ON-BOARD DIAGNOSTICS

S-Type Powertrain Management (Engine)

1999.25 to 2001 Model Years

1 Contents

2 Introduction

2.1 OBD-II Systems

California OBD-II applies to all gasoline engine vehicles up to 14,000 lbs. Gross Vehicle Weight Rating (GVWR) starting in the 1996 MY and all diesel engine vehicles up to 14,000 lbs. GVWR starting in the 1997 MY.

"Green States" are states in the Northeast that chose to adopt California emission regulations, starting in the 1998 MY. At this time, Massachusetts, New York, Vermont and Maine are Green States. Green States receive California-certified vehicles for passenger cars and light trucks up to 6,000 lbs. GVWR.

The National LEV program (NLEV) requires compliance with California OBD-II, including 0.020" evaporative system monitoring requirements. The NLEV program apply to passenger cars and light trucks up to 6,000 lbs. GVWR nation-wide from 2001 MY through 2003 MY

Federal OBD applies to all gasoline engine vehicles up to 8,500 lbs. GVWR starting in the 1996 MY and all diesel engine vehicles up to 8,500 lbs. GVWR starting in the 1997 MY.

OBD-II system implementation and operation is described in the remainder of this document.

2.2 Powertrain Management

All powertrain and associated management functions are controlled form a single unit, the powertrain control module (PCM). These functions are as follows:

- Overall monitoring and control of performance, fuel economy, emissions, driveability and safety.
- Receives and processes direct inputs from engine, transmission, fuel system and ancillary system sensors
- Provides direct control of actuator devices.
- Communicates with other modules via the SCP bus (e.g. to obtain wheel speed information).
- Provides system diagnostics to conform to OBDII requirements.

The basic PCM is common to the V6 and V8 engines but with unique programming to suit the respective engine characteristics and some differences in the interface circuits for the different sensors and actuators.

The PCM is located below the Left or right mounted A/C evaporator/blower unit And has a single connector panel which protrudes through the forward bulkhead into the engine bay.

The PCM has three connectors:

- A 60 pin connector which provides the interface with the engine wiring harness and carries the engine mounted sensor inputs and output control signals.
- A 32 pin connector which carries the transmission sensing and control signals and also the rear HO2 sensor inputs.
- A 58 pin connector which carries non engine mounted sensor and actuator signals and provides the PCM link to the SCP bus.

2.3 Inputs and Outputs

Inputs and outputs are directed to and from the PCM through hard-wired connections and the SCP (Serial Communication) data bus contained in the engine management harness.

PCM Pin Connections

FH001

Pin	Circuit	Pin	Circuit	Pin	Circuit
001	APP2 Signal	021	Gear Selector State	041	D-4 J-Gate Switch
002	)	022	Throttle Motor Control Relay Activate	042	A/C Pressure Sensor Signal
003	SCP +ve	023	APP1 Reference Voltage	043	Ground Supply
004	SCP –ve	024	Ground Supply	044	Battery Power Supply
005	APP1 Reference Ground	025	Ground Supply	045	)
006	EVAP Canister Close Valve Activate	026	Ground Supply	046	)
007	Gear Selector State	027	Ground Supply	047	Air Bag Deployment Signal
008	Gear Selector State	028	Brake Cancel Switch Input	048	)
009	A/C Compressor Clutch Relay Activate	029	)	049	Serial Communications Line
010	APP3 Reference Ground	030	)	050	)
011	)	031	MAF Sensor Ground	051	IAT Sensor Signal
012	EVAP Canister Purge Valve Activate	032	Ignition Switched Power	052	FTP Sensor Signal
013	PCM Programming Line	033	Ignition Switched Power	053	)
014	)	034	)	054	)
015	APP1 Signal	035	)	055	APP3 Sensor Reference Voltage
016	APP3 Signal	036	Cooling Fan Activate	056	Cruise Control Switch Pack Reference ground
017	IAT, FTP, APP2 Sensor Common Reference Ground	037	PSP switch Input	057	Cruise Control Switch Pack Mode Request
018	)	038	MAF Sensor Reference Ground	058	Fuel Pump Control Signal
019	)	039	)	041	D-4 J-Gate Switch
020	APP2, FTP, A/C Pressure Sensors Common Reference Voltage	040	Brake On/Off Signal	042	A/C Pressure Sensor Signal

GB001

Pin	Circuit	Pin	Circuit	Pin	Circuit
001	Shift Solenoid 'A' Control	012	Pressure Regulator 2 Control Drive	023	Fluid Temperature Sensor feedback
002	Shift Solenoid 'B' Control	013	Pressure Regulator 3 Control Drive	024	)
003	Shift Solenoid 'C' Control	014		025	)
004	Shift Solenoid 'D' Control	015	HO2 Sensor Heater, Bank 2 Downstream Control	026	Output Speed Sensor Signal
005	TCC Solenoid Valve Control Drive	016	HO2 Sensor Heater, Bank 1 Downstream Control	027	Turbine Speed Sensor Signal
006	)	017	Sensor Signal Ground	028	HO2 Sensor Bank 1 Downstream
007	Pressure Regulator 1 Control Drive	018	Transmission Range 2	029	HO2 Sensor Bank 2 Downstream
008	)	019	)	030	Pressure Switch Input
009	Transmission Range 3A	020	)	031	
010	Transmission Range 4	021	Intermediate Speed Sensor Signal	032	
011	)	022	Transmission range 1		

PI001

Pin	Circuit	Pin	Circuit	Pin	Circuit
001	Ignition Coil 2 Bank 1, Activate (V8)	021	Injector 3 Bank 2 Activate	041	)
002	Injector 1 Bank 1, Activate	022	Ignition Coil 2 Bank 2, Activate	042	Knock Sensor 1 Ground
003	)	023	Ignition Coil 2 Bank 1, Activate (V8) Ignition Coil 1 Bank 1, Activate (V6)	043	Knock Sensor 2 Ground
004	)	024	Injector 3 Bank 1 Activate	044	HO2 Sensor, Bank 1 Upstream
005	Generator Warning	025	Actual Throttle Angle	045	HO2 Sensor, Bank 2 Upstream
006	)	026	)	046	ECT Sensor Signal (V8)
007	HO2 Sensor Heater, Bank 2 Upstream control	027	)	047	EFT Sensor Signal
008	HO2 Sensor Heater, Bank 1 Upstream Control	028	)	048	TP Sensor Reference Voltage
009	Air Assist Injection Control	029	Injector 3 Bank 2 Activate (V8) IMT Bottom Valve Activate (V6)	049	IP Sensor Signal
010	Variable Valve Timing, Bank 1 Control	030	Ignition Coil 3 Bank 2, Activate	050	Generator Load Signal
011	Injector 2 Bank 2, Activate	031	Ignition Coil 1 Bank 1, Activate	051	Knock Sensor 1 Signal
012	Ignition Coil 1 Bank 2, Activate	032	Injector 4 Bank 1 Activate (V8) Injector 1 Bank 2 Activate (v6)	052	Knock Sensor 2 Signal
013	Ignition Coil 3 Bank 1, Activate	033	Variable Valve Timing, Bank 2 Control	053	CMP Sensor 1 Signal
014	Injector 2 Bank 1 Activate	034	)	054	CMP Sensor 2 Signal
015	TP Sensor Signal Ground	035	)	055	CKP Sensor Signal
016	)	036	)	056	CKP Sensor Ground
017	Sensor Signal Common Ground	037	Injector 4 Bank 2 Activate (V8) IMT Top Valve Activate (V6)	057	TP1 Sensor Signal
018	Throttle Motor Control Signal	038	Ignition Coil4 Bank 2, Activate	058	TP3 Sensor Signal
019	Throttle Motor Control Signal	039	EOT Sensor Signal	059	TP2 Sensor Signal
020	IP, TP Sensor Common reference Voltage	040	CHT Sensor Signal (V6)	060	)

3 Mode $06 Data

SAE J1979 Mode $06 Data			
Test ID	**Comp ID**	**Description**	**Units**
$01	$11	HO2S11 voltage amplitude and voltage threshold	Volts
$01	$21	HO2S21 voltage amplitude and voltage threshold	Volts
$03	$01	Upstream O2 sensor switch-point voltage	Volts
$03	$02	Downstream O2 sensor switch-point voltage	Volts
Conversion for Test IDs $01 through $03: multiply by 0.00098 to get volts			
$10	$11	Bank 1 switch-ratio and maximum limit	None
$10	$21	Bank 2 switch-ratio and maximum limit	None
$10	$10	Bank 1 index-ratio and maximum limit	None
$10	$20	Bank 2 index-ratio and maximum limit	None
Conversion for Test ID $10: multiply by 0.0156 to get a value from 0 to 1.0			
$26	$00	Phase 0 Initial tank vacuum and minimum limit	in H_20
$26	$00	Phase 0 Initial tank vacuum and maximum limit	in H_20
$27	$00	Phase 2 0.040" cruise leak check vacuum bleed-up and maximum 0.040" leak threshold	in H_20
$28	$00	Phase 2 0.020" cruise leak check vacuum bleed-up and max leak threshold	in H_20
$2A	$00	Phase 4 Vapor generation maximum change in pressure and max threshold	in H_20
$2B	$00	Phase 4 Vapor generation maximum absolute pressure rise and max threshold	in H_20
$2C	$00	Phase 2 0.020" idle leak check vacuum bleed-up and maximum "leak" threshold	in H_20
$2D	$00	Phase 2 0.020" idle leak check vacuum bleed-up and max "no-leak" threshold	in H_20
Conversion for Test IDs $26 through $2D: Take value, subtract 32,768, and then multiply result by 0.00195 to get inches of H20. The result can be positive or negative. Note: Default values (-64 in H_20) will be display for all the above TIDs if the EVAP monitor has never completed. If all or some phases of the monitor have completed on the current or last driving cycle, default values will be displayed for any phases that had not completed.			
$30	$11	HO2S11 voltage for upstream flow test and rich limit	Volts
$30	$21	HO2S21 voltage for upstream flow test and rich limit	Volts
$31	$00	HO2S lean time for upstream flow test and time limit	Seconds
Conversion for Test ID $30: multiply by 0.00098 to get volts Conversion for Test ID $31: multiply by 0.125 to get seconds			

SAE J1979 Mode $06 Data - Cont'd

Test ID	Comp ID	Description	Units
$41	$11	Delta pressure for upstream hose test and threshold Replaced by TID $42 in new 2000MY software	in. H_20
$42	$11	Delta pressure for upstream hose test and threshold	in. H_20
$41	$12	Delta pressure for downstream hose test and threshold Replaced by TID $42 in new 2000MY software	in. H_20
$42	$12	Delta pressure for downstream hose test and threshold	in. H_20
Conversion for Test ID $41: If value is > 32,767, the value is negative. Take value, subtract 65,536, and then multiply result by 0.0078 to get inches of H_20. If value is <or= 32,767, the value is positive. Multiply by 0.0078 to get inches of H_2O Conversion for Test ID $42: Take value, subtract 32,768, and then multiply result by 0.0078 to get inches of H_20. The result can be positive or negative.			
$45	$20	Delta pressure for stuck open test and threshold	Volts
Conversion for Test ID $45: Multiply by 0.0156 to get A/D counts (0-1024) or 0.0000763 to get voltage			
$49	$30	Delta pressure for flow test and threshold	in. H_20
$4A	$30	Delta pressure for flow test and threshold TID 4A replaced by 49 in new 2000 MY software	in. H_20
$4B	$30	EVR duty cycle for flow test and threshold	Percent
Conversion for Test ID $4A: If value is > 32,767, the value is negative. Take value, subtract 65,536, and then multiply result by 0.0078 to get inches of H_20. If value is <or= 32,767, the value is positive. Multiply by 0.0078 to get inches of H_2O Conversion for Test ID $4B: multiply by 0.0000305 to get percent duty cycle. Conversion for Test ID $49: Take value, subtract 32,768, and then multiply result by 0.0078 to get inches of H_20. The result can be positive or negative.			
4E	31	Sum of MAP-delta and IMAP delta and maximum threshold	in Hg
4E	B1	Sum of MAP-delta and IMAP delta and minimum threshold	in Hg
4F	10	EGR-On MAP and max threshold	in Hg
Conversion for Test ID 4E and 4F: Take value and multiply result by 0.0078125 to get inches of Hg. The result is always positive.			
$50	$00	Total engine misfire and emission threshold misfire rate	Percent
$53	$00 - $0A	Cylinder-specific misfire and catalyst damage threshold misfire rate (200 revolution counters)	Percent
$54	$00	Highest catalyst-damage misfire and catalyst damage threshold misfire rate (200 revolution counter)	Percent
$55	$00	Highest emission-threshold misfire and emission threshold misfire rate (1000 revolution counter)	Percent
$56	$00	Cylinder events tested and number of events required for a 1000 rev test	Events
Conversion for Test IDs $50 through $55: multiply by 0.000015 to get percent Conversion for Test ID $56: multiply by 1 to get ignition events			

4 On-Board Monitoring

The vehicle drive train is continually monitored throughout its life to maintain its proper function and ensure that emission levels do not exceed accepted limits.

4.1 Catalyst Efficiency Monitor

The Catalyst Efficiency Monitor uses oxygen sensors (HO2S) upstream and downstream of the catalyst. The monitor is run during a standard Federal Test Procedure (FTP). Two slightly different versions of the catalyst monitor are used for 2001 MY and beyond vehicles. Both versions will continue to be used in subsequent model years.

Switch Ratio Method (1996 - 2002)

In order to assess catalyst oxygen storage, the monitor counts upstream and downstream HO2S switches during part-throttle, closed-loop fuel conditions after the engine is warmed-up and inferred catalyst temperature is within limits. Upstream switches are accumulated in up to nine different air mass regions or cells, although 3 air mass regions are typical. Downstream switches are counted in a single cell for all air mass regions. When the required number of upstream switches has accumulated in each cell (air mass region), the total number of downstream switches is divided by the total number of upstream switches to compute a switch ratio. A switch ratio near 0.0 indicates high oxygen storage capacity, hence high HC efficiency. A switch ratio near 1.0 indicates low oxygen storage capacity and hence low HC efficiency. If the actual switch ratio exceeds the threshold switch ratio, the catalyst is considered failed.

Index Ratio Method (some 2001 and beyond)

In order to assess catalyst oxygen storage, the catalyst monitor counts upstream HO2S switches during part-throttle, closed-loop fuel conditions after the engine is warmed-up and inferred catalyst temperature is within limits. Upstream switches are accumulated in up to three different air mass regions or cells. While catalyst monitoring entry conditions are being met, the upstream and downstream HO2S signal lengths are continually being calculated. When the required number of upstream switches has accumulated in each cell (air mass region), the total signal length of the downstream HO2S is divided by the total signal length of upstream HO2S to compute a catalyst index ratio. An index ratio near 0.0 indicates high oxygen storage capacity, hence high HC efficiency. A switch ratio near 1.0 indicates low oxygen storage capacity and hence low HC efficiency. If the actual index ratio exceeds the threshold index ratio, the catalyst is considered failed.

General Catalyst Monitor Operation

If the catalyst monitor does not complete during a particular driving cycle, the already-accumulated switch/signal-length data is retained in Keep Alive Memory (KAM) and is used during the next driving cycle to allow the catalyst monitor a better opportunity to complete, even under short or transient driving conditions. Downstream 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 downstream HO2S sensor is used along with the upstream, 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 under body catalyst. These systems are referred to as Y-pipe systems, and have one downstream HO2S sensor and two upstream, fuel-control HO2S sensors. In Y-pipe systems, the two upstream HO2S sensor signals are combined by the software to infer what the HO2S signal would be upstream of the monitored catalyst. The inferred upstream HO2S signal and the actual single, downstream HO2S signal are then used to calculate the switch ratio.

Most vehicles that are part of the “LEV” catalyst monitor phase-in will 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 ULEV vehicles in order to meet the 1.75 * emission-standard. 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 downstream 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.)

Index ratios for ethanol (Flex fuel) vehicles vary based on the changing concentration of alcohol in the fuel. The malfunction threshold typically increases as the percent alcohol increases. For example, a malfunction threshold of 0.5 may be used at E10 (10% ethanol) and 0.9 may be used at E85 (85% ethanol). The malfunction thresholds are therefore adjusted based on the % alcohol in the fuel. (Note: Normal gasoline is allowed to contain up to 10% ethanol (E10)).

All vehicles employ an Exponentially Weighted Moving Average (EWMA) algorithm to improve the robustness of the FTP catalyst monitor. During normal customer driving, a malfunction will illuminate the MIL, on average, in 3 to 6 driving cycles. If KAM is reset (battery disconnected), a malfunction will illuminate the MIL in 2 driving cycles

Catalyst Monitor Operation

Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
	P0420 (Bank 1)	HC efficiency inferred from oxygen storage capacity.	Rear/ front HO2S switch ratio.	>0. 65 (unitless)	Time since cold engine start.	301 sec if ECT at start < 55 ºF.	Once per driving cycle.	See note g
	P0430 (Bank 2)			0. 65 (unitless)	Time since mid-ambient engine start.	220 sec if ECT at start is between 55 and 215 ºF.	Approximately 660 sec during appropriate FTP conditions.	
					Time since hot engine start.	105 sec if ECT at start > 215 ºF.		
					Engine coolant temperature and ECT sensor OK (P0117/ 0118);	150 – 230 ºF.		

Catalyst Monitor Operation – Cont'd								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
					Intake air temperature and IAT sensor OK (P0112/ 0113)	20 – 180 ºF.		
					Inferred mid bed catalyst temperature;	750 – 1275 ºF.		
					Minimum time since going closed loop and no HO2S monitor DTCs;	7.5 sec.		
					Engine load and MAF sensor OK (P0102/ 0103);	20 %		
					Relative throttle position and TP sensor OK (P0122/ 0123);	9 counts		
					Time since leaving closed throttle;	1 sec		
					Maximum throttle position rate of change;	< 30 counts / sec		
					Crankshaft position circuit (PIP) OK (P0320), HO2S monitor COMPLETE with no DTCs prior to final switch ratio computation;			

Catalyst Monitor Operation – Cont'd

Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
				Air mass range cell 1	0 - 2.0301 lb/ min	Hego 1 switch range: 0- 0		
				Air mass range cell 2	2.03 - 2.701 lb/ min	Hego 1 switch range: 0- 70		
				Air mass range cell 3	2.7 - 3.31 lb/ min	Hego 1 switch range: 0- 50		
				Air mass range cell 4	3.3 - 16 lb/ min	Hego 1 switch range: 0- 0		
				Air mass range cell 5	N/A	N/A		
				Air mass range cell 1	0 - 2.0301 lb/ min	Hego 2 switch range: 0- 0		
				Air mass range cell 2	2.03 - 2.701 lb/ min	Hego 2 switch range: 0- 70		
				Air mass range cell 3	2.7 - 3.31 lb/ min	Hego 2 switch range: 0- 50		
				Air mass range cell 4	3.3 - 16 lb/ min	Hego 2 switch range: 0- 0		
				Air mass range cell 5	N/A	N/A		
					Vehicle speed and VSS sensor OK (P0500);	20 -78 mph		
					Crankshaft position circuit (PIP) OK (P0320), HO2S monitor complete with no DTCs prior to final switch ratio computation, EVAP system OK, no EVAP system DTCs;			

Catalyst Monitor Operation – Cont'd

Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
				EWMA	EWMA "fast" filter constant for first 4 driving cycles after KAM cleared; EWMA "normal" filter constant after first 2 driving cycles.	0.9 unitless 0.5 unitless		

4.2 Misfire Monitor

The misfire monitoring technology used in the S-Type is a High Data Rate (HDR) system. This system is capable of meeting "full-range" misfire monitoring requirements on 6 and 8 cylinder engines. 2002 MY software has been modified to allow for detection of any misfires that occur 6 engine revolutions after initially cranking the engine. This meets the new OBD-II requirement to identify misfires within 2 engine revolutions after exceeding the warm drive, idle rpm.

The HDR Misfire Monitor uses a high data rate crankshaft position signal, (i.e. 18 position references per crankshaft revolution. This high-resolution signal is processed using two different algorithms. The first algorithm, called pattern cancellation, is optimised to detect low rates of misfire. The algorithm learns the normal pattern of cylinder accelerations from the mostly good firing events and is then able to accurately detect deviations from that pattern. The second algorithm is optimised to detect "hard" misfires, i.e. one or more continuously misfiring cylinders. This algorithm filters the high-resolution crankshaft velocity signal to remove some of the crankshaft torsional vibrations that degrade signal to noise. This significantly improves detection capability for continuous misfires. Both algorithms produce a deviant cylinder acceleration value, which is used in evaluating misfire. SEE *Generic Misfire Algorithm Processing.*

Due to the high data processing requirements, the HDR algorithms could not be implemented in the PCM microprocessor. They are implemented in a separate chip in the PCM called an "AICE" chip. The PCM microprocessor communicates with the AICE chip using a dedicated serial communication link. The output of the AICE chip (the cylinder acceleration values) is sent to the PCM microprocessor for additional processing as described below. Lack of serial communication between the AICE chip and the PCM microprocessor, or an inability to synchronize the crank or cam sensors inputs sets a P1309 DTC. For new 2002 MY software, the P1309 DTC is being split into two separate DTCs. A P0606 will be set if there is a lack of serial communication between the AICE chip and the PCM microprocessor. A P1336 will be set if there is an inability to synchronize the crank or cam sensors inputs. This change was made to improve serviceability. A P0606 generally results in PCM replacement while a P1336 points to a cam sensor that is out of synchronization with the crank.

"Profile correction" software is used to "learn" and correct for mechanical inaccuracies in crankshaft tooth spacing under de-fuelled engine conditions (requires three 60 to 40 mph no-braking decelerations after Keep Alive Memory has been reset). If KAM has been reset, the PCM microprocessor initiates a special routine which computes correction factors for each of the 18 (or 20) position references and sends these correction factors back to the AICE chip to be used for subsequent misfire signal processing. These learned corrections improve the high rpm capability of the monitor. The misfire monitor is not active until a profile has been learned.

4.2.1 Generic Misfire Algorithm Processing

The acceleration that a piston undergoes during a normal firing event is directly related to the amount of torque that cylinder produces. The calculated piston/cylinder acceleration value(s) are compared to a misfire threshold that is continuously adjusted based on inferred engine torque. Deviant accelerations exceeding the threshold are conditionally labelled as misfires.

The calculated deviant acceleration value(s) are also evaluated for noise. Normally, misfire results in a non-symmetrical loss of cylinder acceleration. Mechanical noise, such as rough roads or high rpm/light load conditions, will produce symmetrical acceleration variations. Cylinder events that indicate excessive deviant accelerations of this type are considered noise. Noise-free deviant acceleration exceeding a given threshold is labelled a misfire.

The number of misfires is counted over a continuous 200-revolution and 1000 revolution period. (The revolution counters are not reset if the misfire monitor is temporarily disabled such as for negative torque mode, etc.) At the end of the evaluation period, the total misfire rate and the misfire rate for each individual cylinder is computed. The misfire rate evaluated every 200-revolution period (Type A) and compared to a threshold value obtained from an engine speed/load table. This misfire threshold is designed to prevent damage to the catalyst due to sustained excessive temperature (1600°F for Pt/Pd/Rh conventional wash coat, 1650°F for Pt/Pd/Rh advanced wash coat and 1800°F for Pd-only high tech wash coat). If the misfire threshold is exceeded and the catalyst temperature model calculates a catalyst mid-bed temperature that exceeds the catalyst damage threshold, the MIL blinks at a 1 Hz rate while the misfire is present. If the threshold is again exceeded on a subsequent driving cycle, the MIL is illuminated. If a single cylinder is indicated to be consistently misfiring in excess of the catalyst damage criteria, the fuel injector to that cylinder may be shut off for a period of time to prevent catalyst damage. Up to two cylinders may be disabled at the same time. This fuel shut-off feature is used on many 8-cylinder engine and some 6-cylinder engines. It is never used on a 4-cylinder engine. Next, the misfire rate is evaluated every 1000 rev period and compared to a single (Type B) threshold value to indicate an emission-threshold malfunction, which can be either a single 1000 rev exceedence from start-up or four subsequent 1000 rev exceedences on a drive cycle after start-up. Some 2002 MY vehicles will set a P0316 DTC if the Type B malfunction threshold is exceeded during the first 1,000 revs after engine start-up. This DTC is stored in addition to the normal P03xx DTC that indicates the misfiring cylinder(s).

4.2.2 Profile Correction

"Profile correction" software is used to "learn" and correct for mechanical inaccuracies in the crankshaft position wheel tooth spacing. Since the sum of all the angles between crankshaft teeth must equal 360°, a correction factor can be calculated for each misfire sample interval that makes all the angles between individual teeth equal. To prevent any fuelling or combustion differences from affecting the correction factors, learning is done during decel-fuel cutout.

The correction factors are learned during closed-throttle, non-braking, de-fuelled decelerations in the 60 to 40 mph range after exceeding 60 mph (likely to correspond to a freeway exit condition). In order to minimize the learning time for the correction factors, a more aggressive decel-fuel cutout strategy may be employed when the conditions for learning are present. The corrections are typically learned in a single deceleration, but can be learned during up to 3 such decelerations. The "mature" correction factors are the average of a selected number of samples. A low data rate misfire system will typically learn 4 such corrections in this interval, while a high data rate system will learn 36 or 40 in the same interval (data is actually processed in the AICE chip). In order to assure the accuracy of these corrections, a tolerance is placed on the incoming values such that an individual correction factor must be repeatable within the tolerance during learning. This is to reduce the possibility of learning corrections on rough road conditions, which could limit misfire detection capability.

Since inaccuracies in the wheel tooth spacing can produce a false indication of misfire, the misfire monitor is not active until the corrections are learned. In the event of battery disconnection or loss of Keep Alive Memory the correction factors are lost and must be relearned. If the software is unable to learn a profile after 254 attempts, a P0315 DTC is set.

Misfire Monitor Operation								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Cylinder Misfire Detected	P0300 to P0308	Deviations in crankshaft acceleration, processed by High Data Rate chip.	Percentage misfire required to exceed 1700 ºF catalyst damage threshold	Type A: 97 % See table FNMISPCT_97 below			200 revs (Continuous)	See note d
			Percentage misfire required to exceed emission thresholds	Type B: 2.3%			1000 revs (Continuous)	See note e
			Percentage misfire required to clear emission pending code	< .1%				
			FTP misfire range 2750 rpm		Time since engine start, value based on time, ECT and IAT;	(0 + FNMISACT + FNMISECT) seconds. See tables below		
					ECT;	20 - 250 ºF		
					Engine rpm;	500 - 2750 rpm		
					Net engine torque;	>- 25 lb/ ft		
					Closed throttle deceleration (dashpot mode)			
					Cylinder events not counted after noise detected (symmetrical accels/ decals caused by rough road, etc.);	15 events		

Misfire Monitor Operation _Cont'd

Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
					Engine rpm/ load range;	See table FNMISOK_ 97, below monitor disabled when < 0.1		
					Crankshaft position circuit (PIP) OK (P0320);			
					Accessory load state change (A/ C, P/ S);	No accessory state change occurring		
					Fuel shutoff for rpm or vehicle speed limiting	No fuel cutoff occurring		
AICE chip failure	P1309	AICE chip failure to reinitialize	Number of attempts	254 attempts	None	N/ A	N/ A	See note c

Threshold misfire percent/200 revolutions - FNMISPCT_97

Engine Load %	**Engine Speed RPM**									
	600	**650**	**950**	**1250**	**1500**	**1750**	**2000**	**2250**	**2500**	**2750**
80	14.0	13.0	10.0	5.0	3.0	2.7	2.5	2.5	2.0	2.5
70	18.0	17.0	17.0	10.0	10.0	9.0	8.0	2.5	2.0	2.5
60	18.0	17.0	17.0	14.0	12.0	12.0	12.0	5.0	3.5	3.0
50	18.0	17.0	17.0	17.0	14.0	14.0	14.0	10.0	8.0	6.0
40	20.0	20.0	20.0	18.0	17.0	15.0	14.0	15.0	11.0	10.0
30	28.0	26.0	21.0	20.0	19.0	18.0	17.0	15.0	13.0	12.0
20	34.0	34.0	26.0	21.0	20.0	20.0	20.0	15.0	14.0	14.0
10	34.0	34.0	26.0	20.0	20.0	25.0	20.0	15.0	15.0	15.0

Air charge temperature function

FNMISACT - ºF	-20	-10	0	20	120	178	188	240
Time - s	180	180	0	0	0	0	180	180

Engine coolant temperature function						
FNMISECT - ºF	-20	-10	20	70	210	250
Time - s	180	180	0	0	0	0

Monitor disablement function - FNMISOK_97										
Engine Load %	**Engine Speed RPM**									
	600	**650**	**950**	**1250**	**1500**	**1750**	**2000**	**2250**	**2500**	**2750**
80	0	0	0	0	0	0	0.1	0.1	0.1	0
70	0	0	0	0.1	0.15	0.15	0.15	0.13	0.2	0
60	0	0	0.1	0.1	0.5	0.5	0.5	1	0.8	0.15
50	0	0	0.4	0.1	0.5	1	1	1	1	0.15
40	0	0.15	0.15	1	1	1	1	1	1	0.15
30	0.3	0.15	1	1	1	1	1	1	1	0.15
20	1	1	1	1	1	1	0.2	0.15	0.05	0.05
10	0.1	0.1	0.1	0.1	0.1	0	0	0	0	0

4.3 HO2S Monitor

Front HO2S Signal

The time between HO2S switches is monitored after vehicle start-up and during closed loop fuel conditions. Excessive time between switches or no switches since start-up indicate a malfunction. Since “lack of switching” malfunctions can be caused by HO2S sensor malfunctions or by shifts in the fuel system, DTCs are stored that provide additional information for the “lack of switching” malfunction. Different DTCs indicate whether the sensor was always indicates lean/disconnected (P1131 P1151), always indicates rich (P1132 P1152), or stopped switching due to excessive long term fuel trim corrections (P1130 P1150, Note: these DTCs are being phased out of production). Most 2002 MY vehicles will no longer require part throttle operation to run the lack of switching test – lack of switching codes may be set at idle.

The HO2S is also tested functionally. The response rate is evaluated by entering a special 1.5 Hz. square wave, fuel control routine. This routine drives the air/fuel ratio around stoichiometry at a calibrated frequency and magnitude, producing predictable oxygen sensor signal amplitude. A slow sensor will show reduced amplitude. Oxygen sensor signal amplitude below a minimum threshold indicates a slow sensor malfunction. (P0133 Bank 1, P0153 Bank 2). If the calibrated frequency was not obtained while running the test because of excessive purge vapors, etc., the test will be run again until the correct frequency is obtained.

Rear HO2S Signal

A functional test of the rear HO2S sensors is done during normal vehicle operation. The peak rich and lean voltages are continuously monitored. Voltages that exceed the calibrated rich and lean thresholds indicate a functional sensor. If the voltages have not exceeded the thresholds after a long period of vehicle operation, the air/fuel ratio may be forced rich or lean in an attempt to get the rear sensor to switch. This situation normally occurs only with a green catalyst (< 500 miles). If the sensor does not exceed the rich and lean peak thresholds, a malfunction is indicated. Most 2002 MY vehicle will monitor the rear HO2S signal for high voltage, in excess of 1.5 volts and store a unique DTC. (P0138, P0158). An over voltage condition is caused by a HO2S heater or battery power short to the HO2S signal line.

HO2S Monitor Operation								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Lack of front HO2S switch, long-term fuel trim at limit.			**Stage 1:** **(Look for disconnected HO2S at startup)**					
- Bank 1	P1130	Lack of HO2S switches			Relative throttle position and TP sensor OK (P0122/ 0123);	12 counts	Continuous	See Note c
- Bank 2	P1150		Cumulative time in test mode since start up; Number of switches since start up	>30 sec < 4	Idle state; Engine load and MAF sensor OK (P0102/ 0103).	Off idle (not idle rpm, part throttle, vehicle moving) 0.18 to 0.6%		
			Stage 2: **(Look for expected switching)** Time since last switch	>60sec	Time since engine start up: Time entry conditions have been present:	>150sec >15sec		
			Stage 3: **(Determine how/why switching stopped)** Time since last switch while at short term fuel trim limit: Long term fuel trim:	>5 sec after CDS sec At limit	Inferred exhaust temp: Fuel control (stages 2 and 3 only:	>700 ºF Closed loop		

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HO2S Monitor Operation – Cont'd

Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Lack of front HO2S switch, sensor indicates lean			**Stage 1: (Look for disconnected HO2S at startup)**					
0.	P1131	Lack of HO2S switches			Relative throttle position and TP sensor OK (P0122/ 0123);	12 counts	Continuous	See Note c
- Bank 2	P1151		Cumulative time in test mode since start up;	>30 sec	Idle state;	Off idle (not idle rpm, part throttle, vehicle moving)		
			Number of switches since start up	< 4				
					Engine load and MAF sensor OK (P0102/ 0103).	0.18 to 0.6%		
			Stage 2: (Look for expected switching)					
			Time since last switch	>60sec	Time since engine start up:	>150sec		
					Time entry conditions have been present:	>15sec		
			Stage 3: (Determine how/why switching stopped)					
			Time since last switch while at short term fuel trim limit:	>5 sec after CDS sec	Inferred exhaust temp:	>700 ºF		
					Fuel control (stages 2 and 3 only:	Closed loop		
			HO2S signal	Indicates lean				

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HO2S Monitor Operation _ Cont'd								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Lack of front HO2S switch, sensor indicates rich			**Stage 1:** **(Look for disconnected HO2S at startup)**					
0. Bank 1	P1132	Lack of HO2S switches			Relative throttle position and TP sensor OK (P0122/ 0123);	12 counts	Continuous	See Note c
- Bank 2	P1155		Cumulative time in test mode since start up;	>30 sec	Idle state;	Off idle (not idle rpm, part throttle, vehicle moving)		
			Number of switches since start up	< 4				
					Engine load and MAF sensor OK (P0102/ 0103).	0.18 to 0.6%		
			Stage 2: **(Look for expected switching)**					
			Time since last switch	>60sec	Time since engine start up:	>150sec		
					Time entry conditions have been present:	>15sec		
			Stage 3: **(Determine how/why switching stopped)**					
			Time since last switch while at short term fuel trim limit:	>5 sec after CDS sec	Inferred exhaust temp: Fuel control (stages 2 and 3 only:	>700 ºF Closed loop		
			HO2S signal	Indicates rich				

HO2S Monitor Operation _ Cont'd								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Front HO2S circuit slow response -Bank 1 -Bank 2	P0133 P0153	Monitor HO2S switching frequency and amplitude (forced at 1.684Hz fixed rate)	Switching frequency (indicates gross failure):	< 0.1Hz	Time since entering closed loop fuel control:	> 10 sec		
			Switching frequency difference from desired (test run at correct frequency);	< 0.184Hz	Short term fuel trim:	95 – 105%		
			Signal voltage amplitude	< 0.45Hz	Engine coolant temperature and ECT sensor OK (P0117/P0118):	150 – 240 ºF		
					Intake air temperature and IAT sensor OK (P0112/P0113):	< 150 ºF		
					Engine Load and MAF sensor OK (P0102/p0103):	18 – 58 %		
					Vehicle speed and VSS sensor OK (P0500):	33 – 80 mph		
					Engine RPM and CPS circuit (PIP) OK (P0320):	1150 – 2500 rpm		
					TPS OK (P0122/P0123):			
					Camshaft Id (CID) circuit OK (P0340):			
					No misfire monitor DTCs:			
					Fuel rail pressure sensor OK (P0190/P0192/P0193):			
					"lack of HO2s switching" tests have had sufficient time to run:			
					No fuel monitor DTCs			

HO2S Monitor Operation – Cont'd

Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Rear HO2s circuit malfunction 300 Bank 1 - Bank 2	P0136 P0135	Monitor normal signal voltage envelope; forced A/F excursion if required for green catalyst (rationality check)	HO2S minimum and maximum signal voltages.	Rich - < .495v Lean - > .405v	Inferred exhaust temperature: Downstream heater on time: Throttle position: Engine rpm – for forced excursion only: Inferred exhaust temperature:	300 – 1400 ºF [illegible] 0 s Part throttle [illegible] 000 rpm < 1500 ºF	Continuous	See Note c

HO2S Heater Monitor Operation

Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
HO2S heater circuit malfunction		Circuit continuity check, monitor voltage for opens and shorts	Feedback circuit state matches commanded output state (digital signal):	Feedback circuit high or low	Inferred sensor temperature	300 – 1400 ºF	Continuous	See Note c
300 Bank 1; front - Bank 2; front	P0135 P0155		Monitor retries allowed for malfunction (background loops)	30	Heater on time	> 60s		
		Functional check, monitor minimum and maximum heater current	Heater circuit current	0.525> A > 3	Inferred sensor temperature	300 – 1400 ºF	Once per drive cycle	See Note c

HO2S Heater Monitor Operation - Cont'd								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
- Bank 1; rear - Bank 2; rear	P0141 P0161	Circuit continuity check, monitor voltage for opens and shorts	Feedback circuit state matches commanded output state (digital signal):	Feedback circuit high or low	Inferred sensor temperature	300 – 1400 ºF	Continuous	See Note c
			Monitor retries allowed for malfunction (background loops)	30	Heater on time	> 60s		
		Functional check, monitor minimum and maximum heater current	Heater circuit current	0.525> A > 3	Inferred sensor temperature	300 – 1400 ºF	Once per drive cycle	See Note c

4.4 Fuel System Monitor

As fuel system 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. These learned corrections are stored in Keep Alive Memory as long term fuel trim corrections. They may be stored into an 8x10 rpm/load table or they may be stored as a function of air mass. As components continue to change beyond normal limits or if a malfunction occurs, the long-term fuel trim values will reach a calibrated 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 calibrated deviation in short term fuel trim, indicate a rich or lean fuel system malfunction.

Fuel System Monitor								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Fuel System Lean/ Rich								
- Bank 1 lean	P0171	Excessive long and short term fuel trim corrections	Filtered long-term fuel trim exceeds limits.	< 61 or >135 %	Engine R. P. M.	575 - 5000 rpm	Continuous	See Note e
- Bank 1 rich	P0172	*Note: Long term fuel trim corrections are learned into an 8x1 cell table as a function of rpm and air mass*	Short-term fuel trim exceeds limits.	< > 100%	Engine air mass	0 - 12lb/ min		
- Bank 2 lean	P0174				Closed loop fuel, adaptive fuel learning enabled (purge duty cycle = 0%)	Fuel trim learning enabled		
- Bank 2 rich	P0175							

4.5 Evaporation System Monitor

4.5.3 Evaporative Emissions System Monitor – 0.040 inch Diameter Leak Check

Vehicles that meet enhanced evaporative requirements utilize a vacuum-based evaporative system (EVAP) integrity check. The EVAP integrity check uses a Fuel Tank Pressure Transducer (FTPT), a Canister Vent Solenoid (CVS) and Fuel Level Input (FLI) along with the Vapor Management Valve (VMV) to find 0.040" diameter or larger leaks.

The EVAP system integrity test is done under conditions that minimize vapor generation and fuel tank pressure changes due to fuel slosh since these could result in false MIL illumination. The check is run after a 6-hour cold engine soak (engine-off timer), during steady highway speeds at ambient air temperatures (inferred by IAT) between 40 and 100 ^{o}F.

A check for refuelling events is done at engine start. A refuel flag is set in the Keep Alive Memory (KAM) if the fuel level at start-up is at least 20% greater than fuel fill at engine-off. It stays set until the EVAP monitor completes Phase 0 of the test as described below.
The EVAP system integrity test is done in four phases.

4.5.1 Phase 0 - Initial Vacuum Pull Down

First, the Canister Vent Solenoid is closed to seal the entire EVAP system, then the VMV is opened to pull a 7Inch Hg vacuum. If the initial vacuum can not be achieved, a large system leak is indicated (P0455). This could be caused by a fuel cap that was not installed properly, a large hole, an overfilled fuel tank, disconnected or kinked vapor lines, a Canister Vent Solenoid that is stuck open or a VMV that is stuck closed.
If the initial vacuum cannot be achieved after a refuelling event, a gross leak, fuel cap off (P0457) is indicated and the recorded minimum fuel tank pressure during pull down is stored in KAM. A "Check Fuel Cap" light may also be illuminated.

If the initial vacuum cannot be achieved and the purge vapor flow is small, a gross leak, no purge flow condition is indicated (P1443). This could be caused by a VMV that is stuck closed, or a disconnected/blocked vapor line between the VMV and the FTPT.

If the initial vacuum is excessive, a vacuum malfunction is indicated (P1450). This could be caused by kinked vapor lines or a stuck open VMV. If a P0455, P0457, P1443, or P1450 code is generated, the EVAP test does not continue with subsequent phases of the small leak check, phases 1-4.

Note: Not all vehicles will have the P0457 and P1443 tests or the Check Fuel Cap light implemented. These vehicles will continue to generate only a P0455. After the customer properly secures the fuel cap, the P0457, Check Fuel Cap and/or MIL will be cleared as soon as normal purging vacuum exceeds the P0457 vacuum level stored in KAM.

4.5.2 Phase 1 - Vacuum Stabilization

If the target vacuum is achieved, the VMV is closed and vacuum is allowed to stabilize.

4.5.3 Phase 2 - Vacuum Hold And Decay

Next, the vacuum is held for a calibrated time and the vacuum level is again recorded at the end of this time period. The starting and ending vacuum levels are checked to determine if the change in vacuum exceeds the vacuum bleed up criteria. Fuel Level Input is used to adjust the vacuum bleed-up criteria for the appropriate fuel tank vapor volume. Steady state conditions must be maintained throughout this bleed up portion of the test. The monitor will abort if there is an excessive change in load, fuel tank pressure or fuel level input since these are all indicators of impending or actual fuel slosh. If the monitor aborts, it will attempt to run again (up to 20 or more times). If the vacuum bleed-up criteria are not exceeded, the small leak test is considered a pass. If the vacuum bleed-up criteria is exceeded on three successive monitoring events, a 0.040 " dia. leak is likely and a final vapor generation check is done to verify the leak, phases 3-4. Excessive vapor generation can cause a false MIL.

4.5.4 Phase 3 - Vacuum Release

The vapor generation check is done by releasing any vacuum, then closing the VMV, waiting for a period of time, and determining if tank pressure remains low or if it is rising due to excessive vapor generation.
Phase 4 - Vapor Generation
If the pressure rise due to vapor generation is below the threshold limit for absolute pressure and change in pressure, a P0442 DTC is stored.

Evaporation System Monitor								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Vacuum Integrity Test			**Phase 0: (Initial vacuum pull down)**					
EVAP System Unable To Establish Proper Fuel Tank Pressure *(Canister Vent Solenoid stuck closed); (Vapor Management Valve stuck open); (Fuel Tank Pressure Transducer stuck at high vacuum); (Blocked vapor lines).*	P1450	Functional check, too much vacuum	Time to reach target fuel tank pressure; Target fuel tank pressure; Number of test failures to store pending code/ DTC; Number of aborts.	>30 sec; -7.2 >p >1 in H_2O; >1; < 20.	Purge duty cycle; Purge vapor through VMV; Engine load and MAF sensor OK (P0102/ 0103); Intake Air Temperature and IAT sensor OK (P0112/ 0113).	>75 % < .08 lbs/ min 5 to 70 % 40 - 110 ºF	Once per driving cycle	See Note c

Evaporation System Monitor – Cont'd

Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
EVAP System Gross Leak Detected *(Canister Vent Solenoid stuck closed); (Vapor Management Valve stuck open); (Blocked vapor lines); (Loose gas cap).*	P0455	Functional check, not enough vacuum/ large leak	Time to reach target fuel tank pressure; Target fuel tank pressure; Number of test failures to store pending code/ DTC; Number of aborts	>30 sec >- 7 in H 2 O >1 < 20	Vehicle speed and VSS sensor OK (P0500); Test run time; Inferred baro. pressure; Continuous time with engine off prior to start; Percent fuel fill; ECT sensor OK (P0117/ 0118) CP sensor circuit (PIP) OK (P0320) TP sensor OK (P0122/ 0123) HO2S monitor COMPLETE with no HO2S DTC's	40 - 80 mph 330 - 2400 sec >22 in Hg >360 min. 15 - 85 %		
Note: P1450 runs concurrently with P0455					**Phase 0 Abort Conditions:** Outside engine load entry conditions; Outside vehicle speed entry conditions; Outside purge vapor (VMV) duty cycle entry conditions; Outside purge vapor through VMV entry conditions; Open loop fuel; Change in engine load;	>50%		

Evaporation System Monitor – Cont'd								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Vacuum Integrity Test			**Phase 1: (vacuum stabilization time)**					
EVAP System Small Leak Detected	P0442	Functional check - 0.040" dia leak check	Time with sealed system; Allowable fuel tank pressure range to continue test; Number of aborts **Phase 2: (vacuum hold and leak test)** Time with sealed system (function of fuel level); Maximum allowable bleed up in fuel tank pressure (function of fuel fill level and previous purge flow rate); Number of aborts; Number of failures to proceed to Phase 3 and 4; Number of successful tests to pass monitor.	5 sec -6 to -7 in H_2O < 20 > FNPGM_ PH2_TM (see below) FNPGM_ BLD (see below) < 20 > 3 1	P1450 and P0455 tests passed and entry conditions still in effect	N/ A	Once per driving cycle	See Note c

Evaporation System Monitor – Cont'd								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
					Phase 1 and 2 Abort Conditions: Outside engine load entry conditions; Outside vehicle speed entry conditions; Outside purge vapor (VMV) duty cycle entry conditions; Outside purge vapor through VMV entry conditions; Change in engine load; Change in tank pressure; Change in fuel level.	>50 % > .8 in H_2O >20 %		
			Phase 3: (Vent System to Atmosphere)					
					Target fuel tank pressure; Maximum time to achieve target vacuum.	0 in H_2O 30 sec		
			Phase 4: (Vapor generation check of sealed system)					
			Number of aborts	< 20	P0442 test failed and entry conditions met; Time with sealed system; Maximum change in tank pressure; Maximum absolute tank pressure;	>40 sec < 1.5 in H_2O < 1.5 in H_2O		
					Phase 4 Abort Conditions: None			

Evaporation System Monitor – Cont'd								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Vapor management valve circuit malfunction	P0443	Circuit continuity test, open or shorted	Commanded duty cycle full-on on full-off; Signal circuit voltage; Time with circuit malfunction	95 < ? = 0% See below for threshold calculation >5 sec	None	N/ A	Continuous	
Canister vent valve control circuit malfunction	P1451	Circuit driver open or shorted	Time with fault indicated	>5 sec	None	N/ A	Continuous	See Note e
Fuel tank pressure sensor out of range/ circuit malfunction	P0452 (low) P0453 (high)	Range check	Sensor input Time with sensor out of range	-17.82> p > 16.06 in. H_2O >5 sec	None	N/ A	Continuous	See Note e
Fuel tank pressure sensor noisy	P0451	Rationality check-cumulative time with malfunction	Change in fuel tank pressure; Time between samples; Number of intermittent events.	>16 in H_2O per back-ground loop >10s >100	None	N/ A	Once per driving cycle	See Note e
Fuel Level Input Out of Range or Stuck	P0460 (high or low)	Range check	Sensor input; Time with sensor out of range.	5< ?> 200 Ω >30 sec	None	N/ A	Continuous	See Note j

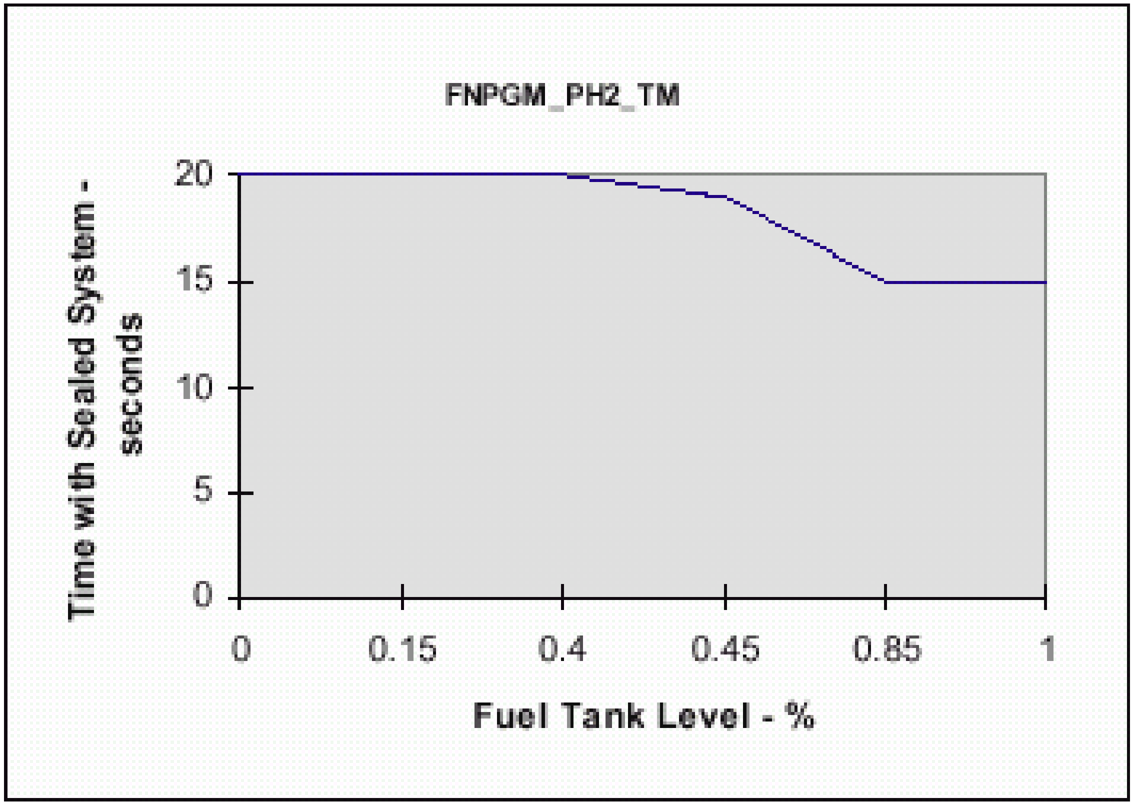
Signal circuit voltage threshold calculation for DTC P0433:

At 98% threshold = {[(42*battery voltage)-150]*5.0/1024}

At 0% threshold = {[(32*battery voltage)-200]*5.0/1024}

Evaporation System Monitor – Cont'd								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
	P0460	Rationality check	Expected change in fuel level (saved in KAM); Time for expected change (saved in KAM).	< 5 % >10000 sec	Vehicle speed Engine load	>20 mph >30%	Continuous Parameters stored in KAM, may require up to 3 or 4 driving cycles to detect malfunction	 See note j
I/ M Readiness			Number of driving cycles to clear I/ M readiness flag at extreme ambient conditions	>1 drive cycle	Monitors which must complete prior to clearing I/ M readiness bit for evap monitor; Time within evap monitor entry condition except IAT and BARO	Catalyst, misfire, secondary air, HO2S, fuel system, EGR, CCM >30 sec	N/ A	N/ A

Vacuum hold and leak test (fuel level function) - **FNPGM_PH2_TM**



Maximum allowable "bleed-up" (fuel level function) - **FNPGM_BLD**					
Fuel level %	Vapour flow – in H_2O				
	0	0.031	0.062	0.093	0.124
0	3	3	3	3	3
40	3	3	3	3	3
85	3.5	3.5	3.5	3.5	3.5
100	3.5	3.5	3.5	3.5	3.5

4.6 Thermostat Monitor

Thermostat Monitor								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Insufficient coolant temperature for closed loop fuel control	P0125	Time to reach minimum engine coolant temperature	Time within test entry conditions: Engine coolant temperature:	See FN654W below < 170 ºF	Vehicle Speed Engine Load	> 15 mph > 30 %	Once per drive cycle	See Note c

Maximum Engine Coolant Temperature warm up time function - FN654W			
IAT ºF	-20	20	70
Maximum ECT warm-up time - secs	1600	1100	500

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4.7 Comprehensive Component Monitor

The Comprehensive Component Monitor looks at sensor inputs from components that are likely to affect emissions: Intake Air Temperature (IAT), Engine Coolant Temperature (ECT), Cylinder Head Temperature (CHT), Mass Air Flow (MAF), Throttle Position (TP) and Fuel Temperature (FP). These components are monitored for circuit continuity, out of range values and functionality. There are different strategies for monitoring inputs and outputs. One involves checking certain input signals at the analogue/ digital (A/D) converter inside the ECM/ PCM for out of range values and electrical faults.

A number of sensors are used to measure engine and vehicle operations and turn them into electrical signals. There are several different designs, ranging in intricacy from a simple switch to complex chemical reaction devices, such as oxygen sensors. Apart from considerations of reliability, range and accuracy, sensors are designed to provide a linear output. Linear in this sense means that the sensor signal is always proportional to the value it is measuring. This is important, since many sensors output analog signals that must undergo conversion to a digital form before processing.

4.7.5 Engine speed /crankshaft position

The crankshaft position sensor (CKP Sensor) is an inductive pulse generator that supplies the Engine Control Module (ECM) with both an engine speed and crankshaft position alternating voltage signal. The sensor is located either on the timing cover or at the rear of the engine. The reluctor, mounted on the crankshaft, has a number of “teeth ”with one or two removed to form a gap, which creates a missing pulse. The missing pulse allows the ECM to determine the crankshaft position for fuel injector pulse synchronization.
Engine speed is one of the two main factors in determining fuel injector pulse duration (fuel metering) and ignition timing.

Comprehensive Component Monitor – Crank/Camshaft Position Sensors								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Ignition system – PIP circuit malfunction	P0320	Rationality Check	Engine rpm: Time between PIP events: Ratio of current PIP periods to last 2 periods:	>350 rpm >400 ms 0.25>?>1.75	None	N/A	Continuous	See Note 2
Camshaft position A input	P0340	Rationality Check	Ratio of PIP events to CID events	6 to 1 (to pass test)	None	575<N<3500	Continuous	See Note 2
Camshaft position B input	P0341	Rationality Check	Ratio of PIP events to CID events	6 to 1 (to pass test)	None	575<N<3500	Continuous	See Note 2

4.7.6 Variable Camshaft Timing

Comprehensive Component Monitor – Variable Camshaft Timing								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Variable Camshaft timing A	P1380 P1381 P1383	VCT A Circuit malfunction VCT A CAM over retard VCT A CAM Over advanced	Time with failure: Valve stuck open: Valve stuck shut:	> 2.8s > 2.9s > 2.9s		> -27deg > 34 deg	Continuous	See Note c
Variable Camshaft timing B	P1385 P1386 P1388	VCT B Circuit malfunction VCT B CAM over retard VCT B CAM Over advanced	Time with failure: Valve stuck open: Valve stuck shut:	> 2.8s > 2.9s > 2.9s		> -27deg > 34 deg		
					Electronic throttle control:	> 120 deg		
					Electronic throttle control:	Not fail		
					CID:	Not fail		
					PIP:	Not fail		
					VCT:	Not fail		

4.7.7 Mass Airflow Sensor

Comprehensive Component Monitor – Mass Airflow Sensor								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Mass airflow sensor input								
- Low	P0102	Range Check	Sensor signal voltage	< 0.27 v	Time since last PIP signal, (engine not stalled):	< 150 ms	Continuous	See Note c
			Fault filter routine	> 5s	Relative throttle position:	>Tp_rel>10		
					Engine mode	Run Mode		
- High	P0103	Range Check	Sensor signal voltage	> 4.79 v	Engine rpm	< 6000 rpm		
			Fault filter routine	> 5s				

4.7.8 Fuel Rail Pressure Sensor

Comprehensive Component Monitor – Fuel Rail pressure Sensor								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Fuel rail pressure input	P0190	Circuit malfunction	Sensor input stuck mid-range: Large control error: Sensor value not moving: Time with sensor input out of range:	15 +/- 5 psig > 5 psig < 0.8 psig/s > 8s	None	N/A	Continuous	See Note c
- Low	P0192	Range check	Sensor input: Time with sensor input out of range:	< 0.0488v > 8s	None	N/A	Continuous	See Note c
- High	P0193		Sensor input: Time with sensor input out of range:	> 4.89v > 8s				

4.7.9 Intake Air Temperature (IAT) sensor

The Intake Air Temperature (IAT) sensor is a thermistor device mounted inside the MAF sensor. It provides an input signal to the ECM proportional to the temperature of air passing through the inlet duct into the engine. A DTC is recorded if the voltage input signal from the sensor to the ECM is outside pre-defined thresholds at the High or Low end of the scale.

Range Performance – 1 Monitor

The voltage input signal from the IAT sensor to the ECM is monitored while the engine is idling. A DTC is stored in the ECM if the signal exceeds a temperature uncharacteristic of air entering a normally functioning engine.

Range Performance – 2 Monitor

The diagnostic flags any large fluctuations in voltage inputs from the IAT sensor to the ECM. Any large fluctuations would be uncharacteristic of a properly functioning engine.

Comprehensive Component Monitor - Intake Air Temperature (IAT) sensor								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
IAT Sensor Input								
- Low	P0112	Range Check	Sensor input: Time with sensor input out of range:	< -40 >5s	None	N/A	Continuous	See Note c
- High	P0113	Range Check	Sensor input: Time with sensor input out of range:	> 265 ºF >5s	None	N/A	Continuous	See Note c

4.7.10 Engine Coolant Temperature (ECT) Sensor

The sensor is a thermistor, a solid-state variable resistor that changes resistance in response to a rise or fall in temperature. It is mounted in the engine block coolant system. The sensor is supplied with a reference voltage through a fixed resistor. As the current passes through the thermistor resistance, the ECM measures the voltage drop across the fixed resistor and translates this into a temperature using a pre-programmed table of values.

The ECT sensor is continually monitored for High and Low Inputs and Range and Performance. A DTC is recorded if the voltage input signal from the sensor to the ECM is outside pre-defined thresholds at the High or Low end of the scale.

Range Performance – 1 Monitor

The engine warm up characteristics is monitored for correct performance. This is done in two parts: first by looking at the time for the system to reach closed-loop fueling conditions, and second, looking at how long it takes to become fully warmed-up.

Range Performance – 2 Monitor

The diagnostic flags any large fluctuations in voltage inputs from the ECT to the ECM. Any large fluctuations would be uncharacteristic of normal coolant circulation in a properly functioning engine.

Comprehensive Component Monitor - Engine Coolant Temperature (ECT) Sensor								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Engine coolant sensor - Low	P0117	Range check	Sensor input	< 0.0488v for > 5s	None	N/A	Continuous	See Note c
- High	P0118	Range check	Sensor input	> 4.575v for > 5s	None	N/A		
							Continuous	See Note c

4.7.11 Engine Oil temperature

Comprehensive Component Monitor - Engine Oil Temperature (EOT) Sensor								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
	P1183	Sensor out of Range	Sensor Input	> 937 counts < 20 counts		Time with failure = 5 sec	Continuous	See note c

4.7.12 Throttle Position Control

The Throttle Position Sensor (TPS) comprises a potentiometer with a pointer that is rotated by the throttle shaft. The PCM supplies the potentiometer with a nominal 5 volts. The signal output from the TPS to the ECM depends on the position of the pointer and ultimately the position of the throttle shaft. The sensor’s position in relation to the shaft cannot be adjusted, and the PCM compensates for wear and ageing in service.

Comprehensive Component Monitor - Throttle Position Control								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Throttle position sensor inconsistent with MAF sensor	P1121	Rationality check vs MAF sensor	Engine rpm: Sensor signal voltage: Time with sensor out of range:	> 500 rpm tp_rel<50 + load> 0.703, tp_rel> 500 + load< 0.203 >3s	Engine coolant temperature	> 67 ºF	Continuous	See Note c
Throttle position not available	P1573	Two of the three throttle position sensors have failed, hence, systems unable to reliably determine throttle position	Sensor circuit high/low or out of correlation	TP1 < 0.51v or > 4.65v, TP2 < 1.11v or > 4.65v, TP3 < 0.55v or > 4.65v		Continuous	> 350ms	See Note c
Pedal position not available	P1577	Two of the three throttle position sensors have failed, hence, systems unable to reliably determine throttle position	Sensor circuit high/low or out of correlation	PPS1 < 0.53v or > 4.75v, PPS2 < 1.09v or > 4.32v, PPS3 < 0.55v or > 3.77v		Continuous	> 350ms	See Note c
Electronic throttle monitor PCM override	P1580	Condition exists which cause the monitor to force engine scale down or shut down mode				Continuous	> 350ms	See Note c
Throttle controller detected electronic throttle malfunction	P1584	Normal closed loop throttle plate control lost	IPE sensor failure: Power driver failure: Motor driver failure			Continuous	N/A	See Note c

Comprehensive Component Monitor - Throttle Position Control								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Throttle controller malfunction	P1585	Failure of the throttle control unit, hence, unable to drive throttle plate open.	Failure of throttle control unit self test			Continuous	N/A	See Note c
Electronic throttle comms. malfunction	P1587	Failure of one or both throttle command lines	Throttle position command 1 out of range and/or throttle position 2 command out of range.			Continuous	N/A	See Note c
Electronic throttle unable to achieve desired throttle angle	P1589	Throttle plate can not be moved to desired angle	Failure of both power derivers: Stuck throttle open			Continuous	N/A	See Note c

4.7.13 Ignition System

Comprehensive Component Monitor - Ignition System								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Ignition Coil primary circuit malfunction - Primary - Coil A - Coil B - Coil C - Coil D - Coil E - Coil F - Coil G - Coil H	P0350 P0351 P0352 P0353 P0354 P0355 P0356 P0357 P0358	Rationality check	Ratio of PIP events to spark events	1 to 1 (to pass test) Minimum of 10 failures to set MIL	None	N/A	Continuous	See Note c

4.7.14 Knock Sensor System

Comprehensive Component Monitor - Vehicle Speed Sensor								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
KNK 1	P0325	Knock sensor malfunction	Fault counts	> 200			Continuous	See Note c
KNK 2	P0330	Knock sensor malfunction	Fault counts	> 200	RPM Disable: ECT Enable: Load: Time after start: KNK:	800>RPM>7000 >90 ºF > 0.29 > 2 sec Not failed	Continuous	See Note c

4.7.15 Idle Speed Control

The Idle Speed Control Valve meters air through a throttle by-pass duct, in conjunction with the ignition timing control, to maintain accurate idle speed control. It comprises a conical valve driven by a stepper motor controlled by the ECM. During closed loop control, a test monitors the cumulative opening and closing of the valve by counting the stepper motor steps. A fault is logged if the number of steps in either direction exceeds the threshold values without a corresponding increase or decrease in the airflow rate.

Comprehensive Component Monitor - Idle Speed Control								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Idle air control over speed error	P1506	Functional check – Over speed error	Difference between actual and desired rpm: Time with solenoid at limit:	> 200 rpm > 20 sec	Engine coolant temperature; Time since engine start: Fuel control: Idle state:	> 127 ºF > 100 s Closed loop At idle	Continuous	See Note c
Idle air control under speed error	P1507	Functional check – Under speed error	Difference between actual and desired rpm: Time with solenoid at limit:	< 100 rpm > 28 sec	Engine coolant temperature; Time since engine start: Fuel control: Idle state:	> 127 ºF > 100 s Closed loop At idle	Continuous	See Note c

4.7.16 Air Injection

Comprehensive Component Monitor - Air Assisted Injector Monitor								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Air Assisted Injection	P0066	Valve circuit malfunction	Time with failure	> 5s			Continuous	See Note c
Air Assisted Injection	P0065	Valve range/performance	Blocked flow	ERR > 0.23	P0066: P1506: P1507: IPSIBR: Throttle angle: Time after power steering pressure change: Airflow: ECT: MAF: ISC: Time after air conditioning pressure change:	Not set Not set Not set > -0.5<?< 0.5 < 0.1 4 sec > 0.05 > 194 ºF Not failed At idle 4 sec	Once per cycle	See Note c

4.7.17 Engine Control Module

The engine management system is centered on a digital engine control module (ECM). The ECM receives input signals from engine sensors to evaluate engine-operating conditions. In addition, the ECM communicates with other power-train systems and vehicle systems. The ECM then processes the sensor information and the information received from other systems using programmed software strategies and issues control output signals to the engine and emission control functional systems.

At its very basic level of control the ECM:

- Takes engine speed and load input signals;
- Applies correction factor inputs and emissions control feedback signals;
- Processes the signals to access pre-programmed software strategies;
- Outputs control signals to the various engine and emission components.
- During this process, the ECM employs diagnostic tests to monitor and report engine management system faults. Faults are stored in ECM memory as codes. Technician access to the fault codes and data is gained through a diagnostic data link.

Comprehensive Component Monitor - Engine Control Module								
Strategy	DTCs	Description	Malfunction Criteria	Value	Secondary parameter	Enable Conditions	Time Required	MIL
Keep alive memory power input	P1633	KAM power input voltage too low or open circuit	Time with error present	> 20 sec	None	None	Continuous	See Note c

5 Notes

DTC Storage:

a) A DTC will be stored after a malfunction has been detected on two consecutive driving cycles. The DTC will be erased after 40 warm-up cycles with no malfunction present, after the MIL has been extinguished for that DTC.
b) A DTC will be stored immediately upon detection of a malfunction. The DTC will be erased after 40 warm-up cycles with no malfunction present, after the MIL has been extinguished for the DTC.

MIL illumination

c) The MIL will be illuminated after a malfunction has been detected on two consecutive driving cycles. The MIL will be extinguished after three consecutive driving cycles where the monitor was run without a malfunction.
d) The MIL will blink immediately upon detection of a misfire rate that exceeds the catalyst damage threshold, regardless of whether fuel is shut off or not. If the misfire rate drops below the catalyst damage threshold, the MIL will stay on solidly. The MIL will be extinguished after three consecutive drive cycles where similar conditions have been seen without the malfunction.
e) The MIL will be illuminated after a malfunction has been detected on two consecutive driving cycles. The MIL will be extinguished after three consecutive drive cycles where similar conditions have been seen without the malfunction.
f) For intake air temperatures below 32 deg F, the MIL will not illuminate for the indicated EGR DTCs. For intake air temperatures below 20 deg F, the MIL will not illuminate for the indicated AIR DTCs. This prevents false MIL illumination due to ice in the EGR hoses or AIR switching valve(s).
g) This monitor employs EWMA. The MIL will be illuminated after a malfunction has been detected on two consecutive driving cycles after DTCs have been erased or Keep Alive Memory has been erased (battery disconnect). The MIL will be illuminated after a malfunction has been detected on up to six consecutive driving cycles during subsequent, "normal" customer driving. The MIL will be extinguished after up to six consecutive driving cycles without a malfunction.
h) Some automatic transmission monitors are demonstrated following the USCAR Abbreviated On-Board Diagnostic Test Procedure for Vehicles Equipped with Automatic Transmissions. This prevents false MIL illumination on this non-turbine speed sensor transmission application.
i) The MIL will be illuminated after a malfunction has been detected on the first driving cycle. The MIL will be extinguished after three consecutive driving cycles where the monitor was run without a malfunction.
j) A DTC will be set after a malfunction has been detected on two consecutive driving cycles.