



ON-BOARD DIAGNOSTICS SIEMENS MS43 ENGINE MANAGEMENT SYSTEM

Vehicle Coverage:
Freelander 2005 MY



1 Contents

1	Contents	2
2	Introduction	5
2.1	Inputs and Outputs	5
3	Mode \$06 Data	7
4	OBD Drive Cycle Information	10
5	Onboard Monitoring	12
5.1	Catalyst Monitoring	12
5.1.1	Description	12
5.1.2	Monitoring Structure	13
5.1.3	Drive Cycle Information	14
5.2	Misfire Monitoring	15
5.2.1	Description	15
	Monitoring Structure	16
	Fault Processing for Emissions Relevant Misfire	22
	Fault Processing for Catalyst Damaging Misfire	23
5.2.5	Drive Cycle Information	25
5.3	Evaporative Emission System Monitoring	26
5.3.1	Description	26
5.3.2	Monitoring Structure	29
5.3.3	Drive Cycle Information	34
4.4	Fuel System Monitoring	36
4.4.1	Description	36
4.4.2	Monitoring Structure	38
5.3.4	Drive Cycle Information	39
5.5	Oxygen Sensor Monitoring	40
5.5.1	Description	40
5.5.2	Oxygen Sensor Switching Time Monitoring	41
5.5.3	Flow Chart of the Oxygen Sensor Switching Monitor – Rich to Lean	42
5.5.4	Oxygen Sensor Control Frequency Monitoring	43
5.5.5	Flow Chart of the Oxygen Sensor Control Frequency Monitor	44
5.5.6	Oxygen Sensor Voltage and Voltage Amplitude Monitoring	45
5.5.7	Oxygen Sensor Heater Monitoring	45
5.5.8	Drive Cycle Information	49
5.6	Thermostat Monitoring	51
5.6.1	Description	51
5.6.2	Monitoring Structure	52
5.6.3	Drive Cycle Information	54
5.7	Positive Crankcase Ventilation (PCV) System Monitoring	55
5.7.1	Description	55



5.8	Crankshaft Position and Engine Speed Sensor	57
5.8.1	Description	57
5.8.2	Drive Cycle Information	57
5.9	Camshaft Position Sensor	58
5.9.1	Description	58
5.9.2	Drive Cycle Information	59
5.10	Engine Coolant Temperature Sensor	60
5.10.1	Description	60
5.10.2	Drive Cycle Information	61
5.11	Mass Airflow Sensor	62
5.11.1	Description	62
5.11.2	Drive Cycle Information	63
5.12	Intake Air Temperature Sensor	64
5.12.1	Description	64
5.12.2	Drive Cycle Information	65
5.13	Knock Sensor	66
5.13.1	Description	66
5.13.2	Drive Cycle Information	66
5.14	Throttle Position Sensor	67
5.14.1	Description	67
5.14.2	Drive Cycle Information	68
5.15	Engine Control Module Self Test	69
5.15.1	Description	69
5.15.2	Drive Cycle Information	69
5.16	Accelerator Pedal Position Sensor	70
5.16.1	Description	70
5.16.2	Drive Cycle Information	71
5.17	Vehicle Speed Signal	72
5.17.1	Description	72
5.17.2	Drive Cycle Information	72
5.18	Fuel Injectors	73
5.18.1	Description	73
5.18.2	Drive Cycle Information	74
5.19	Throttle Control Motor	75
5.19.1	Description	75
5.19.2	Drive Cycle Information	76
5.20	Variable Intake Manifold System	77
5.20.1	Description	77
5.20.2	Drive Cycle Information	80
5.21	Controller Area Network System	81
5.21.1	Description	81
5.21.2	Drive Cycle Information	81



5.22	Fuel Level Sensor	82
5.22.1	Description	82
5.22.2	Drive Cycle Information	82
5.23	Engine Off Timer	83
5.23.1	Description	83
5.23.2	Drive Cycle Information	83
5.24	Ambient Air Temperature	84
5.24.1	Description	84
5.24.2	Drive Cycle Information	85

2 Introduction

The Freelander Petrol Engine Management System (EMS) for North American Specification vehicles consists of the Siemens MS43 ECM controlling the 2.5L KV6 engine. The Engine Control Module (ECM) uses the inputs from sensors to control engine performance and restrict emissions in line with Onboard Diagnostics II (OBDII). These sensors include a Mass Airflow (MAF) sensor, Throttle Position (TP) sensor, Engine Coolant Temperature (ECT) sensor and Oxygen (O2) sensors. The ECM also receives vehicle data, such as road speed from other control modules. The Central Processor Unit (CPU) within the ECM processes all of these inputs, applies correction factors, such as short and long term fuel trim, and issues commands to the engine actuators, injection valves and coils.

2.1 Inputs and Outputs

Input Signals

- Transmission Control Module (TCM) - Torque Down Request (via CAN)
- O2 Sensors
- MAF Sensor
- Camshaft Position Sensor
- ECT Sensor
- TP Sensor
- Crankshaft Position Sensor
- Intake Air Temperature (IAT) Sensor
- Diagnostic Module – Tank Leakage (DMTL) (Pump Motor Current)
- Accelerator Pedal Position (APP) Sensor
- Vehicle Speed Signal
- Radiator Outlet Temperature
- Knock Sensors
- Generator Load Sensing
- Brake Light Switches
- Cruise Control Switches
- Immobiliser
- Real Time Clock (Instrument Pack via CAN)
- Fuel Tank Level (Instrument Pack via CAN)
- Instrument Pack CAN Bus
- Ambient Air Temperature (Instrument Pack via CAN)

Monitored by OBDII?

Yes – bus check
Yes
Yes
Yes
Yes
Yes
Yes
Yes
Yes
Yes
Yes
Yes
Yes
No
No
No
Yes (no Malfunction Indicator Lamp (MIL))
Yes (no MIL)
Yes (no MIL)
Yes (no MIL)



Output Signals

- Injection Valves
- Evaporative Emission (EVAP) Canister Purge Valve
- Throttle Actuator
- MIL (Instrument Pack via CAN)
- Ignition Coils
- O2 Sensor Heaters
- Fuel Pump Relay
- Diagnostic Module – Tank Leakage (Pump Motor and Solenoid Valve)
- Diagnostic Module – Tank Leakage (Heater)
- ECM Main Relay
- Intake Manifold Switching Valves
- Engine Cooling Fan
- Air Conditioning Compressor Relay
- (TCM) - Engine Speed, Torque, Temperature and Throttle Angle (via CAN)

Monitored by OBDII?

Yes
Yes
Yes

Via Misfire Monitoring
Yes

Yes
Yes (no MIL)
No
Yes (no MIL)
No
No
Yes – signals checked separately



3 Mode \$06 Data

Mode \$06 enables access to the most current diagnostic results and thresholds of non-continuous diagnostic routines. A Component Identifier (CID) identifies each individual parameter.

Following a power fail or after a delete error memory (Mode \$03) request all values will be set to \$00.

TID \$00

Identifies the TID services supported by the ECM, 0 = No, 1 = Yes.

Data B -
Bit 7 = 1 = TID \$01 – Catalyst conversion efficiency
Bit 6 = 1 = TID \$02 – Oxygen Sensors
Bit 5 = 0 = TID \$03 – Secondary Air Injection: not supported
Bit 4 = 0 = TID \$04 – Exhaust Gas Recirculation (EGR) System: not supported
Bit 3 = 1 = TID \$05 – Evaporative Emission Loss Control System
Bit 2 = 1 = TID \$06 – Oxygen Sensor heating: not required – continuously monitored
Bit 1 = 0 = TID \$07 – Electrical Catalyst heating: not equipped
Bit 0 = 0 = TID \$08 – Camshaft Position Control (VANOS): not supported
Data C -
Bit 7 = 0 = TID \$09 – Thermostat monitoring: not supported
Bit 6 = 0 = Not Defined
Data D = \$00 = Not Defined
Data E = \$01 = TID \$20: supported

TID \$01

Catalyst conversion efficiency
2 point (switching) Oxygen Sensor control

J1979 Mode \$06 Data				
Data A (limit type & CID)	Data B	Data C	Data D	Data E
0 0000101 = \$05 = Bank 1 single	\$00	Result	\$00	Limit
0 0000110 = \$06 = Bank 2 single	\$00	Result	\$00	Limit
0 0000111 = \$07 = Both banks	\$00	Result	\$00	Limit
0 0001000 = \$08 = Bank 1 sum	\$00	Result	\$00	Limit
0 0001001 = \$09 = Bank 2 sum	\$00	Result	\$00	Limit
0 0001010 = \$0A = Bank 1 short test	\$00	Result	\$00	Limit
0 0001011 = \$0B = Bank 2 short test	\$00	Result	\$00	Limit



TID \$02

O2 Sensors
As mode \$05

TID \$03

Secondary Air Injection
Not supported

TID \$04

EGR
Not supported

TID \$05

EVAP Loss Control system

J1979 Mode \$06 Data					
Data A (limit type & CID)	Data B MSB	Data C LSB	Data D MSB	Data E LSB	
0 0000001 = \$01 = EVAP Canister Purge Valve flow max	Result	Result	Limit	Limit	1
0000001 = \$01 = EVAP Canister Purge Valve flow min	Result	Result	Limit	Limit	0
0001000 = \$08 = EVAP Canister Purge Valve flow Δ rpm	Result	Result	Limit	Limit	1
0010010 = \$12 = DMTL error - min Iref <	Result	Result	Limit	Limit	0
0010011 = \$13 = DMTL error - max Iref >	Result	Result	Limit	Limit	0
0010100 = \$14 = DMTL error - Plausability Ip >	Result	Result	Limit	Limit	1
0010101 = \$15 = Large Leak Finished	Result	Result	Limit	Limit	1
0010110 = \$16 = Small Leak Finished	Result	Result	Limit	Limit	
0 0010111 = \$17 = DMTL error - signal Ifluc >	Result	Result	Limit	Limit	
1 0011000 = \$18 = Extra Large Leak Finish Result	Result	Result	Limit	Limit	

TID \$06

O2 Sensor heating
Not required – continuous monitor



TID \$07

Catalyst heater
Not equipped

TID \$08

VANOS
Not supported

TID \$09

Thermostat monitoring

J1979 Mode \$06 Data				
Data 3 (limit type & CID)	Data 4 MSB	Data 5 LSB	Data 6 MSB	Data 7 LSB
1 0100110 = \$16 = Thermostat test	Result	Result	Limit	Limit



4 OBD Drive Cycle Information

Drive Cycle A

- 1 Switch ignition on for 30 seconds
- 2 Ensure Engine Coolant Temperature (ECT) less than 60 °C (140 °F)
- 3 Start Engine
- 4 Engine idle for 2 minutes
- 5 Connect a generic scan tool and check for fault codes.

Drive Cycle B

- 1 Switch ignition on for 30 seconds
- 2 Ensure Engine Coolant Temperature (ECT) less than 60 °C (140 °F)
- 3 Start Engine
- 4 Allow engine to idle for 2 minutes
- 5 Perform 2 light accelerations (0 to 35 mph with light pedal pressure)
- 6 Perform 2 medium accelerations (0 to 45 mph with moderate pedal pressure)
- 7 Perform 2 hard acceleration (0 to 55 mph with heavy pedal pressure)
- 8 Allow engine to idle for 2 minutes
- 9 Connect a generic scan tool with engine still running and check for fault codes.

Drive Cycle C

- 1 Switch ignition on for 30 seconds
- 2 Ensure Engine Coolant Temperature (ECT) less than 60 °C (140 °F)
- 3 Start Engine
- 4 Allow engine to idle for 2 minutes
- 5 Perform 2 light accelerations (0 to 35 mph with light pedal pressure)
- 6 Perform 2 medium accelerations (0 to 45 mph with moderate pedal pressure)
- 7 Perform 2 hard acceleration (0 to 55 mph with heavy pedal pressure)
- 8 Cruise at 60 mph for 8 minutes
- 9 Cruise at 50 mph for 3 minutes
- 10 Allow engine to idle for 3 minutes
- 11 Connect a generic scan tool with engine still running and check for fault codes.



Drive Cycle C+

- 1 This is an extended drive cycle C to enable the internal diagnostic process to be completed which is not alone achieved by drive cycle C.
- 2 Please perform the additional portion after completing drive cycle C (after completing the three minute idle) when prompted by T4/TestBook.
- 3 Perform medium acceleration to 60 mph and hold for 10 seconds
- 4 Remove foot from gas pedal and decelerate to 50 mph.
- 5 Re-perform medium acceleration to 60 mph and hold for 10 seconds
- 6 Again decelerate to 50 mph.
- 7 Repeat this another 13 times until 15 acceleration/decelerations cycles have been completed
- 8 Connect a generic scan tool with engine still running and check for fault codes.

Drive Cycle D

- 1 Switch ignition on for 30 seconds
- 2 Ensure Engine Coolant Temperature (ECT) less than 35 °C
- 3 Start Engine
- 4 Allow engine to idle for 2 minutes
- 5 Perform 2 light accelerations (0 to 35 mph with light pedal pressure)
- 6 Perform 2 medium accelerations (0 to 45 mph with moderate pedal pressure)
- 7 Perform 2 hard acceleration (0 to 55 mph with heavy pedal pressure)
- 8 Cruise at 60 mph for 5 minutes
- 9 Cruise at 50 mph for 5 minutes
- 10 Cruise at 35 mph for 5 minutes
- 11 Allow engine to idle for 2 minutes
- 12 Connect a generic scan tool and check for fault codes.

Drive Cycle E

- 1 Ensure Fuel Tank is > ¼ full
- 2 Carry out Drive Cycle A
- 3 Switch off ignition
- 4 Leave vehicle undisturbed for 20 minutes
- 5 Switch on ignition
- 6 Connect a generic scan tool and check for fault codes.

Drive Cycle F

Force actuator or function through diagnostic as per EOL test.



5 Onboard Monitoring

5.1 Catalyst Monitoring

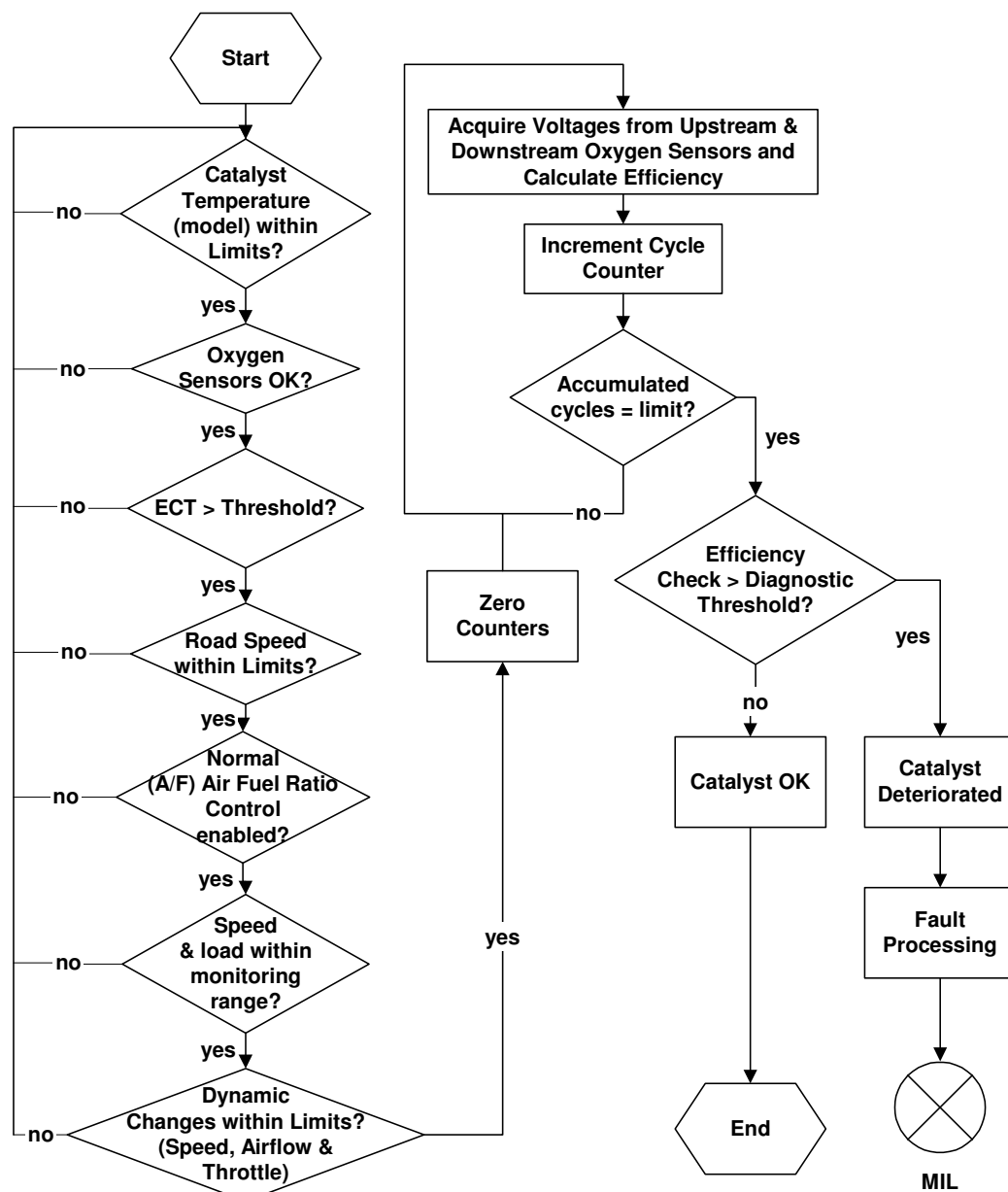
5.1.1 Description

The exhaust system consists of two separate branches with one catalytic converter in each bank and each catalyst is monitored independently of the other. The signals of both the up-stream control exhaust gas oxygen sensor and the corresponding down-stream monitoring sensor are used for the diagnosis of the catalyst.

If the catalyst has a good conversion capability then the lambda deviations, which are produced by the feedback control system are smoothed by the oxygen storage capacity of the catalyst.

If the catalyst has reduced conversion capability due to aging, poisoning or misfire, then the lambda deviations produced in front of the catalyst are also visible after the catalyst. The downstream exhaust gas oxygen sensor measures these post-catalyst lambda deviations.

5.1.2 Monitoring Structure





Catalyst Monitoring Operation								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Catalyst		Oxygen storage capability	Comparison of calculated lambda-cycle to measured lambda-cycle from rear oxygen sensor	> 2.03 during 39 lambda controller cycles	ECT	> 60° C	90 s / once per driving cycle	two driving cycles
Bank 1	P0420				Fuel system status	closed loop		
Bank 2	P0430				Vehicle speed	3.1 < vehicle speed < 124 mph		
					Engine speed and Engine load	1280 to 2912 rpm 0.31 to 0.97 g/rev		
					Engine speed	$\Delta < 308$ rpm		
					Engine load	$\Delta < 0.27$ g/rev		
					Lambda Mean Value	$\Delta < 4.1\%$		
					Delta accelerator pedal movement	$\Delta < 504^\circ$ Throttle Position Sensor (TPS)/s		
					Catalyst temperature (model)	399 < T °C < 899		
					Following Over Run Fuel Cut Off (ORFCO)	Integrated Air Mass > 200g		
			Hydrocarbon (HC) Emissions (1.75 x standard)					

If the above table does not include details of the following enabling conditions: - IAT, ECT, vehicle speed range, and time after engine start-up then the state of these parameters has no influence upon the execution of the monitor.

5.1.3 Drive Cycle Information

P0420 Drive Cycle C
P0430 Drive Cycle C



5.2 Misfire Monitoring

5.2.1 Description

Misfire detection is achieved by monitoring the acceleration of the crankshaft, if the speed of the crankshaft reduces and increases after a firing event then a misfire is suspected.

The time for each firing event is measured over 120 crankshaft degrees; this time is corrected for mechanical variation between the different measurement windows. These correction factors are determined during periods of ORFCO.

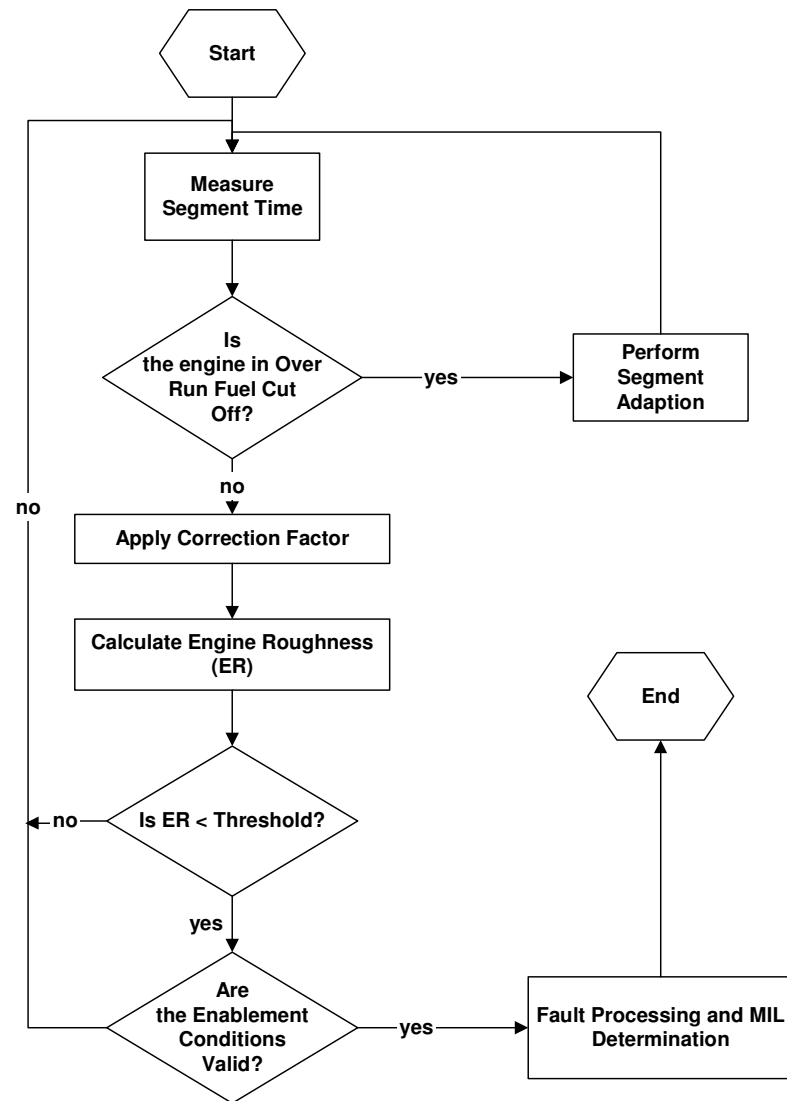
The corrected segment times from a number of firing events are used to calculate an Engine Roughness (ER) value for each individual firing event, if this ER value is less than the ER threshold for that engine operating point then a misfire has occurred.

Misfire detection is suspended when other factors such as a rough road surface or an extreme change in engine speed influence the rotation of the crankshaft and would result in the false detection of misfire.

Misfire events are processed according to the requirements of the OBD regulation to determine if the MIL should be illuminated and a Diagnostic Trouble Code (DTC) stored.

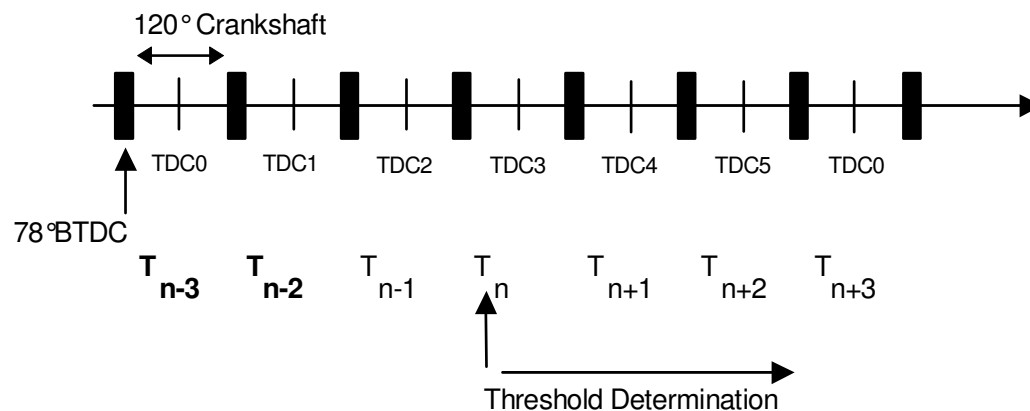
The system will store a single or multi-cylinder misfire DTC, depending on the distribution of the detected misfire across the different cylinders. If two or more cylinders are individually responsible for at least 10 % of the detected misfire, a multiple cylinder DTC will be stored.

5.2.2 Monitoring Structure



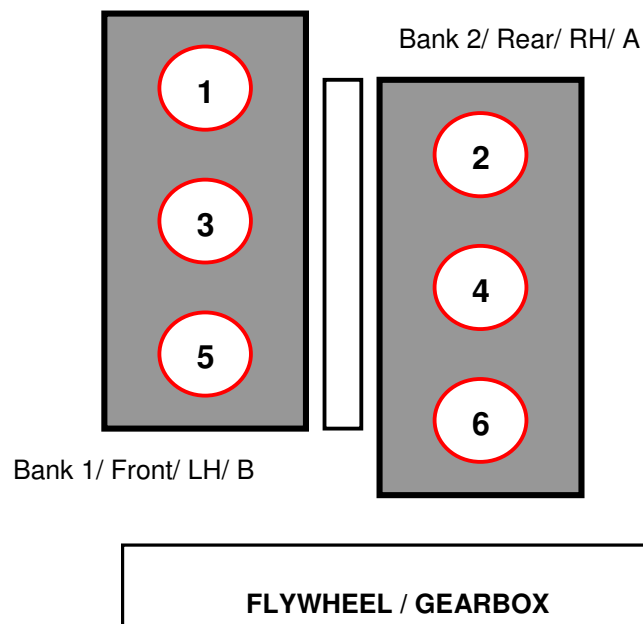
Data Collection

The rotation of the crankshaft is timed according to the following diagram:



Physical engine firing order: 1-6-5-4-3-2 following a software logic order of 0-1-2-3-4-5 respectively.

The engine cylinder numbering is as follows:





The timing period starts 78° before Top Dead Centre (TDC) and finishes 42° after that same TDC. This means that the finish point of one segment is the start point for the next segment.

Since there are likely to be minor differences in the mechanical properties of the 6 cylinders, correction factors are determined for 5 of the cylinders relative to the one reference cylinder. These correction factors are established during periods of ORFCO. The correction factors are applied to the times measured for each crankshaft segment during operation outside of ORFCO. Before these correction values have been established, the detection threshold is reduced to avoid the false detection of misfires.

Data Processing

7 valid successive segments are required for the calculation of an ER value.

$$ER_n = ((\text{Static Component} - \text{Dynamic Component} - \text{Additive Torsional Component}) \times \text{Multiplicative Torsion Factor}) + \text{Curvature Component}$$

Where:

The "Static Component" compares the segment times that directly follow each other and is primarily responsible for the detection of misfire.

The "Dynamic Component " corrects for a regular acceleration or deceleration.

The "Additive Torsion Component " compensates for fluctuations due to torsional vibrations. When no misfire is present, the deviations of the individual cylinders will on average be zero. The deviation is mapped against speed and load for each cylinder.

The "Multiplicative Torsion Factor", when misfire is present the magnitude of the signal excursion of the ER value is normalised for the different cylinders. This factor is mapped against engine speed for each cylinder.

The "Curvature Component" corrects the remaining deviations with strong non-stationary processes (negative curvature). The reason for these deviations lies in the different overlap lengths of the static (determined over 2 crank segments) and dynamic (determined over 7 crank segments) components. Thus, with these strongly negative curvatures, a short ER-shift into the negative region occurs. The "Curvature Component" is used to pull the ER-values for this region back to a zero level again. At higher engine speeds the "Curvature Component" is tuned out.

Misfire Determination

The ER value is compared to a reference value, if it is less than the reference value and the function is enabled according to the conditions below, then a misfire has occurred.

The reference value is formed from the following:

Basic Map

The basic threshold value is extracted from an engine speed and load dependent map.



Temperature Correction

The basic threshold value is multiplied by an ECT dependent factor; this is to take account of the greater signal amplitude and variability at lower temperatures.

Threshold Correction during the Segment Learning Process

As stated above, before the segment correction values have been established, the detection threshold must be reduced to avoid the false detection of misfires.

Threshold Correction during Catalyst Heating

The basic detection threshold map is determined for optimum ignition conditions, if the ignition has been retarded in order to reduce the efficiency of the engine, such as during the operation of the catalyst light-off function, then the detection threshold is multiplied by a factor that depends on the amount of ignition retard that has been applied.

Additionally at idle, there is a factor to take account of the effect of rapid changes in the ignition timing on each cylinder's contribution to the rotation of the engine, which might cause the false detection of misfire.

The corrected threshold, THD_ER_n is compared to the roughness value ER according to the following equation:

If $ER_n < THD_ER_n$,

Then a misfire has occurred.

Function Enable Conditions

The following conditions must be true for misfire detection to be enabled:

Function Enable Conditions	
Condition	Note
Minimum Engine Speed	The physical limitations of the system (16 bit and 0.667 micro-second system clock) prevent this being set below 480 rpm. This threshold maybe set higher, but must be no higher than 150 rpm below the normal, fully warm idle speed in Drive to fulfill the requirements of CARB's OBDII regulation.
Minimum Load	The load must be above an engine speed dependent threshold, according to the regulations this must be no higher than the engine operating region bound by the positive torque line (i.e. engine load with the transmission in neutral), and the two following engine operating points: an engine speed of 3000 rpm with the engine load at the positive torque line, and the redline engine speed with the engine's manifold vacuum at four inches of mercury lower than that at the positive torque line.



Function Enable Conditions

Condition	Note
Maximum MAF Difference	Due to problems with the transition from over-run to positive load, misfire detection is not enabled if the MAF increases by more than a tuneable amount between firing events.
Maximum Throttle Position Gradient	Misfire detection is only enabled if the rate of change of the throttle opening is less than a tuneable threshold. This is because drive-train oscillations can occur during the transition from positive torque to over-run but with only a small change in a MAF and without falling below the minimum load threshold.
Maximum Manifold Air Pressure Gradient	If there is a negative or positive change in manifold pressure greater than a tuneable threshold, then misfire detection is not enabled, unless the change occurs during the period following engine start.
Negative Ignition Angle Differences	If there is an engine torque limitation request, misfire detection is not enabled if the retard exceeds a tuneable threshold, unless the request is during the period following engine start.
After Start Enablement Delay	To avoid the false detection of misfire during the period after engine start and in order to collect sufficient data to start the misfire detection process, misfire detection is not enabled until a tuneable number of crank degrees after leaving the engine start condition. Calibration of this feature must take account of CARB's requirement for misfire detection to start within 2 engine revolutions of the engine starting.
Air Conditioning Compressor Switch On	Due to the change in engine load, misfire detection is suspended for a tuneable length of time following the turning on of the air conditioning compressor.
Rough Road Conditions	The Anti-lock Braking System (ABS) wheel speed sensors are used to detect the presence of rough road conditions that could influence the rotation of the crankshaft and therefore lead to the false detection of misfire. Therefore misfire detection is not enabled if wheel acceleration is greater than a tuneable threshold.

Fault Processing

Having determined that a particular ignition event is a misfire and that the function enable conditions are met, then the result must be processed according to the CARB regulations.

Emissions Critical Misfire

This is assessed every 1000 crankshaft revolutions, the total of the number of misfires across all 6 cylinders is compared with a previously established threshold for exceeding the Federal Test Procedure (FTP) tailpipe emissions by 1.5 times. If the count is over this threshold during the first 1000 revolutions after engine start, then a temporary DTC is stored and if this level is exceeded in the first 1000 revolutions after start on the next driving cycle, then a permanent DTC is stored and the MIL is illuminated.

If the emissions failing threshold is exceeded beyond the first 1000 revolutions, then this must occur on at least 4 occasions during a driving cycle, before a temporary DTC is stored. If there are again at least 4 occurrences during the next driving cycle, then a permanent DTC is stored and the MIL is illuminated.



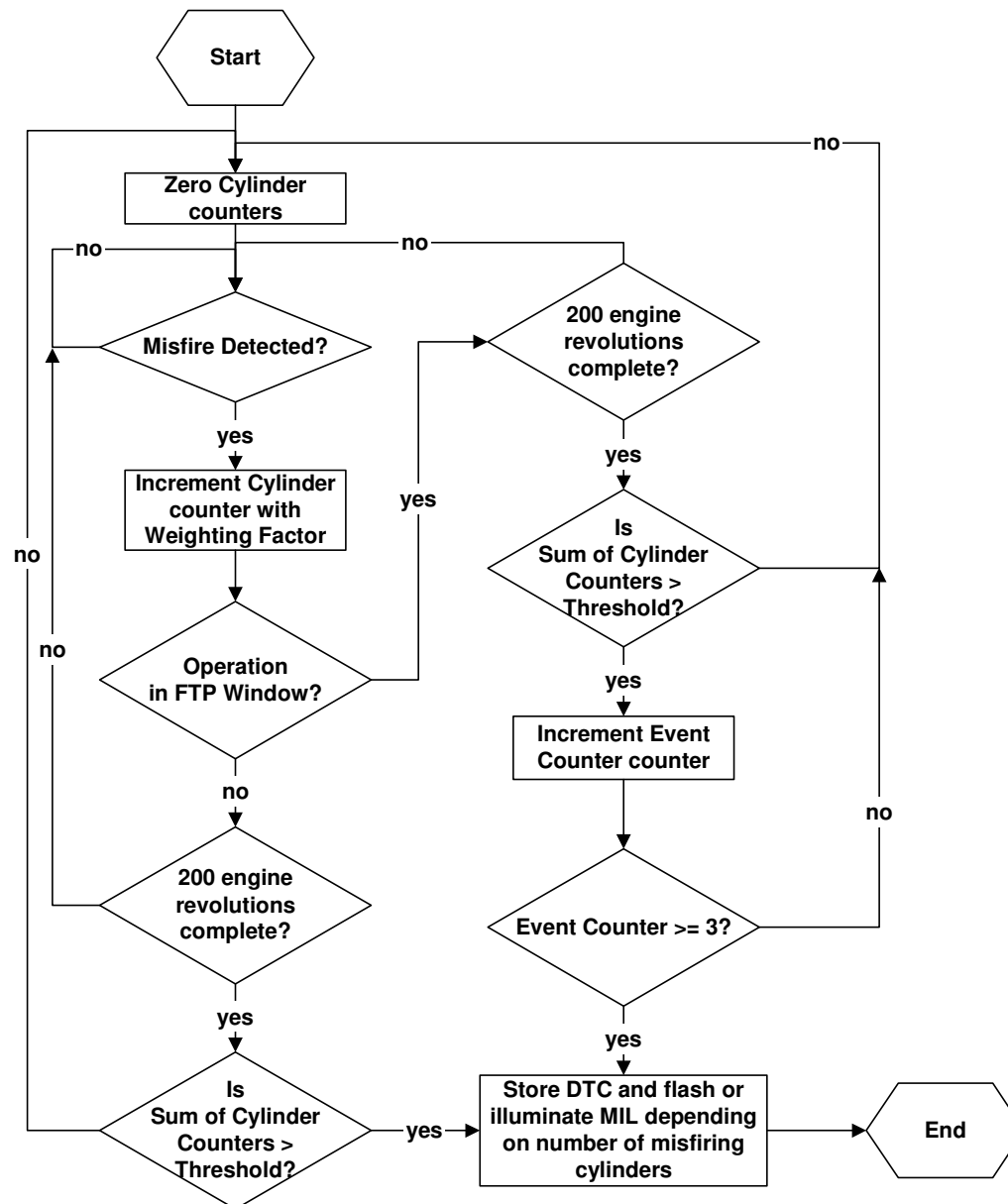
Catalyst Damaging Misfire

This is assessed every 200 crankshaft revolutions. The misfire threshold is established from previously measuring its effect on catalyst temperature, this gives different thresholds for different engine speeds and loads. Since in normal vehicle operation the speed and load of the engine varies, a weighting factor map is used to take account of these differences.

Following the detection of a misfire, the appropriate weighting factor is extracted from a speed and load dependent look-up table. If at the end of the 200 revolution window, the sum of the misfire events multiplied by the weighting factors is over a threshold, then if engine operation has been outside of the speeds and loads encountered during the FTP a diagnostic trouble code is stored. The illumination of the MIL depends on the number of misfiring cylinders identified. If 2 or fewer cylinders have been identified, then the fuel to those cylinders is shut off and the MIL illuminated. If more than 2 cylinders have been identified, then the MIL is flashed for as long as misfire continues to occur and is permanently illuminated thereafter. If engine operation has been within the FTP speed and load window, then misfire has to have exceeded the catalyst damaging threshold on at least 3 occasions before a diagnostic trouble code is stored and the MIL is illuminated or flashed, depending on the number of cylinders that have been identified.

After ORFCO has occurred for longer than a tuneable threshold on at least 4 occasions, then fuel is re-instated to any cylinders that have been shut off due to the detection of misfire.

5.2.4 Fault Processing for Catalyst Damaging Misfire



Misfire Monitoring Operation									
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination	
Misfire Cylinder 1 Cylinder 2 Cylinder 3 Cylinder 4 Cylinder 5 Cylinder 6	P0301	Crankshaft speed fluctuation	FTP emissions threshold exceeded within the first 1000 revolutions after engine start	1.40% / 3000 ignitions	Engine speed	512 < rpm < 6752	1000 revolutions up to 4 times in one drive cycle/ continuous	two driving cycles	
	P0302				At engine speed and air mass	736 to 6400 rpm > 0.26 to > 0.59 g/rev			
	P0303		At air mass and Δ air mass	0.26 to 0.82 g/rev <0.01 to < 0.61 g/rev					
	P0304		At accelerator pedal position and positive Δ accelerator pedal or negative Δ accelerator pedal	7.5 to 50.2 ° <164 to <1465 ° TPS/s					
	P0305	<u>Multi-Cylinder DTCs:</u>	Catalyst damage	% / 600 ignitions: At engine load 0.29 to 1.72 g/rev 21.0 - 4.1% at 1000 rpm 14.0 - 3.4% at 2000 rpm 10.5 - 2.6% at 3000 rpm 7.0 - 1.5% at 4000 rpm 3.7 - 1.3% at 5000 rpm 3.3 - 2.0% at 6000 rpm	At calculated Manifold Absolute Pressure (MAP) and calculated positive Δ MAP or calculated negative Δ MAP	< 117 to <1394 ° TPS/s 24 to 200 kPa <11.0 to <300 kPa <-2.5 to <-300 kPa	200 revolutions/ continuous (x 3 during FTP speed & load conditions)	Immediately	
	P0306								
	P0300				Multi-cylinder, emissions Failing				
	P0316				Multi-cylinder, emissions Failing during first 1000 revs After start				
	P1300				Multi-cylinder, catalyst Damaged	Rough road (wheel acceleration) at vehicle speed			< 9 °CRK < 6.99 to < 65 % 1.9 < vehicle speed<93 mph

If the above table does not include details of the following enabling conditions: - IAT, ECT, vehicle speed range, and time after engine start-up then the state of these parameters has no influence upon the execution of the monitor.

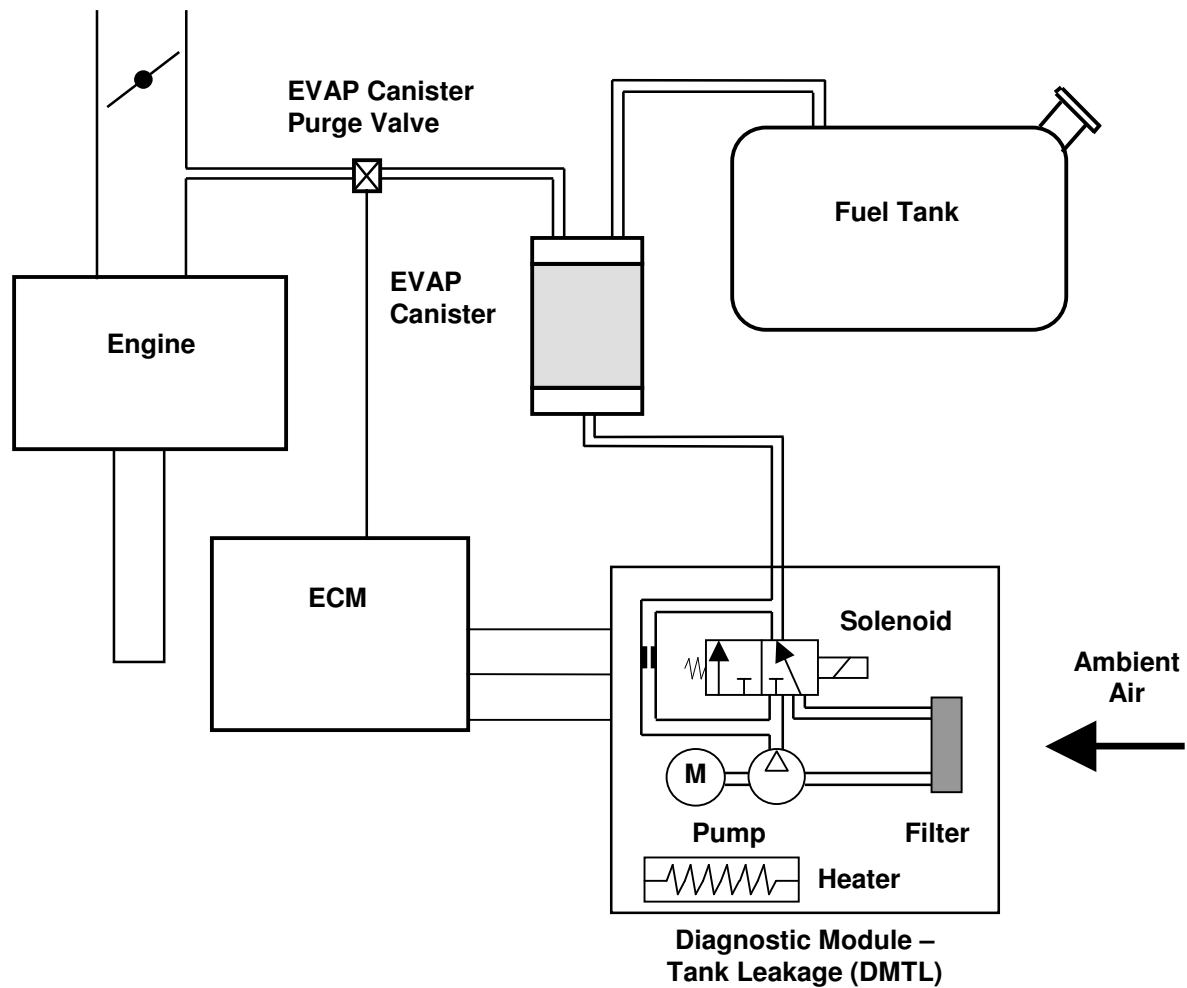


5.2.5 Drive Cycle Information

P0301	Drive Cycle B
P0302	Drive Cycle B
P0303	Drive Cycle B
P0304	Drive Cycle B
P0305	Drive Cycle B
P0306	Drive Cycle B
P0300	Drive Cycle B
P0316	Drive Cycle B
P1300	Drive Cycle B

5.3 Evaporative Emission System Monitoring

5.3.1 Description

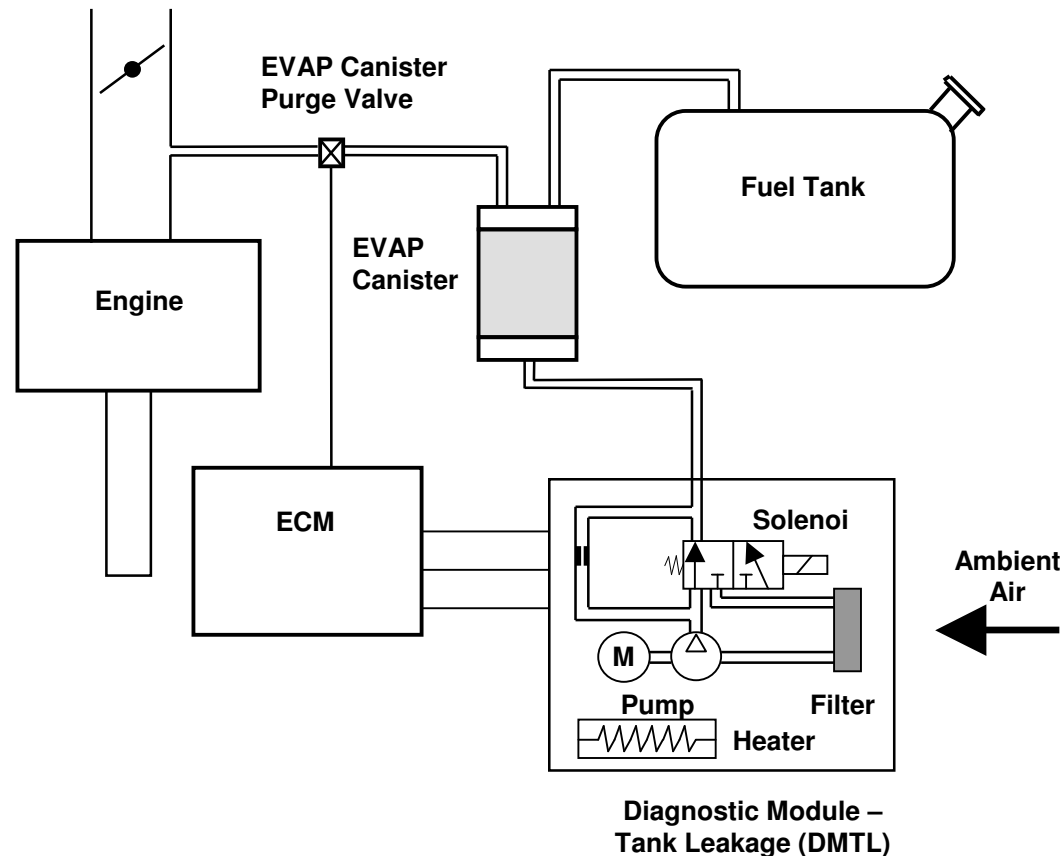


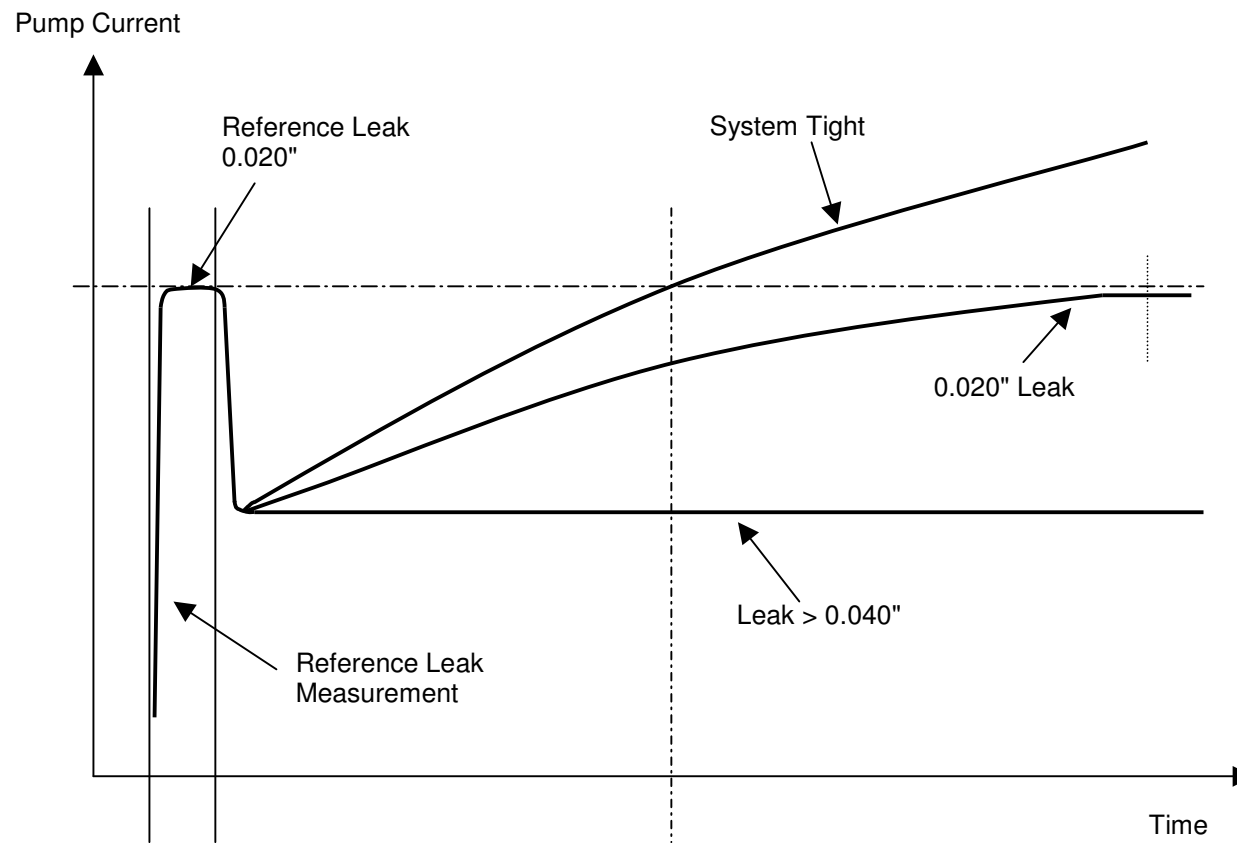
The evaporative emission monitoring system permits the detection of leaks with a diameter of 0.020" or greater.

This is achieved by means of a pressure test of the system. This is performed by the DMTL, which is an electrically operated pump fitted to the atmospheric air intake of the EVAP canister. This unit contains an electric heater to prevent condensate formation, though the ECM contains functionality to inhibit the leak check if humidity is detected. If humidity is detected on more than a tuneable number of test attempts, then the system assumes that there is a fault present.

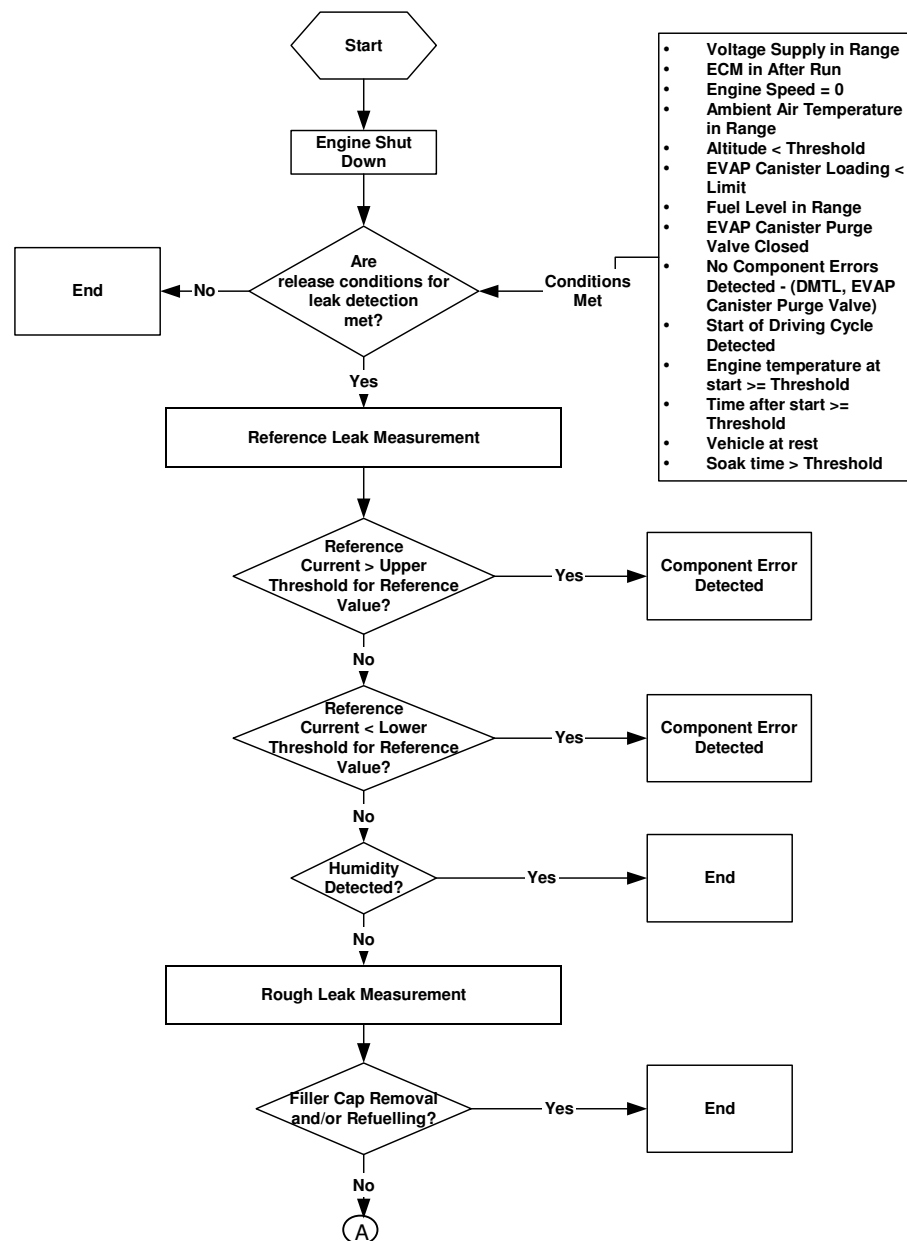
The test proceeds in 2 stages: -

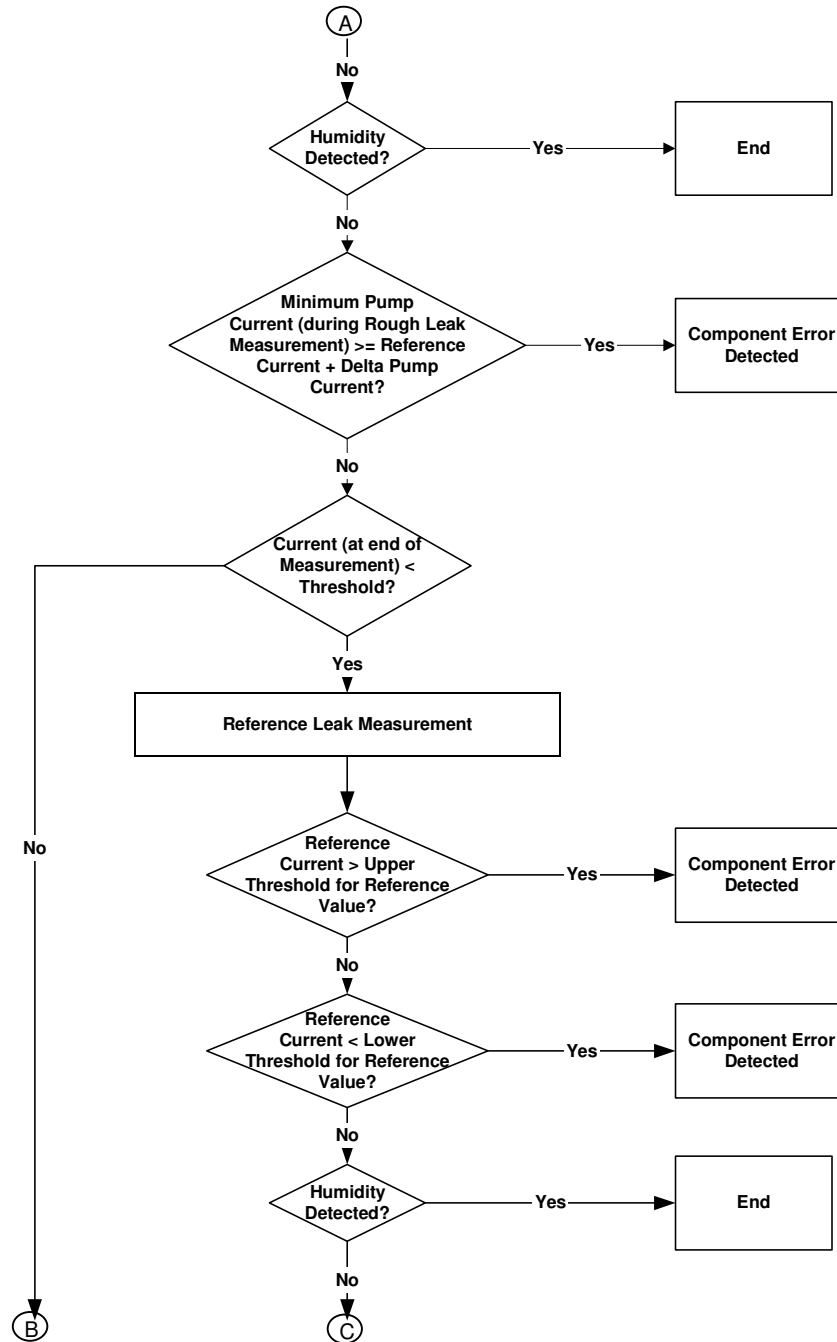
- Reference Leak Measurement - The pump operates against the reference restriction within the DMTL. The ECM measures the current consumption of the pump motor during this phase.
- Leak Measurement (see diagram below) - The solenoid in the DMTL is operated in order to shut off normal purge airflow into the EVAP canister. The pump can now pressurise the fuel tank and vapour handling system. The ECM again measures the current consumed by the pump motor and by comparing this with the reference current, determines if a leak is present or not. A high current indicates a tight system and a low current indicates a leaking system.

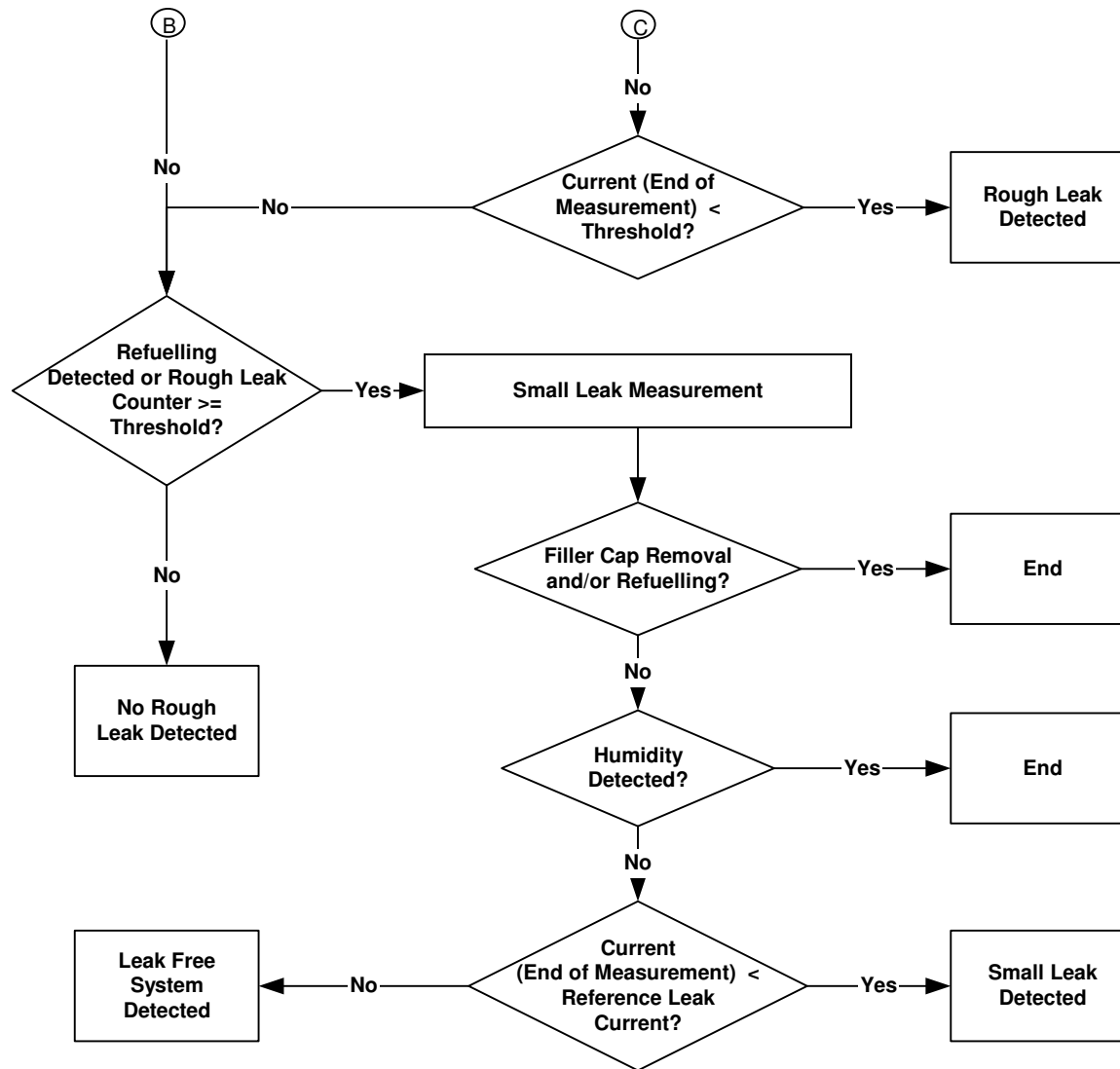




5.3.2 Monitoring Structure







Evaporative Emission System Monitoring

Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold Value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
EVAP Canister Purge Valve	P0445	Short to ground	Voltage	< 2.9V	low-side driver	not active	1.5 s /	two driving
	P0443	Short to battery positive	Current range	0.02 A < Current < 2 A		Active	continuous	cycles
	P0444	Open circuit	(minimum/maximum)					
DMTL Vent	P0448	Short to battery positive	Current range	1.05 A < Current < 1.75 A	Ignition key	On	10 s /	two driving
	P0447	Short to ground or open circuit	Voltage range	0.32*Voltage Common Collector (VCC) to 0.4*VCC (at VCC=5V; 1.6 to2V)			continuous	cycles
DMTL Pump	P2402	Short to battery positive	Voltage range	voltage >4V longer than 50ms	Ignition key	On	10s /	two driving
	P2401	Short to ground or open circuit	Voltage range	0.32*VCC to 0.4*VCC (at VCC=5V; 1.6 to2V)			continuous	cycles
	P2405	Current during reference leak measurement	Pump current (minimum)	< 15 mA	Leak Check	Active	10s	
	P2406		Pump current (maximum)	> 40 mA				
	P2407	Current change during rough leak check	Pump current	>= Reference current –2.002 mA			15s	
	P2404	Signal/heater element	Humidity counter overflow	Counter > 14			< 450s	
DMTL Heater	P240C	Short to battery positive	Current range	1.05 A < Current < 1.75 A	Time elapsed from switch on	> 3 s	10 s /	No MIL
	P240A	Short to ground or open circuit	Voltage range	0.32 * VCC to 0.4 * VCC (at VCC=5V; 1.6 to 2V)			continuous	illumination (leak detection defaults to enabled)



Evaporative Emission System Monitoring

Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold Value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
EVAP Canister Purge Valve	P0441	Flow check - Step 1 (lambda shift)	Lambda controller shift	$\Delta < 6\%$	ECT Normal purge	$> 60^{\circ}\text{C}$ On	18.5 s / once per driving cycle	two driving cycles
		Flow check - Step 2 (engine speed change)	Engine speed	$\Delta < 12\text{ rpm}$	Engine load Engine speed Vehicle speed Engine state	$< 0.61\text{ g/rev}$ $\Delta < 100\text{ rpm}$ 0 mph Idle		
		Flow check - Step 3 (air flow change)	MAF	$\Delta < 0.02\text{ g/rev}$	Vehicle speed Engine state Air conditioning compressor relay	0 mph Idle Not engaged		
EVAP System Leak Detection		Over-pressure System using an ECM driven pump			ECT at start IAT Altitude condition Last driving cycle Time after engine shut off Fuel Tank level ECM running on Battery positive EVAP Canister load Humidity Vehicle speed	$> 1.5^{\circ}\text{C}$ $2^{\circ}\text{C} \leq \text{IAT} \leq 38^{\circ}\text{C}$ $\geq 73\text{ kPa}$ $> 20\text{ min}$ 3 s $14 < \text{level} < 89\%$ Yes $10.9 < \text{battery}$ positive $< 14.5\text{V}$ $< 30\%$ $\Delta 0.452\text{ mA}$ in a 10 s reference measurement = 0 mph		four driving cycles

Evaporative Emission System Monitoring								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold Value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
	P0455	Rough leak Measurement	Pump current at end of test (system leak $\geq 0.040''$) Stage 1 Stage 1	$< \text{idle current} + K1(\text{reference current} - \text{idle current})$ $< \text{ref. current} - K2(\text{reference current} - \text{idle current})$ $K1 = 0.228 \pm 0.037$ $K2 = 0.698$	Soak time No refueling during diagnosis No filler cap removal during diagnosis	> 5 hours Change of pump current $> +1.202\text{mA}$ Change of pump current $< -0.501\text{ mA}$	$< 100\text{ s}$ / once per driving cycle	
	P0442	Small leak Measurement	Pump current (system leak $\geq 0.020''$)	$\leq \text{Reference current}$ <u>OR</u>	Re-fuelling (prior to test) Rough leak counter No refueling during diagnosis No filler cap removal during diagnosis	Detected ≥ 14 Change of pump current $> +1.202\text{ mA}$ Change of pump current $< -0.501\text{ mA}$	Rough leak + up to 360 s / once per driving cycle	

If the above table does not include details of the following enabling conditions: - IAT, ECT, vehicle speed range, and time after engine start-up then the state of these parameters has no influence upon the execution of the monitor.

5.3.3 Drive Cycle Information

P0445	Drive Cycle A
P0443	Drive Cycle A
P0444	Drive Cycle A
P0448	Drive Cycle A
P0447	Drive Cycle A
P2402	Drive Cycle A
P2401	Drive Cycle A
P2405	Drive Cycle A
P2406	Drive Cycle A
P2407	Drive Cycle A



P2404	Drive Cycle A
P240C	Drive Cycle A
P240A	Drive Cycle A
P0455	Drive Cycle F
P0442	Drive Cycle F
P0441	Drive Cycle C

4.4 Fuel System Monitoring

4.4.1 Description

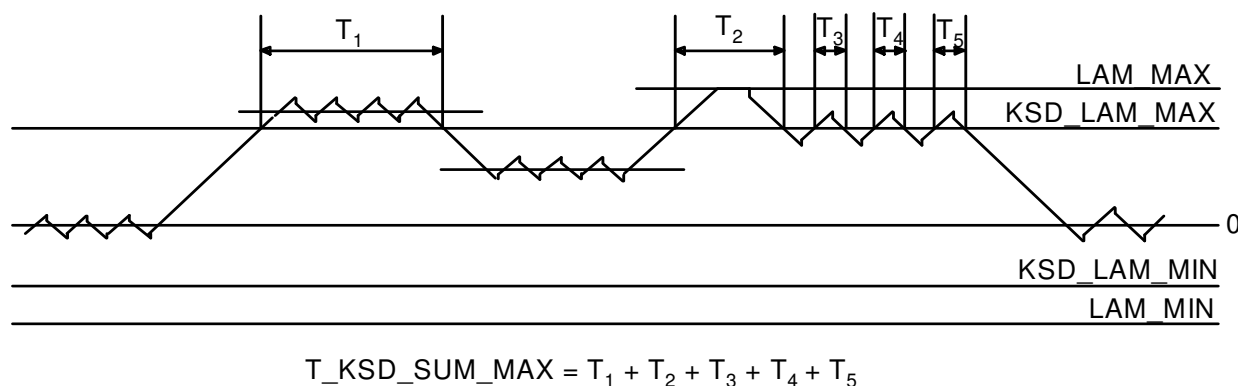
Fuel system monitoring checks the correction that has been applied by the feedback control system against pre-determined limits.

There are 2 elements to this diagnostic. The first checks for the short term exceedance of a rich or lean limit value. This function will usually pick up any step changes that have occurred in the fuel system. The second element checks for a longer term exceedance of a lower limit value. This part of the diagnostic is more likely to detect aging effects in the fuel system. Since the engine consists of 2 banks of cylinders, each with separate fuelling control the fuel system monitor will report faults independently for each of the banks.

Monitoring Structure – Short Term Fuel System Diagnostic

If the enrichment exceeds maximum threshold (LAM_MAX) or the enleanment exceeds a minimum threshold (LAM_MIN), then the EVAP canister purge valve is shut and a timer is started. If the timer reaches a pre-determined value without a rich or lean transition occurring then a fault is present.

Monitoring Structure – Long Term Fuel System Diagnostic



The monitor checks for an excessively rich or lean correction, in both cases the principles are the same, but the thresholds can be set independently of each other.



The above diagram illustrates excessive enrichment, if the relevant enablement conditions are met, then a timer, T_KSD_SUM_MAX, is incremented whenever the fuelling correction factor exceeds KSD_LAM_MAX. In the above example, T_KSD_SUM_MAX is the sum of T1, T2, T3, T4 and T5. If T_KSD_SUM_MAX exceeds a tuneable threshold, then a fault exists.

If the engine speed and MAF are above pre-determined thresholds, then the fuelling correction is given by:

Fuelling Correction = Multiplicative Adaptation Value + Additive Correction Value

If the engine speed and MAF are below these pre-determined thresholds, then the fuelling correction is given by:

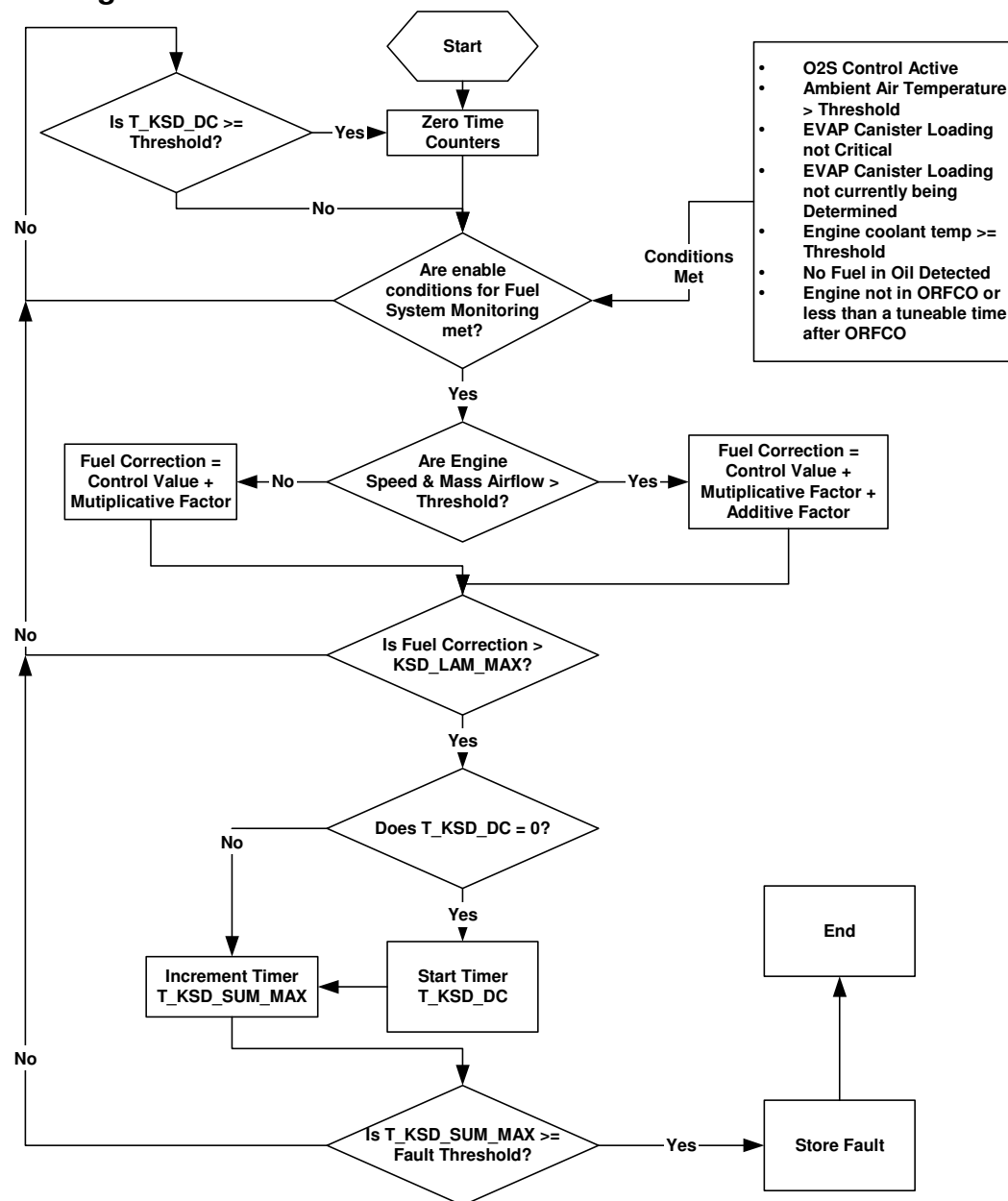
Fuelling Correction = Multiplicative Adaptation Value

When the correction factor threshold, KSD_LAM_MAX, is first exceeded a timer called T_KSD_DC is started, if this timer reaches a tuneable threshold before T_KSD_SUM_MAX reaches the fault threshold, then T_KSD_SUM_MAX is reset to zero.

Abbreviations for the Short and Long Term Fuelling Diagnostics

LAM_MAX	Fuel system short-term adaptation maximum threshold.
LAM_MIN	Fuel system short-term adaptation minimum threshold.
KSD_LAM_MAX	Fuel system long-term adaptation maximum threshold.
KSD_LAM_MIN	Fuel system long-term adaptation minimum threshold.
T_KSD_LAM_MAX	Fuel system long-term adaptation maximum threshold timer.
T_KSD_LAM_MIN	Fuel system long-term adaptation minimum threshold timer.
T_KSD_DC	Fuel system long-term adaptation timer

4.4.2 Monitoring Structure



Fuel System Monitoring								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Fuel System Monitoring	P0171/2 P0174/5	Short term monitor	Enrichment factor	>28% <u>or</u> < -28%	Lambda control	Active	25 s	two driving cycles
		Long term monitor	Fuelling correction Rich Lean	> 13% for a cumulative time ≥ 85 s <u>or</u> < -16% for a cumulative time ≥ 20 s	Lambda control Ambient temp. Can. loading check Charcoal can load factor Load dependent purge correction factor ECT Fuel in Oil Engine state	Active ≥ -5 °C Not in progress > 0.852 > -15.0% > 60 °C Not detected Not in ORFCO or > 1.5 s since ORFCO	20 to 85 s / continuous	
	P2096/7 P2098/9	Lambda trim control	Lambda trim correction <u>OR</u>	> 0.300 s < - 0.300s	EVAP canister load factor EVAP Canister Purge functional check	Not critical Not in progress	1 s / continuous	

If the above table does not include details of the following enabling conditions: - IAT, ECT, vehicle speed range, and time after engine start-up then the state of these parameters has no influence upon the execution of the monitor.

5.3.4 Drive Cycle Information

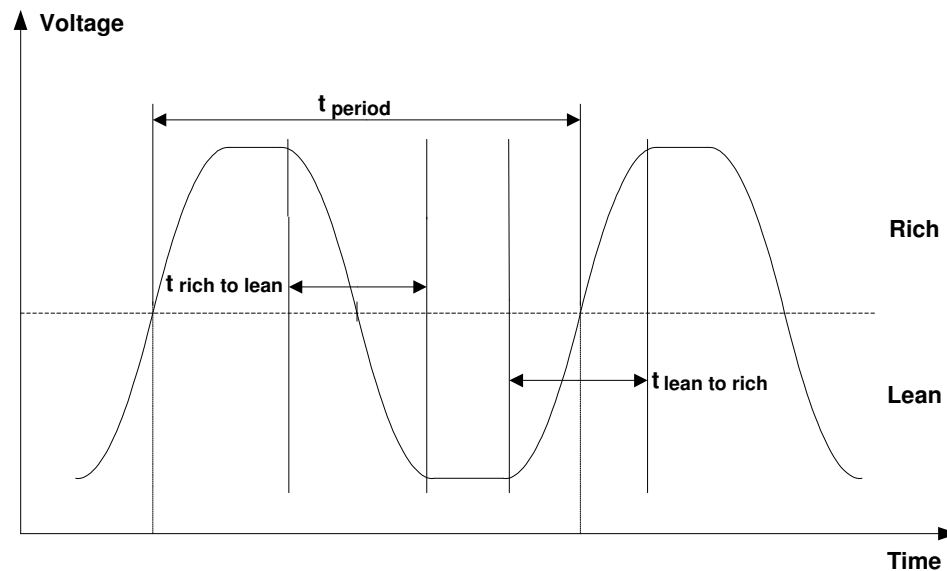
P0171	Drive Cycle C
P0172	Drive Cycle C
P0174	Drive Cycle C
P0175	Drive Cycle C
P2096	Drive Cycle C
P2097	Drive Cycle C
P2098	Drive Cycle C
P2099	Drive Cycle C

5.5 Oxygen Sensor Monitoring

5.5.1 Description

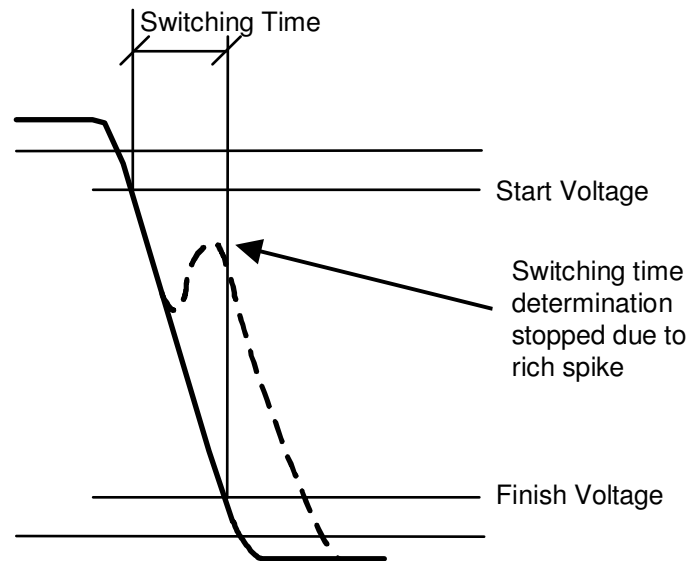
The system uses 4 heated exhaust gas oxygen sensors for the feedback control of the fuel system and the diagnosis of the catalysts. The engine is split into 2 banks of 3 cylinders, with 2 sensors per bank. 1 sensor in each bank is upstream of the catalyst and the other sensor is downstream of the catalyst.

The sensors are monitored for electrical continuity, correct operation of the heaters, time to switch from rich to lean ($t_{\text{rich to lean}}$) and from lean to rich ($t_{\text{lean to rich}}$), correct voltage level whilst in lean or rich operation and correct control frequency (t_{period}).



5.5.2 Oxygen Sensor Switching Time Monitoring

Rich to lean monitoring



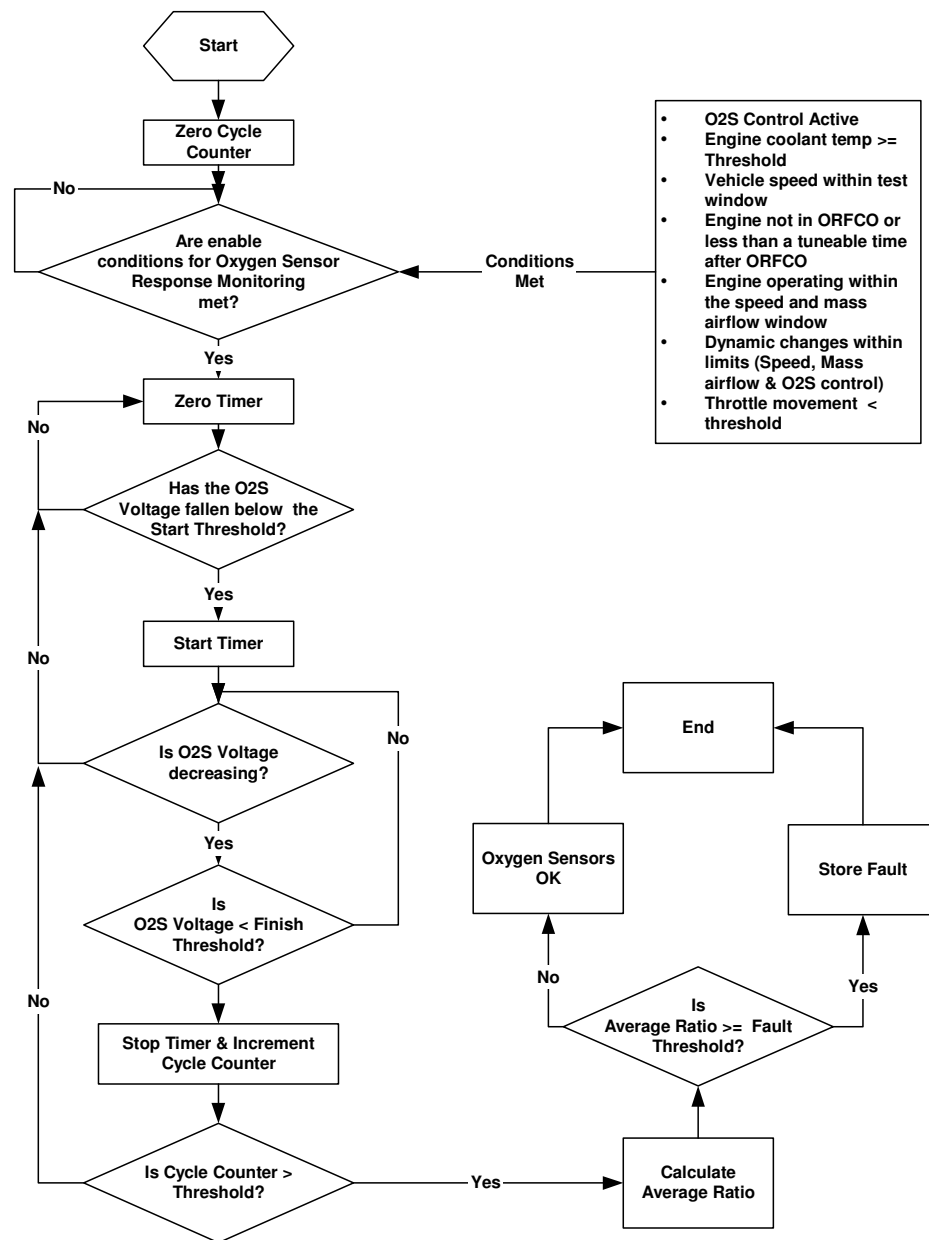
The system separately monitors the time for switching from rich to lean and lean to rich. The process is the same for both monitors, so only the rich to lean function will be described here.

When the voltage falls below the “start voltage” threshold a timer is enabled, the timer is stopped when the voltage reaches the “finish voltage” threshold. Should a rich spike occur during the rich to lean transition, then the timer is stopped and reset to zero, and that particular rich to lean transition is not used in the diagnostic determination.

Since the switching time has a natural level of variation, it is necessary to average the switching times from several measurements. The switching time also varies with engine operating conditions, so each measurement is normalised by dividing it by a speed and load dependent map value. These ratios are then averaged over a tuneable number of transitions in order to produce a value that can be compared with a threshold. If the final value is equal to, or greater than this threshold, then a fault is present.

If required, a weighting factor can be applied to the ratios for cylinder bank 2, in order to take account of bank-to-bank differences.

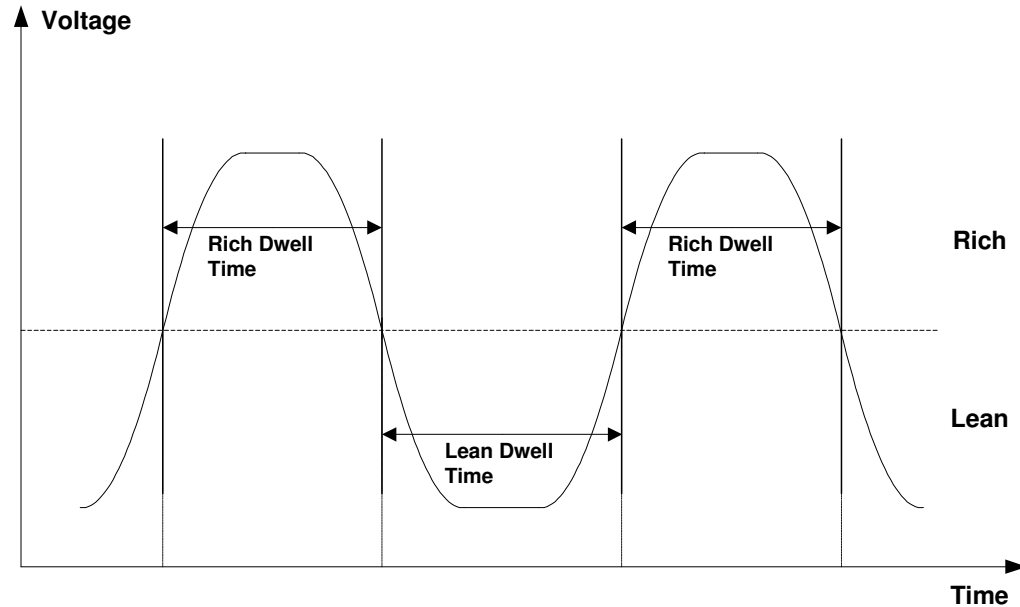
5.5.3 Flow Chart of the Oxygen Sensor Switching Monitor – Rich to Lean



5.5.4 Oxygen Sensor Control Frequency Monitoring

The system monitors the dwell times for both rich and lean operation for both of the control sensors. If either or both of the time limits are exceeded, then a fault is present.

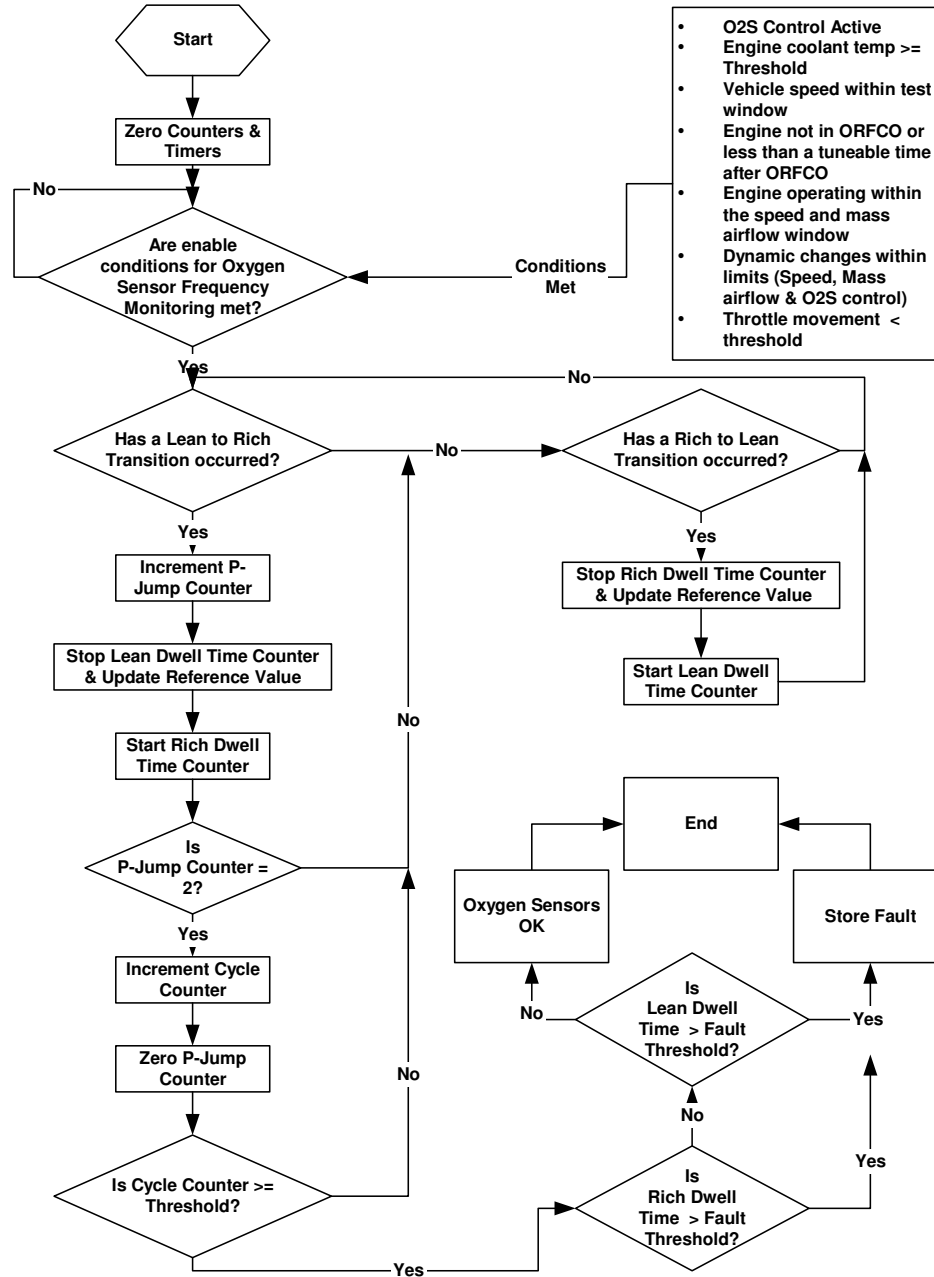
The times are measured according to the following diagram:



The dwell time for rich or lean operation is recorded and the appropriate total incremented with this new value after each rich or lean transition. A reference value for the dwell time is also calculated, this consists of a speed and load dependent constant added to the absolute value of the last lambda trim control multiplied by a weighting factor. A total is also kept of the reference values.

A counter is incremented after each complete cycle and when sufficient data has been recorded the ratio of the sum of the dwell times to the sum of the dwell time reference values is compared to the appropriate limit for lean or rich operation. If either ratio exceeds the limit value, then a fault exists. If required, a weighting factor can be applied to the ratio for cylinder bank 2, in order to take account of bank-to-bank differences.

5.5.5 Flow Chart of the Oxygen Sensor Control Frequency Monitor





5.5.6 Oxygen Sensor Voltage and Voltage Amplitude Monitoring

In addition to the previously described diagnostic monitors, the upstream and downstream O2 sensors are also monitored for the following fault conditions:

- Short to Battery Positive – If the voltage is above a threshold for a tuneable length of time then a fault exists.
- Short to Ground – This is monitored when over-run fuel cut off is not operating. If the sensor voltage is below a threshold for a tuneable time period and the measured sensor resistance is below a threshold, then a fault exists.
- Open Circuit – The sensor voltage lies between 2 thresholds for more than a tuneable time and the measured sensor resistance is greater than a threshold. Additionally, for the downstream sensors the engine must be operating in ORFCO.
- Downstream Sensor Voltage Level – This is checked for plausibility on entry and exit from ORFCO.
- Downstream Sensor Rich to Lean Switching Time – This works in the same way as for the upstream sensors.
- Downstream Sensor Activity Check – If the sensor voltage has not fallen below a lean limit and exceeded a rich threshold within a certain time after engine start, then feedback is turned off and the fuelling biased rich or weak, depending on which limit has not been reached. If the appropriate voltage level is still not attained then a fault exists.

5.5.7 Oxygen Sensor Heater Monitoring

The upstream and downstream O2 sensor heating circuits are checked for the following:

- Short to battery positive.
- Short to ground.
- Open circuit.
- Resistance – The calculated resistance of each of the heater circuits must lie within an upper and a lower threshold, or a fault exists.

Oxygen Sensor Monitoring

Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Oxygen Sensor (front)	P0133 P0153	Response time monitoring (switching time measured, weighted for operating condition and averaged)			ECT Fuel system status Vehicle speed Engine speed and Engine load Engine speed Engine load Lambda mean val.	> 60° C Closed loop 3.1 < vehicle speed < 124 mph 1280 to 2912 rpm 0.31 to 0.97 g/rev Δ < 308 rpm Δ < 0.27 g/rev Δ < 4.1%	25 lambda controller cycles / once per drive cycle	two driving cycles
	P1135 P1153		Response time ratio rich to lean excessive	≥ 200				
	P1136 P1154		Response time ratio lean to rich excessive	≥ 200				
	P0133 P0153	Oxygen control frequency (ratio of dwell times)			Delta pedal movement	Δ < 504 °TPS/s	15 lambda cycles / once per drive cycle	
	P1162 P1164		Time ratio in lean Condition	> 2.5	Catalyst temperature (model) following post ORFCO catalyst enrichment	399 < T °C < 899 Integrated Air Mass > 200 g		
	P1161 P1163		Time ratio in rich Condition	> 2.5				
	P0130 P0150	Open circuit	Voltage	0.38V<V<0.48V	Time since start of normal sensor operation	130 s	20 s / continuous	
	P0132 P0152	Range check (high)	Voltage	> 1.2 V			500 ms/ continuous	
	P0131 P0151	Range check (low)	Voltage <u>AND</u> Resistance	< 0.05 V < 2 Ω	Fuel system status Air Mass Flow	Closed loop & not ORFCO > 0.26 g/rev	50 s / continuous	
	P0134 P0154	Activity check	Mean maximum voltage - mean minimum voltage	< 0.08 V	No. P-jumps after λ control off -> on	> 30	Immediately / continuous	
Oxygen Sensor Heater (front)	P0032 P0052	Heater circuit - short to battery positive	Current <u>or</u> Temperature	> 8 to 11 A > 155 to 185 °C			10 s / continuous	two driving cycles
	P0031 P0051	Heater circuit - short to ground	Voltage (whilst drive is off)	< 2.05 V				
	P0030 P0050	Heater circuit - open circuit	Current (whilst drive is on)	< 10 to 50 mA				



Oxygen Sensor Monitoring

Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
	P0053 P0059	Heater Resistance	Calculated mean resistance	$1\ \Omega > R > 2\ \text{k}\Omega$	MAF Heater drive pulse width O2S temperature	$< 69.4\ \text{g/sec}$ $> 90.2\%$ $200 < T < 850\ ^\circ\text{C}$	40 measures duration	
Oxygen Sensor (rear)					ECT Catalyst temperature (model) Vehicle speed	$> 60\ ^\circ\text{C}$ $> 423\ ^\circ\text{C}$ $3.1 \leq \text{vehicle speed}$ $\leq 124\ \text{mph}$		two driving cycles
	P2271 P2273	Implausible voltage	Voltage on entry to ORFCO	$> 0.3\ \text{V}$	MAF since start of ORFCO	$> 25\ \text{g}$	3.75 s / continuous	
	P2270 P2272		Voltage change since leaving ORFCO	$< 0.01\ \text{V}$	MAF during last ORFCO Mass Airflow since last ORFCO	$> 25\ \text{g}$ $> 250\ \text{g}$		
	P0136 P0156	Open circuit	Voltage <u>AND</u> Resistance	$0.38\text{V} < V < 0.48\text{V}$ $> 63\text{k}\Omega$	Fuel system status Time elapsed since start of normal O2S operation MAF since start of ORFCO	in ORFCO 10 s $> 25\ \text{g}$	10 s / continuous	
	P0138 P0158	Range check (high)	Voltage	$> 1.2\ \text{V}$			500 ms / continuous	
	P0137 P0157	Range check (low)	Voltage <u>AND</u> Resistance	$< 0.05\ \text{V}$ $< 2\ \Omega$	Fuel system status MAF	Closed loop & not in ORFCO $> 0.26\ \text{g/rev}$	50 s	
	P0139 P0159	Switching time rich-to-lean	Mean switching time over 15 cycles	> 1.5	Fuel system status MAF O2S voltage on entry to ORFCO	in ORFCO $4.2 < \text{MAF} < 125\ \text{g/sec}$ $> 0.45\text{V}$	15 cycles at 1.5 s / continuous	
	P0140 P0160	Activity Check	Voltage (lean voltage not reached)	If lean threshold 0.410 V not reached, then	ECT time elapsed since the start of normal	$> 60\ ^\circ\text{C}$ $> 120\ \text{s}$	immediately once/drive cycle	two driving cycles



Oxygen Sensor Monitoring

Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
				turn feedback control and purge off and multiply injection time by 0.852 and wait for MAF not in ORFCO to exceed 100 g. If lean threshold 0.410 V still not reached then a fault exists				
			Voltage (rich voltage not exceeded)	If rich threshold 0.508 V not exceeded, then turn feedback control and purge off and multiply injection time by 1.148 and wait for mass air not in ORFCO to exceed 100 g. If rich threshold 0.508 V still not reached then a fault exists	O2S operation time after engine start MAF since the start of ORFCO MAF since the start of non- ORFCO operation	> 120 s > 25 g > 200 g		
Oxygen Sensor	P0038 P0058	Heater circuit - short to battery positive	Current or Temperature	> 8 to 11 A > 155 to 185 °C			10 s / continuous	two driving cycles



Oxygen Sensor Monitoring								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Heater (rear)	P0037 P0057	Heater circuit - short to ground	Voltage (whilst drive is off)	< 2.05V				
	P0036 P0056	Heater circuit - open circuit	Current (whilst drive is on)	< 10 to 50 mA				
	P0054 P0060	Heater Resistance	Calculated mean resistance	1 Ω > R> 2 k Ω	MAF Heater drive pulse width O2S temperature	< 69.4 g/sec > 90.2% 200 < T < 850 °C	40 measures duration	

If the above table does not include details of the following enabling conditions: - IAT, ECT, vehicle speed range, and time after engine start-up then the state of these parameters has no influence upon the execution of the monitor.

5.5.8 Drive Cycle Information

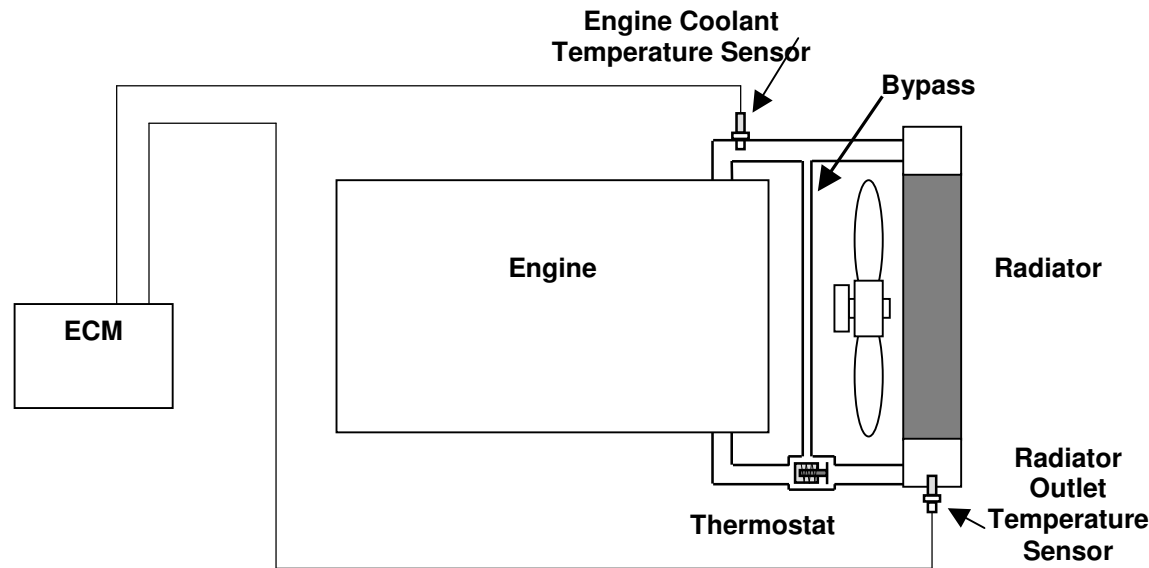
P2271	Drive Cycle C+
P2273	Drive Cycle C+
P0139	Drive Cycle C+
P0133	Drive Cycle C
P0153	Drive Cycle C
P1135	Drive Cycle C
P1155	Drive Cycle C
P1136	Drive Cycle C
P1154	Drive Cycle C
P1162	Drive Cycle C
P1164	Drive Cycle C
P1161	Drive Cycle C
P1163	Drive Cycle C
P0132	Drive Cycle C
P0152	Drive Cycle C
P0131	Drive Cycle C
P0151	Drive Cycle C
P0134	Drive Cycle C
P0154	Drive Cycle C
P0037	Drive Cycle C



P0057	Drive Cycle C
P0031	Drive Cycle C
P0051	Drive Cycle C
P0030	Drive Cycle C
P0050	Drive Cycle C
P0053	Drive Cycle C
P0059	Drive Cycle C
P2270	Drive Cycle C
P2272	Drive Cycle C
P0136	Drive Cycle C
P0156	Drive Cycle C
P0138	Drive Cycle C
P0158	Drive Cycle C
P0137	Drive Cycle C
P0157	Drive Cycle C
P0159	Drive Cycle C
P0140	Drive Cycle C
P0160	Drive Cycle C
P0038	Drive Cycle C
P0058	Drive Cycle C
P0036	Drive Cycle C
P0056	Drive Cycle C
P0054	Drive Cycle C
P0060	Drive Cycle C

5.6 Thermostat Monitoring

5.6.1 Description



The diagnostic checks for a partially open thermostat, under conditions when it would be expected that the thermostat was shut.

A second coolant temperature sensor is installed in the outlet from the radiator. If the engine temperature at start is less than a threshold, then the diagnostic will run. This monitor is divided into 2 steps:

Step 1

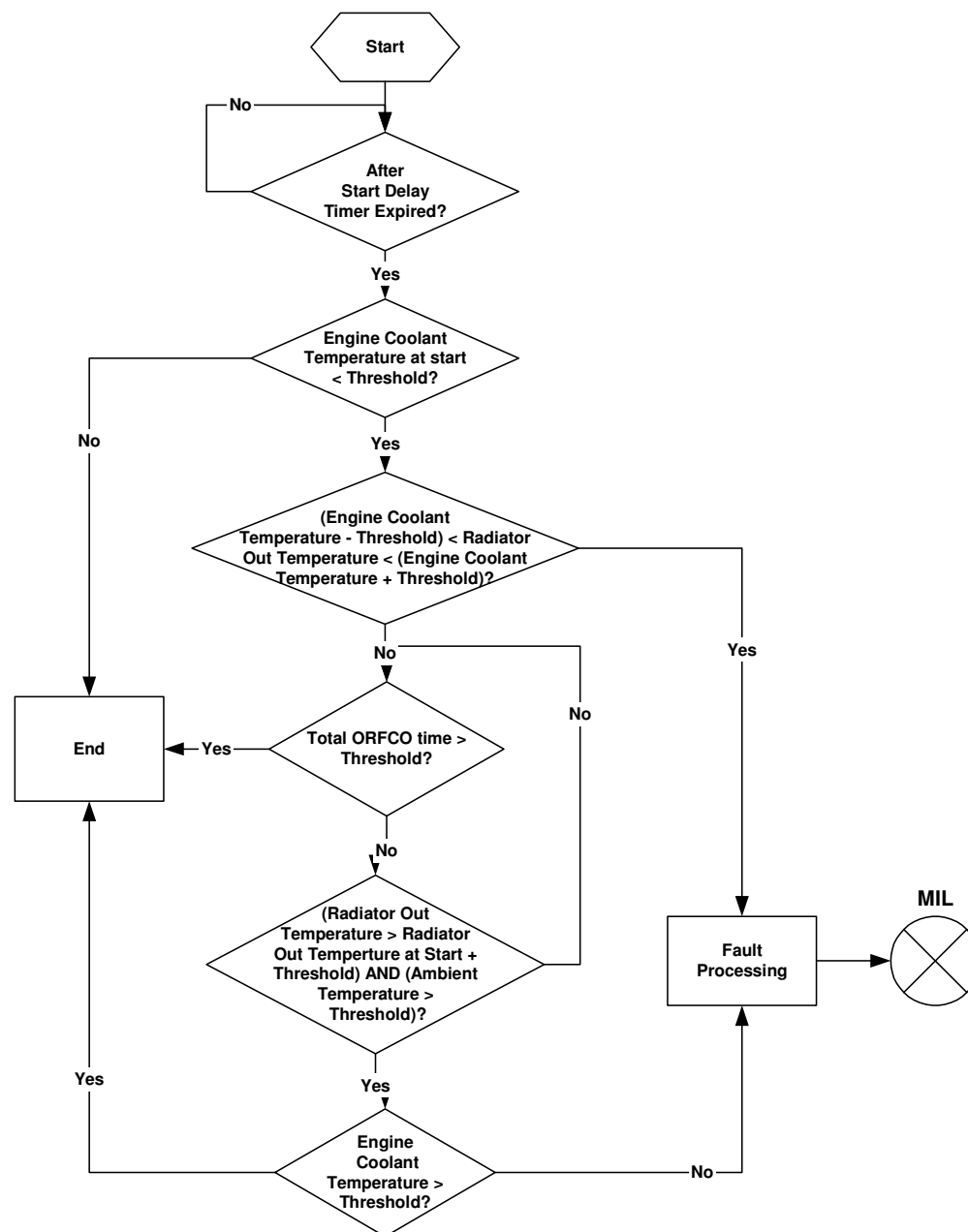
If an ECT dependent after start timer has expired and the radiator outlet temperature is within a tuneable threshold of the ECT, then a fault exists.

If step 1 is completed without a fault and over run fuel cut off has not been present for more than a certain length of time, then the diagnostic passes to step 2, otherwise the diagnostic is ended.

Step 2

If the radiator outlet temperature has risen by more than a tuneable threshold since engine start and the ambient temperature is more than a threshold, then the system checks the ECT. If this is above a threshold, then the system is OK, if not, then a fault is present.

5.6.2 Monitoring Structure



Thermostat Monitoring								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Thermostat stuck open	P0128	Functional check using engine coolant and radiator outlet temperature			Time after start (depends on start temperature) ECT at engine start	from > 300s at -30°C to > 120s at > 8.3°C < 60°C	50 s / once per drive cycle	two driving cycles
			<u>Step 1</u> Radiator outlet temperature within window	ECT - 6.8°C < Radiator out temp < ECT + 6.8°C				
			<u>Step 2</u> Radiator outlet temp <u>AND</u> ECT	> Radiator outlet temperature at start + 30.0°C ≤ 72.0°C	Total time in ORFCO Ambient temperature	< 60 s > -10°C		
Coolant Temperature Sensor (Radiator Outlet)	P2185	Short to Battery positive or open circuit	Implausible reading	< - 38.3°C	If intake air temperature Then wait for	< -5.25°C 20 s after start	2.5 s / continuous	two driving cycles
	P2184	Short to ground		> 138°C				
	P2183	Plausibility checks						
		Short Test (at engine start)	Radiator Outlet Temperature at start - ECT at start	> 15°C	ECT at start	< 60°C	Immediately /Once per engine start	
		Main Test	Maximum radiator outlet temperature – minimum radiator outlet temperature	< 2.3°C	Short test IAT at start Engine speed Engine operating condition Vehicle speed	passed > -7.5 °C > 1000 rpm Part load > 0 mph	Enable Conditions must be valid for > 180 s to 1300s Depending On Start temperature	



Thermostat Monitoring								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
					Engine acceleration Time since start (temperature Dependent(	2 or more accelerations of at Least 700 rpm/s and 2s duration > 960 to 2400s	Once per engine start	

If the above table does not include details of the following enabling conditions: - IAT, ECT, vehicle speed range, and time after engine start-up then the state of these parameters has no influence upon the execution of the monitor.

5.6.3 Drive Cycle Information

P2184 Drive Cycle C+
P0128 Drive Cycle C
P2185 Drive Cycle C
P2183 Drive Cycle C

5.7 Positive Crankcase Ventilation (PCV) System Monitoring

5.7.1 Description



Key:

1. Crankcase breather hose to intake duct
2. Crankcase breather hose to inlet manifold



The crankcase is vented via the oil drain passages in the cylinder blocks and cylinder heads and two ports in each camshaft cover. Pipes connect the larger ports in the camshaft covers to the intake duct on the upstream side of the throttle disc. The smaller ports in the camshaft covers are connected to the inlet manifold, downstream of the throttle body, also by pipes. Each of the smaller ports incorporates a restrictor and a gauze oil separator to prevent oil being drawn out of the camshaft covers with the blow-by gases.

When the engine is running with the throttle disc closed or partially open, the depression downstream of the throttle disc draws crankcase gases into the inlet manifold through the smaller ports or restrictors in the camshaft covers. Clean air, from the upstream side of the throttle disc, is drawn into the crankcase through the larger ports in the camshaft covers to limit the depression produced in the crankcase. When the engine is running with the throttle disc wide open both the upstream and downstream sides of the throttle disc are subjected to similar, relatively weak, depression levels. So crankcase gases are then drawn out of both ports in each camshaft cover, with the majority being drawn out of the unrestricted larger ports and into the throttle body.

Disconnection of the part-load breather, i.e. one of the pipes from the small ports in the cam covers, is likely to result in a tendency of the engine to stall when returning to idle and the quantity of un-metered air, which flows into the intake manifold will result in the detection of fuel system faults by the OBD system. Flow through the larger pipes is negligible under normal driving, but the diagnostic system will detect a fault due to the presence of un-metered air under certain driving conditions.

For these reasons, there are no separate monitors for compliance with the requirements of PCV monitoring.

5.8 Crankshaft Position and Engine Speed Sensor

5.8.1 Description

The engine speed and angular position is determined by use of a Siemens differential 'Hall Effect' sensor attached to the gearbox. The sensor picks up its signal from the reluctor ring within the gearbox which is rotating in front of the sensitive area of the sensor, the integrated circuit detects the magnetic field variations due to the passing of the teeth of the wheel and converts them into a digital signal.

The 'pulse train' generated by the 'switching' of the sensor is fed into the ECM which measures the time between teeth to calculate the engine speed. As there are some 'missing teeth' on the reluctor ring, by detecting the location of these teeth the ECM synchronises itself to the sensor enabling the determination of the angular position of the crankshaft. There are a total of 58 (60-2) teeth on the reluctor each of which are 6 degrees of engine crank apart where the missing 2 teeth denote 36° after TDC.

There are two diagnostic checks on the output signal of this sensor: -

1. No teeth on the reluctor ring have been detected and a cam sensor signal is present.
2. The number of counted reluctor ring teeth is greater than the number of actual reluctor ring teeth.

Crankshaft Position and Engine Speed Sensor								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Crankshaft Position and Engine Speed Sensor	P0335		No teeth detected		Cam Signal	Present, if engine start in progress	up to 3 revolutions/ continuous	two driving cycles
	P0336	Rationality check	counted teeth - actual number of teeth	> 1 tooth			4 revolutions/ continuous	

If the above table does not include details of the following enabling conditions: - IAT, ECT, vehicle speed range, and time after engine start-up then the state of these parameters has no influence upon the execution of the monitor.

5.8.2 Drive Cycle Information

P0335 Drive Cycle A
P0336 Drive Cycle A

5.9 Camshaft Position Sensor

5.9.1 Description

The camshaft position is determined by a Hall effect sensor that detects the passing of a cam profile on the camshaft. The sensor produces one pulse for each camshaft revolution and is used to synchronise the injectors so that fuel is injected into the correct cylinder at the right time.

The sensor is, in effect, a magnetically operated electrical switch. The sensor operates by switching a battery positive supply voltage on or off dependent on the presence or absence of the metal teeth in close proximity to the sensor. As the tooth passes in front of the sensor, it closes the magnetic circuit of the sensor, which in turn activates the 'switch'.

The 'pulse train' generated by the 'switching' of the camshaft position sensor has varying tooth width and tooth gap ratios in order to allow cylinder identification.

There are two diagnostic checks on the output signal of this sensor: -

1. A lack of signal or invalid signal. A fault is detected if the signal is high at 162° or low at 522° after top dead center (TDC) for Number 1 cylinder firing.
2. A rationality check of the camshaft position signal with respect to the crankshaft position signal. A fault is detected if the camshaft position signal state transition is not within the following window - 270° to 372° and 654° to 12° crankshaft after TDC for number 1 cylinder firing.

Camshaft Position Sensor								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Camshaft Position Sensor	P0340	Lack of signal	No signal or invalid signal	Signal high at 162° or signal low at 522° after TDC for number 1 cylinder firing	.		3 revolutions/ continuous	two driving cycles
	P0341	Rationality check (Alignment to crankshaft position and engine speed sensor)	Camshaft sensor transition outside allowable windows	270° to 372° and 654° to 12° crankshaft after TDC for number 1 cylinder Firing	Crankshaft rotation since engine start	> 32 revolutions		

If the above table does not include details of the following enabling conditions: - IAT, ECT, vehicle speed range, and time after engine start-up then the state of these parameters has no influence upon the execution of the monitor.



5.9.2 Drive Cycle Information

P0340	Drive Cycle A
P0341	Drive Cycle A

5.10 Engine Coolant Temperature Sensor

5.10.1 Description

The engine coolant temperature is determined by the use of a temperature sensor, fitted in the cylinder head. The sensor is a temperature dependent resistor (thermistor), i.e. the resistance of the sensor varies with temperature. The thermistor is an Negative Temperature Co-efficient (NTC) type which means that the sensor resistance decreases as the sensor temperature increases.

The sensor forms part of a voltage divider chain with an additional (pull-up to 5V) resistor in the ECM. The voltage from this network changes as the sensor resistance changes, and hence the voltage measured by the ECM is related to the coolant temperature.

The coolant sensor information is used to adapt the fuelling and timing level of the engine with respect to engine temperature. This is to maintain performance and emissions as the engine temperature varies and is also used to ensure a good quality of engine start.

The data is also used by the instrument pack for the control of the coolant temperature gauge. This data is transmitted via CAN.

A fault condition is recognised if the ECT exceeds a minimum or maximum threshold, or the closed loop enable temperature has not been achieved within a temperature dependant time threshold.

Engine Coolant Temperature Sensor								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold Value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Engine Coolant Temperature Sensor	P0118	Range check (minimum)	Implausible temperature	< - 38.3°C	If IAT Then wait for	< -5.25°C 10.0s after start	2.5 s / continuous	two driving cycles
	P0117	Range check (maximum)		> 138°C				
	P0116	Rationality check	Reaches closed loop enable temperature	from > 300 s at below -30°C to > 120 s at above 8.3°C			immediately / continuous	

If the above table does not include details of the following enabling conditions: - IAT, ECT, vehicle speed range, and time after engine start-up then the state of these parameters has no influence upon the execution of the monitor.



5.10.2 Drive Cycle Information

P0117	Drive Cycle B
P0118	Drive Cycle B
P0116	Drive Cycle A

5.11 Mass Airflow Sensor

5.11.1 Description

This is a 'hot film' MAF sensor and it is located between the air filter/engine cover and the throttle body.

The MAF is determined by the cooling effect the flow of intake air has over a "hot film" element contained within the sensor: The higher the air flow the greater the cooling effect and hence the lower the electrical resistance of the "hot film" element.

A fault is detected if the MAF signal exceeds the maximum or minimum threshold or the difference between the calculated load and the actual MAF signal is too great.

Mass Airflow Sensor								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Mass Airflow Sensor	P0102	Range check (minimum)	MAF	< 1.1 g/sec	Accelerator Pedal position	> 0.9°TPS	100 ms / continuous	two driving cycles
	P0103	Range check (maximum)		> 208 g/sec				
	P0101	Rationality check (low/high)	Comparison to Calculated load (engine speed and throttle position) to actual MAF signal	> calculated air mass ±40% (including lambda adaptation short term trim fault)	Engine speed Engine load Lambda adaptation ECT	1500 < N < 3500 rpm 0.46 < Engine Load < 1.05 g/rev Active From > 30°C at a start temperature of -30°C to >12°C at a start temperature of 6.75°C	immediately/ continuous	

If the above table does not include details of the following enabling conditions: - IAT, ECT, vehicle speed range, and time after engine start-up then the state of these parameters has no influence upon the execution of the monitor.



5.11.2 Drive Cycle Information

P0102	Drive Cycle A
P0103	Drive Cycle A
P0101	Drive Cycle B

5.12 Intake Air Temperature Sensor

5.12.1 Description

The IAT sensor is a temperature dependent resistor (thermistor), i.e. the resistance of the sensor varies with temperature. The thermistor is a NTC type which means that the sensor resistance decreases as the sensor temperature increases. It is located between the MAF sensor and the throttle body.

A fault is detected if the resistance of the sensor exceeds a minimum or maximum threshold.

Intake Air Temperature Sensor								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Intake Air Temperature Sensor	P0112 P0113	Range check (minimum) Range check (maximum)	Implausible temperature	< -38.3°C > 138°C	After start	> 10 s	2.5 s / continuous	two driving cycles
	P0111	Plausibility check at higher load Reading expected to decrease	Change in Intake air temperature	> 0°C	Vehicle speed Engine airflow rate	>= 43.5 mph >= 18.1 g/s	Up to 295 s/ Continuous (depends on Engine airflow)	
		Plausibility check at lower load Reading expected to increase	Change in Intake air temperature	< 0°C or 0.75°C (depends on air intake temperature at start and engine airflow)	Vehicle speed Engine airflow rate	<= 3.1mph <= 6.9 g/s	Up to 175 s/ Continuous (depends on engine airflow)	

If the above table does not include details of the following enabling conditions: - IAT, ECT, vehicle speed range, and time after engine start-up then the state of these parameters has no influence upon the execution of the monitor.



5.12.2 Drive Cycle Information

P0112	Drive Cycle B
P0113	Drive Cycle B
P0111	Drive Cycle B

5.13 Knock Sensor

5.13.1 Description

The KV6 engine is fitted with one knock sensor to each bank. The knock sensors work by the piezo-electric effect, which is the excitation, created by movement caused by engine detonation. The ECM reads in this signal and makes the necessary A/F adjustments.

A fault is detected if:

1. The engine speed is greater than 2850 rpm and the noise level received from the sensor is lower than expected. The noise level is checked at every 240 degrees of crank for each sensor.

Knock Sensor								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Knock Sensor	P0327 P0332	Functional check (background noise lower than expected)	Signal output (Average of 3 samples)	< MAP values	Engine speed	> 2850 rpm	9 revolutions / continuous	two driving cycles

If the above table does not include details of the following enabling conditions: - IAT, ECT, vehicle speed range, and time after engine start-up then the state of these parameters has no influence upon the execution of the monitor.

5.13.2 Drive Cycle Information

P0327 Drive Cycle B
P0332 Drive Cycle B

5.14 Throttle Position Sensor

5.14.1 Description

To enable closed loop control, the position of the throttle plate is supplied to the ECM by two feedback potentiometers in the throttle body. The feedback potentiometers have a common 5V supply and a common ground connection from the ECM, and produce separate linear signal voltages to the ECM proportional to the position of the throttle plate.

The ECM uses the signal from feedback potentiometer 1 as the primary signal of throttle plate position, and the signal from feedback potentiometer 2 for plausibility checks.

- The signal from feedback potentiometer 1 varies between 0.5V (0% throttle open) and 4.5V (100% throttle open).
- The signal from feedback potentiometer 2 varies between 4.5V (0% throttle open) and 0.5V (100% throttle open)

There are two diagnostic checks on the output signal of this sensor: -

1. A range check, where a fault is detected if the signal voltage exceeds a minimum or maximum threshold.
2. A rationality check as detailed by the MAF sensor section.

Throttle Position Sensor								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Throttle Position Sensor	P0122 P0222	Range check (minimum)	Voltage	< 0.156V			0.100 s / continuous	two driving cycles
	P0123 P0223	Range check (maximum)		> 4.85V				
		Rationality check	Test combined with MAF sensor					

If the above table does not include details of the following enabling conditions: - IAT, ECT, vehicle speed range, and time after engine start-up then the state of these parameters has no influence upon the execution of the monitor.



5.14.2 Drive Cycle Information

P0122	Drive Cycle B
P0222	Drive Cycle B
P0123	Drive Cycle B
P0223	Drive Cycle B



5.15 Engine Control Module Self Test

5.15.1 Description

The ECM performs a number of self-test integrity diagnostics on its internal hardware and software to check for faults. An error is detected if the ECM receives no CAN messages for at least 0.1 seconds or the calculated checksum at power up/down is incorrect.

Engine Control Module Self Test								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
ECM	P0600	Bus check	No CAN messages received from the TCM	> 0.100s	Battery positive	> 10V	Immediately/	two driving
	P0606	Self check (watchdog)	RAM and ROM check	Invalid checksum	At power up/down		continuous	cycles

If the above table does not include details of the following enabling conditions: - IAT, ECT, vehicle speed range, and time after engine start-up then the state of these parameters has no influence upon the execution of the monitor.

5.15.2 Drive Cycle Information

P0600 Drive Cycle A
P0606 Drive Cycle A



5.16 Accelerator Pedal Position Sensor

5.16.1 Description

The APP sensor is used to determine the engine torque demand requested by the driver. The sensor consists of 2 independent potentiometers that produce an output voltage proportional to the angular position of the throttle pedal. Each potentiometer has a separate 5V supply and ground direct from the ECM.

The ECM determines the driver demand as a percentage of pedal travel, i.e. "foot off" = 0% and full travel = 100%. This information is then used to calculate the percentage of maximum available engine torque demanded by the driver. The ECM will then calculate the throttle angle, fuel quantity and ignition angle required to achieve this demanded torque.

The driver demand information is output on CAN for other systems, in particular to the automatic TCM, which uses this information to determine the "kick down" point and also as part of its normal gearshift control strategies.

The "drive by wire" nature of the ECM means that the correct operation of the APP sensor is vital to the function of the ECM. It is for this reason that the sensor consists of 2 independent potentiometers. In this way the validity of the signals can easily be checked and fault-handling modes used if any error should be detected.

There are two diagnostic checks on the output signal of this sensor: -

1. A range check where a fault is detected if the signal voltage exceeds a minimum or maximum threshold.
2. A rationality check where the two potentiometer voltages are compared. A fault is detected if the difference is greater than a voltage dependant threshold.



NOTE: The voltage signal from potentiometer 1 is twice that of potentiometer 2

Accelerator Pedal Position Sensor								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Accelerator Pedal Position Sensor	P2122 P2127	Range check (minimum)	Voltage	Channel 1 or 2 < 0.151V			0.240 s / continuous	two driving cycles
	P2123 P2128	Range check (maximum)		Channel 1 > 4.84V Channel 2 > 2.72V				
	P2138	Rationality check	Comparison to 2 nd potentiometer voltage channel 1 Δ voltage	0.352V...3.042V Δ > 0.337 V...1.504V			0.340 s / continuous	

If the above table does not include details of the following enabling conditions: - IAT, ECT, vehicle speed range, and time after engine start-up then the state of these parameters has no influence upon the execution of the monitor.

5.16.2 Drive Cycle Information

P2122	Drive Cycle A
P2127	Drive Cycle A
P2123	Drive Cycle A
P2128	Drive Cycle A
P2138	Drive Cycle B



5.17 Vehicle Speed Signal

5.17.1 Description

The vehicle speed signal is transmitted from the ABS control unit to the ECM, via the CAN bus. The ECM has input diagnostics for this signal; a fault is detected if the engine speed greater than 2080 rpm, the engine load is greater than 0.65 g/rev and no input signal is detected.

Vehicle Speed Signal								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Vehicle Speed Signal	P0500	Rationality check	Signal output	No signal	Engine speed Engine load	> 2080 rpm > 0.65 g/rev	5.0 s / continuous	two driving cycles

If the above table does not include details of the following enabling conditions: - IAT, ECT, vehicle speed range, and time after engine start-up then the state of these parameters has no influence upon the execution of the monitor.

5.17.2 Drive Cycle Information

P0500 Drive Cycle B

5.18 Fuel Injectors

5.18.1 Description

For the 2002MY air assist injectors were used, this type of fuel injector consists of a small solenoid, which is used to inject air and fuel so that the fuel is atomised. Later model years use conventional injectors. The injector is activated by the ECM to lift off its base allowing fuel to pass into the intake manifold.

The ECM monitors the output power stages of the injector drivers for electrical faults. A fault is detected if any of the following conditions is satisfied: -

1. Fuel injector driver short circuit to battery positive, i.e. the driver voltage is less than 3V.
2. Fuel injector driver short circuit to ground, i.e. the driver current is greater than 2.4 A.
3. Fuel injector driver open circuit, i.e. the driver voltage is less than 5V.

Fuel Injectors								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Injection Valve	P0201 to P0206	Open circuit	Voltage range (minimum)	< 5V	Battery positive	7.5V < Battery positive < 17V > 320 rpm	1.5 s / continuous	two driving cycles
	P0262/5 P0268 P0271 P0274/7	Short to battery positive	Voltage range (minimum)	< 3V	Engine speed			
	P0261/4 P0267 P0270 P0273/6	Short to ground	Current range (maximum)	> 2.4 A				

If the above table does not include details of the following enabling conditions: - IAT, ECT, vehicle speed range, and time after engine start-up then the state of these parameters has no influence upon the execution of the monitor.



5.18.2 Drive Cycle Information

P0276	Drive Cycle A
P0201	Drive Cycle B
P0202	Drive Cycle B
P0203	Drive Cycle B
P0204	Drive Cycle B
P0205	Drive Cycle B
P0206	Drive Cycle B
P0262	Drive Cycle B
P0265	Drive Cycle B
P0268	Drive Cycle B
P0271	Drive Cycle B
P0274	Drive Cycle B
P0277	Drive Cycle B
P0261	Drive Cycle B
P0264	Drive Cycle B
P0267	Drive Cycle B
P0270	Drive Cycle B
P0273	Drive Cycle B



5.19 Throttle Control Motor

5.19.1 Description

The "drive by wire" throttle body controls the rate of airflow into the engine. The throttle valve position is determined by the ECM based on the airflow required to achieve the current engine torque demand. A geared direct current electric motor arrangement and a return spring control the throttle valve position, and the actual position is fed-back to the ECM by 2 potentiometer type position sensors.

The ECM controls the throttle valve position by means of a PWM and direction controlled H-bridge drive, which controls the current supplied to the motor. With no current supplied to the motor, the throttle valve will return to a 'limp-home' position, which is slightly open to allow a small amount of air through to the engine to allow it to continue running. The ECM will test the throttle valve actuation at 'key on' by quickly opening and closing the throttle valve before the driver starts the engine. Note that under 'steady state' conditions, the throttle valve will vibrate slightly due to the nature of the drive current.

There are four throttle control motor diagnostic checks: -

1. An electrical continuity check when the battery voltage is greater than 9V. A short to battery positive or ground can be detected.
2. A rationality check where a fault is detected if the difference between the actual and target position of the throttle valve is more than 10°.
3. A rationality check where a fault is detected if the throttle control valve duty cycle is equal to or greater than 99%.
4. An idle speed control check where a fault is detected if the engine speed is less than the target idle speed minus 100 rpm or the engine speed is greater than the target idle speed plus 100 rpm.

Throttle Control Motor								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Throttle Control Motor	P2101	Electrical continuity	Short to battery positive or Ground		Battery positive	> 9.0V	0.150 s / continuous	two driving cycles
	P061F	Rationality Check	Difference between actual and target position	> 10°			1.0 s / continuous	
	P1628 P1629		Throttle control duty Cycle	≥ 99%			0.5 s / continuous	
	P0505	Idle speed control check	Engine speed <u>OR</u>	< Target idle speed - 100 RPM > Target idle speed + 100 RPM	Engine state Vehicle speed Throttle closed for ECT	Idle 0 mph > 1.9 s 60 < ECT < 105 °C	20 s / continuous	



Throttle Control Motor								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
					MAF EVAP canister purge valve duty ratio EVAP canister purge functional check	< 0.61 g/rev < 7.03% Not in progress		

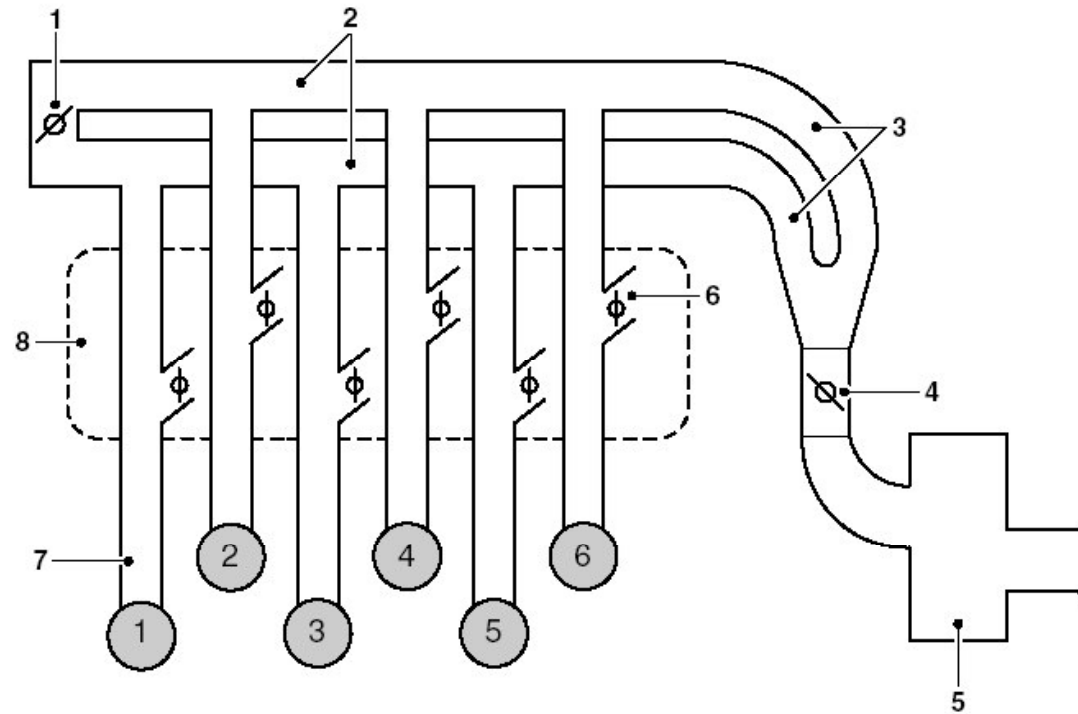
If the above table does not include details of the following enabling conditions: - IAT, ECT, vehicle speed range, and time after engine start-up then the state of these parameters has no influence upon the execution of the monitor.

5.19.2 Drive Cycle Information

P2101	Drive Cycle A
P061F	Drive Cycle A
P1630	Drive Cycle B
P1629	Drive Cycle B
P1628	Drive Cycle B

5.20 Variable Intake Manifold System

5.20.1 Description



- 1 Balance valve – Intake Manifold Tuning Valve 1
- 2 Main plenums
- 3 Secondary tracts
- 4 Throttle housing
- 5 Air cleaner
- 6 Power valves (6 off) – Intake Manifold Tuning Valve 2
- 7 Primary tracts
- 8 Short tract plenum



The induction system operates in three conditions:

- Low speed
- Mid-range
- High speed

Low Speed

At low speed the balance valve and power valves are closed. This effectively allows the engine to breathe as two, three cylinder engines, each having a separate plenum and long primary tracts. The primary and secondary tracts and the plenum volume are tuned to resonate at 2700 rev/min, giving peak torque at this speed.

Mid-Range

For increased mid-range torque performance, the plenums are connected using the balance valve. The power valves remain closed. This allows the engine to use the long primary tract length, which is tuned with the balance valve to produce maximum torque at 3750 rev/min.

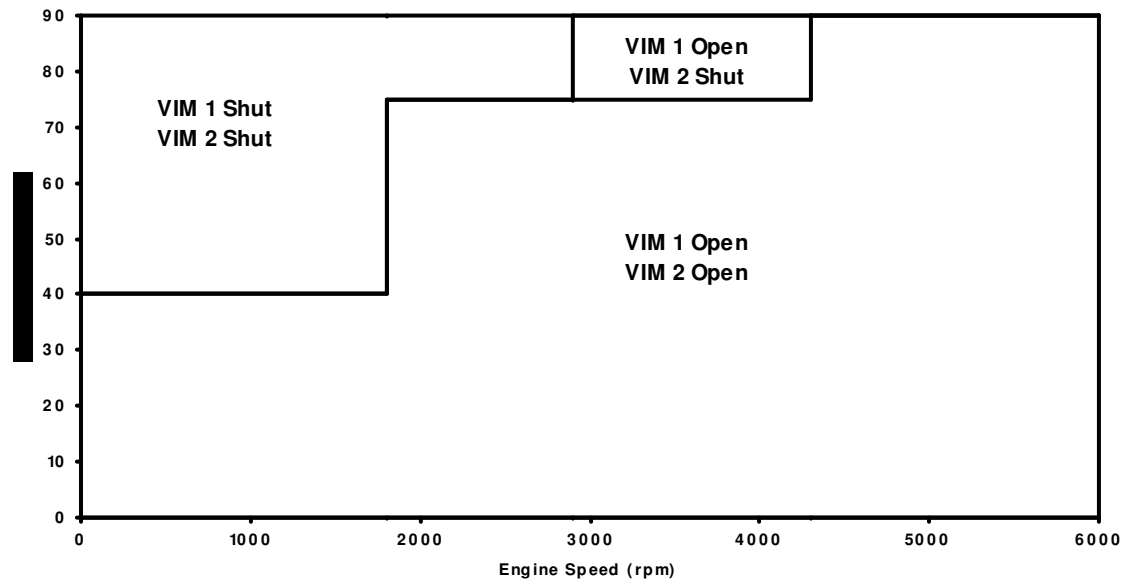
High Speed

At high engine speeds the balance valve remains open and the six power valves are opened. This allows the engine to breathe from the short tract plenum via the short primary tract lengths. These lengths and diameters are tuned to produce a spread of torque from 4000 rev/min upwards, with maximum power produced at 6250 rev/min.

The manifold also gives an improvement in part load fuel consumption. At part load, the manifold operates as at high speed. The pressure dynamics significantly reduce the pump losses below 4000 rev/min resulting in improved fuel consumption.



The following chart shows the status of both of the valves with respect to engine speed and throttle position:



There are two variable intake manifold system diagnostic checks: -

1. An electrical continuity check while the system is active. A short to battery positive, ground or an open circuit condition can be detected.
2. A rationality check where an always closed or always open valve can be detected. A fault is present if the valve is commanded open and the feedback signal is inactive and vice versa.



Variable Intake Manifold System								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Variable Intake Manifold System Intake Manifold Tuning (IMT) Valve 1 IMT Valve 2 IMT Valve 1 IMT Valve 2 IMT Valve 1 IMT Valve 2 IMT Valve 1 IMT Valve 2					Ignition key	on		No MIL illumination
	P0662	Electrical continuity	Short to battery positive		IMT Valve	Active	6.0 s/	
	P1476		Short to ground or open Circuit				continuous	
	P0661							
	P1477	Rationality check	Valve always closed	Feedback signal = Valve active Feedback signal = Valve inactive	IMT Valve	Inactive	72 s/	
	P2017		Valve always open		commanded condition	Active	continuous	
	P1473							
	P2070							
	P1472							

If the above table does not include details of the following enabling conditions: - IAT, ECT, vehicle speed range, and time after engine start-up then the state of these parameters has no influence upon the execution of the monitor.

5.20.2 Drive Cycle Information

P0062	Drive Cycle B
P1476	Drive Cycle B
P0061	Drive Cycle B
P1477	Drive Cycle B
P2017	Drive Cycle B
P1473	Drive Cycle B
P2070	Drive Cycle B
P1472	Drive Cycle B

5.21 Controller Area Network System

5.21.1 Description

A CAN bus architecture is employed on the Freelander vehicle between the engine, transmission, brake and instrument pack control modules. A fault is detected if the battery voltage is greater or equal to 10 V for at least 0.750 s and no CAN messages have been received from the TCM or the instrument pack.

CAN System								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
CAN Bus	P1646	CAN bus activity	No messages received from the TCM		Battery positive	$\geq 10V$ for at least 0.750 s	0.200 s / continuous	two driving cycles
	P1647		No messages received from the Instrument Pack				4 to 20 s/ continuous	No MIL Illumination

If the above table does not include details of the following enabling conditions: - IAT, ECT, vehicle speed range, and time after engine start-up then the state of these parameters has no influence upon the execution of the monitor.

5.21.2 Drive Cycle Information

P1646 Drive Cycle A
P1647 Drive Cycle A



5.22 Fuel Level Sensor

5.22.1 Description

This input is used as part of the EVAP detection system. The EVAP system diagnostic defaults to enabled if a fuel level sensor fault is detected. If a fault is detected by the ECM if an error message is received from the instrument pack.

Fuel Level Sensor								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Fuel level Sensor	P0460	Electrical Fault	Error message received from the instrument pack				25 s / continuous	No MIL illumination (leak check defaults to enabled)
	P0461	Plausibility Fault	Calculated fuel consumed –change in fuel tank level	> 48% Or < -48%	Calculated fuel Consumed. Time after Ignition on (filter function Setting time)	> 52% >250s	5 s / continuous	

If the above table does not include details of the following enabling conditions: - IAT, ECT, vehicle speed range, and time after engine start-up then the state of these parameters has no influence upon the execution of the monitor.

5.22.2 Drive Cycle Information

P0460 Not Applicable
P0461 Not Applicable

5.23 Engine Off Timer

5.23.1 Description

This diagnostic is used as part of the EVAP detection system. The EVAP system diagnostic defaults to enabled if an engine off timer error is detected. The diagnostic consists of a rationality check of the engine off time against engine cool down. The diagnostic runs if the ECT at engine off minus the ECT at engine start is greater than or equal to 39.8°C.

Engine Off Timer								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Engine Off Timer	P2610	Rationality check against engine cool down	Engine stop time	≤ 2700 s	ECT at engine off – ECT at engine start	$\geq 50.3^{\circ}\text{C}$	immediately / continuous	No MIL illumination (leak (check defaults to enabled)

If the above table does not include details of the following enabling conditions: - IAT, ECT, vehicle speed range, and time after engine start-up then the state of these parameters has no influence upon the execution of the monitor.

5.23.2 Drive Cycle Information

P2610 Not Applicable

5.24 Ambient Air Temperature

5.24.1 Description

Ambient air temperature is supplied to the ECM by the instrument pack via the CAN communications network. In addition to the diagnostic checking for error messages from the instrument pack the ECM also performs plausibility checks on the received data.

When the engine is cold (i.e. not run for over 10 hours) the ambient air temperature signal is compared to the intake air temperature signal. If the temperature identified by the two signals is not within 6.8 °C of each other then either a high or low ambient temperature fault is identified depending on which temperature is higher.

When the engine is hot the ambient temperature is continually checked against a modeled ambient temperature. If the actual temperature is not within 10.5 °C of the modeled temperature then either a high or low ambient fault is identified depending on whether the actual temperature is high or low.

Ambient Air Temperature								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
Ambient Temperature	P0070	Electrical Fault	Error message received				0.3 s/ continuous	No MIL illumination
		Plausibility check						(relevant diagnostics default to enabled)
	Too Low Too High P0072 P0073	Engine cold check (if the entry conditions for the cold check are valid, then both the cold and hot checks must detect a fault)	Ambient temperature - IAT at start	$\geq 6.8\text{ °C}$ (high fault) or $\leq -6.8\text{ °C}$ (low fault)	Soak time Change in intake air temperature following engine start	$> 36000\text{ s}$ $\leq 3\text{ °C over}$ 10 s	10 s/ Once per engine start	



Ambient Air Temperature								
Component/ System	Fault Codes	Monitoring Strategy Description	Malfunction Criteria	Threshold value	Secondary Parameter	Enable Conditions	Time Required	MIL Illumination
		Engine hot check (if the cold check entry Conditions were not valid, then only the hot check needs to detect A fault)	Ambient temperature - modeled ambient temperature (model = f(IAT, MAF, ECT)	$\geq 10.5\text{ }^{\circ}\text{C}$ (high fault) or $\leq -10.5\text{ }^{\circ}\text{C}$ (low fault)	Change in intake air temperature Coolant temperature. Intake air temperature Engine speed (rpm) Air mass flow rate Vehicle speed	$\leq 0\text{ }^{\circ}\text{C}$ over 25.5 s 60 to $110.3\text{ }^{\circ}\text{C}$ -6.8 to $75\text{ }^{\circ}\text{C}$ 1500 to 4000 13.9 to 69.4 g/s 25 to 75 mph	34.5 s/ Once per engine start	

If the above table does not include details of the following enabling conditions: - IAT, ECT, vehicle speed range, and time after engine start-up then the state of these parameters has no influence upon the execution of the monitor.

5.24.2 Drive Cycle Information

P0070 ??
P0072 ??
P0073 ??