



2003 MY OBD System Operation Summary for Gasoline Engines

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Introduction – OBD-I and OBD-II

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.

OBD-I Systems

If a vehicle is not required to comply with OBD-II requirements, it utilizes an OBD-I system. OBD-I systems are used on all over 8,500 lbs. GVWR Federal truck calibrations. With the exception of the 1996 MY carryover EEC-IV OBD-I systems, Federal > 8,500 lbs. OBD-I vehicles use that same PCM, J1850 serial data communication link, J1962 Data Link Connector, and PCM software as the corresponding OBD-II vehicle. The only difference is the possible removal of the rear oxygen sensor(s), fuel tank pressure sensor, canister vent solenoid, and a different PCM calibration.

The following list indicate what monitors and functions have been altered for OBD-I calibrations:

Monitor / Feature	Calibration
Catalyst Monitor	Not required, monitor calibrated out, rear O2 sensors may be deleted.
Misfire Monitor	Calibrated in for service, all DTCs are non-MIL. Catalyst damage misfire criteria calibrated out, emission threshold criteria set to 4%, enabled between 150 °F and 220 °F, 254 sec start-up delay.
Oxygen Sensor Monitor	Rear O2 sensor test calibrated out, rear O2 sensors may be deleted, front O2 sensor response test calibrated out, O2 heater current test calibrated out prior to 2002 MY, O2 heater voltage test used for all model years.
EGR Monitor	Same as OBD-II calibration except that P0402 test uses slightly higher threshold.
Fuel System Monitor	Same as OBD-II calibration starting in 2002 MY, earlier calibrations used +/- 40% thresholds.
Secondary Air Monitor	Functional (low flow) test calibrated out, circuit codes are same as OBD-II calibration.
Evap System Monitor	Evap system leak check calibrated out, fuel level input circuit checks retained as non-MIL. Fuel tank pressure sensor and canister vent solenoid may be deleted.
PCV Monitor	Same hardware and function as OBD-II.
Thermostat Monitor	Thermostat monitor calibrated out.
Comprehensive Component Monitor	All circuit checks same as OBD-II. Some rationality and functional tests calibrated out. (MAF/TP rationality, IAC functional)
Communication Protocol and DLC	Same as OBD-II, all generic and enhanced scan tool modes work the same as OBD-II but reflect the OBD-I calibration that contains fewer supported monitors. "OBD Supported" PID indicates OBD-I.
MIL Control	Same as OBD-II, it takes 2 driving cycles to illuminate the MIL.

Catalyst Efficiency Monitor

The Catalyst Efficiency Monitor uses an oxygen sensor before and after the catalyst to infer the hydrocarbon efficiency based on oxygen storage capacity of the ceria and precious metals in the washcoat. 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 switches as compared to the switching frequency and amplitude of the front HO₂S. As catalyst efficiency deteriorates due to thermal and/or chemical deterioration, its ability to store oxygen declines. The post-catalyst HO₂S signal begins to switch more rapidly with increasing amplitude, approaching the switching frequency and amplitude of the pre-catalyst HO₂S. The predominant failure mode for high mileage catalysts is chemical deterioration (phosphorus deposition on the front brick of the catalyst), not thermal deterioration.

All applications utilize an FTP-based (Federal Test Procedure) catalyst monitor. This simply means that the catalyst monitor must run during a standard FTP emission test as opposed to the 20-second steady-state catalyst monitor used in 1994 through some 1996 vehicles. 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 - 2003)

In order to assess catalyst oxygen storage, the monitor counts front and rear HO₂S switches during part-throttle, closed-loop fuel conditions after the engine is warmed-up and inferred catalyst temperature is within limits. Front switches are accumulated in up to nine different air mass regions or cells although 3 air mass regions is typical. Rear switches are counted in a single cell for all air mass regions. When the required number of front switches has accumulated in each cell (air mass region), the total number of rear switches is divided by the total number of front 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, 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 front HO₂S switches during part-throttle, closed-loop fuel conditions after the engine is warmed-up and inferred catalyst temperature is within limits. Front switches are accumulated in up to three different air mass regions or cells. While catalyst monitoring entry conditions are being met, the front and rear HO₂S signal lengths are continually being calculated. When the required number of front switches has accumulated in each cell (air mass region), the total signal length of the rear HO₂S is divided by the total signal length of front HO₂S to compute a catalyst index ratio. An index ratio near 0.0 indicates high oxygen storage capacity, hence high HC efficiency. An index ratio near 1.0 indicates low oxygen storage capacity, 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 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.

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 use three sensors in all. For Y-pipe systems, 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 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 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.)

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. See the section on EWMA for additional information.

CATALYST MONITOR OPERATION:	
DTCs	P0420 Bank 1 (or Y-pipe), P0430 Bank 2
Monitor execution	once per driving cycle
Monitor Sequence	HO2S response test complete and no DTCs (P0133/P0153) prior to calculating switch ratio, no SAIR pump stuck on DTCs (P0412/P1414), no evap leak check DTCs (P0442/P0456)
Sensors OK	ECT, IAT, TP, VSS, CKP
Monitoring Duration	Approximately 700 seconds during appropriate FTP conditions (approximately 100 to 200 oxygen sensor switches are collected)

TYPICAL SWITCH RATIO CATALYST MONITOR ENTRY CONDITIONS:		
Entry condition	Minimum	Maximum
Time since engine start-up (70 °F start)	330 seconds	
Engine Coolant Temp	170 °F	230 °F
Intake Air Temp	20 °F	180 °F
Engine Load	10%	
Throttle Position	Part Throttle	Part Throttle
Time since entering closed loop fuel	30 sec	
Vehicle Speed	5 mph	70 mph
Inferred Catalyst Mid-bed Temperature	900 °F	
EGR flow (Note: an EGR fault disables EGR)	1%	12%
Fuel Level	15%	
Steady Air Mass Flow for each Air Mass cell (typically three cells)	1.0 lb/min	5.0 lb/min
(Note: FTP cycle is biased towards the low air mass range, 25 - 35 mph steady state driving must be performed to complete the monitor)		

TYPICAL INDEX RATIO CATALYST MONITOR ENTRY CONDITIONS:

Entry condition	Minimum	Maximum
Time since engine start-up (70 °F start)	330 seconds	
Engine Coolant Temp	170 °F	230 °F
Intake Air Temp	20 °F	180 °F
Time since entering closed loop fuel	30 sec	
Inferred Rear HO2S sensor Temperature	900 °F	
EGR flow (Note: an EGR fault disables EGR)	1%	12%
Throttle Position	Part Throttle	Part Throttle
Rate of Change of Throttle Position		0.2 volts / 0.050 sec
Vehicle Speed	5 mph	70 mph
Fuel Level	15%	
First Air Mass Cell	1.0 lb/min	2.0 lb/min
Engine RPM for first air mass cell	1,000 rpm	1,300 rpm
Engine Load for first air mass cell	15%	35%
Monitored catalyst mid-bed temp. (inferred) for first air mass cell	850 °F	1,200 °F
Number of front O2 switches required for first air mass cell	50	
Second Air Mass Cell	2.0 lb/min	3.0 lb/min
Engine RPM for second air mass cell	1,200 rpm	1,500 rpm
Engine Load for second air mass cell	20%	35%
Monitored catalyst mid-bed temp. (inferred) for second air mass cell	900 °F	1,250 °F
Number of front O2 switches required for second air mass cell	70	
Third Air Mass Cell	3.0 lb/min	4.0 lb/min
Engine RPM for third air mass cell	1,300 rpm	1,600 rpm
Engine Load for third air mass cell	20%	40%
Monitored catalyst mid-bed temp. (inferred) for third air mass cell	950 °F	1,300 °F
Number of front O2 switches required for third air mass cell	30	
(Note: Engine rpm and load values for each air mass cell can vary as a function of the power-to-weight ratio of the engine, transmission and axle gearing and tire size.)		

TYPICAL MALFUNCTION THRESHOLDS:

Rear-to-front O2 sensor switch/index-ratio > 0.75 (bank monitor)
Rear-to-front O2 sensor switch/index-ratio > 0.60 (Y-pipe monitor)
Rear-to-front O2 sensor switch/index ratio > 0.50 for E10 to > 0.90 for E85 (flex fuel vehicles)

J1979 CATALYST MONITOR MODE \$06 DATA			
Test ID	Comp ID	Description for J1850	Units
\$10	\$11	Bank 1 switch-ratio and max. limit	unitless
\$10	\$21	Bank 2 switch-ratio and max. limit	unitless
\$10	\$10	Bank 1 index-ratio and max. limit	unitless
\$10	\$20	Bank 2 index-ratio and max. limit	unitless
Monitor ID	Test ID	Description for CAN	
\$21	\$80	Bank 1 index-ratio and max. limit	unitless
\$22	\$80	Bank 2 index-ratio and max. limit	unitless
Conversion for J1850 Test ID \$10: multiply by 0.0156 to get a value from 0 to 1.0			

** 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

There are two different misfire monitoring technologies used in the 2003 MY. They are Low Data Rate (LDR) and High Data Rate (HDR). The LDR system is capable of meeting the FTP monitoring requirements on most engines and is capable of meeting “full-range” misfire monitoring requirements on 4-cylinder engines. The HDR system is capable of meeting “full-range” misfire monitoring requirements on 6 and 8 cylinder engines. HDR is being phased in on these engines to meet the “full-range” misfire phase-in requirements specified in the OBD-II regulations. By the 2003 MY all engines except the 6.8L V-10 will be “full-range” capable. 2003 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.

Low Data Rate System

The LDR Misfire Monitor uses a low-data-rate crankshaft position signal, (i.e. one position reference signal at 10 deg BTDC for each cylinder event). The PCM calculates crankshaft rotational velocity for each cylinder from this crankshaft position signal. The acceleration for each cylinder can then be calculated using successive velocity values. The changes in overall engine rpm are removed by subtracting the median engine acceleration over a complete engine cycle. The resulting deviant cylinder acceleration values are used in evaluating misfire in the “General Misfire Algorithm Processing” section below.

“Profile correction” software is used to “learn” and correct for mechanical inaccuracies in crankshaft tooth spacing under de-fueled engine conditions (requires three 60 to 40 mph no-braking decels after Keep Alive Memory has been reset). These learned corrections improve the high-rpm capability of the monitor for most engines. The misfire monitor is not active until a profile has been learned.

High Data Rate System

The HDR Misfire Monitor uses a high data rate crankshaft position signal, (i.e. 18 position references per crankshaft revolution [20 on a V-10]). This high-resolution signal is processed using two different algorithms. The first algorithm, called pattern cancellation, is optimized 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 optimized 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 in the “General Misfire Algorithm Processing” section below.

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 2003 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-fueled engine conditions (requires three 60 to 40 mph no-braking decels 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.

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 labeled 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 labeled a misfire.

The number of misfires are 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 washcoat, 1650°F for Pt/Pd/Rh advanced washcoat and 1800°F for Pd-only high tech washcoat). 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 startup or four subsequent 1000 rev exceedences on a drive cycle after start-up. Many 2003 MY vehicles will set a P0316 DTC if the Type B malfunction threshold is exceeded during the first 1,000 revs after engine startup. This DTC is stored in addition to the normal P03xx DTC that indicates the misfiring cylinder(s).

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 fueling 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-fueled 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 three 60 to 40 mph decels, a P0315 DTC is set.

Misfire Monitor Operation:	
DTCs	P0300 to P0310 (general and specific cylinder misfire) P1309 (no cam/crank synchronization, AICE chip malfunction) P1336 (no cam/crank synchronization) P0606 (AICE chip malfunction) P0315 (unable to learn profile) P0316 (misfire during first 1,000 revs after start-up)
Monitor execution	Continuous, misfire rate calculated every 200 or 1000 revs
Monitor Sequence	None
Sensors OK	CKP, CMP
Monitoring Duration	Entire driving cycle (see disablement conditions below)

Typical misfire monitor entry conditions:		
Entry condition	Minimum	Maximum
Time since engine start-up	0 seconds	0 seconds
Engine Coolant Temperature	20 °F	250 °F
RPM Range (Full-Range Misfire certified, with 2 rev delay)	2 revs after exceeding 150 rpm below "drive" idle rpm	redline on tach or fuel cutoff
Profile correction factors learned in KAM	Yes	
Fuel tank level	15%	

Typical misfire temporary disablement conditions:
Temporary disablement conditions:
Closed throttle decel (negative torque, engine being driven)
Fuel shut-off due to vehicle-speed limiting or engine-rpm limiting mode
Accessory load-state change (A/C, power steering), (used on some applications)
High rate of change of torque (heavy throttle tip-in or tip out)

Typical misfire monitor malfunction thresholds:
Type A (catalyst damaging misfire rate): misfire rate is an rpm/load table ranging from 40% at idle to 4% at high rpm and loads
Type B (emission threshold rate): 1% to 2%

J1979 Misfire Mode \$06 Data			
Test ID	Comp ID	Description for J1850	Units
\$50	\$00	Total engine misfire and emission threshold misfire rate (updated every 1,000 revolutions)	percent
\$53	\$00 - \$0A	Cylinder-specific misfire and catalyst damage threshold misfire rate (either cat damage or emission threshold) (updated when DTC set or clears)	percent
\$54	\$00	Highest catalyst-damage misfire and catalyst damage threshold misfire rate (updated when DTC set or clears)	percent
\$55	\$00	Highest emission-threshold misfire and emission threshold misfire rate (updated when DTC set or clears)	percent
\$56	\$00	Cylinder events tested and number of events required for a 1000 rev test	events
Monitor ID	Test ID	Description for CAN	
A1	\$80	Total engine misfire and catalyst damage misfire rate (updated every 200 revolutions)	percent
A1	\$81	Total engine misfire and emission threshold misfire rate (updated every 1,000 revolutions)	percent
A1	\$82	Highest catalyst-damage misfire and catalyst damage threshold misfire rate (updated when DTC set or clears)	percent
A1	\$83	Highest emission-threshold misfire and emission threshold misfire rate (updated when DTC set or clears)	percent
A1	\$84	Inferred catalyst mid-bed temperature	°C
A2 – AD	\$0B	EWMA misfire counts for last 10 driving cycles	events
A2 – AD	\$0C	Misfire counts for last/current driving cycle	events
A2 – AD	\$80	Cylinder X misfire rate and catalyst damage misfire rate (updated every 200 revolutions)	percent
A2 – AD	\$81	Cylinder X misfire rate and emission threshold misfire rate (updated every 1,000 revolutions)	percent
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			

Profile Correction Operation	
DTCs	P0315 - unable to learn profile in three 60 to 40 mph decels P1309 – AICE chip communication failure
Monitor Execution	once per KAM reset.
Monitor Sequence:	Profile must be learned before misfire monitor is active.
Sensors OK:	CKP, CMP, no AICE communication errors, CKP/CMP in synch
Monitoring Duration;	10 cumulative seconds in conditions (a maximum of three 60-40 mph defueled decels)

Typical profile learning entry conditions:		
Entry condition	Minimum	Maximum
Engine in decel-fuel cutout mode for 4 engine cycles		
Brakes applied	No	No
Engine RPM	1300 rpm	3700 rpm
Change in RPM		600 rpm/background loop
Vehicle Speed	30 mph	75 mph
Learning tolerance		1%

AIR System Monitor

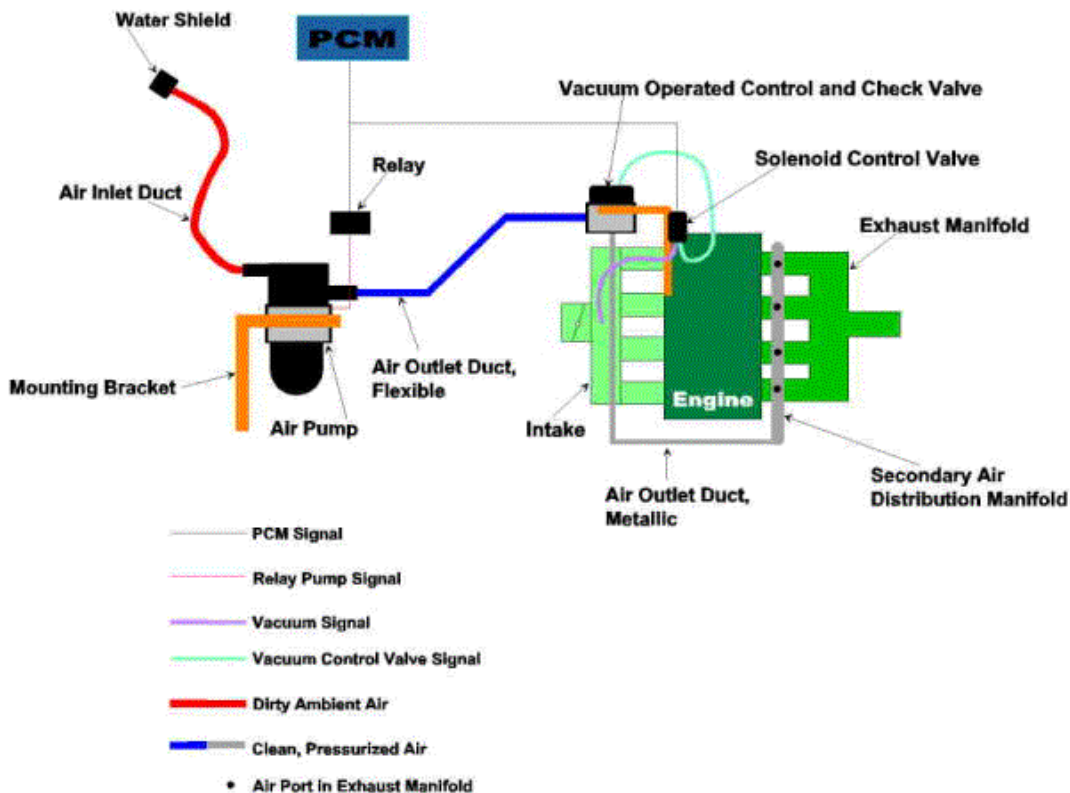
The secondary air systems typically utilize an electric air pump as well as one or two electrically controlled check valves to deliver air into the exhaust manifold.

The only vehicle which uses secondary air in the 2003 MY is the 2.3L PZEV Focus. The Focus uses a system with ported air. This means that airflow is delivered to each individual exhaust port. The secondary air pump is energized immediately after start-up while the fuel system is in open loop. After the O₂ sensors warm up, the secondary air pump continues to be energized while the fuel system goes into closed loop fuel. The secondary air system continues to run in closed loop fuel until the air pump is de-energized.

The AIR pump flow check monitors the HO₂S signal at idle to determine if secondary air is being delivered into the exhaust system. The air/fuel ratio is commanded open-loop rich, the AIR pump is turned on and the time required for the HO₂S signal to go lean is monitored. If the HO₂S signal does not go lean within the allowable time limit, a low/no flow malfunction is indicated. (P0411)

The electric air pump draws high current and must be energized through a separate relay. Both the primary and secondary circuits are checked for opens and shorts. First, the output driver within the PCM (primary circuit) is checked for circuit continuity (P0412). This circuit energizes the relay and the control valve(s). Next, a feedback circuit from the secondary side of the relay to the PCM is used to check secondary circuit continuity (P1413, P1414).

PZEV Port Oxidation System



AIR Monitor Operation:	
DTCs	P0411 functional check, P0412, P1413, P1414 circuit checks
Monitor execution	Functional - once per driving cycle, circuit checks - continuous
Monitor Sequence	Oxygen sensor monitor complete and OK
Sensors OK	ECT, IAT, no fuel system DTCs
Monitoring Duration	20 seconds at idle

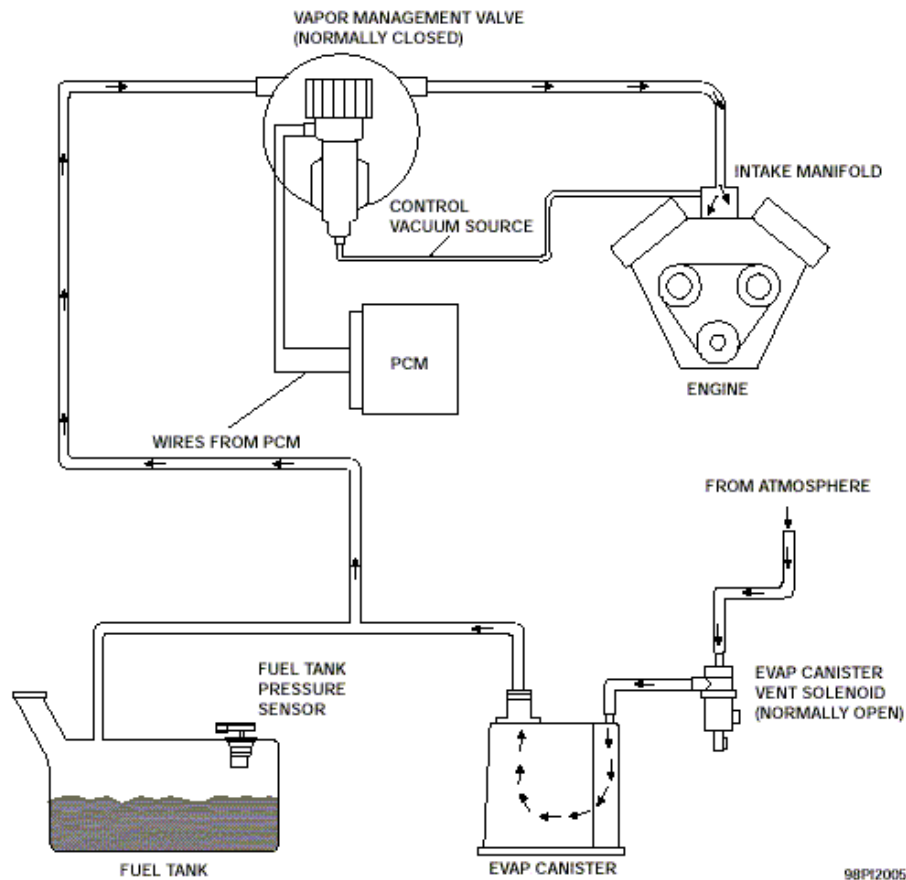
Typical AIR functional check entry conditions:		
Entry condition	Minimum	Maximum
Time since engine start-up	600 seconds	
Engine Coolant Temperature	150 °F	
Short Term Fuel Trim not too lean		5.0%
Fuel Tank Pressure		4.5 in H ₂ O
Closed Throttle	at idle rpm	at idle rpm
Purge Duty Cycle		20%
Purge Fuel Flow	0 lb/min	0.2 lb/min
Battery Voltage	11 volts	
Note: No P0411 DTC is stored if IAT < 20 °F at the start of the functional test although the test runs. (Precludes against identifying a temporary, frozen check valve.)		

Typical AIR functional check malfunction thresholds:
Minimum time allowed for HO ₂ S sensor to indicate lean: < 4 seconds

J1979 Secondary Air Mode \$06 Data			
Test ID	Comp ID	Description for J1850	Units
\$30	\$11	HO ₂ S11 voltage for upstream flow test and rich limit	volts
\$30	\$21	HO ₂ S21 voltage for upstream flow test and rich limit	volts
\$31	\$00	HO ₂ S lean time for upstream flow test and time limit	seconds
Monitor ID	Test ID	Description for CAN	Units
\$71	\$80	HO ₂ S11 voltage for upstream flow test and rich limit	volts
\$71	\$81	HO ₂ S21 voltage for upstream flow test and rich limit	volts
\$71	\$82	HO ₂ S 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			

EVAP System Monitor - 0.040" dia. leak check

Vehicles that meet enhanced evaporative requirements utilize a vacuum-based evaporative system integrity check. The evap system 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 evap system 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 °F.

A check for refueling events is done at engine start. A refuel flag is set in 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.

(Phase 0 - initial vacuum pulldown):

First, the Canister Vent Solenoid is closed to seal the entire evap system, then the VMV is opened to pull a 7" H₂O vacuum. If the initial vacuum could 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/kinked vapor lines, a Canister Vent Solenoid that is stuck open, a VMV that is stuck closed, or a disconnected/blocked vapor line between the VMV and the FTPT

If the initial vacuum could not be achieved after a refueling event, a gross leak, fuel cap off (P0457) is indicated and the recorded minimum fuel tank pressure during pulldown is stored in KAM. A "Check Fuel Cap" light may also be illuminated.

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, 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 test 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.

Phase 1 - Vacuum stabilization

If the target vacuum is achieved, the VMV is closed and vacuum is allowed to stabilize for a fixed time. If the pressure in the tank immediately rises, the stabilization time is bypassed and Phase 2 of the test is entered.

Some 2003 MY software has incorporated a "leaking" VMV test, which will also set a P1450 (excessive vacuum) DTC. This test is intended to identify a VMV that does not seal properly, but is not fully stuck open. If more than 1 " H₂O of additional vacuum is developed in Phase 1, the evap monitor will bypass Phase 2 and go directly to Phase 3 and open the canister vent solenoid to release the vacuum. Then, it will proceed to Phase 4, close the canister vent solenoid and measure the vacuum that develops. If the vacuum exceeds approximately 4 " H₂O, a P1450 DTC will be set.

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 is 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.

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.

0.040" EVAP Monitor Operation:	
DTCs	P0455 (gross leak), P1450 (excessive vacuum), P0457 (gross leak, cap off), P1443 (gross leak, no flow), P0442 (0.040" leak)
Monitor execution	once per driving cycle
Monitor Sequence	HO2S monitor completed and OK
Sensors/Components OK	MAF, IAT, VSS, ECT, CKP, TP, FTP, VMV, CVS
Monitoring Duration	360 seconds (see disablement conditions below)

Typical 0.040" EVAP monitor entry conditions, Phases 0 through 4:		
Entry condition	Minimum	Maximum
Engine off (soak) time	6 hours	
Time since engine start-up	330 seconds	1800 seconds
Intake Air Temp	40 °F	90 - 100 °F
BARO (<8,000 ft altitude)	22.0 " Hg	
Engine Load	20%	70%
Vehicle Speed	40 mph	80 mph
Purge Dutycycle	75%	100%
Fuel Fill Level	15%	85%
Fuel Tank Pressure Range	- 17 H ₂ O	1.5 H ₂ O

Typical 0.040" EVAP abort (fuel slosh) conditions for Phase 2:
Change in load: > 20%
Change in tank pressure: > 1 " H ₂ O
Change in fuel fill level: > 15%
Number of aborts: > 20 (may be up to 255)

Typical 0.040 EVAP monitor malfunction thresholds:
P1450 (Excessive vacuum): < -8.0 in H ₂ O over a 30 second evaluation time or > -4. in H ₂ O vapor generation
P0455 (Gross leak): > -8.0 in H ₂ O over a 30 second evaluation time.
P0457 (Gross leak, cap off): > -8.0 in H ₂ O over a 30 second evaluation time after a refueling event.
P0442 (0.040" leak): > 2.5 in H ₂ O bleed-up over a 15 second evaluation time at 75% fuel fill. (Note: bleed-up and evaluation times vary as a function of fuel fill level)
P0442 vapor generation limit: < 2.5 in H ₂ O over a 120 second evaluation time

J1979 Evaporative System Mode \$06 Data

Test ID	Comp ID	Description	Units
\$26	\$00	Phase 0 Initial tank vacuum and minimum limit	in H ₂ O
\$26	\$00	Phase 0 Initial tank vacuum and maximum limit	in H ₂ O
\$27	\$00	Phase 2 0.040" cruise leak check vacuum bleed-up and max threshold	in H ₂ O
\$2A	\$00	Phase 4 Vapor generation maximum change in pressure and max threshold	in H ₂ O
\$2B	\$00	Phase 4 Vapor generation maximum absolute pressure rise and max threshold	in H ₂ O

Conversion for Test IDs \$26 through \$2B: Take value, subtract 32,768, and then multiply result by 0.00195 to get inches of H₂O. The result can be positive or negative.

Note: Default values (-64 in H₂O) 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.

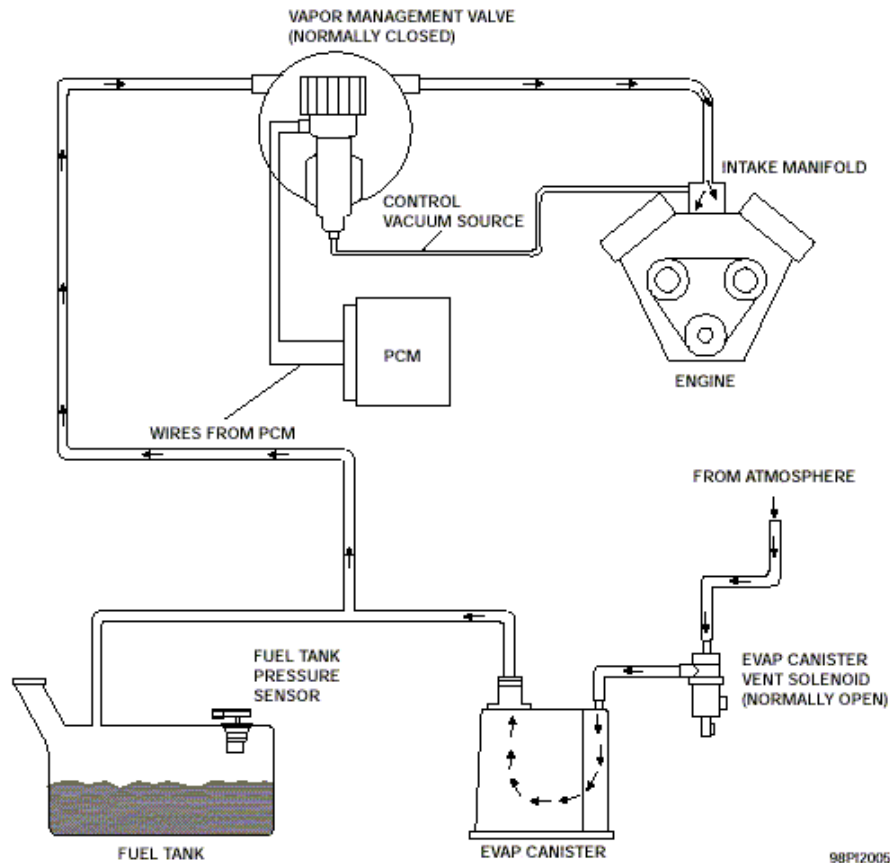
Test ID	Comp ID	Description (new 2003 MY strategies)	Units
\$61	\$00	Phase 0 Initial tank vacuum and minimum vacuum limit (data for P1450 – excessive vacuum)	in H ₂ O
\$62	\$00	Phase 4 Vapor generation minimum change in pressure and minimum vacuum limit (data for P1450, VMV stuck open)	in H ₂ O
\$63	\$00	Phase 0 Initial tank vacuum and gross leak maximum vacuum limit (data for P0455/P0457 – gross leak/cap off)	in H ₂ O
\$64	\$00	Phase 2 0.040" cruise leak check vacuum bleed-up and maximum vacuum limit (data for P0442 – 0.040" leak)	in H ₂ O

Conversion for Test IDs \$61 through \$64: Take value, subtract 32,768, and then multiply result by 0.00195 to get inches of H₂O. The result can be positive or negative.

Note: Default values (0.0 in H₂O) will be displayed for all the above TIDs if the evap monitor has never completed. Each TID is associated with a particular DTC. The TID for the appropriate DTC will be updated based on the current or last driving cycle, default values will be displayed for any phases that have not completed.

EVAP System Monitor - 0.020" dia. leak check

Some vehicles that meet enhanced evaporative requirements utilize a vacuum-based evaporative system integrity check that checks for 0.020" dia leaks. The evap system 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 0.020" diameter, 0.040" diameter, or larger evap system leaks.



The evap system integrity test is done under two different sets of conditions - first a cruise test is performed to detect 0.040" dia leaks and screen for 0.020" leaks. If a 0.020" dia leak is suspected during the cruise test, an idle test is performed to verify the leak under more restrictive, but reliable, cold-start-idle conditions.

The cruise 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 °F.

A check for refueling events is done at engine start. A refuel flag is set in 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 refueling flag is used to prohibit the 0.020" idle test until the gross leak check is done during cruise conditions. This is done to prevent potential idle concerns resulting from the high fuel vapor concentrations present with a fuel cap off/gross leak condition.

The cruise test is done in four phases.

Phase 0 - initial vacuum pulldown

First, the Canister Vent Solenoid is closed to seal the entire evap system, then the VMV is opened to pull a 7" H₂O vacuum.

If the initial vacuum could 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/kinked vapor lines, a Canister Vent Solenoid that is stuck open, a VMV that is stuck closed, or a disconnected/blocked vapor line between the VMV and the FTPT.

If the initial vacuum could not be achieved after a refueling event, a gross leak, fuel cap off (P0457) is indicated and the recorded minimum fuel tank pressure during pulldown is stored in KAM. A "Check Fuel Cap" light may also be illuminated.

If the initial vacuum is excessive, a vacuum malfunction is indicated (P1450). This could be caused by blocked vapor lines between the FTPT and the Canister Vent Solenoid, 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. These codes also prevent the idle portion of the 0.020" dia leak check from executing.

Note: Not all vehicles will have the P0457 test 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.

Phase 1 - Vacuum stabilization

If the target vacuum is achieved, the VMV is closed and vacuum is allowed to stabilize for a fixed time. If the pressure in the tank immediately rises, the stabilization time is bypassed and Phase 2 of the test is entered.

Some 2003 MY software has incorporated a "leaking" VMV test, which will also set a P1450 (excessive vacuum) DTC. This test is intended to identify a VMV that does not seal properly, but is not fully stuck open. If more than 1 " H₂O of additional vacuum is developed in Phase 1, the evap monitor will bypass Phase 2 and go directly to Phase 3 and open the canister vent solenoid to release the vacuum. Then, it will proceed to Phase 4, close the canister vent solenoid and measure the vacuum that develops. If the vacuum exceeds approximately 4 " H₂O, a P1450 DTC will be set.

Phase 2 - Vacuum hold and decay

Next, the vacuum is held for a calibrated time. Two test times are calculated based on the Fuel Level Input. The first (shorter) time is used to detect 0.040" dia leaks, the second (longer) time is used to detect 0.020" dia leaks. The initial vacuum is recorded upon entering Phase 2. At the end of the 0.040" dia test time, the vacuum level is recorded. The starting and ending vacuum levels are checked to determine if the change in vacuum exceeds the 0.040" dia vacuum bleed up criteria. If the 0.040" dia vacuum bleed-up criteria is exceeded on three successive monitoring attempts, a 0.040" dia leak is likely and a final vapor generation check is done to verify the leak (phases 3 and 4).

If the 0.040" dia bleed-up criteria is not exceeded, the test is allowed to continue until the 0.020" dia leak test time expires. The starting and ending vacuum levels are checked to determine if the change in vacuum exceed the 0.020" dia vacuum bleed-up criteria. If the 0.020" dia vacuum bleed-up is exceed on a single monitoring attempt, a 0.020" dia leak is likely and a final vapor generation check is done to verify the leak (phases 3 and 4).

If the vacuum bleed-up criteria is not exceeded, the leak test (either 0.040" or 0.020" dia is considered a pass. For both the 0.040" and 0.020" dia leak check, Fuel Level Input and Intake Air Temperature is used to adjust the vacuum bleed-up criteria for the appropriate fuel tank vapor volume and temperature. 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) until the maximum time-after-start is reached.

Phase 3 - Vacuum release

The vapor generation check is initiated by opening the Canister Vent Solenoid for a fixed period of time and releasing any vacuum. The VMV remains closed.

Phase 4 - Vapor generation

In this phase, the sealed system is monitored to determine if tank pressure remains low or if it is rising due to excessive vapor generation. The initial tank pressure is recorded. The pressure is monitored for a change from the initial pressure, and for absolute pressure. If the pressure rise due to vapor generation is below the threshold limit for absolute pressure and for the change in pressure, and a 0.040" dia leak was indicated in phase 2, a P0442 DTC is stored. If the pressure rise due to vapor generation is below the threshold limit for absolute pressure and for the change in pressure, and a 0.020" dia leak was indicated in phase 2, a 0.020" idle check flag is set to run the 0.020" leak check during idle conditions.

Idle Check

The long test times required to detect a 0.020" dia leak in combination with typical road grades can lead to false 0.020" leak indications while the vehicle is in motion. The Idle Check repeats Phases 0 and 2 with the vehicle stationary to screen out leak indications caused by changes in altitude. The 0.020" idle check is done under cold-start conditions to ensure that the fuel is cool and cannot pick up much heat from the engine, fuel rail, or fuel pump. This minimizes vapor generation. The 0.020" idle check is, therefore, conducted only during the first 10 minutes after engine start.

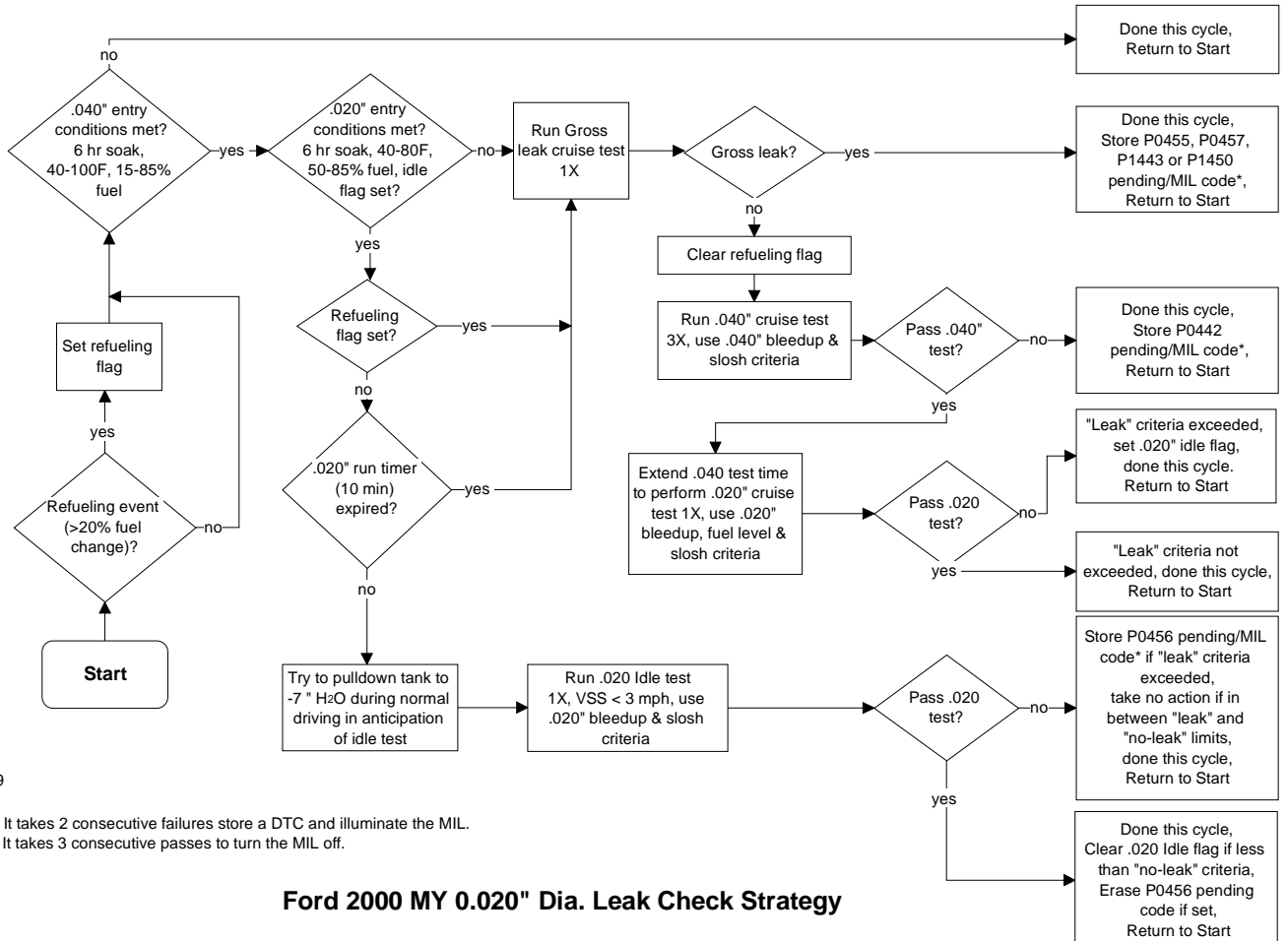
The 0.020" dia leak test entry conditions, test times and thresholds are used. Unique criteria for excessive changes in load, fuel tank pressure and fuel level are used to indicate fuel slosh. The test is aborted if vehicle speed exceeds a calibrated threshold, approx. 10 mph. The initial vacuum pull-down (phase 0) can start with the vehicle in motion in order to minimize the required time at idle to complete the test. If the vacuum bleed-up is greater than the 0.020" dia max. criteria during a single monitoring event, a P0456 DTC is stored. If the vacuum bleed-up is less than the 0.020" dia min. criteria, the pending P0456 DTC may be cleared. If the vacuum bleed-up is in between, no leak assessment is made. A flowchart of the entire 0.020" test sequence is provided below, on a subsequent page.

Ford's 0.020" evaporative system monitor is designed to run during extended, cold-start idle conditions where the fuel is cool and not likely to generate excessive vapors. These conditions will typically occur at traffic lights or immediately after start-up, (e.g. idle in the driveway).

As indicated previously, the 0.020" idle test uses two sets of malfunction thresholds to screen out test results in the area where "leak" and "no-leak" distributions overlap. Loss of vacuum greater than the 0.020" malfunction criteria is designated as a failure. No/low vacuum loss below the pass criteria is designated a pass. Vacuum loss that is greater than the pass criteria but less than the failure criteria is indeterminate and does not count as a pass or a fail.

Test results in this overlap area can stem from high volatility fuel at high ambient temperatures. These situations are not expected to be encountered routinely by customers. Therefore, this strategy will only temporarily hamper monitor performance, while effectively preventing false MIL illumination.

A more detailed description of the functional characteristics of the Evaporative Monitor is provided in the representative calibration submissions to the agency. Additional calibration information is contained on file by Ford Motor Company and may be obtained via agency request.



2/11/99

0.020" EVAP Monitor Operation:	
DTCs	P0455 (gross leak), P1450, (excessive vacuum), P0457 (gross leak, cap off), P1443 (gross leak, no flow), P0442 (0.040" leak), P0456 (0.020" leak)
Monitor execution	once per driving cycle for 0.040" dia leak once per driving cycle, no refueling event for 0.020" dia leak
Monitor Sequence	HO2S monitor for front sensors completed and OK
Sensors/Components OK	MAF, IAT, VSS, ECT, CKP, TP, FTP, VMV, CVS
Monitoring Duration	360 seconds for 0.040" (see disablement conditions below) 60 seconds for 0.020" (see disablement conditions below)

Typical 0.020" EVAP monitor entry conditions, Phases 0 through 4:		
Entry condition	Minimum	Maximum
Engine off (soak) time	6 hours	
Time since engine start-up for 0.040"	330 seconds	1800 seconds
Time since engine start-up for 0.020" idle test	30 seconds	600 seconds
Refueling event (for 0.020" idle test only)	none	
Intake Air Temp for 0.040"	40 °F	90 - 100 °F
Intake Air Temp for 0.020"	40 °F	90 °F
Vehicle Speed for cruise test, 0.040 and 0.020"	40 mph	80 mph
Vehicle Speed for idle test, 0.020"		3 mph
Fuel Fill Level for 0.040"	15%	85%
Fuel Fill Level for 0.020"	40%	85%
BARO (<8,000 ft altitude)	22.0 " Hg	
Engine Load	20%	70%
Purge Duty cycle	75%	100%
Fuel Tank Pressure Range	- 17 H ₂ O	1.5 H ₂ O

Typical 0.020" EVAP abort (fuel slosh) conditions for Phase 2:

Change in load: > 20% for 0.040"
Change in load: > 10% for 0.020"
Change in tank pressure: > 1 " H ₂ O for 0.040"
Change in tank pressure: > 1 " H ₂ O for 0.020"
Change in fuel fill level: > 15% for 0.040"
Change in fuel fill level: > 8% for 0.020"
Number of aborts: > 20 (may be up to 255)

Typical 0.020 EVAP monitor malfunction thresholds:

P1450 (Excessive vacuum): < -8.0 in H₂O over a 30 second evaluation time or > -4. in H₂O vapor generation.
P0455 (Gross leak): > -8.0 in H₂O over a 30 second evaluation time.
P0457 (Gross leak, cap off): > -8.0 in H₂O over a 30 second evaluation time after a refueling event.
P0442 (0.040" leak): > 2.5 in H₂O bleed-up over a 15 sec. evaluation time at 75% fuel fill.
(Note: bleed-up and evaluation times vary as a function of fuel fill level).
P0456 (0.020" leak): > 2.5 in H₂O bleed-up over a 30 sec. evaluation time at 75% fuel fill.
(Note: bleed-up and evaluation times vary as a function of fuel fill level)
P0442 vapor generation limit: < 2.5 in H₂O over a 100 second evaluation time.

J1979 Evaporative System Mode \$06 Data

Test ID	Comp ID	Description for J1850	Units
\$26	\$00	Phase 0 Initial tank vacuum and minimum limit	in H ₂ O
\$26	\$00	Phase 0 Initial tank vacuum and maximum limit	in H ₂ O
\$27	\$00	Phase 2 0.040" cruise leak check vacuum bleed-up and maximum 0.040" leak threshold	in H ₂ O
\$28	\$00	Phase 2 0.020" cruise leak check vacuum bleed-up and max leak threshold	in H ₂ O
\$2A	\$00	Phase 4 Vapor generation maximum change in pressure and max threshold	in H ₂ O
\$2B	\$00	Phase 4 Vapor generation maximum absolute pressure rise and max threshold	in H ₂ O
\$2C	\$00	Phase 2 0.020" idle leak check vacuum bleed-up and maximum "leak" threshold	in H ₂ O
\$2D	\$00	Phase 2 0.020" idle leak check vacuum bleed-up and max "no-leak" threshold	in H ₂ O

Conversion for Test IDs \$26 through \$2D: Take value, subtract 32,768, and then multiply result by 0.00195 to get inches of H₂O. The result can be positive or negative.

Note: Default values (-64 in H₂O) 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.

Test ID	Comp ID	Description for J1850 (new 2003 MY strategies)	Units
\$61	\$00	Phase 0 Initial tank vacuum and minimum vacuum limit (data for P1450 – excessive vacuum)	in H ₂ O
\$62	\$00	Phase 4 Vapor generation minimum change in pressure and minimum vacuum limit (data for P1450, VMV stuck open)	in H ₂ O
\$63	\$00	Phase 0 Initial tank vacuum and gross leak maximum vacuum limit (data for P0455/P0457 – gross leak/cap off)	in H ₂ O
\$64	\$00	Phase 2 0.040" cruise leak check vacuum bleed-up and maximum vacuum limit (data for P0442 – 0.040" leak)	in H ₂ O
\$65	\$00	Phase 2 0.020" idle leak check vacuum bleed-up and maximum vacuum limit (data for P0456 – 0.020" leak)	in H ₂ O
<p>Conversion for Test IDs \$61 through \$65: Take value, subtract 32,768, and then multiply result by 0.00195 to get inches of H₂O. The result can be positive or negative.</p> <p>Note: Default values (0.0 in H₂O) will be displayed for all the above TIDs if the evap monitor has never completed. Each TID is associated with a particular DTC. The TID for the appropriate DTC will be updated based on the current or last driving cycle, default values will be displayed for any phases that have not completed.</p>			
Monitor ID	Test ID	Description for CAN (new 2003 MY strategies)	Units
\$3A	\$80	Phase 0 Initial tank vacuum and minimum vacuum limit (data for P1450 – excessive vacuum)	Pascals
\$3A	\$81	Phase 4 Vapor generation minimum change in pressure and minimum vacuum limit (data for P1450, VMV stuck open)	Pascals
\$3A	\$82	Phase 0 Initial tank vacuum and gross leak maximum vacuum limit (data for P0455/P0457 – gross leak/cap off)	Pascals
\$3B	\$80	Phase 2 0.040" cruise leak check vacuum bleed-up and maximum vacuum limit (data for P0442 – 0.040" leak)	Pascals
\$3C	\$80	Phase 2 0.020" idle leak check vacuum bleed-up and maximum vacuum limit (data for P0456 – 0.020" leak)	Pascals
<p>Note: Default values (0.0 in H₂O) will be displayed for all the above TIDs if the evap monitor has never completed. Each TID is associated with a particular DTC. The TID for the appropriate DTC will be updated based on the current or last driving cycle, default values will be displayed for any phases that have not completed.</p>			

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

- The Vapor Management Valve (purge solenoid) output circuit is checked for opens and shorts (P0443), a stuck closed VMV generates a P0455, a leaking or stuck open VMV generates a P1450.
- The Fuel Tank Pressure Transducer input circuit is checked for out of range values (P0452 short, P0453 open) as well as noisy readings (P0451 noisy). An open power input circuit or stuck check valve generates a P1450.

Fuel Tank Pressure Sensor Transfer Function		
FTP volts = [Vref * (0.14167 * Tank Pressure) + 2.6250] / 5.00		
Volts	A/D Counts in PCM	Fuel Tank Pressure, Inches H ₂ O
0.100	20	-17.82
0.500	102	-15.0
1.208	247	-10.0
2.265	464	0
3.475	712	6.0
4.750	973	15.0
4.90	1004	16.06

- The Canister Vent Solenoid output circuit is checked for opens and shorts (P1451 or P0446), a stuck closed CVS generates a P1450, a leaking or stuck open CVS generates a P0455.
- The Fuel Level Input is checked for out of range values (opens/ shorts). The FLI input can be hardwired to the PCM or be obtained from the serial data link, typically from the instrument cluster. If the FLI signal is open or shorted, a P0460 is set. Some 2003 MY software will be able to discriminate between an open and short and set the appropriate DTC (P0462 circuit low and P0463 circuit high). The FLI signal is also checked to determine if it is stuck. If the PCM calculates the amount of fuel being consumed by accumulating fuel pulsewidth. If 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 from an in-range to out-of-range value repeatedly, a P0461 DTC is set.

The requirement to clear the I/M readiness bit for the evap system monitor after 2 driving cycles was phased in starting in the 1999 MY. (See Readiness Code section below.)

EVAP Component Monitor Operation:

DTCs	P0443, P1451 or P0446, P0452, P0453, P0460, P0461, P0462, P0463
Monitor execution	continuous (5 seconds to identify malfunction or obtain smart driver status)
Monitor Sequence	None
Sensors OK	not applicable
Monitoring Duration	5 seconds for electrical malfunctions

Typical evap component malfunction thresholds:

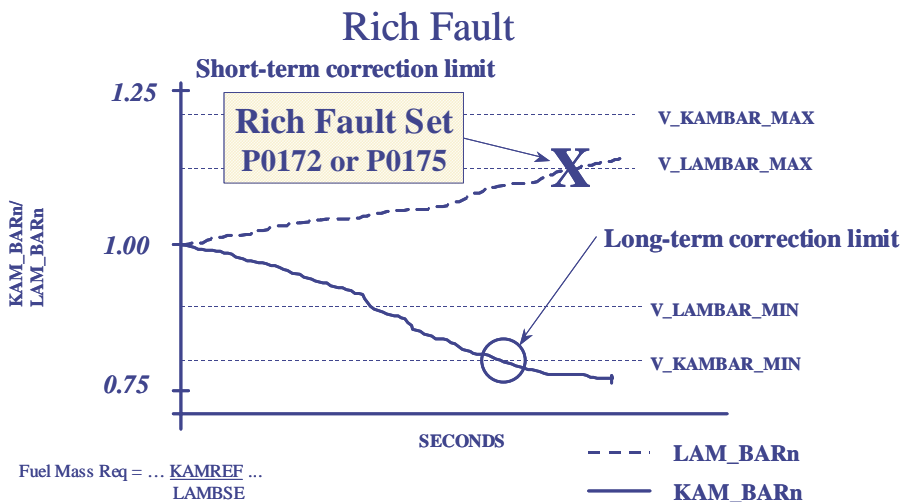
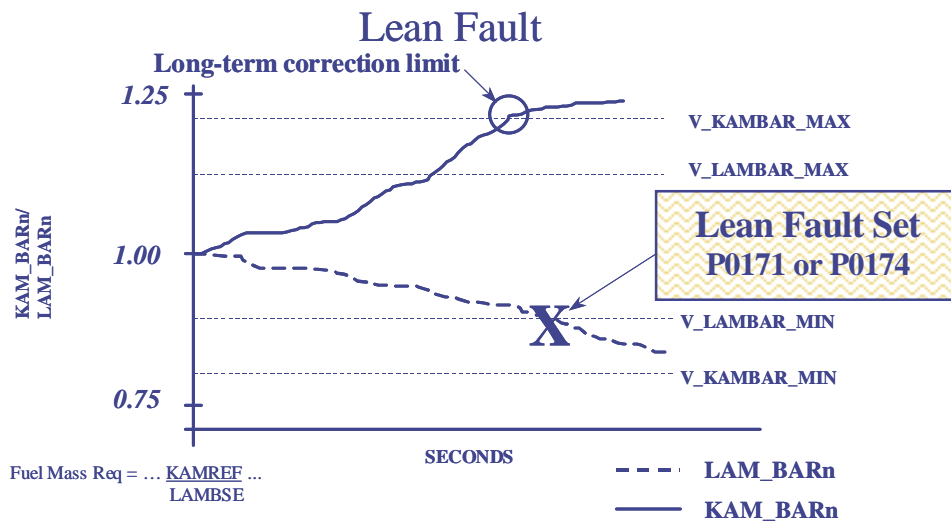
P0443 (Vapor Management Valve Circuit): open/shorted at 0 and 100% duty cycle
P1451 or P0446 (Canister Vent Solenoid Circuit): open/shorted
P0452 (Fuel Tank Pressure Sensor Circuit Low): < -17.82 in H₂O
P0453 (Fuel Tank Pressure Sensor Circuit High): > 16.06 in H₂O
P0451 (Fuel Tank Pressure Sensor Circuit Noisy): > 14 in H₂O change between samples, sampled every 10 seconds, more than 100 fault occurrences
P0460 or P0462 (Fuel Level Input Circuit Low): < 5 ohms
P0460 or P0463 (Fuel Level Input Circuit High): > 200 ohms
P0460 (Fuel Level Input Stuck): > 20% difference in calculated fuel tank capacity consumed versus change in fuel level input reading)
P0461 (Fuel Level Input Noisy): > 100 circuit low or circuit high exceedences, sampled every 0.100 seconds

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 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.

Note that in the PCM, both long and short-term fuel trim are multipliers in the fuel pulse width equation. Scan tools normally display fuel trim as percent adders. If there were no correction required, a scan tool would display 0% even though the PCM was actually using a multiplier of 1.0 in the fuel pulse width equation.

$$\text{Fuel Mass} = \frac{\text{Air Mass} * \text{Long-term Fuel Trim}}{\text{Short-term Fuel Trim} * 14.64}$$



Fuel Monitor Operation:	
DTCs	P0171 Bank 1 Lean, P0174 Bank 2 Lean P0172 Bank 1 Rich, P0175 Bank 2 Rich
Monitor execution	continuous while in closed loop fuel
Monitor Sequence	none
Sensors OK	Fuel Rail Pressure (if available)
Monitoring Duration	2 seconds to register malfunction

Typical fuel monitor entry conditions:		
Entry condition	Minimum	Maximum
RPM Range	idle	4,000 rpm
Air Mass Range	0.75 lb/min	
Purge Duty cycle	0%	0%

Typical fuel monitor malfunction thresholds:
Long Term Fuel Trim correction cell currently being utilized in conjunction with Short Term Fuel Trim: Lean malfunction: LONGFT > 25%, SHRTFT > 5% Rich malfunction: LONGFT < 25%, SHRTFT < 10%

HO2S Monitor

Front HO2S Signal

The time between HO2S switches is monitored after vehicle startup and during closed loop fuel conditions. Excessive time between switches or no switches since startup 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 or P2195, P1151 or P2197), or always indicates rich (P1132 or P2196, P1152 or P2198).

2003 MY vehicles will monitor the HO2S signal for high voltage, in excess of 1.5 volts and store a unique DTC. (P0132, P0152). An over voltage condition is caused by a HO2S heater or battery power short to the HO2S signal line.

HO2S "Lack of Switching" Operation:	
DTCs	P1131 or P2195 - Lack of switching, sensor indicates lean, Bank 1 P1132 or P2196 - Lack of switching, sensor indicates rich, Bank 1 P0132 Over voltage, Bank 1 P1151 or P2197 - Lack of switching, sensor indicates lean, Bank 2 P1152 or P2198 - Lack of switching, sensor indicates rich, Bank 2 P0152 Over voltage, Bank 2
Monitor execution	continuous, from startup and while in closed loop fuel
Monitor Sequence	None
Sensors OK	TP, MAF, ECT, IAT, FTP
Monitoring Duration	30 to 60 seconds to register a malfunction

Typical HO2S "Lack of Switching" entry conditions:		
Entry condition	Minimum	Maximum
Closed Loop Requested		
Engine Load	20%	60%
Time since engine start-up	180 seconds	
Inferred Exhaust Temperature	800 °F	

Typical HO2S "Lack of Switching" malfunction thresholds:
< 5 switches since startup after 30 seconds in test conditions
> 60 seconds since last switch while closed loop

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 calibratable 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.

HO2S Response Rate Operation:	
DTCs	P0133 (slow response Bank 1) P0153 (slow response Bank 2)
Monitor execution	once per driving cycle
Monitor Sequence	None
Sensors OK	ECT, IAT, MAF, VSS, CKP, TP, CMP, no misfire DTCs, FRP
Monitoring Duration	4 seconds

Typical HO2S response rate entry conditions:		
Entry condition	Minimum	Maximum
Short Term Fuel Trim Range	70%	130%
Engine Coolant Temp	150 °F	240 °F
Intake Air Temp		140 °F
Engine Load	20%	50%
Vehicle Speed	30 mph	60 mph
Engine RPM	1000 rpm	2000 rpm
Time since entering closed loop fuel	10 seconds	

Typical HO2S response rate malfunction thresholds:
Voltage amplitude: < 0.5 volts

J1979 Front HO2S Mode \$06 Data			
Test ID	Comp ID	Description for J1850	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
Monitor ID	Test ID	Description for CAN	
\$01	\$80	HO2S11 voltage amplitude and voltage threshold	Volts
\$01	\$01	H02S11 sensor switch-point voltage	Volts
\$05	\$80	HO2S21 voltage amplitude and voltage threshold	Volts
\$05	\$01	H02S21 sensor switch-point voltage	Volts
Conversion for Test IDs \$01 through \$03: multiply by 0.00098 to get volts			

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 calibratable 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.

2003 MY vehicles 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.

Some 2003 Partial Zero Emission Vehicles (PZEV) will utilize three sets of HO2S sensors. The front sensors (HO2S11/HO2S21) are the primary fuel control sensors. The next sensors downstream in the exhaust are utilized to monitor the light-off catalyst (HO2S12/HO2S22). The last sensors downstream in the exhaust (HO2S13/HO2S23) are utilized for very long term fuel trim in order to optimize catalyst efficiency (Fore Aft Oxygen Sensor Control). Ford's first PZEV vehicle uses a 4-cylinder engine so only the Bank 1 DTCs are utilized.

Rear HO2S Check Operation:	
DTCs Sensor 2	P0136 HO2S12 No activity or P2270 HO2S12 Signal Stuck Lean P2271 HO2S12 Signal Stuck Rich P0138 HO2S12 Over voltage P0156 HO2S22 No activity or P2272 HO2S22 Signal Stuck Lean P2273 HO2S22 Signal Stuck Rich P0158 HO2S22 Over voltage
DTCs Sensor 3	P2274 HO2S13 Signal Stuck Lean P2275 HO2S13 Signal Stuck Rich P0144 HO2S13 Over voltage P2276 HO2S23 Signal Stuck Lean P2277 HO2S23 Signal Stuck Rich P0164 HO2S23 Over voltage
Monitor execution	once per driving cycle for activity test, continuous for over voltage test
Monitor Sequence	none
Sensors OK	
Monitoring Duration	continuous until monitor completed

Typical Rear HO2S check entry conditions:

Entry condition	Minimum	Maximum
Inferred exhaust temperature range	400 °F	1400 °F
Rear HO2S heater-on time	120 seconds	
Throttle position	Part throttle	
Engine RPM (forced excursion only)	1000 rpm	2000 rpm

Typical Rear HO2S check malfunction thresholds:

Does not exceed rich and lean threshold envelope:

Rich < 0.25 to 0.50 volts

Lean > 0.40 to 0.65 volts

J1979 Rear HO2S Mode \$06 Data

Test ID	Comp ID	Description for J1850	Units
\$03	\$02	Downstream O2 sensor switch-point voltage	volts
Conversion for Test ID \$03: multiply by 0.00098 to get volts			
Monitor ID	Test ID	Description for CAN	
\$02	\$01	HO2S12 sensor switch-point voltage	volts
\$06	\$01	HO2S22 sensor switch-point voltage	volts
\$03	\$01	HO2S13 sensor switch-point voltage	volts
\$07	\$01	HO2S23 sensor switch-point voltage	volts

HO2S Heaters, front and rear

The HO2S heaters are monitored for proper voltage and current. A HO2S heater voltage fault is determined by turning the heater on and off and looking for corresponding voltage change in the heater output driver circuit in the PCM.

A separate current-monitoring circuit monitors heater current once per driving cycle. The heater current is actually sampled three times. If the current value for two of the three samples falls below a calibratable threshold, the heater is assumed to be degraded or malfunctioning. (Multiple samples are taken for protection against noise on the heater current circuit.)

HO2S Heater Monitor Operation:	
DTCs	Sensor 1 - P0135 Bank 1, P0155 Bank 2 Sensor 2 - P0141 Bank 1, P0161 Bank 2 Sensor 3 - P0055 Bank 1, P0061 Bank 2
Monitor execution	once per driving cycle for heater current, continuous for voltage monitoring
Monitor Sequence	heater voltage check is done prior to heater current check
Sensors OK	
Monitoring Duration	< 5 seconds

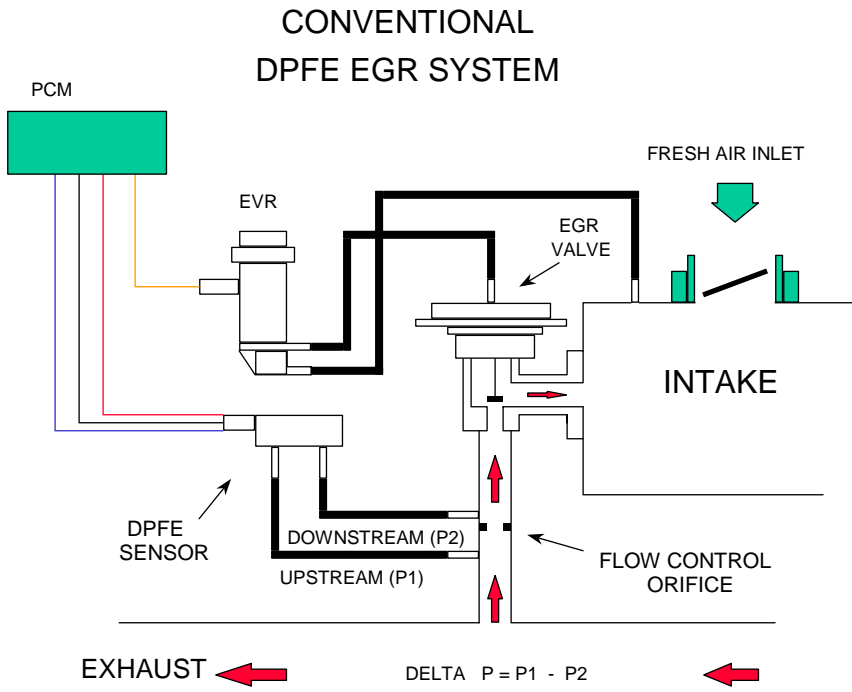
Typical HO2S heater monitor entry conditions:		
Entry condition	Minimum	Maximum
Inferred exhaust temperature range	250 °F	1400 °F
HO2S heater-on time	120 seconds	

Typical HO2S heater check malfunction thresholds:	
Smart driver status indicated malfunction	
Heater current outside limits:	<ul style="list-style-type: none"> < 0.220 amps or > 3 amps, (NTK) < 0.400 amps or > 3 amps, (Bosch) < 0.465 amps or > 3 amps, (NTK Fast Light Off) < 0.230 amps or > 3 amps, (Bosch Fast Light Off)

J1979 HO2S Heater Mode \$06 Data			
Test ID	Comp ID	Description for J1850	Units
\$04	\$11	Maximum HO2S11 Heater Current	Amps
\$04	\$11	Minimum HO2S11 Heater Current	Amps
\$04	\$21	Maximum HO2S21 Heater Current	Amps
\$04	\$21	Minimum HO2S21 Heater Current	Amps
\$04	\$12	Maximum HO2S12 Heater Current	Amps
\$04	\$12	Minimum HO2S12 Heater Current	Amps
\$04	\$22	Maximum HO2S22 Heater Current	Amps
\$04	\$22	Minimum HO2S22 Heater Current	Amps
Conversion for Test IDs \$04: multiply by 0.003906 to get amps			
Monitor ID	Test ID	Description for CAN	Units
\$01	\$81	HO2S11 Heater Current	Amps
\$05	\$81	HO2S21 Heater Current	Amps
\$02	\$81	HO2S12 Heater Current	Amps
\$06	\$81	HO2S22 Heater Current	Amps
\$03	\$81	HO2S13 Heater Current	Amps
\$07	\$81	HO2S23 Heater Current	Amps

DPFE EGR System Monitor

The Delta Pressure Feedback EGR system is a closed loop EGR control system that uses Delta Pressure Feedback EGR sensor (DPFE) to measure EGR flow across an orifice in the EGR tube. When the EGR valve is open, a pressure differential is created across the orifice and measured by the DPFE sensor. This DPFE measurement is used to control the EGR vacuum regulator (EVR), which provides vacuum to open and modulate the EGR valve itself.



The Delta Pressure Feedback EGR Monitor is a series of electrical tests and functional tests that monitor various aspects of EGR system operation.

First, the Delta Pressure Feedback EGR (DPFE) sensor input circuit is checked for out of range values (P1400 or P0405, P1401 or P0406). The Electronic Vacuum Regulator (EVR) output circuit is checked for opens and shorts (P1409 or P0403).

DPFE EGR Electrical Check Operation:	
DTCs	P1400 or P0405 - DPFE Circuit Low P1401 or P0406 - DPFE Circuit High P1409 or P0403 - EVR circuit open or shorted
Monitor execution	Continuous, during EGR monitor
Monitor Sequence	None
Sensors OK	
Monitoring Duration	4 seconds to register a malfunction

Typical DPFE EGR electrical check entry conditions:
EGR system enabled

Typical DPFE EGR electrical check malfunction thresholds:
DPFE sensor outside voltage: > 4.96 volts, < 0.0489 volts
EVR solenoid smart driver status indicates open/short

The DPFE sensor is a ceramic, capacitive-type pressure transducer that monitors the differential pressure across a metering orifice located in the orifice tube assembly. The differential pressure feedback sensor receives this signal through two hoses referred to as the downstream pressure hose (REF SIGNAL) and upstream pressure hose (HI SIGNAL). The HI and REF hose connections are marked on the aluminum DPFE sensor housing for identification (note that the HI signal uses a larger diameter hose). There are two styles of DPFE sensors. The newer, plastic housing utilizes a 1.0-volt offset (zero reading) whereas the older, aluminum housing utilizes either a 0.5-volt or 1.0-volt offset. See the ESM EGR section for the 0.5-volt offset transfer function. The slopes for either offset are identical.

DPFE Sensor Transfer Function		
DPFE volts = $V_{ref} [(0.683 * \text{Delta Pressure}) + 20] / 100$		
Volts	A/D Counts in PCM	Delta Pressure, Inches H ₂ O
0.0489	10	-27.9
0.76	156	-7.0
1.0	204	0
1.24	254	7.0
2.02	415	30
3.05	624	60
4.07	834	90
4.96	1015	116

Note: EGR normally has large amounts of water vapor that are the result of the engine combustion process. During cold ambient temperatures, under some circumstances, water vapor can freeze in the DPFE sensor, hoses, as well as other components in the EGR system. In order to prevent MIL illumination for temporary freezing, the following logic is used:

If an EGR system malfunction is detected above 32 °F, the EGR system and the EGR monitor is disabled for the current driving cycle. A DTC is stored and the MIL is illuminated if the malfunction has been detected on two consecutive driving cycles.

If an EGR system malfunction is detected below 32 °F, only the EGR system is disabled for the current driving cycle. A DTC is not stored and the I/M readiness status for the EGR monitor will not change. The EGR monitor, however, will continue to operate. If the EGR monitor determined that the malfunction is no longer present (i.e., the ice melts), the EGR system will be enabled and normal system operation will be restored.

The differential pressure indicated by the DPFE sensor is also checked at idle with zero requested EGR flow to perform the high flow check. If the differential pressure exceeds a calibratable limit, it indicates a stuck open EGR valve or debris temporarily lodged under the EGR valve seat (P0402).

DPFE EGR Stuck open Check Operation:	
DTCs	P0402
Monitor execution	once per driving cycle
Monitor Sequence	Done after electrical tests
Sensors OK	CPS, ECT, IAT, MAF, TP
Monitoring Duration	10 seconds to register a malfunction

Typical DPFE EGR stuck open check entry conditions:		
Entry Condition	Minimum	Maximum
EVR dutycycle (EGR commanded off)	0%	0%
Engine RPM (after EGR enabled)	at idle	Idle

Typical DPFE EGR stuck open check malfunction thresholds:
DPFE sensor voltage at idle versus engine-off signal: > 0.6 volts

J1979 DPFE EGR Stuck Open Mode \$06 Data			
Test ID	Comp ID	Description for J1850	Units
\$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			
Monitor ID	Test ID	Description for CAN Conventional DPFE	Units
\$31	\$84	Delta pressure for stuck open test and threshold	kPa

On conventional Delta PFE systems, after the vehicle is started, during vehicle acceleration, the differential pressure indicated by the DPFE sensor at zero EGR flow is checked to ensure that both hoses to the DPFE sensor are connected. Under this condition, the differential pressure should be zero. If the differential pressure indicated by the DPFE sensor exceeds a maximum positive threshold, a downstream DPFE hose malfunction is indicated (P1406). If the differential pressure falls below a minimum negative threshold, an upstream DPFE hose malfunction is indicated (P1405).

DPFE EGR Hose Check Operation:	
DTCs	P1405 - Upstream Hose Off or Plugged P1406 – Downstream Hose Off or Plugged
Monitor execution	once per driving cycle
Monitor Sequence	After P0402 test completed
Sensors OK	MAF
Monitoring Duration	4 seconds to register a malfunction

Typical DPFE EGR hose check entry conditions:		
Entry Condition	Minimum	Maximum
EVR dutycycle (EGR commanded off)	0%	0%
Mass Air Flow		8 lb/min
Inferred exhaust backpressure	13 in H ₂ O	

Typical DPFE EGR hose check malfunction thresholds:
DPFE sensor voltage: < 7 in H ₂ O, > 7 in H ₂ O

J1979 DPFE EGR Hose Check Mode \$06 Data			
Test ID	Comp ID	Description for J1850	Units
\$42	\$11	Delta pressure for upstream hose test and threshold	in. H ₂ O
\$42	\$12	Delta pressure for downstream hose test and threshold	in. H ₂ O
Conversion for Test ID \$42: Take value, subtract 32,768, and then multiply result by 0.0078 to get inches of H ₂ O. The result can be positive or negative.			
Monitor ID	Test ID	Description for CAN Conventional DPFE	
\$31	\$80	Delta pressure for upstream hose test and threshold	kPa
\$31	\$81	Delta pressure for downstream hose test and threshold	kPa

After the vehicle has warmed up and normal EGR rates are being commanded by the PCM, the low flow check is performed. Since the EGR system is a closed loop system, the EGR system will deliver the requested EGR flow as long as it has the capacity to do so. If the EVR duty cycle is very high (greater than 80% duty cycle), the differential pressure indicated by the DPFE sensor is evaluated to determine the amount of EGR system restriction. If the differential pressure is below a calibratable threshold, a low flow malfunction is indicated (P0401).

EGR Flow Check Operation:	
DTCs	P0401 – Insufficient Flow
Monitor execution	once per driving cycle
Monitor Sequence	Done after hose tests for conventional DPFE, after P0402 for ESM
Sensors OK	CPS, ECT, IAT, MAF, TP
Monitoring Duration	70 seconds to register a malfunction

Typical EGR flow check entry conditions:		
Entry Condition	Minimum	Maximum
EVR Dutycycle	80%	100%
Engine RPM		2500 rpm
Mass Air Flow Rate of Change		6% program loop
Inferred manifold vacuum	6 in Hg	10 in Hg

Typical EGR flow check malfunction thresholds:
DPFE sensor voltage: < 6 in H ₂ O

J1979 EGR Flow Check Mode \$06 Data			
Test ID	Comp ID	Description for J1850	Units
\$49	\$30	Delta pressure for flow test and threshold	in. H ₂ O
\$4B	\$30	EVR dutycycle for flow test and threshold	percent
Conversion for Test ID \$4B: multiply by 0.0000305 to get percent dutycycle.			
Conversion for Test ID \$49: Take value, subtract 32,768, then multiply result by 0.0078 to get inches of H ₂ O. The result can be positive or negative.			
Monitor ID	Test ID	Description for CAN Conventional DPFE	Units
\$31	\$85	Delta pressure for flow test and threshold	kPa

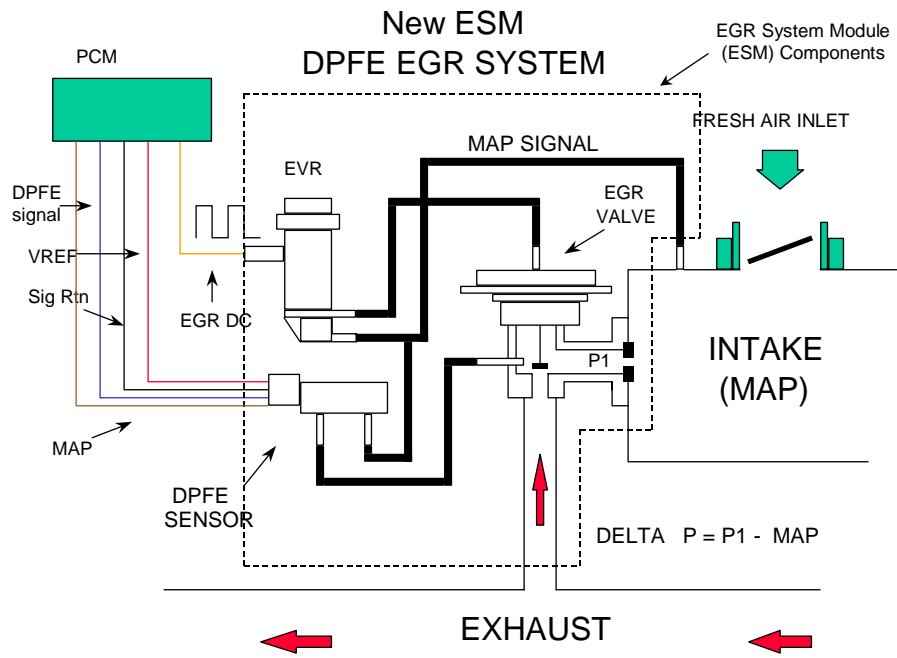
I/M Readiness Indication

If the inferred ambient temperature is less than 32 °F, or greater than 140 °F, or the altitude is greater than 8,000 feet (BARO < 22.5 "Hg), the EGR monitor cannot be run reliably. In these conditions, a timer starts to accumulate the time in these conditions. If the vehicle leaves these extreme conditions, the timer starts decrementing, and, if conditions permit, will attempt to complete the EGR flow monitor. If the timer reaches 500 seconds, the EGR monitor is disabled for the remainder of the current driving cycle and the EGR Monitor I/M Readiness bit will be set to a "ready" condition after one such driving cycle. Starting in the 2002 MY, vehicles will require two such driving cycles for the EGR Monitor I/M Readiness bit to be set to a "ready" condition.

Note: A few 2001 and 2002 MY vehicles do have the above-described bypass logic. If an EGR malfunction is detected below 32 °F, and the EGR system/monitor has been disabled, the EGR Monitor I/M Readiness bit will retain its current status (possibly "not ready" if DTCs had been recently erased).

ESM DPFE EGR System Monitor

In the 2002.5 MY, Ford will introduce a revised DPFE system. It functions in the same manner as the conventional DPFE system, however, the various system components have been combined into a single component called the EGR System Module (ESM). This arrangement increases system reliability while reducing cost. By relocating the EGR orifice from the exhaust to the intake, the downstream pressure signal measures Manifold Absolute Pressure (MAP). The ESM will provide the PCM with a differential DPFE signal, identical to the conventional DPFE system. The DPFE signal is obtained by electrically subtracting the MAP and P1 pressure signals and providing this signal to the DPFE input on the PCM. 2003 MY and later implementation of the ESM system will add a separate input to the PCM for the MAP sensor signal.



The ESM Delta Pressure Feedback EGR Monitor is a series of electrical tests and functional tests that monitor various aspects of EGR system operation.

First, the Delta Pressure Feedback EGR (DPFE) sensor input circuit is checked for out of range values (P1400 or P0405, P1401 or P0406). The Electronic Vacuum Regulator (EVR) output circuit is checked for opens and shorts (P1409 or P0403).

EGR Electrical Check Operation:	
DTCs	P1400 or P0405 - DPFE Circuit Low P1401 or P0406 - DPFE Circuit High P1409 or P0403 - EVR circuit open or shorted
Monitor execution	Continuous, during EGR monitor
Monitor Sequence	None
Sensors OK	
Monitoring Duration	4 seconds to register a malfunction

Typical EGR electrical check entry conditions:
EGR system enabled

Typical EGR electrical check malfunction thresholds:
DPFE sensor outside voltage: > 4.96 volts, < 0.0489 volts EVR solenoid smart driver status indicates open/short

DPFE Sensor Transfer Function		
ESM DPFE volts = $V_{ref} [(0.683 * \text{Delta Pressure}) + 10] / 100$		
Volts	A/D Counts in PCM	Delta Pressure, Inches H ₂ O
0.0489	10	-13.2
0.26	156	-7.0
0.5	204	0
0.74	254	7.0
1.52	415	30
2.55	624	60
3.57	834	90
4.96	1015	130.7

Note: EGR normally has large amounts of water vapor that are the result of the engine combustion process. During cold ambient temperatures, under some circumstances, water vapor can freeze in the DPFE sensor, hoses, as well as other components in the EGR system. In order to prevent MIL illumination for temporary freezing, the following logic is used:

If an EGR system malfunction is detected above 32 °F, the EGR system and the EGR monitor is disabled for the current driving cycle. A DTC is stored and the MIL is illuminated if the malfunction has been detected on two consecutive driving cycles.

If an EGR system malfunction is detected below 32 °F, only the EGR system is disabled for the current driving cycle. A DTC is not stored and the I/M readiness status for the EGR monitor will not change. The EGR monitor, however, will continue to operate. If the EGR monitor determined that the malfunction is no longer present (i.e., the ice melts), the EGR system will be enabled and normal system operation will be restored.

The ESM may provide the PCM with a separate, analog Manifold Absolute Pressure Sensor (MAP) signal. For the 2003 MY, the MAP signal has limited use within the PCM. It may be used to read BARO (key on, updated at high load conditions while driving) or to modify requested EGR rates. Note that if the MAP pressure-sensing element fails in the ESM fails, the DPFE signal is also affected. Therefore, this MAP test is only checking the circuit from the MAP sensing element to the PCM.

The MAP sensor is checked for opens, shorts, or out-of-range values by monitoring the analog-to-digital (A/D) input voltage.

MAP Sensor Check Operation	
DTCs	P0107 (low voltage), P0108 (high voltage)
Monitor execution	continuous
Monitor Sequence	None
Sensors OK	not applicable
Monitoring Duration	5 seconds to register a malfunction

MAP electrical check entry conditions:
Battery voltage > 11.0 volts

Typical MAP sensor check malfunction thresholds:
Voltage < 0.024 volts or voltage > 4.96 volts

On ESM DPFE systems, after the vehicle is started, the differential pressure indicated by the ESM DPFE sensor at idle, at zero EGR flow is checked to ensure that both hoses to the ESM DPFE sensor are connected. At idle, the differential pressure should be zero (both hoses see manifold pressure). If the differential pressure indicated by the ESM DPFE sensor exceeds a maximum threshold or falls below a minimum threshold, an upstream or downstream hose malfunction is indicated (P1405, P1406).

ESM DPFE EGR Hose Check Operation:	
DTCs	P1405 - Upstream Hose Off or Plugged P1406 – Downstream Hose Off or Plugged
Monitor execution	once per driving cycle
Monitor Sequence	after electrical checks completed
Sensors OK	MAF
Monitoring Duration	10 seconds to register a malfunction

Typical ESM DPFE EGR hose check entry conditions:		
Entry Conditions	Minimum	Maximum
EVR dutycycle (EGR commanded off)	0%	0%
Closed throttle (warm engine idle)		
Engine Coolant Temperature	150 °F	220 °F

Typical ESM EGR hose check malfunction thresholds:
DPFE sensor voltage: < -0.122 volts (-11.06 in H ₂ O), > 4.69 volts (122.82 in H ₂ O)

J1979 Mode \$06 Data			
Test ID	Comp ID	Description for J1850	Units
\$43	\$11	Delta pressure sensor voltage for upstream hose test and threshold	volts
\$43	\$12	Delta pressure sensor voltage for downstream hose 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			
Monitor ID	Test ID	Description for CAN ESM DPFE	
\$32	\$82	Delta pressure for upstream hose test and threshold	kPa
\$32	\$83	Delta pressure for downstream hose test and threshold	kPa

Next, the differential pressure indicated by the DPFE sensor is also checked at idle with zero requested EGR flow to perform the high flow check. If the differential pressure exceeds a calibratable limit, it indicates a stuck open EGR valve or debris temporarily lodged under the EGR valve seat (P0402).

EGR Stuck open Check Operation:	
DTCs	P0402
Monitor execution	once per driving cycle
Monitor Sequence	done after hose tests completed
Sensors OK	CPS, ECT, IAT, MAF, TP
Monitoring Duration	10 seconds to register a malfunction

Typical EGR stuck open check entry conditions:		
Entry Condition	Minimum	Maximum
EVR dutycycle (EGR commanded off)	0%	0%
Engine RPM (after EGR enabled)	at idle	Idle

Typical EGR stuck open check malfunction thresholds:
DPFE sensor voltage at idle versus engine-off signal: > 0.6 volts

J1979 Mode \$06 Data			
Test ID	Comp ID	Description for J1850	Units
\$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			
Monitor ID	Test ID	Description for CAN ESM DPFE	Units
\$32	\$84	Delta pressure for stuck open test and threshold	kPa

After the vehicle has warmed up and normal EGR rates are being commanded by the PCM, the low flow check is performed. Since the EGR system is a closed loop system, the EGR system will deliver the requested EGR flow as long as it has the capacity to do so. If the EVR duty cycle is very high (greater than 80% duty cycle), the differential pressure indicated by the DPFE sensor is evaluated to determine the amount of EGR system restriction. If the differential pressure is below a calibratable threshold, a low flow malfunction is indicated (P0401).

EGR Flow Check Operation:	
DTCs	P0401 – Insufficient Flow
Monitor execution	once per driving cycle
Monitor Sequence	done after P0402 completed
Sensors OK	CPS, ECT, IAT, MAF, TP
Monitoring Duration	70 seconds to register a malfunction

Typical EGR flow check entry conditions:		
Entry Condition	Minimum	Maximum
EVR Dutycycle	80%	100%
Engine RPM		2500 rpm
Mass Air Flow Rate of Change		6% program loop
Inferred manifold vacuum	6 in Hg	10 in Hg

Typical EGR flow check malfunction thresholds:
DPFE sensor voltage: < 6 in H ₂ O

J1979 Mode \$06 Data			
Test ID	Comp ID	Description for J1850	Units
\$49	\$30	Delta pressure for flow test and threshold	in. H ₂ O
\$4B	\$30	EVR dutycycle for flow test and threshold	percent
Conversion for Test ID \$4B: multiply by 0.0000305 to get percent dutycycle.			
Conversion for Test ID \$49: Take value, subtract 32,768, then multiply result by 0.0078 to get inches of H ₂ O. The result can be positive or negative.			
Monitor ID	Test ID	Description for CAN ESM DPFE	Units
\$32	\$85	Delta pressure for flow test and threshold	kPa

I/M Readiness Indication

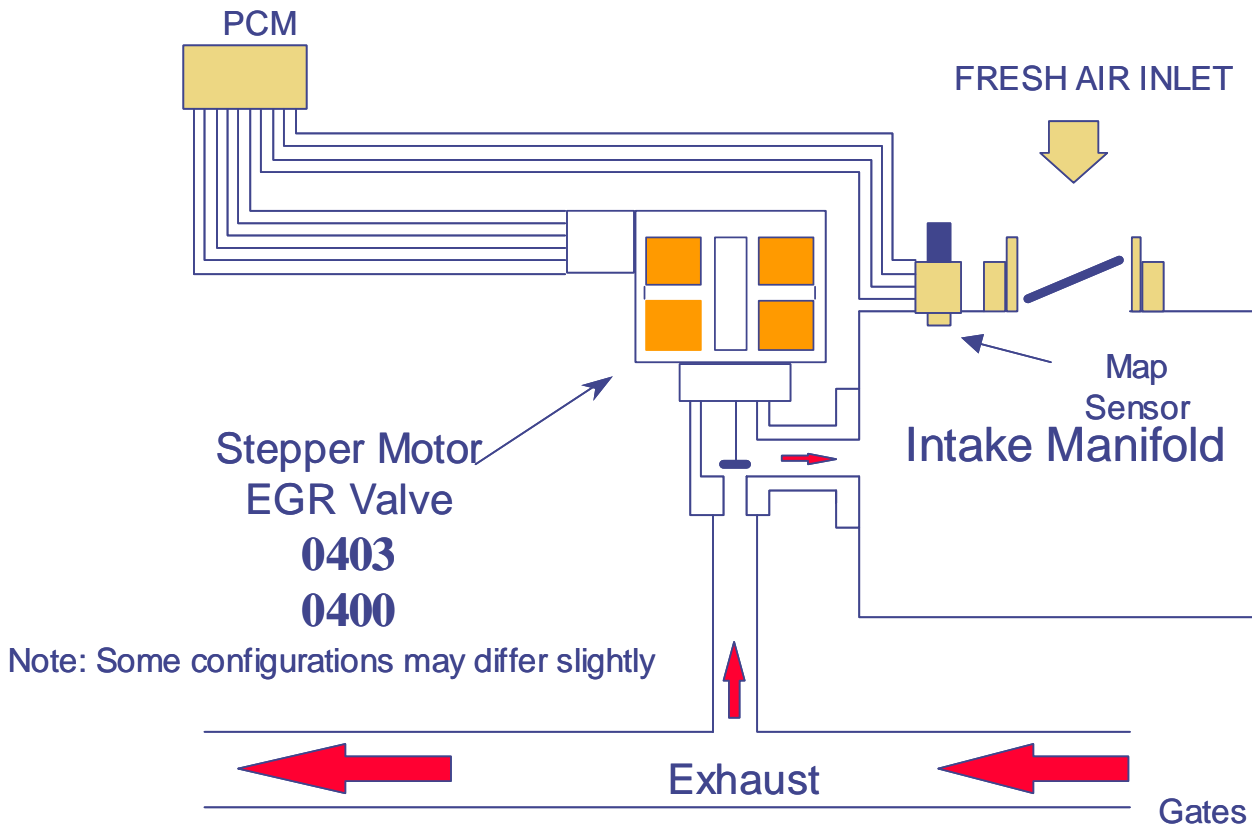
If the inferred ambient temperature is less than 32 °F, or greater than 140 °F, or the altitude is greater than 8,000 feet (BARO < 22.5 "Hg), the EGR monitor cannot be run reliably. In these conditions, a timer starts to accumulate the time in these conditions. If the vehicle leaves these extreme conditions, the timer starts decrementing, and, if conditions permit, will attempt to complete the EGR flow monitor. If the timer reaches 500 seconds, the EGR monitor is disabled for the remainder of the current driving cycle and the EGR Monitor I/M Readiness bit will be set to a "ready" condition after one such driving cycle. Starting in the 2002 MY, vehicles will require two such driving cycles for the EGR Monitor I/M Readiness bit to be set to a "ready" condition.

Note: A few 2001 and 2002 MY vehicles do have the above-described bypass logic. If an EGR malfunction is detected below 32 °F, and the EGR system/monitor has been disabled, the EGR Monitor I/M Readiness bit will retain its current status (possibly "not ready" if DTCs had been recently erased).

Stepper Motor EGR System Monitor

The Electric Stepper Motor EGR System uses an electric stepper motor to directly actuate an EGR valve rather than using engine vacuum and a diaphragm on the EGR valve. The EGR valve is controlled by commanding from 0 to 52 discrete increments or "steps" to get the EGR valve from a fully closed to fully open position. The position of the EGR valve determines the EGR flow. Because there is no EGR valve position feedback, monitoring for proper EGR flow requires the addition of a MAP sensor.

Stepper Motor EGR System



The Stepper Motor EGR Monitor consists of an electrical and functional test that checks the stepper motor and the EGR system for proper flow.

The stepper motor electrical test is a continuous check of the four electric stepper motor coils and circuits to the PCM. A malfunction is indicated if an open circuit, short to power, or short to ground has occurred in one or more of the stepper motor coils for a calibrated period of time. If a malfunction has been detected, the EGR system will be disabled, and additional monitoring will be suspended for the remainder of the driving cycle, until the next engine start-up.

EGR Stepper Monitor Electrical Check Operation:	
DTCs	P0403
Monitor execution	continuous
Monitor Sequence	none
Sensors OK	
Monitoring Duration	4 seconds to register a malfunction

Stepper motor electrical check entry conditions:
Battery voltage > 11.0 volts

Typical EGR electrical check malfunction thresholds:
“Smart” Coil Output Driver status indicates open or short to ground, or short to power

EGR flow is monitored using an analog Manifold Absolute Pressure Sensor (MAP). If a malfunction has been detected in the MAP sensor, the EGR monitor will not perform the EGR flow test.

The MAP sensor is checked for opens, shorts, or out-of-range values by monitoring the analog-to-digital (A/D) input voltage.

MAP Sensor Check Operation	
DTCs	P0107 (low voltage), P0108 (high voltage)
Monitor execution	continuous
Monitor Sequence	none
Sensors OK	not applicable
Monitoring Duration	5 seconds to register a malfunction

MAP electrical check entry conditions:
Battery voltage > 11.0 volts

Typical MAP sensor check malfunction thresholds:
Voltage < 0.024 volts or voltage > 4.96 volts

The MAP sensor is also checked for rational values. The value of inferred MAP is checked against the actual value of MAP at idle, under steady load conditions.

MAP Sensor Rationality Check Operation	
DTCs	P0106
Monitor execution	continuous
Monitor Sequence	None
Sensors OK	not applicable
Monitoring Duration	5 seconds to register a malfunction

Typical MAP Rationality check entry conditions:		
Entry Conditions	Minimum	Maximum
Change in load		5%
Engine rpm	500 rpm	2500 rpm
Closed throttle		

Typical MAP Rationality check malfunction thresholds:
Difference between inferred MAP and actual MAP > 12 in Hg

After the vehicle has warmed up and normal EGR rates are being commanded by the PCM, the EGR flow check is performed. The flow test is performed once per drive-cycle when a minimum amount of EGR is requested and the remaining entry conditions required to initiate the test are satisfied. If a malfunction is detected, the EGR system as well as the EGR monitor is disabled until the next engine start-up.

The EGR flow test is done by observing the behavior of two different values of MAP - the analog MAP sensor reading, and inferred MAP, (MAP calculated from the Mass Air Flow Sensor, throttle position, rpm, BARO, etc.). During normal, steady-state operating conditions, EGR is intrusively commanded on to a specified percentage. Then, EGR is commanded off. If the EGR system is working properly, there is a significant difference in both the observed and the calculated values of MAP, between the EGR-on and the EGR-off states.

When the flow test entry condition have been satisfied, EGR is commanded to flow at a calibrated test rate (about 10%). At this time, the value of MAP is recorded (EGR-On MAP). The value of inferred MAP EGR-On IMAP is also recorded. Next the EGR is commanded off (0%). Again, the value of MAP is recorded (EGR-Off MAP). The value of EGR-Off IMAP is also recorded. Typically, 7 such On/Off samples are taken. After all the samples have been taken, the average EGR-On MAP, EGR-On IMAP, EGR-Off MAP and EGR-Off IMAP values are stored.

Next, the differences between the EGR-On and EGR-Off values are calculated:

$$\begin{aligned} \text{MAP-delta} &= \text{EGR-On MAP} - \text{EGR-Off MAP} && \text{(analog MAP)} \\ \text{IMAP delta} &= \text{EGR-On IMAP} - \text{EGR-Off IMAP} && \text{(inferred MAP)} \end{aligned}$$

If the sum of MAP-delta and IMAP-delta exceeds a maximum threshold or falls below a minimum threshold, a P0400 high or low flow malfunction is registered.

As an additional check, if the EGR-On MAP exceeds a maximum threshold (BARO - a calibrated value), a P0400 low flow malfunction is registered. This test detects reduced EGR flow on systems where the MAP pickup point is not located in the intake manifold, but is located just upstream of the EGR valve, in the EGR delivery tube.

Note: BARO is inferred at engine startup using the KOEO MAP sensor reading. It is updated during high, part-throttle, high rpm engine operation.

EGR Flow Check Operation:	
DTCs	P0400
Monitor execution	once per driving cycle
Monitor Sequence	None
Sensors OK	CPS, ECT, IAT, MAF, MAP, TP, BARO not available yet
Monitoring Duration	15 seconds to register a malfunction (assumes 4 samples)

Typical EGR flow check entry conditions:		
Entry Condition	Minimum	Maximum
Desired EGR Mass Flow	> 0 lb/min	
Engine RPM	1450 rpm	2700 rpm
Inferred Ambient Air Temperature	20 °F	140 °F
Engine Coolant Temperature	164 °F	
Relative Throttle Position	0.09 volts	0.6 volts
Engine Load	42 %	63 %
Vehicle Speed	47 mph	56 mph
Engine RPM Steady (change/0.050 sec)		50 rpm
Throttle Position Steady (change/0.050 sec)		0.024 volts
Engine Load Steady (change/0.050 sec)		1.5 %
BARO	22.5 "Hg	
O2 sensor tests not running: amplitude test, open-loop downstream forced-excursion test		
No accessory state changes:	Neutral/Drive,	
	A/C On/Off,	
	Low Speed Fan On/Off,	
	Power Steering On/Off,	
	High Speed Fan On/Off	

Typical EGR flow check malfunction thresholds:
Sum of MAP-delta and IMAP delta < 0.62 " Hg or
Sum of MAP-delta and IMAP delta > 8.00 " Hg or
EGR-On MAP > BARO – 0

J1979 Mode \$06 Data			
Test ID	Comp ID	Description for J1850	Units
\$4E	\$31	Sum of MAP-delta and IMAP delta and max. threshold	in Hg
\$4E	\$31	Sum of MAP-delta and IMAP delta and min. threshold	in Hg
\$4F	\$00	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.			
Monitor ID	Test ID	Description for CAN	Units
\$33	\$80	Sum of MAP-delta and IMAP delta, min and max thresholds	kPa
\$33	\$81	EGR-On MAP and max threshold	kPa

I/M Readiness Indication

If the inferred ambient temperature is less than 20 °F, greater than 130 °F, or the altitude is greater than 8,000 feet (BARO < 22.5 "Hg), the EGR flow test cannot be reliably done. In these conditions, the EGR flow test is suspended and a timer starts to accumulate the time in these conditions. If the vehicle leaves these extreme conditions, the timer starts decrementing, and, if conditions permit, will attempt to complete the EGR flow monitor. If the timer reaches 500 seconds, the EGR flow test is disabled for the remainder of the current driving cycle and the EGR Monitor I/M Readiness bit will be set to a "ready" condition after one such driving cycle. Starting in the 2002 MY, vehicles will require two such driving cycles for the EGR Monitor I/M Readiness bit to be set to a "ready" condition.

PCV System Monitor

Ford plans to comply with the PCV monitoring requirements by modifying the current PCV system design. The PCV valve will be installed into the rocker cover using a quarter-turn cam-lock design to prevent accidental disconnection. High retention force molded plastic lines will be used from the PCV valve to the intake manifold. The diameter of the lines and the intake manifold entry fitting will be increased so that inadvertent disconnection of the lines after a vehicle is serviced will cause either an immediate engine stall or will not allow the engine to be restarted. Some vehicles will incorporate such designs beginning in the 2001 MY. In the event that the vehicle does not stall if the line between the intake manifold and PCV valve is inadvertently disconnected, the vehicle will have a large vacuum leak that will cause the vehicle to run lean at idle. This will illuminate the MIL after two consecutive driving cycles and will store one or more of the following codes: Lack of O2 sensor switches, Bank1 (P1131 or P2195), Lack of O2 sensor switches Bank 2 (P1151 or P2197), Fuel System Lean, Bank1 (P0171), Fuel System Lean, Bank 2 (P0174)

Thermostat Monitor

Ford plans to comply with the thermostat monitoring requirement by using a slightly-modified version of the current "Insufficient temperature for closed-loop" test (P0125 or P0128). If the engine is being operated in a manner that is generating sufficient heat, the engine coolant temperature (ECT) or cylinder head temperature (CHT) should warm up in a predictable manner. A timer is incremented while the engine is at moderate load and vehicle speed is above a calibrated limit. The target/minimum timer value is based on ambient air temperature at start-up. If the timer exceeds the target time and ECT/CHT has not warmed up to the target temperature, a malfunction is indicated. The test runs if the start-up IAT temperature is below the target temperature. A 2-hour engine-off soak time is required to erase a pending or confirmed DTC. This feature prevents false-passes where engine coolant temperature rises after the engine is turned off during a short engine-off soak. The target temperature is calibrated to the thermostat regulating temperature minus 20 °F. For a typical 195 °F thermostat, the warm-up temperature would be calibrated to 175 °F. This test is being phased in starting in the 2000 MY. A vehicle, which is not part of the thermostat monitor phase-in, utilizes a 140 °F warm-up temperature.

Insufficient Temperature for Closed Loop Check Operation:

DTCs	P0125 or P0128
Monitor execution	Once per driving cycle
Monitor Sequence	None
Monitoring Duration	300 to 800 seconds within test entry conditions, based on ambient temperature

Typical P0125/P0128 check entry conditions:

Entry Condition	Minimum	Maximum
Vehicle speed	15 mph	
Intake Air Temp at Start-up	20 °F	Target ECT temp.
Engine Load	30%	
Engine off (soak) time to clear pending/confirmed DTC	2 hours	

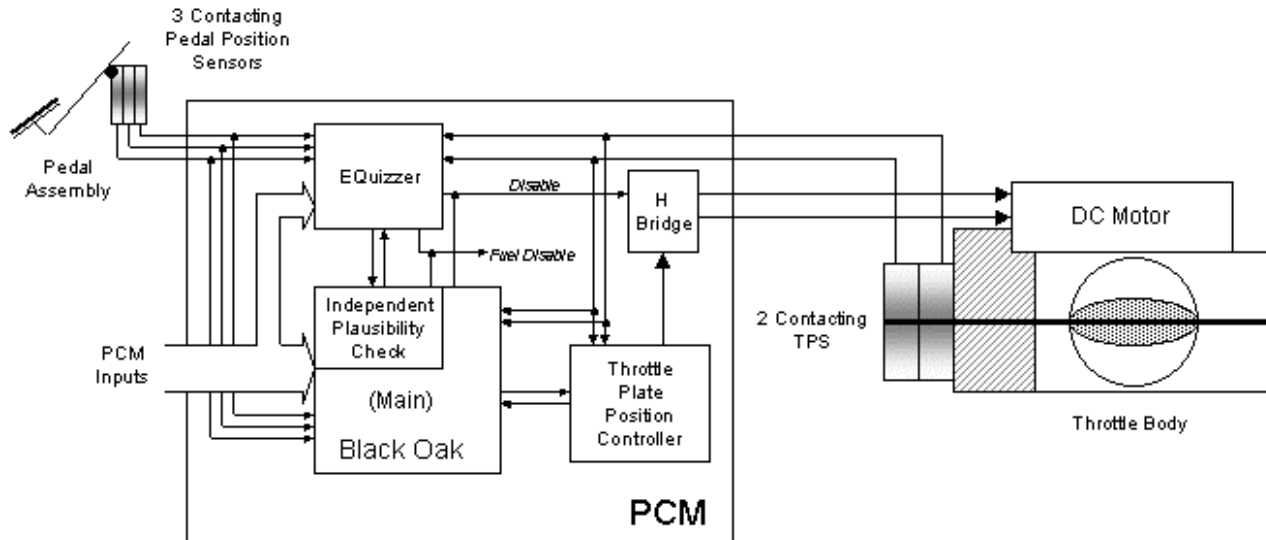
Typical P0125/P0128 check malfunction thresholds:

Time period expired without reaching 175 °F target ECT temperature.

Time period is 300 to 800 seconds based on ambient temperature at start-up.

Electronic Throttle Control

The Gen 2 Electronic Throttle Control system uses a strategy that delivers output shaft torque, based on driver demand, utilizing an electronically controlled throttle body. Gen 2 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 wheel torque. Gen 2 ETC is being introduced on the 2003 MY Lincoln LS and Ford Thunderbird.



Gen 2 ETC

Because safety is a major concern with ETC systems, a complex safety monitor strategy (hardware and software) was developed. The monitor system is distributed across two processors: the main powertrain control processor and a monitoring processor called an Enhanced-Quizzer (E-Quizzer) processor.

The primary monitoring function is performed by the Independent Plausibility Check (IPC) software, which resides on the main processor. It is responsible for determining the driver-demanded torque and comparing it to an estimate of the actual torque delivered. If the generated torque exceeds driver demand by specified amount, the IPC takes appropriate mitigating action.

Since the IPC and main controls share the same processor, they are subject to a number of potential, common-failure modes. Therefore, the E-Quizzer processor was added to redundantly monitor selected PCM inputs and to act as an intelligent watchdog and monitor the performance of the IPC and the main processor. If it determines that the IPC function is impaired in any way, it takes appropriate Failure Mode and Effects Management (FMEM) actions.

ETC System Failure Mode and Effects Management:

Effect	Failure Mode
No Effect on Driveability	A loss of redundancy or loss of a non-critical input could result in a fault that does not affect driveability. The ETC light will turn on, but the throttle control and torque control systems will function normally.
Disable Speed Control	If certain failures are detected, speed control will be disabled. Throttle control and torque control will continue to function normally.
RPM Guard w/ Pedal Follower	In this mode, torque control is disabled due to the loss of a critical sensor or PCM 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 a P2106 is set. EGR, VCT, and IMRC outputs are set to default values.
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 a P2110 is set. EGR, VCT, and IMRC outputs are set to default values.
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 PCM 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 a P2104 is set. EGR, VCT, and IMRC outputs are set to default values.
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 a P2105 is set.
	Note: ETC illuminates or displays a message on the message center immediately, MIL illuminates after 2 driving cycles

Electronic Throttle Monitor

Electronic Throttle Monitor Operation:

DTCs	<p>P0606 - PCM processor failure (MIL, ETC light)</p> <p>P2106 – ETC FMEM – forced limited power; sensor fault: MAF, one TP, CKP, TSS, OSS, stuck throttle, throttle actuator circuit fault (MIL, ETC light)</p> <p>P2110 – ETC FMEM – forced limited rpm; two TPs failed; TPPC detected fault (MIL, ETC light)</p> <p>P2104 – ETC FMEM – forced idle, two or three pedal sensors failed (MIL, ETC light)</p> <p>P2105 – ETC FMEM – forced engine shutdown; EQuizzer detected fault (MIL, ETC light)</p> <p>U0300 – ETC software version mismatch, IPC, EQuizzer or TPPC (MIL, ETC light)</p>
Monitor execution	Continuous
Monitor Sequence	None
Sensors OK	not applicable
Monitoring Duration	< 1 seconds to register a malfunction

Accelerator and Throttle Position Sensor Inputs

Accelerator Pedal Position Sensor Check Operation:	
DTCs	P2122, P2123 – APP D circuit continuity (ETC light, non-MIL) P2121 – APP D range/performance (ETC light, non-MIL) P2138 – APP D / APP E correlation (ETC light, non-MIL) P2127, P2128 – APP E circuit continuity (ETC light, non-MIL) P2126 – APP E range/performance (ETC light, non-MIL) P2140 – APP E / APP F correlation (ETC light, non-MIL) P2132, P2133 – APP F circuit continuity (ETC light, non-MIL) P2131 – APP F range/performance (ETC light, non-MIL) P2139 – APP D / APP F correlation (ETC light, non-MIL)
Monitor execution	continuous
Monitor Sequence	none
Sensors OK	not applicable
Monitoring Duration	< 1 seconds to register a malfunction

APP sensor check malfunction thresholds:
Circuit continuity - Voltage < 0.25 volts or voltage > 4.75 volts
Correlation and range/performance – sensor disagreement between processors (PCM and EQuizzer)

Throttle Position Sensor Check Operation:	
DTCs	P0122, P0123 – TP A circuit continuity (MIL, ETC light) P0121 – TP A range/performance (non-MIL) P2135 – TP A / TP B correlation (ETC light, non-MIL) P0222, P0223 – TP B circuit continuity (MIL, ETC light) P0221 – TP B range/performance (non-MIL)
Monitor execution	Continuous
Monitor Sequence	None
Sensors OK	not applicable
Monitoring Duration	< 1 seconds to register a malfunction

TP sensor check malfunction thresholds:
Circuit continuity - Voltage < 0.25 volts or voltage > 4.75 volts
Correlation and range/performance – sensor disagreement between processors (PCM and EQuizzer), TP inconsistent with TPPC throttle plate position

Throttle Plate Position Controller (TPPC) Outputs

The purpose of the TPPC is to control the throttle position to the desired throttle angle. It is a separate chip embedded in the PCM. The desired angle is communicated from the main CPU via a 312.5 Hz duty cycle signal. The TPPC interprets the duty cycle signal as follows:

0% <= DC < 5% - Out of range, limp home default position.

5% <= DC < 6% - Commanded default position, closed.

6% <= DC < 7% - Commanded default position. Used for key-on, engine off.

7% <= DC < 10% - Closed against hard-stop. Used to learn zero throttle angle position (hard-stop) after key-up

10% <= DC <=92% - Normal operation, between 0 degrees (hard-stop) and 82%, 10% duty cycle = 0 degrees throttle angle, 92% duty cycle = 82 degrees throttle angle.

92% < DC <= 96% - Wide Open Throttle, 82 to 86 degrees throttle angle.

96% < DC <= 100% - Out of Range, limp home default position

The desired angle is relative to the hard-stop angle. The hard-stop angle is learned during each key-up process before the main CPU requests the throttle plate to be closed against the hard-stop. The output of the TPPC is a voltage request to the H-driver (also in PCM). The H driver is capable of positive or negative voltage to the Electronic Throttle Body Motor.

Throttle Plate Controller Check Operation:	
DTCs	P2107 – processor test (MIL) P2111 – throttle actuator system stuck open (MIL,) P2112 – throttle actuator system stuck closed (MIL) P2100 – throttle actuator circuit open, short to power, short to ground (MIL,) P2101 – throttle actuator range/performance test (MIL) 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
Monitoring Duration	< 5 seconds to register a malfunction

Comprehensive Component Monitor - Engine

Engine Inputs

Analog inputs such as Intake Air Temperature (P0112, P0113), Engine Coolant Temperature (P0117, P0118), Cylinder Head Temperature (P1289, P1290), Mass Air Flow (P0102, P0103) and Throttle Position (P0122, P0123, P1120), Fuel Temperature (P0182, P0183), Engine Oil Temperature (P0197, P0198), Fuel Rail Pressure (P0192, P0193) 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 (low input), P0118 (high input)
Monitor execution	continuous
Monitor Sequence	None
Sensors OK	not applicable
Monitoring Duration	5 seconds to register a malfunction

Typical ECT sensor check malfunction thresholds:

Voltage < 0.244 volts or voltage > 4.96 volts

The ECT rationality test checks to make sure that ECT is not stuck high in a range that causes other OBD to be disabled. If after a long soak, ECT is very high (> 230 °F) and is also much higher than IAT at start, it is assumed that ECT is stuck high.

ECT Sensor Rationality Check Operation:

DTCs	P0116 (ECT stuck high)
Monitor execution	Once per driving cycle
Monitor Sequence	None
Sensors OK	ECT, CHT, IAT
Monitoring Duration	100 seconds to register a malfunction

Typical ECT Sensor Rationality check entry conditions:

Entry Condition	Minimum	Maximum
Engine-off time (soak time)	360 min	
Difference between ECT and IAT		50 deg
Engine Coolant Temperature	230 °F	

Typical ECT Sensor Rationality check malfunction thresholds:

Catalyst, Misfire, Fuel System or HO2S Monitors have not run this drive cycle

Currently, vehicles use either an ECT sensor or CHT sensor, not both. The CHT sensor measures cylinder head metal temperature as opposed to engine coolant temperature. At lower temperatures, CHT temperature is equivalent to ECT temperature. At higher temperatures, ECT reaches a maximum temperature (dictated by coolant composition and pressure) whereas CHT continues to indicate cylinder head metal temperature. If there is a loss of coolant or air in the cooling system, the CHT sensor will still provides an accurate measure of cylinder head metal temperature. If a vehicle uses a CHT sensor, the PCM software calculates both CHT and ECT values for use by the PCM control and OBD systems.

Cylinder Head Temperature Sensor Check Operation:	
DTCs	P1289 (high input), P1290 (low input), P1299 (fail-safe cooling activated)
Monitor execution	continuous
Monitor Sequence	none
Sensors OK	not applicable
Monitoring Duration	5 seconds to register a malfunction

Typical CHT sensor check malfunction thresholds:	
Voltage < 0.244 volts or voltage > 4.96 volts	
For P1299, MIL illuminates immediately if CHT > 270 ° Fuel shut-off is activated to reduce engine and coolant temperature	

Intake Air Temperature Sensor Check Operation:	
DTCs	P0112 (low input), P0113 (high input)
Monitor execution	continuous
Monitor Sequence	none
Sensors OK	not applicable
Monitoring Duration	5 seconds to register a malfunction

Typical IAT sensor check malfunction thresholds:	
Voltage < 0.244 volts or voltage > 4.96 volts	

Engine Oil Temperature Sensor Check Operation:	
DTCs	P0197 (low input), P0198 (high input)
Monitor execution	continuous
Monitor Sequence	none
Sensors OK	not applicable
Monitoring Duration	5 seconds to register a malfunction

Typical EOT sensor check malfunction thresholds:	
Voltage < 0.20 volts or voltage > 4.96 volts	

Fuel Rail Pressure Sensor Check Operation:	
DTCs	P0192 (low input), P0193 (high input)
Monitor execution	continuous
Monitor Sequence	None
Sensors OK	not applicable
Monitoring Duration	8 seconds to register a malfunction

Typical FRP sensor check malfunction thresholds:
Voltage < 0.049 volts or voltage > 4.88 volts

The FRP range/performance test checks to make sure that fuel rail pressure can be properly controlled by the electronic returnless fuel system. The FPS sensor is also checked for in-range failures that can be caused by loss of Vref to the sensor. Note that the FRP is referenced to manifold vacuum (via a hose) while the fuel rail pressure sensor is not referenced to manifold vacuum. It uses gage pressure. As a result, a mechanical gage in the fuel rail will display a different pressure than the FPR PID on a scan tool. The scan tool PID will read higher because of manifold vacuum.

FRP Range/Performance Check Operation:	
DTCs	P0191 (FRP range/performance), P1090 (stuck in range)
Monitor execution	Continuous
Monitor Sequence	None
Sensors OK	FRP
Monitoring Duration	8 seconds to register a malfunction

Typical FRP Sensor Range/Performance check entry conditions:		
Entry Condition	Minimum	Maximum
Demand pressure reasonable	35 psig	60 psig
Fuel level	15%	

Typical FRP Range/Performance check malfunction thresholds:
Fuel pressure error (demand – actual pressure) > 40 psig

Typical FRP Sensor Stuck check entry conditions:		
Entry Condition	Minimum	Maximum
FRP sensor input	0 psig	46 psig
FRP input not moving		1 psig / sec

Typical FRP Stuck check malfunction thresholds:
Fuel pressure error (demand – actual pressure) > 5 psig

Throttle Position Sensor Check Operation:	
DTCs	P0122 (low input), P0123 (high input), P1120 (closed throttle too low)
Monitor execution	continuous
Monitor Sequence	none
Sensors OK	not applicable
Monitoring Duration	5 seconds to register a malfunction

Typical TP sensor check malfunction thresholds:
Voltage < 0.20 volts or voltage > 4.80 volts or voltage < 0.488

MAF Sensor Check Operation:	
DTCs	P0102 (low input), P0103 (high input)
Monitor execution	continuous
Monitor Sequence	none
Sensors OK	not applicable
Monitoring Duration	5 seconds to register a malfunction

Typical MAF sensor check malfunction thresholds:
Voltage < 0.244 volts and engine running or voltage > 4.785 volts engine rpm < 4,000 rpm

The MAF and TP sensors are cross-checked to determine whether the sensor readings are rational and appropriate for the current operating conditions. (P1121/P0068)

MAF/TP Rationality Check Operation:	
DTCs	P1121 or P0068
Monitor execution	Continuous
Monitor Sequence	None
Sensors OK	
Monitoring Duration	3 seconds within test entry conditions

Typical MAF/TP rationality check entry conditions:		
Entry Condition	Minimum	Maximum
Engine RPM	1000 rpm	minimum of 3800 rpm
Engine Coolant Temp	100 °F	

Typical MAF/TP rationality check malfunction thresholds:
Load > 60% and TP < 2.4 volts or Load < 30% and TP > 2.4 volts

Miscellaneous

Loss of Keep Alive Memory (KAM) power (a separate wire feeding the PCM) results in a P1633 DTC and immediate MIL illumination on most applications.

Vehicles that require tire/axle information to be programmed into the Vehicle ID block (VID) will store a P1639 if the VID block is not programmed or corrupted.

The PCM "engine off" or "soak" timer is tested to ensure that it is functional.

The value of engine coolant temperature decays after the engine is turned off. This decay is modeled as a function of ECT, IAT and soak time. If, during a cold start, (difference between ECT and IAT is low), the actual ECT at start is much lower than the predicted ECT at start, it means that the soak timer is not functioning and a P0606 DTC is stored. (If the timer fails, it will read zero seconds and the model will predict that ECT will be the same temperature as when the engine was last turned off.)

Ignition

Distributor Ignition systems (TFI) are no longer in production. Electronic Ignition systems (Electronic Distributorless Ignition System - EDIS or Coil on Plug - COP) systems are being used on all applications.

The EDIS system uses a chip to process the 36 (or 40) tooth crankshaft position signal, generate a low data rate PIP signal for the PCM microprocessor and control a 4 or 6 terminal coil pack which fires a pair of spark plugs. One of these sparkplugs is on the compression stroke, while the other is on the exhaust stroke. The EDIS chip can be incorporated within the PCM or in a separate ignition control module.

The COP system also uses an EDIS chip in the same way as described above, however, each sparkplug has its own coil which is fired only once on the compression stroke.

The ignition system is checked by monitoring three ignition signals during normal vehicle operation:

Profile Ignition Pickup (CKP, commonly known as PIP), the timing reference signal derived from the crankshaft 36-tooth wheel and processed by the EDIS chip. PIP is a 50% duty cycle, square wave signal that has a rising edge at 10 deg BTDC.

Camshaft Identification (CMP, commonly known as CID), a signal derived from the camshaft to identify the #1 cylinder

Ignition Diagnostic Monitor (IDM), a signal that indicates that the primary side of the coil has fired. This signal is received as a digital pulse width signal from the EDIS chip. The EDIS chip determines if the current flow to the ignition coil reaches the required current (typically 5.5 Amps for COP, 3.0 to 4.0 Amps for DIS) within a specified time period (typically > 200 microseconds for both COP and DIS). The EDIS chip also outputs status information when the engine is not running.

First, the relationship between successive PIP events is evaluated to determine whether the PIP signal is rational. Too large a change in 3 successive PIP indicates a missing or noisy PIP signal (P0320). Next, the CMP edge count is compared to the PIP edge count. If the proper ratio of CMP events to PIP events is not being maintained (for example, 1 CMP edge for every 8 PIP edges for an 8-cylinder engine), it indicates a missing or noisy CMP signal (P0340). Finally, the relationship between IDM edges and PIP edges is evaluated. If there is not an IDM edge (coil firing) for every PIP edge (commanded spark event), the PCM will look for a pattern of failed IDM events to determine which ignition coil has failed. If the ignition coil cannot be identified or if the engine is running and there are no IDM edges, the IDM circuit is malfunctioning (P1351).

Ignition System Check Operation:	
DTCs	P0320 (CKP), P0340 (CMP) P0351 - P0360 (Coil primary)
Monitor execution	continuous
Monitor Sequence	none
Sensors OK	
Monitoring Duration	< 5 seconds

Typical ignition check entry conditions:		
Entry Condition	Minimum	Maximum
Engine RPM for CKP, CMP	200 rpm	
Engine RPM for coil primary	200 rpm	minimum of 3200 rpm

Typical ignition check malfunction thresholds:
For PIP: Time between PIP edges: > 350 milliseconds
Ratio of current PIP period to last two periods: < 0.75, > 1.75
For CMP: Ratio of PIP events to CMP events: 4:1, 6:1, 8:1 or 10:1 based on engine cyl.
For coils: Ratio of PIP events to IDM events: 1:1

Engine Outputs

The Idle Air Control (IAC) solenoid is checked electrically for open and shorts (P1504 or P0511) and 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 (+100) or low rpm error (-200) greater than the malfunction threshold, an IAC malfunction is indicated. (P1506 or P0507, P1507 or P0506)

IAC Check Operation:	
DTCs	P1504/P0511 (opens/shorts) P1506/P0507 (functional - overspeed) P1507/P0506 (functional - underspeed)
Monitor execution	once per driving cycle
Monitor Sequence	None
Sensors OK	
Monitoring Duration	30 seconds

Typical IAC functional check entry conditions:		
Entry Condition	Minimum	Maximum
Engine Coolant Temp	150 °F	
Time since engine start-up	30 seconds	
Closed loop fuel	Yes	
Throttle Position (at idle, closed throttle, no dashpot)	Closed	Closed

Typical IAC functional check malfunction thresholds:
For underspeed error: Actual rpm 100 rpm below target, closed-loop IAC correction > 1 lb/min
For overspeed error: Actual rpm 200 rpm above target, closed-loop IAC correction < .2 lb/min

Starting in the 2002 MY, some vehicle application will perform a fuel injector continuity test. The PCM will monitor the "smart" driver fault status bit that indicates either an open circuit, short to power or short to ground.

Injector Check Operation:	
DTCs	P0201 through P0210 (opens/shorts)
Monitor execution	Continuous within entry conditions
Monitor Sequence	None
Monitoring Duration	10 seconds

Typical injector circuit check entry conditions:		
Entry Condition	Minimum	Maximum
Battery Voltage	11.0 volts	
Engine Coolant Temp		240 °F
Intake Air Temp		150 °F

Electronic Returnless Fuel Systems (ERFS) utilize a Fuel Pump Driver Module (FPDM) to control fuel pressure. The PCM uses a Fuel Rail Pressure Sensor (FRP) for feedback. The PCM outputs a duty cycle to the FPDM to maintain the desired fuel rail pressure. During normal operation, the PCM will output a FP duty cycle from 5% to 51%. The FPDM will run the fuel pump at twice this duty cycle, e.g. if the PCM outputs a 42% duty cycle, the FPDM will run the fuel pump at 84%. If the PCM outputs a 75% duty cycle, the FPDM will turn off the fuel pump.

The FPDM returns a duty cycled diagnostic signal back to the PCM on the Fuel Pump Monitor (FPM) circuit to indicate if there are any faults in the FPDM.

If the FPDM does not output any diagnostic signal, (0 or 100% duty cycle), the PCM sets a P1233 DTC. This DTC is set if the FPDM loses power. This can also occur if the Inertia Fuel Switch is tripped.

If the FPDM outputs a 25% duty cycle, it means that the fuel pump control duty cycle is out of range. This may occur if the FPDM does not receive a valid control duty cycle signal from the PCM. The FPDM will default to 100% duty cycle on the fuel pump control output. The PCM sets a P1235 DTC.

If the FPDM outputs a 75% duty cycle, it means that the FPDM has detected an open or short on the fuel pump control circuit. The PCM sets a P1237 DTC.

If the FPDM outputs a 50% duty cycle, the FPDM is functioning normally.

Fuel Pump Driver Module Check Operation:	
DTCs	P1233 – FPDM disabled or offline P1235 – Fuel pump control out of range P1237 – Fuel pump secondary circuit
Monitor execution	Continuous, voltage > 11.0 volts
Monitor Sequence	None
Monitoring Duration	3 seconds

Some vehicle applications (2.3L Ranger) use an electric thermostat heater. These vehicles use a high temperature thermostat (220 °F versus 192 °F) to achieve faster warm-up times. The heater circuit can be energized by the PCM whenever additional cooling is required. (The PCM energizes the heater based primarily on ECT/CHT, but can allow for additional cooling based on inputs from rpm, load, IAT and TFT.) The heat generated by the heater causes the thermostat to open at a lower temperature than the rated temperature of the thermostat (up to 50 °F lower), thereby, providing additional engine and transmission cooling. The PCM duty cycles the heater output at 100% to open the thermostat, 70% to keep it open and 0% to provide rated thermostat function. The PCM monitors the "smart" driver fault status bit that indicates either an open circuit, short to power or short to ground. If the heater circuit fails such that it is always off, the vehicle can run hotter than normal. If the heater fails such that it is always on, the vehicle may also fail the thermostat test (P0125/P0128).

Thermostat Heater Check Operation:	
DTCs	P1432 or P0597 (opens/shorts)
Monitor execution	Continuous at 0 and 100% duty cycle
Monitor Sequence	None
Monitoring Duration	5 seconds

Typical thermostat heater check entry conditions:		
Entry Condition	Minimum	Maximum
Battery Voltage	11.0 volts	

There are several different styles of hardware used to control airflow within the engine air intake system. In general, the devices are defined based on whether they control in-cylinder motion (charge motion) or manifold dynamics (tuning).

Systems designed to control charge motion are defined to be Intake Manifold Runner Controls. IMRC systems generally have to modify spark when the systems are active because altering the charge motion affects the burn rate within the cylinder.

Systems designed to control intake manifold dynamics or tuning are defined to be Intake Manifold Tuning Valves. IMTV systems generally do not require any changes to spark or air/fuel ratio because these systems only alter the amount of airflow entering the engine.

Intake Manifold Runner Control Systems

The Intake Manifold Runner Control (IMRC) consists of a remote mounted, electrically motorized actuator with an attaching cable for each housing on each bank. Some applications will use one cable for both banks. The cable or linkage attaches to the housing butterfly plate levers. (The 2.0L (2V) Focus/Escort IMRC uses a motorized actuator mounted directly to a single housing without the use of a cable.)

The IMRC housing is an aluminum casting with two intake air passages for each cylinder. One passage is always open and the other is opened and closed with a butterfly valve plate. The housing uses a return spring to hold the butterfly valve plates closed. The motorized actuator houses an internal switch or switches, depending on the application, to provide feedback to the PCM indicating cable and butterfly valve plate position.

Below approximately 3000 rpm, the motorized actuator will not be energized. This will allow the cable to fully extend and the butterfly valve plates to remain closed. Above approximately 3000 rpm, the motorized actuator will be energized. The attaching cable will pull the butterfly valve plates into the open position. (Some vehicles will activate the IMRC near 1500 rpm.)

The Intake Manifold Swirl Control used on the 2.3L Ranger consists of a manifold mounted vacuum actuator and a PCM controlled electric solenoid. The linkage from the actuator attaches to the manifold butterfly plate lever. The IMSC actuator and manifold are composite/plastic with a single intake air passage for each cylinder. The passage has a butterfly valve plate that blocks 60% of the opening when actuated, leaving the top of the passage open to generate turbulence. The housing uses a return spring to hold the butterfly valve plates open. The vacuum actuator houses an internal monitor circuit to provide feedback to the PCM indicating butterfly valve plate position.

Below approximately 3000 rpm, the vacuum solenoid will be energized. This will allow manifold vacuum to be applied and the butterfly valve plates to remain closed. Above approximately 3000 rpm, the vacuum solenoid will be de-energized. This will allow vacuum to vent from the actuator and the butterfly valve plates to open.

IMRC System Check Operation:	
DTCs	P1516/P2014 - IMRC input switch electrical check, Bank 1 P1517/P0219 - IMRC input switch electrical check, Bank 2 P1520/P2008 - IMRC output electrical check P1518/P2004 - IMRC stuck open, electric operated P1537/P2004 – IMRC stuck open, vacuum operated, Bank 1 P1538/P2005 – IMRC stuck open, vacuum operated, Bank 2
Monitor execution	continuous
Monitor Sequence	None
Sensors OK	
Monitoring Duration	5 seconds

Typical IMRC functional check malfunction thresholds

IMRC plates do not match commanded position (functional)
IMRC switches open/shorted (electrical)

Intake Manifold Tuning Valve Systems

The intake manifold tuning valve (IMTV) is a motorized actuated unit mounted directly to the intake manifold. The IMTV actuator controls a shutter device attached to the actuator shaft. There is no monitor input to the PCM with this system to indicate shutter position.

The motorized IMTV unit will not be energized below approximately 2600 rpm or higher on some vehicles. The shutter will be in the closed position not allowing airflow blend to occur in the intake manifold. Above approximately 2600 rpm or higher, the motorized unit will be energized. The motorized unit will be commanded on by the PCM initially at a 100 percent duty cycle to move the shutter to the open position and then falling to approximately 50 percent to continue to hold the shutter open.

IMTV Check Operation:	
DTCs	P1549 or P0660 - IMTV output electrical check (does not illuminate MIL)
Monitor execution	continuous
Monitor Sequence	None
Sensors OK	
Monitoring Duration	5 seconds

Variable Cam Timing Systems

Variable Cam Timing (VCT) enables rotation of the camshaft(s) relative to the crankshaft (phase-shifting) as a function of engine operating conditions. There are four possible types of VCT with DOHC engines:

- Intake Only (phase-shifting only the intake cam);
- Exhaust Only (phase-shifting only the exhaust cam);
- Dual Equal (phase-shifting the intake and exhaust cams equally);
- Dual Independent (phase-shifting the intake and exhaust cams independently).

All four types of VCT are used primarily to increase internal residual dilution at part throttle to reduce NO_x, and to improve fuel economy. This allows for elimination the external EGR system. Ford currently uses Exhaust Only but is introducing Intake Only on the 2003 MY Lincoln LS.

With Exhaust Only VCT, the exhaust camshaft is retarded at part throttle to delay exhaust valve closing for increased residual dilution and to delay exhaust valve opening for increased expansion work.

With Intake Only VCT, the intake camshaft is advanced at part throttle and WOT (at low to mid-range engine speeds) to open the intake valve earlier for increased residual dilution and close the intake valve earlier in the compression stroke for increased power.

The VCT system hardware consists of a control solenoid and a pulse ring on the camshaft. The PCM 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 N equally spaced teeth are used for cam phasing; the remaining tooth is used to determine cylinder # 1 position. Relative cam position is calculated by measuring the time between the rising edge of profile ignition pickup (PIP) and the falling edges of the VCT pulses.

The PCM 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 VCT solenoid valve. When energized, engine oil is allowed to flow to the VCT unit thereby advancing and retarding cam timing. The variable cam timing unit assembly is coupled to the camshaft through a helical spline in the VCT unit chamber. When the flow of oil is shifted from one side of the chamber to the other, the differential change in oil pressure forces the piston to move linearly along the axis of the camshaft. This linear motion is translated into rotational camshaft motion through the helical spline coupling. A spring installed in the chamber is designed to hold the camshaft in the low-overlap position when oil pressure is too low (~15 psi) to maintain adequate position control. The camshaft is allowed to rotate up to 30 degrees.

The VCT output driver in the PCM is checked electrically for opens and shorts (P1380/P0010, P1385/P0020). 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 VCT control malfunction is indicated (P1381/P0011, P1383/P0012, P1386/P0021, P1388/P0022).

Camshaft Position Control System Check Operation:]	
DTCs	P1380/P0010 Camshaft Position Actuator Circuit (Bank 1) P1381/P0011 Cam Position Actuator Over Advanced (Bank 1) P1383/P0012 Cam Position Actuator Over Retarded (Bank 1) P1385/P0020 - Camshaft Position Actuator Circuit (Bank 2) P1386/P0021 - Cam Position Actuator Over Advanced (Bank 2) P1388/P0022 - Cam Position Actuator Over Retarded (Bank 2)
Monitor execution	Continuous
Monitor Sequence	ECT > 150 °F
Sensors OK	
Monitoring Duration	5 seconds

Typical CPC functional check malfunction thresholds:
timing over-advanced/over-retarded by > 10 crankshaft degrees

Comprehensive Component Monitor - Transmission

General

The MIL is illuminated for all emissions related electrical component malfunctions. For malfunctions attributable to a mechanical component (such as a clutch, gear, band, valve, etc.), some transmissions are capable of not commanding the mechanically failed component and providing the remaining maximum functionality (functionality is reassessed on each power up)- in such case a non-MIL Diagnostic Trouble Code (DTC) will be stored and, if so equipped, a Transmission Control Indicator Light (TCIL) will flash.

Transmission Inputs

Transmission Range Sensor Check Operation:	
DTCs	P0708, P0705 (open/invalid pattern for digital TRS) P0707, P0708 (opens/shorts for analog TRS) P0705 (Out of range signal frequency for PWM TRS) P0706, P0707 (Low /High duty cycle for PWM TRS)
Monitor execution	Continuous
Monitor Sequence	None
Sensors OK	
Monitoring Duration	30 seconds

Typical TRS check entry conditions:		
Auto Transmission Entry Conditions	Minimum	Maximum
Gear selector position	each position for up to 30 seconds	480 seconds

Typical TRS malfunction thresholds:
For digital sensor: Invalid pattern from 3 or 5 digital inputs and/or 1 analog circuit open for 5 seconds
For analog sensor: Voltage > 4.8 volts or < 0.2 voltage for 5 seconds
For Pulse Width Modulated (PWM) sensor : Frequency > 160 Hz or < 100 Hz, Duty Cycle > 90% or < 10%

Most vehicle applications no longer have a standalone vehicle speed sensor input. The PCM sometimes obtains vehicle speed information from another module on the vehicle, i.e. ABS module. In most cases, however, vehicle speed is calculated in the PCM by using the transmission output shaft speed sensor signal and applying a conversion factor for axle ratio and tire programmed into the Vehicle ID block. A Vehicle Speed Output pin on the PCM provides the rest of the vehicle with the standard 8,000 pulses/mile signal.

Note: If the Vehicle ID block has not been programmed or has been programmed with an out-of-range (uncertified) tire/axle ratio, a P1639 DTC will be stored and the MIL will be illuminated immediately.

Vehicle Speed Sensor Functional Check Operation:	
DTCs	P0500
Monitor execution	Continuous
Monitor Sequence	None
Sensors OK	
Monitoring Duration	30 seconds

Typical VSS functional check entry conditions:		
Auto Transmission Entry Conditions	Minimum	Maximum
Gear selector position	drive	
Engine rpm (above converter stall speed) OR	3000 rpm	
Turbine shaft rpm (if available) OR	1500 rpm	
Output shaft rpm	650 rpm	
Vehicle speed (if available)	15 mph	
Manual Transmission Entry Conditions		
Engine load	50 %	
Engine rpm	2400 rpm	

Typical VSS functional check malfunction thresholds:
Vehicle is inferred to be moving with positive driving torque and VSS is < 1 - 5 mph for 5 seconds

Output Shaft Speed Sensor Functional Check Operation:	
DTCs	P0720
Monitor execution	Continuous
Monitor Sequence	None
Sensors OK	
Monitoring Duration	30 seconds

Typical OSS functional check entry conditions:		
Auto Transmission Entry Conditions	Minimum	Maximum
Gear selector position	drive	
Engine rpm (above converter stall speed) OR	3000 rpm	
Turbine shaft rpm (if available) OR	1500 rpm	
Output shaft rpm	650 rpm	
Vehicle speed (if available)	15 mph	

Typical OSS functional check malfunction thresholds:
Vehicle is inferred to be moving with positive driving torque and OSS < 100 to 200 rpm for 5 seconds

Intermediate Shaft Speed Sensor Functional Check Operation:	
DTCs	P0791
Monitor execution	Continuous
Monitor Sequence	None
Sensors OK	
Monitoring Duration	30 seconds

Typical ISS functional check entry conditions:		
Auto Transmission Entry Conditions	Minimum	Maximum
Gear selector position	drive	
Engine rpm (above converter stall speed) OR	3000 rpm	
Turbine shaft rpm (if available) OR	1500 rpm	
Output shaft rpm	650 rpm	
Vehicle speed (if available)	15 mph	

Typical ISS functional check malfunction thresholds:
Vehicle is inferred to be moving with positive driving torque and ISS < 250 rpm for 5 seconds

Turbine Shaft Speed Sensor Functional Check Operation:	
DTCs	P0715
Monitor execution	Continuous
Monitor Sequence	None
Sensors OK	
Monitoring Duration	30 seconds

Typical TSS functional check entry conditions:		
Auto Transmission Entry Conditions	Minimum	Maximum
Gear selector position	drive	
Engine rpm (above converter stall speed) OR	3000 rpm	
Turbine shaft rpm (if available) OR	1500 rpm	
Output shaft rpm	650 rpm	
Vehicle speed (if available)	15 mph	
Torque converter lock-up (some applications)	3 rd gear only	

Typical TSS functional check malfunction thresholds:
vehicle is inferred to be moving with positive driving torque and TSS < 200 rpm for 5 seconds

Transmission Fluid Temperature Sensor Functional Check Operation:	
DTCs (non-MIL)	P0712, P0713 (open/short) P1713,(stuck low), P1718 (stuck high) or P0711 (stuck low/high)
Monitor execution	continuous
Monitor Sequence	none
Sensors OK	(ECT substituted if TFT has malfunction)
Monitoring Duration	5 seconds for electrical, 600 seconds for functional check

Typical TFT functional check entry conditions:		
Auto Transmission Entry Conditions	Minimum	Maximum
Engine Coolant Temp (hot or cold, not midrange)	> 100 °F	< 20 °F
Time in run mode	500 sec	
Time in gear, vehicle moving, positive torque	150 sec	
Time with engine off (soak time)	420 min	
Vehicle Speed	15 mph	

Typical TFT malfunction thresholds:
<p>Electrical check:</p> <p>TFT voltage <0.05 or > 4.6 volts for 5 seconds</p> <p>TFT functional check (TFT stuck at high temperature or stuck at low temperature):</p> <p>< 6 °F rise or fall in TFT after startup</p>

Transmission Outputs

Shift Solenoid Check Operation:	
DTCs	SS A - P0750 electrical, P1714 ISIG functional, or P0751 mechanical functional SS B - P0755 electrical, P1715 ISIG functional, or P0756 mechanical functional SS C - P0760 electrical, P1716 ISIG functional, or P0761 mechanical functional SS D - P0765 electrical, P1717 ISIG functional, or P0766 mechanical functional SS E - P0770 electrical, or P0771 mechanical functional
Monitor execution	electrical - continuous, functional - during off to on solenoid transitions
Monitor Sequence	None
Sensors OK	
Monitoring Duration	10 solenoid events

Typical Shift Solenoid ISIG functional check entry conditions:		
Entry Conditions	Minimum	Maximum
Transmission Fluid Temp	70 °F	225 °F
Throttle position	positive drive torque (actual TP varies)	

Typical Shift Solenoid mechanical functional check entry conditions:		
Entry Conditions (with turbine speed)	Minimum	Maximum
Gear ratio calculated	each gear	
Throttle position	positive drive torque	

Typical Shift Solenoid mechanical functional check entry conditions:		
Entry Conditions (without turbine speed)	Minimum	Maximum
Rpm drop is obtained	each shift	
Throttle position	positive drive torque	

Typical SS malfunction thresholds:
Electrical check: Output driver feedback circuit does not match commanded driver state for 5 seconds
ISIG functional check: ISIG chip hardware circuit does not detect characteristic current dip and rise produced by solenoid movement.
Mechanical functional check: Actual obtained gear or shift pattern indicates which shift solenoid is stuck on or off.

Torque Converter Clutch Check Operation:	
DTCs	P0743 electrical, P1740 ISIG functional, or P1744 mechanical functional P1742 or P0741 mechanical functional, stuck on
Monitor execution	electrical - continuous, mechanical - during lockup
Monitor Sequence	none
Sensors OK	VSS
Monitoring Duration	5 lock-up events

Typical Torque Converter Clutch ISIG functional check entry conditions:		
Entry Conditions	Minimum	Maximum
Transmission Fluid Temp	70 °F	225 °F
Engine Torque	positive drive torque	
Commanded TCC dutycycle for 0 rpm slip	60%	90%

Typical Torque Converter Clutch mechanical functional check entry conditions:		
Entry Conditions	Minimum	Maximum
Throttle Position	steady	
Engine Torque	positive drive torque	
Transmission Fluid Temp	70 °F	225 °F
Commanded TCC dutycycle (0 rpm slip)	60%	100%
Not shifting		

Typical TCC malfunction thresholds:
<p>Electrical check:</p> <p>Output driver feedback circuit does not match commanded driver state for 5 seconds(> 1.0 volt if commanded on, < 2.0 volts if commanded off.)</p> <p>ISIG functional check:</p> <p>ISIG chip hardware circuit does not detect characteristic current dip and rise produced by solenoid movement.</p> <p>Mechanical check:</p> <p>Slip across torque converter > 100 rpm or (on some applications) speed ratio < 0.93</p> <p>Mechanical check:</p> <p>Slip across torque converter < 20 rpm with converter commanded off (some applications)</p>

Electronic Pressure Control Check Operation:	
DTCs	P1747 or P0962 electrical, P1789 or P0966, P0797 or P0970(some applications) short to ground (low pressure) P0745, P0775, P0795 mechanical functional (some applications)
Monitor execution	Continuous
Monitor Sequence	none
Sensors OK	
Monitoring Duration	Electrical: 5 seconds, Mechanical functional: up to 30 seconds

Typical Electronic Pressure Control mechanical functional check entry conditions:		
Entry Conditions	Minimum	Maximum
Gear ratio calculated	each gear	
Transmission Fluid Temperature	70 °F	225 °F
Throttle Position	positive drive torque	

Typical EPC malfunction thresholds:
Electrical check: Current feedback circuit is less than commanded current for 5 seconds Mechanical functional check: Actual obtained gear pattern indicates EPC fault

Inductive Signature Chip Communication Check Operation:	
DTCs	P1636 loss of communication
Monitor execution	off-to-on solenoid transitions
Monitor Sequence	none
Sensors OK	
Monitoring Duration	< 100 solenoid events

Typical Inductive Signature Chip Communication Check entry conditions:		
Entry Conditions	Minimum	Maximum
Transmission Fluid Temp	70 °F	225 °F
Solenoid commanded off duration		< 2 seconds

Typical Inductive Signature Communication Chip malfunction thresholds:
Checksum error, chip not responding

4R70W (RWD) Transmission

(no turbine speed sensor)

Transmission Inputs

The Digital Transmission Range (DTR) sensor provides a single analog and three digital inputs to the PCM. The PCM decodes the inputs to determine the driver-selected gear position (Park, Rev, Neutral, OD, 2, 1). This input device is checked for opens and invalid input patterns. (P0708 P0705)

The Vehicle Speed Sensor (VSS) and Output Shaft Speed (OSS) sensor, if equipped, are inputs that are checked for rationality. If the engine rpm is above the torque converter stall speed and engine load is high, it can be inferred that the vehicle must be moving. If there is insufficient output from the VSS sensor, a malfunction is indicated (P0500). If there is insufficient output from the OSS sensor, a malfunction is indicated (P0720).

Transmission Outputs

Shift Solenoids

The Shift Solenoid (SSA and SSB) output circuits are checked for opens and shorts by the PCM by monitoring the status of a feedback circuit from the output driver (P0750 SSA, P0755 SSB).

All vehicle applications will utilize an inductive signature circuit to monitor the shift solenoids functionally. The ISIG circuit monitors the current signature of the shift solenoid as the solenoid is commanded on. A solenoid that functions properly will show a characteristic decrease in current as the solenoid starts to move. If the solenoid is malfunctioning, the current will not change (P1714 SSA, P1715 SSB). The lack of communication between the ISIG chip and the PCM microprocessor is also monitored (P1636).

Torque Converter Clutch

The Torque Converter Clutch (TCC) output circuit is a duty-cycled output that is checked electrically for opens and shorts by the PCM by monitoring the status of a feedback circuit from the output driver (P0743).

All vehicle applications will utilize an inductive signature circuit to monitor the torque converter clutch. The ISIG circuit monitors the current signature of the TCC solenoid as the solenoid is commanded on. A solenoid that functions properly will show a characteristic decrease in current as the solenoid starts to move. If the solenoid is malfunctioning, the current will not change (P1740). In some applications, the ISIG test is run in conjunction with the other transmission functional tests. The lack of communication between the ISIG chip and the PCM microprocessor is also monitored (P1636).

Electronic Pressure Control

The EPC solenoid is a variable force solenoid that controls line pressure in the transmission. The EPC solenoid has a feedback circuit in the PCM that monitors EPC current. If the current indicates a short to ground (low pressure), engine torque may be reduced to prevent damage to the transmission. (P1747, PCA)

AX4S/4F50N (AX4N) (FWD) Transmission

(has turbine speed sensor)

Transmission Inputs

The Digital Transmission Range (DTR) sensor provides a single analog and three digital inputs to the PCM. The PCM decodes the inputs to determine the driver-selected gear position (Park, Rev, Neutral, OD, D, 1). This input device is checked for opens and invalid input patterns. (P0708 P0705)

The Turbine Shaft Speed (TSS) sensor and Output Shaft Speed (OSS) sensor, if equipped, are analog inputs that are checked for rationality. If the engine rpm is above the torque converter stall speed and engine load is high, it can be inferred that the vehicle must be moving. If there is insufficient output from the TSS sensor, a malfunction is indicated (P0715). If there is insufficient output from the OSS sensor, a malfunction is indicated (P0720).

Transmission Outputs

Shift Solenoids

The Shift Solenoid (SSA SSB and SSC) output circuits are checked for opens and shorts by the PCM by monitoring the status of a feedback circuit from the output driver (P0750 SSA, P0755 SSB, P0760 SSC).

All vehicle applications will utilize an inductive signature circuit to monitor the shift solenoids functionally. The ISIG circuit monitors the current signature of the shift solenoid as the solenoid is commanded on. A solenoid that functions properly will show a characteristic decrease in current as the solenoid starts to move. If the solenoid is malfunctioning, the current will not change (P1714 SSA, P1715 SSB, P1716 SSC). The ISIG test runs in conjunction with the other transmission functional tests. The lack of communication between the ISIG chip and the PCM microprocessor is also monitored (P1636).

Torque Converter Clutch

The Torque Converter Clutch (TCC) output circuit is a duty-cycled output that is checked electrically for opens and shorts by the PCM by monitoring the status of a feedback circuit from the output driver (P0743).

All vehicle applications will utilize an inductive signature circuit to monitor the torque converter clutch. The ISIG circuit monitors the current signature of the TCC solenoid as the solenoid is commanded on. A solenoid that functions properly will show a characteristic decrease in current as the solenoid starts to move. If the solenoid is malfunctioning, the current will not change (P1740). The ISIG test runs in conjunction with the other transmission functional tests. The lack of communication between the ISIG chip and the PCM microprocessor is also monitored (P1636).

Electronic Pressure Control

The EPC solenoid is a variable force solenoid that controls line pressure in the transmission. The EPC solenoid has a feedback circuit in the PCM that monitors EPC current. If the current indicates a short to ground (low pressure), engine torque may be reduced to prevent damage to the transmission. (P1747, PCA)

CD4E (FWD) Transmission

(has turbine speed sensor)

Transmission Inputs

The Analog Transmission Range (TR) sensor provides a single analog input to the PCM. The voltage corresponds to the driver-selected gear position (Park, Rev, Neutral, OD, 2, 1). This input is checked for opens and shorts. (P0707, P0708)

The Turbine Shaft Speed (TSS) sensor and Output Shaft Speed (OSS) sensors are analog inputs that are checked for rationality. If the engine rpm is above the torque converter stall speed and engine load is high, it can be inferred that the vehicle must be moving. If there is insufficient output from the TSS sensor, a malfunction is indicated (P0715). If there is insufficient output from the OSS sensor, a malfunction is indicated (P0720).

Transmission Outputs

Shift Solenoids

The Shift Solenoid (SSA and SSB) output circuits are checked for opens and shorts by the PCM by monitoring the status of a feedback circuit from the output driver (P0750 SSA, P0755 SSB).

All vehicle applications will utilize an inductive signature circuit to monitor the shift solenoids functionally. The ISIG circuit monitors the current signature of the shift solenoid as the solenoid is commanded on. A solenoid that functions properly will show a characteristic decrease in current as the solenoid starts to move. If the solenoid is malfunctioning, the current will not change (P1714 SSA, P1715 SSB). The ISIG test runs in conjunction with the other transmission functional tests. The lack of communication between the ISIG chip and the PCM microprocessor is also monitored (P1636).

Torque Converter Clutch

The Torque Converter Clutch (TCC) output circuit is a duty-cycled output that is checked electrically for opens and shorts by the PCM by monitoring the status of a feedback circuit from the output driver (P0743).

The PWM used to control CD4E's TCC does not have sufficient inductive signature, therefore on these applications the TCC solenoid is functionally tested by monitoring converter slip. If the TCC is failed on when commanded off, a P1742 fault code will be stored. If the TCC off when commanded on, a P1744 fault code will be stored.

Electronic Pressure Control

The EPC solenoid is a variable force solenoid that controls line pressure in the transmission. The EPC solenoid has a feedback circuit in the PCM that monitors EPC current. If the current indicates a short to ground (low pressure), engine torque may be reduced to prevent damage to the transmission. (P1747, PCA)

5R44E (RWD) Transmission

(has turbine speed sensor)

Transmission Inputs

The Digital Transmission Range (DTR) sensor provides a single analog and three digital inputs to the PCM. The PCM decodes these inputs to determine the driver-selected gear position (Park, Rev, Neutral, OD, 2, 1).

This input device is checked for opens and invalid input patterns. (P0708 P0705)

The Turbine Shaft Speed (TSS) sensor and Output Speed Sensor (OSS) are inputs that are checked for rationality. Provided one of the two speed sensors has sufficient signal and engine load is high enough and the engine speed is above the torque converter stall speed, it can be inferred that the vehicle must be moving. If there is insufficient output from the TSS sensor, a malfunction is indicated (P0715). If there is insufficient output from the OSS sensor, a malfunction is indicated (P0720).

Transmission Outputs

Shift Solenoids

The Shift Solenoid (SSA, SSB, SSC, and SSD) output circuits are checked for opens and shorts by the PCM by monitoring the status of a feedback circuit from the output driver (P0750 SSA, P0755 SSB, P0760 SSC, and P0765 SSD).

All vehicle applications will utilize an inductive signature circuit to monitor the shift solenoids functionally. The ISIG circuit monitors the current signature of the shift solenoid as the solenoid is commanded on. A solenoid that functions properly will show a characteristic decrease in current as the solenoid starts to move. If the solenoid is malfunctioning, the current will not change (P1714 SSA, P1715 SSB, P1716 SSC, P1717 SSD). The ISIG test runs in conjunction with the other transmission functional tests. The lack of communication between the ISIG chip and the PCM microprocessor is also monitored (P1636).

Torque Converter Clutch

The Torque Converter Clutch (TCC) output circuit is a duty-cycled output that is checked electrically for opens and shorts by the PCM by monitoring the status of a feedback circuit from the output driver (P0743).

These vehicle applications will utilize an inductive signature circuit to monitor the torque converter clutch. The ISIG circuit monitors the current signature of the TCC solenoid as the solenoid is commanded on. A solenoid that functions properly will show a characteristic decrease in current as the solenoid starts to move. If the solenoid is malfunctioning, the current will not change (P1740). The ISIG test is run in conjunction with the other transmission functional tests. The lack of communication between the ISIG chip and the PCM microprocessor is also monitored (P1636).

Electronic Pressure Control Output

The EPC solenoid is a variable force solenoid that controls line pressure in the transmission. The EPC solenoid has a feedback circuit in the PCM that monitors EPC current. If the current indicates a short to ground (low pressure), engine torque may be reduced to prevent damage to the transmission. (P1747, PCA)

5R55E (RWD) Transmission

(has turbine speed sensor)

Transmission Inputs

The Digital Transmission Range (DTR) sensor provides a single analog and three digital inputs to the PCM. The PCM decodes these inputs to determine the driver-selected gear position (Park, Rev, Neutral, OD, 2, 1). This input device is checked for opens and invalid input patterns. (P0708, P0705)

The Turbine Shaft Speed (TSS) and Output Shaft Speed (OSS) sensors are inputs that are checked for rationality. Provided one of the two speed sensors has sufficient signal and engine load is high enough and the engine rpm is above the torque converter stall speed, it can be inferred that the vehicle must be moving. If there is insufficient output from the TSS sensor, a malfunction is indicated (P0715). If there is insufficient output from the OSS sensor, a malfunction is indicated (P0720).

Transmission Outputs

Shift Solenoids

The Shift Solenoid (SSA, SSB, SSC and SSD) output circuits are checked for opens and shorts by the PCM by monitoring the status of a feedback circuit from the output driver (P0750 SSA, P0755 SSB, P0760 SSC, P0765 SSD).

These vehicle applications will utilize an inductive signature circuit to monitor the shift solenoids functionally. The ISIG circuit monitors the current signature of the shift solenoid as the solenoid is commanded on. A solenoid that functions properly will show a characteristic decrease in current as the solenoid starts to move. If the solenoid is malfunctioning, the current will not change (P1714 SSA, P1715 SSB, P1716 SSC, P1717 SSD). The ISIG test is run in conjunction with the other transmission functional tests. The lack of communication between the ISIG chip and the PCM microprocessor is also monitored (P1636).

Torque Converter Clutch

The Torque Converter Clutch (TCC) output circuit is a duty-cycled output that is checked electrically for opens and shorts by the PCM by monitoring the status of a feedback circuit from the output driver (P0743).

These vehicle applications will utilize an inductive signature circuit to monitor the torque converter clutch. The ISIG circuit monitors the current signature of the TCC solenoid as the solenoid is commanded on. A solenoid that functions properly will show a characteristic decrease in current as the solenoid starts to move. If the solenoid is malfunctioning, the current will not change (P1740). The ISIG test runs in conjunction with the other transmission functional tests. The lack of communication between the ISIG chip and the PCM microprocessor is also monitored (P1636).

Electronic Pressure Control Output

The EPC solenoid is a variable force solenoid that controls line pressure in the transmission. The EPC solenoid has a feedback circuit in the PCM that monitors EPC current. If the current indicates a short to ground (low pressure), engine torque may be reduced to prevent damage to the transmission. (P1747, PCA)

5R55S (RWD) Transmission – without ETC

(has turbine speed sensor)

The 5R55S replaces the 5R55W transmission from 2002 MY. The diagnostics for the 5R55S and 5R55W are identical. The controls are slightly different for vehicles that use Electronic Throttle Control (ETC) versus vehicles that do not use ETC.

Transmission Inputs

The Digital Transmission Range (DTR) sensor provides a single analog and three digital inputs to the PCM. The PCM decodes these inputs to determine the driver-selected gear position. This input device is checked for opens and invalid input patterns. (P0708, P0705)

Turbine Shaft Speed (TSS) and Output Shaft Speed (OSS) sensors are analog inputs that are checked for rationality. If the engine rpm is above the torque converter stall speed and engine load is high, it can be inferred that the vehicle must be moving. If there is insufficient output from the TSS sensor, a malfunction is indicated (P0715). If there is insufficient output from the OSS sensor, a malfunction is indicated (P0720).

Transmission Outputs

Shift Solenoids

The Shift Solenoid (SSA, SSB, SSC, SSD) output circuits are checked for opens and shorts by the PCM by monitoring the status of a feedback circuit from the output driver (P0750 SSA, P0755 SSB, P0760 SSC, P0765 SSD).

These vehicle applications will utilize an inductive signature circuit to monitor the shift solenoids functionally. The ISIG circuit monitors the current signature of the shift solenoid as the solenoid is commanded on. A solenoid that functions properly will show a characteristic decrease in current as the solenoid starts to move. If the solenoid is malfunctioning, the current will not change (P1714 SSA, P1715 SSB, P1716 SSC, P1717 SSD). The ISIG test runs in conjunction with the other transmission functional tests. The lack of communication between the ISIG chip and the PCM microprocessor is also monitored (P1636).

Electronic Pressure Control Outputs

The VFS solenoids are variable force solenoids that control line pressure and gear selection in the transmission. The VFS solenoids have a feedback circuit in the PCM that monitors VFS current. If the current indicates a short to ground (low pressure), engine torque may be reduced to prevent damage to the transmission. (P1747, P1789, P0797).

The VFS solenoids are also checked for functionality by utilizing a rationality test that looks at gear ratios. If VFS/shift solenoid electrical faults and shift solenoid ISIG faults are not present, then actual ratios versus expected ratios are used to infer VFS failures. (P0745 PCA, P0775 PCB, P0795 PCC)

Torque Converter Clutch

The Torque Converter Clutch (TCC) output circuit is a duty-cycled output that is checked electrically for opens and shorts by the PCM by monitoring the status of a feedback circuit from the output driver (P0743).

These vehicle applications will utilize an inductive signature circuit to monitor the torque converter clutch. The ISIG circuit monitors the current signature of the TCC solenoid as the solenoid is commanded on. A solenoid that functions properly will show a characteristic decrease in current as the solenoid starts to move. If the solenoid is malfunctioning, the current will not change (P1740). The ISIG test runs in conjunction with the other transmission functional tests. The lack of communication between the ISIG chip and the PCM microprocessor is also monitored (P1636).

Direct One Way Clutch

The Direct One Way Clutch is checked for functionality by utilizing a rationality test that looks at transmission input torque relative to commanded throttle position while in 1st, 3rd, or 4th gear. If a direct one way clutch fault is present, then the transmission will not be able to carry torque at high throttle angles in 1st, 3rd, or 4th gears. (P1700)

5R55S (RWD) Transmission – with ETC

(has turbine speed sensor)

The 5R55S replaces the 5R55W transmission from 2002 MY. The diagnostics for the 5R55S and 5R55W are identical. The controls are slightly different for vehicles that use Electronic Throttle Control (ETC) versus vehicles that do not use ETC.

Transmission Inputs

The Digital Transmission Range (DTR) sensor provides a single analog and three digital inputs to the PCM. The PCM decodes these inputs to determine the driver-selected gear position. This input device is checked for opens and invalid input patterns. (P0708, P0705)

Turbine Shaft Speed (TSS) and Output Shaft Speed (OSS) sensors are analog inputs that are checked for rationality. If the engine rpm is above the torque converter stall speed and engine load is high, it can be inferred that the vehicle must be moving. If there is insufficient output from the TSS sensor, a malfunction is indicated (P0715). If there is insufficient output from the OSS sensor, a malfunction is indicated (P0720).

Transmission Outputs

Shift Solenoids

The Shift Solenoid (SSA, SSB, SSC, SSD) output circuits are checked for opens and shorts by the PCM by monitoring the status of a feedback circuit from the output driver (P0750 SSA, P0755 SSB, P0760 SSC, P0765 SSD).

These vehicle applications will utilize an inductive signature circuit to monitor the shift solenoids functionally. The ISIG circuit monitors the current signature of the shift solenoid as the solenoid is commanded on. A solenoid that functions properly will show a characteristic decrease in current as the solenoid starts to move. If the solenoid is malfunctioning, the current will not change (P1714 SSA, P1715 SSB, P1716 SSC, P1717 SSD). The ISIG test runs in conjunction with the other transmission functional tests. The lack of communication between the ISIG chip and the PCM microprocessor is also monitored (P1636).

Electronic Pressure Control Outputs

The VFS solenoids are variable force solenoids that control line pressure and gear selection in the transmission. The VFS solenoids have a feedback circuit in the PCM that monitors VFS current. If the current indicates a short to ground (low pressure), engine torque may be reduced to prevent damage to the transmission. (P0962, P0966, P0970).

The VFS solenoids are also checked for functionality by utilizing a rationality test that looks at gear ratios. If VFS/shift solenoid electrical faults and shift solenoid ISIG faults are not present, then actual ratios versus expected ratios are used to infer VFS failures. (P0745 PCA, P0775 PCB, P0795 PCC)

Torque Converter Clutch

The Torque Converter Clutch (TCC) output circuit is a duty-cycled output that is checked electrically for opens and shorts by the PCM by monitoring the status of a feedback circuit from the output driver (P0743).

These vehicle applications will utilize an inductive signature circuit to monitor the torque converter clutch. The ISIG circuit monitors the current signature of the TCC solenoid as the solenoid is commanded on. A solenoid that functions properly will show a characteristic decrease in current as the solenoid starts to move. If the solenoid is malfunctioning, the current will not change (P1740). The ISIG test runs in conjunction with the other transmission functional tests. The lack of communication between the ISIG chip and the PCM microprocessor is also monitored (P1636).

Direct One Way Clutch

The Direct One Way Clutch is checked for functionality by utilizing a rationality test that looks at transmission input torque relative to commanded throttle position while in 1st, 3rd, or 4th gear. If a direct one way clutch fault is present, then the transmission will not be able to carry torque at high throttle angles in 1st, 3rd, or 4th gears. (P1700)

4R100 (E4OD) (RWD) Transmission

(turbine speed sensor in most applications)

Transmission Inputs

The Digital Transmission Range (DTR) sensor provides a single analog and three digital inputs to the PCM. The PCM decodes the inputs to determine the driver-selected gear position (Park, Rev, Neutral, OD, 2, 1). This input device is checked for opens and invalid input patterns. (P0708, P0705)

The Vehicle Speed Sensor (VSS), Turbine Shaft Speed (TSS) sensor and Output Shaft Speed (OSS) sensor, if equipped, are analog inputs that are checked for rationality. If the engine rpm is above the torque converter stall speed and engine load is high, it can be inferred that the vehicle must be moving. If there is insufficient output from the VSS sensor, a malfunction is indicated (P0500). If there is insufficient output from the TSS sensor, a malfunction is indicated (P0715). If there is insufficient output from the OSS sensor, a malfunction is indicated (P0720).

Transmission Outputs

Shift Solenoids

The Shift Solenoid (SSA and SSB) output circuits are checked for opens and shorts by the PCM by monitoring the status of a feedback circuit from the output driver (P0750 SSA, P0755 SSB).

All vehicle applications will utilize an inductive signature circuit to monitor the shift solenoids functionally. The ISIG circuit monitors the current signature of the shift solenoid as the solenoid is commanded on. A solenoid that functions properly will show a characteristic decrease in current as the solenoid starts to move. If the solenoid is malfunctioning, the current will not change (P1714 SS1, P1715 SS2). The ISIG test runs in conjunction with the other transmission functional tests. In all applications, the lack of communication between the ISIG chip and the PCM microprocessor is also monitored (P1636).

Torque Converter Clutch

The Torque Converter Clutch (TCC) output circuit is a duty-cycled output that is checked electrically for opens and shorts internally in the PCM by monitoring the status of a feedback circuit from the output driver (P0743).

4R100's TCC solenoid does not have sufficient inductive signature, therefore the solenoid is functionally tested thru ratio. All vehicle applications use duty-cycled output drivers which utilize a rationality check for TCC operation. Actuation of the TCC on and off will result in a change of the calculated speed ratio under high engine load. If a speed ratio delta does not occur, a malfunction is indicated (P1744).

Electronic Pressure Control

The EPC solenoid is a variable force solenoid that controls line pressure in the transmission. The EPC solenoid has a feedback circuit in the PCM that monitors EPC current. If the current indicates a short to ground (low pressure), engine torque may be reduced to prevent damage to the transmission. (P1747, PCA)

5R110W (RWD) Transmission

Transmission Inputs

Transmission Range Sensor

The Non-contacting Pulse Width Modulated Transmission Range Sensor (TRS) provides a duty cycle signal for each position. This signal is transmitted at a frequency of 125 Hz. The PCM decodes the duty cycle to determine the driver-selected gear position (Park, Rev, Neutral, OD, 3, 2, 1). This input device is checked for out of range frequency, low duty cycle and high duty cycle input signals. (P0706, P0707, P0708)

Speed Sensors

The Turbine Shaft Speed (TSS) sensor, Intermediate Shaft Speed (ISS) sensor and Output Shaft Speed (OSS) sensor, if equipped, are hall effect inputs that are checked for rationality. The vehicle speed signal is provided from the ABS system to the PCM. If the engine rpm is above the torque converter stall speed and engine load is high, it can be inferred that the vehicle must be moving. If there is insufficient output from the VSS sensor, a malfunction is indicated (P0500). If there is insufficient output from the TSS sensor, a malfunction is indicated (P0715). If there is insufficient output from the ISS sensor, a malfunction is indicated (P0791). If there is insufficient output from the OSS sensor, a malfunction is indicated (P0720).

Transmission Fluid Temperature

5R110W has a feature called "Cold mode". If TFT is below 0 deg F, the transmission will limit operation to 1st, 2nd, 3rd, and 4th gears (5th and 6th gears are disabled). Cold mode remains in effect until TFT rises above 0 deg F or vehicle operation (based on shift times or heat generated by driving) indicates that TFT should not be in the cold mode range, at which point normal operation is enabled.

Direct clutch apply times cold have forced the addition of this cold mode (DC takes excessive times to apply below -10 deg F), and require revisions to TFT failure management – if TFT is failed at start up the transmission will be placed in cold mode and remain there until TFT is no longer failed and above 0 deg F or the vehicle operating conditions listed above trigger an exit from cold mode.

Once out of cold mode a TFT failure will not trigger cold mode (can only go into cold mode once/power-up); but this mode is new to 5R110W.

TFT is monitored for circuit faults (P0712, P0713) and in-range failures (P0711)

For this reason all TFT diagnostics illuminate the MIL on 5R110W.

Transmission Outputs

Shift Solenoids

The Shift Solenoid (SSA, SSB, SSC, SSD, and SSE) output circuits are checked for opens and shorts by the PCM by monitoring the status of a feedback circuit from the output driver (SSA P0750, P0973, P0974; SSB P0755, P0976, P0977; SSC P0760, P0979, P0980; SSD P0765, P0982, P0983; SSE P0770, P0985, P0986).

The shift solenoids will be tested for function. This is determined by vehicle inputs such as gear command, and gear. Shift solenoid malfunction codes (SSA P2700, SSB P2701, SSC P2702, SSD P2703, SSE P2704)

Torque Converter Clutch

The Torque Converter Clutch (TCC) output circuit is a duty-cycled output that is checked electrically for opens and shorts internally in the PCM by monitoring the status of a feedback circuit from the output driver (P0740, P0742, P0744).

The TCC solenoid is checked functionally by evaluating torque converter slip under steady state conditions when the torque converter is fully applied. If the slip exceeds the malfunction thresholds when the TCC is commanded on, a TCC malfunction is indicated (P0741).

Electronic Pressure Control

The EPC solenoid is a variable force solenoid that controls line pressure in the transmission. The EPC solenoid has a feedback circuit in the PCM that monitors EPC current. If the current indicates a short to ground (low pressure), a high side switch will be opened. This switch removes power from all 7 VFS's, providing Park, Reverse, Neutral, and 5M (in all forward ranges) with maximum line pressure based on manual lever position. (P0960, P0962, P0963)

High Side Switch

5R110W has a high side switch that can be used to remove power from all 7 VFS's simultaneously. If the high side switch is opened, all 7 solenoids will be electrically off, providing Park, Reverse, Neutral, and 5M (in all forward ranges) with maximum line pressure based on manual lever position. The switch is tested for open faults (switch failed closed will provide normal control). If the switch fails, a P0657 fault code will be stored.

CAN Communications error

The TCM receives critical information from the ECM via CAN. If the CAN link fails, the TCM no longer has torque or engine speed information available – the high side switch will be opened. The TCM will store a U0100 fault code if unable to communicate with the TCM.

4F27E (FN) (FWD) Transmission

(has turbine speed sensor)

Transmission Inputs

The Transmission Range Sensor (TRS) provides five digital inputs, one for Park and Neutral, one for Reverse, one for Drive, one for Second and one for First. These inputs are monitored for opens and shorts (P0705).

The Turbine Shaft Speed (TSS) sensor and Output Shaft Speed (OSS) sensors are analog inputs that are checked for rationality. If the engine rpm is above the torque converter stall speed or one of the two speed sensors has sufficient signal and engine load is high enough, it can be inferred that the vehicle must be moving. If there is insufficient output from the TSS sensor, a malfunction is indicated (P0715). If there is insufficient output from the OSS sensor, a malfunction is indicated (P0720).

Transmission Outputs

Shift Solenoids

The Shift Solenoid (SSA, SSB, SSC, SSD, and SSE) output circuits are checked for opens and shorts by the PCM by monitoring the status of a feedback circuit from the output driver (P0750, P0755, P0760, P0765 and P0770 respectively).

The shift solenoids are functionally (mechanically) checked by means of a comprehensive malfunction pattern test. This monitor examines learned gear states and the TCC function to determine if a shift solenoid mechanical failure has occurred

(P0751, P0756, P0761, P0766 and P0771 respectively).

Torque Converter Clutch

No single solenoid controls the TCC in the FN. Electrical checks for all shift solenoids are performed as indicated above. The TCC is checked functionally by evaluating torque converter slip under steady state conditions when the torque converter is fully applied. If the slip exceeds the malfunction thresholds when the TCC is commanded on, a TCC malfunction is indicated (P0741). If slip is below an open converter threshold when the TCC is commanded off, a TCC malfunction is indicated through the shift solenoid functional test (P0756).

On Board Diagnostic Executive

The On-Board Diagnostic (OBD) Executive is a portion of the PCM strategy that manages the sequencing and execution of all diagnostic tests. It is the "traffic cop" of the diagnostic system. Each test/monitor can be viewed as an individual task, which may or may not be able to run concurrently with other tasks. The Diagnostic Executive enables/disables OBD monitors in order to accomplish the following:

- Sequence the OBD monitors such that when a test runs, each input that it relies upon has already been tested.
- Controls and co-ordinates the execution of the individual OBD system monitors: Catalyst, Misfire, EGR, O2, Fuel, AIR, EVAP and, Comprehensive Component Monitor (CCM).
- 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), and the Output Test Mode (OTM).
- 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 responds to special diagnostic requests (J1979 Mode 08 and 09).

The diagnostic also executive controls several overall, global OBD entry conditions.

- The Diagnostic Executive waits for 4 seconds after the PCM is powered before initiating any OBD monitoring. For the 2001 MY and beyond, this delay has been eliminated to meet the "zero startup delay" misfire monitoring requirements.
- 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%

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:

$$\text{New Average} = [\text{New data point} * \text{“filter constant”}] + [(1 - \text{“filter constant”}) * \text{Old Average}]$$

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 Keep Alive Memory (KAM). This normally occurs each driving cycle. The MIL is illuminated and a DTC is stored based on the New Average store in KAM.

In order to facilitate repair verification and DDV demonstration, 2 different filter constants are used. A “fast filter constant” is used after KAM is cleared/DTCs are erased and a “normal filter constant” is used for normal customer driving. The “fast filter” is used for 2 driving cycles after KAM is cleared/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.

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:

$$\text{Time constant} = [(1 / \text{filter constant}) - 1] * \text{evaluation period}$$

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.

Catalyst Monitor EWMA

EWMA has been incorporated in the catalyst monitor. There are 3 calibrateable parameters that determine the MIL illumination characteristics.

- “Fast” filter constant, used for 2 driving cycles after DTCs are cleared or KAM is reset
- “Normal” filter constant, used for all subsequent, “normal” customer driving
- Number of driving cycles to use fast filter after KAM clear (normally set to 2 driving cycles)

Several examples for a typical calibration (4.6L Mark VIII) are shown in the tables below. Specific calibration information can be obtained from the parameter listing provided for each strategy.

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 100K system
1.0	$1.0 * (0.4) + .15 * (1 - 0.4)$	0.49	1	catastrophic failure
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
1.0	$1.0 * (0.4) + .82 * (1 - 0.4)$	0.89	4	MIL on
0.15	$.15 * (0.4) + .15 * (1 - 0.4)$	0.15		normal 100K system
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	exceeds threshold
0.8	$0.8 * (0.4) + .75 * (1 - 0.4)$	0.77	6	MIL on

I/M Readiness Code

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 considered complete once all the non-continuous monitors have been evaluated. Because the evaporative system monitor requires ambient conditions between 40 and 100 °F and BARO > 22.5 " Hg (< 8,000 ft.) to run, special logic can "bypass" the running the evap monitor for purposes of clearing the evap system I/M readiness bit due to the continued presence of these extreme conditions.

Evap bypass logic for 1997, 1998 and 1999 MY c/o vehicles:

If the evaporative system monitor cannot complete because ambient temperature conditions were encountered outside the 40 to 100 °F and BARO range at speeds above 40 mph during a driving cycle in which all continuous and non-continuous monitors were evaluated, the evaporative system monitor is then considered complete due to the continued presence of extreme conditions. If the above conditions are repeated during a second driving cycle, the I/M readiness bit for the evaporative system is set to a "ready" condition. (Note: Some 1997 and 1998 vehicles do not require catalyst monitor completion to bypass.)

Evap bypass logic for new 1999 MY, 2000 MY, and beyond vehicles:

If the evaporative system monitor conditions are met with the exception of the 40 to 100 °F ambient temperatures or BARO range, a timer is incremented. The timer value is representative of conditions where the Evap monitor could have run (all entry conditions met except IAT and BARO) but did not run due to the presence of those extreme conditions. If the timer continuously exceeds 30 seconds during a driving cycle in which all continuous and non-continuous monitors were evaluated, the evaporative system monitor is then considered complete. If the above conditions are repeated during a second driving cycle, the I/M readiness bit for the evaporative system is set to a "ready" condition.

Power Take Off Mode

While PTO mode is engaged, the I/M readiness bits are set to a "not-ready" condition. When PTO mode is disengaged, the I/M readiness bits are restored to their previous states prior to PTO engagement. During PTO mode, only CCM circuit checks continue to be performed.

Catalyst Temperature Model

A catalyst temperature model is currently used for entry into the catalyst and oxygen sensor monitors. The catalyst temperature model uses various PCM parameters to infer exhaust/catalyst temperature. For the 1998 MY, the catalyst temperature model has been enhanced and incorporated into the Type A misfire monitoring logic. The model has been enhanced to include a misfire-induced exotherm prediction. This allows the model to predict catalyst temperature in the presence of misfire.

The catalyst damage misfire logic (Type A) for MIL illumination has been modified to require that both the catalyst damage misfire rate and the catalyst damage temperature is being exceeded prior to MIL illumination. This change is intended to prevent the detection of unserviceable, unrepeatable, burst misfire during cold engine start-up while ensuring that the MIL is properly illuminated for misfires that truly damage the catalyst.

Serial Data Link MIL Illumination

The instrument cluster on some vehicles uses the J1850 serial data link to receive and display various types of information from the PCM. For example, the engine coolant temperature information displayed on the instrument cluster comes from the same ECT sensor used by the PCM for all its internal calculations.

These same vehicles use the J1850 serial data link to illuminate the MIL rather than a circuit, hard-wired to the PCM. The PCM 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.