communication
NVLDII temperature sensor rationality diagnosis
Electrical diagnostic
SWI_NVLD, TAM_SMT, SMT_COM

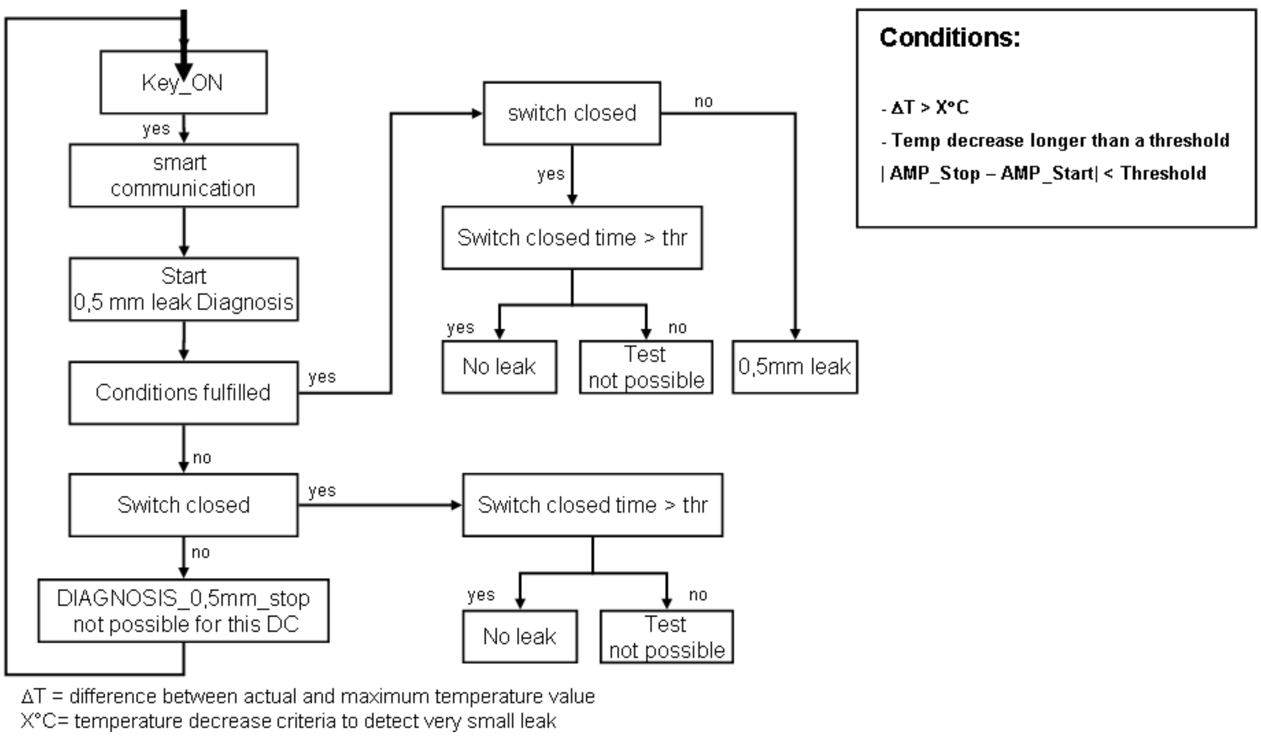
Small leak (0.020") detection algorithm:

The small leak algorithm is designed to detect a .020" leak in the evaporative purge system as well as a stuck open purge valve. The small leak (0.020" diameter) monitor evaluates the data collected from the NVLD II-module during the ignition key off/engine off phase. After key off, a leak free evap system will generate a vacuum condition in the fuel tank as the fuel cools down. If the pressure switch in the NVLD II module remains closed for a sufficient time (typically 10 minutes), the monitor passes.

If a temperature drop of 8°C was observed over at least 2 hours with no significant increase in fuel tank vacuum since start of the ignition key off/engine off phase, (i.e. the pressure switch has not closed for the minimum time), a small leak is detected. (P0456)

If the diagnostic entry conditions are not met, no diagnostic results are obtained (no call).

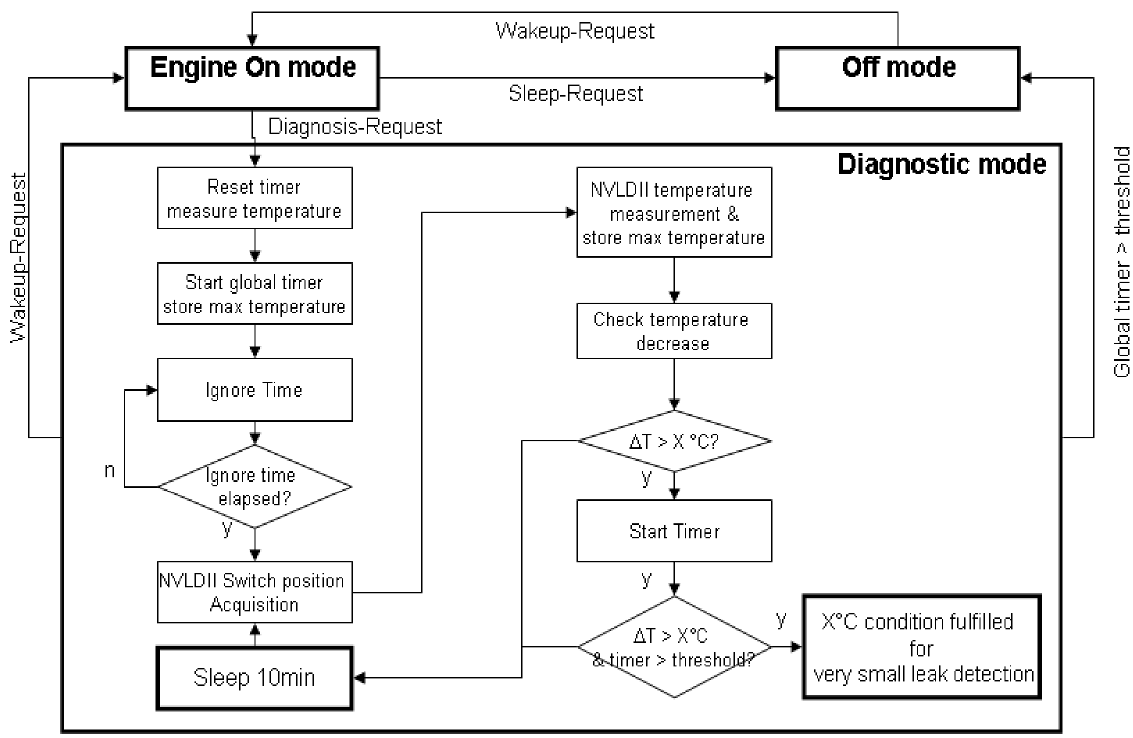
The overall evap monitor diagnostics are shown in the diagram below. The 0.020: dia leak monitor data is collected by the NVLD II module during ignition off and evaluated by the ECM during engine-on. The NVLD-II module diagnostics are performed during ignition on and ignition off.



NVLD II Module Operation

NVLD II module diagnostic operation is divided into three operational modes, which are entered depending on external conditions.

- **Engine On mode:** The NVLD II module receives and responds to a communication request from the ECM. These requests are sent during engine run operation. On a key on event, a Wakeup-Request is sent to establish communication between to NVLD II module and ECM.
- **Diagnostic mode:** At the end of a driving cycle (ECM powerlatch active), the NVLD II module receives a Diagnosis-Request to go into "diagnostic mode" and perform engine-off switch and temperature monitoring for very small leak detection.
- **Off mode:** When diagnostic mode is finished or conditions for very small leak detection are not met, the NVLD II module receives a Sleep-Request and goes into "Off mode";



ΔT = difference between actual and maximum temperature value
X°C= temperature decrease criteria to detect very small leak

Note: ΔT = difference between actual and maximum temperature value

In diagnostic mode, after an initial delay time has elapsed, the temperature and switch position are checked every 10 minutes and two separate conditions for small leak detection are determined by checking if the calibrated temperature difference between the actual temperature and the minimum temperature is met for at least 2 hours. If this occurs, a corresponding condition flag is set.

I

0.020” EVAP Monitor Operation:	
DTCs	P0456 (0.020” leak)
Monitor execution	once per driving cycle for ≥ 0.020” dia leak while engine off
Sensors/Components OK	PU029F, PU05A0, P0450, P0451, P0452, P0453, P2025, P2026, P2027, P0444, P0458, P0459, P0497, P0460, P0461, P0462, P0463, P0128, P0116, P0117, P0118, P2227, P2228, P2229, P0072, P0073
Monitoring Duration	Data reported every 10 minutes while engine off

Typical 0.020” EVAP monitor entry conditions (vacuum decay and engine off):		
Entry condition	Minimum	Maximum
Engine off (soak) time	120 minutes	
Engine Coolant Temperature	48 °C	
Ambient Air Temperature	4.5 °C	
Engine on time	300 seconds	5400 seconds
Cumulative purge flow	97 grams	
Idle ratio		30%
Fuel Level	15%	90%
BARO	75 kPa	
Change in Fuel Vapor Temperature during engine off test	8 °C	
Change on BARO during engine off test		10 kPa
Engine off vacuum decay time less than threshold	70 seconds	

Typical 0.020" EVPA monitor malfunction thresholds:
NVLD II pressure switch open for > 24 hours after engine off test condition met

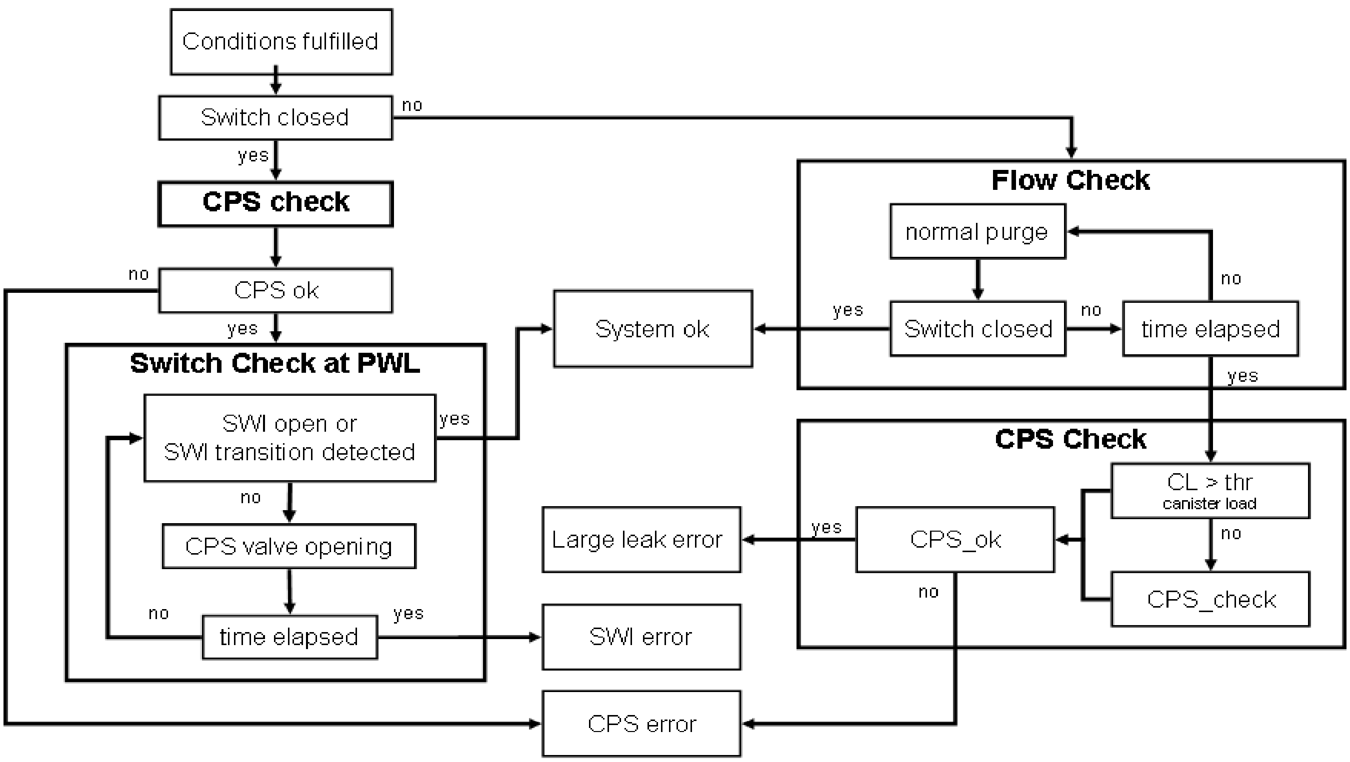
J1979 NVLD II 0.020" leak monitor Mode $06 Data			
Monitor ID	Comp ID	Description	Units
$3C	$A2	Time after key off for NVLD II switch to remain open for small leak check and max limit	minutes

Canister Purge Solenoid, switch and large-leak (0.090") test algorithm:

The large leak monitor is divided into two paths depending on the NVLD II pressure switch position determined at the start of the test. If the switch is already closed, the system is considered not to have a large leak, (as long as the NVLD II switch is not stuck in the closed position). This is determined by opening the CPS during the power-latch phase (i.e. engine stopped) to relieve the vacuum in the tank and force the switch to open. If the switch does not open within a defined time, a mechanical switch error is detected. In order to know that the CPS valve will open and allow the vacuum to be released, the CPS check is done after the switch is detected as closed.

If the switch is open at the start of the diagnostic test, the canister purge solenoid is opened with a defined maximum flow through the CPS valve. As soon as a minimum flow is achieved, the switch position is monitored. If the switch closes within a defined time, the system is considered not to have a large leak. Also the CPS valve must be functioning properly and the NVLD II switch is not stuck in one position.

If the switch does not close, the detection of the large leak or CPS valve error (blocked line) is complete.



Canister Purge Solenoid CPS - Flow-check

The canister purge valve plausibility checks ensure that the canister purge valve is able to be open to purge the canister, but due to consistency of the test results, the flow check will not uniquely determine a flow fault from a large leak. Therefore the large leak diagnostic fault (P0455) will be invoked.

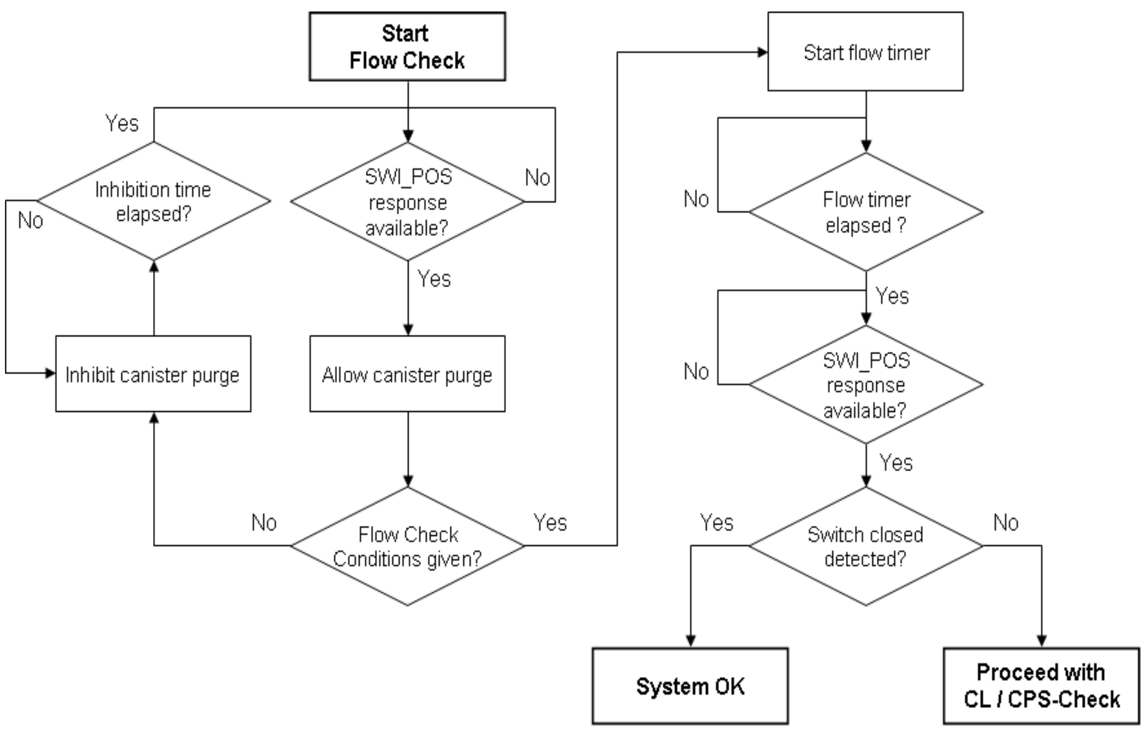
The canister purge valve plausibility checks can be done in three ways:

- When NVLD II module switch closed during large leak test
- When Canister load higher than a threshold during a calibrated time
- With Canister purge valve control (intrusive test).

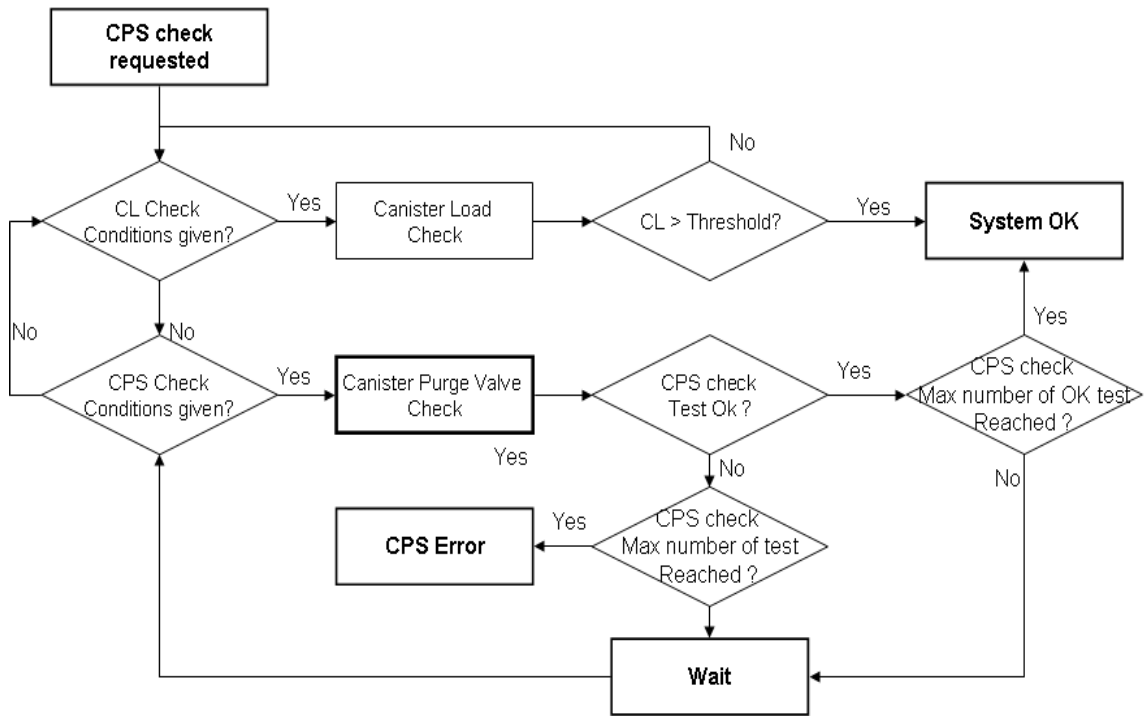
The canister purge valve control can act in via flow request or pwm request. The main difference between the two tests is the following.

- With PWM control CPS check make intrusive test into the ECM functionality and the reaction expected when the CPS valve opens, is engine parameter deviations.
- With FLOW control, CPS check we make non intrusive test into the ECM functionality and the reaction expected when the CPS valve opens is no engine parameter deviations.

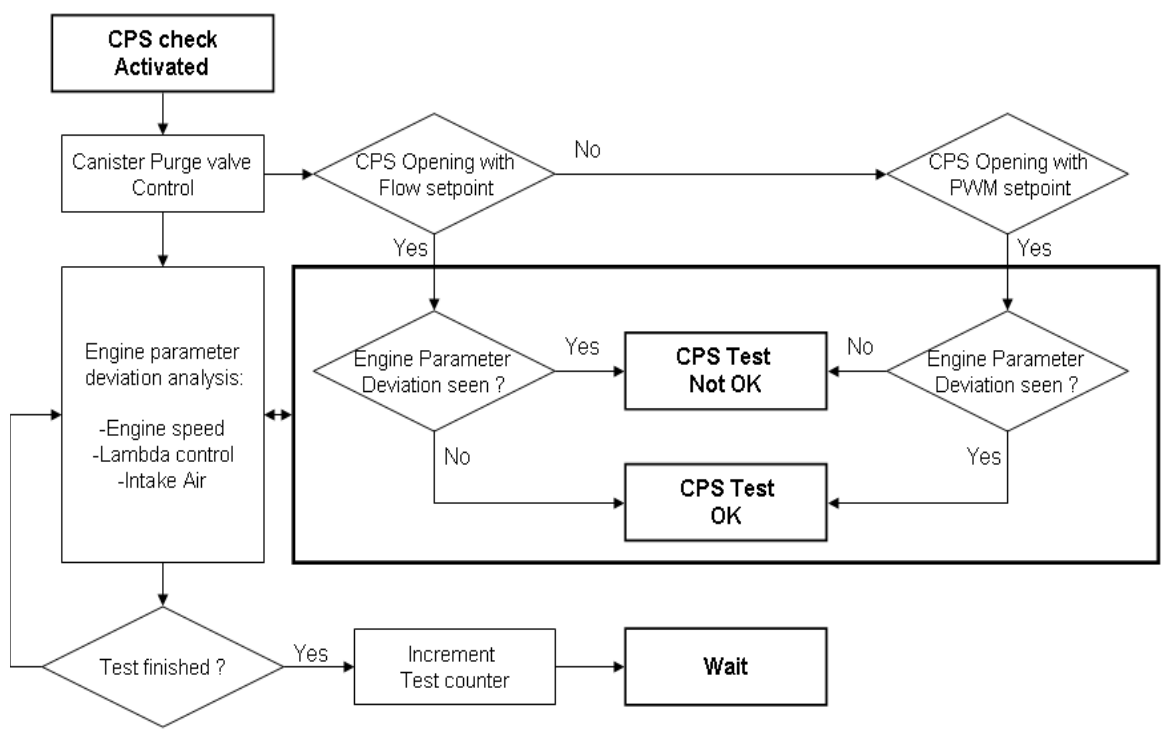
The canister purge valve control test can be done several times before an error is reported.



Flow check algorithm



Canister Purge valve Functional check algorithm



Canister Purge Valve Check algorithm

0.090” Leak/Low Purge Flow Monitor Operation:	
DTCs	P0455 (0.090” leak/no purge flow)
Monitor execution	once per driving cycle
Sensors/Components OK	PU029F, PU05A0, P0450, P0451, P0452, P0453, P0497, P0444, P0458, P0459, P0460, P0461, P0462, P0463, P0128, P0116, P0117, P0118, P2227, P2228, P2229, P0072, P0073, P0500
Monitoring Duration	80 seconds

Typical 0.090” Leak/Low Purge Flow monitor entry conditions:		
Entry condition	Minimum	Maximum
Engine run time	60 seconds	
Engine Coolant Temperature	48 °C	
Ambient Air Temperature	4.5 °C	
Fuel Fill Level	15%	90%
BARO	75 kPa	
Stable idle rpm		100 rpm
Stable idle torque		5 Nm
Vehicle speed		0.6 mph

Typical 0.090" Leak/Low Purge Flow monitor malfunction thresholds:
Evaporative emission system pressure switch state open for > 150 sec AND
Manifold pressure change > 1.4 kPa AND Manifold pressure min/max delta > 1.4 kPa AND
Mass air flow change >0.906 kg/h AND Mass air flow min/max delta >0.906 kg/h AND
Air adaptive change >45% AND air adaptive min/max delta >45% AND
Engine idle speed change >20 rpm AND Engine idle speed min/max delta >20 rpm AND
Idle speed controller change >0.3125 Nm AND Idle speed controller min/max delta > 0.3125 Nm AND
Lambda change > 10% AND Lambda min / max delta > 10%

J1979 NVLD II 0.090" leak monitor Mode $06 Data			
Monitor ID	Comp ID	Description	Units
$3A	$A1	Time for NVLD II switch to close during large leak check	seconds

J1979 NVLD II Purge Flow monitor Mode $06 Data			
Monitor ID	Comp ID	Description	Units
$3D	$B0	Time for NVLD II switch to close during purge flow check	Seconds
$3D	$B1	Air adaption change during intrusive flow check and max limit	percent
$3D	$B2	Lambda change during intrusive flow check and max limit	percent
$3D	$B3	Idle speed change during intrusive flow check and max limit	Rpm
$3D	$B4	Manifold flow change during intrusive flow check and max limit	Kg/h
$3D	$B5	Manifold air pressure change during intrusive flow check and max limit	hPa
$3D	$B6	Idle speed controller change during intrusive flow check and max limit	Nm

EVAP System Monitor Component Checks

Additional malfunctions that are to be identified as part of the evaporative system integrity check are as follows:

The Canister Purge Solenoid circuit is checked for opens and shorts (P0444, P0458, P0459)

Note that a CPS that is stuck closed will generate a P0455, and a CPS that is stuck open will generate a P0496.

Canister Purge Solenoid Check Operation:	
DTCs	P0444 – Canister Purge Solenoid open circuit P0458 – Canister Purge Solenoid short to ground P0459 – Canister Purge Solenoid short to battery
Monitor execution	continuous
Monitor Sequence	None
Sensors OK	not applicable
Monitoring Duration	1 sec to obtain smart driver status

Canister Purge Solenoid check entry conditions:		
Entry condition	Minimum	Maximum
P0444 Canister Purge Pulsewidth	7.81%	98%
P0458 Canister Purge Pulsewidth		98%
P0459 Canister Purge Pulsewidth	7.81%	

EVAP Pressure Switch Check Operation:	
DTCs	P0450 – Evap pressure switch position fault P0452 – Evap pressure switch low P0453 – Evap pressure switch high
Monitor execution	continuous
Monitor Sequence	None
Sensors OK	U029F
Monitoring Duration	30 seconds during engine running, 10 min during engine off

EVAP Pressure Switch check malfunction thresholds:
P0450 – Switch value within fail range, > 0.366 V, or < 0.574 V P0452 – Switch position value low < 0.256 V P0453 – Switch position value high > 2.857 V

EVAP Pressure Switch Performance Monitor Operation:	
DTCs	P0451 - Evap pressure switch performance
Monitor execution	once per driving cycle
Sensors/Components OK	
Monitoring Duration	80 seconds

EVAP Pressure Switch Performance monitor entry conditions:		
Entry condition	Minimum	Maximum
Engine run time	60 seconds	
Engine Coolant Temperature	48 °C	
Ambient Air Temperature	4.5 °C	
Fuel Fill Level	15%	99.6%
BARO	75 kPa	
Time at Idle	4 seconds	
Stable idle rpm		100 rpm
Stable idle torque		5 Nm
Vehicle speed		0.6 mph

EVAP Pressure Switch Performance check malfunction thresholds:
P0451 – "IF Switch closed at engine start AND Switch closed during a passing CPS check (P0496)" OR "IF Switch open at engine start AND Switch open during high canister purge duty cycle" OR "IF Switch closed at ECU power latch AND Switch closed after power latch CPS cycle"

EVAP Fuel Temperature Sensor Check Operation:	
DTCs	P2026 – EVAP Fuel Temperature Sensor Circuit Low P2027 – EVAP Fuel Temperature Sensor Circuit High
Monitor execution	continuous
Monitor Sequence	None
Sensors OK	U029F, U05A0
Monitoring Duration	0.10 seconds

EVAP Fuel Temperature Sensor check malfunction thresholds:
P2026 – sensor voltage > 4.85 V P2027 – sensor voltage < 0.18 V

EVAP Pressure Switch Performance Monitor Operation:	
DTCs	P2025 – EVAP Fuel Temperature Sensor Performance
Monitor execution	once per driving cycle
Sensors/Components OK	P0116, P0117, P0118, P0119, P0111, P0112, P0113, P0072, P0073, P2610, P2229, P2228, P2227, U029F,
Monitoring Duration	80 seconds

EVAP Pressure Switch Performance monitor entry conditions:		
Entry condition	Minimum	Maximum
Engine Off Time from previous drive cycle	50 minutes	
BARO	75 kPa	
Ambient Air Temperature	4.5 °C	
Fuel tank level	15%	90%
Engine Coolant Temperature	48 °C	

EVAP Pressure Switch Performance check malfunction thresholds:
EVAP Fuel Temp sensor temperature change within 10 minutes > 20 deg C OR abs value of the difference between EVAP Fuel Temp and IAT at cold start > = 15 deg C AND abs value of the difference between EVAP Fuel Temp and ECT at cold start > = 15 deg C

NVLD II Communication Check Operation:	
DTCs	U029F - Lost Communication with EVAP Leak Detection Module U05A0 - Invalid Data Received form EVAP Leak Detection Module
Monitor execution	continuous
Monitor Sequence	None
Sensors OK	
Monitoring Duration	150 msec for U029F, 300 msec for U05A0

NVLD II Communication check malfunction thresholds:
U029F - Invalid Response from NVLD module OR
Time out error on NVLD module communication line OR
Open circuit fault on NVLD module communication line OR
Short circuit to ground fault on NVLD module communication line OR
Short circuit to positive fault on NVLD module communication line
U05A0 - Leak Detection Control module reset occurred (power loss) OR
Difference between Leak Detection Control module timer and ECU internal timer > 2.0 sec

The ECM receives the FLI signal via the CAN data link from the instrument cluster. The Fuel Level Input is checked for out of range values, opens and shorts. If the FLI signal is stuck, a P0460 is set. The ECM calculates the amount of fuel being consumed by accumulating fuel pulse width. If the there is an insufficient corresponding change in fuel tank level, a P0460 DTC is set. Finally, the Fuel Level Input is checked for noisy readings. If the FLI input changes rapidly, a P0461 DTC is set.

Fuel Level Input Check Operation:	
DTCs	P0460 – Fuel Level Input Circuit Erratic P0461 – Fuel Level Input Circuit Stuck P0462 – Fuel Level Input Circuit Low (short to ground/open circuit) P0463 – Fuel Level Input Circuit High (short to power)
Monitor execution	continuous
Monitor Sequence	None
Sensors OK	FLI errors
Monitoring Duration	12.7 sec for circuit tests, 10 sec for noisy test, 120 miles for stuck test

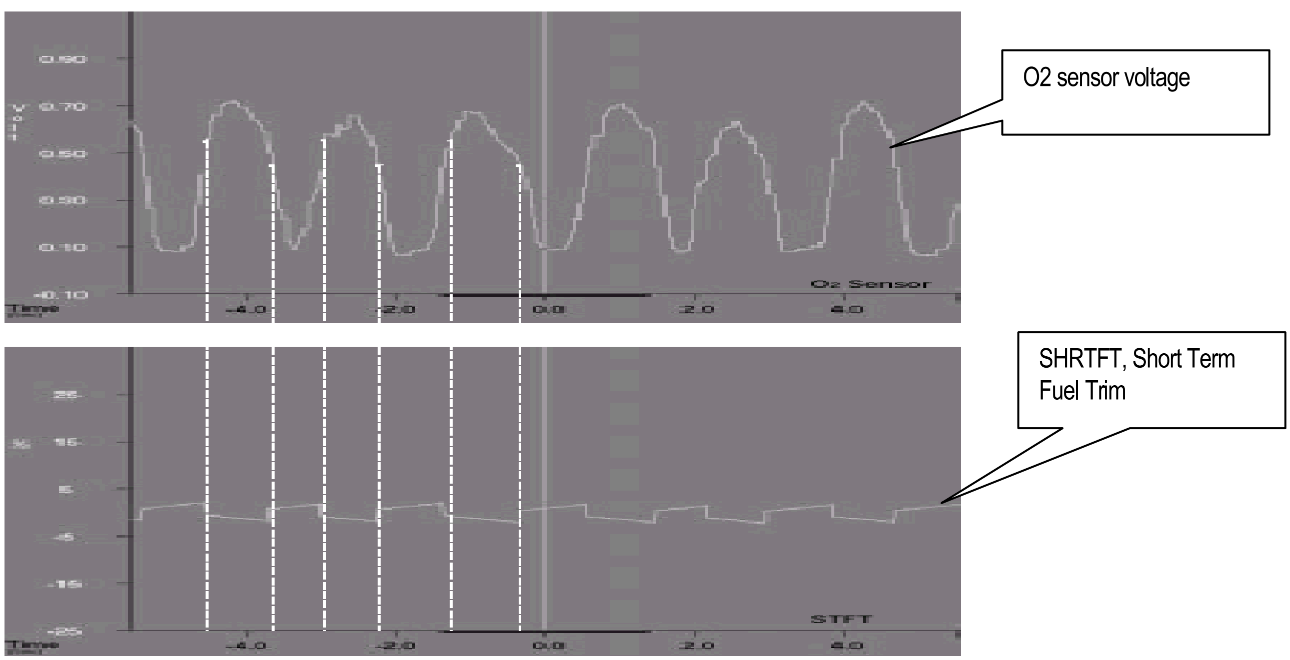
Typical Fuel Level Input check malfunction thresholds:
P0462 (Fuel Level Input Circuit Low): < 0.01 V ratio
P0463 (Fuel Level Input Circuit High): > 0.9902 V ratio
P0460 (Fuel Level Input Stuck): < 0.4L change after 1.0 L has been consumed.
P0461 (Fuel Level Input Gradient): > 0.5 L change over a 660 msec sample period

Fuel System Monitor

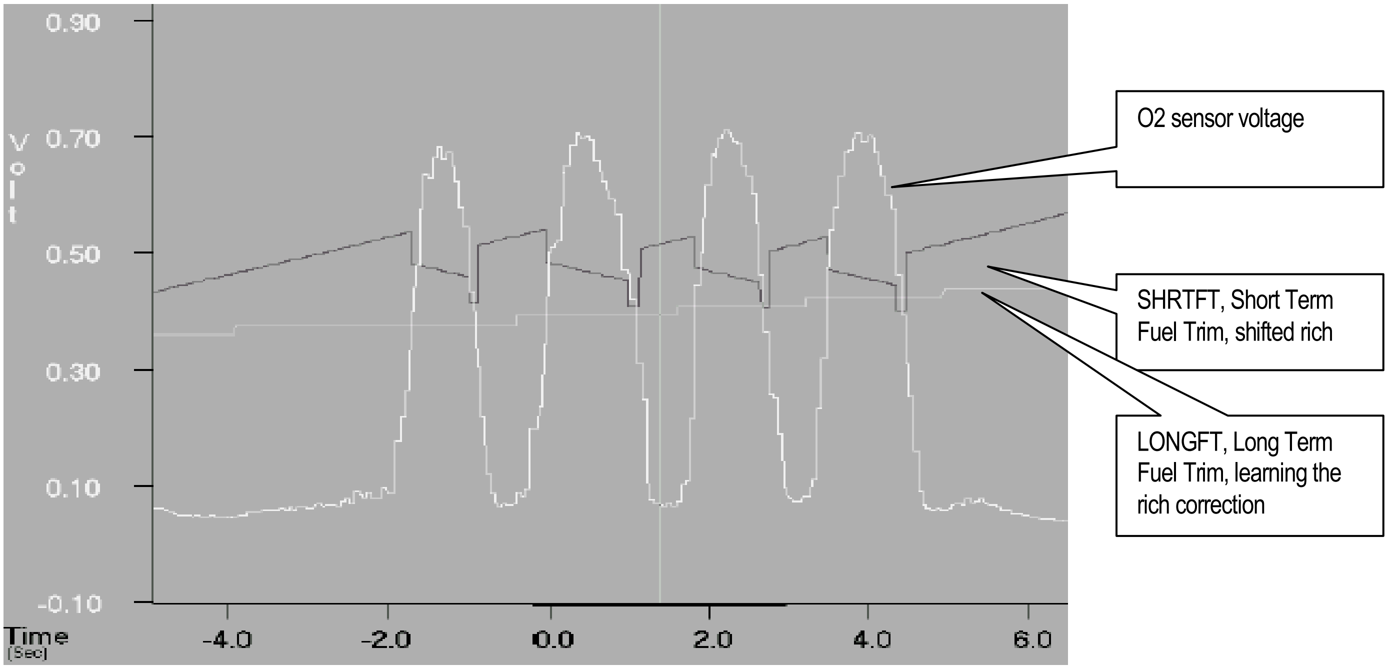
The closed loop fuel strategy uses O2 sensors for feedback. The fuel equation includes short and long term fuel trim modifiers:

A conventional O2 sensor (not a wide-range sensor) can only indicate if the mixture is richer or leaner than stoichiometric. During closed loop operation, short term fuel trim values are calculated by the ECM using oxygen sensor inputs in order to maintain a stoichiometric air/fuel ratio. The ECM is constantly making adjustments to the short term fuel trim, which causes the oxygen sensor voltage to switch from rich to lean around the stoichiometric point. As long as the short term fuel trim is able to cause the oxygen sensor voltage to switch, a stoichiometric air/fuel ratio is maintained.

When initially entering closed loop fuel, SHRTFT starts 1.0 and begins adding or subtracting fuel in order to make the oxygen sensor switch from its current state. If the oxygen sensor signal sent to the ECM is greater than 0.45 volts, the ECM considers the mixture rich and SHRTFT shortens the injector pulse width. When the cylinder fires using the new injector pulse width, the exhaust contains more oxygen. Now when the exhaust passes the oxygen sensor, it causes the voltage to switch below 0.45 volts, the ECM considers the mixture lean, and SHRTFT lengthens the injector pulse width. This cycle continues as long as the fuel system is in closed loop operation.



As fuel, air, or engine components age or otherwise change over the life of the vehicle, the adaptive fuel strategy learns deviations from stoichiometry while running in closed loop fuel. Corrections are only learned during closed loop operation, and are stored in the ECM as long term fuel trim values (LONGFT). They may be stored into a rpm/load table. LONGFT values are only learned when SHRTFT values cause the oxygen sensor to switch. If the average SHRTFT value remains above or below stoichiometry, the ECM “learns” a new LONGFT value, which allows the SHRTFT value to return to an average value near 1.0. LONGFT values are stored in Keep Alive Memory as a function of air mass. The LONGFT value displayed on the scan tool is the value being used for the current operating condition.

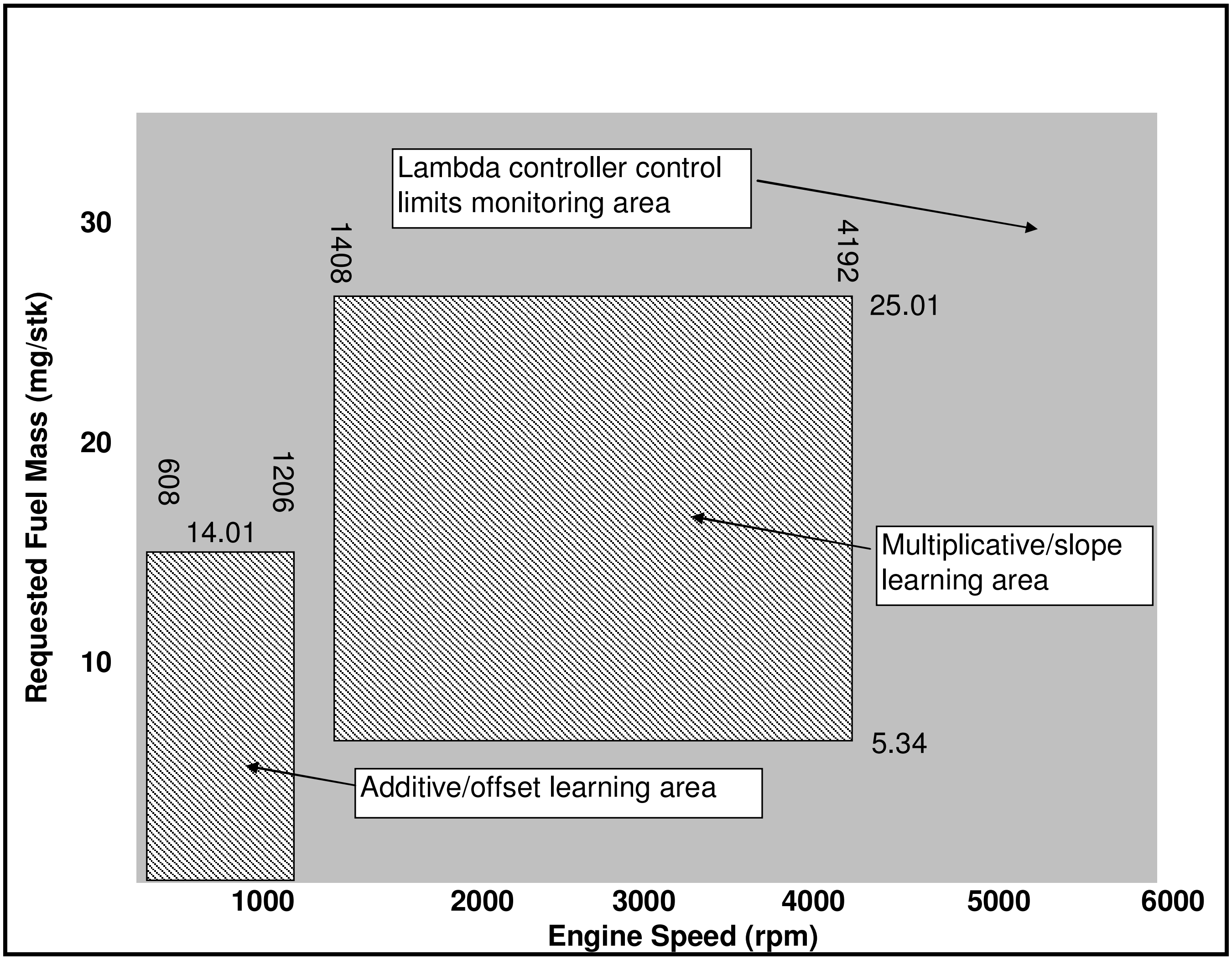


As components continue to change beyond normal limits or if a malfunction occurs, the long-term fuel trim values will reach a calibratable rich or lean limit where the adaptive fuel strategy is no longer allowed to compensate for additional fuel system changes. Long term fuel trim corrections at their limits, in conjunction with a calibratable deviation in short term fuel trim, indicate a rich or lean fuel system malfunction.

The fuel system monitor has two distinct monitoring paths. The fast path is used to determine if the lambda controller is unable to maintain fuel control. In this case, the controller has reached the minimum or maximum control limits (lack of switching) and a DTC is stored. The slow path is used when normal fuel adaption is taking place on a system under normal lambda control. If the fuel adaption values reach the minimum or maximum adaption limits, a DTC is stored. The fuel monitor learns both a slope and offset term. The additive/offset term is learned at idle while the slope/multiplicative term is learned at higher loads and engine speeds.

Note that Positive Crankcase Ventilation monitoring occurs at idle. A disconnected PCV hose will result in a lean condition at idle that will be detected by the fuel monitor.

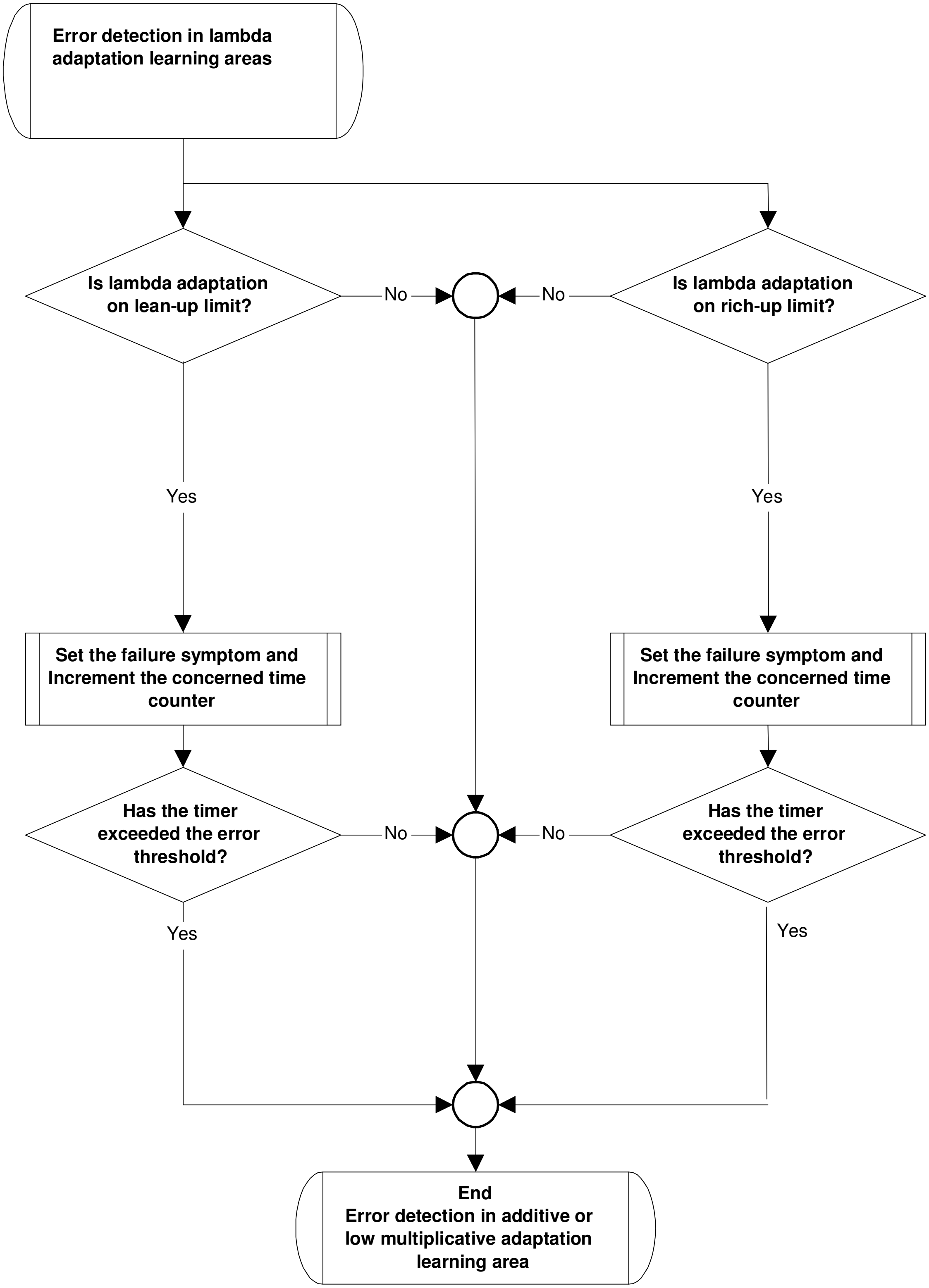
The diagram below shows the calibratable areas where fuel monitor learning takes place during closed loop fuel control.



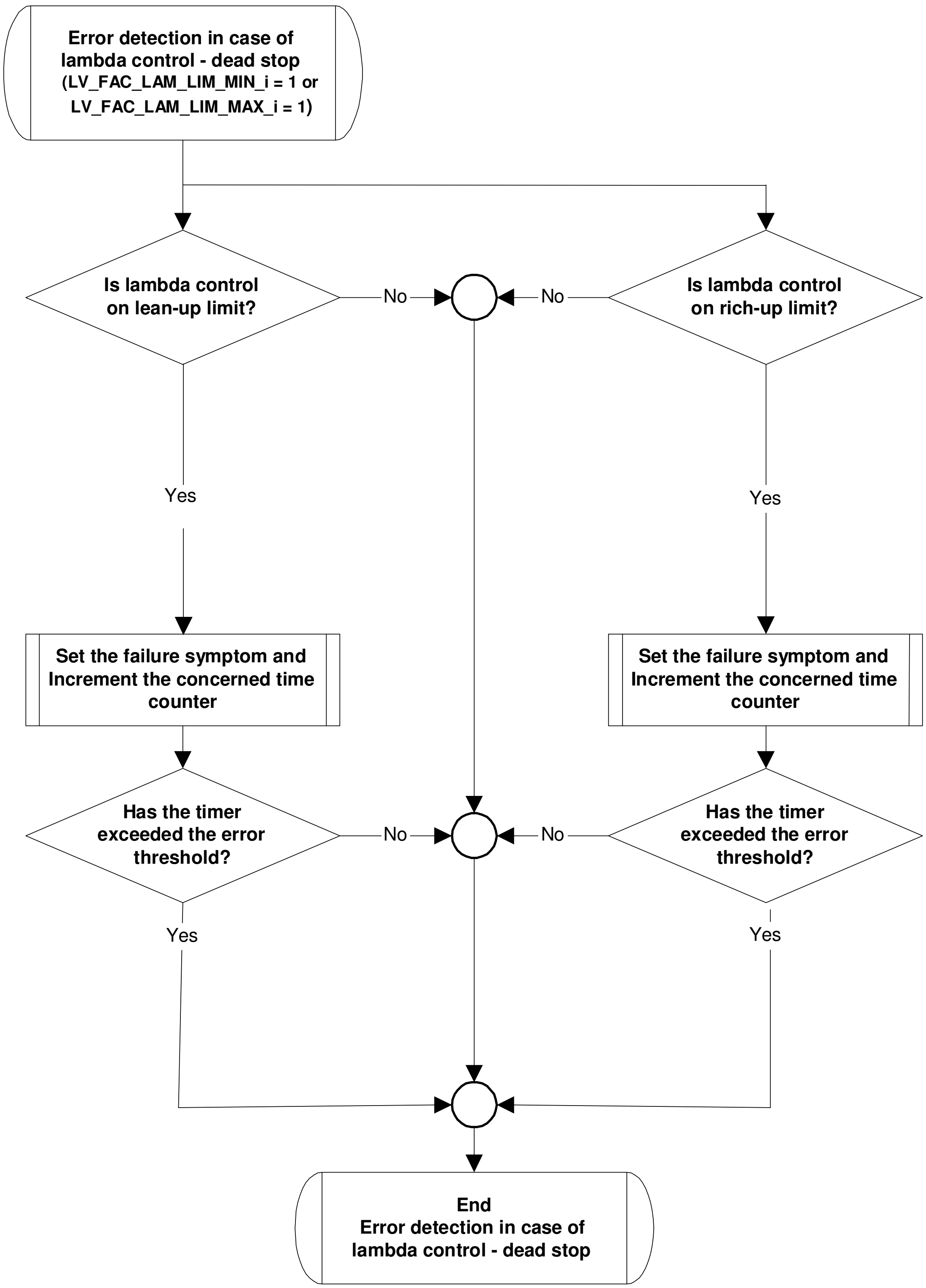
Similar Conditions

When the ECM recognizes a failure in the misfire or fuel systems, the software stores the conditions present when the fault occurred. These conditions recorded include engine speed, engine load (MAF), and warm up status of the first event that resulted in the storage of a DTC. These stored conditions are referred to as similar conditions. If the similar conditions are met without a failure in the misfire or fuel system, a flag is set to 1 which allows the driving cycle counter for that failure to decrement. Any misfire or fuel system DTCs are erased if similar conditions are not encountered during the next 80 driving cycles immediately following the initial detection of the malfunction. The MIL is extinguished after three consecutive driving cycles in which similar conditions have been encountered without exceeding the misfire or fuel system diagnostic thresholds.

Fuel Monitor Adaption Monitoring



Fuel Monitor Lambda Controller Monitoring



Fuel Monitor Operation:	
DTCs	P0171 System Lean P0172 System Rich
Monitor execution	continuous while in closed loop fuel
Monitor Sequence	NA
Sensors OK	CPS, ECT, MAF, Misfire, IAT, TPS, HO2S, CAM, TPS, CRK, Injectors , AMP, AAT, VVT
Monitoring Duration	continuous

Typical fuel monitor entry conditions:		
Entry condition	Minimum	Maximum
Engine running and lambda closed loop		
BARO	75 kPa	
Mass Air Flow		65 mg/stk
Engine Speed	608 rpm	redline
Engine Coolant Temperature	69.75 ^{o}C	
Intake Air Temperature	-10.5 ^{o}C	
Ambient Air Temperature	-10.5 ^{o}C	
Engine speed for offset lambda adaptation	608 rpm	1206 rpm
Fuel mass for offset lambda adaptation		14.01 mg/stroke
Engine speed for multiplicative lambda adaptation	1408 rpm	4192 rpm
Fuel mass for multiplicative lambda adaptation	5.34 mg/stroke	25.01 mg/stroke

Typical fuel monitor malfunction thresholds:
P0171 Lambda controller at maximum limit, short term fuel trim > 39.99% for > 40 sec OR Lambda adaptation > 25% for > 20 sec P0172 Lambda controller at minimum limit, short term fuel trim < -39.99% for > 60 sec OR Lambda adaptation < - 25% for 20 sec

HO2S Monitor

Upstream Oxygen Sensor Monitoring - Switching Sensor

The upstream oxygen sensor circuit monitor detects if the HO2S sensor voltage is above or below a calibratable threshold or if it is not active, (lack of switching) or stuck at the bias voltage.

The upstream oxygen sensor monitor detects if the HO2S signal circuit voltage is:

Shorted to ground or an air leak is present (low signal),

Signal circuit voltage is high (high signal),

Open circuit causing the signal circuit voltage to be inactive or stuck at the bias voltage.

The open circuit detection strategy is described below

Open Circuit Check

This check detects if the HO2S signal circuit is not active (lack of switching) or stuck at the bias voltage at the beginning of the driving cycle. This check allows the service technician to find the root cause of the upstream HO2S sensor "not ready for closed loop". If the "open circuit check" stores a DTC (P0130) then an additional DTC is also stored automatically (P016A) - O2 Sensor Not Ready (Bank 1 Sensor 1)).

This additional check is performed because there are two different possible root causes for this symptom at engine start. The upstream signal voltage can be inactive (stuck at the bias voltage) because of an open circuit, or because of a weak HO2S heater. These cases are described below:

Case 1: HO2S Open Circuit at engine start

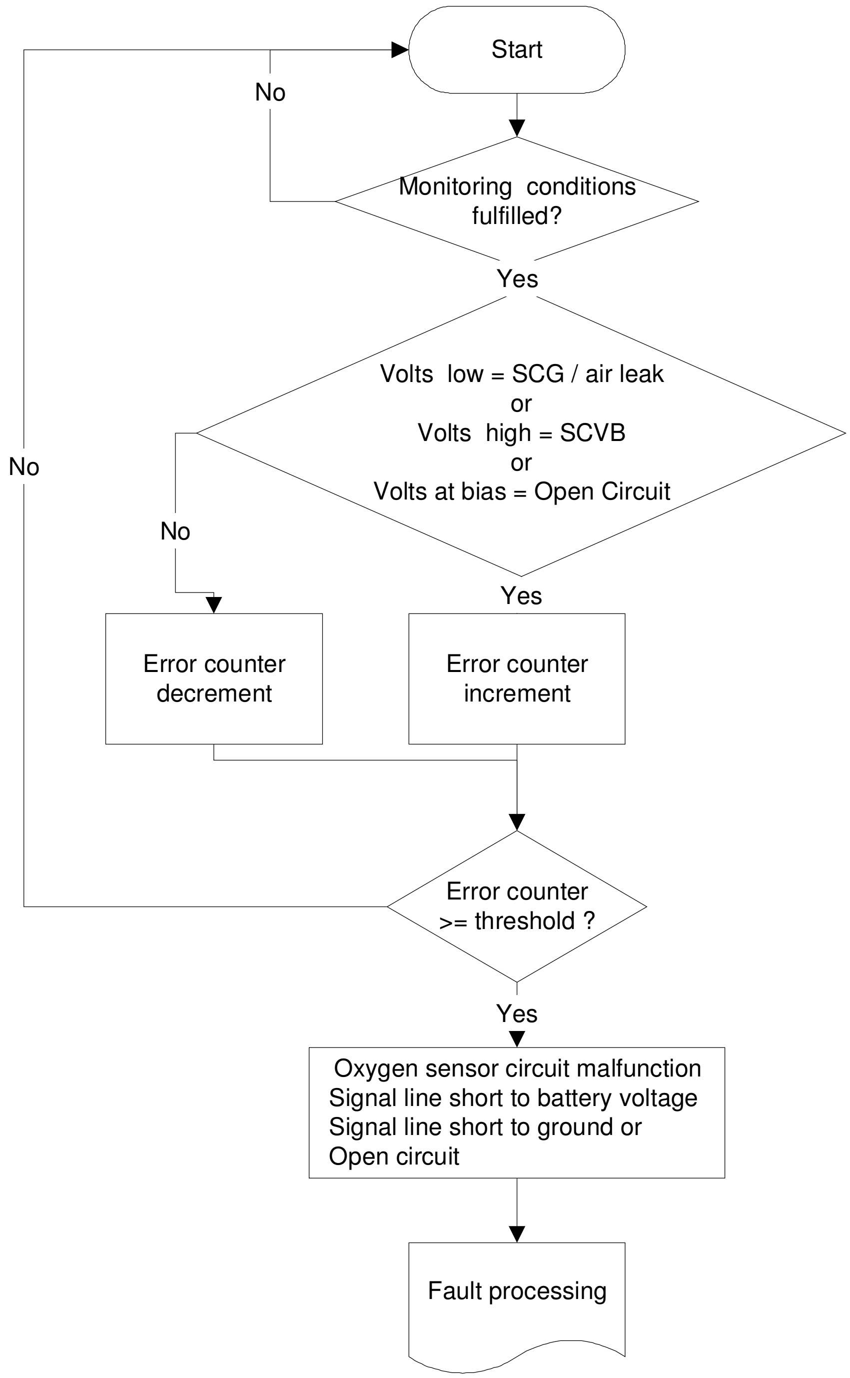
An open circuit power integral starts and activates the open circuit diagnosis to check if a real open circuit is present or if the P016A was set because of a weak O2 sensor heater.

If the power integral exceed its limit, the signal is checked again. If the signal voltage is still stuck at the bias voltage and the internal resistance is above a calibrated limit, a P0130 is stored for an open circuit.

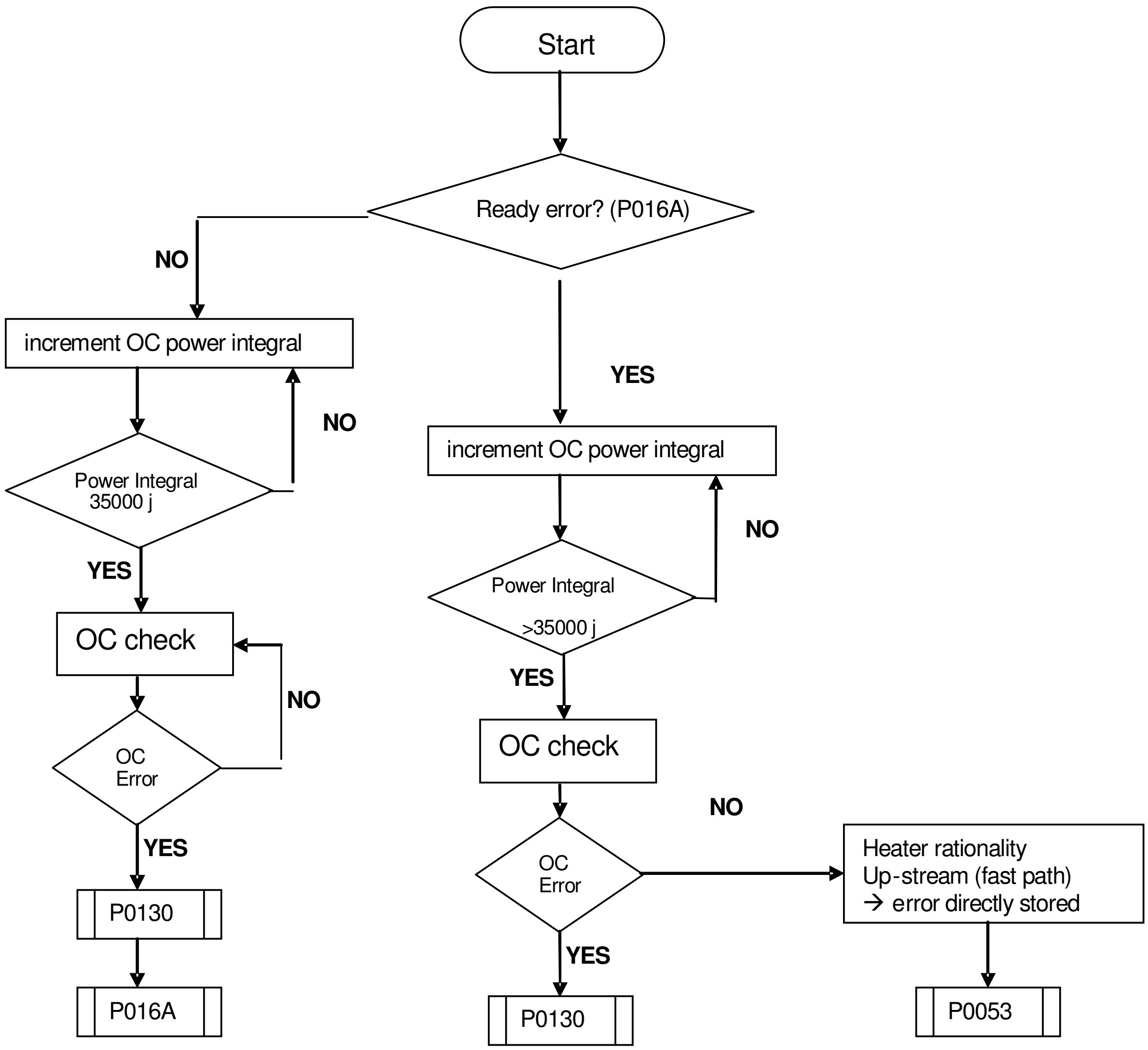
Case 2: HO2S heater low performance at engine start

The open circuit power integral starts and the signal is checked again. The power integral is calibrated based on low activity of the signal voltage with a weak heater. After the power integral exceeds its limit, and the upstream voltage is outside the open circuit limits, if no real open circuit present, the P0053 for the heater rationality upstream is stored.

Upstream HO2S Circuit Check



Upstream HO2S Open Circuit and Heater Rationality Check



HO2S11 circuit check operation:	
DTCs	P0130 – HO2 circuit open (Bank 1, Sensor 1) P0131 – HO2 circuit low voltage (Bank 1, Sensor 1) P0132 – HO2 circuit high voltage (Bank 1, Sensor 1)
Monitor execution	Continuous
Monitor Sequence	None
Sensors OK	HO2S (P0131, P0132, P0133, P0134, P2297, P2A00), HO2S heaters (P0030, P0031, P0032), MAF (P0101, P0102, P0103)
Monitoring Duration	12.7, 20, or 50 seconds to register a malfunction

Typical HO2S11 circuit check entry conditions:		
Entry condition	Minimum	Maximum
Stuck above lean voltage limit (P0130 only)	0.35 volts	
Stuck below rich voltage limit (P0130 only)		0.5 volts
Time stuck (P0130 only)	50 seconds	
Closed loop fuel control (P0131 only)		
Exhaust gas temp (P0131 only)		799.97 °C
Mass Air Flow (P0131 only)	6 kg/hr	
Time stuck at low voltage (P0131 only)	20 seconds	
Oxygen sensor internal resistance (P0131 only)		2 ohms
Integrated mass air flow after purge solenoid closed (P0131 only)	30 g	
Time stuck at high voltage (P0132 only)	12.7 seconds	

Typical HO2S11 circuit check malfunction thresholds:

P0130

O2 sensor resistance ≥ 50000 ohms, voltage stuck between 0.35 and 0.5 volts

P0131

O2 sensor resistance < 2 ohms and O2 sensor voltage stuck at < .009 volts

P0132

O2 sensor voltage stuck above 1.1volts

Upstream Oxygen Sensor Slow Response Monitor - Switching Sensor

A fuel control routine drives the air/fuel ratio around stoichiometry at a calibratable frequency and magnitude. This produces a predictable oxygen sensor signal amplitude and duration used to evaluate the response time and frequency response of the sensor.

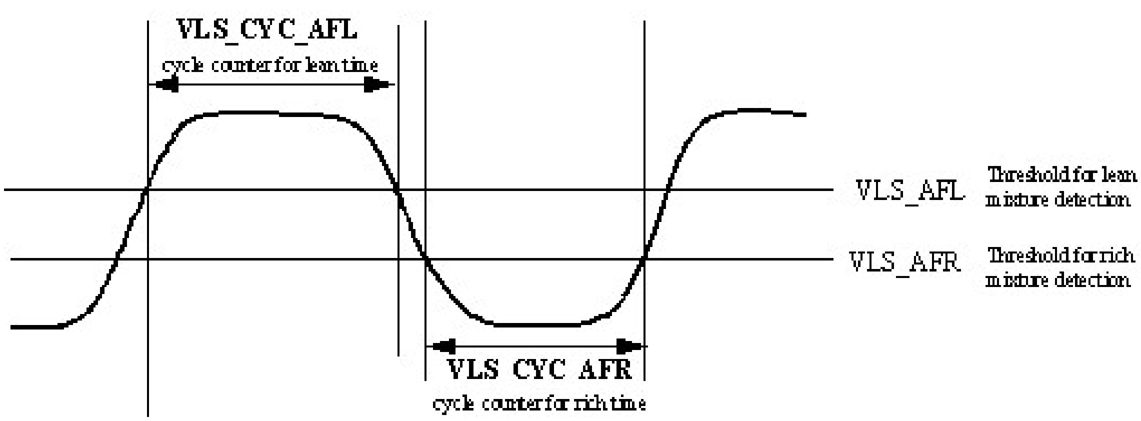
At each cycle, the lean and the rich duration are measured and accumulated separately. After a calibrated number of cycles are exceeded, the accumulated lean and rich durations and periods are compared to the expected durations and periods.

Actual rich to lean switch time is compared to expected rich to lean switch time (as a function of MAF)

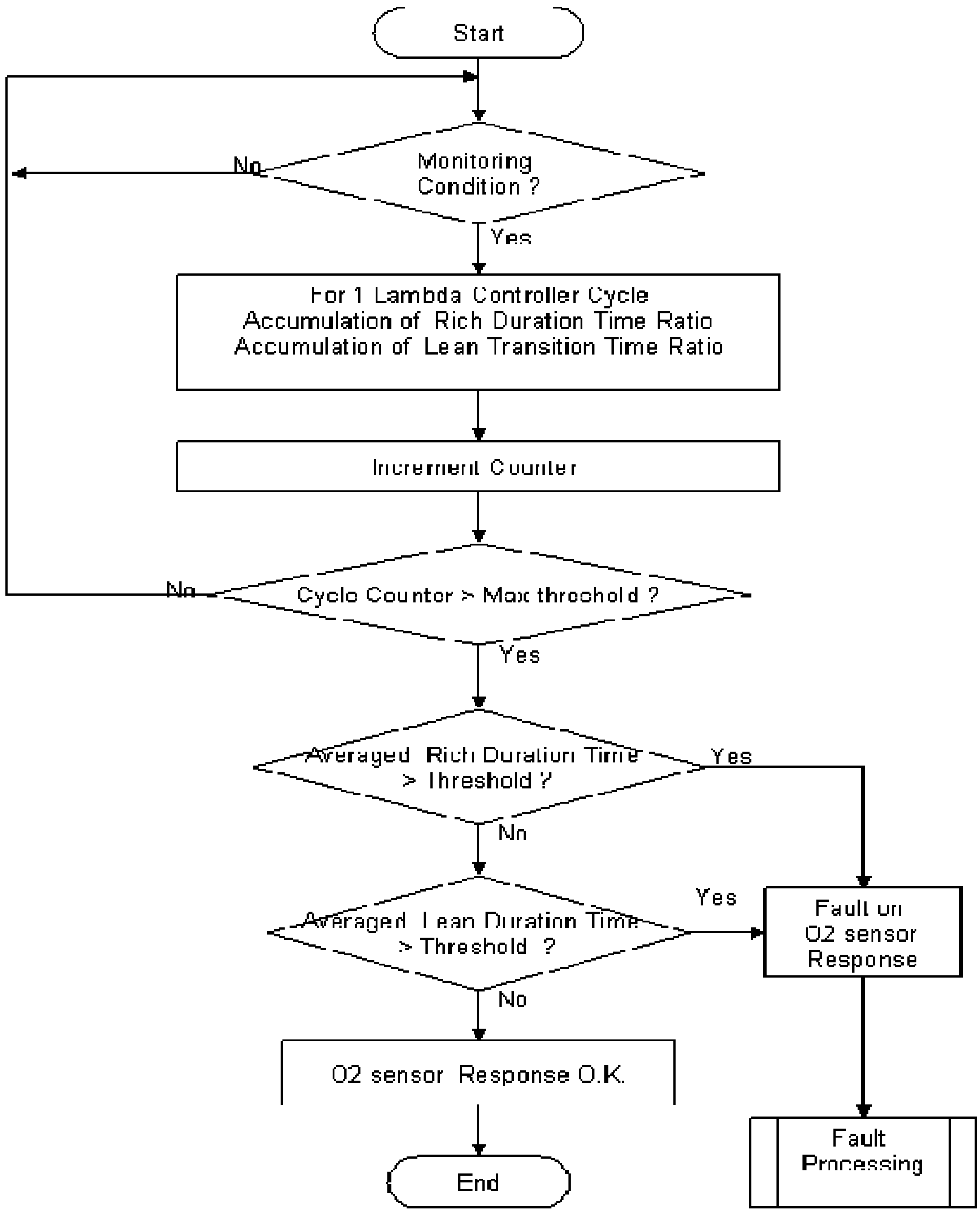
Actual lean to rich switch time is compared to expected lean to rich switch time (as a function of MAF)

Actual rich to lean switch period is compared to expected rich to lean switch period (as a function of MAF & RPM)

Actual lean to rich switch period is compared to expected lean to rich switch period (as a function of MAF & RPM)



Upstream HO2S Slow Response Check



HO2S11 “Signal Dynamics – Slow Response” Operation:	
DTCs	P0133 O2 Sensor Circuit Slow Response (Bank 1 Sensor 1) P0134 O2 Sensor Circuit No Activity Detected (Bank 1 Sensor 1)
Monitor execution	Once per driving cycle
Monitor Sequence	None
Sensors OK	MAF, HO2S, ECT, HO2S heater, CPS
Monitoring Duration	12.7 to 18 seconds to register a malfunction

Typical HO2S11 response rate entry conditions:		
Entry condition	Minimum	Maximum
Exhaust gas temperature	399 ^{o}C	
Engine coolant temperature	50.25 ^{o}C	
Engine speed	1504 rpm	300 rpm
Mass air flow	25 kg/h	350 kg/h
Number of rich/lean cycles in closed loop (P0134 only)	50	
Air fuel lean / air fuel rich cycle time (P0134 only)		1 s

Typical HO2S11 response rate malfunction thresholds:

P0133

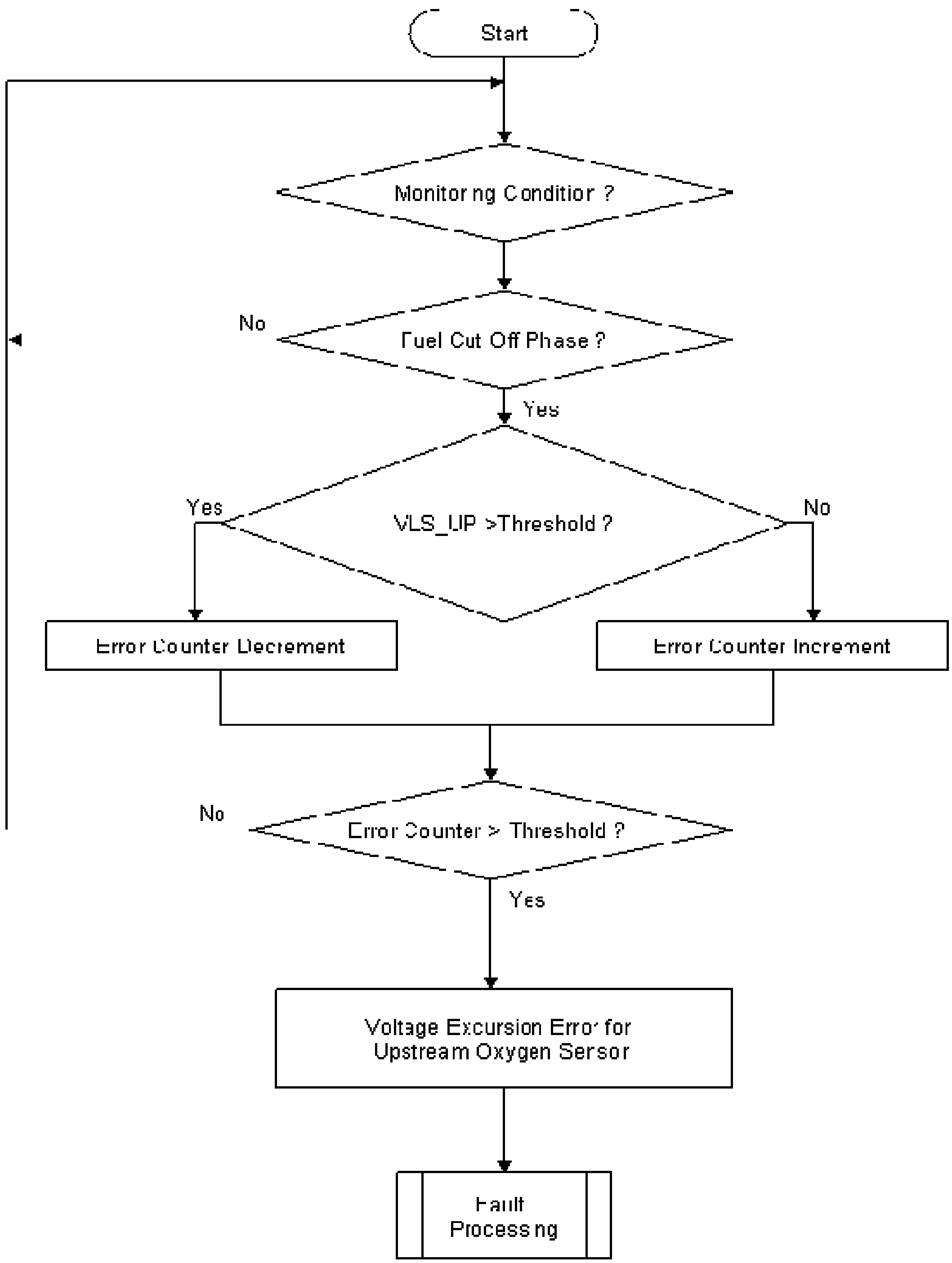
Frequency Check - Actual R/L or L/R switch period compared to expected switch period: > 1.75

P0134

Sensor signal voltage amplitude difference:: < 0.3 V

J1979 HO2S11 Mode $06 Data			
Monitor ID	Test ID	Description	Units
$01	$81	Signal voltage amplitude difference	Volts
$01	$83	Difference between lean and rich frequency ratios	None
$01	$86	Actual switch period compared to expected switch period for rich time	None
$01	$87	Actual switch period compared to expected switch period for lean time	None

Up-Stream Oxygen Sensor Rationality during Fuel Cut-Off



HO2S11 Out of Range during DFCO Operation:	
DTCs	P2297 – O2 Sensor Out of Range During Deceleration (Bank 1 Sensor 1)
Monitor execution	Once per driving cycle
Monitor Sequence	None
Sensors OK	MAF (P0102, P0103), HO2S (P0130, P0131, P0132, P0133, P0134, P2A00), HO2S heater (P0053,P0030, P0031, P0032), CPS (P0458, P0444, P0459, P0497)
Monitoring Duration	3 seconds to register a malfunction

Typical HO2S11 Out of Range during DFCO entry conditions:		
Entry condition	Minimum	Maximum
O2 sensor heater	on	
Decel Fuel Cut Out (DFCO) active		
Mass air flow	15 g	40 g
Mass Air Flow during DFCO > Mass Air Flow during DFCO from last recurrence	Yes	

Typical HO2S11 Out of Range during DFCO malfunction thresholds:
P2297 Upstream O2 sensor voltage during DFCO: > 0.15 V

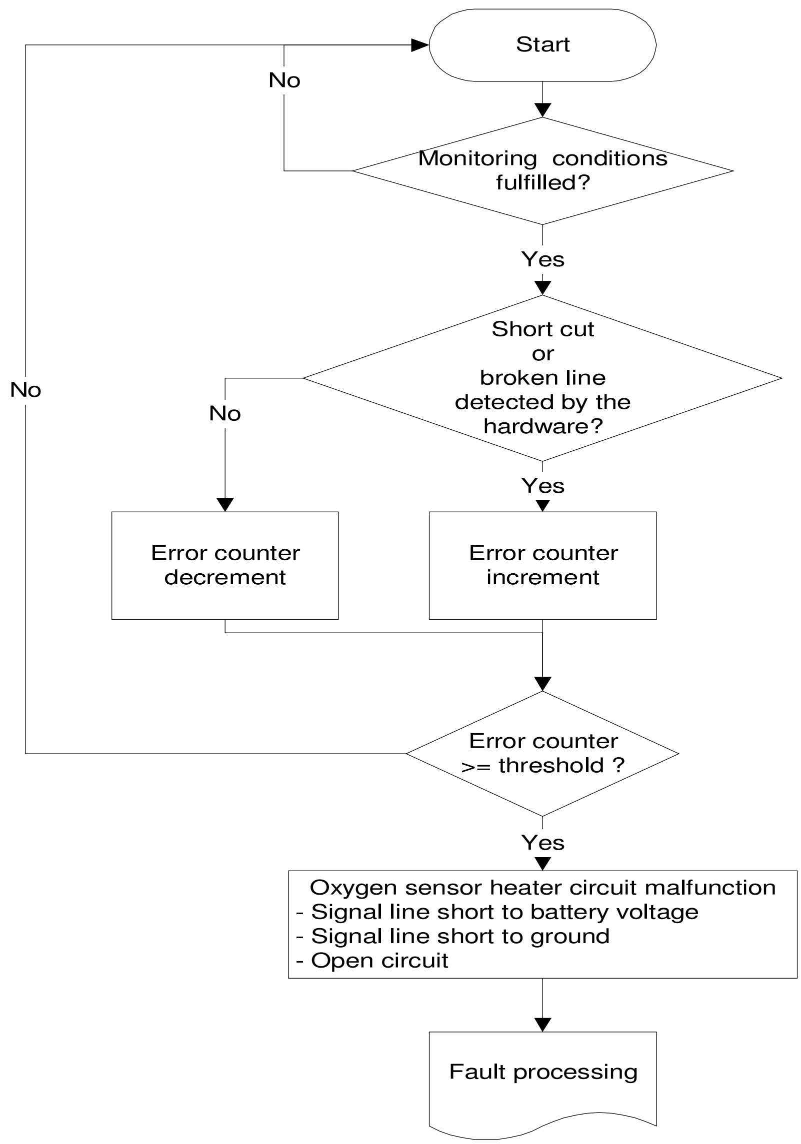
Upstream Oxygen Sensor Heater Circuit Monitor

For proper function of the oxygen sensor, the sensor element must be heated. A non functioning heater delays the sensor readiness for closed loop control and thus influences emissions. The signal for the O2 sensor heater is pulse-width modulated. The oxygen sensor heater circuit monitor detects the following malfunctions by evaluating the error information received from the heater power driver in the ECM: heater short circuit to battery, short circuit to ground, and open circuit.

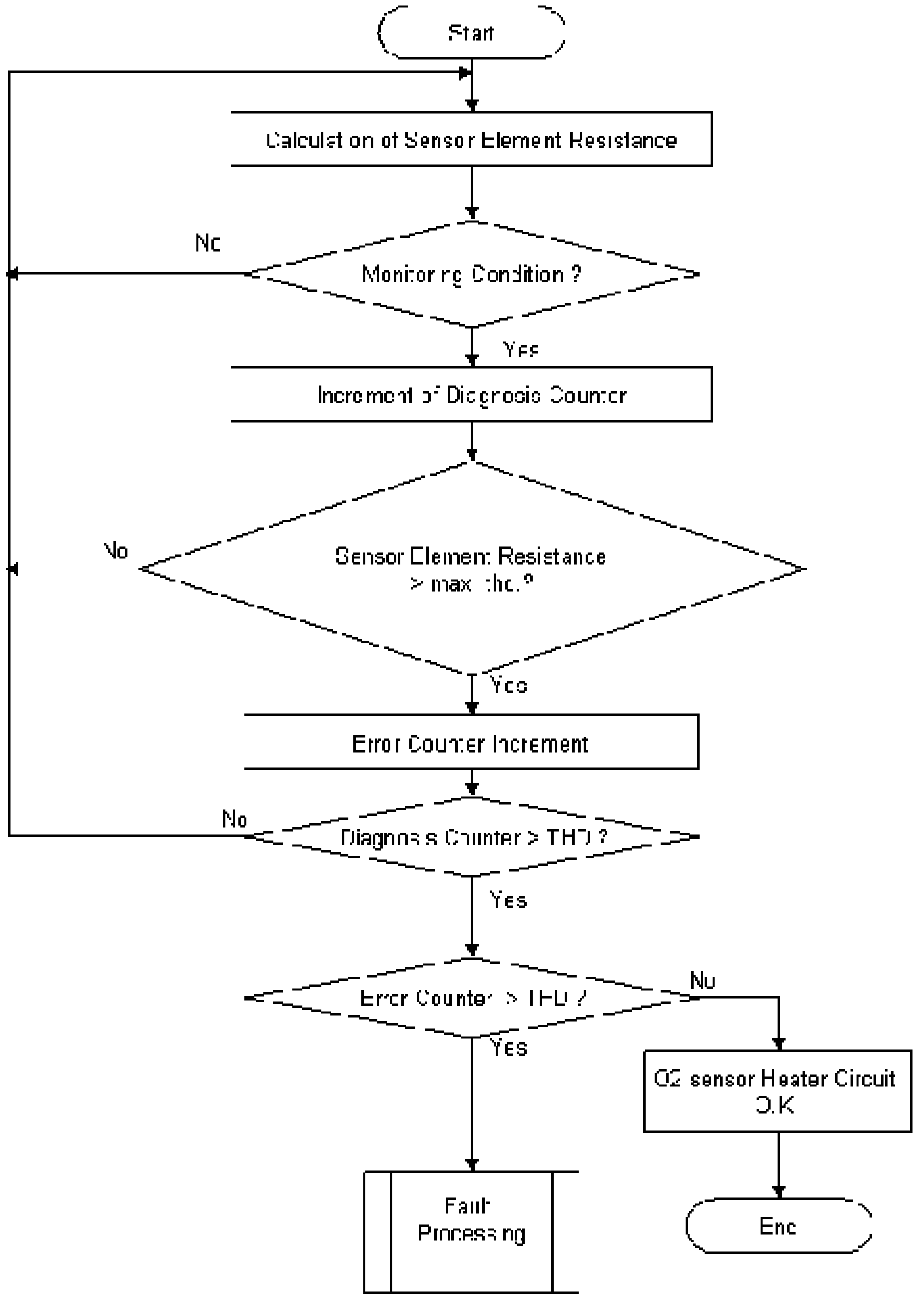
Heater Performance

This monitor determines the rationality of the upstream(or downstream) O2 sensor heater fault if the measured upstream (or downstream) O2 sensor resistance is lower than the predetermined threshold after a number of monitoring cycles have been carried out. Note: If the rationality test stores an error (P0053) then an additional P-code is stored automatically (P016A).

Upstream HO2S11 Heater Electrical Checks



Upstream HO2S11 Heater Rationality



HO2S Heater Monitor Operation:	
DTCs Sensor 1	P0030 O2 Heater Control Circuit, Bank 1, Sensor 1 P0031 O2 Heater Control Circuit Low, Bank 1, Sensor 1 P0032 O2 Heater Control Circuit High, Bank 1, Sensor 1 P0053 O2 Heater Resistance, Bank 1, Sensor 1
Monitor execution	once per driving cycle for heater current, continuous for voltage monitoring
Monitor Sequence	None
Sensors OK	HO2S, HO2S heater, MAF
Monitoring Duration	400 ms for heater voltage check, 20 sec for heater current check

Typical HO2S heater monitor entry conditions:		
Entry condition	Minimum	Maximum
Battery voltage	11 V	16 V
O2 heater pulsewidth (P0032)	5.07 %	99.6 %
Modeled Exhaust gas temp at upstream sensor (P0032 only)	200 °C	
Modeled Exhaust gas temp at upstream sensor (P0053 only)		699 °C
O2 heater pulsewidth (P0053 only)	1.18 %	99.6 %
Minimum required cooling energy at upstream position (P0053 only)	10000 J	
MAF (P0053 only)	25 kg/h	65 kg/h
O2 heater on time (P0053 only)	30 s	

Typical HO2S heater check malfunction thresholds:
<u>P0030</u> Open circuit determined by heater driver <u>P0031</u> Short to ground determined by heater driver <u>P0032</u> Short to battery determined by heater driver <u>P0053</u> Heater resistance: ≥ 500 ohms for 15 of 20 test samples

J1979 HO2S Heater Mode $06 Data			
Monitor ID	Test ID	Description for CAN	Units
$41	$C1	HO2S11 Heater Resistance	Ohms
$42	$C2	HO2S21 Heater Resistance	Ohms

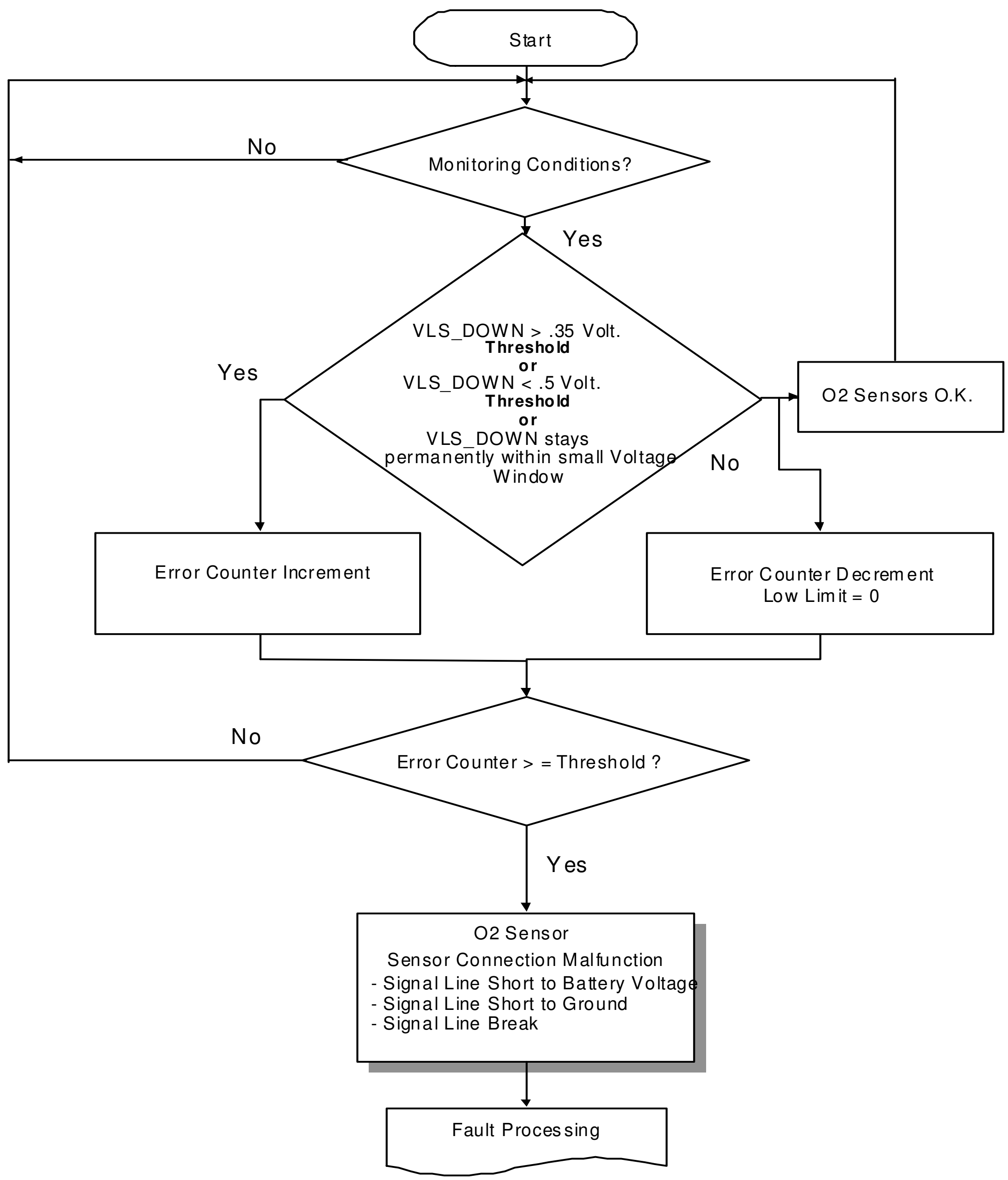
Downstream Oxygen Sensor Monitoring

The downstream oxygen sensor circuit monitor detects the HO2S sensor voltage is above or below a calibratable threshold or if it is not active, stuck at some voltage.

The downstream oxygen sensor monitor detects if the HO2S signal circuit voltage is shorted to ground (low signal), signal circuit voltage is high (high signal), or an open circuit causing the signal circuit voltage to be inactive or stuck at some voltage.

Sensor signal plausibility and signal activity monitoring is performed during coasting conditions during fuel cut-off (Slow Response). A malfunction is also detected, if the sensor signal is permanently above the minimum threshold.

Downstream HO2S Circuit Check



HO2S12 circuit check operation:	
DTCs	P0136 – HO2 circuit (Bank 1, Sensor 2). P0137 – HO2 circuit low voltage (Bank 1, Sensor 2). P0138 – HO2 circuit high voltage (Bank 1, Sensor 2). P2A01 – O2 Sensor Circuit Range/Performance (Bank 1 Sensor 2).
Monitor execution	Continuous
Monitor Sequence	None
Sensors OK	HO2S, HO2 heater, MAF
Monitoring Duration	12.7, 25.5 or 105 seconds to register a malfunction

Typical HO2S12 DFSO check entry conditions:		
Entry condition	Minimum	Maximum
Stuck above lean voltage limit (P0136 only)	0.35 volts	
Stuck below rich voltage limit (P0136 only)		0.5 volts
Time stuck (P0136 only)	5 seconds	
Exhaust gas temp (P0136 only)	350 °C	
Time since entry conditions meet (P0136 only)	100 sec	
Mass Air Flow (P0137 only)	12 kg/hr	
Time stuck at low voltage (P0137 only)	25.5 sec	
Time stuck at high voltage (P0132 only)	12.7 seconds	
Oxygen sensor voltage for activation of DFCO test (P2A01 only)	0.601 V	
Integrated Mass Air Flow to start DFCO monitor (P2A01 only)	500 g	
Integrated Mass Air Flow to enter DFCO monitor (P2A01 only)	20 g	
Integrated Mass Air Flow to exit DFCO monitor (P2A01 only)		150 g
Integrated Mass Air Flow during DFCO monitor > Integrated Mass Air Flow from previous DFCO monitor (P2A01 only)		

Typical HO2S12 circuit check malfunction thresholds:
P0136
O2 sensor internal resistance: ≥ 50000 ohms, voltage stuck between 0.35 and 0.5 volts
P0137
O2 sensor resistance $<$ 2 ohms and O2 sensor voltage stuck at $<$ .009 volts
P0138
O2 sensor voltage stuck above 1.1volts
P2A01
O2 sensor voltage stuck $>$ 0.3 V during DFCO

Downstream Oxygen Sensor Slow Response Monitor

This non intrusive diagnosis can detect the sluggish behavior of the rich/lean switch times during the transition to decel fuel cut-off. The malfunction thresholds are a function of MAF and signal band limits.

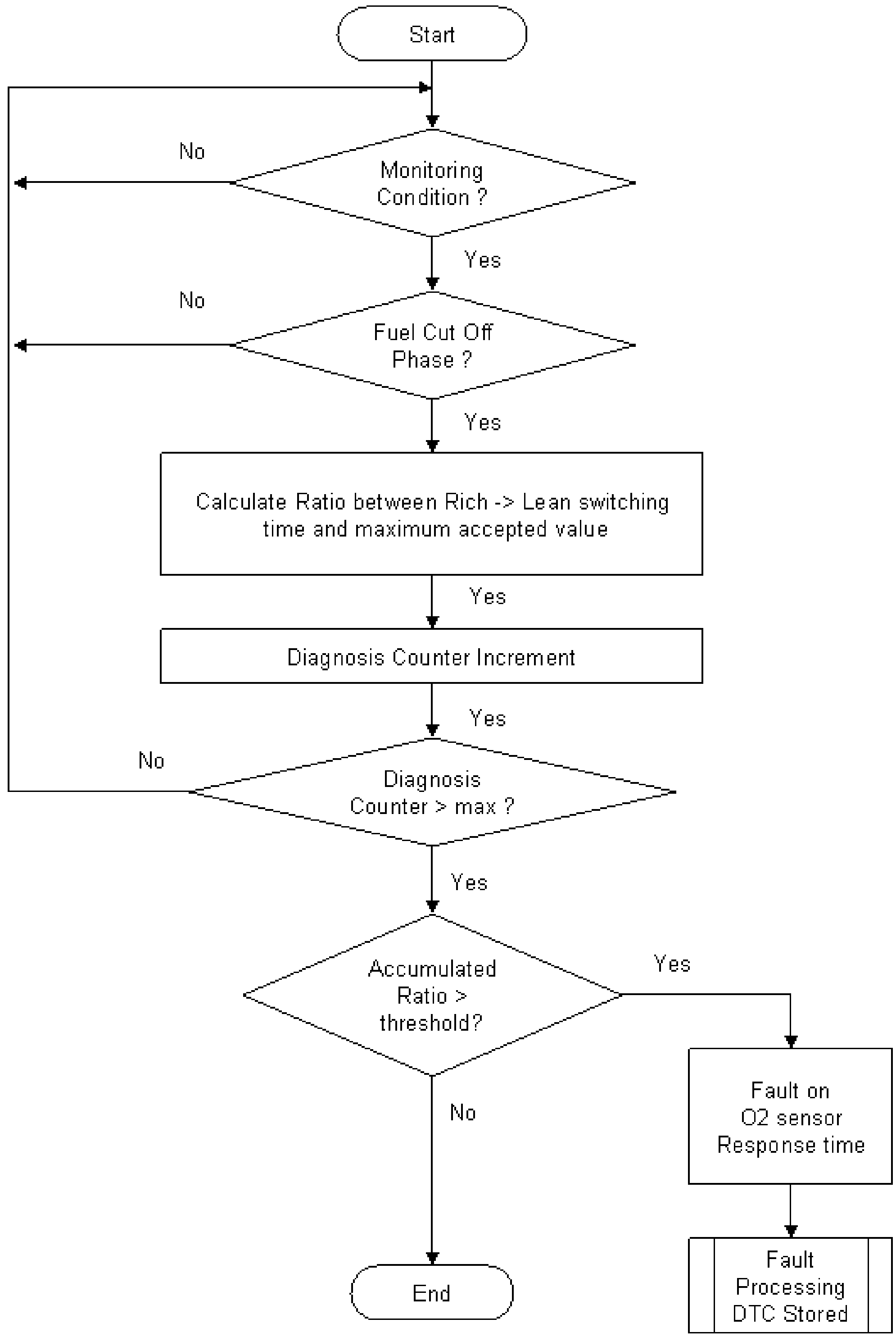
Monitoring function:

After the enable conditions are met and DFCO is determined to be active, the current downstream O2 voltage is monitored and stored. If the stored value is above a calibratable threshold, and MAF is within a calibratable window, the test is started.

Once the sensor voltage drops a calibratable percentage of the stored value, a timer is started. This timer is then stopped when the voltage drops a calibratable percentage of that stored value. At this point the test is determined to be valid and the diagnostic counter is incremented by one.

The switching time value is then converted to a weighted value. This process is repeated for a calibratable number of DFCO events. Each time the diagnostic counter is incremented the weighted value is added to a total value. At the end of the maximum number of DFCO events, the total value is divided by the number of DFCO events and another value is developed. This value is then compared to a threshold. If the value exceeds the threshold the sensor is determine to be slow and the corresponding fault code is stored.

Downstream Oxygen Sensor - Signal Switching check



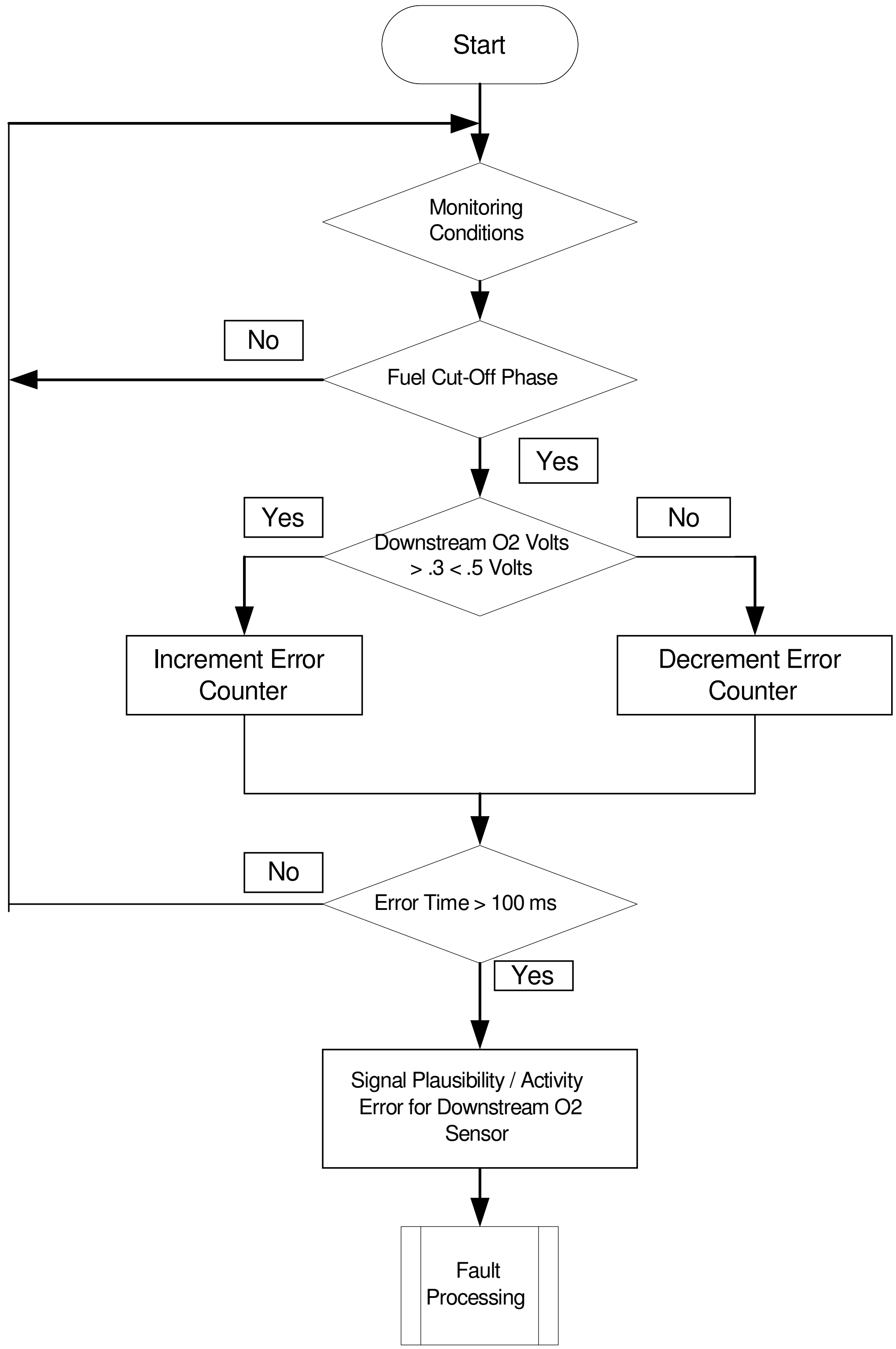
Downstream HO2S12 Response Rate Operation:	
DTCs	P013A HO2S12 (Slow response - Rich to Lean)
Monitor execution	Once per driving cycle
Monitor Sequence	None
Sensors OK	HO2S, HO2S heater, MAF, VS, ECT
Monitoring Duration	3 DFCO events > 1 second long

Typical Downstream HO2S12 response rate entry conditions:		
Entry condition	Minimum	Maximum
Closed Loop Fuel Control	Yes	
Engine Coolant Temperature	60 °C	
Catalyst temperature	348 °C	
Vehicle speed	12 mph	77 mph
DFCO active		
Down stream O2 sensor Voltage at start of DFCO	0.5 V	
Maximum Increase of O2 Voltage during DFCO test		< 0.029 V
Mass Air Flow during DFCO	6 kg/h	110 kg/h
Internal resistance of downstream oxygen sensor		5000 ohms
MAF integral out of DFCO	10 g	1000 g
Catalyst temperature	300 °C	1000 °C

Typical Downstream HO2S12 response rate malfunction thresholds:
P013A Slow Response (Average ratio for the rich to lean switching time determination): ≤ 0.1 Slow Response (Diagnostic window based on O2 voltage at start of DFCO): > 15 % and < 70 %

J1979 Downstream HO2S12 response rate Mode $06 Data			
Monitor ID	Test ID	Description for CAN	
$02	$84	Monitoring downstream sensor signal during throttle cut off	Volts
$02	$8A	Rich to lean switching time ratio	None

Downstream O2 Sensor Functional Check



Downstream HO2S12 Functional Check Operation:	
DTCs Sensor 2	P0140 HO2S12 No activity P2270 HO2S12 Signal Stuck Lean P2271 HO2S12 Signal Stuck Rich
Monitor execution	once per driving cycle for activity test
Monitor Sequence	None
Sensors OK	CKP, CMP, VVT, MAF, HO2S, HO2S heater, misfire, CPS, TPS, ECT, Fuel monitor
Monitoring Duration	continuous until monitor completed

Typical Downstream HO2S12 functional check entry conditions:		
Entry condition	Minimum	Maximum
Lambda set point for lean fault detection	0.80	
Integrated mass air flow outside of DFCO		400 g
Integrated mass air flow needed for open loop test to ensure the desired lambda at downstream sensor		50 g
Integrated mass air flow in DFCO	10 g	
Time after start	120 s	

Typical Downstream HO2S12 functional check malfunction thresholds:
P0140 No activity, O2 sensor voltage stuck between 0.298 V and 0.550 V P2270 Rich voltage could not be achieved, O2 sensor stuck lean: < 0.249 V P2271 Lean voltage could not be achieved, O2 sensor stuck rich:> 0.555 V

Downstream Oxygen Sensor Heater Circuit Monitor

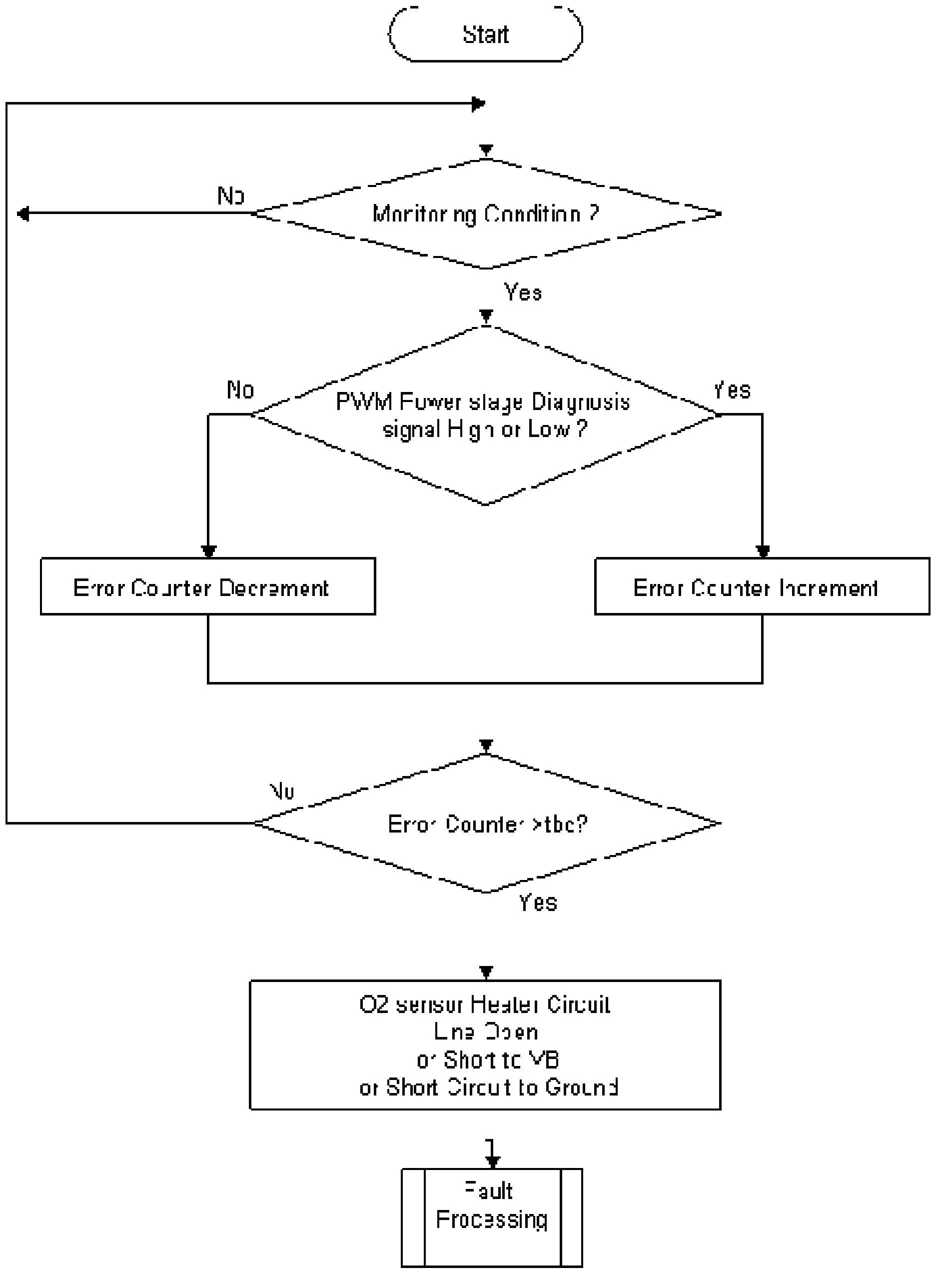
For proper function of the oxygen sensor, the sensor element must be heated. A non functioning heater delays the sensor readiness for closed loop control and thus influences emissions. The signal for the O2 sensor heater is pulse-width modulated. The oxygen sensor heater circuit monitor detects the following malfunctions by evaluating the error information received from the heater power driver in the ECM: heater short circuit to battery, short circuit to ground, and open circuit.

Heater Performance

The monitoring strategy is based on the comparison of the O2 sensor heater resistance to an absolute threshold during deceleration conditions where the exhaust temperature is sufficiently low as to cause the sensor ceramic temperature to fall outside normal operating levels in cases where the heating power is insufficient.

The cooling energy of the exhaust gas is calculated and compared to a calibrated threshold. The heater monitor is active if the calculated energy is equal or exceeds the threshold. Then the O2 sensor heater is compared to a calibrated threshold. If the heater resistance is equal or exceeds the threshold, an O2 sensor heater malfunction is detected.

Downstream HO2S Heater Electrical Checks



HO2S12 Heater Monitor Operation:	
DTCs Sensor 1	P0036 O2 Heater Control Circuit, Bank 1, Sensor 2 P0037 O2 Heater Control Circuit Low, Bank 1, Sensor 2 P0038 O2 Heater Control Circuit High, Bank 1, Sensor 2 P0054 O2 Heater Resistance, Bank 1, Sensor 2
Monitor execution	once per driving cycle for heater current, continuous for voltage monitoring
Monitor Sequence	None
Sensors OK	HO2S, HO2S heater, MAF
Monitoring Duration	400 ms for heater voltage check, 20 sec for heater current check

Typical HO2S12 heater monitor entry conditions:		
Entry condition	Minimum	Maximum
Battery voltage	11 V	16 V
O2 heater pulsewidth (P0038)	5.07 %	99.6 %
Modeled Exhaust gas temp at downstream sensor (P0038 only)	349 °C	
O2 heater pulsewidth (P0054 only)	1.18 %	99.6 %
Modeled Exhaust gas temp at downstream sensor (P0054 only)		750 °C
Minimum required cooling energy at upstream position (P0054 only)	10000 J	
MAF (P0054 only)	25 kg/h	65 kg/h
O2 heater on time (P0054 only)	180 s	

Typical HO2S12 heater check malfunction thresholds:
<u>P0036</u> Open circuit determined by heater driver <u>P0037</u> Short to ground determined by heater driver <u>P0038</u> Short to battery determined by heater driver <u>P0054</u> Heater resistance: ≥ 300 ohms for 15 of 20 test samples

J1979 HO2S Heater Mode $06 Data			
Monitor ID	Test ID	Description for CAN	Units
$41	$C1	HO2S11 Heater Resistance	Ohms
$42	$C2	HO2S21 Heater Resistance	Ohms

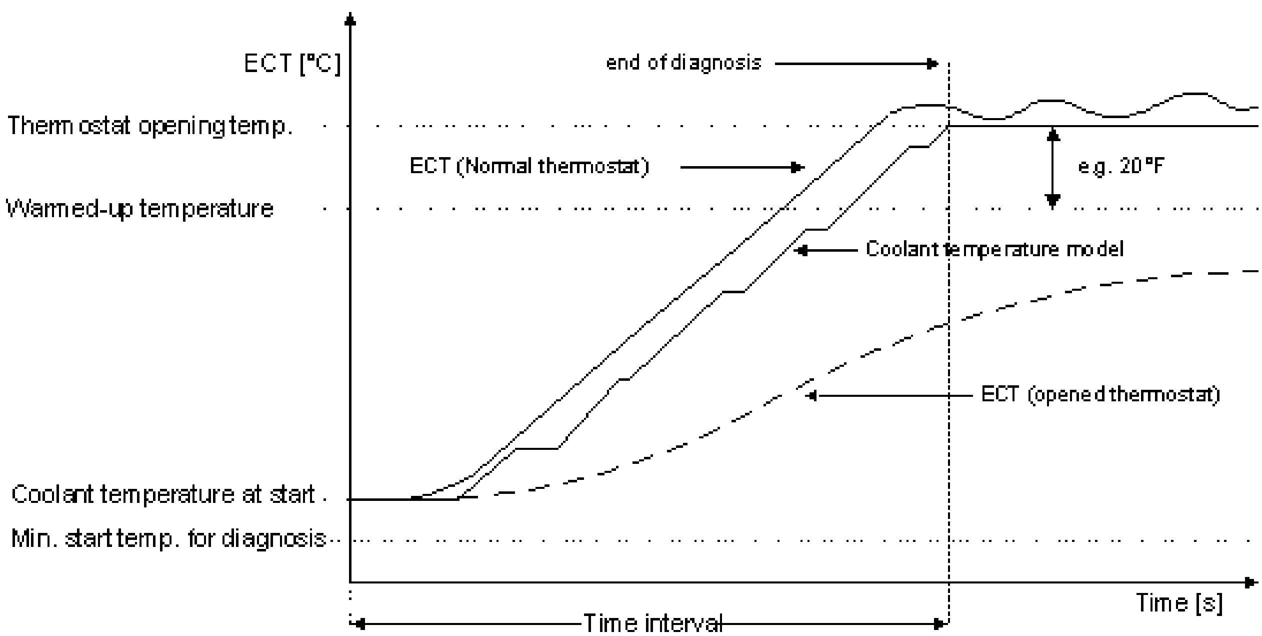
Thermostat Monitor

The coolant thermostat monitor is designed to detect a thermostat that is slow to open or is stuck open. It is based on the comparison of the measured Engine Coolant Temperature (ECT) sensor signal and the calculated ECT model. The ECT model calculation is depending on engine load/speed and the intake air temperature.

A malfunctioning coolant thermostat is detected if the calculated ECT model has exceeded the thermostat opening temperature and the measured ECT sensor signal remains below a threshold (the highest diagnostic enable temperature).

To prevent false DTCs, conditions for low load, long deceleration duration and Intake Air Temperature (IAT) during the monitoring period are checked. If the monitoring conditions are met, the thermostat DTC is set; otherwise the thermostat monitor is suspended for the current driving cycle.

Thermostat Monitor Method:

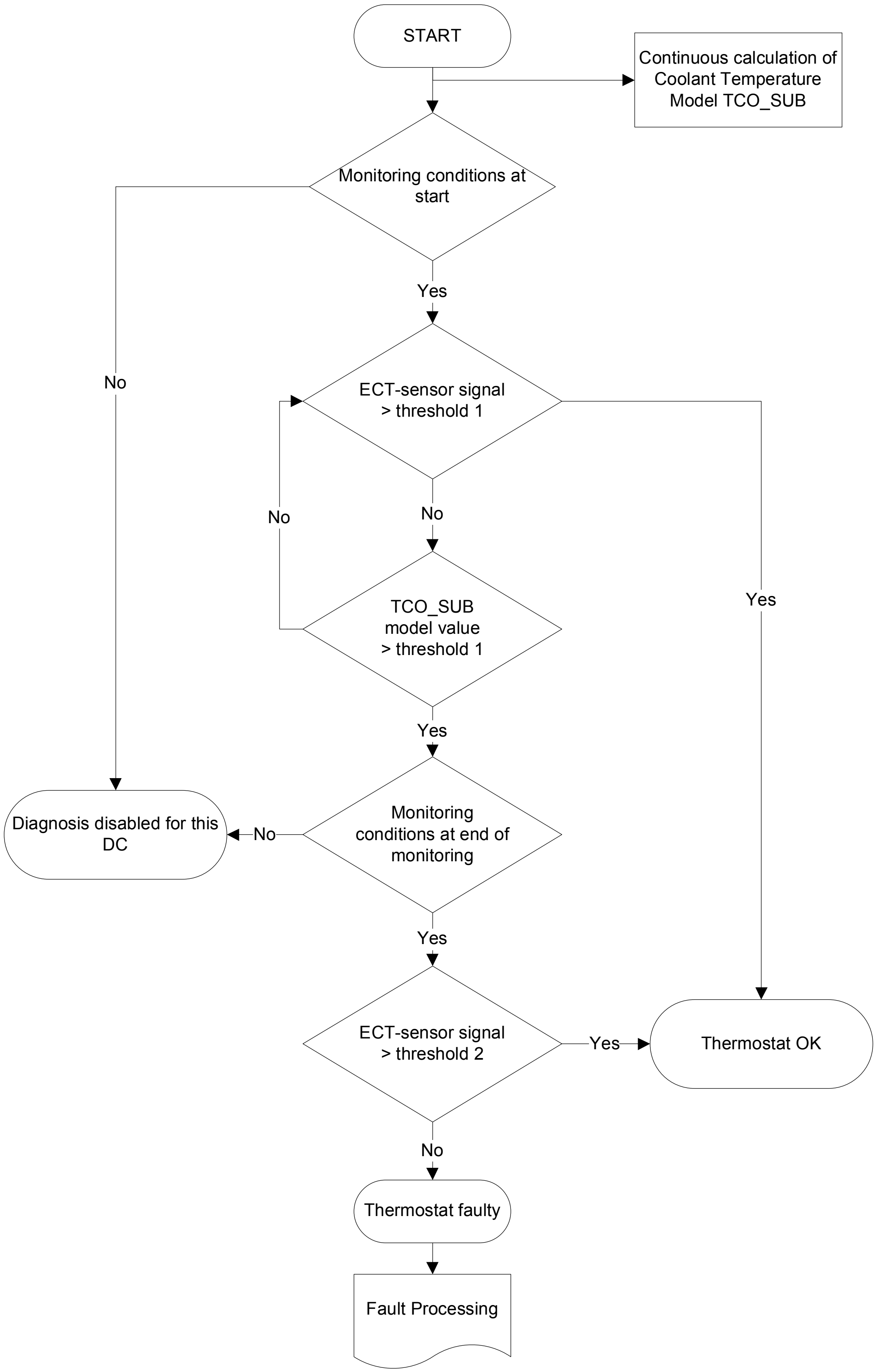


A comparison between the measured coolant temperature and the "warmed-up temperature" is done after a specific time interval. The interval itself is based on the coolant temperature model.

As soon as the model temperature exceeds the thermostat opening temperature and all other monitoring conditions are fulfilled at the same time, a valid diagnosis occurs.

At that time, if the measured coolant temperature is higher than warmed-up temperature, the thermostat is considered to be a normal thermostat. If the measured coolant temperature is lower than warmed-up temperature, the thermostat is considered to be stuck open.

Thermostat Monitoring



ECT Below Thermostat Regulating Temperature	
DTCs	P0128
Monitor execution	Once per driving cycle
Monitor Sequence	None
Sensors OK	ECT, MAF, VS, CKP, TPS, IAT
Monitoring Duration	127 seconds, based on Inlet Air temperature

Typical ECT Below Thermostat Regulating Temperature check entry conditions:		
Entry Condition	Minimum	Maximum
Percentage of Time at Vehicle speed > than 20 mph	60.15 %	
Percentage of time at MAF > 18 … 20 kg/h	36%	
Percentage of time in DFCO		10%
Percentage of Time at Vehicle speed > than 47 mph		36%
Difference between IAT and ECT		-20.25 °C

Typical ECT Below Thermostat Regulating Temperature check malfunction thresholds:
Measure ECT > 72.75 °C after modeled ECT exceeds 81.75 °C

Cold Start Emission Reduction Component Monitor

The Cold Start Emission Reduction (CSER) Component Monitor works by validating the operation of the components of the system required to achieve the cold start emission reduction strategy, namely retarded spark timing and elevated idle airflow.

Low Idle RPM Test

When the CSER strategy is enabled, the idle air control system will request a higher idle rpm, elevating engine airflow.

CSER low rpm test operation:	
DTCs	P050A – Cold Start Idle Air Control System Performance
Monitor execution	Once per driving cycle, from startup with CSER active
Monitor Sequence	None
Sensors OK	CPS, ECT, MAF, TPS
Monitoring Duration	3 seconds

CSER typical low rpm test entry conditions:		
Entry Condition	Minimum	Maximum
Engine speed	100 rpm	
ECT	-10 °C	
Engine Run Time	100 s	
Torque control at limit	2 s	
Battery voltage	11 V	16 V
Mass Air Flow	240 mg/stk	
Stabilization Period	3 s	

CSER typical low rpm flow test malfunction thresholds:
RPM Lower than Commanded (Table Based on RPM & ECT & Time after start): > 100 to 150 rpm RPM Higher than Commanded (able Based on RPM & ECT & Time after start): > 350 to 400 rpm

Spark Timing Monitor

When the CSER strategy is enabled, the idle air control system will request a retarded spark timing, increasing engine airflow.

CSER spark timing test operation:	
DTCs	P050B – Cold Start Ignition timing Performance
Monitor execution	Once per driving cycle, from startup with CSSRE active
Monitor Sequence	None
Sensors OK	CPS, ECT, MAF, TPS
Monitoring Duration	3 seconds

CSER typical spark timing test entry conditions:		
Entry Condition	Minimum	Maximum
Ignition angle at idle speed		0 deg
Ignition angle at part throttle		0 deg
ECT	-6.75 °C	70 °C
Engine run time	0 sec	
BARO	75 kPa	

CSER typical spark timing test malfunction thresholds:
Ignition angle integral and Time in idle. (Table based on ECT & MAF) > 0.2 Ignition angle integral and Time in part load. (Table based on ECT & MAF) > 0.2

Cold Start Variable Cam Timing Monitor

If the VCT cam phasing is used during a cold start to improved catalyst heating, the VCT system is checked functionally by monitoring the closed loop cam position error correction. If the proper cam position cannot be maintained and the system has an advance or retard error greater than the malfunction threshold, a cold start emission reduction (CSER) VCT control malfunction is indicated (P052B (Bank 1).

CSER VCT Target Error Check Operation:	
DTCs	P052B – Cold start intake camshaft timing over-retarded (Bank 1) P054B – Cold start exhaust camshaft timing over-retarded (Bank 1)
Monitor execution	Continuous
Monitor Sequence	None
Sensors OK	VVT(P2089, P2088, P0010, P2091, P2090, P0013), system voltage (P0562, P0563), No ECU errors (P061C)
Monitoring Duration	100 ms

Typical CSER VCT target error entry conditions:		
Entry condition	Minimum	Maximum
VVT active		
Battery Voltage	10 V	
Engine speed	1500	5000
Engine Oil Temperature Model	0 °C	120 °C
Camshaft commanded position steady		0.75 deg crank

Typical CSER VCT target error malfunction thresholds:
Integrated difference between camshaft actual position and camshaft setpoint ≥ 100 deg crank

Cold Start Emission Reduction System Monitor

The Cold Start Emission Reduction System Monitor was introduced for the 2007 MY on vehicles that meet the LEV-II emission standards. It replaces the Cold Start Emission Reduction Component Monitor. The Cold Start Emission Reduction (CSER) Monitor detects the lack of catalyst warm up resulting from a failure to apply sufficient CSER during a cold start. It does this by using the inferred catalyst temperature model to determine how closely the actual catalyst temperature follows the expected catalyst temperature during a cold start. How closely the actual temperature follows the expected temperature is reflected in a ratio which is compared with a calibratable threshold.

Temperatures Used

The actual catalyst temperature is the same inferred catalyst temperature that is used by other portions of the engine control system, including the CSER control system. The inputs to this actual temperature are measured engine speed, measured air mass, and commanded spark.

The expected catalyst temperature is calculated using the same algorithm as the actual catalyst temperature, but the inputs are different. Desired engine speed replaces measured engine speed, desired air mass replaces measured air mass, and desired cold start spark replaces commanded spark. The resulting temperature represents the catalyst temperature that is expected if CSER is functioning properly.

Ratio Calculation

A ratio is calculated to reflect how closely the actual temperature has followed the expected temperature. This ratio is the difference between the two temperatures at a certain time-since-start divided by the increase in expected temperature over the same time period. The ratio, then, provides a measure of how much loss of catalyst heating occurred over that time period.

This ratio correlates to tailpipe emissions. Therefore applying a threshold to it allows illumination of the MIL at the appropriate emissions level. The threshold is a function of ECT at engine start.

General CSER Monitor Operation

During the first 15 seconds of a cold start, the monitor checks the entry conditions, counts time in idle, and observes catalyst temperature.

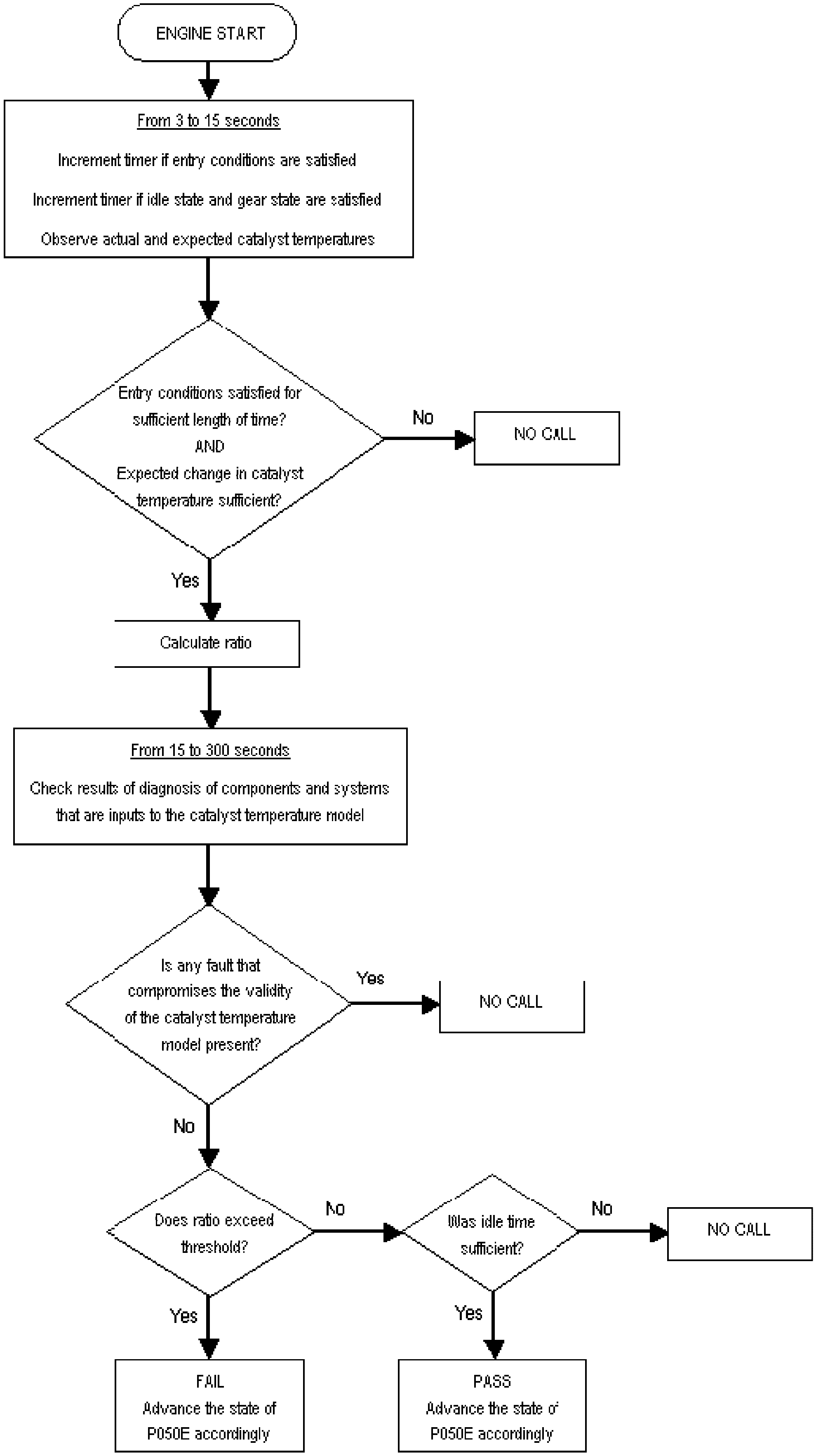
If the expected change in catalyst temperature is large enough, the monitor calculates the ratio as described above. Otherwise the monitor does not make a call.

The monitor then begins the waiting period, which lasts from the time the ratio is calculated (15 seconds after engine start) until 300 seconds after engine start. This 5-minute wait allows time to diagnose other components and systems that affect the validity of the catalyst temperature model. During this waiting period, there are no constraints on drive cycle and the monitor cannot be disabled without turning off the key.

At the end of the waiting period, if no other faults that could compromise the validity the catalyst temperature model are found, the monitor compares the ratio to the threshold.

If the ratio exceeds the threshold, the monitor considers the test a fail, and the monitor is complete.

If the ratio falls below the threshold, the monitor determines whether the idle time was sufficient. If so, it considers the test a pass and the monitor is complete. If idle time was not sufficient, the monitor does not make a call and does not complete. This prevents tip-ins from resulting in false passes.


ENGINE START
From 3 to 15 seconds
Increment timer if entry conditions are satisfied
Increment timer if idle state and gear state are satisfied
Observe actual and expected catalyst temperatures
Entry conditions satisfied for sufficient length of time?
AND
Expected change in catalyst temperature sufficient?
No
NO CALL
Yes
Calculate ratio
From 15 to 300 seconds
Check results of diagnosis of components and systems that are inputs to the catalyst temperature model
Is any fault that compromises the validity of the catalyst temperature model present?
Yes
NO CALL
No
Does ratio exceed threshold?
No
Was idle time sufficient?
No
NO CALL
Yes
Yes
FAIL
Advance the state of P050E accordingly
PASS
Advance the state of P050E accordingly

CSER Monitor Operation	
DTC	P050E: Cold Start Engine Exhaust Temperature Out Of Range
Monitor Execution	Once per driving cycle, during a cold start
Monitor Sequence	Monitor data collection takes place during first 15 seconds of cold start as long as there are no active DTCs
Sensors OK	MAF, TPS, misfire, injectors, Fuel monitor, CKP, ignition coils, IAT, ECT, VVT
Monitoring Duration	Monitor completes in 100 ms after conditions are meant

Typical CSER VCT target error entry conditions:		
Entry condition	Minimum	Maximum
Engine run time	3 s	
Battery voltage	11 V	16 V
ECT @ start	1.6 °C	38 °C
Catalyst temp @ start	1.6 °C	52 °C
BARO	75 kPa	
Fuel level	5%	
Expected change in Cat Temp	20 °C	
Injectors "ON", DFCO not active		

Typical CSER Monitor malfunction thresholds:
Ratio reflecting lack of observed catalyst temperature increase compared with expected catalyst temperature increase (Table Based on ECT at engine start): > 0.5

Variable Valve Timing System Monitor

Variable Valve / Cam Timing (VVT/VCT) enables rotation of the camshaft(s) relative to the crankshaft (phase-shifting) as a function of engine operating conditions. With Dual Equal VCT, both intake and exhaust camshafts are retarded from the default, fully advanced position to increase EGR residual and improve fuel economy by reducing intake vacuum pumping losses. The residual charge for NOx control is obtained by backflow through the late-closing exhaust valve as the piston begins its intake stroke.

The VCT system hardware consists of a control solenoid and a pulse ring on the camshaft. The ECM calculates relative cam position using the CMP input to process variable reluctance sensor pulses coming from the pulse ring mounted on the camshaft. Each pulse wheel has N + 1 teeth where N = the number of cylinders per bank.

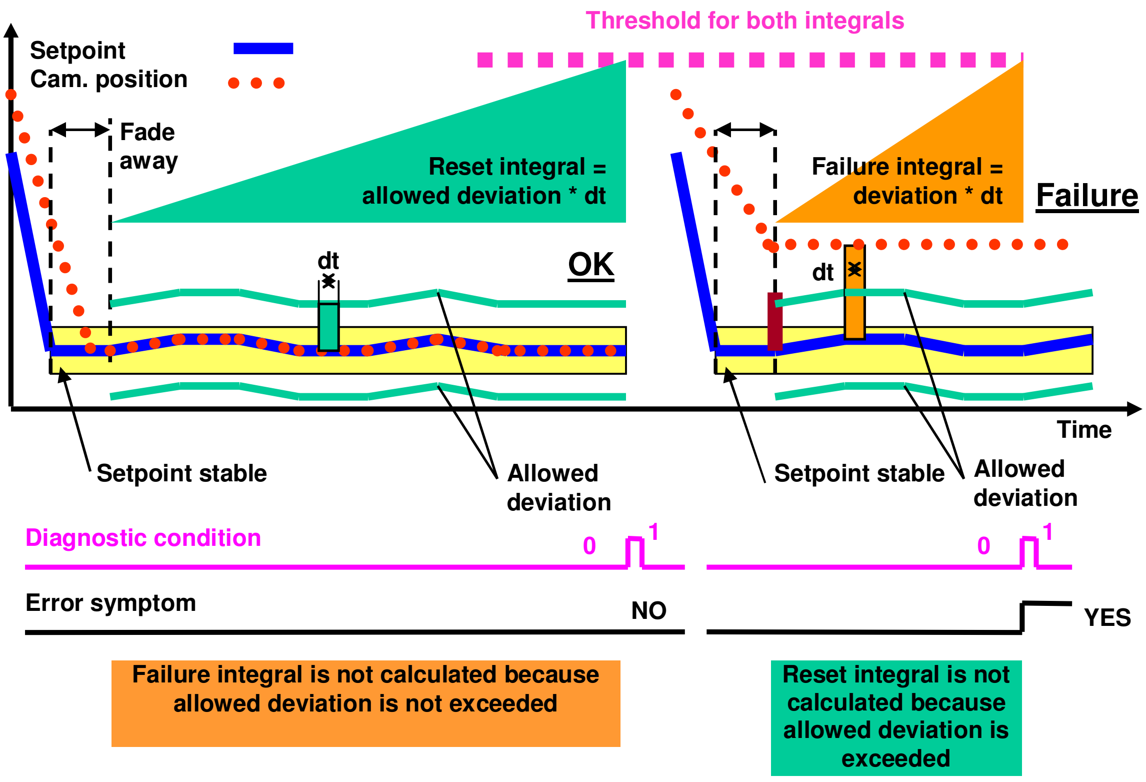
The ECM continually calculates a cam position error value based on the difference between the desired and actual position and uses this information to calculate a commanded duty cycle for the VVCT solenoid valve. When energized, engine oil is allowed to flow to the VCT unit thereby advancing and retarding cam timing.

Variable Cam Timing Target Error

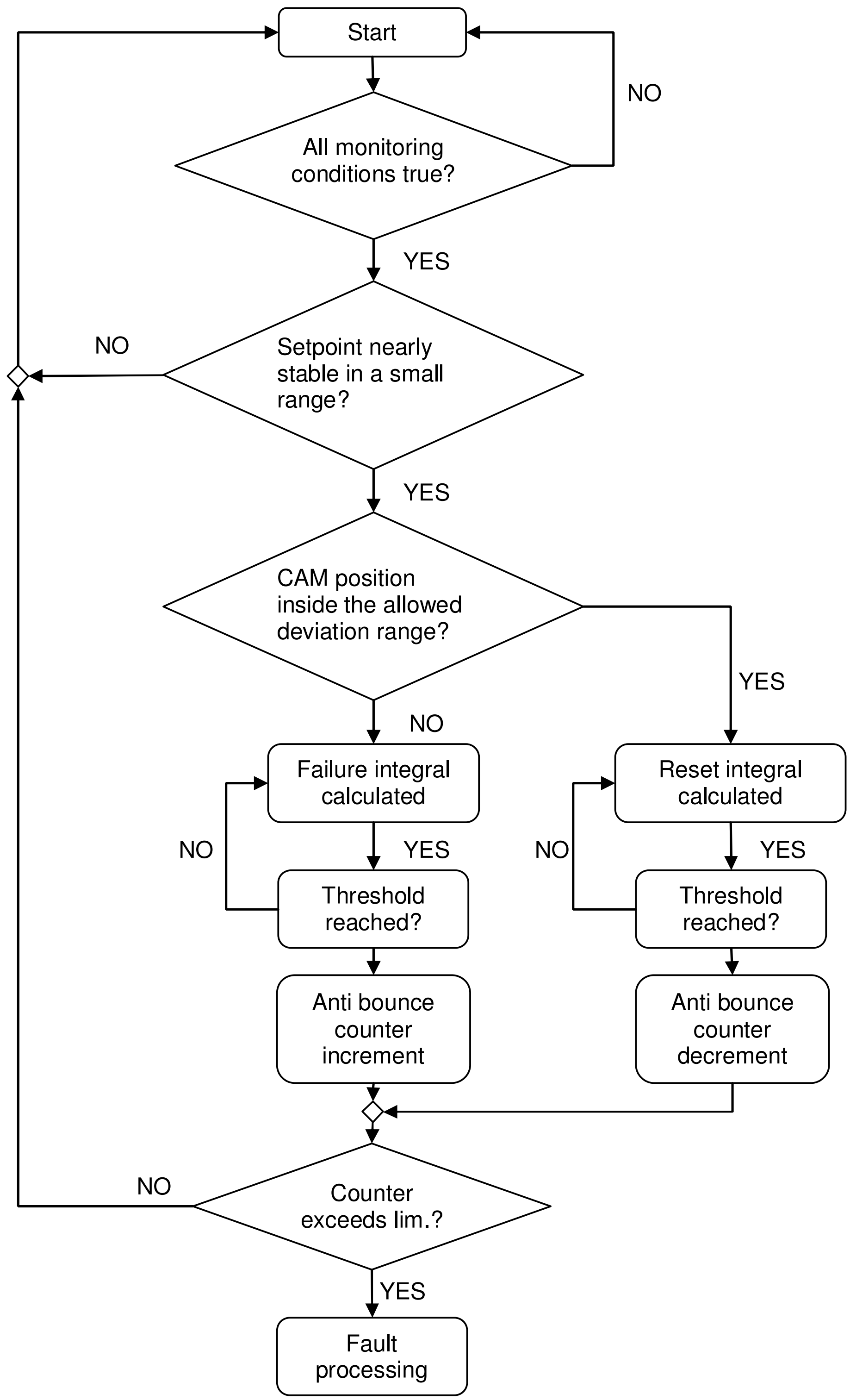
The difference between the actual cam position and the target cam position is checked. The target position has to be in a limited stable range for a certain time. If the actual position is near the target (calibratable range) the diagnosis is ok, otherwise not. This will be checked by calculating two integrals (reset integral and failure integral). Both integral values have the same thresholds

If the failure integral reaches this threshold at first, an anti-bounce counter is started; otherwise the counter will be decremented. If the counter exceeds an adjustable limit, the appropriate DTC will be stored.

Example: Target Error



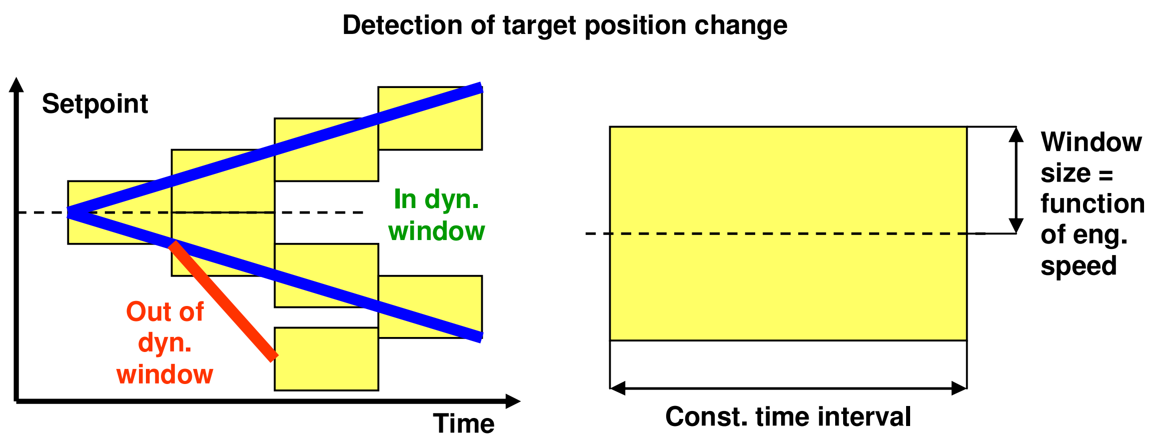
Variable Camshaft Timing Target Error



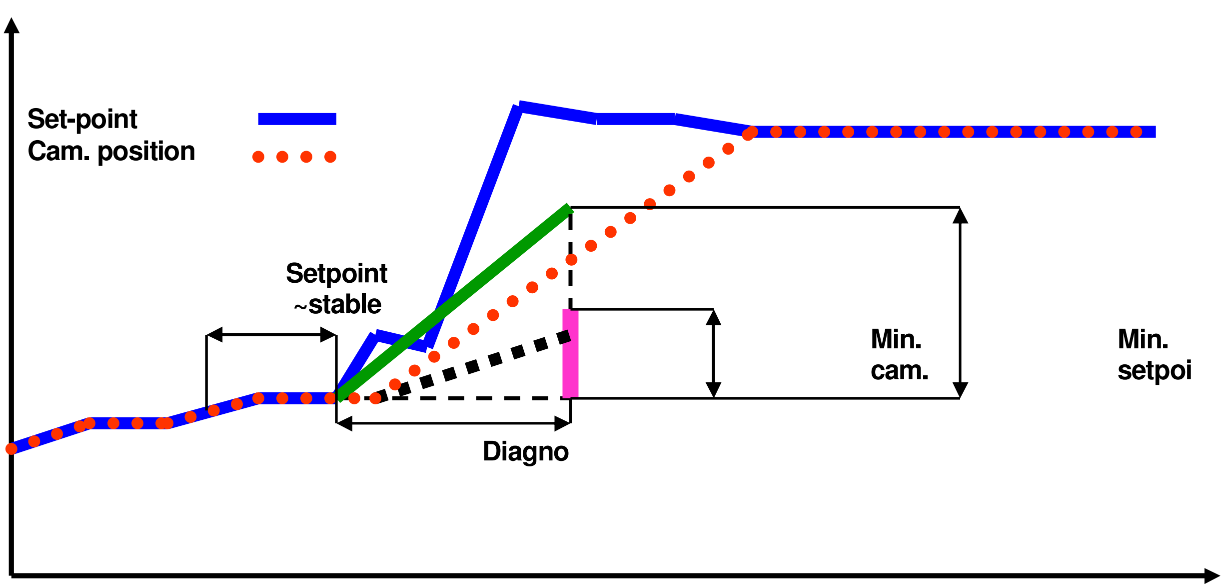
Variable Cam Timing Slow Response

The response of the actual position on a target position change, which has to be big and quick enough, is evaluated. The set point and camshaft position are saved at the beginning of a set point change. If this change over a time is big enough (gradient), the camshaft phasing change is evaluated. If the change after the diagnostic time is smaller than a threshold, a slow response is detected, and if the value is greater, then there is no malfunction. By detecting a malfunction, an anti-bounce counter is incremented otherwise the counter will be decremented. If the counter exceeds an adjustable limit, the appropriate DTC will be stored.

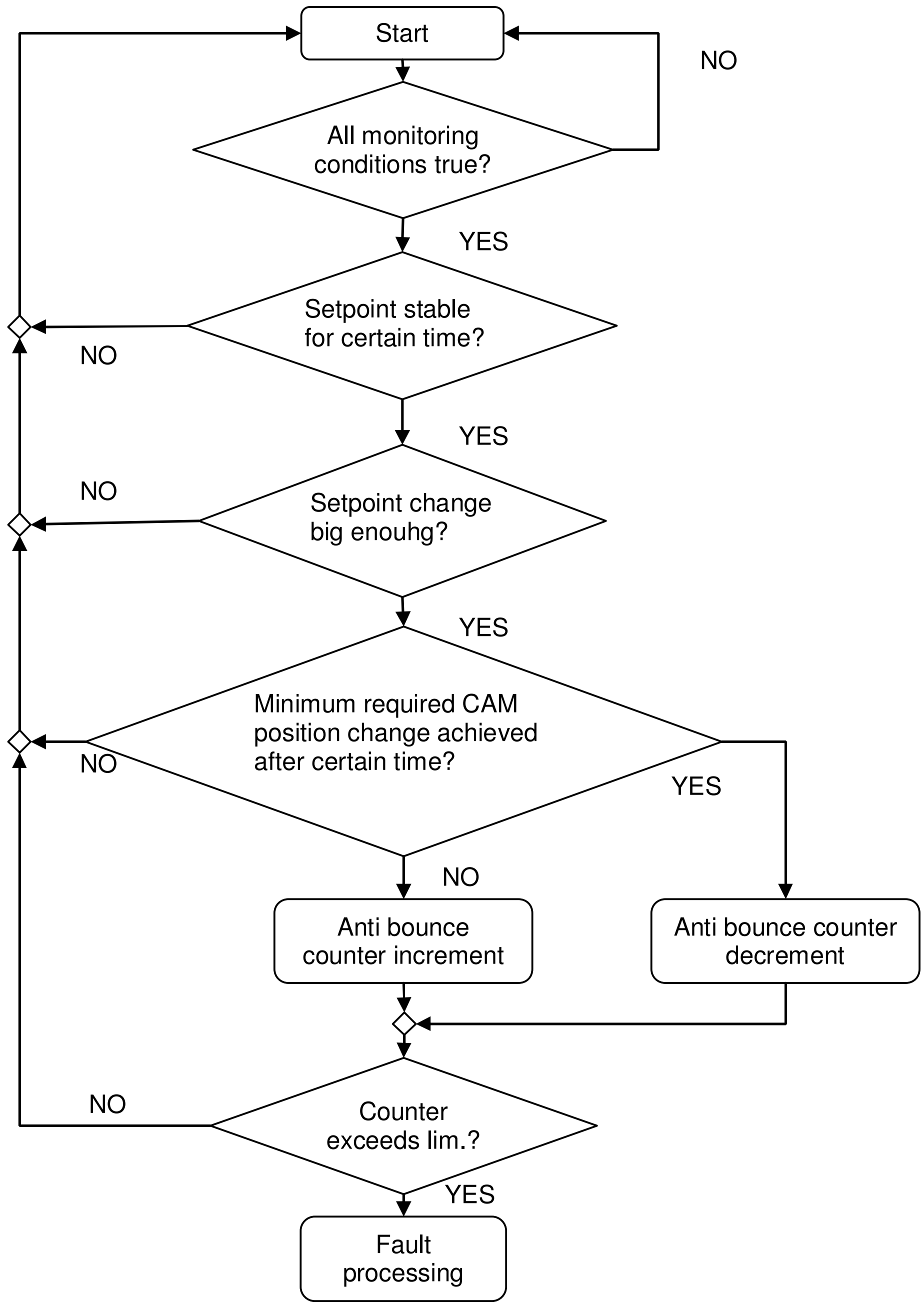
Example 1:



Example 2:



Variable Cam Timing Slow Response



VVT Target Error/Slow Response Monitor Operation:	
DTCs	P000A – Intake Cam Position Actuator Slow Response P0011 – Intake Cam Position Actuator Target Error P0010 – Intake Camshaft Position Actuator Circuit P000B – Exhaust Cam Position Actuator Slow Response P0014 – Exhaust Cam Position Actuator Target Error P0013 – Exhaust Camshaft Position Actuator Circuit P2088 – Intake Cam Position Actuator Circuit Low P2089 – Intake Cam Position Actuator Circuit High P2090 – Exhaust Cam Position Actuator Circuit Low P2091 – Exhaust Cam Position Actuator Circuit High
Monitor execution	Continuous
Monitor Sequence	None
Sensors OK	VVT, system voltage, internal control module engine rpm performance
Monitoring Duration	3 sec for circuit faults, 1 second for target error/slow response

Typical VVT Target Error/Slow Response monitor entry conditions:		
Entry condition	Minimum	Maximum
VVT active		
Battery Voltage	10 V	
Engine speed	1500 rpm	5000 rpm
Engine Oil Temperature Model	50 °C	105 °C
Camshaft commanded position change (P00A/P00B)	6.0 ° crank angle	
Delay time for actual Camshaft position change when commanded position is advanced or retarded (Table based on rpm and modeled oil temp) (P00A/P00B)	0.95 seconds	1.25 seconds
Camshaft commanded position steady (P0011/P0014)		0.75 ° crank angle
Camshaft commanded position steady for a required number of cam edges (Table based on rpm and modeled oil temp) (P0011/P0014)	60 cam edges	100 cam edges
Camshaft PWM Signal P0010/P0013)	10 %	100 %

Typical VVT Target Error/Slow Response malfunction thresholds:
P000A & P000B
Slow Response (Actual Camshaft position change): ≤ 1.875 deg crank intake, ≤ 4.125 deg crank exhaust
P0011 & P0014
Target Error (Integrated difference between camshaft actual position and camshaft setpoint): ≥ 100 deg crank
P0010, P2088, P2089 & P0013, P2090, P2091
Open Circuit detected by hardware driver circuit

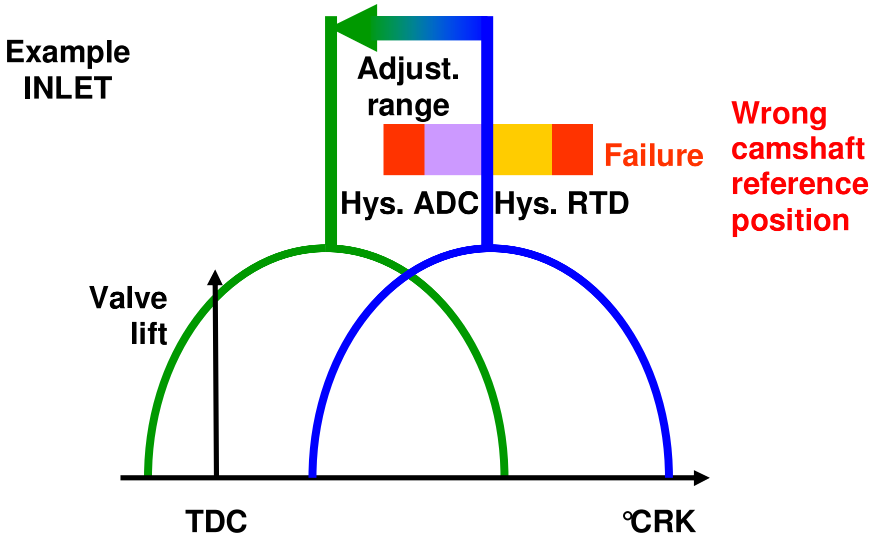
J1979 VVT Monitor Mode $06 Data			
Monitor ID	Test ID	Description for CAN	Units
$35	$B8	Intake camshaft deviation at steady state	degrees
$35	$B9	Exhaust camshaft deviation at steady state	degrees
$35	$BA	Intake camshaft deviation while changing state	degrees
$35	$BB	Exhaust camshaft deviation while changing state	degrees

Camshaft/Crankshaft Position Correlation

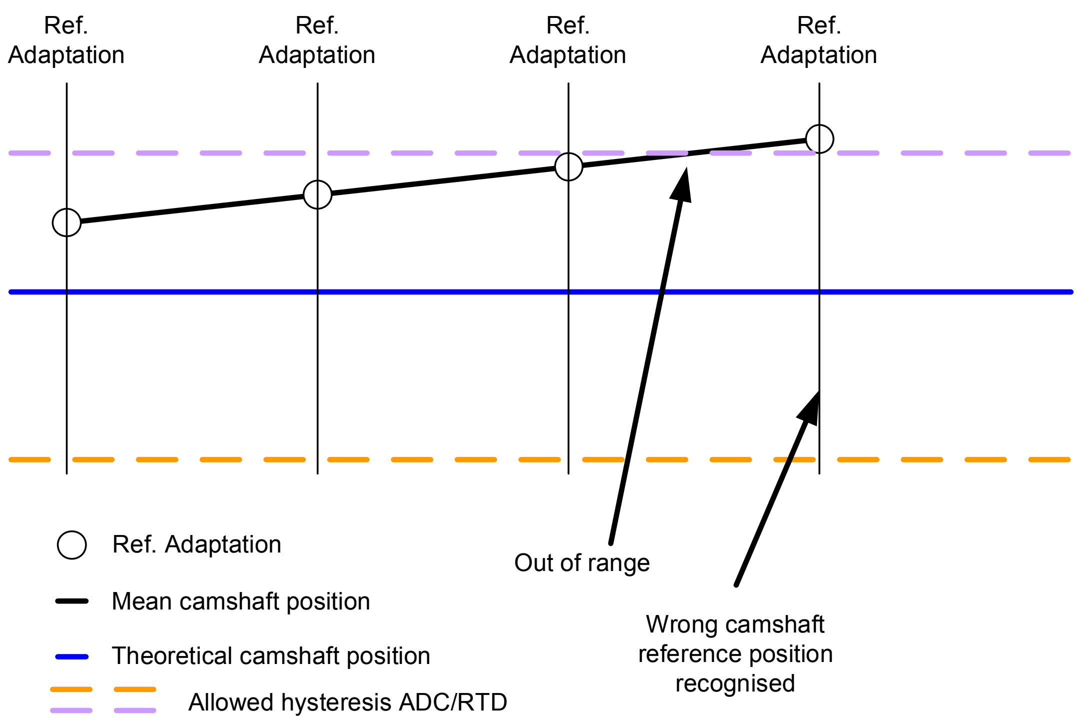
This diagnostic monitors whether the mean camshaft signal is within a plausible range during the reference position adaptation. The reference position adaptation is enabled if the target camshaft position is the reference one. This occurs after every engine start or during engine operation depending on the engine operating state.

A mean camshaft position is calculated from several camshaft signals. If the mean camshaft position is outside the hysteresis area, an incorrect camshaft reference position is detected. If this position is within the hysteresis, area, then there is no malfunction. After detecting a malfunction, an anti-bounce counter is incremented; otherwise the counter is decremented. If the counter exceeds an calibrated threshold, the appropriate DTC will be stored.

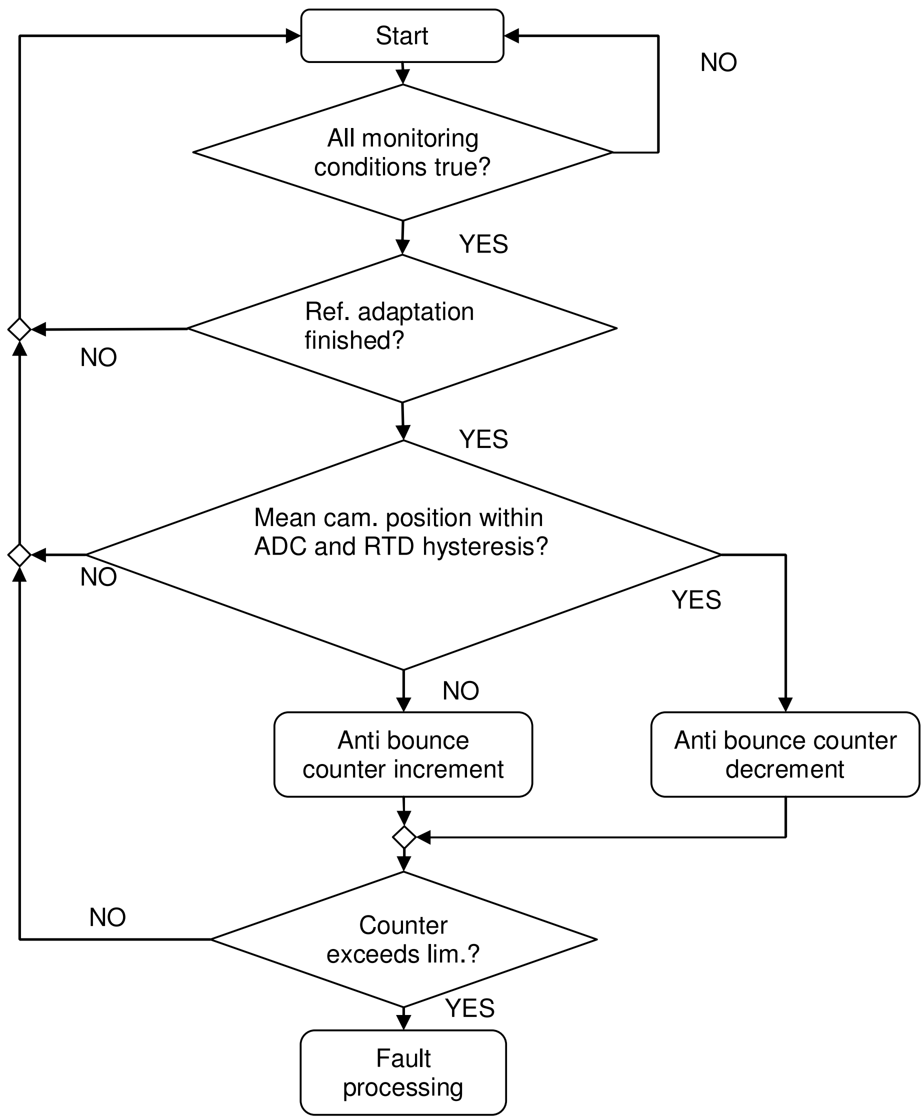
Example 1:



Example 2:



Camshaft/Crankshaft Position Correlation



VVT Camshaft/Crankshaft Position Correlation Monitor Operation:	
DTCs	P0016 - Crank/Cam Position Correlation (Bank 1 Sensor A) P0017 - Crank/Cam Position Correlation (Bank 1 Sensor B)
Monitor execution	Continuous, with the exception of P052x codes which are only run during CSER operation
Monitor Sequence	None
Sensors OK	CMP
Monitoring Duration	2160 crank degrees

Typical VVT Camshaft/Crankshaft Position Correlation monitor entry conditions:		
Entry condition	Minimum	Maximum
VVT active		
CAM adaptation active		
Engine speed		3296 rpm
Failure Time	2160 ° crank angle	

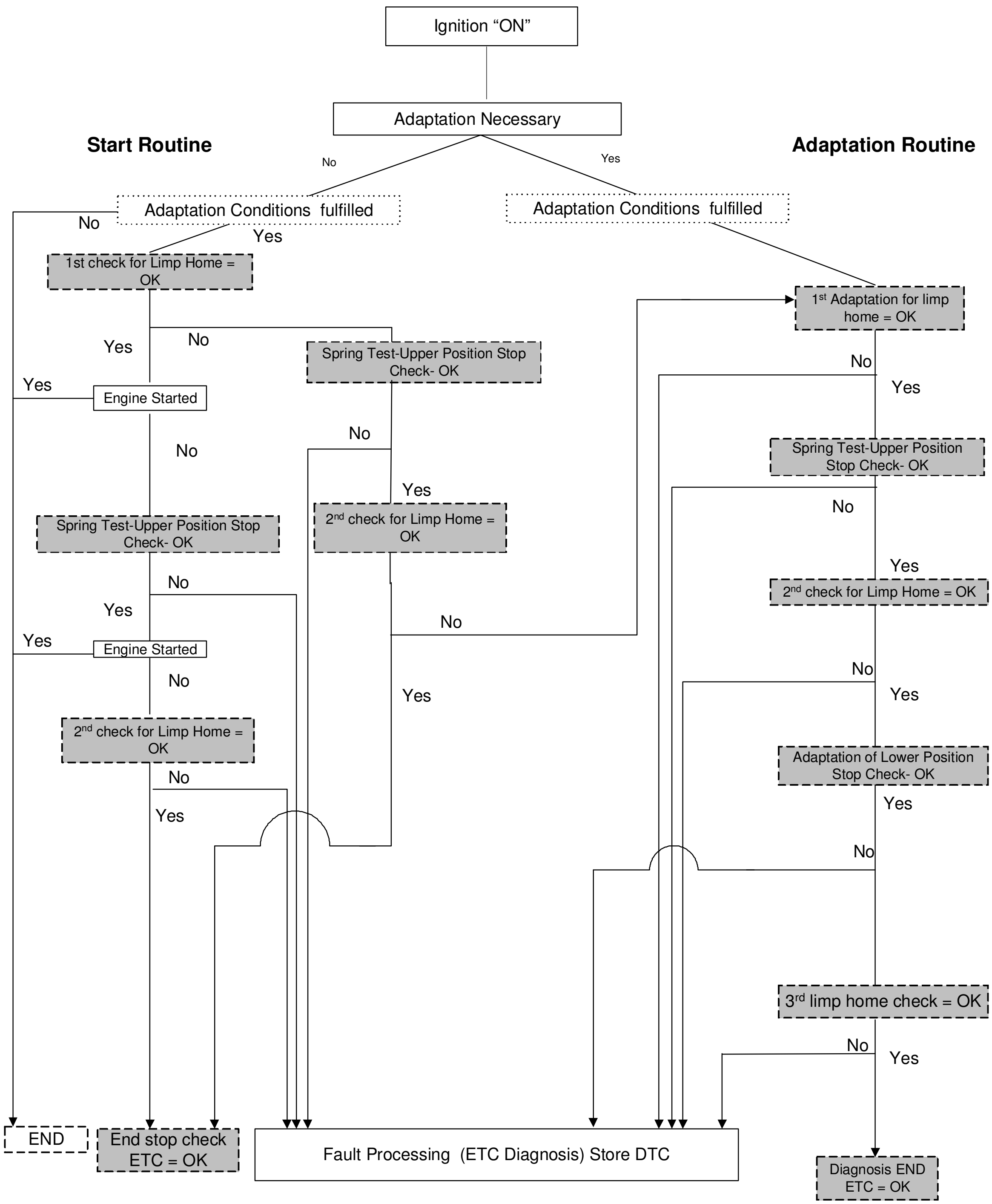
Typical In-Use Performance monitoring thresholds:
P0016
camshaft adapted reference position out of range: < -15 or > +15 deg crank
Excessive change in consecutive camshaft adaptations: > 15 deg crank
P0017
camshaft adapted reference position out of range: < -15 or > +15 deg crank
Excessive change in consecutive camshaft adaptations: > 15 deg crank

Electronic Throttle Control

The Electronic Throttle Control (ETC) system uses a strategy that delivers engine or output shaft torque, based on driver demand, utilizing an electronically controlled throttle body. ETC strategy was developed mainly to improve fuel economy. This is possible by decoupling throttle angle (produces engine torque) from pedal position (driver demand). This allows the powertrain control strategy to optimize fuel control and transmission shift schedules while delivering the requested engine or wheel torque.

ETC System Failure Mode and Effects Management:	
Effect	Failure Mode
No Effect on Drivability	A loss of redundancy or loss of a non-critical input could result in a fault that does not affect drivability. The ETC light will turn on, but the throttle control and torque control systems will function normally.
RPM Guard w/ Pedal Follower	In this mode, torque control is disabled due to the loss of a critical sensor or ECM fault. The throttle is controlled in pedal-follower mode as a function of the pedal position sensor input only. A maximum allowed RPM is determined based on pedal position (RPM Guard.) If the actual RPM exceeds this limit, spark and fuel are used to bring the RPM below the limit. The ETC light and the MIL are turned on in this mode and the corresponding trouble code will be stored.
RPM Guard w/ Default Throttle	In this mode, the throttle plate control is disabled due to the loss of Throttle Position, the Throttle Plate Position Controller, or other major Electronic Throttle Body fault. A default command is sent to the TPPC, or the H-bridge is disabled. Depending on the fault detected, the throttle plate is controlled or springs to the default (limp home) position. A maximum allowed RPM is determined based on pedal position (RPM Guard.) If the actual RPM exceeds this limit, spark and fuel are used to bring the RPM below the limit. The ETC light and the MIL are turned on in this mode and the corresponding trouble code will be stored.
RPM Guard w/ Forced High Idle	This mode is caused by the loss of 2 or 3 pedal position sensor inputs due to sensor, wiring, or ECM faults. The system is unable to determine driver demand, and the throttle is controlled to a fixed high idle airflow. There is no response to the driver input. The maximum allowed RPM is a fixed value (RPM Guard.) If the actual RPM exceeds this limit, spark and fuel are used to bring the RPM below the limit. The ETC light and the MIL are turned on in this mode and the corresponding trouble code will be stored.
Shutdown	If a significant processor fault is detected, the monitor will force vehicle shutdown by disabling all fuel injectors. The ETC light and the MIL are turned on in this mode and the corresponding trouble code will be stored. Note: Vehicle shutdown does not increase emissions; therefore the MIL is not required to be illuminated for this fault.
	Note: ETC illuminates or displays a message on the message center immediately, MIL illuminates after 2 driving cycles

Throttle Actuator (ETC) (Controller Diagnosis)



Electronic Throttle Control (ETC) Motor Control Circuit

The ETC Motor Control Circuit diagnostics are able to detect a short circuit to power, a short circuit to ground and an open circuit. The diagnostic is initialized after a module reset or a “Key ON”. After initialization (Key "ON"), the following are all reset: The diagnostic conditions, the symptom, the counter, and the failure stored in the Error Management.

The circuit diagnostics execute every 10 milliseconds and are continuous. A short circuit can only be detected when the H-bridge switches are open, so the condition for the each short circuit is calculated during all ranges of the PWM.

The ETC motor control circuit diagnostic is activated between a battery voltage range. This is to eliminate false low limit voltage detection. The deactivation threshold for the ETC motor control circuit diagnostic is typically calibrated to a low voltage.

Spring check (start routine)

This diagnostic checks if the throttle spring is working correctly and if the throttle limp home position can be achieved. The diagnostic is performed at the beginning of every driving cycle at ignition "Key ON" position. The throttle body spring check is executed as part of the start routine and is carried out with every “Key ON” of the engine control unit. More specifically the spring check is run during the TPS adaptation routine. The routine includes the following:

- Limp-home position check
- Adaptation of the limp-home position
- Upper return spring check

The start routine is only carried out when the adaptation conditions are maintained, (Key "ON" / Engine Running). The diagnostic will report when a spring-check error occurs, which includes the upper or lower return spring limits.

There is a throttle position set-point, calibratable, used for the upper return spring check. The TPS set-point should be approximately 10 ° greater than the limp-home position.

After the adaptation of the lower mechanical stop, the set point is used for the lower return spring check. The objective is to adjust the throttle in a position between the lower limit and limp-home. Without this set point, the throttle could stick in the lower mechanical stop after the adaptation. A typical value of 2 ° is recommended.

ETC adaptation diagnostic

After the initial engine start and / or component change, the characteristic Potentiometer values for the limp home position and the lower mechanical stop are learned within an adaptation routine. The values are stored at the end of the driving cycle in the non-volatile memory. If the conditions are not fulfilled, the malfunction errors (DTC's) are stored.

Due to the electrical and mechanical tolerances of the ETC system, the sensor characteristic has to be learned and the ETC system controller must adapt. The TPS adaptation is executed as part of the start routine and is carried out the very first time there is a “Key ON” of the engine control unit at the vehicle assembly plant or when the engine control unit is changed in service.

The TPS adaptation includes the following functions:

- Adaptation and check of the limp-home position
- Adaptation and check of the lower mechanical stop
- Lower return spring check
- Adaptation of the amplifier amplification (TPS 1 channel)
- Upper return spring check

Due to the electrical and the mechanical tolerances of the throttle position system, the sensor characteristic has to be learned. The adaptation and diagnosis of the lower mechanical stop and limp-home position occurs within the adaptation routines. The adapted lower mechanical stop and the upper check position are used for the calculation of TPS channel 1. The upper mechanical stop is not learned. During the TPS adaptation no limitation of the throttle position set-point is active. The learned value for the limp-home position, the lower mechanical stop and the TPS channel1 values are stored at the end of each driving cycle as „non-volatile".

The first step is the adaptation of the limp-home position. The actuator is without current and is forced by spring power to the limp home position. During the adaptation all the voltage values must be in the adaptation windows. A hysteresis is set up around each of the first recorded values (TPS 1 and 2). If all the TPS values are with in this hysteresis during a calibrated time, then the adaptation values are determined from the first and last value for each TPS. If a TPS value is outside the hysteresis, then the process is started over for both TPS channels. The learning function is limited by a calibratable time. An adaptation error is detected if the adaptation could not be carried out during the maximum time.

The next step is the adaptation of the lower mechanical stop. The throttle is driven into the lower mechanical stop by switching on the position controller and gradually decreasing the set point. As soon as the mechanical stop is reached, the adaptation of the lower mechanical stop for all TPS input channels is started. The adaptation procedure is the same as the limp-home position except the calibration values are different. As with the limp-home position, if the maximum adaptation time is exceeded, an adaptation error is indicated.

Now the lower return spring is checked. The throttle is positioned between lower mechanical stop and limp-home by switching on the position controller and increasing the set point gradually until a calibrated set point for testing the lower return spring is reached. An adaptation error is indicated if the throttle does not reach the requested position in a defined time limit. Then the ETC power stage is switched off and the throttle has to return by spring power to the limp-home position or a return spring error is indicated.

Next is the adaptation of the amplification from the TPS measuring amplifier (TPS 1 channel). The controller is switched on and the set point is gradually increased and the throttle is moved to a position above limp-home until the calibrated set point for the adaptation of the measuring amplifier is reached. An adaptation error is indicated if the throttle does not reach the requested position in a defined time limit.

The final step is the check of the upper return spring. The throttle is gradually driven further away from limp home position until a calibrated set point for the upper spring check is reached. An adaptation error will be indicated if the throttle does not reach the requested position in a defined time limit. The ETC power stage is switched-off and the throttle has to return by spring power to the limp-home position, or an upper return spring error is indicated.

If all of the adaptations and checks pass, the learned value for the limp-home position, the lower mechanical stop and the TPS channel 1 values are stored at the end of each driving cycle in non-volatile memory. This provides the initial control settings for the next "Key ON".

Electronic Throttle Control (ETC) Motor Control Performance

The task of this diagnostic is to detect a throttle valve error or a jammed ETC actuator. The diagnosis observes the ETC position controller system deviation dependent on the gradient of the throttle position setpoint. The anti-bounce of the error detection is done by the generic error management. The increment and decrement value of the anti-bounce counters can be calibrated.

Additionally the PWM output of the digital position controller is monitored by this diagnosis function. If the moving mean value exceeds a defined diagnosis threshold than an error will be indicated.

The diagnostic first observes the TPS sensor signal difference relative to the throttle position set point. If the difference is determined to be greater than a calibrated value, a control error is indicated. If the control system is unable to reach a set point within a calibrated time after multiple attempts, a jammed ETC actuator is indicated. In very low temperatures it is possible that the throttle actuator may become jammed by ice. If this is detected, an attempt to remove the ice will be made by varying the controller set point. The throttle position set point is varied by a rectangle function (Note: During active icebreaking engine speed limitation is requested!). If the ice-breaking is not successful after a defined number of pulses, the throttle position set point will be limited in lower or upper direction depending on the detected ice location. If the actual throttle position exceeds a defined threshold during limitation in the closed-throttle direction, then an additional error entry will be made with fault reaction of ETC power stage switch-off and engine speed limitation.

A second part of the diagnostic is to check the PWM output of the ETC system's position controller. If the moving-mean value of the PWM output exceeds a calibrated diagnostic threshold, then an error will be indicated.

Throttle Plate Controller and Actuator Monitor Operation:	
DTCs	P2100 – throttle actuator circuit open, short to power, short to ground (MIL) P2101 – throttle actuator range/performance test (MIL) P2104 – throttle actuator stuck open/closed (MIL) P2109 – throttle actuator sensor "A" minimum stop performance P2118 – Over heat protection P2119 – throttle body ice blockage (non-MIL) P2176 - Minimum Throttle Position Not Learned Note: For all the above DTCs, in addition to the MIL, the ETC light will be on for the fault that caused the FMEM action.
Monitor execution	Continuous
Monitor Sequence	None
Sensors OK	
Monitoring Duration	< 100 ms to register a malfunction

Typical Throttle Plate Controller and Actuator monitor entry conditions:		
Entry condition	Minimum	Maximum
Ignition “ON”		
Battery voltage	11 V	16 V
Engine speed (P2109)	64 rpm	
Pedal Position (P2109)		5 %
ECT (P2109)	-30 °C	105 °C
IAT (P2109)	-30 °C	
Vehicle Speed (P2109)		1.2 mph
Time since ignition on (P2109)	1 s	

Typical In-Use Performance monitoring thresholds:

P2100

ETC – open circuit detected by hardware driver circuit

P2101

Range / Performance detected by hardware driver circuit

P2104

TPS Stuck Throttle Blade - Open /Closed (Maximum permitted throttle position for the throttle position setpoint limitation): > 5 deg throttle

P2109

Adaptation values of lower mechanical stop out of range, Throttle position offset > .05 V

P2118

Over heat condition detected by hardware driver circuit

P2119

Pulsewidth from controller: > 90 %

TPS limit adaptation out of range: > - 60 %

MAF/TPS correlation, Actual vs. Model

Spring check - Lower position not reached during TPS adaptation: > - 60 deg

Spring check - Upper position not reached during TPS adaptation: > - 60 deg

P2176

Adaptation conditions exceeded / adaptation inhibited

Accelerator and Throttle Position Sensor Inputs

Accelerator Pedal Position Sensor Check Operation:	
DTCs	P2122, P2123 – APP D circuit continuity P2138 – APP D/E circuit correlation P2127, P2128 – APP E circuit continuity
Monitor execution	continuous
Monitor Sequence	none
Sensors OK	not applicable
Monitoring Duration	< 1 seconds to register a malfunction

APP sensor check malfunction thresholds:
APP D circuit continuity: frequency < 120 Hz or > 280 Hz APP E circuit continuity: voltage < 4.644 APP D/E correlation : > 7%

Typical Throttle Position Sensor Check Operation:	
DTCs	P0122, P0123 – TP A circuit continuity P0121 – TP A range/performance P0222, P0223 – TP B circuit continuity
Monitor execution	Continuous
Monitor Sequence	None
Sensors OK	not applicable
Monitoring Duration	< 1 seconds to register a malfunction

Typical TP sensor check malfunction thresholds:
TP A circuit continuity - voltage < 0.04 volts or voltage > 4.7 volts TP B circuit continuity - voltage < 0.32 volts or voltage > 4.95 volts TP A Range/performance – modeled airflow/actual airflow disagree > 35%

Comprehensive Component Monitor - Engine

Engine Temperature Sensor Input

Analog inputs such as Intake Air Temperature (P0112, P0113), Engine Coolant Temperature (P0117, P0118), Mass Air Flow (P0102, P0103), and Throttle Position (P0122, P0123) P0222, P0223) are checked for opens, shorts, or rationality by monitoring the analog -to-digital (A/D) input voltage.

Engine Coolant Temperature Sensor Check Operation:	
DTCs	P0117 - Engine Coolant Temperature circuit low P0118 - Engine Coolant Temperature circuit high
Monitor execution	Continuous
Monitor Sequence	None
Sensors OK	not applicable
Monitoring Duration	5 seconds to register a malfunction

Typical Engine Coolant Temperature Sensor Check monitor entry conditions:		
Entry condition	Minimum	Maximum
Intake air temperature OR	- 30 °C	
Time after engine start	20 s	

Typical ECT sensor check malfunction thresholds:
P0117 Short to ground: < 0.03 V P0118 Short to battery plus or open circuit: > 3.26 V

ECT Sensor Rationality Check Operation:	
DTCs	P0116 - Engine Coolant Temperature stuck high or stuck in range
Monitor execution	Once per driving cycle
Monitor Sequence	None
Sensors OK	ECT, IAT, AAT
Monitoring Duration	5 seconds to register a malfunction

Typical ECT Sensor Rationality check entry conditions:		
Entry Condition	Minimum	Maximum
Engine coolant temp at start-up (stuck low)		45 ℃
Time after Start (stuck low)	5 s	
ECT model change since start (stuck low)	0.75 to 35.25 ℃	
Engine Off Time (stuck in range)	240 min	
Battery Voltage (stuck in range)	11 V	16 V
Intake Air Temperature at start (stuck in range)	-30 ℃	80 ℃
Ambient Air Temperature at start (stuck in range)	-30 ℃	
Difference between AAT at start and IAT at start (stuck in range)	8.25 ℃	

Typical ECT sensor rationality check malfunction thresholds:
ECT Stuck Low: Actual vs. Model Temperature: > 3.75 to 71.25 ℃ ECT stuck in range: ECT and IAT difference at engine start: > 9.75 ℃ AND Expected ECT at engine start: > a table value 9.75 to 60 ℃

Intake Air Temperature Sensor Input

Intake Air Temperature Sensor Check Operation:	
DTCs	P0112 – Intake Air Temperature circuit low P0113 Intake Air Temperature circuit high P0114 Intake Air Temperature circuit intermittent/erratic
Monitor execution	continuous
Monitor Sequence	None
Sensors OK	IAT
Monitoring Duration	5 seconds to register a malfunction

Typical ECT Sensor Rationality check entry conditions:		
Entry Condition	Minimum	Maximum
Battery voltage	11 V	16 V
Minimum time after start	3 s	

Typical IAT sensor check malfunction thresholds:
P0112 - Short to ground: ≤ 0.02 V P0113 - Short to battery / Open circuit: ≥ 3.17 V P0114 - Signal intermittent / Noisy (IAT difference from moving average): ≥ 8.25 °C

IAT Rationality Test

The IAT rationality test determines if the IAT sensor is producing an erroneous temperature indication within the normal range of IAT sensor input.

Intake Air Temperature Sensor Cold Start Plausibility Check Operation:	
DTCs	P009A - Intake Air Temperature /Ambient Air Temperature Correlation
Monitor execution	Once per driving cycle, at start-up
Monitor Sequence	None
Sensors OK	P2610, P0113, P0112, P0114, P0111, P0073, P0072, P0074, P0118, P0117, P0119, P0116, P0500
Monitoring Duration	Immediate or up to 30 minutes to register a malfunction

Typical Intake Air Temperature Sensor Cold Start Plausibility Entry Conditions		
Entry condition	Minimum	Maximum
Engine off time	6.7 h	
Abs | Engine Coolant Temperature at start minus Intake Air Temp at start |		18 °C
Block heater not present		
engine run time		240 s

Typical IAT Sensor Cold Start Plausibility check malfunction thresholds:
P009A Abs | Ambient Air Temp minus Engine Coolant Temperature at start | > 18 °C AND Abs | Ambient Air Temp minus Intake Air Temperature at start | > 18 °C

Intake Air Temperature Sensor Plausibility (Hot) Check Operation:	
DTCs	P0111 - Intake Air Temperature Sensor 1 Circuit Range/Performance
Monitor execution	Continuous
Monitor Sequence	None
Sensors OK	ambient pressure, MAF, IAT, vehicle speed
Monitoring Duration	100 ms to register a malfunction

Typical Intake Air Temperature Sensor Plausibility (Hot) Entry Conditions		
Entry condition	Minimum	Maximum
Battery voltage	11 V	16 V
Low vehicle speed (rationality)		3 mph
High vehicle speed (rationality)	36 mph	
Medium load (rationality)	100 kg/h	
Low load (rationality)		100 kg/h
air mass flow integral value (rationality)	4.6	kg
ECT (stuck)	-9.75 ℃	
IAT (stuck)	-9.75 ℃	
Time since start (stuck)	25 s	
Distance driven since start (stuck)	6.25 miles	

Typical IAT Sensor Plausibility (Hot) check malfunction thresholds:
If the P009A diagnostic enable conditions are met prior to exceeding maximum engine run time, the P011 test will not be run. P0111 Rationality: Expected Intake Air Temp decrease at low vehicle speed / low load: > 24.75 ℃ OR Expected Intake Air Temp increase at high vehicle speed / medium load: > 24.75 ℃ Stuck: Change in IAT since engine start: < 1.5 ℃

Ambient Air Temperature Sensor Input

Ambient Air Temperature Sensor Check Operation:	
DTCs	P0072 - Ambient Air Temperature circuit low P0073 - Ambient Air Temperature circuit high
Monitor execution	Continuous
Monitor Sequence	None
Sensors OK	AAT, IAT
Monitoring Duration	12.7 seconds to register a malfunction

Typical Ambient Air Temperature Sensor Plausibility Entry Conditions		
Entry condition	Minimum	Maximum
ECU power up time	1.5 s	

Typical IAT sensor check malfunction thresholds:
P0072 Short to ground, open circuit: < 0.47 V P0073 Short to battery: > 4.93

Mass Air Flow Sensor

MAF Sensor Check Operation:	
DTCs	P0102 (MAF low input) P0103 (MAF high input)
Monitor execution	continuous
Monitor Sequence	none
Sensors OK	TPS, CKP
Monitoring Duration	100 ms to register a malfunction

Typical Ambient Air Temperature Sensor Plausibility Entry Conditions		
Entry condition	Minimum	Maximum
Engine speed (P0102 only)	704 rpm	
Throttle position (P0102 only)	0.503 deg	
DFCO not active (P0102 only)		

Typical MAF sensor check malfunction thresholds:
P0102 Short to ground, open circuit: < 0.06 V P0103 Short to battery: > 4.9 V

Mass Air Flow Range Performance

T

TPS Load Check Operation:	
DTCs	P0101
Monitor execution	Continuous
Monitor Sequence	None
Sensors OK	MAF, IAT, CPS, ambient sensor, TP,supply voltage, CAM, VVT, ECT
Monitoring Duration	2.4 sec within test entry conditions

TPS Load Check Operation entry conditions:		
Entry Condition	Minimum	Maximum
Closed Loop Fuel Control	Active	
Battery voltage	10 V	
ECT	70 deg C	
IAT	15 deg C	
Engine run time	30 s	
Filtered lambda correction	-30%	
Filtered lambda correction		30%
BARO	75 kPa	108 kPa
Engine speed (idle test)	640 rpm	1056 rpm
Throttle position (idle test)	4 to 14 deg	
Engine speed (part throttle test)	992 rpm	4000 rpm
Throttle position (part throttle test)	15 to 28 deg	
Normalized load (part throttle test)	35%	63%

Typical TPS Load Check Operation malfunction thresholds:
Actual Air Flow - Modeled Airflow for idle test > 30% AND lambda correction <-30% OR Actual Air Flow - Modeled Airflow for idle test < 30% AND lambda correction >-30% Actual Air Flow - Modeled Airflow for part throttle test > 18 to 25% AND lambda correction <-22.5% OR Actual Air Flow - Modeled Airflow for part throttle test < 18 to -25% AND lambda correction > -22.5%

TPS Load Test

The MAF and TP sensors are cross-checked to determine whether the sensor readings are rational and appropriate for the current operating conditions. (P0068)

TPS Load Check Operation:	
DTCs	P0068
Monitor execution	Continuous
Monitor Sequence	None
Sensors OK	MAF, IAT, CPS, ambient sensor, TP,supply voltage, CAM, VVT, ECT
Monitoring Duration	20 ms within test entry conditions

TPS Load Check Operation entry conditions:		
Entry Condition	Minimum	Maximum
Closed Loop Fuel Control	Active	
Battery voltage	10 V	
ECT	70 deg C	
IAT	15 deg C	
Engine run time	30 s	
Filtered lambda correction	-22.5%	
Filtered lambda correction		22.5%
BARO	75 kPa	108 kPa
Engine speed (idle test)	640 rpm	1056 rpm
Throttle position (idle test)	4 to 14 deg	
Engine speed (part throttle test)	992 rpm	4000 rpm
Throttle position (part throttle test)	15 to 28 deg	
Normalized load (part throttle test)	35%	63%

Typical TPS Load Check Operation malfunction thresholds:
Actual Air Flow - Modeled Airflow for idle test < - 35%
Actual Air Flow - Modeled Airflow for part throttle test > 30.5 to 50%
Actual Air Flow - Modeled Airflow for part throttle test < -30.5 to -50%

5 Volt Sensor Reference Voltage A Check:	
DTCs	P0642 (low input) P0643 (high input)
Monitor execution	Continuous
Monitor Sequence	None
Sensors OK	not applicable
Monitoring Duration	100 ms to register a malfunction
5 Volt Sensor Reference Voltage B Check:	
DTCs	P0652 (low input) P0653 (high input)
Monitor execution	Continuous
Monitor Sequence	None
Sensors OK	not applicable
Monitoring Duration	100 ms to register a malfunction

Typical 5 Volt Sensor Reference Voltage A & B check entry conditions:		
Entry Condition	Minimum	Maximum
Ignition "ON"	NA	NA

Typical 5 Volt Sensor Reference Voltage A & B check malfunction thresholds:
<u>P0642 & P0652</u> Short to ground (signal voltage): < 4.75 V <u>P0643 & P0653</u> Short to battery plus (signal voltage): > 5.25 V

Engine Off Timer Monitor

The engine off timer function is obtained via a CAN message from the instrument panel cluster. There are multiple parts to the diagnosis of the engine off timer.
The first is performed by the instrument panel cluster. If the engine off time is not available due to low power mode, the CAN message is set to FFFFh and a default soak time will be used.
The next diagnosis checks the availability of engine off time from CAN before engine start. Once detected, this failure can only be reset by a key off to on transition or ECU reset.
The final diagnostic verifies that the engine off timer itself is plausible as compared to a global timer.

Engine Off Timer Check Operation:	
DTCs	P2610
Monitor execution	Continuous within entry conditions
Monitor Sequence	None
Monitoring Duration	1 s to 4 seconds to set malfunction depending on which failure.

Typical Engine Off Timer check malfunction thresholds:
Difference between engine off timer compared to Global Real Time > 327 s
Difference between time after start calculated by ECU and time after start calculated from Global Real Time clock: ≥ 2 - 10 min
Engine Off time from CAN > 300 s AND engine off time based on Global Real Time clock: < 6552 s
Engine off timer from CAN not available before engine start after two battery disconnects

Idle Speed Control Monitor

The Idle Speed Control system is functionally checked by monitoring the closed loop idle speed correction required to maintain the desired idle rpm. If the proper idle rpm cannot be maintained and the system has a high rpm (+200) or low rpm error (-100) greater than the malfunction threshold, an Idle Speed malfunction is indicated. (P0506, P0507) If an idle speed deviation occurs during cold start, a P050A will be stored as part of the cold start monitoring strategy.

Idle Speed Check Operation:	
DTCs	P0506 (functional - under speed) P0507 (functional - over speed)
Monitor execution	every idle condition
Monitor Sequence	None
Sensors OK	P0459, P0443, P0497, P0458, P0116, P0117, P0118, P0119, P0101, P0068, P0102, P0103
Monitoring Duration	3 seconds

Typical Idle Speed functional check entry conditions:		
Entry Condition	Minimum	Maximum
Ignition "ON"		
Canister purge		7.99 kg
MAF		240 m/s
ECT	60 °C	
Engine Run Time	100 s	
Torque control at limit	2 s	
Battery voltage	11 V	16 V
Stabilization Period	3 s	

Typical IAC functional check malfunction thresholds:
P0506
RPM Lower than Commanded (engine speed commanded minus actual engine speed): > 100 rpm
P0507
RPM Higher than Commanded (actual engine speed minus engine speed commanded): > 200 rpm

The ECM monitors the "smart" driver fault status bit that indicates either an open circuit, short to power or short to ground.

Injector Check Operation:	
DTCs	P0201 (Cyl 1 injector open) P0261 (Cyl 1 injector low) P0262 (Cyl 1 injector high) P0202 (Cyl 2 injector open) P0264 (Cyl 2 injector low) P0265 (Cyl 2 injector high) P0203 (Cyl 3 injector open) P0267 (Cyl 3 injector low) P0268 (Cyl 3 injector high) P0204 (Cyl 4 injector open) P0270 (Cyl 4 injector low) P0271 (Cyl 4 injector high)
Monitor execution	Continuous within entry conditions
Monitor Sequence	None
Sensors OK	No injector errors
Monitoring Duration	2 seconds

Typical injector circuit check entry conditions:		
Entry Condition	Minimum	Maximum
Ignition “ON”		

Typical injector circuit check malfunction thresholds:
<u>P0201 & P0202 & P0204 & P0204</u> Open circuit: Error detection is performed by ECM circuit driver <u>P0261 & P0264 & P0267 & P0270</u> Short to ground: Error detection is performed by ECM circuit driver <u>P0262 & P0265 & P0268 & P0271</u> short to battery: Error detection is performed by ECM circuit driver

Knock Sensor

Two basic diagnostic tests are performed on each knock sensor – circuit continuity tests and a knock processing chip tests.

Due to the design of the knock sensor input circuitry, after filtering and integration, a short to battery, short to ground, or open circuit all result is a low knock signal voltage. This voltage is compared to a noise signal threshold (function of rpm) to determine knock sensor circuit high and circuit low faults.

Another indication of a sensor failure is the standard deviation of the signal noise which decreases when there is a failure. The knock signal standard deviation is compared to a threshold (function of rpm).

The knock signal processing chip SPI bus is checked to make sure it is not off. This would indicate there is no communication between the main processor and the chip used as the interface the knock sensor.

Knock Sensor Check Operatio	
DTCs	P0325 – Knock Sensor 1 Circuit P0326 – Knock Sensor 1 Circuit/Range Performance P0330 – Knock Sensor 2 Circuit P0331 – Knock Sensor 2 Circuit/Range Performance P06B6 - Internal Control Module Knock Sensor Processor 1 Performance
Monitor execution	Continuous within entry conditions
Monitor Sequence	None
Sensors OK	P0326, P0330,P0331
Monitoring Duration	2.5 seconds

Typical Knock Sensor check entry conditions:		
Entry Condition	Minimum	Maximum
Ignition “ON”		
Engine Coolant Temperature	42 °C	
Mass Air Flow	158 mg/stroke	
Engine speed	1088 rpm	

Typical Knock Sensor functional check malfunction thresholds:
P0325 & P0330
Knock signal too low (function of engine speed): < 0.3516 V
P0326 & P0331
Knock signal standard deviation too low (function of engine speed): < 0.0195 V to 0.0586V
P06B6
SPI bus failure

Barometric Pressure Sensor

The purpose of the diagnosis shall be to detect electrical faults as defined by OBD I requirements.
The signal of the altitude pressure sensor on the A/D-input of the microcontroller is checked.

Barometric Pressure Sensor Check Operation:	
DTCs	P2227 – Barometric Pressure Sensor "A" Circuit Range/Performance P2228 – Barometric Pressure Sensor "A" Circuit Low P2229 – Barometric Pressure Sensor "A" Circuit High
Monitor execution	Continuous within entry conditions
Monitor Sequence	None
Sensors OK	TP, MAF, ECT, ambient pressure, supply voltage, VS
Monitoring Duration	5 seconds

Typical Barometric Pressure Sensor check entry conditions:		
Entry Condition	Minimum	Maximum
Ignition "ON"		
Engine running		
Vehicle speed	0 mph	
Engine at Idle (closed throttle)		
Mass air flow		
Intake manifold pressure	99.9 kPa	
Engine Coolant Temperature	-48 °C	

Typical Barometric Pressure Sensor functional check malfunction thresholds:
P2227
BARO gradient (Table Based on vehicle speed): > 10 kPa/s OR
BARO from last driving cycle minus BARO @engine start): > 10 kPa -AND-
mass air flow calculated from BARO sensor minus mass air flow): > 3 kg/h
P2228
Short to ground or open circuit: ≤ 0.85 V
P2229
Short to battery: ≥ 4.50 V

Ignition Coil

The purpose of this diagnosis function is to detect all major failures, which can happen between the ECU output and ignition coils.
The diagnosis is performed separate for each ignition coil. The feedback signal from the specific ignition coil (following the firing order) is evaluated by the microcontroller.

Ignition Coil:	
DTCs	P0351 – Ignition Coil A Primary Control Circuit Open P2301 – Ignition Coil A Primary Control Circuit High P0352 – Ignition Coil B Primary Control Circuit Open P2304 – Ignition Coil B Primary Control Circuit High
Monitor execution	Continuous within entry conditions
Monitor Sequence	None
Sensors OK	Oposite Coil errors
Monitoring Duration	50 ms

Typical ignition circuit check malfunction thresholds:
P0351 & P0352 Open circuit: Error detection is performed by ECM circuit driver P2301 & P2304 Short to battery: Error detection is performed by ECM circuit driver

Camshaft Position Sensor Monitor

A P0340/P0365 malfunction is indicated if no signal edge is detected for a calibratable time between two expected camshaft signal edges. A P0341/P0366 malfunction is indicated if the camshaft position is outside of the calibrated range specified for the engine. A P0344/P0369 malfunction is detected if a tooth segment period is too short.

Camshaft Position Sensor:	
DTCs	P0340 – Camshaft Position Sensor "A" Circuit P0341 – Camshaft Position Sensor "A" Circuit Range/Performance P0344 – Camshaft Position Sensor "A" Circuit Intermittent P0365 – Camshaft Position Sensor "B" Circuit P0366 – Camshaft Position Sensor "B" Circuit Range/Performance P0369 – Camshaft Position Sensor "B" Circuit Intermittent
Monitor execution	Continuous within entry conditions
Monitor Sequence	None
Sensors OK	CKP, CMP
Monitoring Duration	4 engine cycles

Typical Camshaft Position check entry conditions:		
Entry Condition	Minimum	Maximum
Ignition	On	
Engine speed		3712 rpm

Typical Camshaft Position check malfunction thresholds:
P0340 - Signal Implausible / Loss of Sync. No signal edge is detected for a max time between two camshaft signal edges: > 4 counts P0341 - Plausibility check Number of missing camshaft edges seen from the previous camshaft edge: > 3 P0344 - Intermittent/erratic Cam Segment Period to Short: > 3 P0365 - Signal Implausible / Loss of Sync. No signal edge is detected for a max time between two camshaft signal edges: > 4 counts P0366 - Plausibility check Number of missing camshaft edges seen from the previous camshaft edge: > 3 P0369 - Intermittent/erratic Cam Segment Period to Short: > 3

Crankshaft Position Sensor Monitor

A P0335 malfunction is indicated if there is no crankshaft signal detected. A P0336 malfunction is indicated if a camshaft signal is present (engine is spinning) but a crankshaft signal is not present, or the number of teeth detected is incorrect, or if the time between teeth is implausible.

Crankshaft Position Sensor:	
DTCs	P0335 – Crankshaft Position Sensor "A" Circuit P0336 – Crankshaft Position Sensor "A" Circuit Range/Performance
Monitor execution	Continuous within entry conditions
Monitor Sequence	None
Sensors OK	CRK, CMP
Monitoring Duration	12 ms

Typical Crankshaft Position check entry conditions:		
Entry Condition	Minimum	Maximum
Ignition "ON"		
Maximum engine speed to enable tooth number diagnosis		512 rpm

Typical Crankshaft Position check malfunction thresholds:
P0335 Signal missing: No signal Signal missing (Sensor signal voltage): > 2.487 V - OR - < 1.2199 V Signal missing (Min and max difference between the voltage based on Engine speed): (Table based on engine speed) 2 V at 992 rpm and 3 V at 8000 rpm P0336 Synchronization Error (Signal available): Missing Teeth (Not enough teeth per CAM pulses): Additional Teeth (two or more teeth seen per CAM pulses): Signal Implausible / Loss of Sync. (Did not sync): Crankshaft signal missing: No Signal

Miscellaneous CPU Tests

U0101 - Lost Communications With Transmission Control System (for vehicles with standalone TCM)

U0121 - Lost Communication With Anti-Lock Brake System (ABS) Control Module (for vehicles with manual trans)

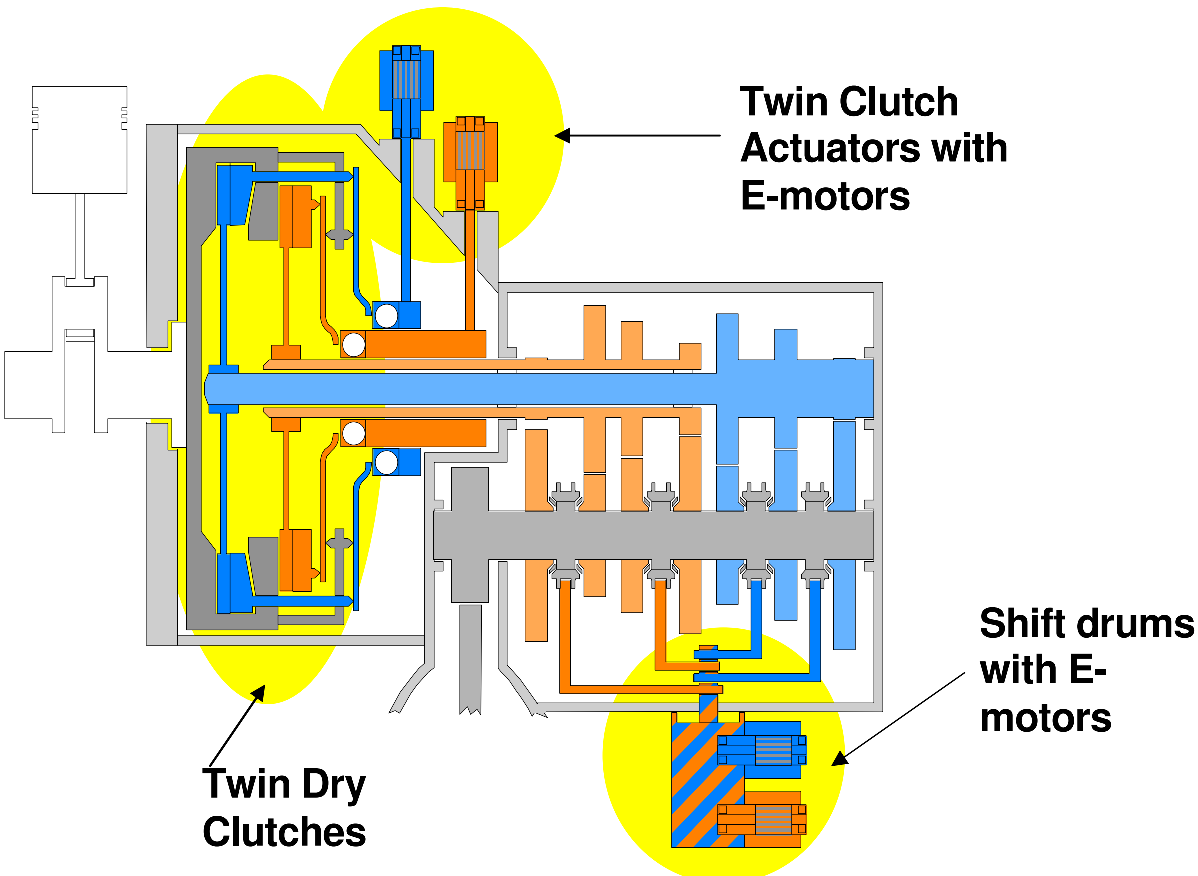
U0423 - Invalid Data Received from Instrument Panel Cluster Control Module

U2012 - Car Configuration Parameter(s) - vehicle configuration not plausible

DPS6 (FWD) Transmission

DPS6 is a fully automatic 6 speed transmission made up of manual transmission gearing, combined with electro-mechanical actuators, and conventional automatic transmission controls.

The Gearbox & Dual-Clutch System Physical Architecture



DPS6 has 2 clutches:

1. Clutch A – on in 1st, 3rd and 5th gear
2. Clutch B – on in Reverse, 2nd, 4th and 6th gear

Each clutch system consists of:

- Clutch
- 3 phase electric motor – rotates a screw driven fulcrum that controls clutch position (and torque). There are end stops at the full open and full closed positions
- Each motor phase has a hall position sensor that combine to provide a relative position – the system must sweep the clutch full open to full closed, then count increments on the sensors to know position. It takes many rotations of the motor to sweep the clutch from fully open to fully closed.
- Spring that returns the clutch to the full open position if the motor is turned off.

DPS6 has 2 shift drums:

1. Shift Drum A – controls the shift forks that engage 1st, 3rd and 5th gear
2. Shift Drum B – controls the shift forks that engage Reverse, 2nd, 4th and 6th gear

Each shift drum system consists of:

- Shift drum with groove that controls the position of shift forks
- Shift forks that engage synchronizers and gears
- 3 phase electric motor that controls the position of the shift drum
- Hall sensor system that knows the position of the motor within a rotation, used to calculate the shift drum angular position (the shift drum motor rotates 61.44 times for a single revolution of the shift drum)

Relationship between shift drum angle and gears;

Angle	Shift drum 1 position	Shift drum 2 position
0 deg	End stop near 1st	End stop near Reverse
10 deg	Centered in 1st	Centered in Reverse
55 deg	Neutral between 1st and 3rd	Neutral between R and 2nd
90 deg	Centered in 3rd	Centered in 2nd
135 deg	Neutral between 3rd and 5th	Neutral between 2nd and 4th
190 deg	Centered in 5th	Centered in 4th
200 deg	End stop near 5th	4th gear
235 deg		Neutral between 4th and 6th
280		Centered in 6th
290		End stop near 6th

Transmission Inputs

Transmission Range Sensor

DPS6 is range by wire with mechanical Park. DPS6 uses a dual PWM output (at 250 Hz) TRS where one signal is the inverse of the other and the sum of the two signals add up to 100%. Each signal is tested for frequency errors (P0706 / P2801), duty cycle out of range low (P0707 / P2802) and duty cycle out of range high (P0708 / P2803). There is also a correlation error (P2805) if the two signals do not add up to 100%.

Speed Sensors

Input 1 Speed Sensor (I1SS) – detects input shaft 1 speed, connected to clutch 1 and the odd gears (1^{st}, 3^{rd} and 5^{th}). I1SS is tested for power supply faults (P06A6), circuit failures detected by the TCM hardware (P0715), erratic signal (P0716), and lack of signal (P0717).

Input 2 Speed Sensor (I2SS) – detects input shaft 2 speed, connected to clutch 2 and the even gears (R, 2^{nd}, 4^{th} and 6^{th}). I2SS is tested for power supply faults (P06A7), circuit failures detected by the TCM hardware (P2765), erratic signal (P2766), and lack of signal (P2767).

Output Speed Sensor (OSS) – detects output speed. OSS is tested for power supply faults (P06A8), circuit failures detected by the TCM hardware (P0720), erratic signal (P0721), and lack of signal (P0722).

Note: because DPS6 is "Dry clutch" the only transmission fluid is for splash lube (no pump, no pressure control solenoids), so DPS6 does not have a temperature sensor.

Transmission Outputs

DPS6 has four 3-phase electric motors:

1. Clutch A motor – controls clutch A torque capacity. The Clutch A system is tested for:
   a. ATIC faults (P0805) – the ATIC is an internal TCM component that controls motor current.
   b. Hall sensor faults (P0806) – each phase has a hall sensor that provides motor position information
   c. Sequence faults (P0809) – as the motor rotates it generates an defined pattern from the 3 hall sensors, if the sequence of hall sensor patterns is off this code sets.
   d. Open circuit (P0900)
   e. Short to ground (P0902)
   f. Short to power (P0903)
   g. Clutch functionally stuck off (P07A2)
   h. Clutch functionally stuck on (P07A3)

2. Clutch B motor – controls clutch B torque capacity. The Clutch B system is tested for:
   a. ATIC faults (P087A) – the ATIC is an internal TCM component that controls motor current.
   b. Hall sensor faults (P087B) – each phase has a hall sensor that provides motor position information
   c. Sequence faults (P087E) – as the motor rotates it generates an defined pattern from the 3 hall sensors, if the sequence of hall sensor patterns is off this code sets.
   d. Open circuit (P090A)
   e. Short to ground (P090C)
   f. Short to power (P090D)
   g. Clutch functionally stuck off (P07A4)
   h. Clutch functionally stuck on (P07A5)

3. Shift drum A motor – controls the shift forks that engage 1st, 3rd and 5th gear. The system is tested for:
    a. ATIC faults (P2831) – the ATIC is an internal TCM component that controls motor current.
    b. Sequence faults (P2835) – as the motor rotates it generates an defined pattern from the 3 hall sensors, if the sequence of hall sensor patterns is off this code sets.
    c. Open circuit (P285B)
    d. Short to ground (P285D)
    e. Short to power (P285E)
    f. Stuck in gear (P072C, P072E, P073A)
    g. Position error (P2832) – includes blocked motor, or any failure that results in the TCM losing confidence in the relative position of the shift drum.

4. Shift drum A motor – controls the shift forks that engage 1st, 3rd and 5th gear. The system is tested for:
    a. ATIC faults (P2836) – the ATIC is an internal TCM component that controls motor current.
    b. Sequence faults (P283A) – as the motor rotates it generates an defined pattern from the 3 hall sensors, if the sequence of hall sensor patterns is off this code sets.
    c. Open circuit (P285F)
    d. Short to ground (P2861)
    e. Short to power (P2862)
    f. Stuck in gear (P072B, P072D, P072F, P073B)
    g. Position error (P2837) – includes blocked motor, or any failure that results in the TCM losing confidence in the relative position of the shift drum.

Transmission Control Module (TCM)

The TCM monitors itself by using various software monitoring functions. The TCM is monitored for:

a. If a RAM Read/Write error is detected during initialization, a P0604 fault code will be stored

b. the flash ROM is checked using a checksum calculation. If the checksum is incorrect during a P0605 fault will be stored

c. CPU performance is monitored for incorrect instructions or resets, if detected a P0607 fault code is set

d. If an error is found with NVRAM a P06B8 fault code will be stored

CAN Communications error

The TCM receives information from the ECM via CAN. If the CAN link fails the TCM no longer has torque or engine speed information available. The TCM will store a U0073 fault code if the CAN Bus is off. The TCM will store a U0100 fault code if it doesn't receive any more CAN messages from the ECM. A U0401 fault codes will be stored if the ECM received invalid/faulted information for the following CAN message items: engine torque, pedal position.

System voltage:

the TCM monitors system voltage and stores fault codes if it is out of range low (P0882) or out of range high (P0883). These thresholds are set based on hardware capability.

On Board Diagnostic Executive

The On-Board Diagnostic (OBD) Executive is a portion of the PCM strategy that manages the diagnostic trouble codes and operating modes for all diagnostic tests. It is the "traffic cop" of the diagnostic system. The Diagnostic Executive performs the following functions:

- Sequence the OBD monitors such that when a test runs, each input that it relies upon has already been tested. For 2008 MY and beyond ISO 14229 programs, the OBD monitors are no longer sequenced by the diagnostic executive.
- Controls and co-ordinates the execution of the individual OBD system monitors: Catalyst, Misfire, EGR, O2, Fuel, AIR, EVAP and, Comprehensive Component Monitor (CCM). For 2008 MY and beyond ISO 14229 programs, the execution of the OBD monitors is no longer controlled and coordinated by the diagnostic executive.
- Stores freeze frame and "similar condition" data.
- Manages storage and erasure of Diagnostic Trouble Codes as well as MIL illumination.
- Controls and co-ordinates the execution of the On-Demand tests: Key On Engine Off (KOEO) Key On Engine Running (KOER).
- Performs transitions between various states of the diagnostic and powertrain control system to minimize the effects on vehicle operation.
- Interfaces with the diagnostic test tools to provide diagnostic information (I/M readiness, various J1979 test modes) and responses to special diagnostic requests (J1979 Mode 08 and 09).
- Tracks and manages indication of the driving cycle which includes the time between two key on events that include an engine start and key off.

  The diagnostic executive also controls several overall, global OBD entry conditions.
  The battery voltage must fall between 11.0 and 18.0 volts to initiate monitoring cycles.
  The engine must be started to initiate the engine started, engine running, and engine off monitoring cycles.
  The Diagnostic Executive suspends OBD monitoring when battery voltage falls below 11.0 volts.
  The Diagnostic Executive suspends monitoring of fuel-system related monitors (catalyst, misfire, evap, O2, AIR and fuel system) when fuel level falls below 15%. For 2005 MY and beyond, the execution of the fuel related OBD monitors is no longer suspended for fuel level by the diagnostic executive.

The diagnostic executive controls the setting and clearing of pending and confirmed DTCs.

A pending DTC and freeze frame data is stored after a fault is confirmed on the first monitoring cycle. If the fault recurs on the next driving cycle, a confirmed DTC is stored, freeze frame data is updated, and the MIL is illuminated. If confirmed fault free on the next driving cycle, the pending DTC and freeze frame data is erased on the next power-up.
Pending DTCs will be displayed as long as the fault is present. Note that OBD-II regulations required a complete fault-free monitoring cycle to occur before erasing a pending DTC. In practice, this means that a pending DTC is erased on the next power-up after a fault-free monitoring cycle.
After a confirmed DTC is stored and the MIL has been illuminated, three consecutive confirmed fault-free monitoring cycles must occur before the MIL can be extinguished on the next (fourth) power-up. After 40 engine warm-ups, the DTC and freeze frame data is erased.

The diagnostic executive controls the setting and clearing of permanent DTCs.

A permanent DTC is stored when a confirmed DTC is stored, the MIL has been illuminated, and there are not yet six permanent DTCs stored.

After a permanent DTC is stored, three consecutive confirmed fault-free monitoring cycles must occur before the permanent DTC can be erased.

After a permanent DTC is stored, one confirmed fault-free monitoring cycle must occur, following a DTC reset request, before the permanent DTC can be erased. For 2010MY and beyond ISO 14229 programs a driving cycle including the following criteria must also occur, following the DTC reset request, before a permanent DTC can be erased:

- Cumulative time since engine start is greater than or equal to 600 seconds;
- Cumulative vehicle operation at or above 25 miles per hour occurs for greater than or equal to 300 seconds (medium-duty vehicles with diesel engines certified on an engine dynamometer may use cumulative operation at or above 15% calculated load in lieu of at or above 25 miles per hour for purposes of this criteria); and
- Continuous vehicle operation at idle (i.e., accelerator pedal released by driver and vehicle speed less than or equal to one mile per hour) for greater than or equal to 30 seconds.

A permanent DTC can not be erased by a battery disconnect. Additionally, its confirmed DTC counterpart will be restored after completion of the system reset (battery reconnect).

Exponentially Weighted Moving Average

Exponentially Weighted Moving Averaging is a well-documented statistical data processing technique that is used to reduce the variability on an incoming stream of data. Use of EWMA does not affect the mean of the data; however, it does affect the distribution of the data. Use of EWMA serves to “filter out” data points that exhibit excessive and unusual variability and could otherwise erroneously light the MIL.

The simplified mathematical equation for EWMA implemented in software is as follows:

New Average = [New data point * “filter constant”] + [(1 - “filter constant”) * Old Average]

This equation produces an exponential response to a step-change in the input data. The "Filter Constant" determines the time constant of the response. A large filter constant (i.e. 0.90) means that 90% of the new data point is averaged in with 10% of the old average. This produces a very fast response to a step change. Conversely, a small filter constant (i.e. 0.10) means that only 10% of the new data point is averaged in with 90% of the old average. This produces a slower response to a step change.

When EWMA is applied to a monitor, the new data point is the result from the latest monitor evaluation. A new average is calculated each time the monitor is evaluated and stored in Non Volatile Memory (NVRAM). This normally occurs each driving cycle. The MIL is illuminated and a DTC is stored based on the New Average store in NVRAM.

In order to facilitate repair verification and DDV demonstration, 2 different filter constants are used. A “fast filter constant” is used after are erased and a “normal filter constant” is used for normal customer driving. The “fast filter” is used for 2 driving cycles after DTCs are erased, and then the “normal filter” is used. The “fast filter” allows for easy repair verification and monitor demonstration in 2 driving cycles, while the normal filter is used to allow up to 6 driving cycles, on average, to properly identify a malfunction and illuminate the MIL. This feature is called Fast Initial Response (FIR). The fast filter is always calibrated to 1.0 which means that the EWMA is effectively disabled because the new average is 100% of the new data point. Since the EWMA is effectively disabled, it takes twp driving cycles to set the MIL. The first driving cycle with a fault will set a pending DTC; the second driving cycle will set a confirmed code and illuminate the MIL. This feature is called Fast Initial Response (FIR). The fast filter is always calibrated to 1.0 which means that the EWMA is effectively disabled because the new average is 100% of the new data point. Since the EWMA is effectively disabled, it takes twp driving cycles to set the MIL. The first driving cycle with a fault will set a pending DTC; the second driving cycle will set a confirmed code and illuminate the MIL.

The other unique feature used with EWMA is called Step Change Logic (SCL). This logic detects an abrupt change from a no-fault condition to a fault condition. This is done by comparing the new data point to the EWMA old average. If the two points differ by more than a calibrated amount (i.e. the new data point is outside the normal distribution), it means that a catastrophic failure has occurred. The fast filter is then used in the same manner as for the FIR feature above. Since the EWMA is effectively disabled, it takes twp driving cycles to set the MIL. The first driving cycle with a fault will set a pending DTC; the second driving cycle will set a confirmed code and illuminate the MIL. The SCL becomes active after the 4th "normal" monitoring cycle to give the EWMA a chance to stabilize.

During "normal" EWMA operation, a slower filter constant is used. The "normal filer" allows the MIL to be illuminated in 1 to 6 driving cycles. A confirmed code is set and the MIL is illuminated as soon as the EWMA crosses the malfunction threshold. There is no pending DTC because EWMA uses a 1-trip MIL.

In order to relate filter constants to driving cycles for MIL illumination, filter constants must be converted to time constants. The mathematical relationship is described below:

Time constant = [(1 / filter constant) - 1] * evaluation period

The evaluation period is a driving cycle. The time constant is the time it takes to achieve 68% of a step-change to an input. Two time constants achieve 95% of a step change input.

EWMA Examples

EWMA with FIR and SCL has been incorporated in the IAF catalyst monitor, the Rear O2 response test and the EONV Evaporative system leak check monitor. There are 3 parameters that determine the MIL illumination characteristics.

"Fast" filter constant (0.9999), used for 2 driving cycles after DTCs are cleared (FIR) and for Step Change Logic (SCL)

"Normal" filter constant(typically 0.4), used for all subsequent, "normal" customer driving

Number of driving cycles to use fast filter after DTC clear (set to 2 driving cycles)

Several examples for a typical catalyst monitor calibration are shown in the tables below. The first example does not show SCL in order to better illustrate the EWMA calculation and the 1-trip MIL.

Monitor evaluation ("new data")	EWMA Filter Calculation, "normal" filter constant set to 0.4 Malfunction threshold = .75	Weighted Average ("new average")	Driving cycle number	Action/Comment
0.15	.15 * (0.4) + .15 * (1 - 0.4)	0.15		normal 120K system
1.0	1.0 * (0.4) + .15 * (1 - 0.4)	0.49	1	large failure occurs
1.0	1.0 * (0.4) + .49 * (1 - 0.4)	0.69	2	
1.0	1.0 * (0.4) + .69 * (1 - 0.4)	0.82	3	exceeds threshold, MIL on
1.0	1.0 * (0.4) + .82 * (1 - 0.4)	0.89	4	MIL on
0.8	0.8 * (0.4) + .15 * (1 - 0.4)	0.41	1	1.5 * threshold failure
0.8	0.8 * (0.4) + .41 * (1 - 0.4)	0.57	2	
0.8	0.8 * (0.4) + .57 * (1 - 0.4)	0.66	3	
0.8	0.8 * (0.4) + .66 * (1 - 0.4)	0.72	4	
0.8	0.8 * (0.4) + .72 * (1 - 0.4)	0.75	5	equals threshold, MIL on
0.8	0.8 * (0.4) + .75 * (1 - 0.4)	0.77	6	MIL on
0.8	0.8 * (0.99) + 0* (1 - 0.99)	0.8	1	1.5 * threshold failure after code clear, pending DTC
0.8	0.8 * (0.99) + .8 * (1 - 0.99)	0.8	2	MIL on (I/M Readiness set to "ready"

I/M Readiness

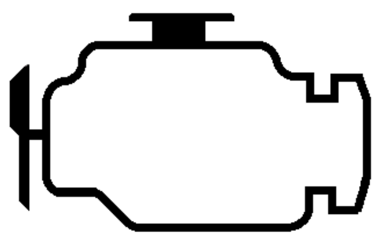
The readiness function is implemented based on the J1979 format. A battery disconnection or clearing codes using a scan tool results in the various I/M readiness bits being set to a "not-ready" condition. As each non-continuous monitor completes a full diagnostic check, the I/M readiness bit associated with that monitor is set to a "ready" condition. This may take one or two driving cycles based on whether malfunctions are detected or not. The readiness bits for comprehensive component monitoring, misfire and fuel system monitoring are immediately considered complete since they are continuous monitors.

Serial Data Link MIL Illumination

The OBD-II diagnostic communication messages utilize an industry standard 500 kbps CAN communication link.

The instrument cluster on some vehicles uses the same CAN data link to receive and display various types of information from the ECM. For example, the engine coolant temperature information displayed on the instrument cluster comes from the same ECT sensor used by the ECM for all its internal calculations.

These same vehicles use the CAN data link to illuminate the MIL rather than a circuit, hard-wired to the ECM. The ECM periodically sends the instrument cluster a message that tells it to turn on the MIL, turn off the MIL or blink the MIL. If the instrument cluster fails to receive a message within a 5-second timeout period, the instrument cluster itself illuminates the MIL. If communication is restored, the instrument cluster turns off the MIL after 5 seconds. Due to its limited capabilities, the instrument cluster does not generate or store Diagnostic Trouble Codes.



Closed Loop Fuel Control Enable Conditions

Closed loop fuel control is enabled (with a delay) at the start of a driving cycle and can be temporary inhibited (open loop) during the driving cycle. The turn-on delay at the start of a driving cycle is described by the following enable conditions:

- the upstream oxygen sensor is functional, i.e. the upstream HO2S' operating temperature has been reached
- a calibrated delay time, after end of engine start, has elapsed
- the engine coolant temperature (if used) must have exceeded a calibrated threshold or the modeled engine coolant temperature (substitute for a faulty temperature sensor minimum) must have exceeded a calibrated threshold after a calibrated period of time

Closed loop fuel operation is also inhibited during a driving cycle when any of the following conditions exist:

- During fuel cut-off or cylinder shut-off
- When catalyst over temperature protection is active.
- Full load enrichment active.
- When Catalyst purge is active.

Closed loop lambda control is inhibited during a driving cycle if any of the following errors exist:

- a catalyst damaging misfire rate
- Upstream HO2S sensor malfunction present

Calculated Load Value

LOAD_PCT (PID $04) =

$$\frac{\text{current airflow}}{\text{(peak airflow at WOT@STP as a function of rpm)} * \text{(BARO/29.92)} * \text{SQRT(298/(AAT+273))}}$$

Where: STP = Standard Temperature and Pressure = 25 °C, 29.92 in Hg BARO,
SQRT = square root,
WOT = wide open throttle,
AAT = Ambient Air Temperature and is in °C